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FINAL REPORT
INFORMATION TRANSFER SATELLITE CONCEPT STUDY

VOLUME III ✦ APPENDICES

GENERAL DYNAMICS
Convair Aerospace Division

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15 May 1971

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FOREWORD

This report was prepared by the Convair Aerospace Division of General Dynamics under Contract No. NAS 2-5571 for the office of Advance Research and Technology (OART) of the National Aeronautics and Space Administration. The work was administered under the Technical direction of the Advanced Missions and Concepts Division of OART located at Ames Research Center.

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CONTENTS

APPENDIX A

ANALYSIS OF DATA FROM PREVIOUS STUDIES

1. INTRODUCTION

This paper consists of brief reviews of the various documents which the Phase I contractors supplied as background information. These documents were introduced as part of the data base for the contractor's requirements studies.

There were sixteen separate papers supplied. Of these, three were originated as part of the requirements study by the contracting teams; two are general descriptions of the requirements studies prepared for delivery as speeches. The remainder are third-party papers which deal with information transfer needs in one of the various service or demand categories being considered by the Phase I contractors.

Each of the sixteen papers are reviewed independently in the following sections and are evaluated in terms of:

a. the category of service or demand being treated,

b. the extent to which information transfer predictions are quantified,

c. the degree to which the data supplied is adequate for the purposes of system synthesis and conforms to the format used in the Convair computer analysis, and

d. some assessment as to the overall utility of the data presented in the paper.

2. Paper No. 1, ANALYSIS AND RANKING OF DEMAND CATEGORIES BY POTENTIAL BENEFITS, LMSC/A956712

This is a principal paper of one of the Phase I contractors. It deals with a methodology for ranking some 32 categories of demand which the authors have designated to cover the 212 separate demands that they have identified. There is some quantitative information supplied about each of the major demand categories but it is not sufficient to generate a continuous prediction over time of either the level of demand or use for any of the categories. The computer printout of the list of individual demand categories, the number of users, coverage/location, information type, bit rate, MSG duration, spacing quality reliability, priority and privacy is the most complete and useful data in the entire collection from the point of view of system synthesis. In a subsequent report this data will be translated into an appropriate format for the Convair computer program.

The actual ranking procedure is a comprehensive quantitative algorithm based on weighted subjective ratings for each of nine different indicators of potential benefit. The analysis is reasonably useful despite a moderate degree of interdependence between the factors and limited dimensional character. For this reason, the weighted sum used by the authors is no less applicable than other more sophisticated mathematical manipulations. The assertion that demand correlates with benefit is correct when there is no price elasticity of demand. However, since this is generally not the case for most of the services being considered this postulate should be used with constraint. In short, although the ranking procedure is of use as a correlate, the principal information of value that can be gained from this paper is the descriptive listing of the 32 demand categories with quantitative estimates of their magnitudes in 1970 - 1975 and 1985.

3. Paper No. 2, PROFILE FOR SPACE TELECOMMUNICATIONS

This paper describes the various communication requirements for the future NASA space program. This includes both qualitative and some quantitative projected requirements of a space satellite and space station as detailed by the NASA Goddard Space Flight Center. Various transmission calculations for space-to-space links are also included. While the form of a space information network of the 1980's could be extracted from this material, it would be difficult to fix the size or capacity of the various links (almost no quantitative data is included in the descriptive material). The schedule of space missions provided should also be brought up to date as a result of recent major changes in NASA plans and budgets before it could be used to estimate the communication environment required to support these programs.

4. Paper No. 3, PROFILE FOR COMPUTATIONAL INFORMATION TRANSFER SYSTEMS

This paper provides quantitative indications of the demand for information transfer which will derive from the computational systems of the 1980's and 90's. The trade-off between communications costs and the economies of large control processors are explored and the potential growth of remote access installations is estimated. The capability of the switched telephone network for carrying digital communication is also discussed. The U.S. Geological survey teleprocessing system was selected and described in the paper as prototypical of a large computer-communication system of the 70's. The information provided would be highly useful for describing this particular form of system but would be of only limited use for system design or synthesis due to the limited treatment of specific link capacity requirements.

5. Paper No. 4, REQUIREMENTS FOR INTEGRATED INFORMATION NETS (Year 1990)

This paper was prepared for delivery to the American Astronautical Society. It essentially covers the material that was given at the Phase I contractor's final presentation in December, 1970. A prediction of various "demand indicators" such as school population, welfare expenditures, intercity freight are presented. Five basic service categories are described: data collection and/or distribution information distribution, inquiry and response, broadcast, and information exchange. Some examples of each of these service categories are provided. The quantitative data is limited and its form will require considerable conversion in order to lend itself to the Convair computer synthesis program.

6. Paper No. 5; DEMAND FORCASTING FOR INFORMATION TRANSFER SATELLITES

This material also was prepared for presentation to the American Astronautical Society and deals with methods for predicting the demand for information transfer services. The principal conclusion advanced is that data communications will account for less than 1 percent of voice traffic rather than the 50 percent often quoted. The data are presented only in aggregate form - i.e., total bits per year for a service. Because of this there is insufficient detail on system characteristics and long and short haul requirements to be directly useful for system design or synthesis using the Convair computer program.

7. Paper No. 6, PROFILE FOR METEOROLOGICAL INFORMATION

This paper provides a description of the World Weather Watch and the Global Atmospheric Research Program. Descriptive material concerning the form of the present Meteorological information network consisting of a National Meteorological Center (Wash. D.C.), Regional Centers, and individual station is provided. However, no specific quantitative data about the traffic density or the number of locations for transmitting and receiving is included. As an appendix a description of the WEFAX (WEather FAcsimile experiment) is included without indications of the data rates and network configuration. This article contains no data that could be used as input to the Convair system synthesis computer program.

8. Paper No. 7, A STUDY OF LAND MOBILE SPECTRUM UTILIZATION

This paper provides a detailed look at frequency occupancy in the 40 M Hz, 150 M Hz and 450 M Hz bands in Detroit and Los Angeles as contrasted with actual FCC assignments. Some indication is given of the magnitude of use being made of mobile communications and the scheduling and coordination problems that have occurred in larger metropolitan areas. The information relates mostly to short range voice links and therefore will probably be of little use in a study of satellite data information transfer. A direct application of this material to the present study or as input to the Convair computer program could not be found.

9. Papers No. 8 through No. 15, REFERENCE PROFILE FOR EARTH SCIENCES AND OCEANOGRAPHY

This group of papers is intended to give some indication of the information transfer requirements of such activities as fish, sea state and resource monitoring, agricultural crop surveillance, hydrology, topography, geology and pollution and erosion control.

The first paper included in this collection deals with the legal implications of atmospheric water resources. There is nothing in this paper that relates to information transfer requirements.

The second paper deals with remote sensing studies of the ocean. Three principal parameters can be measured; surface roughness, surface temperature, and water color. Some data about the value of reduced search time for fishing fleets might be useful for benefit evaluation but no quantitative data is presented concerning the information rate and network pattern that would be required of an operational system.

The third reference is an extract from the Agriculture Handbook on the world-wide use of airphotos in agriculture. This paper indicates what areas of the world have been photo surveyed but there is no obvious link of this material to information transfer requirements.

The fourth paper is titled, "Earth Resources Survey from Space" and provides a good indication of the types of data that are likely to result from ERTS satellites. Although no data rates per se are given, the sensor resolution and available data dump times for different orbits are provided. This information can serve as the basis for calculating preliminary data transmission requirements. As the article acknowledges, "the arguments are still mainly qualitative" - they have to do with such things as vibrationless sensing synoptic viewing, interpretating data, focused efforts. The program can not move into a more quantitative phase until more flight testing of all types is done.

The fifth paper details an agricultural resources information system. The types of information, their usefulness, and pattern of flow are all discussed in general terms. The actual quantity of information of interest in such a system is not discussed nor are the number of potential suppliers or receivers of this information estimated. It provides a good model of a system but additional research would be required to establish a quantitative measure of the potential demand.

The sixth article in this set is concerned with forcasting the economic impact of future space station operations. This reference contains a number of interesting estimates of the yearly benefits that could result from a variety of space programs in the areas of agriculture, geology, oceanography, atmospheric sciences, etc. The long range benefits of improved weather prediction are estimated at $2 billion per year. This paper sets forth some sound logical principles for developing a benefit analysis based on user information requirements. Unfortunately the entire article has not been included so it is not possible to say if the user information requirements and the value of resulting benefits are specified in quantitative terms.

The seventh article is concerned with agricultural applications of remote sensing. This article gives data for resolution and repetition rate for various kinds of sensor data, but no estimates of total data rates or information flow patterns. A fairly extensive bibliography is included with this material.

The eighth article is titled, "Aerospace Applications in Agriculture". The necessary resolution, frequency of coverage and other information are converted to quantitative data. A simple determination of the data rate from ERTS-A is made which comes out to be 8.7×10^5 bits per sec. on an average basis. For the short readout times that are typically available, 100×10^6 bits/sec capability could be required.

The ninth and final article in this series is a survey of non-federal purchasers of airphotos. This material gives some idea of the size of the market for the type of data represented by airphotos. A detailed description is also given of the photo sales by customers but end uses and benefits are not discussed.

While the material in these eight articles gives a reasonable picture of potential information transfer activities in the fields of earth sciences and oceanography, it is not adequately detailed or sufficiently quantitative for the purpose of setting actual communication systems requirements.

10. CONCLUSION

The material available in these 15 papers provides an overview of future information transfer operations and indications of the importance of such services to a variety of specific fields. Furthermore, some feeling for the form of the networks requirements can be derived from these papers. However, very few quantitative indications are given or can be derived of the magnitude of the communications requirements, either for individual channels or for a total system. Such estimates are only available in the Lockheed summation and the basis of these is not described in the papers.

To carry the analysis forward from this point requires acceptance of the Lockheed data as given and the adaptation of it into the Convair/Hughes system synthesis. The necessary interpretation of this data to fit the input requirements for the Convair computer program will be presented in a subsequent paper.

TRANSFORMATION OF LMSC DATA INTO FORMAT SUITABLE
FOR INPUT TO CONVAIR COMPUTER PROGRAM

A. L. Horley

A number of data items were not included in the LMSC Phase I material supplied. For those cases best estimates were made of what the values should be.

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	MEDICAL DIAGNOSTIC VIDEO
LMSC NO.	032
NO. OF TRANSMITTERS	50
NO. OF RECEIVERS	50
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	6 MHz
NO. OF CHANNELS	1
MODE	SIMPLEX
S/N OR ERROR RATE	30 dB
NOISE ENVIRONMENT	URBAN
USER IDENT	MEDICAL DATA
LMSC NO.	030, 028, 032
NO. OF TRANSMITTERS	209
NO. OF RECEIVERS	209
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	4800 bps
NO. OF CHANNELS	50
MODE	DUPLEX
S/N OR ERROR RATE	10-5
NOISE ENVIRONMENT	URBAN

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	EARTH RESOURCES
LMSC NO.	173
NO. OF TRANSMITTERS	1 (satellite moving)
NO. OF RECEIVERS	1
AREA OF COVERAGE	GLOBAL
NO. OF BEAMS	1
BW OR DATA RATE	4 MHz
NO. OF CHANNELS	4 CH
MODE	ONE WAY
S/N OR ERROR RATE	20 dB
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	WEATHER BALOON AND BUOY
LMSC NO.	078, 079
NO. OF TRANSMITTERS	1000
NO. OF RECEIVERS	3
AREA OF COVERAGE	GLOBAL RELAY
NO. OF BEAMS	3 SPOT 1 GLOBAL
BW OR DATA RATE	100 BPS
NO. OF CHANNELS	1
MODE	ONE WAY - BROAD GATHERING
S/N OR ERROR RATE	10^{-4}
NOISE ENVIRONMENT	RURAL
USER IDENT	ORBIT FLIGHT TEST
LMSC NO.	182
NO. OF TRANSMITTERS	5
NO. OF RECEIVERS	1
AREA OF COVERAGE	GLOBAL RELAY
NO. OF BEAMS	3
BW OR DATA RATE	20 Kbps
NO. OF CHANNELS	2
MODE	DUPLEX
S/N OR ERROR RATE	10^{-4}
NOISE	SUBURBAN

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	MANNED SPACE SUPPORT
LMSC NO.	175
NO. OF TRANSMITTERS	3
NO. OF RECEIVERS	1
AREA OF COVERAGE	GLOBAL RELAY
NO. OF BEAMS	3 SPACE 1 EARTH
BW OR DATA RATE	6 MHz or 60 Kbps
NO. OF CHANNELS	2 CH
MODE	ONE WAY
S/N OR ERROR RATE	20 dB or DATA 10-6
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	ASTRONOMY SATELLITE RELAY
LMSC NO.	176
NO. OF TRANSMITTERS	1
NO. OF RECEIVERS	1
AREA OF COVERAGE	GLOBAL RELAY
NO. OF BEAMS	3 SPACE 1 EARTH
BW OR DATA RATE	6 MHz or 20 Kbps
NO. OF CHANNELS	2 CH
MODE	ONE WAY
S/N OR ERROR RATE	20 dB or 10-5
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	AIRCRAFT COLLISION AVOIDANCE
LMSC NO.	088
NO. OF TRANSMITTERS	6
NO. OF RECEIVERS	4500
AREA OF COVERAGE	GLOBAL
NO. OF BEAMS	3
BW OR DATA RATE	1 KHz
NO. OF CHANNELS	4500
MODE	ONE WAY
S/N OR ERROR RATE	10-6
NOISE	RURAL

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	CIVIL DEFENSE
LMSC NO.	154
NO. OF TRANSMITTERS	60
NO. OF RECEIVERS	60
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	3 KHz
NO. OF CHANNELS	15
MODE	DUPLEX
S/N OR ERROR RATE	30 dB
NOISE ENVIRONMENT	URBAN
USER IDENT	UN MEETINGS
LMSC NO.	114
NO. OF TRANSMITTERS	1
NO. OF RECEIVERS	10^6
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	6 MHz
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	20 dB
NOISE ENVIRONMENT	URBAN
USER IDENT	WEATHER SATELLITE RELAY
LMSC NO.	089
NO. OF TRANSMITTERS	3
NO. OF RECEIVERS	1
AREA OF COVERAGE	GLOBAL RELAY
NO. OF BEAMS	3 SPACE 1 EARTH
BW OR DATA RATE	6 MHz
NO. OF CHANNELS	3
MODE	ONE WAY
S/N OR ERROR RATE	20 dB
NOISE	SUBURBAN

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	MIGRATION OF WILD ANIMALS
LMSC NO.	162, 163
NO. OF TRANSMITTERS	50
NO. OF RECEIVERS	1
AREA OF COVERAGE	REGIONAL
NO. OF BEAMS	1
BW OR DATA RATE	100 bps
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	10-4
NOISE ENVIRONMENT	RURAL
USER IDENT	DEEP SPACE RELAY
LMSC NO.	177
NO. OF TRANSMITTERS	3
NO. OF RECEIVERS	1
AREA OF COVERAGE	SPACE
NO. OF BEAMS	3 SPACE 1 EARTH
BW OR DATA RATE	100 bps
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	10-6
NOISE ENVIRONMENT	SPACE
USER IDENT	ORBIT ASSEMBLY
LMSC NO.	181
NO. OF TRANSMITTERS	1
NO. OF RECEIVERS	1
AREA OF COVERAGE	GLOBAL
NO. OF BEAMS	3 SPACE 1 EARTH
BW OR DATA RATE	6 MHz
NO. OF CHANNELS	2
MODE	DUPLEX
S/N OR ERROR RATE	20 dB
NOISE	RURAL

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	AIR TRAFFIC POSITION
LMSC NO.	086
NO. OF TRANSMITTERS	1,300
NO. OF RECEIVERS	50
AREA OF COVERAGE	GLOBAL
NO. OF BEAMS	3 SPACE 1 EARTH
BW OR DATA RATE	2,400 bps
NO. OF CHANNELS	1,000
MODE	DUPLEX
S/N OR ERROR RATE	10-6
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	COMPUTER SERVICES
LMSC NO.	169
NO. OF TRANSMITTERS	50
NO. OF RECEIVERS	350,000
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	280 Kbps
NO. OF CHANNELS	1
MODE	SIMPLEX
S/N OR ERROR RATE	10-6
NOISE ENVIRONMENT	URBAN
USER IDENT	OCEAN FISHING
LMSC NO.	105
NO. OF TRANSMITTERS	1
NO. OF RECEIVERS	15,000
AREA OF COVERAGE	OCEAN
NO. OF BEAMS	1
BW OR DATA RATE	3 KHz
NO. OF CHANNELS	27
MODE	ONE WAY
S/N OR ERROR RATE	30 dB
NOISE	RURAL

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	AIRCRAFT COMMUNICATION
LMSC NO.	050, 051
NO. OF TRANSMITTERS	5,000
NO. OF RECEIVERS	5,000
AREA OF COVERAGE	GLOBAL
NO. OF BEAMS	3
BW OR DATA RATE	3 KHz
NO. OF CHANNELS	100
MODE	DUPLEX
S/N OR ERROR RATE	20 dB
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	AIR TRAFFIC POSITION
LMSC NO.	087
NO. OF TRANSMITTERS	1
NO. OF RECEIVERS	5,023
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	2,400 bps
NO. OF CHANNELS	50
MODE	ONE WAY
S/N OR ERROR RATE	10-6
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	AIRCRAFT PERFORMANCE
LMSC NO.	113
NO. OF TRANSMITTERS	1,300
NO. OF RECEIVERS	1
AREA OF COVERAGE	OCEAN
NO. OF BEAMS	1
BW OR DATA RATE	2,400 bps
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	10-6
NOISE	RURAL

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	CROP SURVEILLANCE
LMSC NO.	147
NO. OF TRANSMITTERS	3
NO. OF RECEIVERS	1
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	6 MHz
NO. OF CHANNELS	6
MODE	ONE WAY
S/N OR ERROR RATE	10-5
NOISE ENVIRONMENT	RURAL
USER IDENT	WEATHER STATION
LMSC NO.	081
NO. OF TRANSMITTERS	4,100
NO. OF RECEIVERS	1
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	300 bps
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	10-4
NOISE ENVIRONMENT	SUBURBAN
USER IDENT	SHIP COLLISION AVOIDANCE
LMSC NO.	098
NO. OF TRANSMITTERS	27,000
NO. OF RECEIVERS	27,000
AREA OF COVERAGE	OCEAN
NO. OF BEAMS	1
BW OR DATA RATE	1 KHz
NO. OF CHANNELS	1
MODE	SIMPLEX
S/N OR ERROR RATE	10-6
NOISE	RURAL

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	SHIP COMMUNICATION
LMSC NO.	090
NO. OF TRANSMITTERS	1,200
NO. OF RECEIVERS	1,200
AREA OF COVERAGE	OCEAN
NO. OF BEAMS	1
BW OR DATA RATE	3 KHz
NO. OF CHANNELS	100
MODE	DUPLEX
S/N OR ERROR RATE	20 dB
NOISE ENVIRONMENT	RURAL
USER IDENT	SHIP POSITION
LMSC NO.	095
NO. OF TRANSMITTERS	27,000
NO. OF RECEIVERS	1
AREA OF COVERAGE	OCEAN
NO. OF BEAMS	1
BW OR DATA RATE	2,400 bps
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	10-5
NOISE ENVIRONMENT	RURAL
USER IDENT	LAW ENFORCEMENT
LMSC NO.	002
NO. OF TRANSMITTERS	52
NO. OF RECEIVERS	52
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	2,400 bps
NO. OF CHANNELS	50
MODE	DUPLEX
S/N OR ERROR RATE	10-5
NOISE	URBAN

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	LAW ENFORCEMENT
LMSC NO.	004
NO. OF TRANSMITTERS	52
NO. OF RECEIVERS	52
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	6 MHz
NO. OF CHANNELS	3
MODE	SIMPLEX
S/N OR ERROR RATE	35 dB
NOISE ENVIRONMENT	URBAN
USER IDENT	LIBRARY NETWORK
LMSC NO.	065
NO. OF TRANSMITTERS	70
NO. OF RECEIVERS	70
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	4,800 bps
NO. OF CHANNELS	20
MODE	SIMPLEX
S/N OR ERROR RATE	10-6
NOISE ENVIRONMENT	URBAN
USER IDENT	STOCK QUOTATION
LMSC NO.	075
NO. OF TRANSMITTERS	1
NO. OF RECEIVERS	25×10^9
AREA OF COVERAGE	US
NO. OF BEAMS	1
BW OR DATA RATE	360 Kbps
NO. OF CHANNELS	1
MODE	ONE WAY
S/N OR ERROR RATE	10-6
NOISE	URBAN

CONVAIR INPUT VARIABLES	VALUE
USER IDENT	HYDROLOGICAL DATA
LMSC NO.	152
NO. OF TRANSMITTERS	25,000
NO. OF RECEIVERS	1
AREA OF COVERAGE	US
NO. OF BEAMS	3
BW OR DATA RATE	2.5 Kbps
NO. OF CHANNELS	3
MODE	ONE WAY
S/N OR ERROR RATE	10^{-4}
NOISE ENVIRONMENT	RURAL
USER IDENT	
LMSC NO.	
NO. OF TRANSMITTERS	
NO. OF RECEIVERS	
AREA OF COVERAGE	
NO. OF BEAMS	
BW OR DATA RATE	
NO. OF CHANNELS	
MODE	
S/N OR ERROR RATE	
NOISE ENVIRONMENT	
USER IDENT	
LMSC NO.	
NO. OF TRANSMITTERS	
NO. OF RECEIVERS	
AREA OF COVERAGE	
NO. OF BEAMS	
BW OR DATA RATE	
NO. OF CHANNELS	
MODE	
S/N OR ERROR RATE	
NOISE	

APPENDIX B

SYSTEMS DEFINITION

B.1 Terrestrial Long Haul Communication System Costs - In order to develop viable parametric cost data for use in determining system tradeoffs various types of transmission systems have been considered. Construction costs and annual costs for different kinds of transmission systems have been analyzed by several sources.[1,2,3,4]

Construction costs and recurring annual costs per channel mile for different communication media are shown in Figures B-1 to B-6. These figures were plotted from data published in Reference 3. In estimating system costs hypothetical systems were assumed. For the line-of-sight microwave relay system a length of 3,000 miles was assumed and an operating frequency of 7125-8400 MHz was utilized. The capital recovery is based on a useful life of 20 years and an interest rate of four percent.

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1. DCS Applications Engineering Manual-Volume I: System Planning and Performance Criteria, Defense Communication Agency, January 1968.

2. R. D. Chipp and T. Cosgrove, "Economic Analysis of Communication Systems", IRE Trans. Communication Systems, Vol. CS-10, pp. 416-421, December 1962.

3. T. Cosgrove and R. D. Chipp, "Economic Considerations for Communication Systems", IEEE Trans. Communications Technology, Vol. COM-16, No. 4, August 1968.

4. D. H. Homsher, Ed., Communication System Engineering Handbook, McGraw-Hill, 1967.

Leased facilities were considered by Cosgrove and Chipp in Reference 3. Data published in Reference 3 is plotted in Figure B-7. It was noted that the cost for a 60-channel system for 1000 miles would be $1,200,000 per year while the commercial leased rate for similar service would be $1,290,000 per year.

In using the cost data for systems to be installed in various geographic areas a "location factor" should be used to account for price variation due to varying equipment costs and transportation and labor rates. Typical location factors are listed in Table B-1[5].

Location	Factor
Alaska	
Adak	3.0
Anchorage	1.7
Fairbanks	1.9
Nome	2.3
Hawaii	
Coastal	1.4
Mountainous	1.6
Alabama	.9
Washington, D. C.	1.0
Colorado	1.05

Table B-1. Typical Location Cost Factor

The data plotted in figures applies to present-day equipment. These numbers are representative of present-day transmission system costs but these systems may be outmoded by new developments in long distance waveguide or surface wave transmission. Waveguides, usually of rectangular cross-section, are commonly used for antenna feed lines. The configuration most likely to be used for longer distance transmission employs a very low loss mode of propagation in circular cross-section guide. The design of economical repeaters and guide components is a problem which requires consideration.

5. DCA Cost Manual, Volume I, Communication Costs.

The G-Line or surface wave transmission line consists of a single wire with coaxial-to-surface wave transitions mounted at appropriate intervals. An estimate of the comparative costs of three hypothetical systems in the same situation is shown in Table B-2[6].

Coaxial Cable	Microwave Relay	G-Line
2.5	3	1

Figure B-2. Transmission Media Comparative Cost.

Guided wave transmission media have a significant advantage over radiated wave systems in that the frequency spectrum is conserved. The frequency spectrum of coaxial cable, waveguide or surface wave transmission lines is iterative in that an arbitrary number of guided wave transmission lines can be operated on the same frequency.

In order to utilize available cost data properly a knowledge of system implementation scheduling is required to take advantage of cost reductions which accrue because of technology advancement and mass production techniques. In some cases considerations other than dollar cost may predominate because of factors such as security or spectrum conservation.

6. T. Hafner, "Surface Wave Corridors" - Communications for High Speed Ground Transportation Systems. IEEE International Conference on Communications, June 9-11, 1969. CAT No. 69C29-Com.

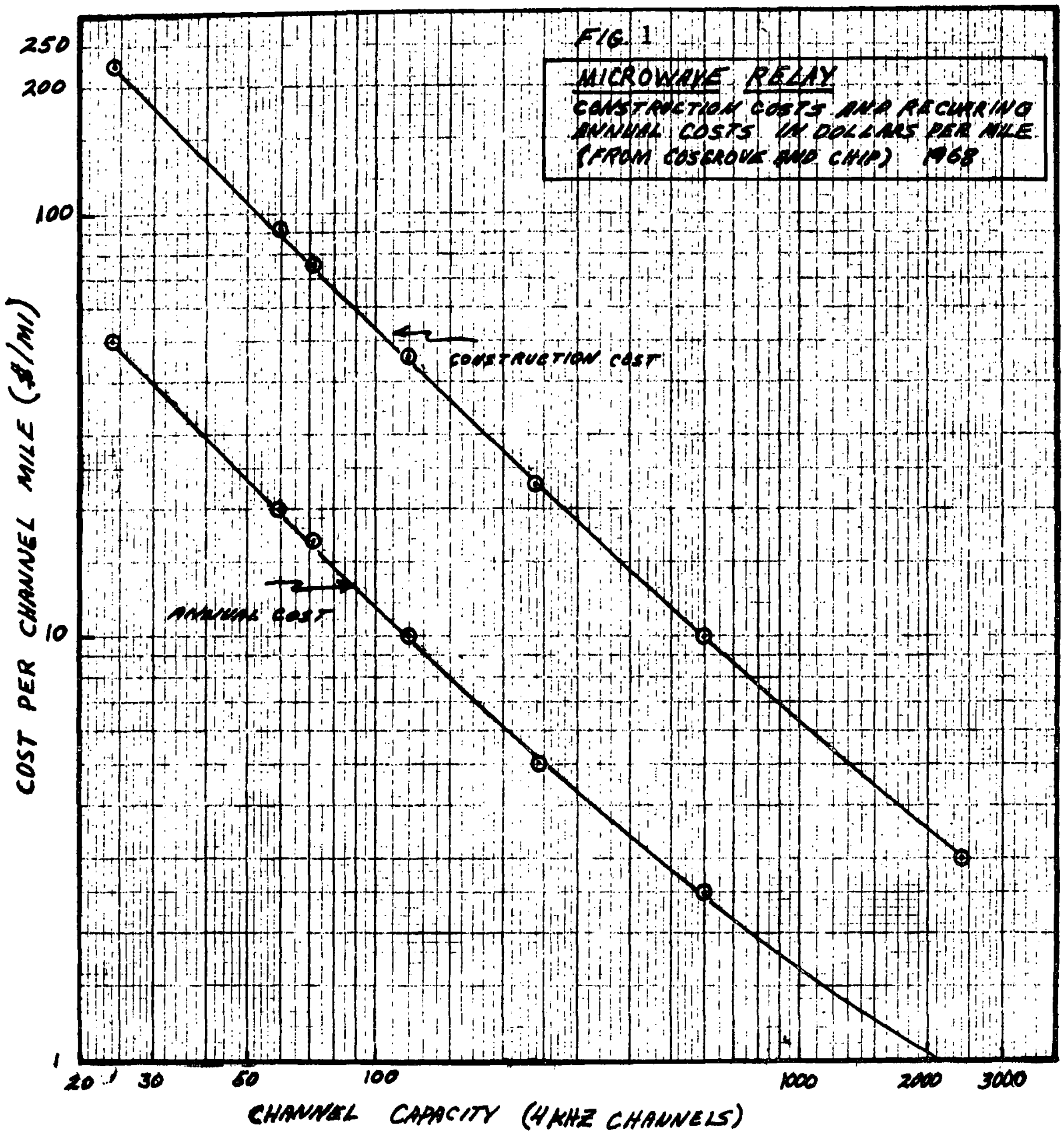


Figure B-1. Microwave Relay Costs

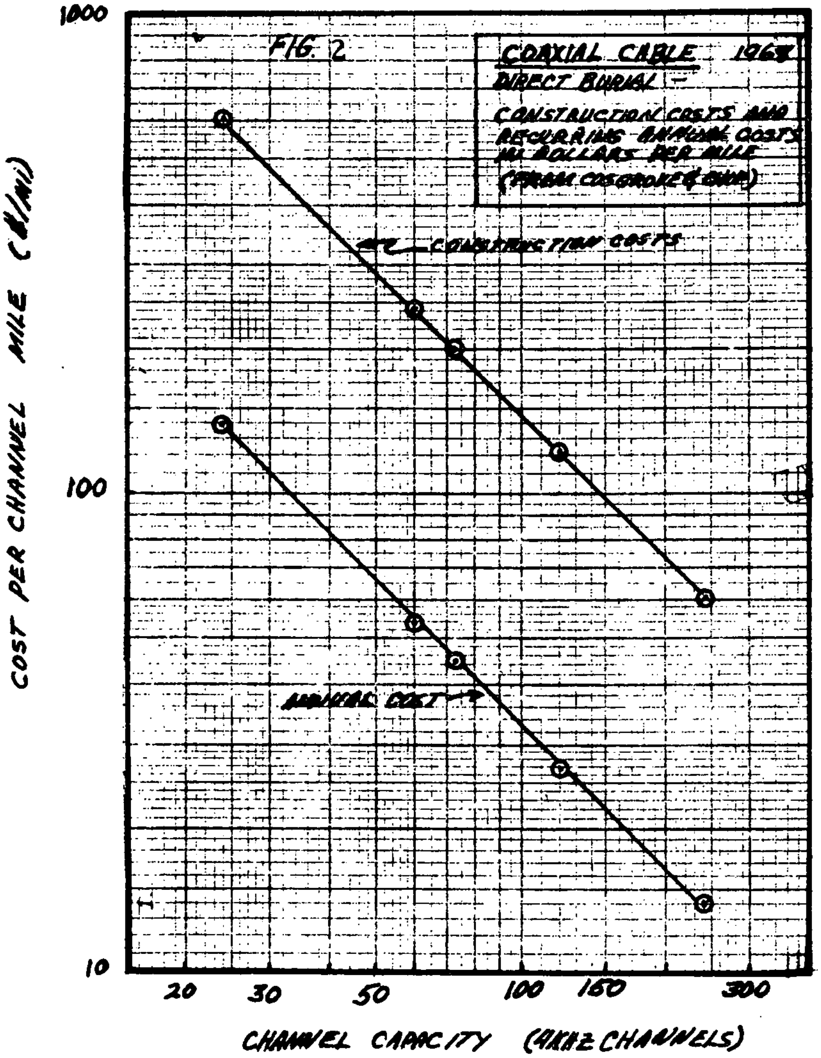


Figure B-2. Coaxial Cable Costs

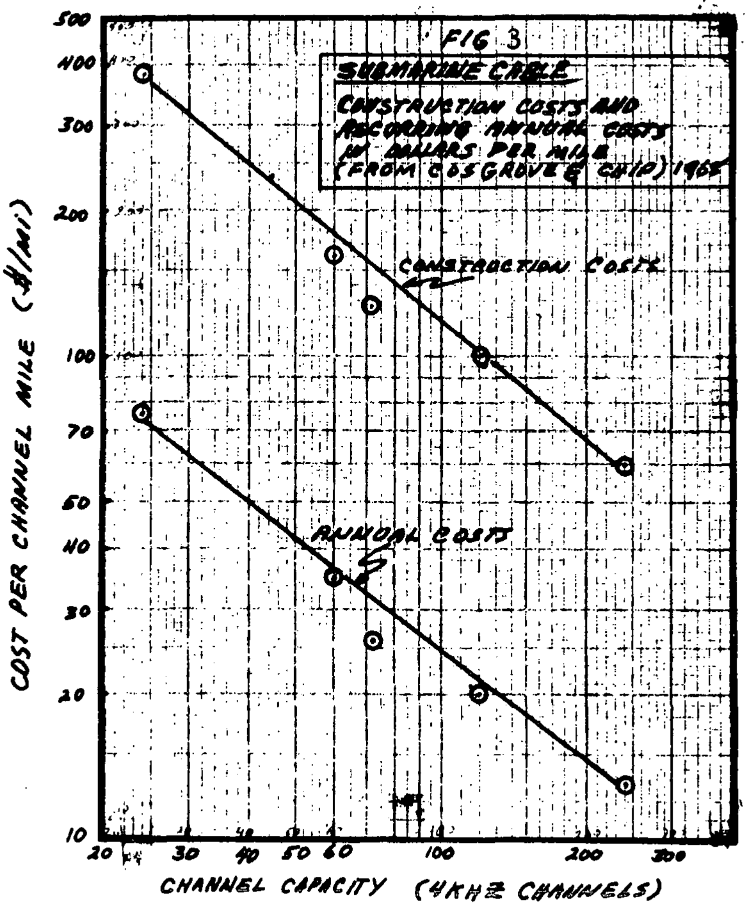


Figure B-3. Submarine Cable Costs

Figure B-4. HF Radio Relay Costs

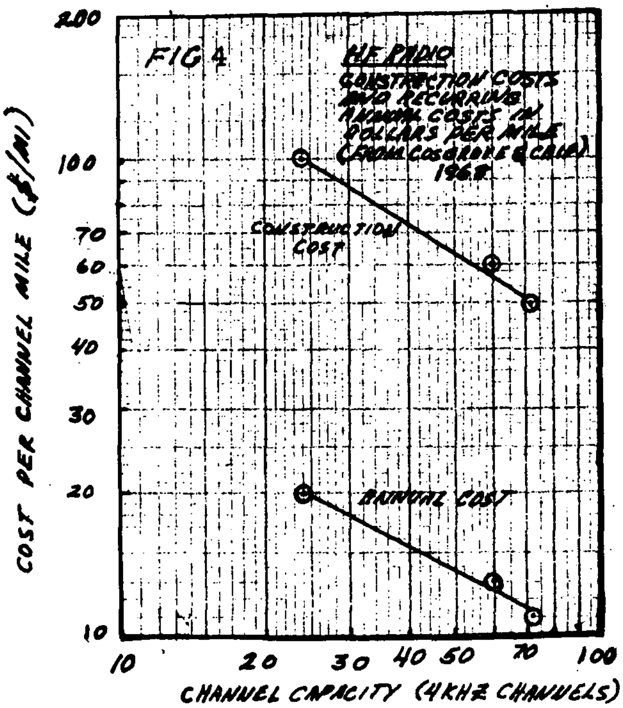
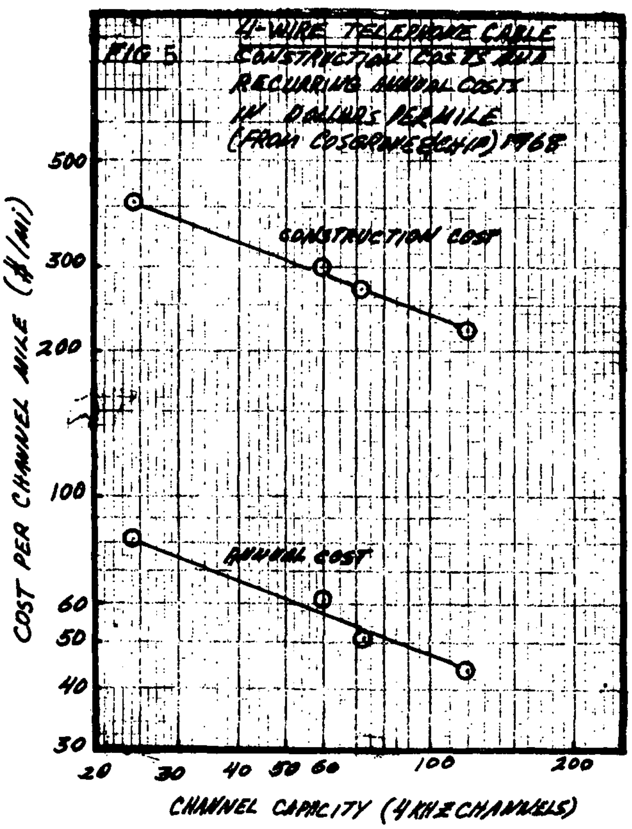


Figure B-5. 4-Wire Telephone Cable Costs



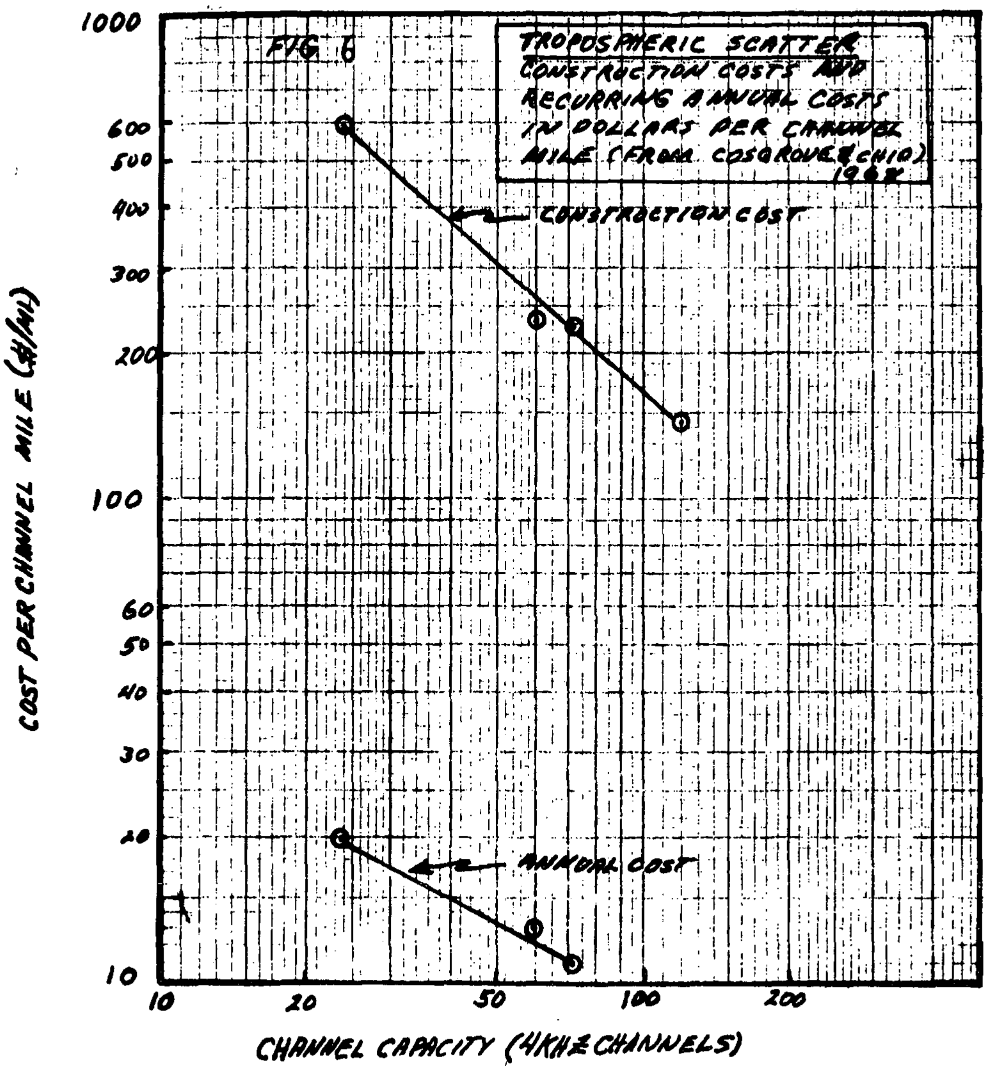


Figure B-6. Tropospheric Scatter Relay Costs

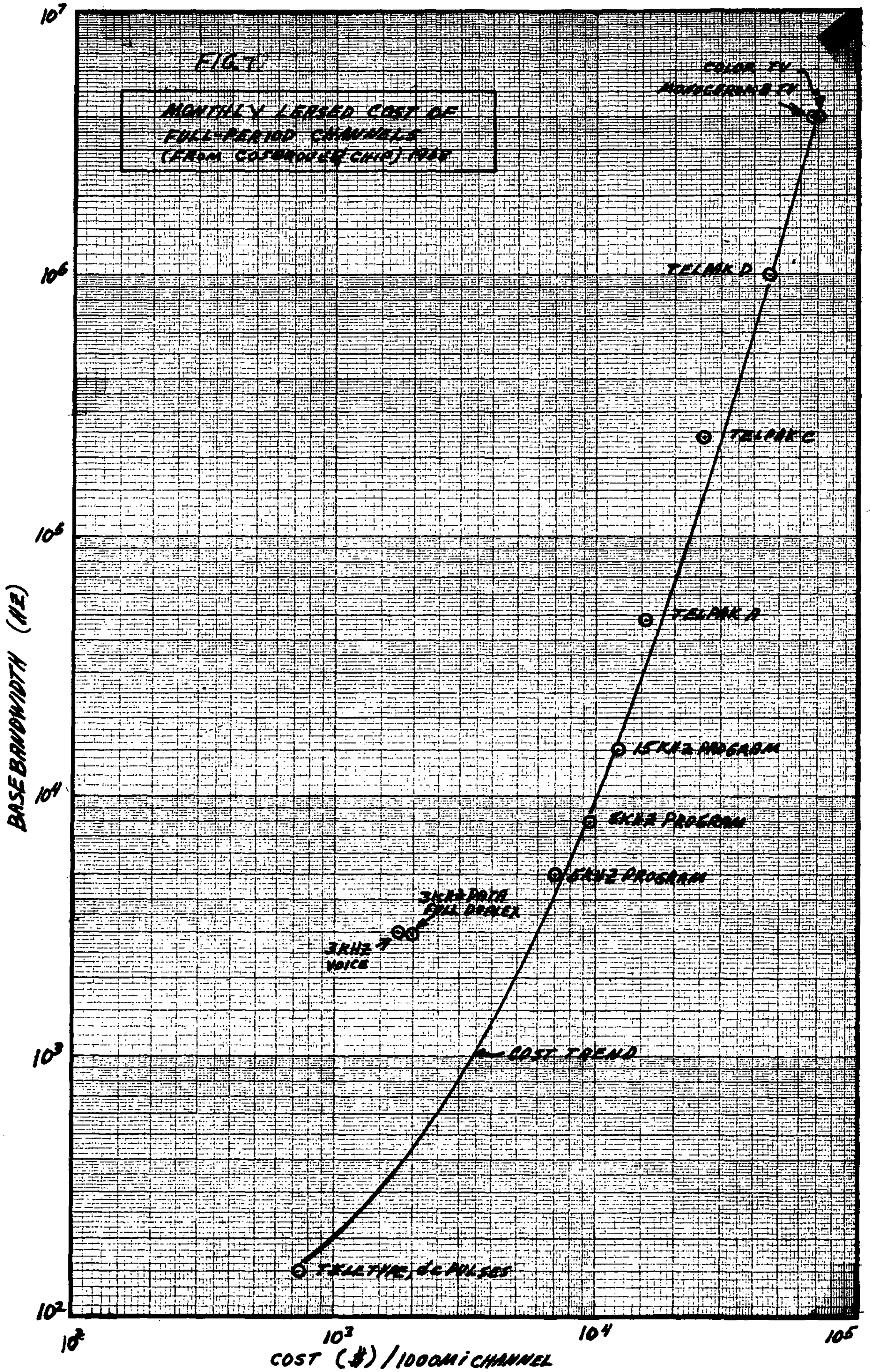


Figure B-7. Monthly Leased Cost of Full-Period Channels

B.2 MULTIPLE ACCESS TECHNIQUES

1.0 REVIEW OF MULTIPLE ACCESS TECHNIQUES

1.1 Introduction

The need for multiple access operation constitutes one of the most important factors influencing modulation system design. The multiple access problem is characterized by two particularly significant requirements:

1) The need to accommodate an appreciable range of user "sizes".

2) The requirement for the several different accesses to handle various kinds and volumes of traffic.

In addition to these are many concomitant considerations such as graceful degradation capability, flexibility to respond to changing traffic flow requirements (reallocation of satellite repeater resources on a demand basis for efficient use of satellite power), ease of ground terminal implementation and operation, etc.

Considerations of the above types in various forms are encountered constantly with respect to multiple access satellite communication, which is to say in all but the most elementary applications of communication, satellites. In the past several years much background has been compiled at Hughes in the solution of such problems.

The need to accommodate various user sizes and to handle different traffic loads through different accesses constitutes two especially significant multiple access requirements. That is, relayed signals carrying higher data rates and/or those destined for smaller-sized ground terminals require relatively large shares of down-link power. If efficient use is to be made of satellite power then the multiple access technique must lend itself to such apportionment.

Before embarking on detailed parameter studies, it is of interest to briefly review the characteristics of the four basic multiple access techniques:

1) Frequency division multiple access (FDMA),

2) Spread spectrum multiple access (SSMA),

3) Pulse address multiple access (PAMA), and

4) Time division multiple access (TDMA).

1.2 Multiple Access Techniques

1.2.1 Frequency Division Multiple Access

In FDMA each ground terminal is assigned a specific frequency band within the total bandwidth capacity of the repeater. Thus all users are contiguously stacked in non-overlapping bands within the passband of the repeater. Sufficient guard band between channels must be provided to eliminate undesirable adjacent channel interference effects. This basic concept is illustrated in Figure B-8. Each modulated up link carrier is received within its preassigned frequency band, amplified, and retransmitted with a frequency offset to permit simultaneous transmission and reception through a single antenna system.

If all up link carriers are of equal power, a single wide-band repeater without receiver channelization can be employed to provide the most simple of all multiple access repeater configurations.* However, if there is a large disparity among the individual up link power levels and receiver terminals, the available repeater RF power may not be shared in the most effective manner. This is of particular concern in a communication environment which includes a varied mix of large and small ground terminals. Repeater channelization and on-board control of down link power may be required to achieve efficient operation of the repeater.

A linear repeater with adequate dynamic range can relay any type of FDMA modulated input signal, including amplitude modulation, with negligible distortion and interference, provided there is no crosstalk between the up link input signals. Studies of present and planned communication satellite networks indicate that angle modulation techniques will be used exclusively. This eliminates the need for processing AM signals through a linear repeater. Studies have shown that better dc to RF conversion efficiency can be obtained with a nonlinear repeater as compared to a linear repeater.

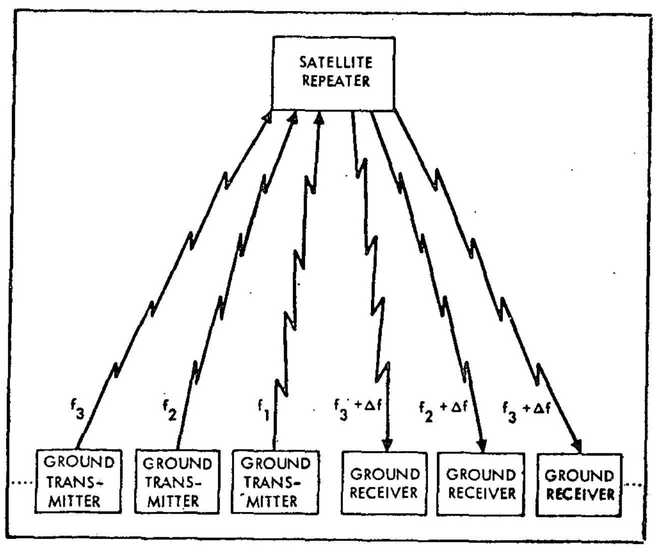


Figure B-8. Schematic Representation of FDMA Links

*This implies equal sensitivity for all ground terminals.

When two or more signals simultaneously pass through a FDMA repeater, nonlinearities in the repeater will produce intermodulation distortion which will result in a multiplexing loss of -1.3 dB and which may also interfere with the desired signal. In the case of a hard limiting repeater, the desired signal to intermodulation noise ratio will be 9.0 dB. This ratio is shown in Figure B-9 (Reference 1). It is interesting to note that it is almost independent of the channel spacing. The dotted curve corresponds to Cahn's result for rectangular input channels (Reference 2). When only a few signals are present, it may be possible to select specific carrier frequencies for which there will be little or no inband intermodulation products. When there are a large number of signals, the repeater bandwidth required for intermodulation free channels becomes prohibitively large and impractical.

When the required detection signal-to-noise ratio at the ground terminal approaches the signal-to-intermodulation ratio, the repeater transmitter power requirement tends toward infinity. To maintain the power requirement within acceptable bounds, it may be necessary

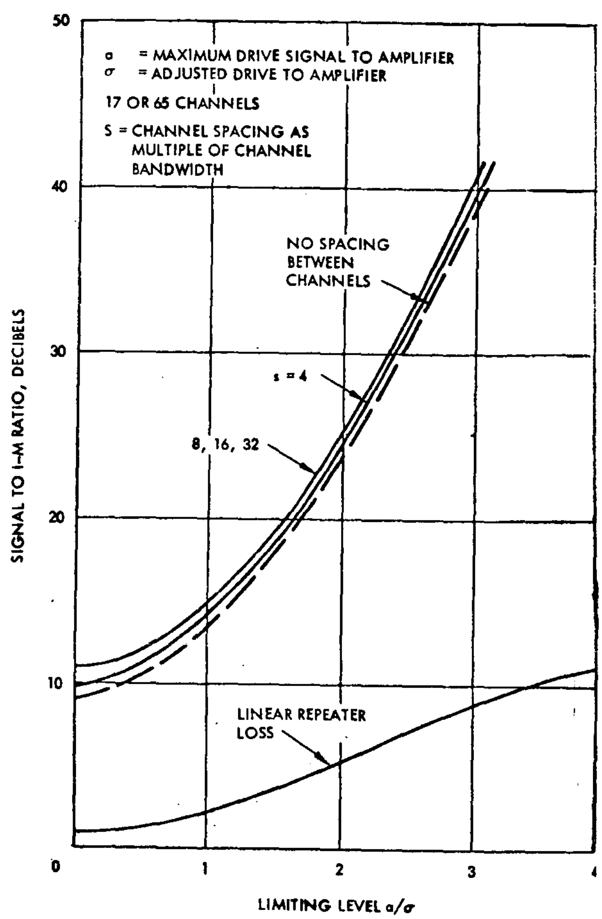


Figure B-9. Signal-to-Intermodulation Spectral Density Ratio in Nonlinear Amplifier to back off from hard limiting operation. Reducing the input drive signal will improve the signal-to-intermodulation ratio. However, as shown in Figure B-9 the output power will decrease approximately in proportion to the degree of backoff. This leads to an optimization problem in which the best degree of backoff is selected for a particular detection signal-to-noise ratio requirement.

Another consequence of operating with a nonlinear repeater is signal suppression. When a strong and weak sinusoidal signal are simultaneously present in the repeater, the output power ratio of the two signals will differ from the input power ratio. With a hard limiting repeater, the weaker signal is suppressed an additional 6 dB below the input power ratio when the larger signal is greater than the smaller by 6 dB or more. If the larger signal can be represented by wide-band noise, the small signal will be suppressed by only 1 dB. When many independent input signals of nearly equal power are present at the input to the repeater, the summed signals will tend to act like gaussian noise, and therefore any one of the signals will be suppressed by only 1 or 2 dB.

1.2.2 Spread Spectrum Multiple Access

In SSMA the repeater relays wide-band noise-like signals. Each up-link signal occupies the entire bandwidth of the repeater. Thus all signals simultaneously overlap each other in the same frequency band. At the ground terminal each message or information bit of a message is modulated with a wide-band pseudo-noise (P-N) digital bit stream. Each terminal in the net is assigned a different and orthogonal P-N sequence. To establish communication with a particular receiving terminal, the transmitter modulates the message sequence with the P-N sequence assigned to the receiving terminal. The receiver detects the message by a correlation process in which the receiving terminal multiplies the incoming P-N sequence by its assigned sequence and integrates the product for a time equivalent to an information bit (see Figure B-10. In order to accomplish this correlation process, the receiver P-N code generator must be in synchronization with the incoming P-N sequence.

Link synchronization is accomplished by initiating each transmission with a sync interval. This preamble provides sufficient time for the receiver P-N code generator to search in time until its code sequence coincides with the incoming bit stream, at which time link synchronization has been achieved. Thereafter, automatic lockon circuitry maintains synchronization during message transmission. If the P-N codes for the individual terminals are truly orthogonal (i.e., exhibit zero correlation with respect to each other) each receiving terminal can detect its message without interference from all of the other overlapping signals in the same transmission bandwidth. For a large number of users, complete orthogonality may require network synchronization.

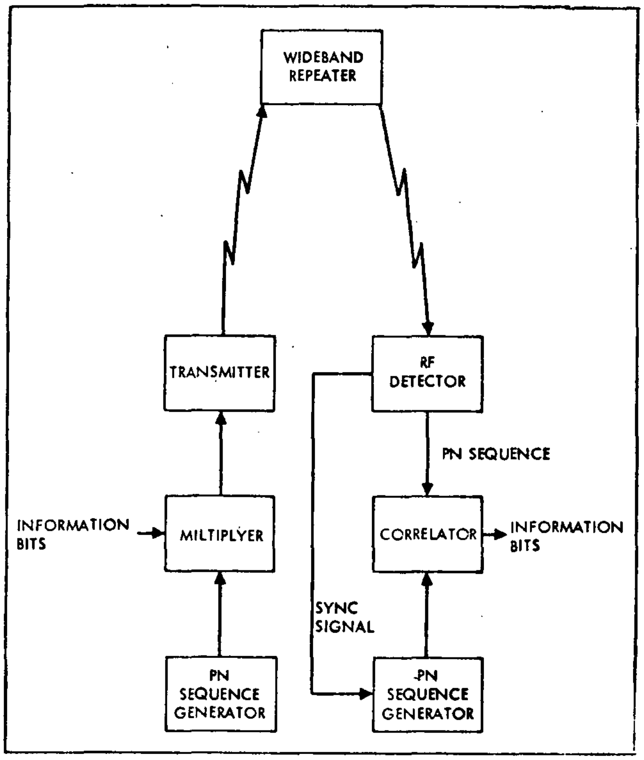


Figure B-10 Elements of SSMA Link

Since the up-link signal structure resembles noise, signal suppression effects in a hard limiter will be less severe than for FDMA. If the power in any one signal is small compared to sum of all other signals, the suppression effect will be negligible and only the 1 dB multiplexing loss need be assigned to the hard limiter. Also, with SSMA the intermodulation product created in a nonlinear repeater tends to be more uniformly spread across the entire band, and consequently the correlation process in the receiver will provide significant processing gain against intermodulation signal energy.

SSMA imposes a fairly complex coding and decoding requirement on the ground terminals. Each station must include not only code generating equipment for its own receiver but also transmitter code generating equipment for all other co-active terminals. For short message transmissions, link synchronization time might exceed the message time, and thus might lead to poor overall network efficiency. Overall network sync can be employed to minimize link synchronization time. However the satellite must then be capable of supplying a suitable sync signal to the entire net.

1.2.3 Pulse Address Multiple Access

Each terminal station is assigned a unique set of pulses within a group of transmission bands. A message bit is represented by the complete set of pulses assigned to each of the terminals. Each code set can be represented as a waveform on a frequency-time plane as shown in Figure B-11. The set of pulses representing a message bit is termed a transmission frame. Each terminal in the net is identified by the unique code pulses comprising its transmission frame. In the basic PAMA system the frame code is invariant, and the frame transmission rate corresponds to the information bit rate associated with the transmitting terminals.

Transmissions are initiated with a short sync preamble that permits the receiver to achieve bit synchronization. The receiver is equipped with a matched filter which yields optimum processing of the received waveform. This matched filter is usually implemented by tapped delay lines or shift registers arranged to sum the individual pulse energies in the received waveform (Figure B-12. Each receiver must be equipped with the unique "matched filter" corresponding to its address, and each transmitter must be capable of generating the frame codes for all co-active terminals.

No particular time slots in the frequency-time plane are exclusively assigned to any one terminal in the net. In practice, pulses associated with transmission frames from different terminals may overlap each others frame and tend to introduce errors in the received message. For a specified number of network users, the frame code and "matched filter" in the receivers are designed to cope with an acceptable degree of pulse overlapping when all links in the net are active.

One of the most characteristic features of PAMA net is its behavior under different system loading conditions. This behavior

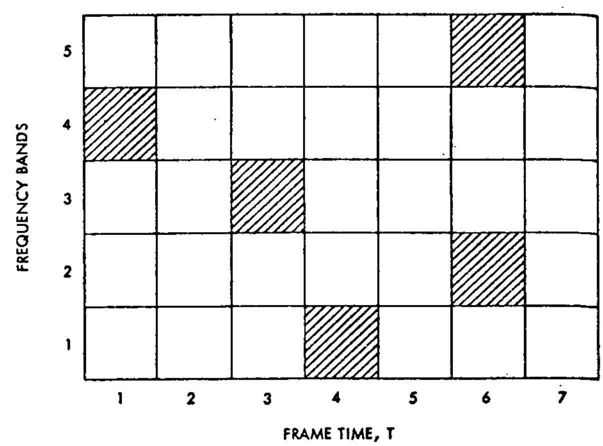


Figure B-11. Representative Transmission Frame for PAMA

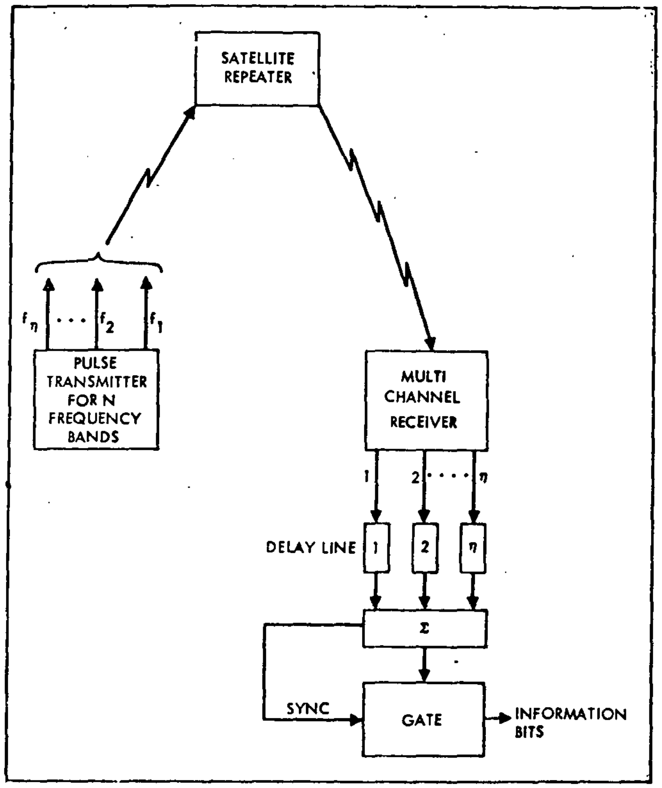


Figure B-12. Elements of PAMA Link

is represented in Figure B-13 which illustrates the error rate as a function of the number of users for a system based on utilizing an SHF bandwidth of 100 MHz. With less than 125 users, the error rate is constant and is determined by the thermal noise in the RF links. As the number of users increases, interference at any one receiver (due to the presence of undesired pulses intended for other receivers) will increase rapidly with the number of simultaneous users. Thus for a small number of users the system error rate is determined by thermal noise and can be improved by increasing transmitter power or receiver sensitivity. However, with a large number of users, the error rate is determined by the system self-interference and cannot be significantly improved by increasing the signal-to-noise ratio in the RF link.

Because PAMA exhibits such a rapid deterioration of performance with increasing number of simultaneous users, it finds its most useful applications in a net consisting of a large number of users with low average duty factor per user. Assuming an average duty factor of 10 percent permits a ten-fold increase in the number of simultaneous users shown in Figure B-13.

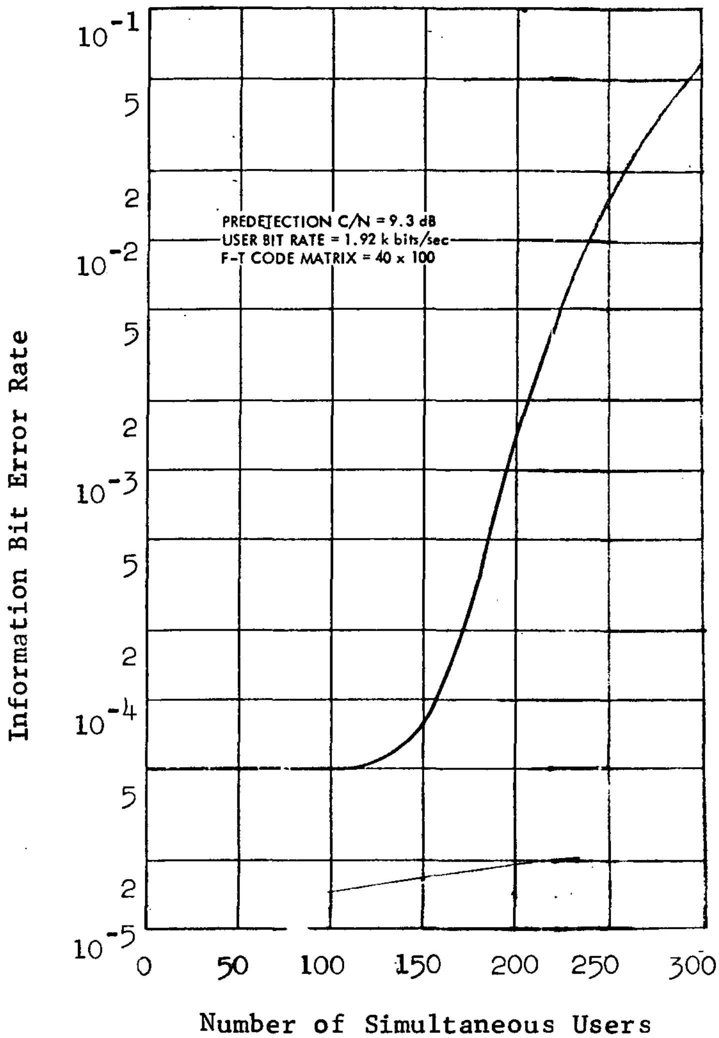


Figure B-13. Characteristics of Representative PAMA Link

1.2.3.1 Network Timing and Link Synchronization

Since the frame codes themselves will represent the terminal addresses, network synchronization is not required in PAMA. However, with network sync it is possible to reduce the amount of self-interference in the net and to improve performance by 2 or 3 dB (Reference 3). This improvement results from the fact that network synchronization permits a greater selection of noninterfering codes from a class of available codes than does a nonsynchronous net.

Link bit synchronization is required for optimum time gating of the receiver so that noise and interference can be minimized. Link synchronization can be readily achieved by initiating each transmission with a series of information "ones" that can be recognized by the receiver matched filter as the synchronization sequence. The sync preamble can be coded into a Barker sequence to provide correlation gain for a sync pulse at some submultiple of the information bit rate. This may permit more rapid synchronization in a noisy environment. Once bit sync has been established, automatic lockon circuitry can maintain synchronization during message transmission.

1.2.3.2 Linear Versus Limiting Repeater

In an ideal linear repeater the PAMA signals will be relayed without distortion or additional interference and will be degraded only by the signal-to-noise ratio developed at the receiver. In a hard limiting repeater, intermodulation and signal suppression will tend to degrade system performance. However, because of its greater dc to RF conversion efficiency, it may be advantageous to employ a limiting type of repeater.

It is difficult to estimate the effects of a nonlinear repeater on PAMA signals. These signals are characterized by very narrow pulse widths (typically 0.5 microsecond) with a low duty factor. Since the frame codes will usually employ a relatively large number of frequencies and time slots, more than one frequency may be simultaneously present in the receiver, and therefore intermodulation products will be generated. However, because of the low duty factor of the pulses it can be expected that at times only one or two pulses at different frequencies will be present simultaneously, and therefore intermodulation effects should be less than those experienced with constant envelope signals. For similar reasons signal suppression effects due to the momentary presence of a strong pulse signal will be diluted because of the short duty factor of the pulses.

1.2.4 Time Division Multiple Access

In TDMA each terminal in the network is time sampled at the Nyquist rate corresponding to twice the highest information rate at the transmitting terminal. The complete network is synchronized so that each terminal has exclusive use of the repeater during the sampling time (see Figure B-14. Each terminal is assigned a specific time slot within the sampling frame period. The terminal receivers include synchronized gating circuitry which permits each receiver to extract its time addressed pulse with maximum signal-to-noise ratio.

It is important to note that for TDMA the satellite processes each up-link signal at separate time intervals. Hence there are no intermodulation and signal suppression effects in the repeater. Consequently TDMA is potentially capable of providing maximum communication efficiency through the repeater.

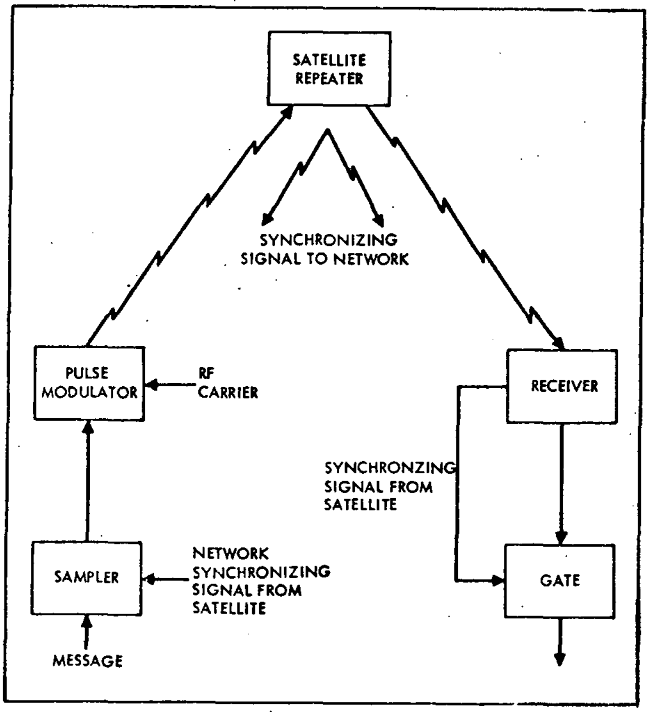


Figure B-14. Elements of TDMA Link

The primary disadvantages of TDMA are the requirement for network synchronization. The need for rigid network time synchronization imposes some significant disadvantages in terms of network flexibility. For example, addition of new terminals to a network previously designed to operate at maximum efficiency would require resynchronizing the entire net. If spare time slots are provided for growth in the original net, the repeater would not be operating at maximum efficiency since its noise bandwidth would have to be increased to support the additional time slots. Also, because the slot width is dependent not only on the number of terminals within the net but also on the data transmission rate, it is difficult to accommodate terminals with widely varying data transmission rates efficiently in a single net. Depending on the sampling rate requirements, it may be advantageous to provide for high and low data rate terminals on separate repeater channels.

In order to achieve and maintain network synchronization, a common timing signal must be available to all stations in the net. This signal can be generated on the ground, modulated on an up-link carrier, and retransmitted to the net via a reserved channel in the repeater. Preferably, a stable on-board beacon signal generator modulated with timing code would provide the required sync signal by direct transmission from the satellite.

In practice each terminal is adjusted with respect to the frame sync signal received from the satellite so that its transmission time occurs within its assigned time slot. This can be accomplished at the terminal by simultaneously monitoring both the sync signal and the terminal transmissions as relayed by the satellite. It is estimated that timing accuracies of about 50 nanoseconds would represent the present and near future state-of-the-art for an SHF network sync signal.

1.3 Comparison of Multiple Access Techniques

It is convenient to subdivide the four multiple access techniques into:

A) Those utilizing continuous carrier waveforms (FDMA and SSMA), and

B) Those with pulse waveforms (TDMA and PAMA).

Since a carrier is always present with the information in Class A, power distribution and control is a primary consideration. If the communication network is composed of ground receiver stations with various sensitivities (characterized by antenna size, noise figure, and effective noise temperature), Class A systems require some method of allocation of the effective radiated power (ERP) from the satellite. This allocation, for simplicity, could be linearly proportional to the received signal at the satellite repeater. The ground transmitters must individually adjust their power output for variations in atmospheric attenuation so that the ERP of the satellite is properly distributed. The linear distribution requires that the traveling wave tube amplifier must operate well below its saturation level where power amplification is not efficient. For more efficient power amplification, the TWT may be operated in a near saturated state (hard limiting). However, this requires monitoring and controlling the power level of all transmitter terminals so that large signals will not suppress smaller ones (power control), also intermodulation distortion must be limited to acceptable levels.

Power control is not necessary for TDMA while some power control may be necessary for PAMA as the number of users and their corresponding information rates increase to the range where considerable overlap, in time, of user signals occur. TDMA requires synchronization of the entire communication network for providing non-overlapping transmission time slots. The synchronization may be provided by timing equipment aboard the satellite. PAMA requires a sync signal within each link in order that the orthogonally coded information may be extracted from the receiver signal.

Class A can be further divided on the basis of whether the communication links are spectrally separated (FDMA) or each link uses the entire, available bandwidth (SSMA). Class B is divided on the basis of whether the data transmission on individual links overlap in time (PAMA) or they do not (TDMA). These further divisions are important when considering user assignment and interference between communication links. FDMA requires assignment of frequency slots on either fixed or demand basis (network control). In a non-linear

TWT, FDMA signals will be mixed causing intermodulation noise to other links and suppression of the weaker links (power robbing). TDMA also requires assignment of time slots but has the advantage of no interference between links. SSMA and PAMA have the disadvantage of increasing interference with the number of users when a non-linear satellite power amplifier is utilized.

Summarizing, some of the most important criteria for comparing the relative merits of the various multiple access techniques are:

1) Signal interference (intermodulation).
2) Signal suppression (power robbing).
3) The necessity of allocating frequency or time slots (network control).
4) Power control.
5) Graceful degradation.
6) Power amplifier efficiency of TWT.
7) Link synchronization.
8) Network synchronization.

The characteristics of the various multiple access techniques are summarized on a preliminary qualitative basis as shown in Table B-3. Comparisons are based on both linear and limiting type of repeaters. For FDMA, significant performance differences can be expected between a linear and limiting repeater. However, for TDMA only one signal is present at any one time, and therefore the intermodulation and signal suppression effect usually associated with limiting repeater is not present. Becuase of its higher dc to RF conversion efficiency, a limiting repeater can be recommended for TDMA without more detailed trade studies. In PAMA the signal code structures will tend to dilute the interference and suppression effects associated with a limiting repeater. More detailed study is required to define these effects for PAMA. It may be anticipated that a limiting repeater operating somewhat below full saturation would represent the best compromise for PAMA and FDMA.

TABLE B-3 GROSS PERFORMANCE COMPARISON OF MULTIPLE ACCESS METHODS

Type	Multiplexing Technique	Network Control	Signal Interference	Power Robbing	Network Sync	Link Sync	Power Control	Graceful Degradation	TWT Power Amplifier Efficiency
FDMA (Linear)	Separate channel frequency assignments	Yes	None	None	No	No	No	No	Low
FDMA (Limiting)	Separate channel frequency assignments	Yes	-9 dB (intermodulation)	-6 dB maximum	No	No	Yes, or channelization	No	High
SSMA (Linear)	Overlapping noise-like signals in single band	No	None for orthogonal signals	None	No[(1)]	Yes	Yes	Yes	Low
SSMA (Limiting)	Overlapping noise-like signals in single band	No	Some	Some	No[(1)]	Yes	Yes	Yes	High
TDMA (Limiting)	Time commutation	Yes	None	None	Yes	No	No	No	High
PAMA	Time/ frequency codes	No	Some	Low	No	Yes	Some	Yes	Medium

[(1)] May be required for complete orthogonality.

2.0 MULTIPLE ACCESS SYSTEMS - ANALYSIS AND PARAMETRIC DATA

2.1 Introduction

In this part the characteristics of the various multiple access techniques are examined in greater detail. For illustrative purposes, initial performance analysis is made on the basis of meeting a simple but hypothetical communication requirement consisting of M number of identical digital modulated voice links.

2.2 Frequency Division Multiple Access

In FDMA, individual channels occupy adjacent portions of the frequency spectrum, and the repeater amplifies and retransmits the complete up link spectrum to the ground terminals. If the repeater operates linearly, the retransmitted spectrum has the same relative power distribution among the channels as in the up link spectrum. However, the power available for any one down link signal is inversely proportional to the total power at the input to the repeater. Thus, up line noise robs power from the down link retransmissions.

Alternatively, the repeater can be operated in a nonlinear mode, where a higher level of output power is available. However, the limiting action of the repeater introduces intermodulation among the channels which appears as additive noise to the ground receivers. In addition, individual channel power levels are reduced, and stronger up link channels tend to further suppress weaker channels in the down link transmissions. As in linear repeaters, input noise acts to rob the available repeater power from the channels.

2.2.1 Performance Analysis, Linear Repeater

Consider first a linear repeater. The signal power, P_{ri}, received at the ground in the i^{th} link is

$$P_{ri} = P_T\left(\frac{P_i}{\Gamma}\right)A = AP_i\left(\frac{P_T}{\Gamma}\right) \tag{2-1}$$

where

P_i = i^{th} link power received at repeater input

P_T = repeater transmitter power

Γ = total power input to the repeater (sum of all up link signal and noise power)

A = total down link transmission loss (space loss plus Spacecraft and Ground antenna gains)

The total noise power received at the ground terminal in the i^{th} channel

$$N_{ri} = N_u W_i \left(\frac{AP_T}{\Gamma}\right) + C_i \left(\frac{AP_T}{\Gamma}\right) + N_d W_i \tag{2-2}$$

where

N_u, N_d = repeater and ground noise spectral density level, respectively

C_i = crosstalk in i^{th} channel due to other channels

W_i = i^{th} channel bandwidth

The resulting signal-to-noise ratio (S/N) for the i^{th} channel is then

$$\left(\frac{S}{N}\right)_i = \frac{AP_i P_T}{N_u W_i P_T A + C_i P_T A + N_d W_i \Gamma} \tag{2-3}$$

Solving for the transmitter power to achieve a given $(S/N)_i$ yields

$$P_T = \frac{\frac{1}{A}\left(\frac{S}{N}\right)_i N_d W_i \frac{\Gamma}{P_i}}{1 - \left(\frac{S}{N}\right)_i \left[\alpha_i\right]} \tag{2-4}$$

where

$\alpha_i = \dfrac{N_u W_i + C_i}{P_i}$ = up link noise plus crosstalk-to-signal ratio in i^{th} channel

$\Gamma = \sum_{j=1}^{M} \left[P_j + N_u W_j + C_j\right]$ = total up link power

M = number of channels

Equations (2-4) and (2-8) are plotted in Figure B-15 for parameter values illustrated.

2.2.3 Crosstalk and Channel Spacing

The crosstalk power represents interference due to spillover of adjacent channels and depends upon the spacing of the channels and their power levels. If gaussian channels spectra are assumed, with bandwidths set to the inflection points of the spectrum, the resulting crosstalk-to-signal ratio of two neighboring equal power channels on a third middle channel is obtained by evaluation of

$$\left(\frac{C}{P}\right) = \left(\frac{P_1}{P_0}\right) \frac{2\int_{\frac{2x}{w}-1}^{\frac{2x}{w}+1} f(y)\,dy}{\int_{-w}^{w} f(y)\,dy} \tag{2-9}$$

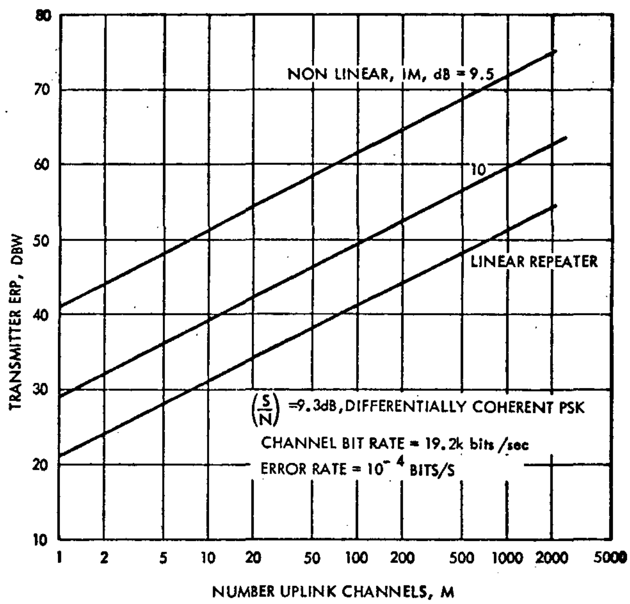


Figure B-15. Transmitter Power Versus Number of Simultaneous Digital Voice Links for Linear and Nonlinear Repeater

2.2.2 Performance Analysis, Nonlinear Repeater

When operated in a saturating mode, intermodulation and suppression effects are introduced into the previous equations, depending upon the type of frequency characteristics of the channels and the degree of saturation. For gaussian shaped channel spectra, the effect is to suppress the available repeater power by 0.78 (1 dB). The interference in a bandwidth W_i is given by

$$(0.78)N_u W_i \left(\frac{AP_T}{\Gamma}\right) + (0.78)C_i \left(\frac{AP_T}{\Gamma}\right) + N_d W_i + \frac{(\beta)P_T W_i}{B} \tag{2-5}$$

where β is the intermodulation coefficient, B is the total repeater bandwidth and the last term represents the added intermodulation noise. The resulting S/N in a ground terminal of bandwidth W_i is

$$S/N = K_1 \frac{(0.78)AP_T P_i}{(0.78)N_u W_i AP_T + 0.78\, C_i AP_T + \frac{\beta AP_T W_i \Gamma}{B} + N_d W_i \Gamma} \tag{2-6}$$

where K_1 is a suppression factor to account for channel power suppression arising from power unbalance in passing through a hard limiter. This factor basically represents an increase in power margin that must be made available for weak up signals when in the presence of strong signals. This suppression may be as much as -6 dB when the strong signal is more than 6 dB greater than the weak signal. Solving (2-6) for repeater power yields

$$P_T = \frac{\frac{1}{A}\left(\frac{S}{K_1 N}\right) N_d W_i \left(\frac{\Gamma}{P_i}\right)}{0.78 - \frac{S}{K_1 N}\left[0.78\alpha_i + \beta\left(\frac{Wi\Gamma}{BPi}\right)\right]} \tag{2-7}$$

For equal channels, Equation 2-7 reduces to

$$P_T = \frac{\frac{1}{A}\left(\frac{S}{K_1 N}\right) N_d W\, M(1+\alpha)}{0.78 - \left(\frac{S}{K_1 N}\right)[\beta + 0.9\alpha]} \tag{2-8}$$

where

P_1/P_0 = the power unbalance of the interfering channels to the middle channel

$f(y) = e^{-y^2/2}$

w = spectrum bandwidth

x = channel spacing in multiples of half bandwidths

Equation 2-9 is plotted in Figure B-16 for different degrees of unbalance. The results indicate that with FDMA operation, having at most a 10 dB unbalance, a center-to-center channel spacing of approximately twice the channel bandwidth is needed to obtain crosstalk ratios of less than -15 dB.

2.3 Spread Spectrum Multiple Access

In spread spectrum multiplexing, binary information on each channel is modulated on to a wide band digital sequence. This sequence then phase modulates an RF carrier, and is transmitted to the intended ground station through the repeater. Each up link carrier uses its own distinct sequence, which is chosen to have low correlation with all other sequences being used. Information is retrieved at the ground terminals by correlating with the proper sequence. By modulating on to a high rate digital sequence, the binary information in a particular up link is effectively spread over a wide bandwidth. Since only the interference

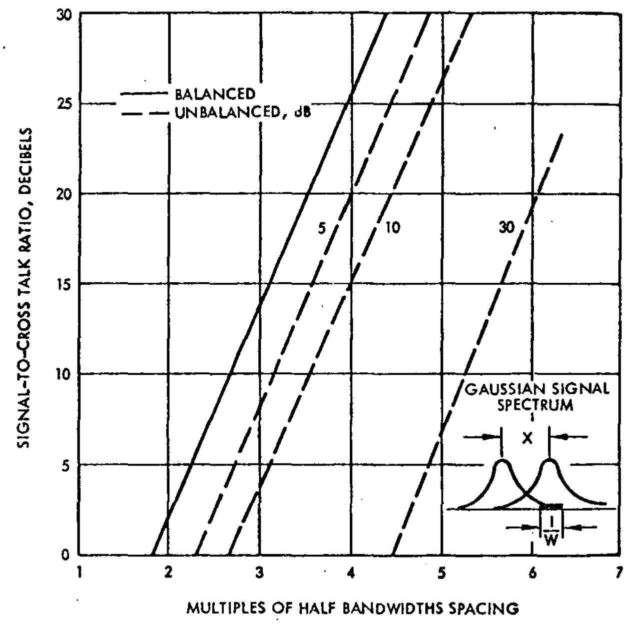


Figure B-16. Signal-to-Crosstalk Ratio Between Up Link Signals Versus Frequency Spacing in the information bandwidth ultimately affects the probability of detection, this technique can provide antijam protection. One may alternatively view SSMA as a coding of information bits into binary words and achieving an improvement in detectability in accordance with the number of "chips" per bit.* All channels use the same nominal rf carrier frequency. The wide band RF signals are superimposed upon each other, and each appears as an additive source of noise during transmission. If the binary sequences for the different links are orthogonal, the crosstalk interference can be eliminated by the receiver correlation process.

2.3.1 Performance Analysis, Linear Repeater

Consider the case where the repeater operates linearly. If P_i is the power in the i^{th} channel at the repeater, the received energy, E_i, at the ground terminal after correlation with the proper sequence is

$$E_i = P_i \tau \left(\frac{AP_T}{\Gamma}\right) \tag{2-10}$$

where

P_T = repeater power

A = transmission loss (including satellite and Gnd Antenna Gains)

Γ = total up link power

$= \sum_j [P_j + N_u W_j]$

P = power of the i^{th} channel

τ = time per information bit

W_j = RF bandwidth of the channel

N_u = repeater noise density

The interference power P_c after receiver correlation is

$$P_c = \sum_{\substack{j \\ j \neq i}} (\rho_j E_i)^2 + N_d E_i + N_u E_i \left(\frac{AP_T}{\Gamma}\right) \tag{2-11}$$

*"Chip" refers to pulse in pseudo-random sequence.

where

ρ_j = cross-correlation coefficient of the j^{th} channel with the i^{th} channel

N_d = receiver noise spectral density

The corresponding detectability, d_i, of the receiver, defined as the ratio received energy squared to the interference power, is then

$$d = \frac{E_i^2}{P_c} = \frac{E_i^2}{\sum_j \left(\rho_j^2 E_i E_j\right) + N_d E_i + N_u E_i \left(\frac{AP_T}{\Gamma}\right)}$$

$$= \frac{E_i}{\sum_j \rho_j^2 E_j + N_d + N_u \left(\frac{AP_T}{\Gamma}\right)} \tag{2-12}$$

For gaussian noise interference, the parameter d uniquely determines the channel error probability, for example, d = 9.3 dB corresponds to an error probability of 10^{-4}.

Assuming equal channel power, P, bit rate, τ, and correlation coefficient, ρ, and solving for the repeater power, P_T, we have

$$P_T = \frac{\left(\frac{d}{A}\right) N_d \left(\frac{1}{\tau}\right) (M+\alpha_W)}{1 - d\left[(M-1)\rho^2 + \alpha_\tau\right]} \tag{2-13}$$

where

M = number of spread spectrum channels

$\alpha_W = N_u W/P$ = up link NSR in RF band W

$\alpha_\tau = N_u/\tau P$ = up link NSR in band $1/\tau$

2.3.2 Performance Analysis, Nonlinear Repeater

For a nonlinear repeater, Equation 2-13 must be modified to

$$P_T = \frac{\left(\frac{d}{A}\right) N_d \left(\frac{1}{\tau}\right)(M+\alpha_W)}{0.78 - d\left[(M-1)\rho^2 \frac{\beta M}{\tau W} + \alpha_\tau\right]} \qquad (2\text{-}14)$$

Equation 2-14 includes the multiplexing power loss and intermodulation interference associated with nonlinear repeaters. The parameter β is the intermodulation coefficient and depends upon the amount of limiter backoff. For the range of transmitter ERPs, the up link noise-to-signal ratios, α_τ and α_W, will be negligible.

Since the product τW can be interpreted as the maximum number of orthogonal signals having length, τ, and bandwidth, W, the term $M/\tau W$ can be considered to be the ratio of the number of signals to the maximum possible number of orthogonal signals. Thus, for orthogonal signals, $M/\tau W$ has a maximum value of unity, which will be used in the following analyses. Note that the quantity τW is also the processing gain of the receiver correlator. Equation 2-14 indicates that the intermodulation term involving β can be made negligible with large τW products. Physically, this means the intermodulation spectrum is spread over such a wide bandwidth that only a relatively small portion appears in the information bandwidth.

2.3.3 Number of Orthogonal Signals

When using spread spectrum techniques, it is of interest to estimate the number of orthogonal signals that may be available to the network. This problem has been investigated by J.K. Wolf and B. Elspas (Reference 4). The upper bound for this number is given by

$$\log_2\left(\frac{N}{n}\right) = n\rho \qquad (2\text{-}15)$$

where

N = number of signals

ρ = correlation coefficient between signals

n = 2 x system τW product (τ = information bit period, W = bandwidth)

Equation (2-15) can be written as

$$\frac{N}{n} = 2^{n\rho}$$

Imposing complete orthogonality ($\rho = 0$), leads to $N = 2\,\tau W$.

2.4 Time Division Multiple Access

In TDMA, each terminal has exclusive use of the satellite repeater for short time intervals. The entire net is time synchronized so that fixed time slots can be assigned to the ground terminals. For illustrative purposes, the performance of an idealized TDMA system will first be analyzed on the basis of satellite ERP required to support M number of digital voice channels.

Assume a voice channel with maximum bandwidth of 2500 Hz. The Nyquist sampling rate is 5 kHz. Let each sample be encoded into four binary bits. If M channels are seeking access, M can be related to the sampling rate by Equation 2-16. Figure B-17 identifies the transmission format associated with this simple requirement. This format assumes perfect synchronization and no guard time between pulses.

$$T = M\,\tau'$$

$$\tau' = \text{slot time duration per channel}$$

$$T = \text{time per frame } 2 \times 10^{-4} \qquad (2\text{-}16)$$

Since each voice sample is encoded into four bits, the bit time for each channel is

$$t = \frac{\tau'}{4} = \frac{T}{4M} = \frac{2 \times 10^{-4}}{4M} \text{ seconds} \qquad (2\text{-}17)$$

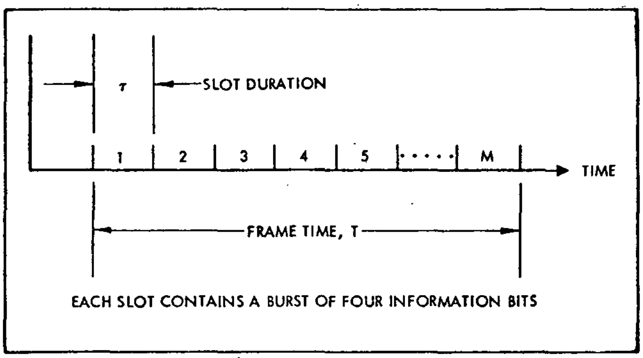


Figure B-17. Transmission Format for Simplified TDMA System

The minimum bit time is related to link bandwidth as shown in Equation 2-18.

$$t = \frac{E}{N_o} \Big/ \frac{P_r}{N_o} \qquad (2\text{-}18)$$

where

E/N_o = bit energy/noise density

P_r/N_o = bandwidth for which S/N ratio at ground terminal is unity

Assume differentially coherent detection. For example, to satisfy the requirement of a bit error rate of 10^{-4}, $E/N_o = 9.3$ dB.

Combining Equations (2-17) and (2-18) and substituting the factor of 8.5 for 9.3 dB, the number of channels M can be determined from

$$M = \frac{1 \times 10^{-4}}{2 \times 8.5} (P_r/N_o) \qquad (2\text{-}19)$$

With equation 2-19, the number of up links M, can be calculated as a function of repeater down link ERP.

2.5 Pulse Address Multiple Access

Pulse address multiple access (PAMA) systems have certain characteristics which appear attractive. The two most important properties of these systems are:

1) The ability to address literally an infinite number of users with a relatively simple address form, and
2) The ability to operate without the need for network synchronization.

In the following subsection, a representative type of PAMA system will be described and its performance analyzed.

2.5.1 Description of Representative PAMA Technique

Consider the frequency-time matrix shown in Figure B-18. The darkened squares represent pulses being transmitted, at appropriate time intervals, on various frequencies, F_1 through F_N. The following rules will be imposed upon this matrix:

1) The first time slot T_1 shall be filled by exactly one pulse.
2) Each frequency slot shall be filled by exactly one pulse.
3) More than one pulse may occur in all time slots except T_1.

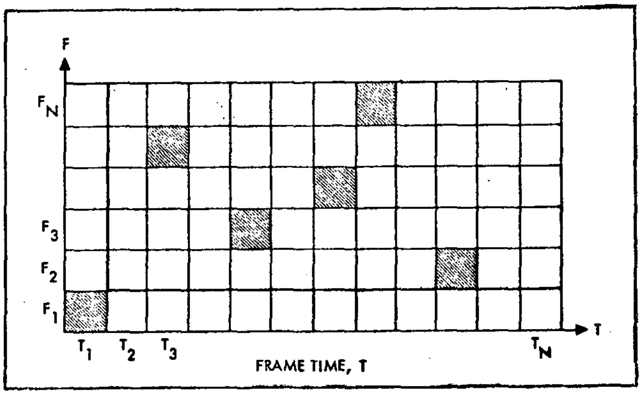


Figure B-18. Frequency-Time Matrix

Under these conditions, we may calculate the maximum number of address forms possible. Consider the matrix of Figure B-18. The first time and frequency slot has been filled. There are F_N ways of filling the first time slot. Having filled the first time slot, we must fill F_{N-1} additional frequency slots one time and T_{N-1} additional time slots zero, once, or more than one time. From this we may deduce that there are

$$F_N \left[T_{N-1}\right]^{\left[F_{N-1}\right]} \qquad (2\text{-}20)$$

address forms available under the rules adopted.

For example, for $F_N = 8$, $T_N = 16$, there are about 1.37×10^9 address forms possible, and for $F_N = 12$, $T_N = 12$, there are about 3.42×10^{12} address forms possible, which is far in excess of any contemplated number of user terminals.

Each user transmits his own address form; the transmission of an address form corresponding to a logical "one," and the nontransmission of an address form corresponding to a "logical zero."

The receiver employs a certain type of detection logic to identify the address form of a particular user, and that logic will be described as follows:

1) The receiver looks only for pulses falling in the particular frequency-time slots corresponding to the address form it is looking for, and ignores what occurs in other frequency-time slots.

2) A partial overlap of a pulse from the intended or non-intended receiver into a frequency-time slot predetermined by the receiver is regarded as a pulse received in that particular frequency-time slot.

3) The receiver samples only once per address period.

2.5.2 Performance Analysis

Assuming adequate signal energy, the matrix detection process will determine the performance of a PAMA link. This section of the report describes the theory of matrix detection, and derives a functional relationship between carrier-to-noise ratio, desired error rate, and the frequency-time parameters of the matrix. The analysis is then extended to include application of PAMA to the simple requirement of M number of identical links.

A typical PAMA address matrix is shown in Figure B-19. The openings correspond to a particular address form. The horizontal axis represents time, the vertical axis frequency. The incoming pulse field is moving from right to left. The decoding circuitry samples in only one pulse interval out of every T_{Nth} pulse interval. If a pulse or a portion of a pulse appears in all openings, the reception of an address form is recorded, indicating presence of a logical one. If this does not occur, a logical zero is recorded.

We are now in a position to estimate the expected error rate for the N^{th} user in the presence of N_{-1} users. The N_{-1} users are transmitting address matrices at random time intervals relative to each other. The Poisson function, which is a probability function of semi-continuous form, is applicable to the solution of this problem. The function is

$$P_{(k)} = \frac{(\nu T)^k}{k} e^{-\nu T} \qquad (2\text{-}21)$$

where

$P_{(k)}$ = probability of exactly k random events occurring in interval T

T = time interval under consideration

ν = average density of occurrence of random events per unit time

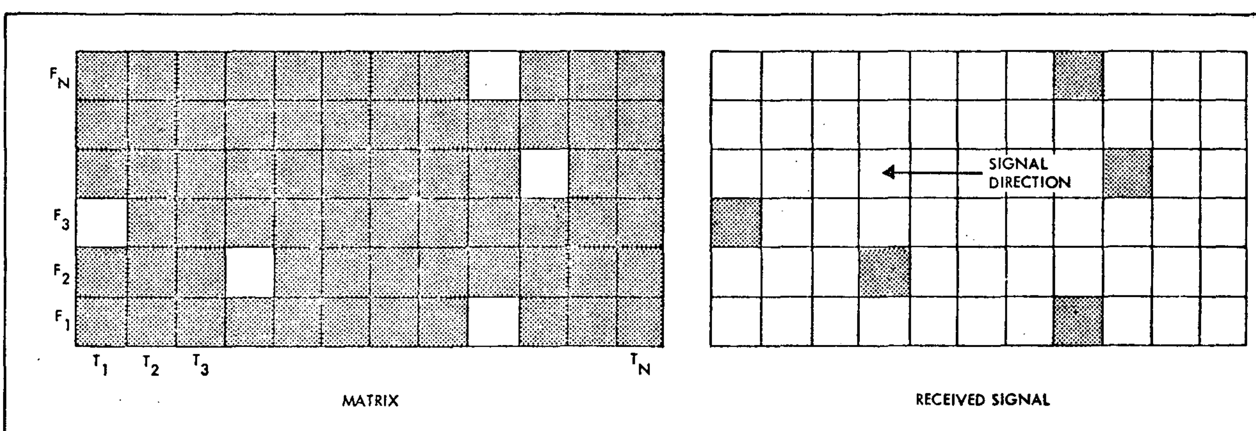


Figure B-19. PAMA Code Matrix and Matching Signal from Equation 2-21, the zero order function is

$$P_{(0)} = e^{-\nu T} \tag{2-22}$$

which is the probability of exactly zero events occurring in an interval T. The probability of one or more events occurring in an interval T is

$$P_{(1\text{ or more})} \cong 1 - P_{(0)} = 1 - e^{-\nu T} \tag{2-23}$$

The approximation sign is necessary, since in this particular problem, the values of k do not extend to infinity (assuming a finite number of users). However, for k extending to five or more, the approximation is very close.

Consider now a single opening in the frequency-time matrix. What is the single look (instantaneous) probability of one or more pulses overlapping this opening? This probability is

$$\left[1 - e^{\dfrac{-\underset{\text{Number Users}}{(N-1)} \times \underset{\text{Number of Ones in a Row}}{(1)} \times \underset{\text{Two Time Slot Width}}{(2)} \times (1) \times \underset{\text{Address Transmitted on Average of 1/2 Time}}{(1/2)}}{\underset{\text{Number Time Slots in Row}}{T_N}}}\right] \tag{2-24}$$

$$= \left[1 - e^{-(N-1)/T_N)}\right] \tag{2-25}$$

Note that a period equal to twice the slot opening must be considered.

Figure B-20 illustrates two pulses on the verge of overlapping a slot interval. The centers of these two pulses fall on the boundaries of a two slot width interval. All pulse centers falling within that interval will cause an overlap of one slot width interval. We also note that each user transmits a logical one on the average only 1/2 of the time, so that the factor of 1/2 must be included in Equation 2-24.

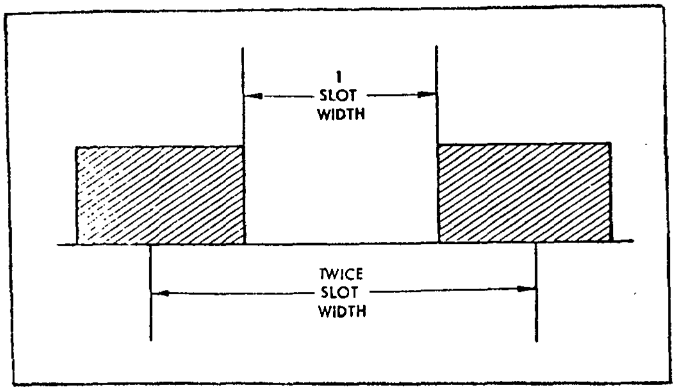


Figure B-20. Two Pulses Overlapping Slot Interval

We may therefore conclude that the probability of receiving a false address for the N^{th} user in the presence of N-1 users is just

$$\left[1 - e^{-(N-1)/T_N}\right]^{F_N} \tag{2-26}$$

According to the way we have defined the receiver logic, a transmitted address form is always received (in a noise free system) with unity probability. Therefore, if a transmitted address form corresponds to a logical one in a digital system, and the non-transmittal of an address form a logical zero, the bit error rate is

$$1/2\left[1 - e^{-(N-1)/T_N}\right]^{F_N} \tag{2-27}$$

The factor of 1/2 represents the fact that logical ones are transmitted one-half of the time, and logical zeros are transmitted one-half of the time.

One may now include the effects of a finite receiver S/N ratio on the expected bit error rates. Let P_{NB} be the probability of mistaking noise for a pulse, and P_d the probability of being able to recognize a pulse if it is transmitted.

The probability of not receiving a logical one if one is transmitted is just the probability of not receiving a single pulse, since one pulse missing from the address form prevents it from being received. That probability is

$$\left[1 - P_d\right] \tag{2-28}$$

Note that P_d is equivalent to the error rate for each pulse or "chip" of the matrix. The probability of receiving a logical one when one is not transmitted by the intended sender is

$$\left[\left(1 - e^{-(N-1)/T_N}\right) + P_{NB} - P_{NB}\left(1 - e^{-(N-1)/T_N}\right)\right]^{F_N} \tag{2-29}$$

The overall information bit error probability is thus

$$P_b = 1/2 \left\{\left(1 - P_d\right) + \left[\left(1 - e^{-(N-1)/T_N}\right) + P_{NB} - P_{NB}\left(1 - e^{-(N-1)/T_N}\right)\right]^{F_N}\right\} \tag{2-30}$$

Equation 2-30 permits us to calculate the information bit error rate as a function of the received error rate for the individual pulses in the matrix, the matrix frequency-time parameters, and the false alarm probability, P_{NB}. It is customary to set receiver threshold so that P_{NB} will equal the pulse error rate $(1 - P_d)$. Such adjustment of threshold tends to minimize the required transmitter power.

The behavior of PAMA systems can be illustrated by substituting appropriate numerical values into Equation 2-30 and calculating the information and error rate as a function of the number of simultaneous users. As an example, the following system parameters are assumed:

Total bandwidth = 100 MHz

Link bit rate = 19.2 kilobits/second

Desired bit error rate = 10^{-4}

Matrix size, $F_N = 40$, $T_N = 100$

The performance curves in Figure B-21 were developed by assigning representative carrier-to-noise ratios, and substituting the corresponding pulse error rate, $(1 - P_d)$, and false alarm rate, P_{NB}, into Equation 2-30. The number of users, N, as a function of the information bit error rate was then computed for C/N ratios of 5.8, 8.0, 9.3, 10.3, and ∞ dB.

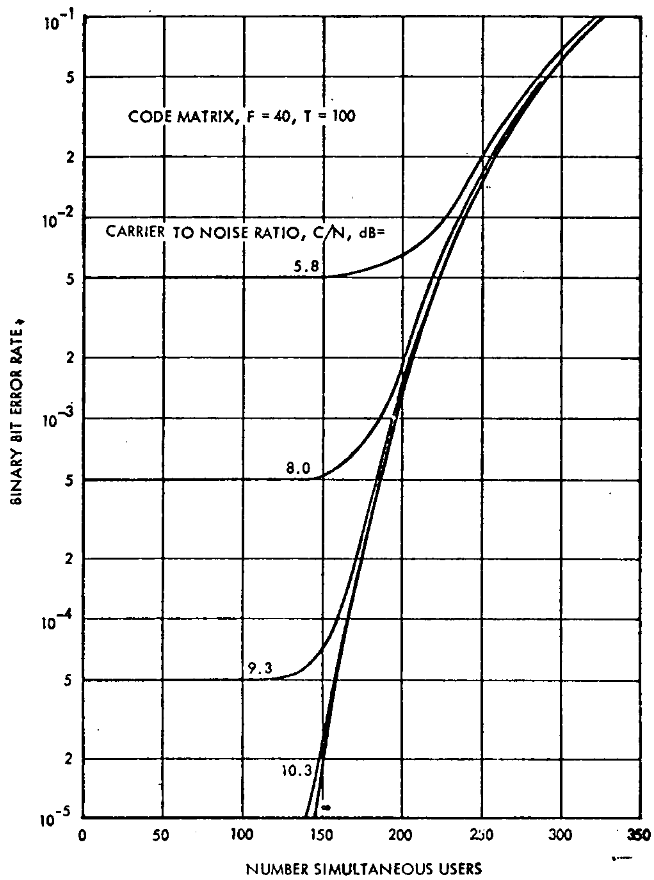


Figure B-21. Binary Bit Error Rate Versus Number of Users

These curves illustrate the most characteristic feature of PAMA links; vulnerability to self-jamming. For relatively few simultaneous users, self-interference will be negligible and the information bit rate is essentially determined by the C/N ratio of the link. As the number of users increase, the error rate rapidly increases to unacceptable levels. For the selected parameters, the transition from negligible interference to self-jamming occurs for about 150 users.

2.5.3 REFERENCES

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2. C. R. Cahn, "Crosstalk Due to Finite Limiting of FM Signals," Proc. IEE, p. 53-59, January 1960.

3. J. W. Schwartz, J. M. Aein, and J. Kaiser, "Modulation Techniques for Multiple Access to Hard Limiting Repeater," Proc. IEE, p. 773, May 1966.

4. J. K. Wolf and B. Elspas, Multiple Access to a Communication Satellite with a Hard Limiting Repeater, IDA Report R-108, Vol. II, April 1965.

3.0 MULTIPLE ACCESS SYSTEMS - MODELING

In a communications satellite system multiple access provides interconnection between a number of earth stations via a satellite repeater; the satellite repeater serving as a node for the circuits interconnecting the earth stations. The functions performed by the satellite repeater are to multiplex a number of r.f. carriers received from ground stations for purposes of amplification and retransmission to other earth stations. A similar interconnection by terrestrial means would be routed through a number of switching offices and associated repeaters. Figure B-22 shows the signal flow in a multiple access satellite communication network. Two types of modulation are required, message modulation and multiple access modulation. The multiple-access modulation takes a form that depends upon the type of multiple access technique used. In time division multiple access the multiple access modulation locates a transmission burst with respect to a reference time. In the spread spectrum multiple access technique (SSMA), the multiple-access modulator superimposes a PN coded phase or frequency modulation on the carrier. In frequency division multiple access (FDMA) multiple-access modulation is essentially an a priori choice of carrier center frequency. Figure B-23 illustrates the difference between the different multiple-access techniques by means of a 3 dimensional domain that is apportioned in various ways depending upon the technique used. Each technique has unique characteristics and advantages and disadvantages. TDMA requires no control of ground transmitter power but requires precise synchronization between participating ground terminals. FDMA, although the simplest technique, requires power control. Supervision is required in both FDMA and

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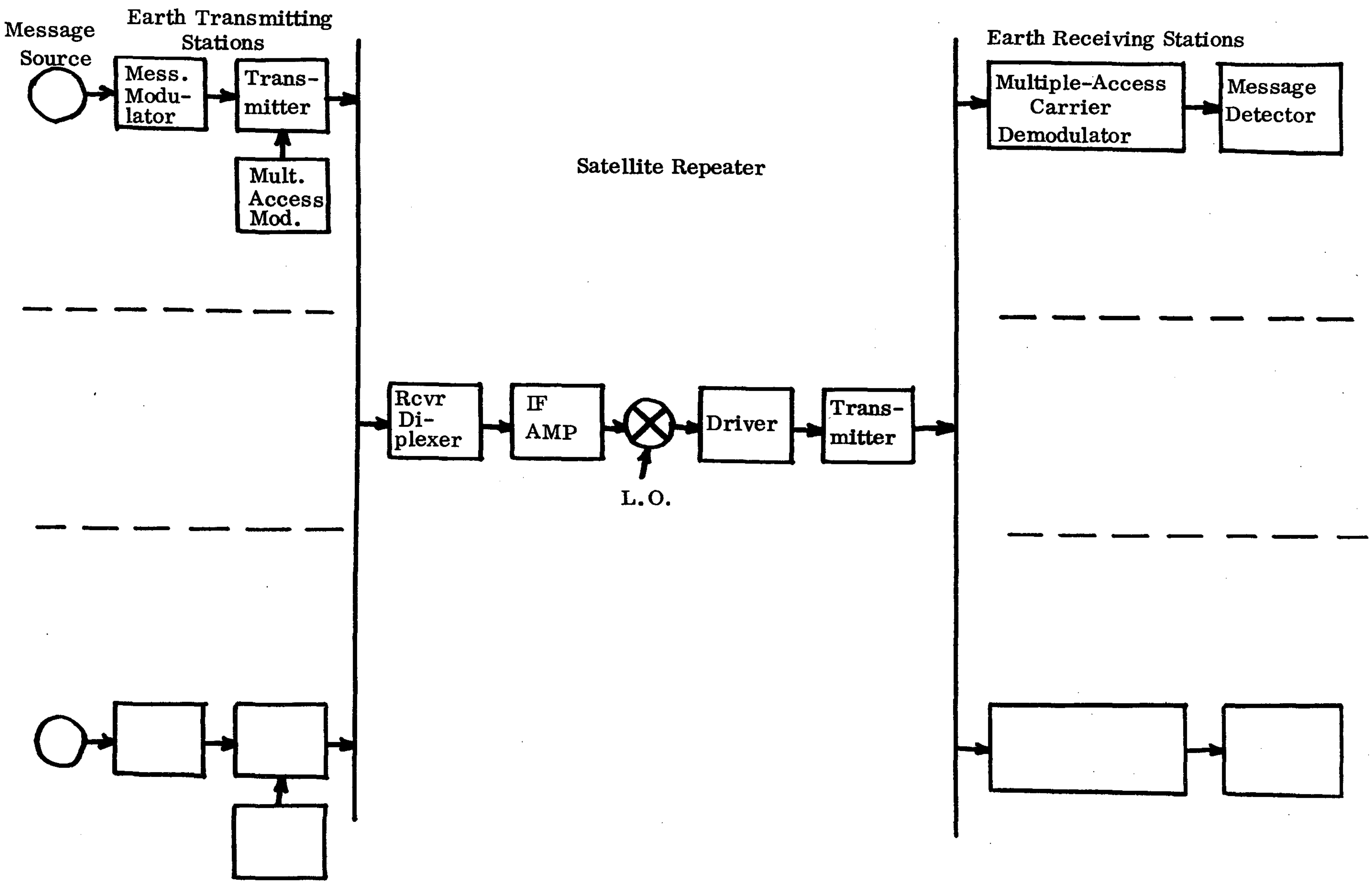


Figure B-22. Multiple-access signal flow.

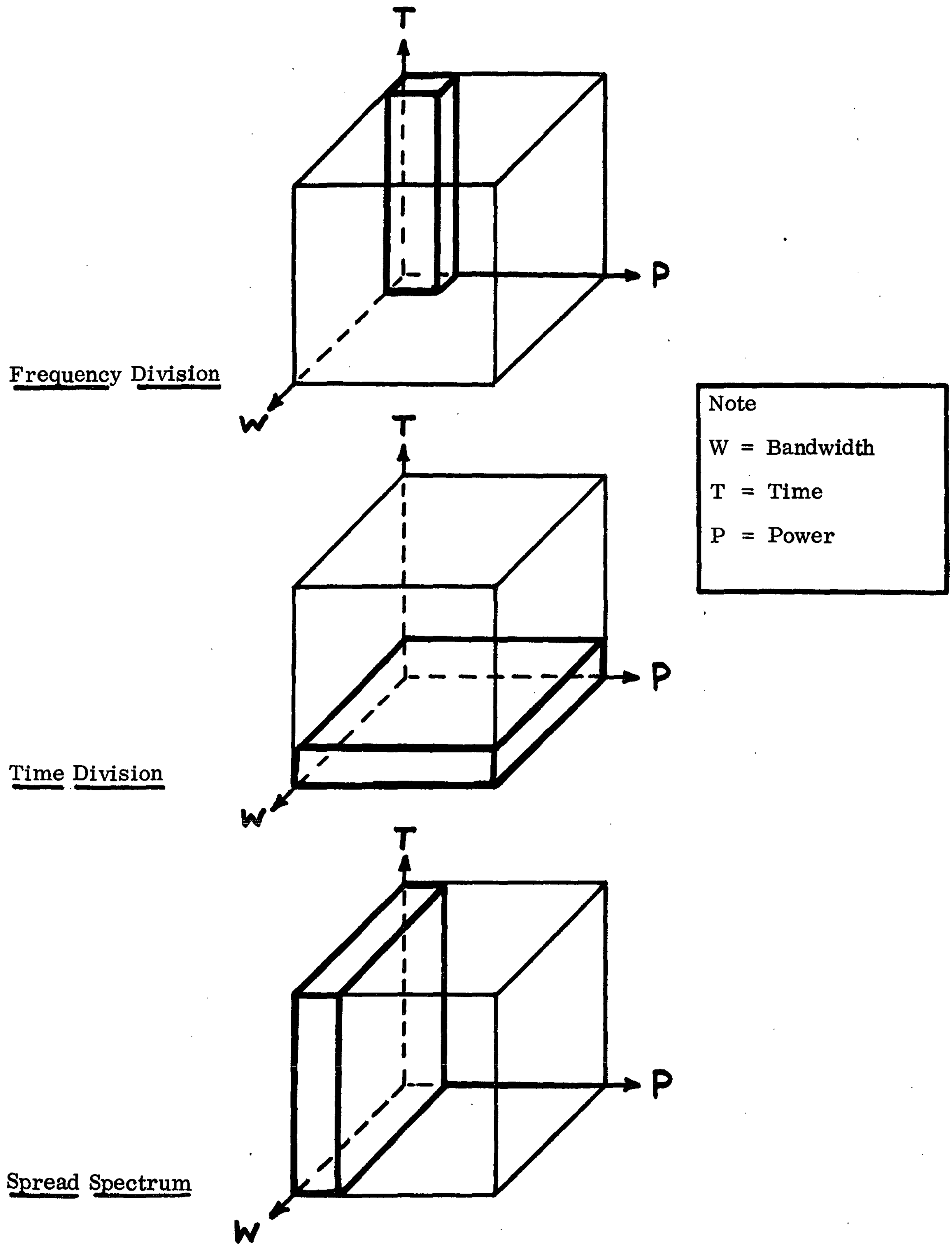


Figure B-23. Multiple-access methods.

TDMA system for allocation of time slots or frequency channels to efficiently allocate channels according to traffic load. Spread spectrum systems permit random access but require power control and may require synchronization between ground stations.

There are essentially three methods by which earth stations might gain access to a multiple access channel:

a) Controlled access — the earth station requests and obtains access from a network manager.

b) Self-ordered access — The station desiring access would ascertain what time slot or frequency channel is available and then have the capability of entering that channel or time slot.

c) Un-ordered access — access would be gained to a channel without first determining the availability of a channel. (This method would apply to the SSMA technique).

Controlled access would require a coordinating ground station to perform the channel assignment function. In the case of digital message transmission some type of priority assignment might be required. Also a queueing function may be desirable. These functions as well as store and forward capability are options to be determined in the design of the communications network.

Multiple-access system models to be considered will be based on the following basic guide lines:

a) One synchronous satellite will serve a number of ground stations.

b) Switching will only be done at the ground stations, not in the satellite.

c) Both fixed and demand assigned multiple access channels will be considered.

d) Service will not be limited to telephone channels.

3.1 FREQUENCY DIVISION MULTIPLE ACCESS (FDMA)

The basic FDMA system is illustrated by Figure B-22where typically a number of ground stations are linked by a single synchronous satellite repeater. Figure B-24 is a simplified block diagram of a typical FDMA repeater, the Intelsat III. Allowance must be made in the design of an FDMA system for the distortion that is inherent with this type of system:

1) Intelligible Crosstalk — amplitude variations in the repeater convert some FM to AM and the TWT converts the AM back to FM which intelligibly interferes with the original signal.

2) Delay Distortion — lack of phase linearity delays some frequencies more than others.

3) Intermodulation between Multiple Carriers — caused principally by amplitude non-linearity of TWTs plus those in earth stations.

4) Amplitude Crosstalk between Multiple Carriers — caused by AM to PM conversion in TWT repeater.

Due to this intermodulation distortion CCIR has designated for an FDMA system that the allowable 9000 pWOp noise power shall be allocated as follows:[1]

2250 pWOp intermodulation noise arising in earth station;

3000 pWOp intermodulation noise arising in common repeater;

750 pWOp thermal noise in the uplink;

3000 pWOp thermal noise in the downlink.

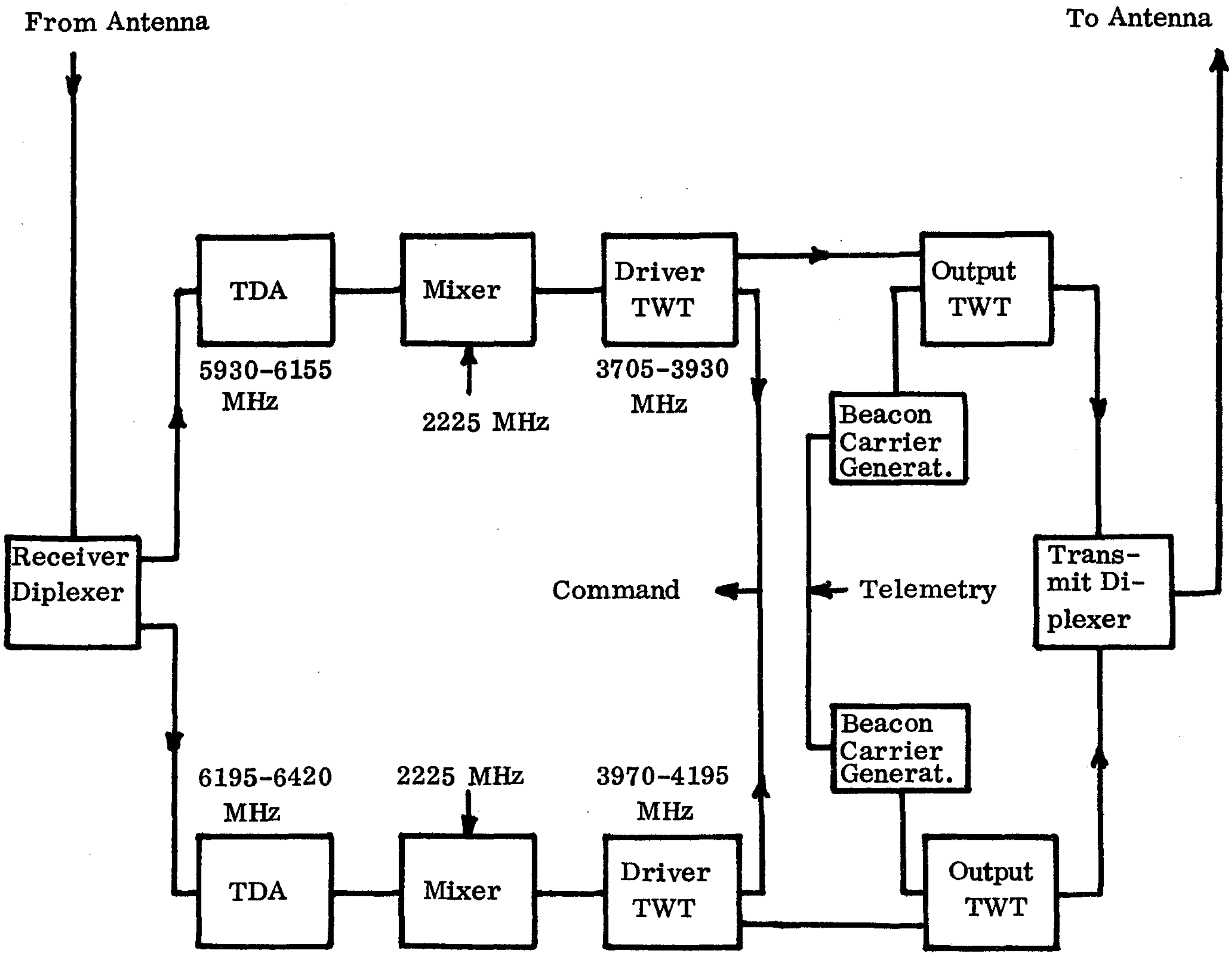


Figure B-24. Simplified block diagram of the Intelsat III.

In order to keep the distortion below the allowable levels it is necessary to back off the modulation level of the repeater well below the saturation level, to closely control the r.f. power received at the satellite on all links and to insert guard bands between all r.f. carriers received at the satellite. To control the received power level it is necessary to monitor the uplink signal levels at the satellite and by telemetry transmit this information back to the ground stations. The ground stations must provide a means of reacting to this information and maintain the EIRP to within approximately ±0.5 db of the required level. Guard bands equal to 25% of the occupied bandwidths is required between all multiple access carriers.

To provide assignment of channels based on demand, additional complexity must be included in an FDMA system. A callup subsystem must be provided to assign available channels, release channels when calls are terminated and provide busy signals. This would require additional equipment at one of the ground stations or at a separate ground station and an additional narrowband channel must be provided so that the supervisory control can be implemented. In addition, each of the ground stations transmitters and receivers must be tunable and a more elaborate method of power control is required to keep the modulation level optimum as the carrier multiplex load at the repeater continuously changes.

A limiting case of multiple access is the assignment of channels on a per call basis whereby each voice channel (or data) modulates a separate carrier. In addition to the usual complexity mentioned above for callup control and transmitter and receiver tunability, there is an additional penalty of requiring separate ground transmitters and receivers for each channel. Figure B-25 illustrates the additional repeater bandwidth that would be required compared to multiplexing several channels on a carrier. Table B-4 shows how the bandwidth varies for a 1200 channel FDMA system as a function of the number of carriers.

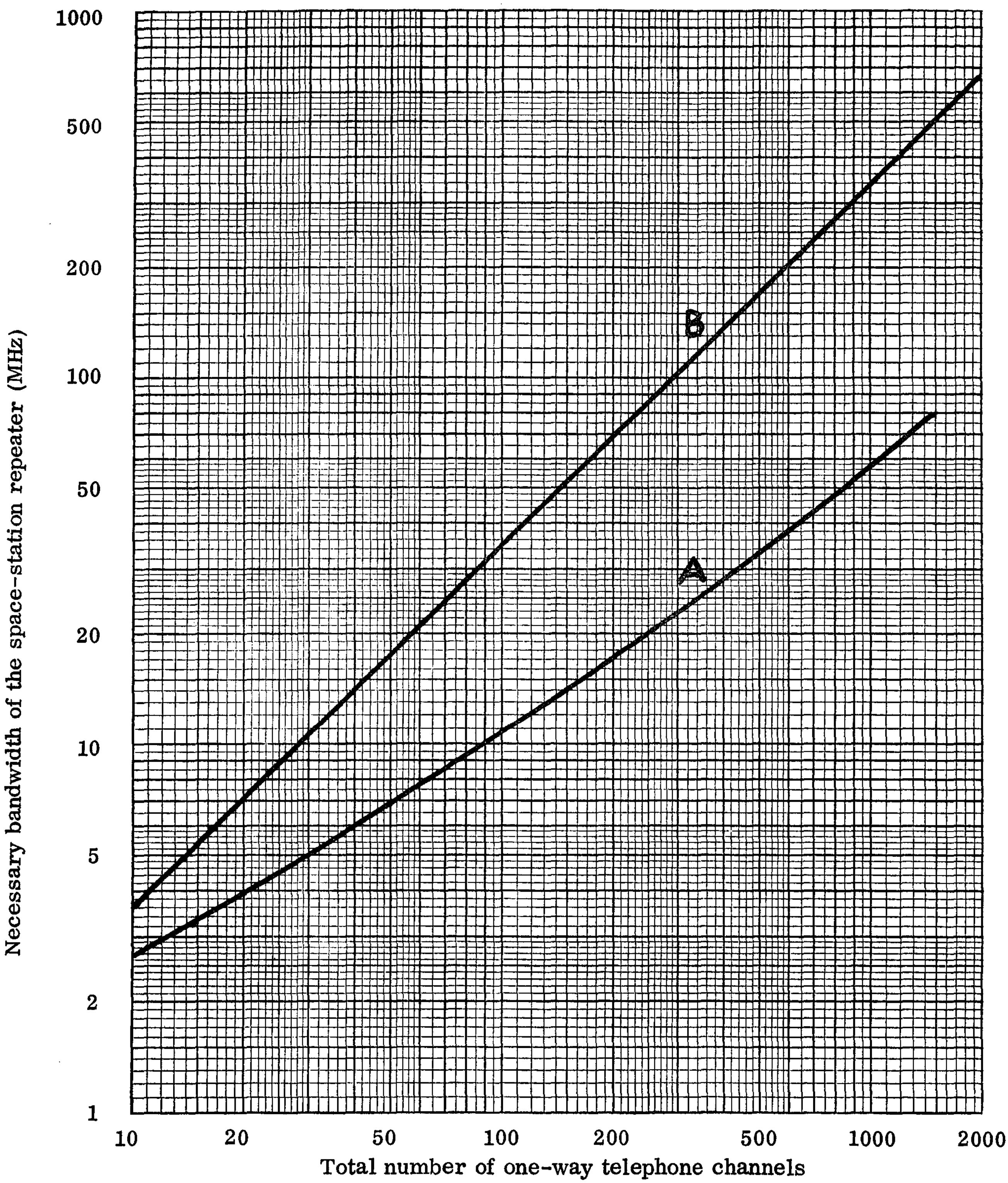


Figure B-25. Necessary space-station bandwidth for multiple-carrier FDM-FM systems.

Curve A: One-carrier per space-station repeater
Curve B: Single channel per carrier

Table B-4 . Repeater Bandwidth as a function of number of carriers for a 1200 channel FDMA system.

No. of Carriers	No. of Telephone Channels per Carrier	Total BW (MHz)
5	240	135
10	120	178
20	60	226
50	24	332
100	12	424

For a fixed channel assigned system consisting of several heavy traffic ground stations of approximately equal capacity, the FDMA system is competitive with other methods of multiple access. However, there are these disadvantages that must be accepted with an FDMA system:

- Distortion due to intermodulation, intelligible crosstalk, phase nonlinearity and amplitude crosstalk.
- Requirement for precise carrier power control.
- Loss of TWT efficiency and bandwidth to reduce intermodulation noise.
- Undue complexity of demand assigned access.

One advantage of the FDMA system which will greatly influence the continued use of this system is the availability of FM hardware applicable to this type of system.

3.2 TIME DIVISION MULTIPLE ACCESS (TDMA) — Frequency Division Multiple Access (FDMA) because of compatibility was a logical extension of the standard FDM telephone transmission system. However, the extension of an FDM terrestrial telephone system to a multiple access satellite repeater carried with it the disadvantages of the FDM system and introduced additional problems when operated in a satellite repeater multiple access system. These disadvantages which have been mentioned are intermodulation distortion, requirement for precise ground transmitter power control, inflexibility and inadaptability to demand access.

Associated with the trend of conversion of terrestrial telephone systems to digital PCM, there is considerable activity leading to the eventual operational use of digital time division multiple access systems associated with the synchronous satellite relay repeater. Some of the advantages of PCM systems are:

1) PCM is easily switched and routed.
2) PCM is less sensitive to interference.
3) There is no crosstalk or intermodulation distortion in the satellite repeater.
4) PCM is less sensitive to interference from other stations on the same frequency.
5) With an increasing amount of digital data traffic, a PCM system is more adaptable than an analog system to the transmission of digital data.
6) There is a favorable exchange of R.F. bandwidth and power in PCM system compared to an analog FM system.
7) Precise control of transmitted power is not required as with FDMA.
8) In a PCM system the pulse stream can be regenerated in the satellite repeater to improve signal-to-noise ratio (uplink noise is not present on downlink).
9) PCM lends itself to secure communications.
10) TDMA is adaptable to demand assigned multiple access.

1. BASIC TDMA SYSTEM CONFIGURATION. Figure B-22 defines the signal flow in a multiple access network. For a TDMA system the message source is a number of telephone channels, the message modulator is a PCM coder and the multiple access modulator is a

PSK modulator. Not shown, but a vital element in a TDMA system, is a control subsystem that provides the functions of synchronization, memory and formatting. Figure B-26 shows the basic format of a TDMA system. Within each time slot, B, in the frame is a transmission burst from a ground station. Each participating ground station transmits one or more data bursts during a time frame. Included in the data burst are binary words corresponding to digitized samples of analog voice signals or digital data words in the case of digital data sources. Also included within the burst are synchronization bits to assist a receiving station in acquiring and maintaining synchronization and a unique word to identify the originating station. In a fixed assigned multiple access system the format remains fixed with each time slot within the frame assigned to a specific station whereas in a demand assigned system, time slots are assigned to stations instantaneously on a demand basis. Also, the time width of data bursts within a frame may be variable. The bit rate within a frame would normally be constant. However, to accommodate small users of system capacity the bit rate within a given time slot can be lowered to reduce transmitter power and receiver sensitivity requirements.

Various factors impose limitations on the parameters of the TDMA system. The frame duration depends on the transmission delay allowable and the cost of storing data. Assuming the frame length has been established, the time slot duration depends upon the number of stations and the data load per station. If it is required to transmit voice channels long delays are intolerable. In fact the propagation delay associated with a synchronous satellite is significant for a telephone system. If in such a system the frame period is made equal to the speech sampling interval (typically 125 microseconds) no storage is required and the system is referred to as a "real-time" system. Although at the present time a frame period of 125 microseconds is the most prevalent, one recently completed study has made an economic tradeoff analysis to determine an optimum frame length.[2] This was based upon the fact that the number of bits required for synchronization and station identification remains fixed whereas increasing the frame length increases the number of data bits per burst and thus reduces the capacity lost to synchronization per frame. The analysis was made under these assumptions:

1. A one way channel is worth $15,000 per year.
2. Storage costs are $1.00 per bit, amounting over a 5 year period to $0.20 per bit per year.
3. A 24 bit word is sufficient to provide the required synchronization information.

Figure B-27 shows the results of this tradeoff and shows that a 6 millisecond frame length is optimum for the assumptions. The additional delay is insignificant compared to the 250 milliseconds of delay associated with a synchronous satellite link.

Making the frame duration less than 125 microseconds not only results in an economic disadvantage but synchronization and timing become more critical.

These are some of the parameter limits in the TDMA format: For a fixed frame time the time-slot duration decreases as the number of time-slots per frame are increased. The minimum allowable time-slot duration is equal to twice the uncertainty in propagation time before acquisition between any ground station and the satellite so that an initiating synchronizing pulse, transmitted when access is initiated, does not overlap adjoining time-slots.

Guard time between time slots must not be less than the minimum time uncertainty associated with ranging after acquisition.

To assure proper interleaving of time slots of a station making access, a time reference must be established and maintained either at the satellite or at a ground station.

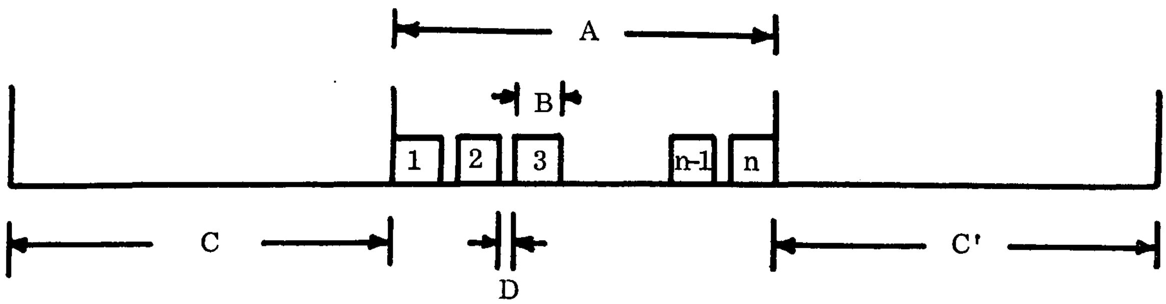


Figure B-26 Format of a time-division multiple-access system.

A:	Recurring time-frame
B:	Time-slot
C, C':	Time-frames
D:	Guard time

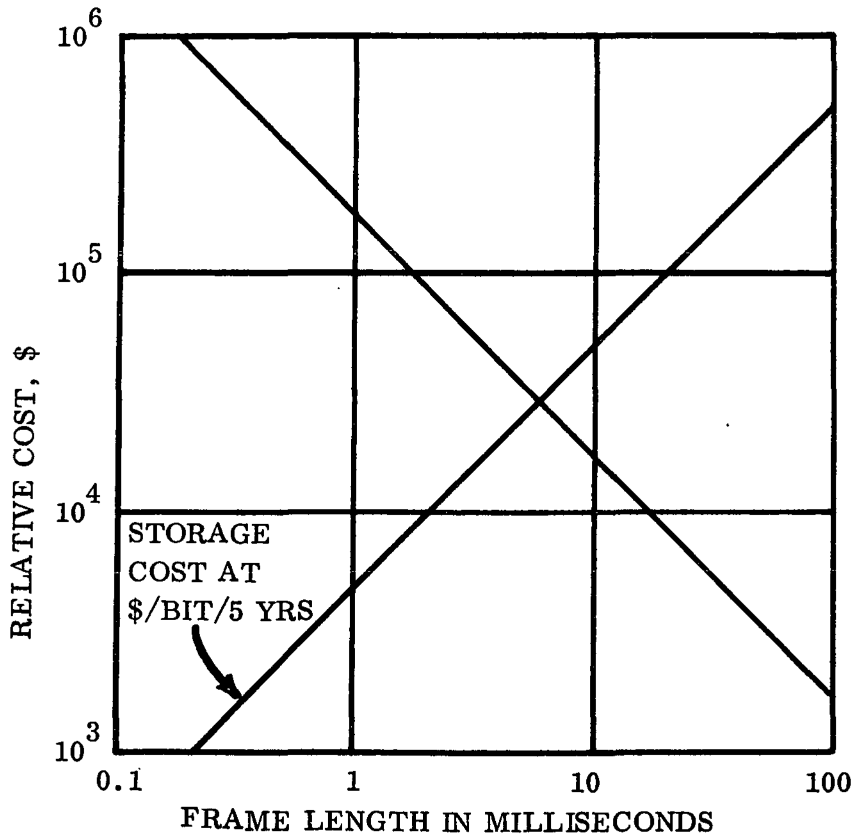


Figure B-27 Cost as function of frame length.

Corrections for path delay and path delay variations must continuously be maintained to assure that time slots are synchronized to the frame reference. The station burst of each participating station has a format that contains preamble bits and information bits, according to Figure B-28.

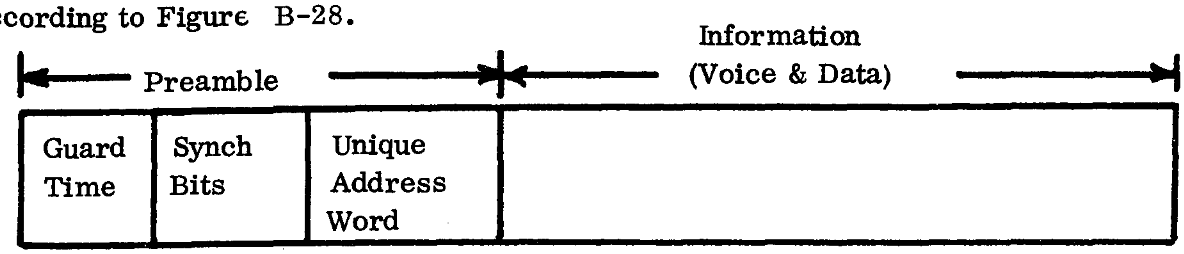


Figure B-28. Preamble Format.

The preamble is made as short as possible to maximize efficiency of transmission or TDMA efficiency. The various parts of the preamble provide the following functions:

a. Guard time — this is non-transmission time inserted between data bursts to prevent accidental overlapping of bursts.

b. Synchronization bits are required to recover a coherent carrier and establish bit timing. This must be repeated for each burst because earth stations are not coherently related. During the first part of the preamble after the guard time only the carrier comes on to enable the receiver to achieve lock-on to the carrier and the system clock. The time required depends upon the characteristics of the receiver phase lock loops.

c. The purpose of the unique address word is to determine the time at which the burst begins by correlation detection of this unique word. This word also identifies which station originates the burst.

2. TDMA EXPERIMENTAL RESULTS

a. <u>ComSat/Intelsat I Experiment</u>[3] — Field tests were made of a TDMA system that included three ground stations and the Intelsat I (Early Bird) satellite. Figure B-29 illustrates the equipment and parameters of the system used and Figure B-30 illustrates the format. The parameters of this system are:

No. of voice channels	24
System bit rate	6.176 M bits/sec
Frame period	125 microseconds
Burst period	Approx. 40 microseconds
Type of Modulation	Coherent 2-phase PSK

The following parameters resulted from these tests:

1) Acquisition accuracy (the accuracy with which the center of the time slot is entered) within ± 2 microseconds.

2) Lock-up time — less than 3 seconds after initial acquisition.

3) Guard time — 100 nanoseconds was determined to be adequate.

b. <u>ATS Satellite Experiment</u>[4] — A medium altitude ATS satellite served as a repeater for three earth stations participating in the experiment. The system was characterized by the following unique features:

1) Time synchronization is established with a low level PN sequence transmitted continuously during acquisition by the acquiring station. This PN sequence is repeated every frame. Knowledge of range is not required.

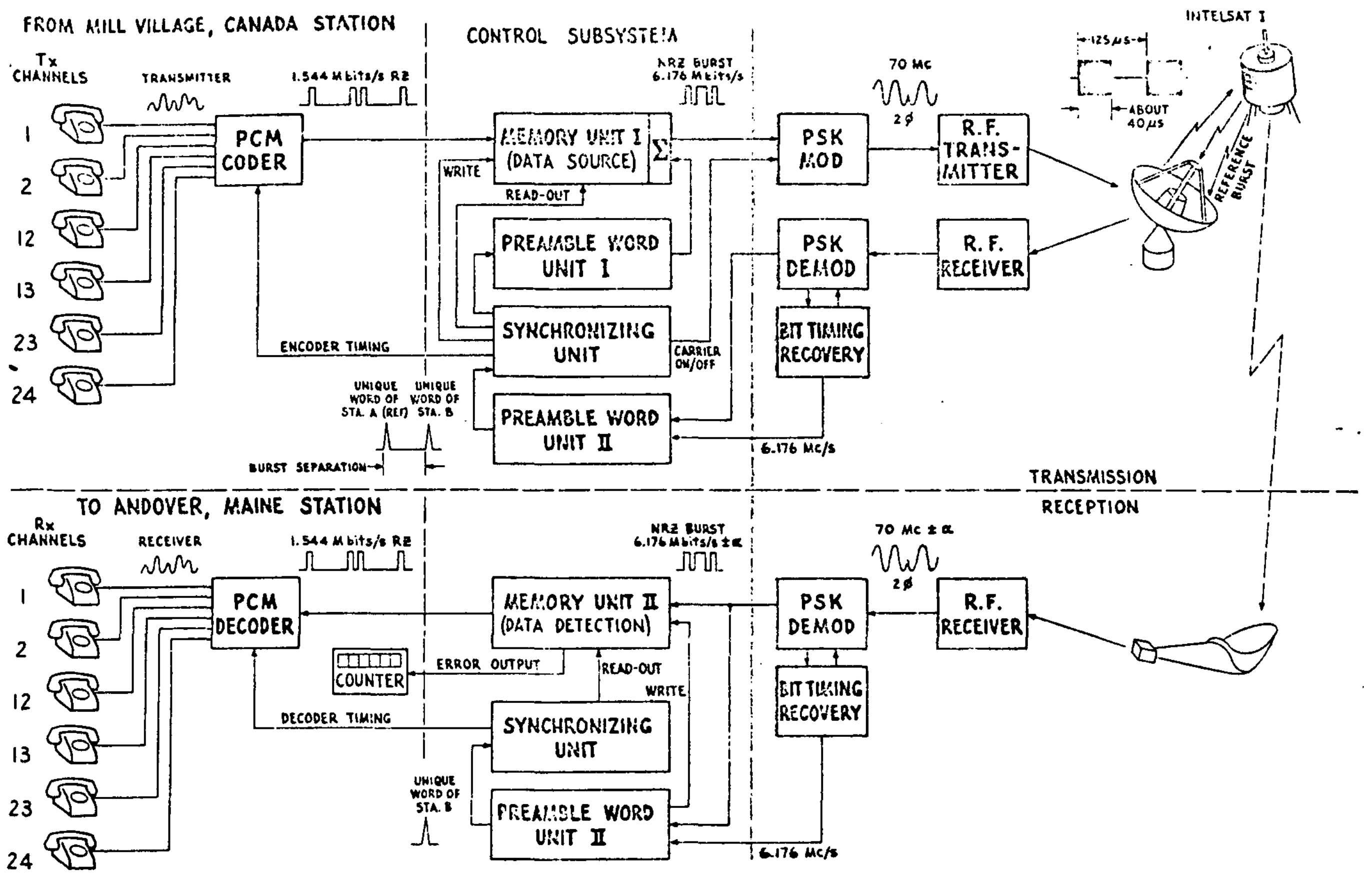


Figure B-29 Simplified block diagram of the experimental equipment. One-way transmission and reception.

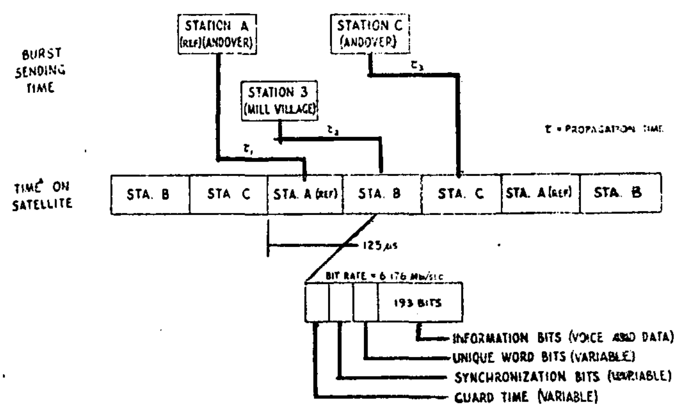


Figure B-30 TDMA access time format.

2) Participating earth stations have control loops which maintain bit and frame coherency referred to the satellite.

3) One station in the system is a reference station. A local station derives its own clock and frame synchronization by comparing its code with the reference station code, both as received from the satellite.

These are the system parameters:

Clock frequency		13.664 MHz
Frame length		125 microseconds
Subframe length		40.98 microseconds
Preamble	- data channel	7 bits
	station code	7 bits
Type of detection		PSK 2-phase differential

Test results were as follows:

1) Differential vs. synchronous detection — differential requires only one overlap bit per access for demodulation of subframe bit stream. Synchronous detection requires approximately 20 bits at beginning of each subframe for carrier recovery.

2) Acquisition time depended upon initial ΔF. Up to 100 seconds required. Once established it could be maintained with signal degraded to a 10^{-1} bit error rate.

3) Clock Synchronization — above a C/N of 7 db the clock synchronization capture range measured greater than 450 Hz. (at the satellite altitude of 6000 n.m. there was a ± 300 Hz doppler on the bit rate).

4) Carrier recovery time for synchronous detection was 1.3 microseconds.

c. A 50 M Bit/Sec Comsat TDMA Experiment[5] — This experimental system was designed for tests that included ten earth station and the Intelsat III satellite repeater. The maximum capacity of the system is 782 voice channels.

System characteristics are as follows:

Maximum capacity	782 voice channels
Frame period	125 microseconds

No fixed order of stations within frame and no fixed burst length - demand assigned.

There is no master station in the network but one of ground stations is a reference station for burst synchronization purposes and this assignment can be passed on from station to station.

Test Results — Lab tests completed. Field tests with Intelsat III to have been performed in Mid-1969.

Preamble word	57 bits PSK
	47 bits DPSK
Combined carrier & clock recovery	20 bits PSK
	10 bits DPSK
TDMA efficiency	better than 90%

(defined as data time × 100 /data time + preamble time)

The implementation of demand assignment in this system is accomplished by identifying unused time slots as a pool of time that is distributed among the participating stations. Each station thus has its own pool of unassigned capacity called "slack time." These parameters are known quantities:

Total system Capacity, C_T

Number of Stations, n

Equivalent loss in channels per preamble, C_P

The identification and assignment of spare channels proceeds as follows: on signal from the reference station each station transmits the number of its highest numbered channel, Ci. Channel capacity of the unassigned channel pool is:

$$C_S = C_T - n\,(C_P) - \sum_{i=1}^{n} Ci.$$

Divided equally, each station thus has Cs/n unassigned channels and the burst length of each station is, Ti = Cp + Ci + Cs/n. Each station from information which it has available computes its position in the frame with respect to the reference signal.

3. DETERMINATION OF BASIC PARAMETERS FOR A TDMA SYSTEM — In order to compare and optimize the various multiple-access techniques it is necessary to define the communications network configuration the data flow requirements, and the basic system parameters. Since TDMA is still in an experimental stage it is necessary to make some assumptions concerning the implementation of a TDMA system. These assumptions are based mainly on the results of TDMA experiments that have been initiated by Comsat and are briefly described herein. Assumptions for the configuration of a TDMA system are as follows:

No. of preamble bits	47
Guard time	100 nanoseconds
Frame period	125 microseconds
No. of bits per voice channel	8
Type of modulation	DPSK

A fixed access system will have a fixed number of information bits in each burst within a frame whereas in a demand access system the total number of channels will remain constant but the distribution of channels between bursts of the participating stations will vary.

A TDMA Example

Based on the above assumptions it is desired to define the bit rate, bandwidth and TDMA efficiency of a 5 station demand access system that has a total capacity of 300 voice channels or equivalent.

The total information bits per frame $= 300 \times 8 = 2400$

The no. of bursts per frame is 5 and the number of preamble bits per frame is $47 \times 5 = 235$.

The system bit rate

$$= \frac{\text{information bits} + \text{preamble bits}}{\text{frame period}}$$

$$= \frac{2400 + 235}{125 \times 10^{-6}} \text{ bits/sec.}$$

$$= 21 \times 10^{6} \text{ bits/sec.}$$

The information bandwidth for the receivers in the satellite and the participating ground stations is

$$1.2 \times \text{bit rate or } 26 \text{ MHz.}$$

The TDMA efficiency is the ratio of information bits to preamble bits within a frame or

$$\text{TDMA efficiency} = \frac{\text{information bits}}{\text{information bits} + \text{preamble bits}}$$

$$= \frac{2400}{2400 + 235}$$

$$= 0.91$$

The effect of guard time has been neglected in these calculations. Based on a 21×10^{6} bits/sec. rate the number of equivalent guard time bits is

$$\frac{\text{guard period}}{\text{bit period}} = 0.1 \times 10^{-6} \times 21 \times 10^{+6} = 2.1 \text{ bits per guard period}$$

or assuming 2 bits per guard period, 10 bits per frame are allocated for guard channels. This has negligible effect on bit rate or TDMA efficiency.

3.3 SPREAD SPECTRUM MULTIPLE ACCESS (SSMA)

1. GENERAL CHARACTERISTICS — Spread spectrum multiple access communications systems can be illustrated by the 3 dimensional domain shown in Figure B-23. This type of signal usually takes up the entire repeater bandwidth. The repeater carrier power may vary depending upon the number of active users. In this multiple access technique a relatively narrowband signal is converted to a new signal with much greater bandwidth before modulating the transmitter. In one method the bandspreading is accomplished by inserting a wideband phase or frequency PN coding on a carrier on which the message information is also superimposed. In another method the modulated carrier hops in a pseudo random manner between various frequency slots distributed over a wide bandwidth. PN coding of the signals is used because it makes possible an efficient means of asynchronous multiplexing of many messages in a common frequency band. Since the mutual clutter contributed by all but the desired correlation received signal have properties similar to thermal noise, signal detection should be optimum according to communications theory.

In a SSMA system the number of active users is limited; however, the system degrades very gradually with overloading. In a repeater employing a TWT hard limiting is usually permissible, thus allowing greater TWT efficiency. Most SSMA systems require synchronization between the receiver and the desired transmitted signal and some degree of transmitter power control is desirable.

2. FREQUENCY-TIME HOPPING — Frequency-time hopping is a pulse communication technique where generally the pulses are transmitted in different frequency and time slots. This system is most applicable where the number of potential users is large, the number of active users at any one time is small and the data sources have low data rates. Multiple receivers at each station could be used to detect each short duration pulse or frequency stepping may be used at the transmitter and receiver. It is necessary for the receiver to be synchronized to the incoming signal. The spectrum may be more easily spread over extremely broad bands than other SSMA techniques, but is vulnerable to concentrated narrowband interference.

One study pertaining to this technique[6] illustrates the time-frequency plane by Figure B-31. Each user selects a set of distinct cells within each time frame to represent a mark and a non-overlapping set of distinct cells to represent a space. In the detection process matched filters are used to individually detect each chip and a majority voting is used to determine the final decision of whether the transmitted set is a mark or a space. According to the results of this study the chip error rate increases monotonically with the number of active users assuming a fixed b/MK where

b = number of distinct cells selected

M = number of distinct frequency channels

K = number of distinct time slots

This has been ascribed to being caused by the increased interference resulting from additional users and the corresponding decrease in the E/No ratio. If the number of active users, N, remains fixed, chip error increases monotonically with b/MK. This is attributed to:

1) the probability of encountering interference is increased, and 2) the available energy per chip is decreased.

A recent study[7] describes a frequency-hopping multiple access system designed to link small mobile terminals via a communications satellite. These characteristics typify this tactical system:

1) a very large number of low duty cycle circuits and nets must efficiently share the limited available channel capacity afforded by the satellite,

2) much traffic will consist of short messages or interchanges interspersed between long periods of radio silence,

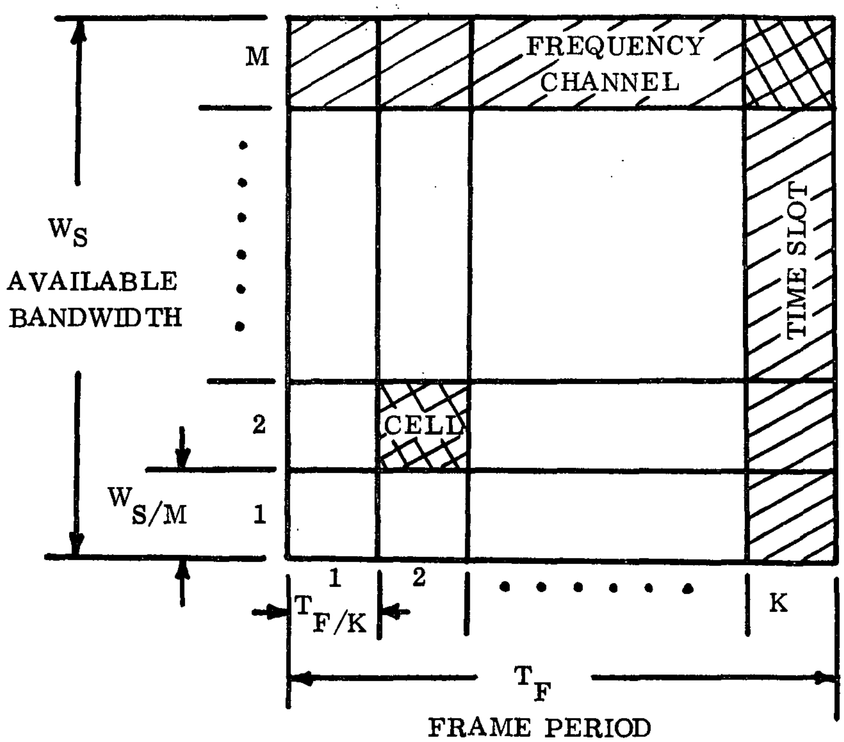
3) most terminals will be located on high-speed aircraft, ships, or small land vehicles, and

4) the equipment must be simple to use, since its operation will often be a secondary duty for the operator.

These characteristics might be quite similar in certain geographical regions to needs via a domestic satellite.

This system has the following characteristics: The data rates are 75 bits/sec. and 2400 bits/sec. and uses multiple frequency shift keying, MFSK, type of modulation. Each pulse or "chip" is a sine wave carrier of duration Tc seconds on one of eight frequencies spaced at $\frac{1}{Tc}$ - Hz increments. There are 64 possible code words made up of sequences of seven such pulses with an added fixed frequency pulse starting each code word to provide synchronization information. Figure B-32 illustrates the frequency-time modulation frame. It follows that the time required to transmit a code word is 8Tc and there are six information bits per code word.

Figure .Partitioning of the time-frequency plane.



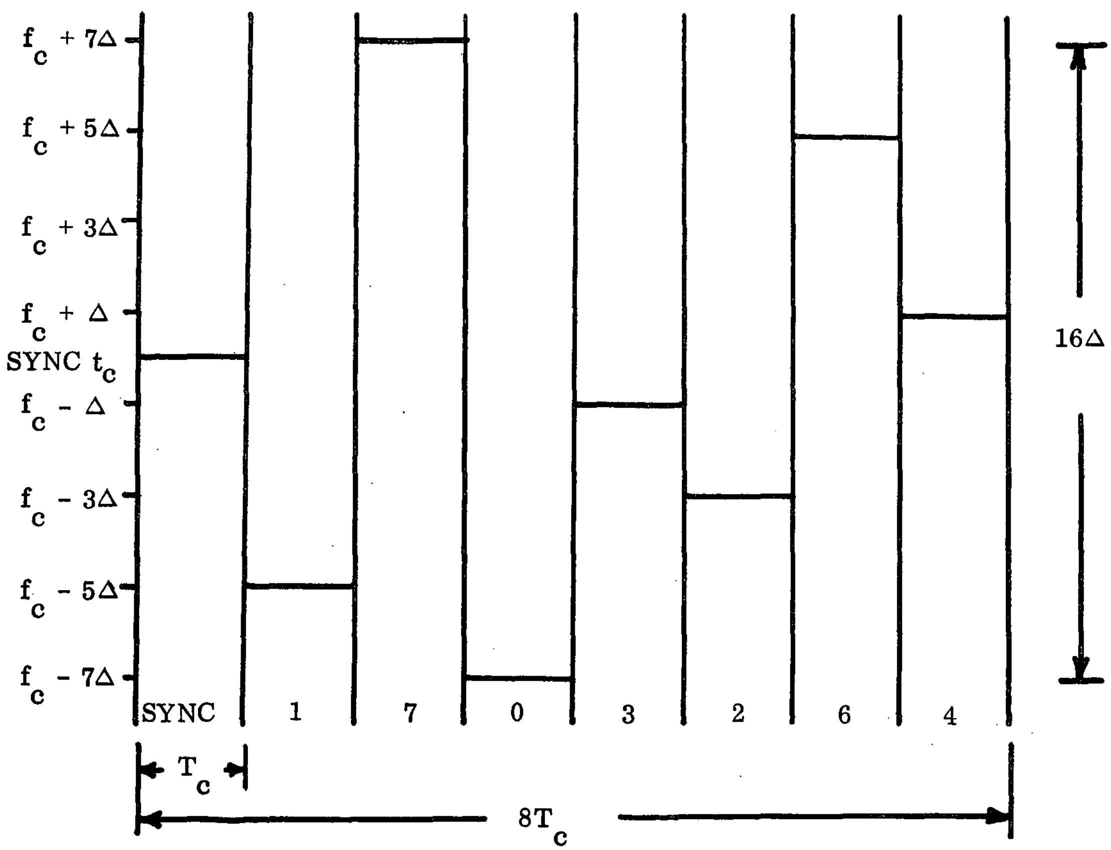


Figure B-32. Modulation frame.

The receiver utilizes eight channels with matched filter detection. A decoder and majority vote logic selects the transmitted code word having the highest probability. The receiver continuously searches and locks to the expected synchronization pattern and on detection pulls in and tracks so that a locally generated oscillator signal frequency hops with the same time-frequency pattern as the received carrier.

The bit error rate for the system in the presence of Gaussian noise is 10^{-3} for an E/No of 8 db. The effect of other users of the same channel is a drop in received signal power and an increase in background noise. A signal with a different frequency-hopping pattern will look to the receiver like Gaussian noise.

3. MATCHED FILTER AND CORRELATION-LOCK TECHNIQUES — A comprehensive study of SSMA techniques[8] has classified SSMA techniques employing PN modulation as: 1) PN signal transmission with matched filter reception, 2) PN signal transmission with correlation-locked reception, and 3) frequency-time hopping communications systems.

The correlation-locked system is described by Figure B-33 for digital PSK modulation and by Figure B-34 for analog phase modulation.

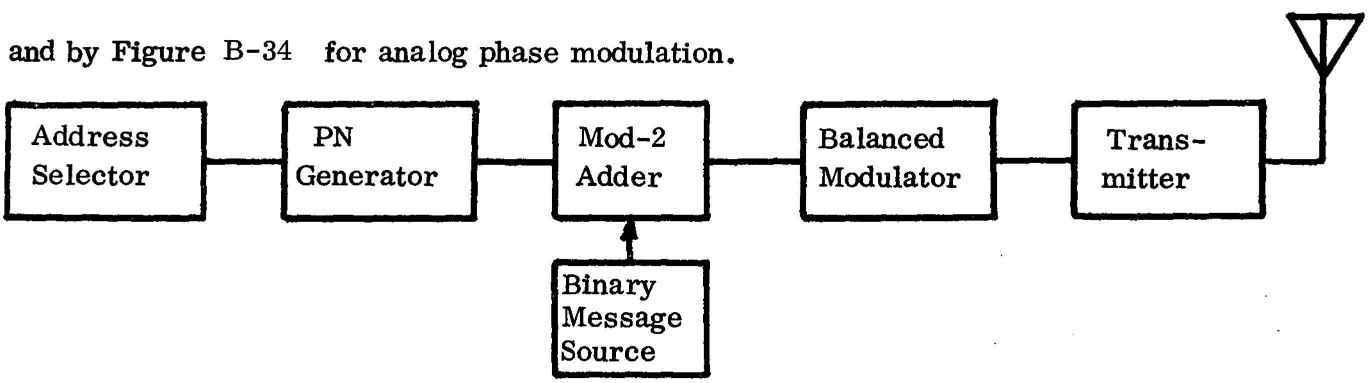


Figure B-33. Correlation-Locked System with Digital Modulation.

The address selector sets the PN sequence generator to the called party's address. In the digital system the PN sequence is bi-phase modulated by the message. The transmitted spectrum is double sideband suppressed carrier.

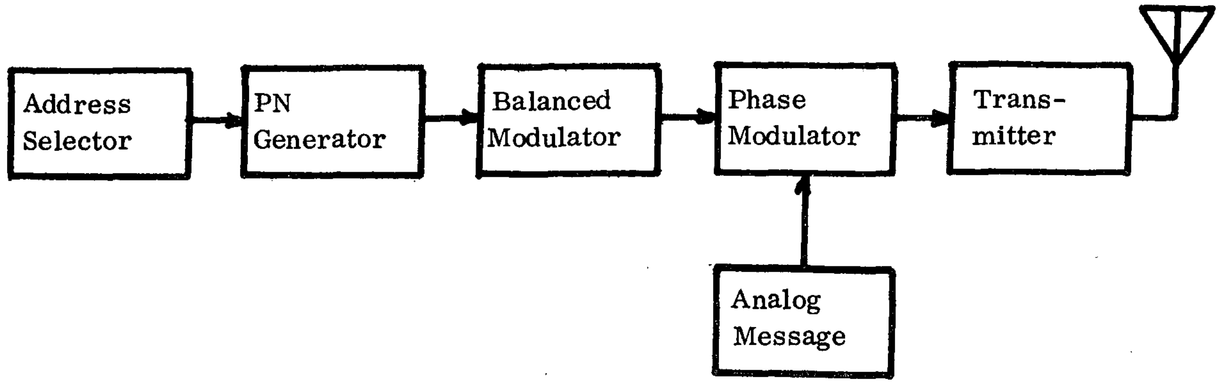


Figure B-34. Correlation-Locked System with Analog Message.

In the analog system a PN subcarrier is phase modulated by the message. The message is extracted at the receiver by multiplying an exact replica of the PN subcarrier into the received signal and narrowband filtering this output as shown in Figure B-35, a simplified block diagram.

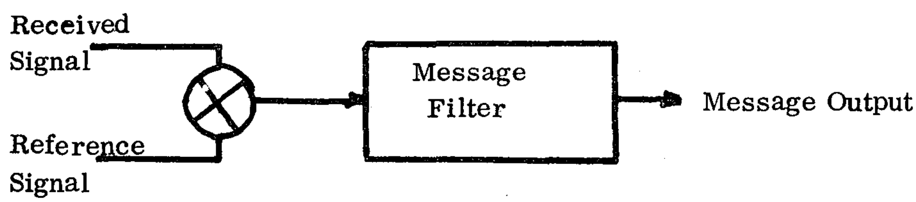


Figure B-35. Correlation-Locked Receiver.

The correlation locked system requires precise synchronization between the transmitter and the receiver at all times whereas in the matched filter technique the output of the matched filter can serve as a synchronizing signal.

The output of a filter that is matched to the input signal is the autocorrelation function of the input signal. At the instant of match the filter output is maximum. A matched filter SSMA transmitter is shown diagramatically in Figure B-36. Two PN sequence generators are driven in synchronism. Generator I corresponds to binary message symbol 1 and Generator II corresponds to message symbol 0. The binary message source selects the PN wave corresponding to 1 and 0.

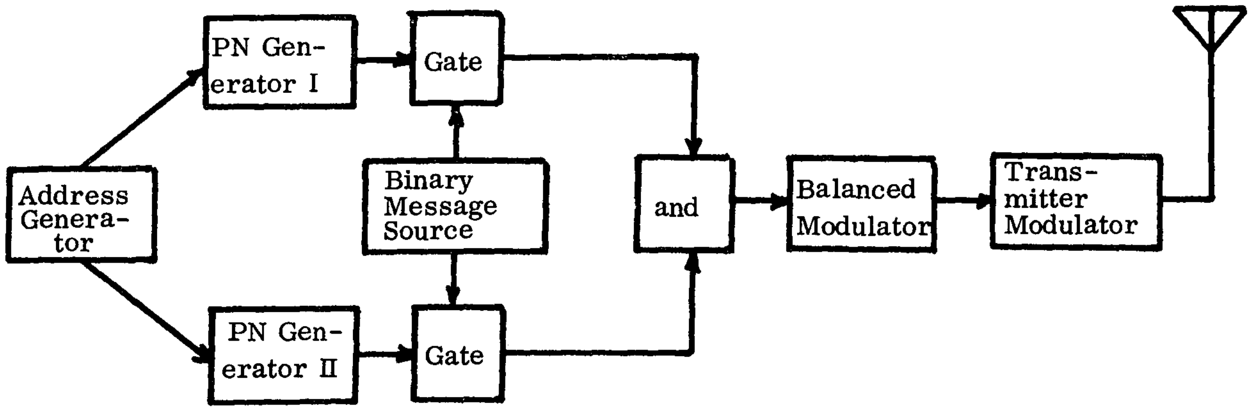


Figure B-36. Matched Filter SSMA Transmitter

A receiver for a matched filter system is shown in Figure B-37.. A combination of signal and noise is fed into the bandpass limiter and then into the matched filter which selects the desired signals and suppresses the undesired ones. The output of the matched filter is passed into an envelope detector and then into a decision device which chooses the message signal that is largest at the instant of sampling.

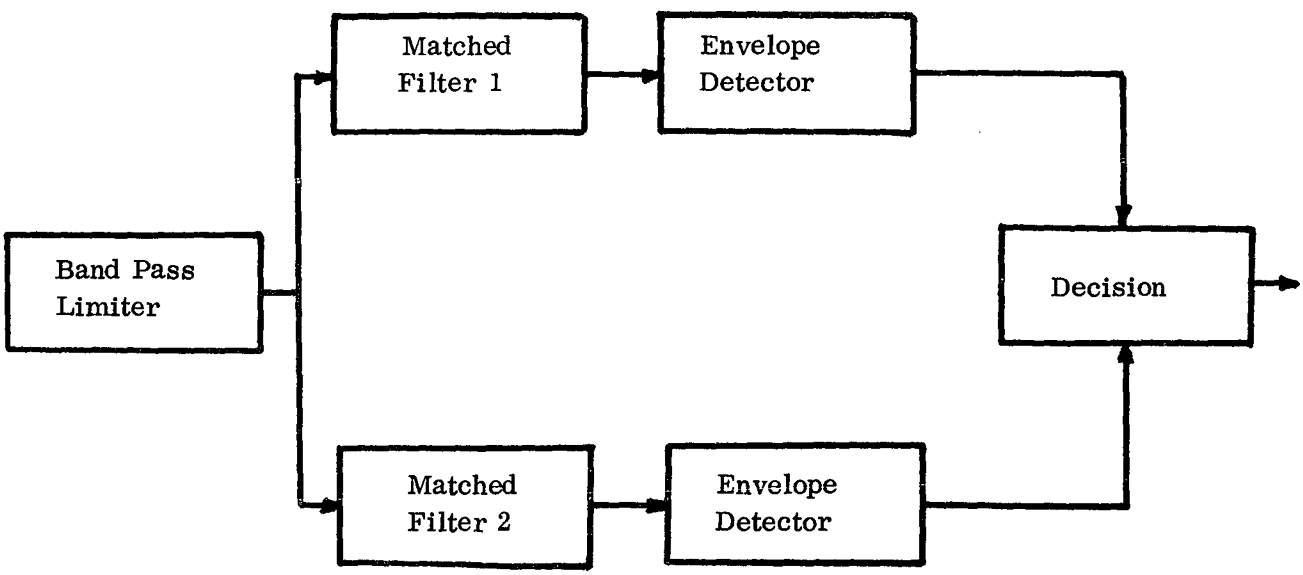


Figure B-37.. Matched Filter SSMA Receiver

One of the most important signal parameters pertaining to PN signals is referred to as "processing gains" which relates information bandwidth to RF bandwidth. The clock rate or "chip" rate determines the RF bandwidth and the duration of the message symbol corresponds to the message information bandwidth.

SSMA techniques have been proposed in a recent GSFC NASA study as a method of combating multipath and RFI problems for a communications system using satellites to relay tracking and data from scientific satellites. In this system the available RF spectrum is limited to 2 MHz and there are 40 users that might make access to the satellite simultaneously. Tentative system parameters are as follows: 1) because of the limited RF spectrum the clock rate is limited to 500 KHz; 2) the 40 users occupy 40 10KHz channels centered in the 2 MHz band; 3) all users use the same PN codes; 4) all users use the same clock rate; 5) users are identified on the basis of each having a unique carrier frequency; and 6) overall PN acquisition would take minutes.

3.4 CIRCUITS REQUIRED VS. TRAFFIC LOAD

To define multiple access system parameters it is first necessary to specify the traffic requirements. Included in these requirements is the number and type of channel and the grade or quality of service required for each channel. Type of channel refers to whether it is telephone, facsimile, digital data, teletype or TV. The "grade of service" has different meanings for the different channel types. For telephone channels, in addition to specifying the number of completed calls that fall within certain specified quality with respect to volume, distortion, noise and fidelity, grade of service in a switched system also refers to the probability of making a connection. This definition is also applicable to digital data or record transmission over a switched network. In a store-and-forward or message-switching system grade of service defines the average time to forward a message through the system.[9]

This connotation for grade of service is particularly pertinent in assessing the traffic load for a demand assigned multiple access satellite communication system.[10] Erlang formulas are generally used to ascertain the number of circuits required to accommodate a given traffic load at a particular loss probability. There are three so-called blocking formulas in use. The formula most frequently used by CCITT and ITU is the Erlang B which assumes all blocked calls are "lost" or "cleared" because of the caller "hanging up" immediately instead of waiting. CCITT has recommended that the loss probability during the mean busy hour should not exceed 1%. Thus the loss probability for a single-circuit route will be 1% when carrying only 0.01 Erlang. (An Erlang is defined as that traffic load whose calls if placed end to end will keep one path continuously occupied). In order to determine the Erlang load the stations busy hour must be determined based on an hourly distribution of the day's traffic. Then the Erlang load is calculated based on the formula.

$$\text{Erlang load} = \frac{\text{No. of calls} \times \text{average holding time per call (sec.)}}{3600}$$

Based on a required loss probability and the Erlang load, the number of required circuits can be determined using the Erlang formula or a table based on the Erlang formula as shown in Table B-5.

Similar techniques might be used to determine the number of circuits required for other than telephone channels. Analysis of all traffic loads will result in the requirement for a communication network that must provide a given number of demand assigned and fixed assigned circuits of various bandwidths between each of the terminal stations in the network.

Formula:

Let p = loss probability
y = the traffic to be carried (in erlangs)
n = the number of circuits

$$E_{1,n}(y) = p = \frac{y^n/n!}{1 + y/1 + y^2/2! + \cdots + n^n/n!}$$

n	$p = 1\%$	$p = 3\%$	$p = 5\%$	n	$p = 1\%$	$p = 3\%$	$p = 5\%$
1	0.01	0.03	0.05	51	38.80	42.89	45.52
2	0.15	0.28	0.38	52	39.70	43.84	46.52
3	0.46	0.715	0.90	53	40.60	44.80	47.53
4	0.87	1.26	1.52	54	41.50	45.77	48.53
5	1.36	1.875	2.22	55	42.41	46.73	49.53
6	1.91	2.54	2.96	56	43.31	47.69	50.52
7	2.50	3.25	3.74	57	44.22	48.66	51.52
8	3.13	3.99	4.54	58	45.13	49.62	52.50
9	3.78	4.75	5.37	59	46.04	50.6	53.5
10	4.46	5.53	6.22	60	46.95	51.5	54.5
11	5.16	6.33	7.08	61	47.86	52.5	55.5
12	5.88	7.14	7.95	62	48.77	53.4	56.5
13	6.61	7.97	8.83	63	49.69	54.4	57.5
14	7.35	8.80	9.73	64	50.60	55.4	58.5
15	8.11	9.65	10.63	65	51.52	56.3	59.5
16	8.87	10.505	11.54	66	52.44	57.3	60.5
17	9.65	11.37	12.46	67	53.35	58.3	61.5
18	10.44	12.24	13.38	68	54.27	59.2	62.5
19	11.23	13.115	14.31	69	55.19	60.2	63.6
20	12.03	14.00	15.25	70	56.11	61.2	64.6
21	12.84	14.885	16.19	71	57.03	62.1	65.6
22	13.65	15.78	17.13	72	57.96	63.1	66.6
23	14.47	16.675	18.08	73	58.88	64.1	67.6
24	15.29	17.58	19.03	74	59.80	65.1	68.6
25	16.12	18.48	19.99	75	60.73	66.0	69.6
26	16.96	19.39	20.94	76	61.65	67.0	70.7
27	17.80	20.305	21.90	77	62.58	68.0	71.7
28	18.64	21.22	22.87	78	63.51	69.0	72.7
29	19.49	22.14	23.83	79	64.43	70.0	73.7
30	20.34	23.06	24.80	80	65.36	70.9	74.7
31	21.19	23.99	25.77	81	66.29	71.9	75.8
32	22.05	24.91	26.75	82	67.22	72.9	76.8
33	22.91	25.84	27.72	83	68.15	73.9	77.8
34	23.77	26.78	28.70	84	69.08	74.9	78.8
35	24.64	27.71	29.68	85	70.02	75.9	79.9
36	25.51	28.65	30.66	86	70.95	76.9	80.9
37	26.38	29.59	31.64	87	71.88	77.8	81.9
38	27.25	30.53	32.63	88	72.81	78.8	82.9
39	28.13	31.47	33.61	89	73.75	79.8	84.0
40	29.01	32.41	34.60	90	74.68	80.8	85.0
41	29.89	33.36	35.59	91	75.62	81.8	86.0
42	30.77	34.30	36.58	92	76.56	82.8	87.0
43	31.66	35.25	37.57	93	77.49	83.8	88.1
44	32.54	36.20	38.56	94	78.43	84.8	89.1
45	33.43	37.15	39.55	95	79.37	85.7	90.1
46	34.32	38.11	40.54	96	80.31	86.7	91.1
47	35.21	39.06	41.54	97	81.24	87.7	92.2
48	36.11	40.02	42.54	98	82.18	88.7	93.2
49	37.00	40.97	43.54	99	83.12	89.7	94.2
50	37.90	41.93	44.53	100	84.06	90.7	95.2

Table B-5. Erlang No. 1 formula for loss probabilities of 1, 3, and 5 per cent*.

*CCITT Red Book, vol. II bis, Geneva, 1961.

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B.3 FREQUENCY SHARING PARAMETERS

Satellite systems have been defined and optimized for downlink transmissions in the ITFS 2.5 to 2.69 GHz and the 11.7 to 12.7 GHz frequency bands. Since channels in these two bands are already assigned for terrestrial users, it is necessary, if the satellite system and the terrestrial users share these bands, that it be on a non-interference basis. Typical models are assumed for each of the bands in order to determine the allowable conditions for sharing.

B.3.1 FREQUENCY SHARING IN THE ITFS BAND

EXISTING TERRESTRIAL FACILITIES

a. Characteristics of ITFS Fixed Service.

The ITFS service has available 31 six MHz channels in the 2.5 - 2.69 GHz band that are modulated essentially in the same manner as broadcast TV (VSB-AM video and FM aural). In a typical ITFS system four separate programs originate in a studio. Each program channel is modulated onto a carrier and fed to a separate transmitter operating in the 2.5 to 2.69 GHz frequency band. The combined outputs of the transmitter are fed to a broad area coverage transmitting antenna. The radiated signal is received by directional parabolic antennas at the various user sites. The signal is down-converted from the 2.5 GHz band to VHF channels and fed to TV receivers that are part of the user distribution system. Nominal transmitting power is 10 watts PVP although higher power is sometimes authorized. The nominal area of coverage is a 20 mile radius.

At a typical receiving site parabolic dishes are used that range in size from 1 to 6 foot. Polarization is either vertical or horizontal. Typical four channel receivers have 8 - 11 db noise figures and an RF bandwidth of 42 MHz. The four 2.5 GHz channels appear at the output of a down-converter as channels 7, 9, 11 and 13. Frequency assignments for ITFS are shown on Table B-6

b. ITFS System Model.

An ITFS terrestrial facility currently being implemented is taken as a model for purposes of this study. This system is a four channel system with a studio located at Palo Alto, Calif. and relay transmitters located on three mountain peaks in the area providing adequate coverage for users in the San Francisco Bay region. An example of the broad beam coverage of one of the relay transmitter antennas is shown in Figure B-38 providing an ERP of greater than 20 dBw over an azimuth angle of 120°.

The required receiver input signal level to yield a given picture quality will be based on this formula:

$$\left(\frac{S}{N}\right)_{TASO} = \frac{C}{N} - 1.6 + W + 10 \log\left(1 + \frac{B_{VIDEO}}{B_{BB}}\right) \qquad (1)$$

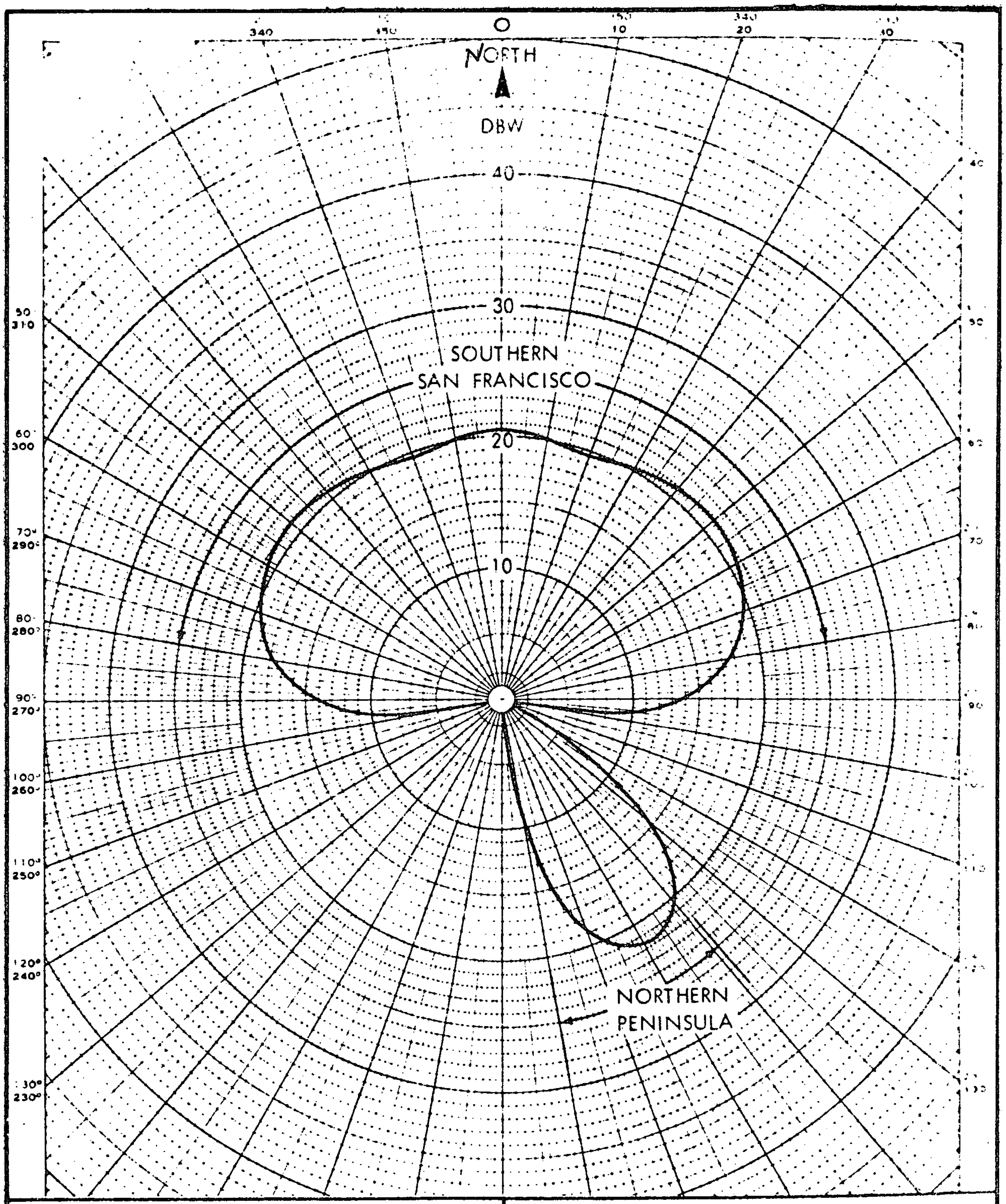
where W = weighting factor $\begin{pmatrix} \text{6.0 Db for monochrome} \\ \text{4.0 Db for color} \end{pmatrix}$

$B_{VIDEO} = 4.2$ MHz

$B_{BB} = 6.0$ MHz

GROUP	CHANNEL NUMBER	BAND LIMIT MHz
A	A-1	2500-2506
	A-2	2512-2518
	A-3	2524-2530
	A-4	2536-2542
B	B-1	2506-2512
	B-2	2518-2524
	B-3	2530-2536
	B-4	2542-2548
C	C-1	2548-2554
	C-2	2560-2566
	C-3	2572-2578
	C-4	2584-2590
D	D-1	2554-2560
	D-2	2566-2572
	D-3	2578-2584
	D-4	2590-2596
E	E-1	2596-2602
	E-2	2608-2614
	E-3	2620-2626
	E-4	2632-2638
F	F-1	2602-2608
	F-2	2614-2620
	F-3	2626-2632
	F-4	2638-2644
G	G-1	2644-2650
	G-2	2656-2662
	G-3	2668-2674
	G-4	2680-2686
H	H-1	2650-2656
	H-2	2662-2668
	H-3	2674-2680

Table B-6. **ETV Frequency Assignments for Instructional Television Fixed Service.**



N LAT 37° 41 14"
W LONG. 122° 26 01"

7.5 WATTS
ESA-H2X2 ZIGZAG

POWER SHOWN PER CHANNEL
AT INPUT TO TRANSMISSION LINE

2.5 WATTS
2-EPA-1T 1' DISHES

EFFECTIVE RADIATED POWER
T-1B, T-2B, T-3B, T-4B
SAN BRUNO MOUNTAIN SITE

Figure B-38

The receiver noise figure for the model is assumed to be 10 dB. The required receiver input signal power for a TASO 1 color picture quality $\left(\frac{S}{N} = 44.5 \text{ dB}\right)$ is - 90 dBw. The assumed receiving antenna for the model is a two foot parabola with a 21 db gain and a 13 degree HPBw. The input power to the antenna is,

$$- 90 \text{ dBw} + \text{LOSSES} - G_R$$

$$= - 90 \text{ dBw} + 2 \text{ dB} - 21 \text{ dB} = - 109 \text{ dBw}.$$

Neglecting fading over the transmission path, free space attenuation is the difference between the transmitter ERP and the required signal power at the input to the receiving antenna,

$$A_{SP} = 20 \text{ dBw} - 109 \text{ dBw} = - 129 \text{ dB}.$$

The line-of-sight distance corresponding to this value of free space attenuation is 15 miles.

Consider for an interference condition a satellite in geostationary orbit sharing the same frequency and at an orbital position and antenna directivity such that R.F. energy is directed within the main lobes of the antennas of the model ITFS receiving station. It is assumed that the transmitter of the satellite model is frequency modulated with a TV signal. To maintain the ITFS model system signal quality a minimum unwanted FM to wanted VSB - AM protection ratio, (P/R), of 35 dB is assumed.

The minimum allowable satellite ERP for the assumed parameters and conditions is,

$$\text{ERP} = P_{\text{WANTED}} - P/R + L_P + L_F - G_R + A_{SP} \tag{2}$$

where P_{WANTED} is power level of desired signal to receiver input

P/R = protection ratio required

L_P = polarization loss (3 dB)

L_F = line losses (2 dB)

G_R = receiver antenna gain (21 dB)

A_{SP} = free space attenuation (193 dB)

ERP = - 90 dBw - 35 dB + 3 dB + 2 dB - 21 dB + 193 dB = + 52 dBw.

According to CCIR recommendation 358-1(OSLO 1966) the maximum flux density produced at the surface of the earth by emissions from a space station for all conditions and methods of modulation shall not exceed

$$-152 + \frac{\theta}{15} \text{ dbw/m}^2/4\text{KH}_2 \text{ band} \tag{3}$$

where θ is the angle of arrival of the wave in degrees above the horizon. Flux density produced at the earth's surface is related to satellite ERP by,

$$H = \frac{G_t P_t}{4\pi R^2} = \frac{\text{ERP}}{4\pi R^2} \tag{4}$$

where G_t = satellite antenna gain

P_t = satellite transmitter power output

R = 35,700 km (synchronous orbit to subsatellite point)

H = flux density

expressed in db

$$H_{\frac{\text{dbw}}{\text{m}^2}} = \text{ERP (dbw)} - 162 \tag{5}$$

Equating (3) and (5) gives

$$\text{ERP (dbw)}\Big|_{\max} = \left[162 + (-152 + \frac{\quad}{15})\right] \text{(dbw)} + BW_r \tag{6}$$

where

BW_r = ratio of operating bandwidth to $4KH_2$ in db.

$$ERP_{(dbw)}\Big|_{max} = 10 + \frac{\theta}{15} + 10 \log_{10} \frac{BW}{4KHz} \quad (7)$$

let us assume for our model,

$BW = 33.6$ MHz

$\theta = 15°$

$$\text{then } ERP\ (dbw)\Big|_{max} = 10 + 1 + 10 \log_{10} \frac{33.6 \times 10^6}{4 \times 10^3}$$

$= 10 + 1 + 39.25$

$= 50.25$ dbw

which differs by less than 2 db the value based on the assumed ground model and frequency sharing criteria.

Assignment of constraints on the satellite position that would in effect eliminate the lower elevation angles with respect to the ITFS system sharing the same frequency would allow greater satellite ERP in accordance with the discrimination provided by the ITFS receiving antenna. There is also the interference condition whereby a ground station receiving from a satellite is interfered by the ITFS terrestrial relay station sharing the same frequency. The resultant AM on FM interference problem does not require as high a P/R ratio as the FM on AM interference situation. The assumed P/R for AM on FM is 16 dB, the ratio of the average FM carrier power to the average AM power during the synch pulse.

In this situation the required signal power level at the FM receiver is determined whereupon the conditions for non-interference are established. Signal-to-noise ratio requirements for a given picture quality are:

$$\left(\frac{S}{N}\right)_{TASO} = \frac{C}{N} + I_{FM} + W + I_{PRE} + P \quad (8)$$

where I_{FM} (FM IMPROVEMENT) $= 3\ M^2\ (M + 1)$

(M = MODULATION INDEX)

$$W\text{, WEIGHTING, } = \begin{cases} 10.3 \text{ dB CCIR/ATT MONO} \\ 7.0 \text{ dB EIA/ATT COLOR} \end{cases}$$

$$I_{PRE}\text{, PREEMPHASIS IMPROVEMENT, } = \begin{cases} 2.6 \text{ dB MONO} \\ 0 \quad \text{dB COLOR} \end{cases}$$

P, PEAKING FACTOR, = 7.6 dB

For a M of 3 a TASO 1 quality color picture is obtained at a $\frac{C}{N}$ of 10 dB which is FM threshold.

$$I_{FM} = 10 \log \left[3 \times 3^2\ (3 + 1)\right] = 20.3 \text{ dB}$$

$$\left(\frac{S}{N}\right)_{dB} = 10 + 20.3 + 7.0 + 7.6 = 44.9 \text{ dB}$$

For a system noise temperature of 1000 degrees K and a 33.6 MHz R.F. bandwidth the required receiver input signal power is - 113 dBw. The allowable unwanted signal power for a non-interference condition is - 113-16 = -129 dBw.

A 6 ft. parabolic dish would be required at the FM ground station to provide the required signal level at the receiver input assuming a 52 dBw ERP at the satellite. A typical 6' dish (Andrews P6-24) has the following characteristics:

gain	31.2 dB
HPBW	4.5 degrees
1st Side Lobe	-20 dB*
Wide angle lobe	-33 dB*
Front to back ratio	38 db

*Relative to main lobe.

Assuming the FM ground station is located within the main beam of the ITFS relay transmitter, (see Figure E-1) the minimum allowable distance between the ITFS relay transmitter and the FM receiving ground station is:

$$A_{SP} = ERP_{AM} - P_{UNW} - L + G_R$$

Based on an ERP_{AM} of + 20 dBw, a P_{UNW} of - 129 dBw, line losses, L, of 2 dB and antenna gain, G_R, the position of the FM receiving station with respect to the ITFS relay transmitter, the minimum allowable separation would be 100 miles, when the FM antenna main angle lobe is in line with the ITFS transmitter.

To alleviate this severe constraint of relative location and separation, a solution might be to locate the earth station, where possible, below the level of the surrounding or nearby terrain. The following site shielding factor could then be included:

ELEVATION ANGLE (DEGREES)	SITE-SHIELDING FACTOR** (dB)
0-1	0
1-2	10
2-3	17
3-4	23
4	25

** CCIR OSLO 1906 IV_2 Rept. 382 p.356.

B.3.2 SHARING IN THE 12 GHz BAND

3.2.3.1 CHARACTERISTICS OF 12 GHz BAND - The following parameters are applicable to the 12 GHz band:

a. Band limits - 11.7 to 12.7 GHz

b. Channel bandwidth - 20 MHz

c. Frequency deviation - 8 MHz maximum

d. Frequency tolerance - .05%

e. Maximum R. F. Power - 5 watts average

f. Beamwidth - 4^o

3.2.3.2 12 GHz SYSTEM MODEL - An assumed system model is a 20 mile terrestrial link relaying a T. V. signal. Sharing the same frequency spectrum with this terrestrial system is an earth station transmitting a TV signal to a relay satellite in geostationary orbit.

A typical receiver/transmitter selected for the terrestrial relay stations has the following Characteristics: Manufacturer - Microwave Associates MA-1313

a. Frequency band - 10.5 - 13.25 GHz

b. Tuning range - 250 MHz

c. Deviation - 8 MHz

d. Modulation - FM

e. Transmitted power - + 20 dbm

f. Receiver noise figure - 12 db
(with low noise pre-amp) - 2.6 db

Identical parabolic dishes are assumed for the transmitter and receiver. Typical characteristics are as follows:

a. Diameter - 2 ft.

b. Gain - 35.3 db

c. Beam width - 2.7^o

d. 1st sidelobe - 16 db*

e. Wideangle lobe - 35 db*

f. Front to back ratio - 40 db

* (Relative to main lobe)

The applicable formula for determination of signal to noise requirements for the desired picture quality is

$$\frac{S}{N}_{TASO} = \frac{C}{N} + I_{fm} + W + I_{pre} + P$$

where

I_{fm} (fm improvement) = $3M^2(M+1)$

(M = modulation index)

W, weighting, = 10.3 db CCIR/ATT mono
7.0 db EIA/ATT color

I_{pre}, preemphasis improvement, = 2.6 db mono
0 db color

P, peaking factor, = 7.6 db

$$I_{fm} = 3\left(\frac{8}{4.2}\right)^2 \left(\frac{8}{4.2} + 1\right) = 31.2$$

or 15 db

For a TASO 1 color picture quality the required $\frac{C}{N}$ = 44.5 - 15 - 7.0 - 7.6 = 15 db

The required receiver input power level, Pr, based on a 12 db noise figure, 20 MHz bandwidth and a 15 db $\frac{C}{N}$ is -104 dbw.

15.6 db is allocated for fading margin, F, based on these factors:

$$F = P_t + G_t - L_t - A_s - L_r + G_r - P_r$$

$$= -10 \text{ dbw} + 35.3 - 2 - 145 - 2 + 35.3 - (-104 \text{ dbw}) = 15.6 \text{ db}$$

where, P_t = transmitter power

G_t = transmitting antenna gain

L_t = transmitting losses

A_s = space attenuation (20 mi at 12 GHz)

L_r = receiver losses

G_r = receiving antenna gain

P_r = required receiver input power level

There is an interference condition caused by the relay link receiver sharing the same frequency as an earth station transmitting to a satellite in geostationary orbit. It is necessary to establish a minimum allowable flux density in the vicinity of the terrestrial relay receiver as radiated by the earth station. To meet this requirement careful location of the earth station to provide antenna discrimination, geographical separation and sits shielding would be required.

There is an alternate interference situation that exists when a satellite transmitter shares the same frequency as a terrestrial relay system. Again it is necessary to establish a minimum allowable flux density in the vicinity of the terrestrial relay receiver as radiated by the satellite. To meet this requirement it is necessary to limit satellite ERP, orbital location and antenna characteristics.

The allowable flux density, H, in the vicinity of the terrestrial relay receiver is based on these factors:

Protection ratio, P_r for FM on FM interference of 15 db

Receiver line loss, L_r, of 2 db

a 55% efficient 2' antenna

Interference is within the antenna main beam

Required receiver input power level = -104 dbm

Effective antenna area, A_e, is,

$$(2 \times 0.3048)^2 \quad \times .55 = 0.643 \text{ square meters}$$

allowable signal power at antenna terminal is,

$$-104 \text{ dbm} - 15\text{db} + 2\text{db} = -117 \text{ dbw}$$

allowable flux density is,

$$H = -117 \text{ dbw} + 10 \log \left(\frac{1}{0.643}\right)$$

$$= -117 \text{ dbw} + 1.92 \text{ db} = -115.1 \text{ dbw/M}^2$$

Finally, consider an interference condition that exists when a satellite in geosynchronous orbit radiates at the same frequency as the 12 GHz terrestrial system model. To determine the allowable satellite ERP, the following equation is applicable,

$$\text{ERP dbw} = H + 10 \log 4\pi R^2 + L_{atm} + L_p$$

Where H = allowable flux density at receiving site in dbw/M^2

R = 35,700 Km (synchronous orbit to subsatellite point)

L_{atm} = Minimum low elevation angle stmospheric loss at 12 GHz (1db)

L_p = polarization loss (3db)

$$\text{ERP} = 115.1 + 10 \log (4\pi \times 35,700,000^2) + 3 + 1$$

$$= -115.1 + 162.1 + 3 + 1$$

$$= 51 \text{ dbw}$$

B.4 SYSTEM MODELS/SPIN STABILIZED SATELLITES - The objective of this part of the study is to model the attitude control system for spin stabilized satellite configurations and to determine the effect of spin stabilization on other satellite subsystems (power in particular) so that comparative size, weight, and cost data can be generated.

Three basic configurations of spinning satellites are apparent, these are: full spin, dual spin/mechanically de-spun antenna, and dual spin/ mechanically de-spun antenna and directed solar array.

Ground rules established to reduce the number of possible variations of basic configurations considered are:

1. Full spin is assigned low priority. Omnidirectional and electronically de-spun antennas are not particularly compatible with the narrow beams under study. Furthermore, the squat configuration necessary for full spin will generally result in inefficient use of launch vehicle payload envelope.

2. Configuration A, dual spin with mechanically design antennas, has a cylindrical spinning solar array which constitutes the major part of the spinning mass.

3. Configuration B, dual spin with directed solar array, uses an internal momentum storage device, and has an external overall configuration identical to the 3-axis stabilized system.

4. Only horizontal spin - parallel to the earth's axis is considered.

5. This attitude control system analysis is limited to a low level system, a high-level system if required for use during maneuvering and station keeping is part of the station keeping subsystem.

Configurations A and B are similar in their requirement for external torque for spinup and power to overcome bearing friction, and for that matter, similar to the 3-axis system in torque required to overcome external bias torques and thrust requirements and control torques for station keeping.

The essential difference between the 3-axis system and the spin stabilized satellite is how it behaves when a disturbing torque is applies. When torque (unbalanced solar pressure, outgassing, thruster leakage, etc.) disturbes a 3-axis system, angular momentum is imparted and the satellite rotates until a diplacement or rate is sensed and a correction is made. The correction can be made by storing the momentum or dumping it through use of an opposing torque.

When the same torque impulse is applied to the spinning satellite, the momentum error perturbs the spin momentum vector causing wobble. A damper, in the non-spinning body, will remove energy (some fraction each wobble cycle) until the wobble has damped out. The resulting stable spin vector of the satellite will be displaced slightly in direction and magnitude. As long as the disturbances are small and random, the spinning satellite will tend to maintain the same orientation in space without the use of non-conservative systems. Unfortunately, the major external torques applied are not random, and the external torque required to maintain the spin vector is essentially the same as that for the 3-axis system.

B.4.1 <u>Weight Analysis for Configuration A.</u> The major weight penalty of this configuration is not in attitude control equipment but in additional solar array weight (a factor of π) resulting from the use of a spinning array.

The elements of the attitude control system for Configuration A have been identified and preliminary weights assigned . The elements are:

1. Spin table
2. Spin motors
3. Bearing system and drive
4. Damping system
5. Low level thrust subsystem
6. Sensors and electronics

SPIN TABLE

The spin table weight allowance is the weight difference resulting from installation of a bearing and caging system in the satellite/launch vehicle adapter and separation system. Using AREA (area of the equivalent directed solar array) as an indication of satellite size:

Weight (spin table) = 10 x 0.02 * AREA

SPIN MOTORS

An allowance is made for solid propellant motors to spin the rotating portion of the satellite. For a satellite mass with spin radius, L(ft), spin rate of 4.5/L (rps), spin mass, 2*π* AREA/32.2 (slugs), motor Isp of 150 (sec.), and propellant faction of 0.80:

Weight (Motor) = 0.045 * AREA

BEARING SYSTEM AND DRIVE

A bearing system is required between the spinning and "stationary" parts of the satellite, and a motor is needed to overcome bearing friction to hold the stationary part in its earth pointing orientation. Lumped here is also an allowance for balance weights.

Weight (Bearing system) = 5 + 0.035 * AREA

DAMPING SYSTEM

(Weight not yet assigned)

LOW LEVEL THRUST SYSTEM

A low level system is sized to compensate for solar torque. Using an ammonium system for a satellite life of LSAT (yrs.):

Weight (Thrusters) = (.706 + 1.36 * LSAT)* .001 *π* AREA

SENSORS AND ELECTRONICS

A tentative weight allowance of 25 lb. is assigned for sensors and electronics. The spin stabilized satellite does not require the gyro inertial reference system.

B.4.2. Weight Analysis Configuration B. This configuration has an outward appearance of the 3-axis system. It uses an internal spinning mass because the lighter, high-spped wheel results in a weight saving, and the use of rotating satellite body part s does not provide a useful platform for mounting of sensors in this application.

Halstenberg (AD-70-11) proposes the weight of a reaction wheel as 8*SQRT*H) where H is the angular momentum. Including the damper and motor, he suggests a value of 20*SQRT(TI/P) where TI is the transverse moment of inertia of the satellite and P is the wobble period. The wobble period should be at least 10 times the resonaut period of the extended solar panels or 10 to 100 sec. Using TI = AREA * M **2/32.2, and P = 100 sec., where M is the moment arm of the panel:

Weight (wheel system) = 2*SQRT (AREA*M**2/32.2)

In addition, as before:

Weight (Thrust system) = (.706 + 1.36 * LSAT)*AREA*M*.001/L

Weight (Sensors/Electronics) = 25.

It is assumed that the wheel can be brought up to speed during coast, and the attitude control system of the launch vehicle provides the compensating torque so that spin motors are not required.

B.5 A REVIEW OF RELIABILITY FACTORS CONTRIBUTING TO LONG LIFE IN COMMUNICATION SATELLITES

1. Introduction

The Hughes Aircraft Company has been responsible for programs involving more than twenty synchronous satellites, beginning with SYNCOM I in 1963, and extending through the current INTELSAT IV series. A great deal of valuable and unique experience has been accumulated by the personnel involved in these programs. This paper is a brief summary of reflections of key reliability specialists from Hughes satellite programs. It discusses those reliability factors which have emerged as significant in the evaluation of long life systems. Problem areas with high current need for improvement are also identified. Much of the material in this review was condensed from a paper presented at WINCON, 12 February 1970, by Dean L. Lindstrom, Assistant Manager of Product Effectiveness at Hughes Space Systems Division.

2. Summary of Reliability Experience With Spacecraft Subsystems

Table B-7 is a summary of the mean time between failure (MTBF) for representative spacecraft subsystems. This data was compiled principally from hardware in the TACSAT and INTELSAT IV series of spacecraft and is representative of the state of the art.

TABLE B-7

MEAN TIME BETWEEN FAILURES (MTBF) OF TYPICAL SPACECRAFT ASSEMBLIES

SUBSYSTEM	ASSEMBLY	MTBF (HOURS)
COMMUNICATION	TUNNEL DIODE AMPLIFIER	12,000,000
	MIXER	10,000,000
	TRAVELING WAVE TUBE & DRIVER	370,000
	REGULATOR	1,300,000
	OSCILLATOR MULTIPLIER	2,700,000
TELEMETRY	TRANSMITTER	340,000
	ENCODER	170,000
COMMAND	RECEIVER	210,000
	DECODER	260,000
ATTITUDE CONTROL	SUN SENSOR	500,000
	EARTH SENSOR	360,000
	DESPIN CONTROL ELECTRONICS	80,000
POWER	BATTERY CONTROL ELECTRONICS	5,500,000
	BATTERY	16,000,000

3. Conservative Design

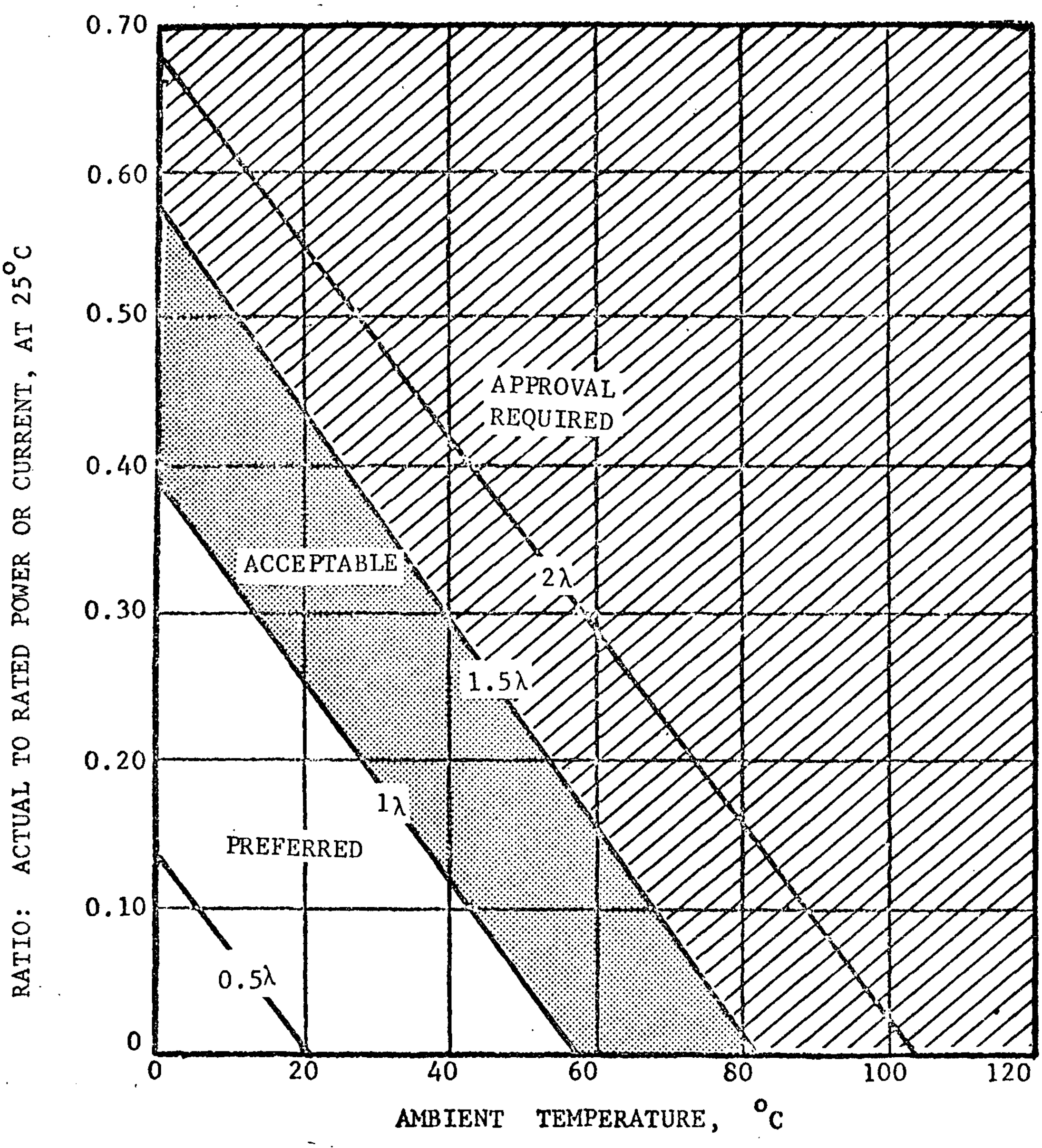
Conservative design requires a selective compromise between high performance and safety margins. A good example is the derating of parts. In representative satellite subsystems most parts are derated at 20% or less; sometimes parts are derated to less than 1% of rated value.

Another important factor is the control of thermal environment. Much care is given during the design to assure that all units are operated within a fairly uniform temperature range. This moderate temperature environment has been fairly easily controlled with spinning satellites. The average temperature is about 25^{o}C, with extremes occurring only during eclipse periods. The use of design safety margins is important in achieving long life. In digital equipment, for example, 5% resistors employed where the required tolerances are only of 15% to 20%. In the bearing of the TACSAT, although the life requirement is only 5 years, 50 years' supply of lubricant is provided.

The derating method used for a typical semiconductor is shown in Figure B-39 The derating requirements are dependent upon both the stress and temperature of the part. The policy established for each program requires that all parts, wherever possible, be operated in the acceptable range shown in the figure. There are two cases which require consideration. These are when the part stress is operated outside the acceptable or preferred ragion, or when more

FIGURE B-39

ELECTRICAL STRESS VERSUS TEMPERATURE
FOR TYPICAL TRANSISTOR



than 20% of the parts are operated outside the preferred range.

Derating of other parts is performed on a similar basis. Derating of integrated circuits is a little more complex, but consists primarily of maintaining control of the junction temperature. A typical derating curve for microcircuits is shown in Figure B-40. The Hughes philosophy is that an electronic part properly applied and derated will last indefinitely, and hence is not a life factor on systems currently under consideration.

4. Design Optimization

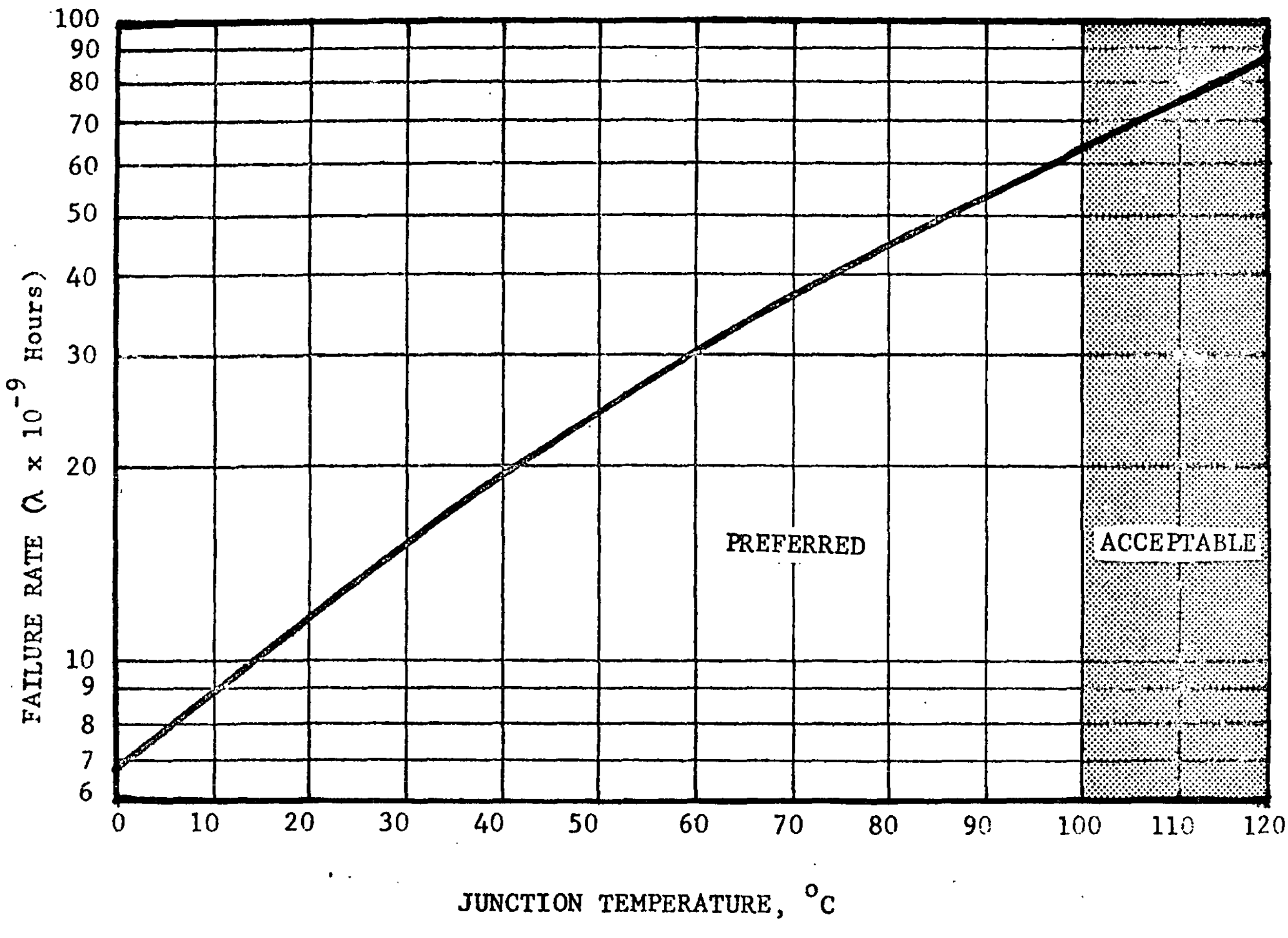
To obtain high reliability consideration of an optimum design must occur during the conceptual design period. On the Hughes communication satellites nearly all electronic units are redundant. In retrospect the question may be asked as to whether this level of redundancy was necessary. However, the design tradeoffs conducted were based upon the data available at the time of the design. Extensive effort was given to configuration tradeoffs at the concept and during the early design phase of the system. In each case design was optimized to achieve the reliability required.

5. Parts and Materials Program

A significant factor in the development of long life and high reliability is the parts and materials program. To obtain reliable parts and materials controls must be established for the production process. When practicable, specifications are written using the manufacturer's processes as a basis. Qualification of a new part or material includes evaluation of the vendor's process controls

FIGURE B-40

FAILURE RATE VERSUS JUNCTION TEMPERATURE
FOR MICROCIRCUITS



as well as the performance of the part. Parts are tested to the specification rather than to the requirements of a particular program. When qualified, a part is included on an Approved Parts List. Parts used on a particular program are evaluated relative to the program requirements then, if acceptable, entered on a Program Authorized Parts List.

The terms "reliability control" and "parts and materials control" are often interpreted to mean control at the expense of new development. Such extensive control is neither required nor is practiced on communication satellites. Each program has required considerable innovation and development of new parts and materials. A proper term to describe this process is "managed innovation". In other words, innovation is necessary and desirable; however, to achieve high reliability and to maintain control of costs and schedules, some management of this innovation is necessary. Therefore, when discussing parts and materials program and parts and materials control, it should be understood that what is meant is control in terms of managed innovation.

In addition to the standard test limits and methods imposed by the applicable Government specifications, the general parts screening requirements of Table B-8 are imposed as a minimum.

TABLE B-8

PARTS SCREENING STEPS

1. VISUAL INSPECTION BEFORE SEALING
2. ACCELERATION
3. X-RAY - WHEN APPLICABLE
4. TEMPERATURE CYCLING
5. BURN-IN AT RATED POWER OR VOLTAGE
   a. SEMICONDUCTORS AND INTEGRATED CIRCUITS 168 - 672 HOURS
   b. RESISTORS AND CAPACITORS 96 - 168 HOURS

On the INTELSAT II and ATS Programs the parts burn-in was conducted for 1500 hours. The selection of parts was based upon parameter drift screening. Parameter drift screening consists of taking readings on critical parameters at several points during the burn-in process, and analyzing the data to select those parts which are the most uniform in their performance and whose drift is within specific limits. Analysis of data on the ATS Program indicated that the 1500 hours could be reduced. On the INTELSAT IV Program the burn-in of semiconductors is 4 weeks or 672 hours.

6. Test Program

The space programs introduced test philosophies with significant differences from earlier programs. Previously, acceptance testing on hardware was conducted primarily to identify workmanship defects. Hence, the tests were conducted at levels lower than operational to avoid degradation of operational performance. On both the Surveyor Programs and Communication Satellite Programs, acceptance testing of hardware was conducted at expected operational levels. In some cases these have been more stringent than the operational levels actually experienced in space. The current criteria is that if a system survives the acceptance test, then it will continue to operate successfully in its operational environment. Acceptance and qualification tests are conducted at many levels of hardware, from piece parts through complete systems. A solar-thermal-vacuum test simulating operational conditions serves as a final test of a system's capability of survival. An orderly system for failure correction is particularly important during this time phase.

7. The Space Environment

Another factor affecting the communication satellites' long life capability is the space environment itself. At synchronous altitude the environment for a spinning satellite is relatively benign - probable better than a laboratory environment. The only new factor introducted is Van Allen Belt radiation. This has not been a significant factor in satellite operation except for degradation of solar cell capability. With a spinning satellite at moderate temperatures the affects of the sun are distributed uniformly over the satellite, resulting in a uniform and moderate temperature. There is little shock or vibration except for that introducted by the satellite's own motion. Elimination of failure induced by manned checkout and adjustment is probably a significant factor. Extremely well-controlled conditions would be required to duplicate a space environment in the laboratory.

8. Conclusions

The capability for designing and testing for long life was advanced during a period when innovation reached a peak. We know much more about the space environment now, but we should not take the achievements of the 1960's for granted. While the technology may change, the "reliability approach" must continue to be emphasized.

Although the state-of-the-art situation today on integrated circuits, hybrids, and large scale integrated circuits (LSI) is similar to that of diodes and transistors ten years ago, there is a significant difference. We know much more about the physical and chemical properties of parts, and the importance of controlling them during production. The effects of handling, fabrication, and testing on these sensitive parts must be determined and understood. The development of high reliability in these devices will depend more on knowledge of these properties than on large test programs.

Introduction of these new parts will affect the role of the circuit designer. He will become more involved in the development of these sophisticated devices and less involved in systems design.

The growth in complexity of the communication satellites, and the achievement of the Surveyor and Apollo Programs, are indicative of the trend that we can expect in the 1970's. The life and reliability capabilities have increased similarly, leading to considerations of missions which were not practical in the 1960's. Because of the duration of some of these missions, greater life span assurance will be required prior to initiation than has been practical in the 1960's. For this reason, we are likely to see a shift of emphasis in favor of greater assurance as opposed to innovation.

Table B-9 presents a list of communications satellite equipment which has a high current need for improvement, and indicates the key problem areas, potential solutions and further study actions required to resolve these problem areas to provide the support required on the spacecraft. The listed items are in essence expected to be the life-limiting components on the next generation of communications satellites. By illustrative comparison, the SYNCOM spacecraft designed for 18 months life uses no moving parts and has moderate redundancy in its electrical and electronic equipment. As a result the satellite is still in operational service after seven years.

3 (4)

TABLE B-9

COMMUNICATIONS SATELLITE EQUIPMENT HAVING HIGH CURRENT NEED FOR IMPROVEMENT

ITEM	USE	KEY PROBLEMS	BEST PRESENT SOLUTION	DIRECTION OF FURTHER ACTION
Reaction Wheels	3-Axis Stabilization	Bearing life and lubrication	. Lightly loaded bearings . Proper selection of lubricants . Hermetic seal . Cleanliness . Redundant wheels	. Lubricant studies . Test program to determine proper bearing loads and lubricant selection. . Redundancy analyses . Analyze use of standby vs. active wheels . Establish cleanliness requirements
High Wattage Power Supply	Transmitter	Heat dissipation, corona from high voltage components	. Special thermal control . Selection of proper potting materials . Parts derating	. Thermal studies . Potting materials evaluation . Optimum parts selection . Advanced packaging technology
Gimbals and Drive Assembly	Antenna Drive	Bearing life and lubrication	. Selection of appropriate lubricants . Cleanliness . Redundant antennas . Labyrinth seals	. Dry vs. wet lube studies . Redundancy analyses
Bearings and Power Transformer Assembly	Gyrostat	Bearing life and lubrication	. Lightly loaded bearings . Proper lubricant . Labyrinth seals . Cleanliness	. Lubricant studies . Tests to determine proper bearing loads . Establish cleanliness requirements

(Continued)

TABLE B-9 (Continued)

ITEM	USE	KEY PROBLEMS	BEST PRESENT SOLUTION	DIRECTION OF FURTHER ACTION
Thruster Valves	Attitude Control	Poppet and seat life	. Control of poppet and seat materials . Cleanliness . Material compatibility	. Evaluate new seat and poppet materials . Evaluate materials compatibility . Establish cleanliness controls
Antennas	Communication Subsystem	Thermal control and distortion	. Special thermal radiation	. Antenna thermal analysis . Structural analyses
Batteries	Eclipse period power supply	Life	. Control depth of discharge . Materials selection . Thermal control . Deactivated batteries	. Depth of discharge vs. . life tradeoff studies . Battery test programs
Solar Panel	Power Supply	. Solar cell radiation damage . Epoxy life	. Provide power margin for predictable degradation . Selection of epoxy for long life	. Radiation damage studies . Evaluate epoxy materials
Thermal Control	Satellite Temperature Control	. Heat dissipation . Low temperature control	. Radiators and reflectors . Heat pipes . Location . Insulation	. Spacecraft thermal analyses

APPENDIX C

SUBSYSTEMS DEFINITIONS

C.1 VOICE COMMUNICATION PARAMETERS

1. Channel Quality Requirements. To determine the basic requirements for a voice channel it is necessary to define the quality of voice transmission needed. Subjective tests have been made on subjects listening to speech under various degrees of channel quality. Tests have been made using syllables, words and sentences to produce data that correlates the percentage of syllables, words and sentences understood to voice channel quality. Voice channel quality is defined by the parameter, articulation indices which depends upon frequency response, overall gain or speech levels, noise conditions and distortion. A technique has been developed to compute articulation index. The frequency range that contributes to intelligibility extends from 200 Hz to 6100 Hz. This spectrum is divided into 20 bands that contribute equally to speech intelligibility. In Figure C-1, the articulation index is computed by taking the ratio of

$$\frac{(\text{Area between B and D}) - (\text{Shaded Area})}{\text{Area between B and D}}$$

where the shaded area corresponds to the noise that overlaps the dynamic speech range. Limitation of frequency response that reduces speech levels below the threshold of audibility within the 200 Hz to 6100 Hz frequency range degrades the articulation index so that if superior speech quality is desired the channel frequency response should extend from 200 Hz to 6100 Hz with very little extraneous noise occurring above the threshold of audibility. Most communications systems do not provide this type quality for voice channels Figure C-2, the relationship between articulation index and intelligibility, shows that an intelligibility of 95% can be achieved with an articulation index of 0.4. An articulation index of 0.4 corresponds to a speech channel limited to a frequency response of 430 to 1660 Hz and a signal to noise ratio of 30 db. A channel of this quality would be acceptable for a limited number of applications where sentence and word repeats and spelling of critical words are acceptable.

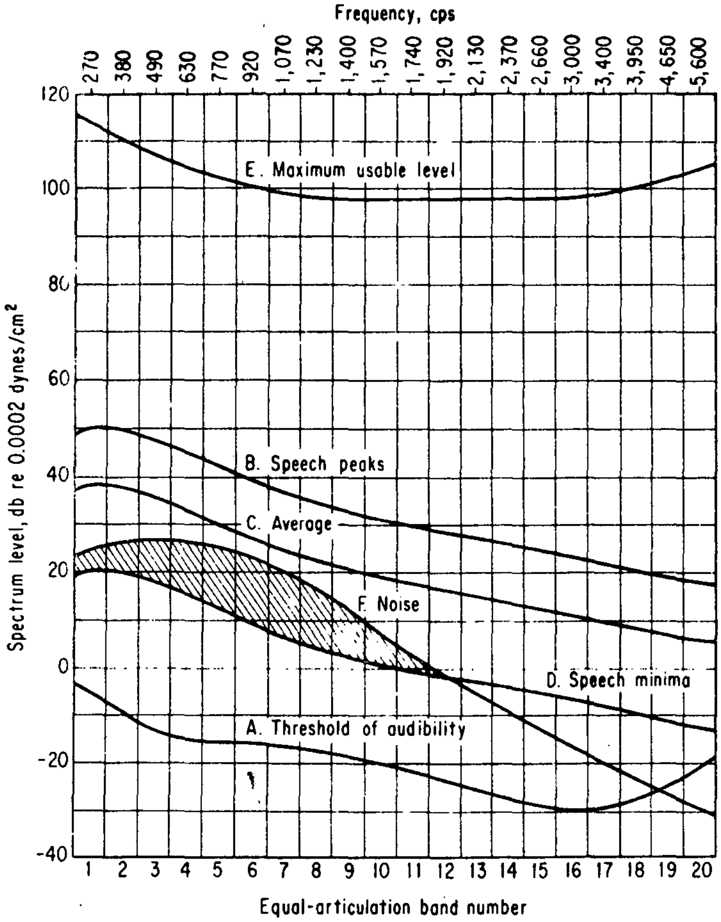


Diagram illustrating the articulation-index computation. Here noise intrudes into the dynamic range of the speech and masks a part of it (indicated by the shaded area), thus reducing intelligibility.

Figure C-1. Diagram Illustrating the Articulation-Index Computation.

The frequency response of a voice channel in a standard frequency division multiplex telephone system is limited to the range of 300 Hz to 3400 Hz. The signal to noise ratio varies over a wide range depending upon the type of circuit from that obtainable on a leased network where there is often a noticeable background hiss to the stringent requirements of radio relay circuits. Noise level standards have developed as the result of international conclaves of the CCITT and CCIR. The recommendations resulting from these sessions are generally followed by the various public communications services. The total allowable noise is made up of two components, thermal and intermodulation noise. The allocation of allowable noise based on a percent of any month is shown in Figure C-3. The latest CCIR recommendation on noise (Rec. 353-1 Oslo 1966, Vol IV, part 2, p. 205) specifies that total noise shall not exceed:

10,000 pW psophometrically-weighted mean power in and hour; and

10,000 pW psophometrically-weighted one-minute mean power for more than 20% of any month.

Based on a telephone channel zero reference level of one milliwatt this corresponds to a signal to noise ratio of 50 db in the worst (top) channel of a frequency division multiplex system.

2. Typical Satellite FDM-FM System. CCIR Report 211-1 (Oslo Vol. 4, Part 2, p. 307) recommends parameters for the design of a multiple voice channel FDM-FM telephone relay system. Here the basic relationship between carrier-to-noise ratio and signal-to-noise ratio is given as:

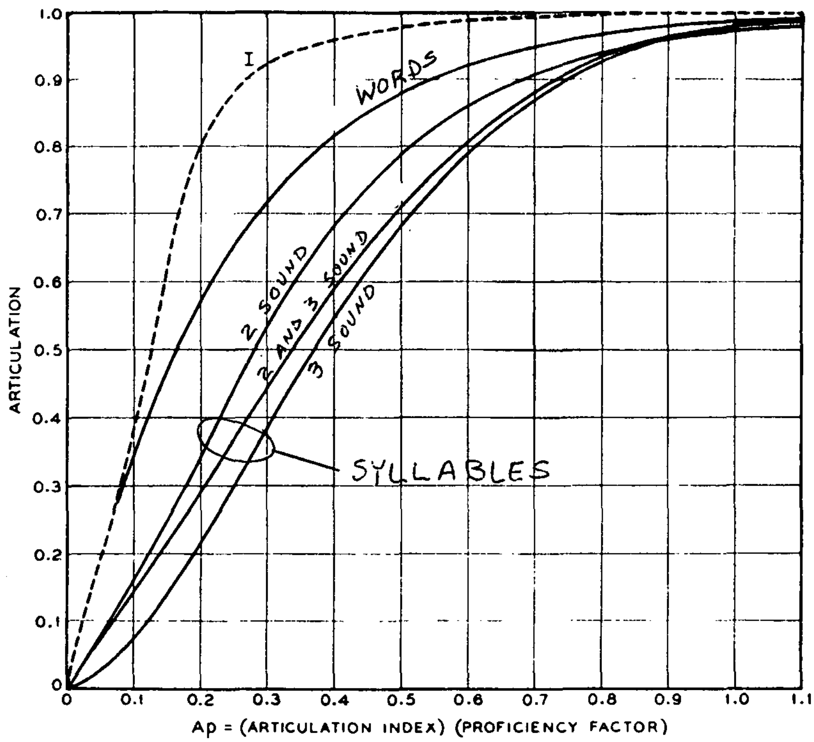


FIG. 179. RELATION BETWEEN VARIOUS MEASURES OF ARTICULATION AND THE ARTICULATION INDEX.

Figure C-2. Relation Between Various Measures of Articulation and the Articulation Index.

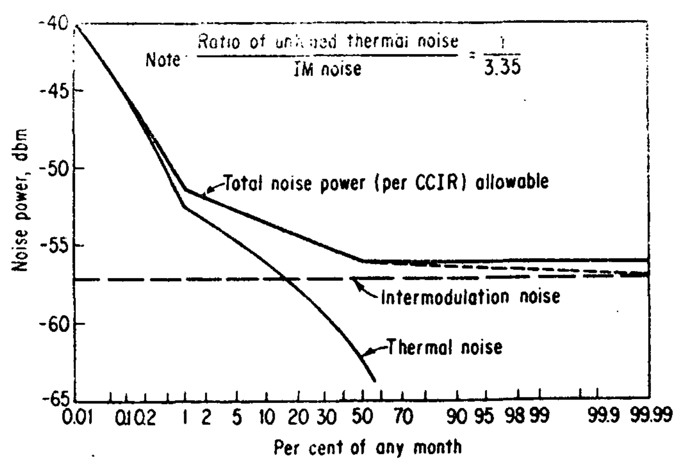


FIG. 10. CCIR recommendation for intermodulation and thermal-noise allocation. (*Courtesy of Comité Consultatif International des Radio Communications CCIR.*)

Figure C-3. CCIR Recommendation for Intermodulation and Thermal-Noise Allocation.

$$\frac{S}{N} = \left(\frac{C}{N}\right)\left(Fch/fm\right)^2 \left(Brf/b\right) \cdot P \cdot W \qquad (1)$$

where $\frac{S}{N}$ is the ratio of test tone power (i.e., 1 mW at a point of zero relative level) to the psophometrically-weighted noise power in the highest telephone channel.

C/N is the carrier-to-noise ratio

Brf is the occupied radio frequency bandwidth (Hz)

b is the bandwidth of the telphone channel (Hz)

Fch is the r.m.s. test-tone deviation per channel

fm is the mid-frequency of the highest baseband channel (Hz)

P is the pre-emphasis improvement factor

W is the psophometric weighting factor

Brf and Fch are the only unknown quantities in equation (1).

Brf can be expressed by Carson's rule,

$$Brf = 2 (\Delta F + fm) \qquad (2)$$

Where ΔF is the multi-channel peak deviation to keep truncation noise to a tolerable level an acceptable relationship between ΔF and Fch must be established. Bandwidth limiting due to Fch being too small with respect to ΔF causes intermodulation noise (truncation noise). An equation expressing this relationship is suggested as

$$\Delta F = Fch \cdot 10^{(Ln - 1)/20} \qquad (3)$$

where Ln is a factor which is numerically equal to the equivalent peak power level. CCIR recommendation 353 (Geneva 1963, Vol. IV, p. 158) gives the following equations for calculating the r m s value of white noise power, simulating the equivalent busy hour load of a given number of voice channels,

$$P = (- 15 + 10 \log_{10} N) \text{ dbm} \qquad (4)$$

$$N > 240$$

and $$P = (-1 + 4 \log_{10} N) \text{ dbm} \qquad (5)$$

$$(N = 12 \text{ to } 240)$$

The peak value of white noise power is usually taken as 13 db above the r m s power. Thus by adding 13 db to values calculated using equations (4) and (5) there is agreement between these equations and values of Ln as tabulated in Table II of CCIR Rep. 211-1.

A pre-emphasis improvement factor, P, is necessary in FM systems whenever filter networks are used to compensate for the parabolic characteristic of thermal noise in an FM system. Without this compensation the signal-to-noise ratios on the individual telephone channels degrade as the square of frequency corresponding to the channel location in the baseband spectrum. At the transmitter the baseband signal is passed through a pre-emphasis filter ahead of the modulator. When the baseband signal is demodulated at the receiver a de-emphasis network is used to restore the baseband to its uniform characteristic prior to modulation. When pre-emphasis and de-emphasis networks as recommended by CCIR[6] are employed, a pre-emphasis improvement factor of 4 db should be used.

The psophometric weighting factor, W, takes into consideration the frequency response of the telephone instrument and the human ear and the effect of an interfering noise spectrum on intelligibility by means of subjective tests. The value for W is usually assumed to be 2.5 db.

REFERENCES

1. Speech and Hearing in Communications; Fletcher; Norstrand

2. Communication System Engineering Handbook; Hamsher; McGraw Hill

3. CCIR Recommendation 353-1 Oslo 1966; Volv. IV part 2, p. 205

4. CCIR Report 211-1; Oslo 1966, Vol. 4, part 2, p. 307

5. CCIR Rec. 353 (Geneva 1963, Vol. IV, p. 158)

6. CCIR Rec. 275-1; Oslo 1966, Vol. IV part 1, p. 83

C.2 TWO-WAY TELEPHONE COMMUNICATIONS BY SATELLITE

An important service that a satellite can provide to a geographical area with limited communications facilities such as Alaska is two-way telephone and digital data transmission between remote subscribers within the area. The mode of operation is fundamentally different from that of a typical communications satellite or radio relay. A typical radio relay, whether satellite or microwave usually relays a number of telephone and/or television channels from one point to another. An example of this type of service is that supplied by communications satellites to supplement trans-atlantic Cable relay links. A recent study has proposed an Intelsat global type satellite to provide a network of relays for an intra-South American Communications system.[1] This South American satellite would link the principle cities in South America to provide telephone service. Multiple access modes of operation and a frequency translating satellite repeater are considered.

1 "Multiple-Access Tradeoff Study for Intra-South American Satellite Communications System" Yeh, L. P.; Trans. on Communications Technology, Vol. Com-16 No. 5 October 1968

The system requirements therin would be different from that of the referenced study. Instead of a satellite relay between a number of heavily populated cities, two-way phone service via satellite would be provided to remote villages and sparsely populated areas such as exist in Alaska and undeveloped areas in Asia.

The satellite should be accessible to any ground station within the coverage area for the purpose of transmitting messages to any other station within the area. Therefore the satellite up-link and down-link antenna systems would have the same pattern requirements and should therefore be a single antenna depending upon the proximity of up-link and down-link operating frequencies. The satellite would serve private, industrial, governmental or educational users.

All signalling, calling, control and switching would be done on the ground with the satellite operating only as a frequency translating repeater. Various system configurations might be used to provide two-way telephone service:

1) Each ground station continuously monitors all channels relayed by the satellite. When a station recognizes that it is being called the subscriber's line is connected to the circuit, a transmitter is activated on the associated up-link channel, and the subscriber's telephone rings. The

disadvantage of this arrangement is that each ground station must be burdened with a complete set of receiving; demodulating, and detection equipment. Although this method is technically feasible the cost would be prohibitive for all but a few large stations.

2) All telephone calls are relayed to a central exchange for switching and routing to the intended destination. For instance, assume a central telephone exchange, C, and two remote exchanges, A and B (see Figure C-4, Subscriber A, calls subscriber B, via the satellite and the central exchange. The call is transmitted from A to C via Channel 1. Exchange C connects subscriber B, to subscriber A, via a two-way circuit that activates Channels 2, 3 and 4 in addition to Channel 1. Thus four channels are required to complete a telephone circuit between any two remote stations via the central exchange with a time delay of approximately 600 milliseconds due to being relayed twice through the satellite.

3) All telephone calls initially utilize the central exchange but channels common to stations A and B are provided so that once a call has been initiated between A and B, B will switch over to Channels 1 and 4 and make channels 2 and 3 available for other traffic.

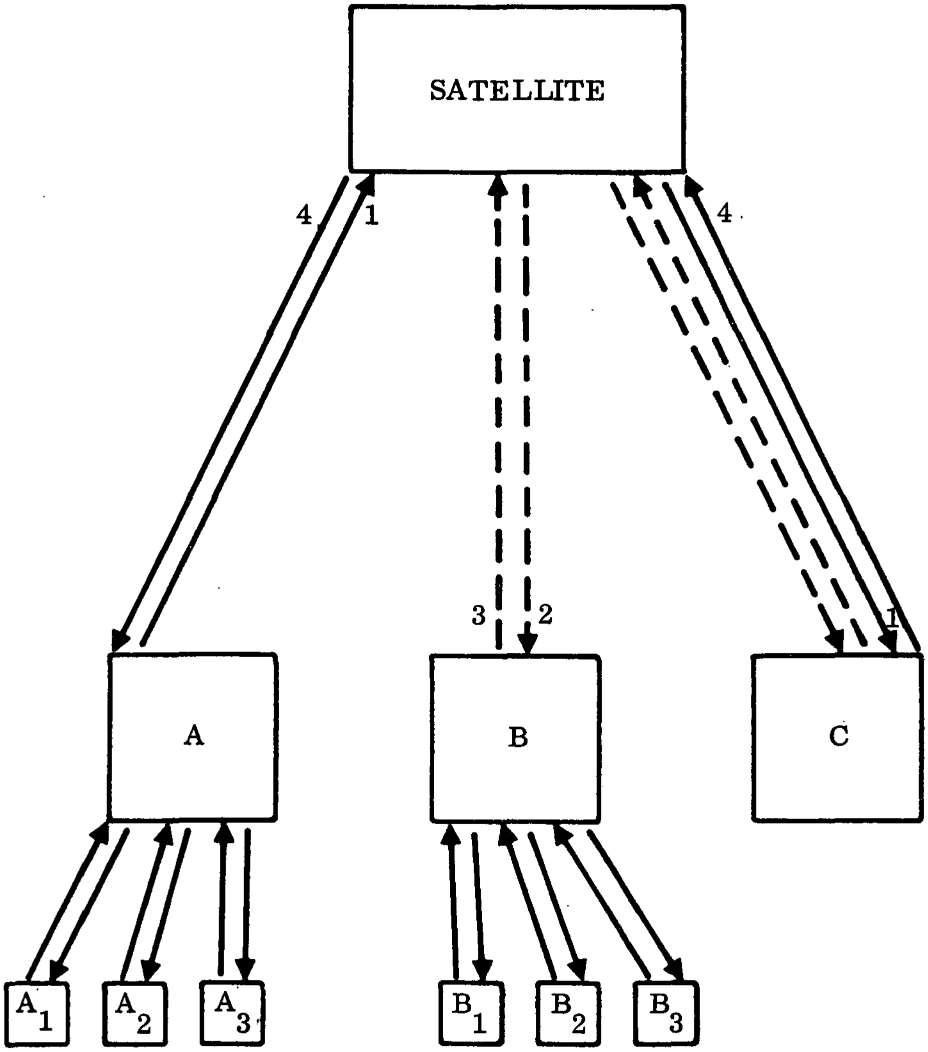


Figure C-4. Remote Telephone Service Via Satellite.

4) A common circuit might serve a number of remote stations whose traffic volume and number of subscribers would not justify separate r.f. channels. Two up-link and two down-link channels would be shared by a number of users. To make a phone call a station monitors the two down-link channels. If a channel is open a call is initiated. The connection is completed when the called station responds. Continuous monitoring of the down-link Channels would be required by all subscribers sharing these common channels. The number of subscribers that can feasibly share the common channels would depend on the traffic requirements of each user.

Modulation Characteristics

Each telephone channel is assumed to have a frequency response of 3.1 KHz with a bandwidth extending from 0.3 KHz to 3.4 KHz in accordance with standard telephone pra ctice. In the case of Multiple Channels Frequency Division Multiplex-Frequency Modulation, FDM-FM is used. Individual single sideband suppressed, carrier voice channels frequency modulate the carrier. (SSB-SC). Each single sideband signals is translated in frequency to make up a baseband structure with channels spaced 4KHz apart with a bottom baseband frequency of 12 KHz. The baseband and bandwidth characteristics are shown in Table C-1.

Table C-1. Approximate Parameter Values for SSB-SC Frequency Div. Multiplex (FOM) Telephone Channels

		SSB-SC-FM				SSB-SC-AM			
CARRIER CAPACITY	No. Channels	12	24	60	132	12	24	60	132
Allocated Satellite Bandwidth	MHz	0.655	0.865	1.65					
Bottom Baseband Frequency	KHz	12	12	12	12	212	12	12	12
Top Baseband Frequency	KHz	56	108	252	552	56	108	252	552
RMS per Channel Deviation for OdbmO Test Tone (CCIR Rec. 404-1)	KHz	35	35	50	100	-	-	-	-
Occupied Bandwidth (w/o Guard Band)	MHz	0.524	0.689	1.32	3.014	0.116	0.224	0.512	1.112
Required C/N (Threshold for FM)	DB	12.0	12.0	12.0	12.0	16.3	13.3	9.8	6.5
Required Carrier *Power	DBM	-134.5	-132.2	-131.5	-127	-138.9	-136.9	-136.8	-136.7

*Assuming IF Bandwidth can be same as occupied bandwidth

Values are shown calculated for both amplitude and frequency modulation. The per channel deviation values used in the calculations are in accord with CCIR Rec. 404-1. It may be noted that SSB-SC-AM requires less RF bandwidth and carrier power than an FM system. A 30 db signal to noise ratio was assumed for adequate voice quality and a C/N of 12 db was assumed an adequate level to be above threshold for the case of FM.

The Intelsat III ground stations utilize threshold extension demodulators to greatly improve the performance of frequency modulated signals. However, there is an associated penalty of greater receiver cost and complexity and greater spectrum occupancy. Table C-2 shows the approximate parameter values for the Intelsat III.

There are cases, particularly in providing telephone service to a remote location, where a single voice channel might be transmitted via a radio link. In this case the voice signal can directly frequency modulate the transmitter assuming a baseband width of 4 KHz and a deviation ratio of 3, the approximate RF bandwidth would be $2 \times 4\ (1 + 3) = 32$ KHz. Above threshold the S/N would be approximately 30 db. In Figure 2 are shown carrier bandwidths as a function of the number of telephone channels for single sideband frequency division multiplexed systems. Also plotted is the required carrier to noise ratio as a function of the number of channels for an SSB-SC/AM system. The equations from which the curves were derived are also shown in Figure C-5.

TABLE C-2

Approximate Parameter Values for a Intelsat III Telephone Relay using Threshold Extension Demodulators

CARRIER CAPACITY	N	Number of Channels	24	60	132
Allocated Satellite Bandwidth	ba	MHz	5	10	20
Bottom Baseband Frequency (excluding Service channels channels etc)	f_b	KHz	12	12	12
Top Base Band Frequency	fm	KHz	108	252	552
Deviation (RMS) for OdbmO Test tone	fr	KHz	250	410	630
Occupied Bandwidth w/o guard band	bs	MHz	3.95	7.95	14.4
Minimum carrier-to-total noise temperature ratio at operating point	c/T	$\frac{dbw}{^oK}$			

FOLDOUT FRAME 1

FOLDOUT FRAME 2

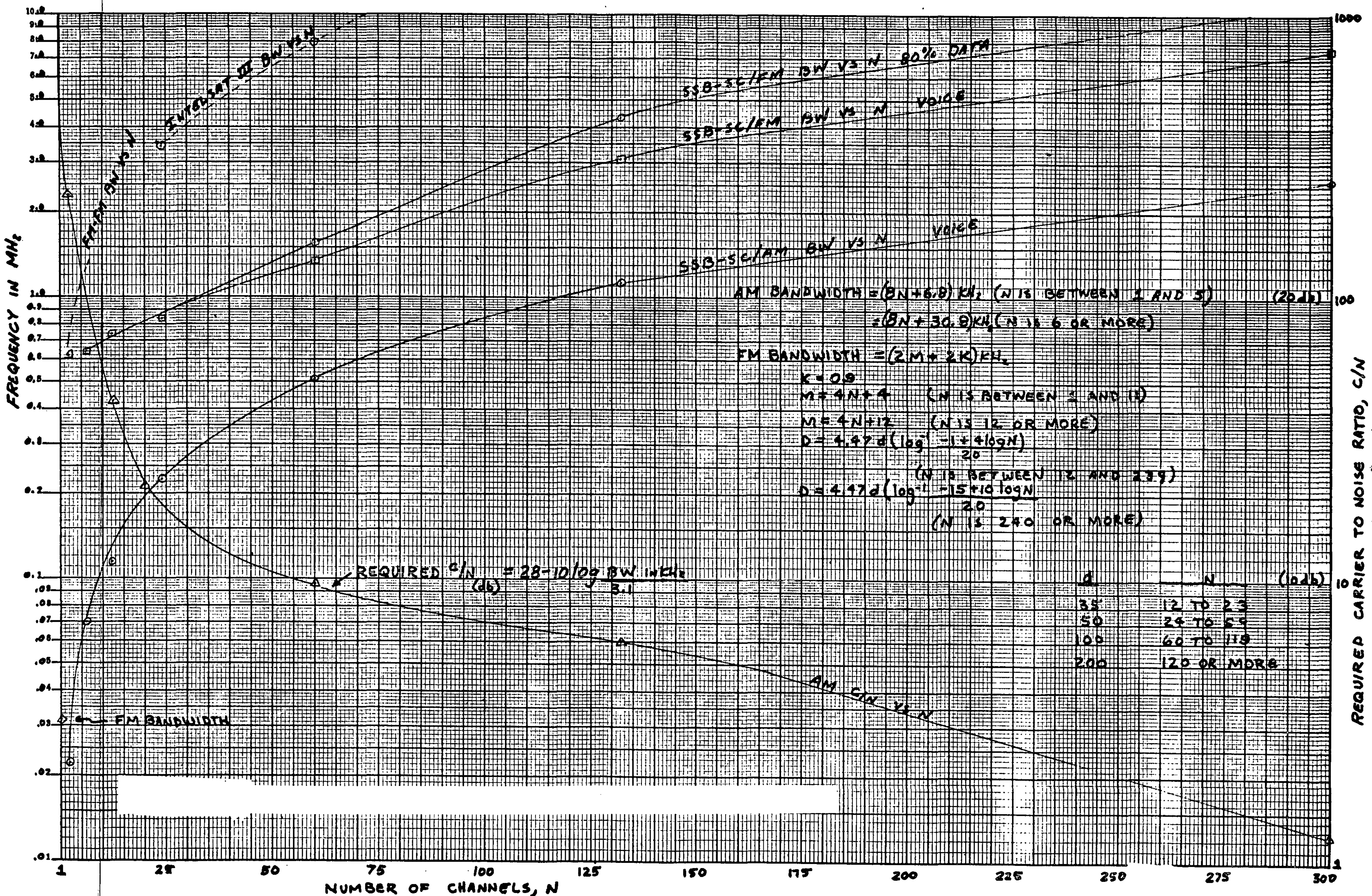


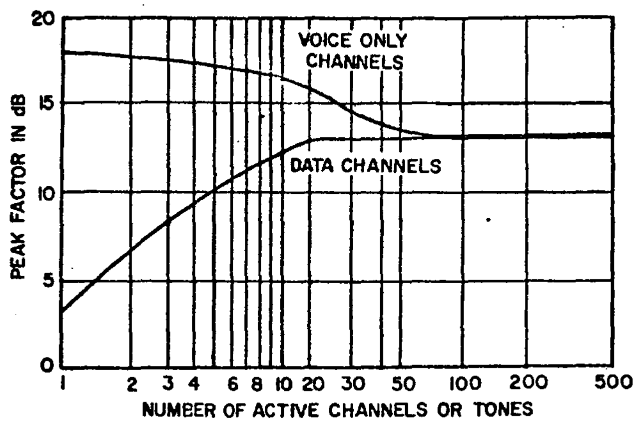
Figure C-5. Parameters for Multiplexed Voice Channels

C.3 DIGITAL DATA TRANSMISSION

Digital data transmission parameters are confined essentially to serial PCM. Although existing digital data transmission rates are limited to the restrictions of voice, group and super group Circuits, future bit rates will be determined more by special PCM circuits such as the AT&T T1 and the now experimental 225 MB/S system. The most frequently used modulation techniques are frequency shift keying (FSK or PCM-FM) and phase shift keying (PCM-PSK). Bit rates on voice circuits are from 1800 to 2400 bits per second depending upon line quality. Wider bandwidth channels are generally leased or dedicated and the allowable bit rate is approximately equivalent to the channel frequency response. Shown below are capacities of commonly used circuits:

Transmission Circuit	Equivalent Voice	Usable Bandwidth	Bit Rate Bits/Sec.
Voice	1	1800-2400 Hz	1800-2400
Group (Telpack A)	12	41 KHz	50 K
Super Group (Telpack C)	60		250 K
T 1	24 digital		1.544 M

When data is transmitted on frequency division multiplexed (FDM) voice channels the increased loading is such that greater RF bandwidth is required. Bandwidth is plotted in Fig. C-5 versus number of channels for SSB-SC-FM with 80% of the channels devoted to data. It may be noted that when the number of channels is less than 30 bandwidth requirements for 80% data is no greater than required for voice. This is because the peak factors for data channels is less than voice when the number of channels is few. Fig. C-6 shows this relationship.



– The patterns for the two peak factors — peak to rms ratios — of data and voice are essentially the same when the number of channels is large.

Figure C-6

When bit rates are greater than can be accommodated by voice grade circuits, a separate RF carrier is required in the case of microwave or satellite relay or a special leased or dedicated line is necessary if common carrier facilities are used. To model a digital link, parametric data as plotted in Fig. C-7 and -8 is necessary. For a given bit rate Fig. C-7 will be used to determine the required receiver bandwidth as well as allowable bit rate within an allocated transmitter bandwidth. Equations of these curves will provide parametric data for computer modeling. Allowable bit error rate for PCM-FM and PCM-PSK based on user requirement are translated to required signal to noise ratios by the use of the curves of Figure C-8.

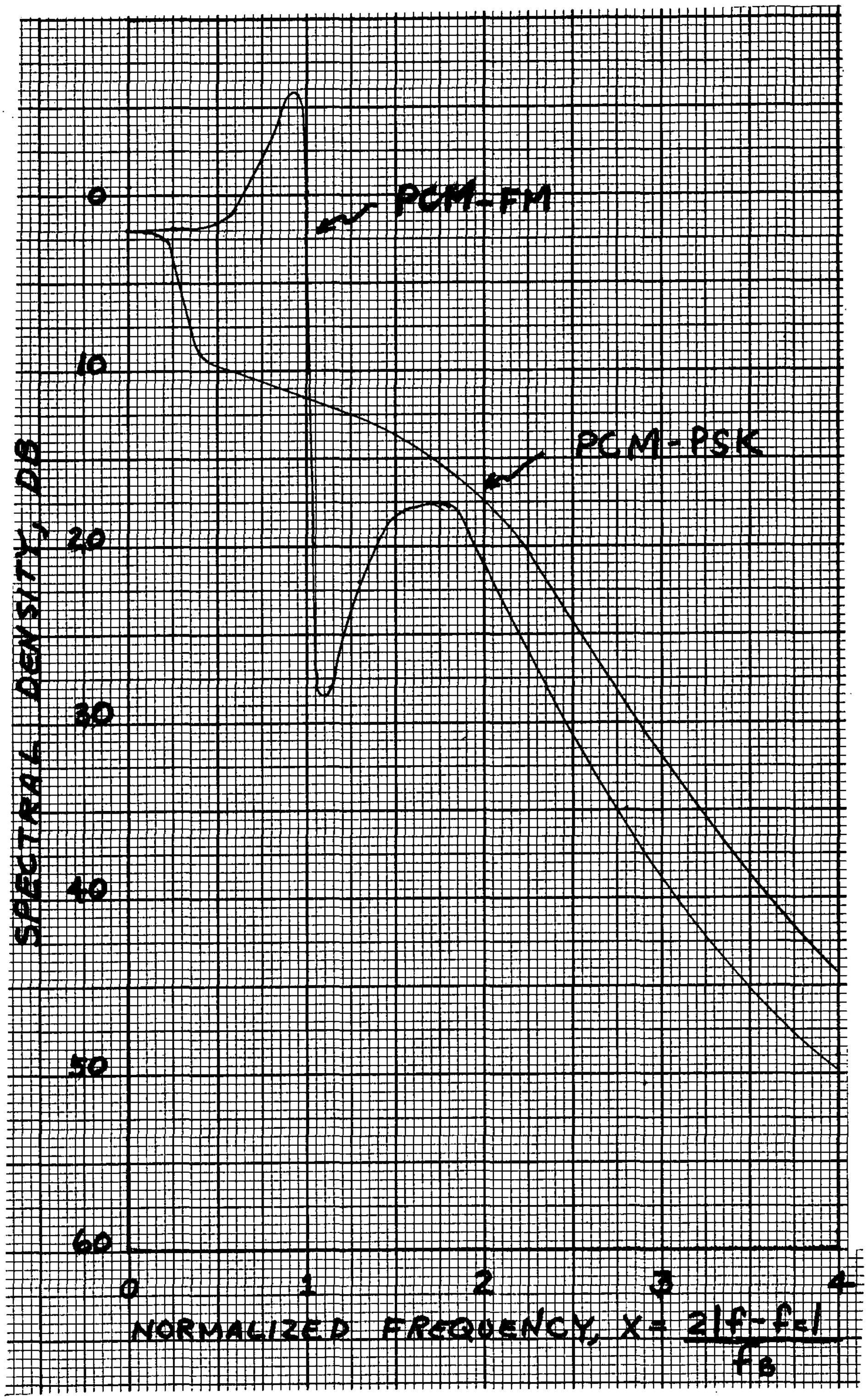


Figure C-7. Power Spectrum of PCM-FM and PCM-PSK

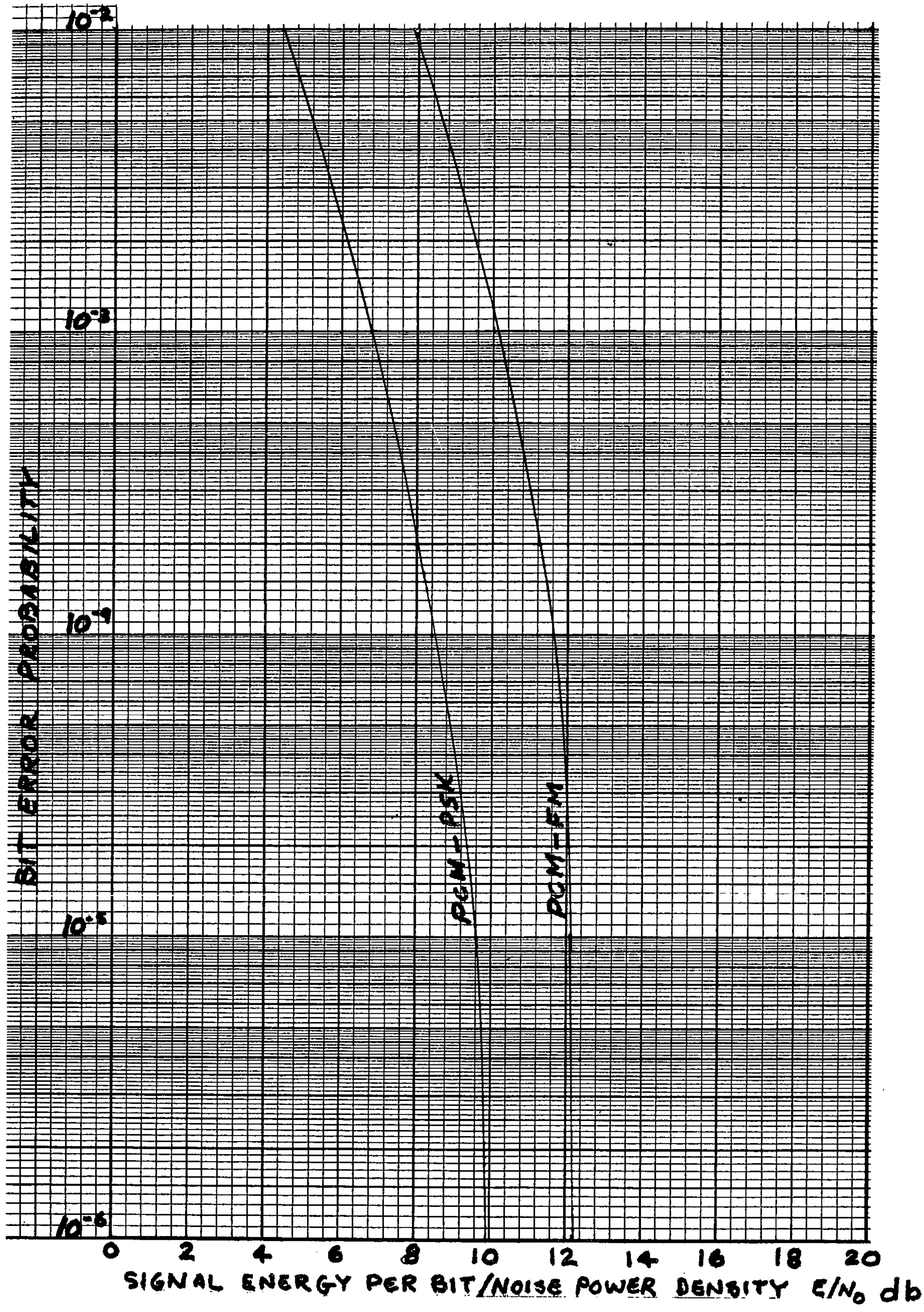


Figure C-8. Bit Error Probabilities for PCM-FM and PCM-PSK

1. General Characteristics and Requirements. The standard form of a baseband digital signal is a binary (two-level) serial pulse stream. This basic format is manipulated and converted in various ways depending upon the data transmission system requirements. If data is transmitted over a common carrier switched network the interfacing element with the network is a modem or data set as shown in Figure C-9. There are two types of switching associated with data transmission:

Circuit Switching - Used to establish a circuit between two terminals connected to the network. This function is normally carried on within the network.

Message Switching - This is a store and forward function normally done in a computer external to the network. If a computer is part of the network it could be done within the network.

In order to determine the type of service required and the associated cost, the following must be specified for each channel by the user:

a. bit rate
b. allowable error rate
c. type of circuit (simplex, half duplex or full duplex)
d. source and destination
e. nature of transmitted data
   - message
   - tabular
   - numerics
f. delivery time requirement
g. response time

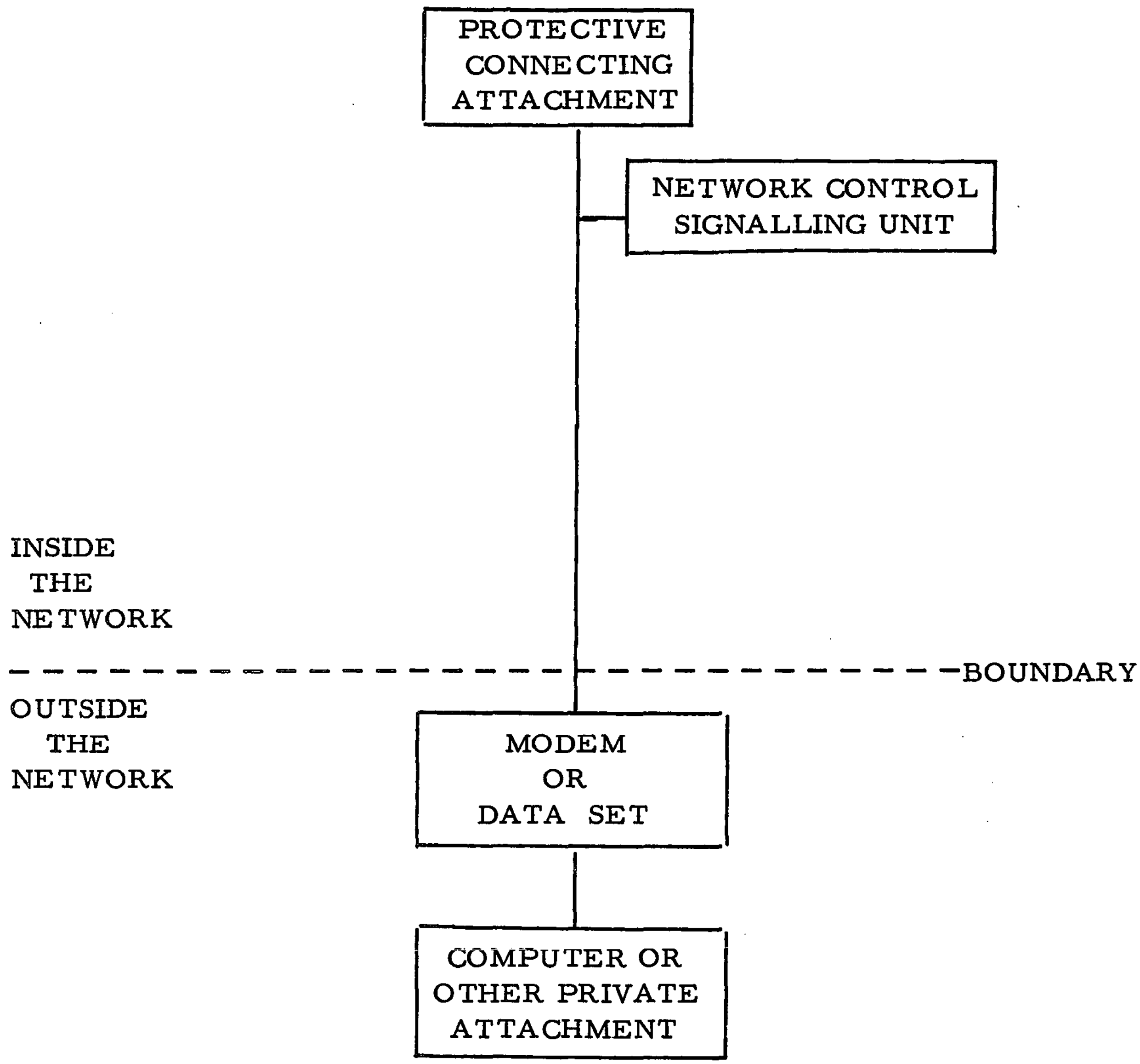


Figure C-9. The Boundary Between the Network and What is Outside the Network in the Case of Data Communications.

One of the more important driving functions for specifying digital data transmission requirements is the data processing equipment communications needs. Table C-3 lists these needs compared to common carrier services available.[1] The data processing industry is in need of a number of types of services from the common carriers such as two-way lines with different data rates in each direction and error correction capability. There are delays in getting data service and equipment.

2. Common Carrier Service. Existing communications systems, both commercial and military, are based on the 4 KHz voice channel. Frequency division Multiplex is employed to transmit a number of voice channels over a single transmission link. Low data rate requirements, such as teletype, are accommodated by combining a number of channels on a single voice channel. By means of special data sets up to 9600 bit/sec can be transmitted on a voice channel. Higher speed data is accommodated by wideband channels made up of discrete multiples of voice channel bandwidths as follows:

voice channels - nominal 4 KHz
group (Telpak A) - 12 voice channels
super group (Telpak C) - 5 groups - 60 voice channels
master group (Telpak D) - 5 or 10 super groups - 300 or 600 channels

These channel bandwidths can provide for bit rates up to 10^6 per sec. There are a number of disadvantages to using these channels for digital data transmission.

a. Unless a channel is dedicated there is impulse noise present due to switching.

Table 3.2-1

COMPARISON OF DATA PROCESSING EQUIPMENT OPERATING SPEEDS WITH AVAILABLE COMMUNICATIONS CAPABILITIES(1)

DATA PROCESSING EQUIPMENT	TYPICAL OPERATING SPEED (Bits/Second)	COMMUNICATIONS LINK CAPABILITIES (Bits/Second)	TYPE OF COMMUNICATIONS LINK
Card Readers			
300 cards per minute	3,200	2,000	Switched voice
600 cards per minute	6,400	2,400	Leased voice
1,000 cards per minute	10,600	50,000	Broadband leased
Card Punch			
300 cards per minute	3,200	2,000	Switched voice
500 cards per minute	5,300	2,400	Leased voice
Paper Tape Reader			
	75	110/180	TTY switched or leased
	2,800	2,000	Switched voice
	4,000	2,400	Leased voice
	8,000	50,000	Broadband leased
Printer			
300 lines per minute	6,000	2,000	Switched voice
600 lines per minute	10,600	2,400	Leased voice
1,000 lines per minute	19,400	50,000	Broadband leased
Typewriter	45-150	110/180	TTY switched or leased
Cathode Ray Tube	8,000	50,000	Broadband leased
Magnetic Tape Transport	150-3,000	110/180-2,400	TTY and voice channels
	120,000		
	240,000		
	480,000	250,000	Telpak C Leased
	720,000	500,000	Telpak D Leased
	960,000		
	1,440,000		
	2,720,000		
Disc Units	1,248,000 2,496,000	500,000	Telpak D Leased
Drum Units	1,000,000 8,000,000	500,000	Telpak D Leased
Central Processors	2,000,000 6,400,000 16,000,000	500,000	Telpak D Leased

(1) From: Response of the Business Equipment Manufacturers Association Response to Docket No. 16979, March 5, 1968.

C-24

b. There is a degradation of data quality with a number of cascaded linear amplifier repeaters. This results in pulse distortion, lower signal-to-noise ratio and a higher bit error rate.

c. Inflexibility as a result of the availability of a few discrete channel bandwidths.

d. Higher cost of linear amplifier analog repeaters compared to digital pulse restoration repeaters.

NARROWBAND - Narrowband service is that class of service that has a nominal bandwidth of 150 Hz and will accommodate either one 75 baud teletype channel or digital data with bit rates to 150 b/sec. According to a recent study[2] the low data rate segment (>300 b/sec) is the fastest growing segment of the data communications market with the 300 to 10,000 bit per sec segment accounting for most of the remainder of the present market. The data segment above 10 kilobits per second is smaller in size and lower in growth rate. This is illustrated in Figure C-10, which projects the number of data sets connected to the Bell system.[2] Teletype data can be transmitted on a voice grade channel with twelve 75-band teletype channels transmitted on a single voice channel. Each TTY signal would modulate one of twelve tones spaced by 170 Hz within the 425 - 2975 Hz frequency band.

VOICE GRADE - The allowable bit rate that can be transmitted on a voice channel depends on the grade of line and the sophistication of the modem. At the present time 2 kilobits per second is the typical data rate for a voice channel on a switched network. AT&T projects an improvement to 4.8 KBS by 1975 on a switched voice band channel. Private voice

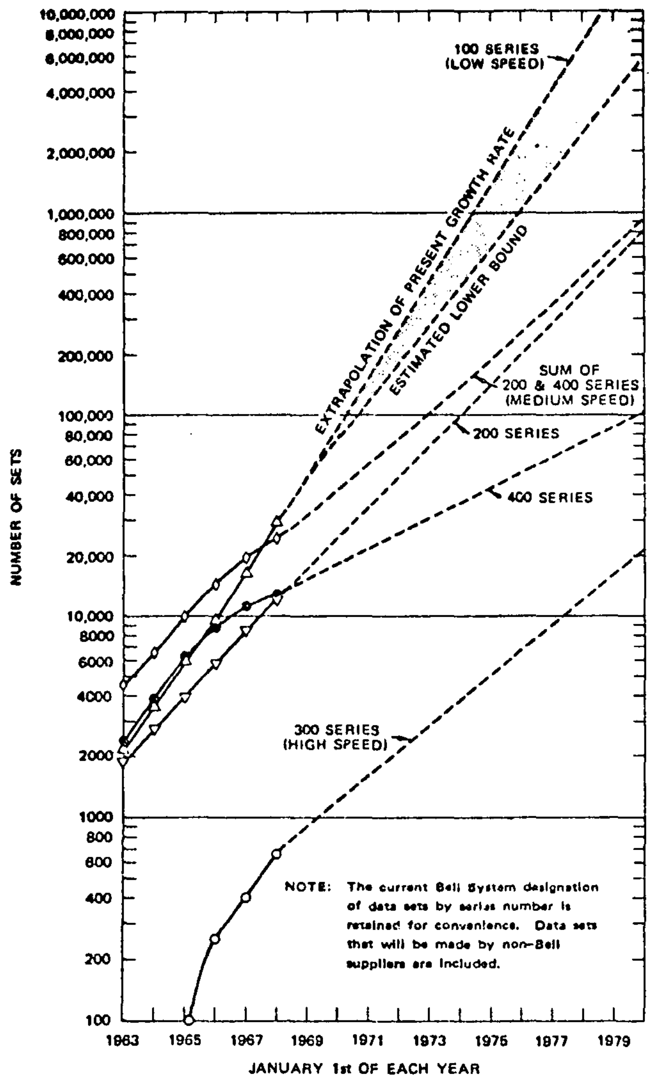


Figure C-10. Projected Number of Data Sets Connected to the Bell System Private, Message, and Wideband Data Network.

grade circuits allow a 2.5 kilobit per second data rate with a projected rate of 9.6 KBS by 1975. Conditioned private lines can be provided at extra cost to allow use of higher bit rates. Private lines also have predictable properties whereas a dialed up call will result in a random selection of lines that will yield different properties for each data transmission. Some of the factors that adversely affect data transmission characteristics of a switched line and their effects are:

Delay Distortion - This does not affect a voice signal but smears and spreads out individual bits in a data pulse stream resulting in higher error rates.

Compandors - These are used to improve voice intelligibility but cause a noisier signal when the line is used for data.

Echo Suppressors - Allow transmission in only one direction at a time. When the direction of transmission is reversed, echo suppressors cause delays as great as 120 milliseconds on a long line.

Single Frequency Noise - Noise due to cross talk or leak through of carriers, pilots, or supervisory tones.

In order to transmit data at the response limits of a switched voice grade line it is often necessary to use adaptive equalization in the modem, adding complexity and cost. Table C-4, lists services available on common carrier voice grade circuits. Achieving bit rates of 4800 and 9600 bits per second on a voice channel is accomplished by using multi-level and multi-phase modulation techniques. Using these techniques requires a higher signal-to-noise ratio for a given allowable bit error rate. The effect of distortion and noise is to

Table C-4. Available Voice Grade Service

Line Grade	Allowable Bits/Sec. Rate	Modem	
		Type	Supplier
Dial Service	2000	201 A Dataphone	AT&T
Dedicated C2	2400	201B Dataphone	AT& T
Broadband Switched	2400		W. U.
Dial Service	3600	203A Dataphone	AT&T (Future)
Dedicated C2 & C4	4800	TE-216A -4 - AD	Collins
Dedicated C4	9600	SEBIT-96	Rixon

increase the bit error rate probability. On telephone networks within the U.S., on an average of one character error will occur for each 100,000 characters transmitted.[16]

WIDEBAND SERVICE - Wideband service may be defined as that requiring a greater bit rate than can be provided on a voice grade channel. There is a large discontinuity in data services available between voice grade and wideband. The next option above voice grade is the group band of nominal 48 KHz bandwidth. Modems are available that utilize the half group bandwidth at a 19.2 KBS bit rate. However, the entire 48 KHz service must be ordered. The unused portion can be arranged for up to six telephone channels. Common carrier wideband services are listed in Table C-5.

Table C-5. Wideband Services

Circuit Type	Allowable Bit Rate	Data Set
Group Telpak A	19.2 KBS & 40.8 KBS	AT&T 301B
	50 KBS	AT&T 303C
Super Group Telpak C	230.4 KBS	AT&T 303D
Greater than Super Group (Telpack D)	460.8 KBS	AT&T

3. Digital Data Transmission Costs. In spite of the increase in volume of digital data transmission, the data market is still less than one percent of the telephone market.[2] Cost forecasts, based on bit rate capability of data transmission systems, show that decided cost advantages should accrue as higher bit rates are transmitted and points to the advantages of all - digital types of data transmission. Figure C-11 illustrates this

FOLDOUT FRAME 1

FOLDOUT FRAME 2

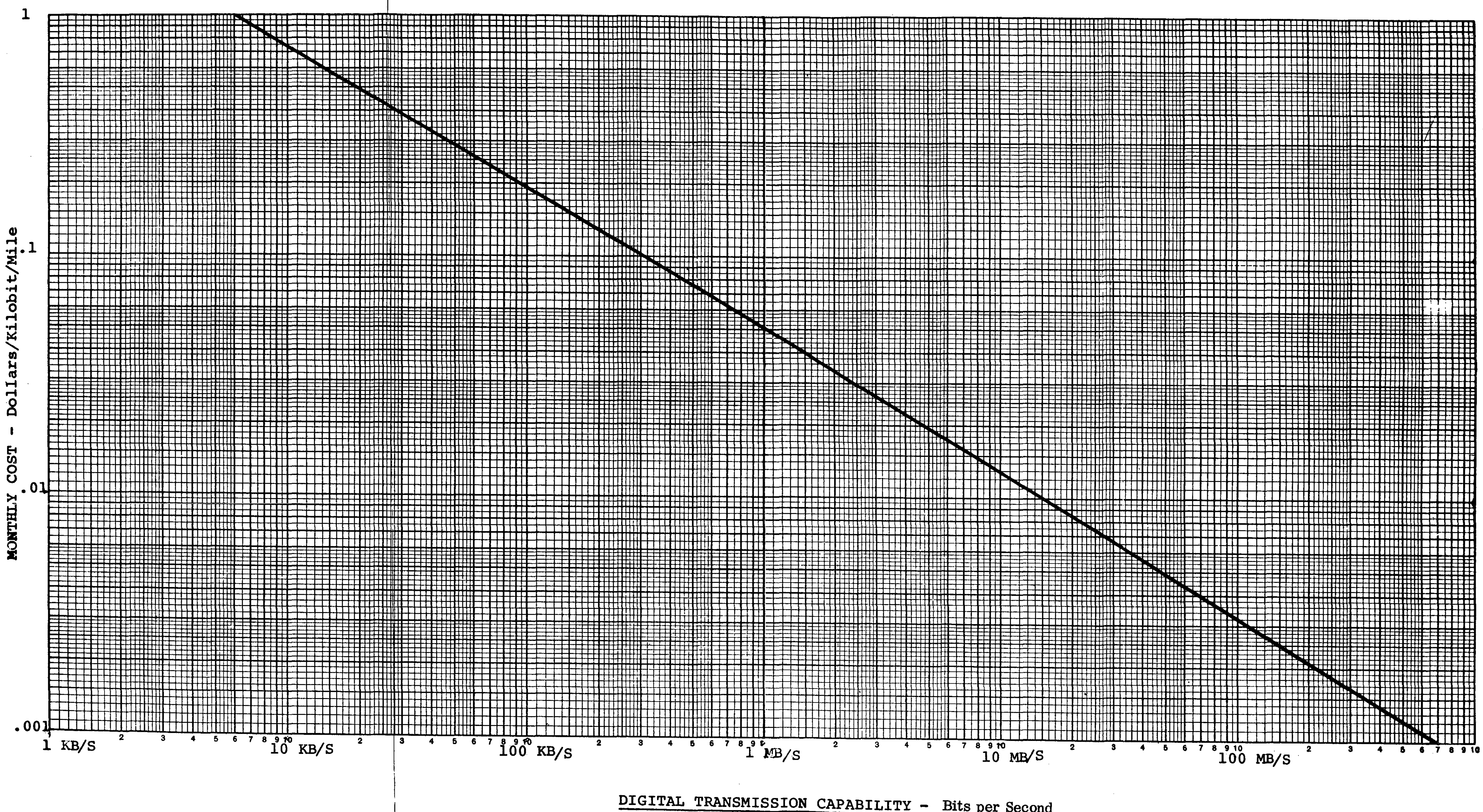


Figure C-11.

cost trend.[3] Table C-3, , which compares potential communications requirements to services presently available, shows that in many cases users are forced to utilize circuits that have a greater data rate capability than needed for the application. Thus a user is often required to pay for a higher capacity circuit than he requires. The only way in some cases to bring down costs would be by line sharing with other users or re-sale of excess capacity. This is difficult under present regulations.

Cost of leasing common carrier lines for digital data transmission, shown in Table C-6, , was taken from "The Challenge of the Computer Utility".[4] This is substantially in agreement with Chipp and Cosgrove.[5]

Table C-6. Basic Transmission Costing Data

Type of Service (AT&T Nomenclature)	$/Mile/Month*	Bits/sec
Schedule 1	.70	45
Schedule 2	.70	56
Schedule 3	.77	75
Schedule 4	1.79	2,400
Telpak A	15.00	41,000
Telpak B	20.00	82,000
Telpak C	28.00	230,000
Telpak D	60.00	1,000,000
Western Union (Spec.)**	287.50	12,000,000

* Normalized to 1000 mi. distance
** This is a special service provided to the military on a one-time basis.

The data from Table C-6 has been plotted and fitted with a regression line as shown in Figure C-12.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

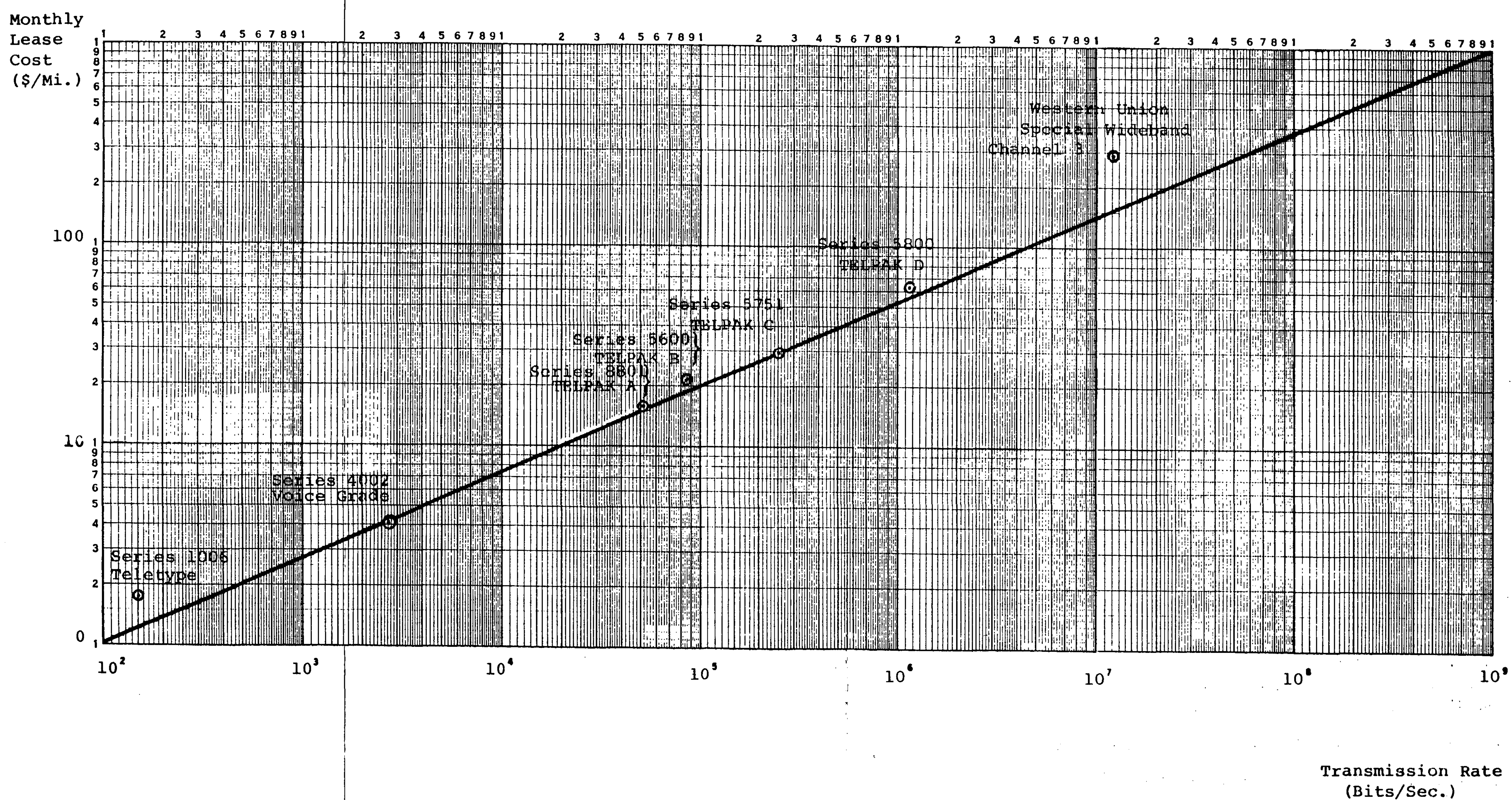


Figure C-12. Communications Line Costs as a Function of Date Rate.

Digital communications terminal equipment cost data is presented in Table C-7. Figure C-13 is a plot of this data with a trend line based on the data points.[3] This data agrees in general with quoted lease cost for modems in the range up to 10,000 bits/sec. Above this bit rate recently developed modems tend to level off in cost up to 100,000 bits/sec[7].

Table C-7. Basic Cost data for Data Terminal Devices

Data Point	Type	$/Mo.	Bits/Sec.	Source
1	Dataphone 100	20	200	CU[4]
2	Dataphone 200	40	1,200	CU[4]
3	Dataphone 200	72	2,400	CU[4]
4	Telpak A	435	41,000	DC[6]

If AT&T is granted rate increases on Telpak service that it has filed for with FCC, the cost data will require revision.

4. Future Trends in Digital Data Transmission. Table C-8, from a recent study[3], is useful to refer to in assessing the capability and potential of various transmission media. The only criticism of this table pertains to the satellite system. Bandwidths of 500 MHz are in use on communications satellites and the frequency range of use is expected to extend into the millimeter region.

THE BELL T-1 SYSTEM- The Bell T-1 system, providing for analog-to-digital conversion of voice channels to a PCM time division multiplex format, allows transmission of 24 voice channels over a 2-wire pair, thus accommodating voice transmission economically over a switched network. This system is expected to eventually replace all analog voice channels in the 1970's. As a result data transmission will also shift from

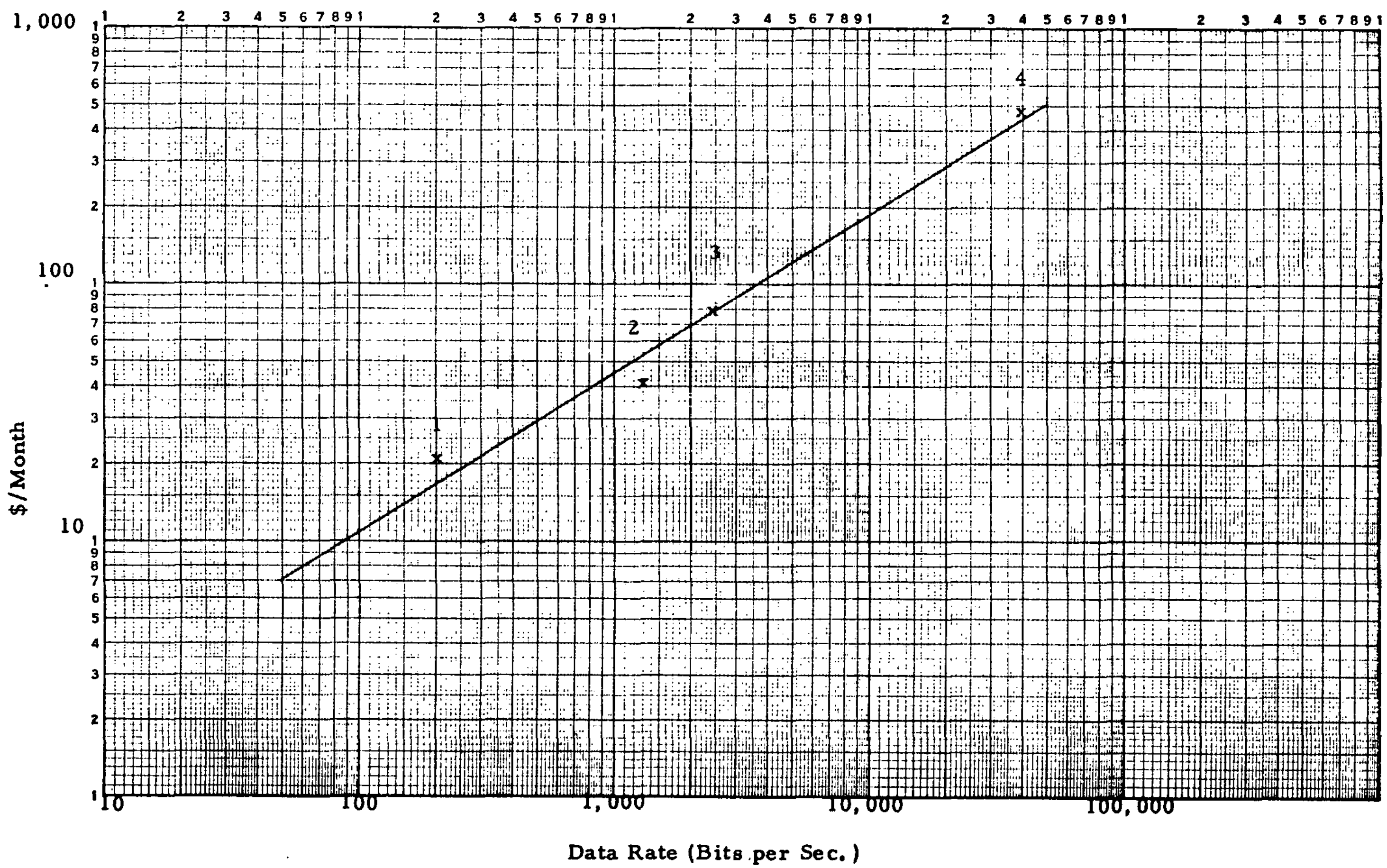


Figure C-13. Terminal Equipment Rental.

Table 3.2-6

POTENTIAL FOR IMPROVEMENT IN TRANSMISSION SYSTEMS

MODE OF PROPAGATION	FREQUENCY RANGE OF USE	USEFUL BANDWIDTHS	APPROXIMATE ERROR RATES	APPROXIMATE BIT RATES (bps)	RANGE	POTENTIAL FOR IMPROVEMENT
Wirelines	0-250 KHz	240 KHz	10^{-5} to 10^{-6}	50 to 500,000	Indefinite with repeaters.	Increased bit rate (1.5 Mbps) with digital T1 carrier.
Wideband Cable	0-10 MHz	10 MHz	10^{-5} to 10^{-6}	10 M	4 mile repeater distance.	Wider Bandwidth Cable such as L-4 (18 MHz).
HF Scatter	3-30 MHz	5 KHz	10^{-3}	2400	300-5000 miles.	Reduction in error susceptibility through use of coding.
Tropo Scatter	300-5000 MHz	100 KHz-1 MHz	10^{-3}	1 M	100-800 miles.	Reduction in error susceptibility through use of coding.
VHF	30-300 MHz	50 KHz-100 KHz	10^{-4} to 10^{-5}	50,000	Line of Sight.	Increased data rates for mobile use.
UHF	300-3000 MHz	100 KHz-10 MHz	10^{-4} to 10^{-5}	10 M	Line of Sight.	Same.
Microwave	3000-30000 MHz	10-20 MHz	10^{-5} to 10^{-6}	10 M	Line of Sight.	Higher data rates through additional development.
Satellite	300-10000 MHz	100 KHz-20 MHz	10^{-5} to 10^{-6}	10 M	Line of Sight.	Reduction in error susceptibility and increase in bit rate through greater ERP.
Millimeter Wave	30-100 GHz	50 MHz-500 MHz	10^{-6}	300 M	15 mile repeater distance.	Development of controlled environment for long haul transmission.
Optical	Light	1-10 GHz	10^{-6}	$>$ 1000 M	Line of Sight.	Same, plus development of modulation, detectors and processsing equipment.

the present analog circuits to the digital PCM systems. Present T-1 equipment allows a 50 kb/s data stream to replace three voice channels[8]. Table C-9 shows the present capability of the T-1 circuit to handle assynchronous digital data.

Table C-9 T-1 Digital Data Capability

T-1 Line Loading	No. of Channels per Line	Max Data Rate in KB/S	Max. Timing Error
1/8	8	64	$\pm$ 1/3 microsecond
1/4	4	128	$\pm$ 0.65 "
1/2	2	256	$\pm$ 0.35 "
1/1	1	512	$\pm$ 0.17 "

The terminals can be accommodated to the different data rates by plug-in units. A mix of data and voice can also be accommodated. If standard synchronous data rates were adopted, the terminals could be designed so that efficiencies approaching one data bit per line bit could be achieved which would make a 50 KB/S data circuit equivalent to one voice channel and allow a maximum data rate on a T-1 line of 1.5 megabits/sec. Thus as the T-1 system grows and 50 KB/S were to become a standard rate, the 50 KB/S rate should be more economical than the 9600 bp/s rate is at present, (9600 bp/s being the highest achievable bit rate on a dedicated voice channel).

PRIVATE-LINE MICROWAVE NETS - A recent FCC decision allows a private company, Microwave Communications, Inc., (MC) to operate a microwave data communications transmission system between Chicago and St. Louis.[9,10] A newly formed company, MCI, New York West, Inc., has filed for a license to provide similar service between Chicago and New York. The service to be provided differs from that supplied by the Bell System and regulated carriers.

a. It will be a private line - not a switched network.
b. It will be very flexible. Customized analog and digital services will be provided to subscribers.

Each microwave carrier will have a 8.5 MHz baseband width divided into three master groups of 2.4 MHz each. The upper two will be for single sideband FDM analog and the bottom group will be a serial bit stream, with the analog and digital channels completely separate. Analog channels will be available in 48 different bandwidths from 200 Hz to 960 KHz. Digital data will be available in 20 different bit rates from 75 bps to 19.2 Kb/s. Regenerative pulse type repeaters for digital channels will allow low error rates of 1 in 10^7 maximum. It is planned that the subscriber pay only for the capacity needed for the time he needs it. One-way or two-way links can be ordered with different capacities in each direction. Consideration is being given to charging for the actual number of bits transmitted. <u>The rates are estimated to be about one-half that of existing common carrier rates.</u>

It is planned to use infrared and millimeter-wave short haul communications links to connect subscribers to the main network. Initially these local tie-ins will use 18 GHz equipment with a gradual transition to 50 GHz equipment as it becomes available.

5. Digital Voice Transmission.

SAMPLING AND ENCODING PARAMETERS - The significant parameters to be considered in converting voice signals to digital PCM are sampling rate, the number of digits encoded, companding technique and formatting:

A sampling frequency of 8 KHz is a universally accepted standard as required to provide a good quality digital speech channel.

The number of digits per sample to be encoded is still not completely resolved. Replies to CCITT and CCIR inquiries indicated that 7 bit per sample associated with non-linear coding would yield adequate voice quality.[11] Operational systems in this country (AT&T D-1 Coder) and Japan encode 7 bits per sample and COMSAT has experimented with and presently favors 7 bit encoding. However, coding will eventually be to eight binary bits based on an agreement to that effect reached a by CCITT Special Group D in a meeting at Geneva in November 1969. The AT&T D-2 coder which will soon go into service encodes to eight binary bits and European telephone equipment makers have begun making necessary hardware changes.[13] According to AT&T, quantizing noise is 6 db lower using eight bits instead of seven and eight bits are necessary to provide relay quality on international telephone calls.

Standardization is still required for companding. The companding law defines the input-output transfer characteristic from the analog sample to the encoded word.[12] There are two companding laws in use: the Mu law which is used by AT&T and Japan, and the A law which has been adopted by the Conference of European Postal and Telecommunications (CEPT) administration.

Japan is reevaluating the Mu law so that AT&T may eventually be the only user of the Mu law for companding.

International agreements are still required in areas of framing and signalling, load capacity and synchronization:

Framing and signalling -

AT&T - speech and signalling in each time slot;

framing pulse after 24th time slot (193rd bit)

England - one of 24 time slots for framing

CEPT - one time slot for framing; one for signalling

Time slots per frame -

24 - AT&T, Japan and England

32 - CEPT

Synchronization -

Synchronize all oscillators to master clock

AT&T, GT&E

Derive clock at each office by averaging phase of signals - AT&T (some networks)

Pulse stuffing - AT&T (some networks), Japan, England, France

Load Capacity -

Europe - + 2 dbm O

America - + 3 dbm O

ADVANTAGES OF PCM VOICE CHANNELS - The T-1 carrier system was originally developed by AT&T to provide better utilization of existing trunking facilities in metropolitan areas.[14] This was accomplished by being able to transmit 24 voice channels instead of one on existing 2 wire conductors. The lower cost of terminal equipment also makes it economically attractive for trunks between local offices within a city. For short-haul service (10 to 100 miles) PCM has been determined to be the cheapest system to use. However, even for long haul requirements, PCM is still cost effective. One important factor is the ability to use relatively simple digital repeaters that are required only to regenerate pulses compared to the thousands of expensive ultra-linear repeaters that are required for long distance analog FDM systems.

Another reason for the attractiveness of PCM is the large variety of signals that can be coded and time division multiplexed without suffering from intermodulation distortion. In a radio microwave link there is a bandwidth/power trade-off that favors transmitted power in a PCM system. Interference is also minimized between systems operating at the same frequency. Experiments at millimeter waves verify the feasibility of transmitting digital data at 50 megabits/sec.[15]

TIME DIVISION MULTIPLEXING PARAMETERS - There are two methods suggested for encoding telephone voice channels.[11]

a. Encoding individual telephone channels (TDM-PCM) as is being done in the AT&T T-1 system and most operational PCM systems world-wide. Based on a sampling rate of 8000 samples/sec., seven bits per voice channel.

b. Encoding the FDM baseband (FDM-PCM)
The above referenced CCIR report suggests these parameters be used to provide relay quality voice when 120 or more FDM voice channels are digitized:

8 bits per sample

sampling frequency is 2.3 Fm

where Fm is the highest baseband frequency (4200 n) and n = no. of telephone channels

With 5% added for synchronization the bit rate for n channels is 81,000 n bits/sec (1.05 x 2.3 x Fm)

Assuming an r.f. bandwidth of 1.2 x bit rate, Table C-10 compares bandwidth requirements as a function of the number of telephone channels for TDM-PCM-PSK, FDM-PCM-PSK and FDM-FM.

Table C-10. Required Bandwidth for Single Access Multiplexed Channels

Total Number of Channels	12	24	60	120	240	600	960	1200
TDM-PCM-PSK Occupied BW in MHz	0.97	1.93	4.84	9.68	19.3	48.4	77.4	96.8
FDM-PCM-PSK Occupied BW in MHz	1.17	2.34	5.86	11.7	23.4	58.5	93.8	117.0
FDM-FM Occupied BW in MHz	2.96	4.64	8.1	12.5	19.0	36.5	51.6	64.7

It may be noted in Table C-10 that PCM requires less bandwidth for less than 240 channels and FDM-FM is more conservative of bandwidth for more than 240 channels.

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C.4 FACSIMILE TRANSMISSION

Facsimile comes under a special and an important class of information transfer. As with digital data transmission systems, facsimile systems have been designed to be compatible with available transmission circuits. Most of the facsimile systems utilize voice grade circuits. For high speed messages and newspaper transmission higher capacity circuits such as Telpack A and above are used. Pertinent parameters on a variety of facsimile services and systems are tabulated in Table C-11.

TABLE C-11 FACSIMILE TRANSMISSION PARAMETERS

COPY SIZE	Transmission Time or Rate	Modulating Frequency	Transmission Circuit	Modulation Type	RF or Channel Bandwidth	Req. S/N	APPLICATION
8 1/2 X 11	1.88 in/min.	1200 H_z	VOICE	DSB-AM or VSB-AM	4 KHz	10	Messages, letters and business documents
8 3/8 X Cont.	18 X 11 1 Min.	6600 H_z	15 KHz Broadcast	DSB-AM or VSB-AM	15 KHz	10	Letters and business documents
8 1/2 X 15	8 X 11 45 Sec.	15,600	48 KHz Telpak A	DSB-AM VSB-AM	35 KHz 20 KHz	10	High Speed Message Transmission
18 X 22	0.625, 1.25 in/min,	900/1800 Hz	VOICE	DSB-AM VSB-AM	4 KHz	16db	Weather Maps and Charts
Newspaper Page	21 min/pg.	40,000 Hz	Telpak A Telpak C	VSB-AM FM(D=z)	48 KHz 240 KHz	10	Newspaper Transmission (Pressfax)
Newspaper Page	4.5 min/pg	0.74 MHz		DSB-AM VSB-AM FM-(D-2)	1.5 MHz 1.0 MHz 4.5 MHz	20	Newspaper Transmission (Pressfax)

C.4.1 Facsimile Data Transmission Parameters

1. Introduction. Parameters are presented which define communications channel requirements for the transmission of facsimile data. Shown are the constraints on transmission parameters of

1. Type of material to be transmitted
2. Size of copy
3. Allowable transmission time per page
4. Type of modulation

To facilitate comparison of transmission via satellite and competing terrestrial links and to provide for compatibility in a hybrid system, channel bandwidths are usually limited to discrete values corresponding to that available from common carriers, namely voice, group, supergroup and wideband. Nominal copy sizes are 8-1/2" x 11" for documents, messages, drawings and pictures, and 22" x 15.4" for newspaper transmission.

2. Fundamental Relationships. Scanning is usually either electromechanical using a rotating drum and high intensity light scanning the copy by attachment to a lead screw or electronic using a CRT tube to produce a flying spot scan of a copy moving linearly past the beam. The resolution of the transmitted copy is determined by the scanning lines per inch. In order to determine the Communications Channel Characteristics to satisfy a specific facsimile transmission requirement, it is first necessary to specify signal quality (see Table C-12), and the allowable transmission time. The channel response characteristics can be determined from

$$fm = \frac{H\ W\ d^2}{120\ T}$$

where H = height of document in inches

W = width of document in inches

d = scanning density in lines/inch

T = transmission time in minutes

fm = frequency response in Hz/sec.

Table C-12

FACSIMILE SIGNAL QUALITY REQUIREMENTS

TYPE OF COPY	Lines per inch Resolution, d	Required contrast in db
Alpha-numeric (messages, letters and business documents)	96-130	20
Photographs	100 to 150	35
Weather maps, charts, drawings	96 to 190	20
Newspapers, magazines	300-1000	20

3. Modulation Characteristics. The channel requirements are specified for analog and digital facsimile systems.

a. Analog Systems (amplitude modulation)

DSB-AM, double-sideband amplitude modulation, requires a channel bandwidth of 2 fm + guard bands. VSB-AM, vestigial sideband amplitude modulation, requires a channel bandwidth of approximately 1.2 fm + guard bands. The carrier frequency selected must be greater than fm. The signal to noise ratio for the channel must be adequate to meet the black to white contrast requirements. (see Table C-12).

b. Digital Systems

In a digital system the scanning is performed in the same manner as an analog facsimile system but the output is sampled and a comparator converts the samples to a two-level signal corresponding to black or white elements. The resulting bit rate is 2 fm. The two-level signal can modulate a channel as either frequency shift keying (FSK) or phase shift keying (PSK).

If PSK is used further choices can be made as follows:

binary (non-coherent) FSK

binary or quaternary coherent PSK

binary differentially coherent PSK

quaternary differential coherent PSK

Figure C-14 shows a comparison of the various keying techniques in the presence of additive gaussian noise. The ultimate choice depends upon trade-offs of spectral occupancy, power and cost.

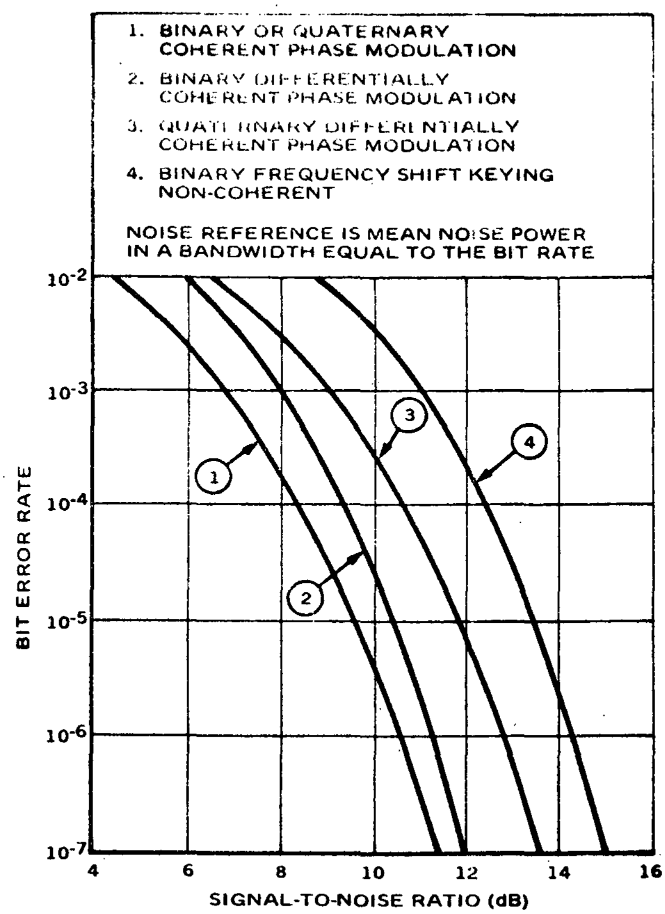

Fig. 1 — Theoretical comparison of modulation techniques in the presence of additive Gaussian noise.

Figure C-14

4. Representative Wideband Facsimile Equipment. Two widely used types of wideband facsimile equipment are representative of facsimile newspaper transmission and high speed document transmission; the "Litcom Pressfax" and the "Xerox LDX". Their characteristics are listed as follows:

a. Litcom Pressfax

Effective picture size: 22" x 15.4"

Drum speeds: 300, 400 and 2000 RPM

Scanning line density: 300, 400 and 600 lines/inch

Modulation: AM

Maximum amplitude corresponds to picture black (or white). Black to white ratio greater than 12 db

Carrier frequency: 32 KHz and 500 KHz

Using the highest resolution of 600 lines/inch and a 2000 RPM drum speed, a newspaper page can be transmitted in 4.5 minutes requiring a DSB-AM channel of 500 $\pm$ 154 KHz

b. **Xerox LDX**

Document size: 8-1/2" x 11" nominal (width may vary from 4 to 9 inches; length may vary from 5 inches to virtually any length)

Speed/Resolution: Five speed/resolution combinations are available and are related to the bandwidth of the communications circuit according to Table C-13.

Table C-13

XEROX LDX FACSIMILE CHARACTERISTICS

Communication Circuit Bandwidth (KHz)	Speed in No. of 8-1/2" x 11" ocuments/min.	Resolution in Scans per inch
240	8.7	135
240	4.3	190
48	3.3	100
48	1.7	135
48	0.9	190

Video Channel - The video signal is a 2-level, non-synchronous, dc coupled, wideband signal. At the beginning of each sweep of the scanner there is a short burst of "synch" signal followed by the two-level scanning data.

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C.4.2 HIGH QUALITY FACSIMILE TRANSMISSION OF NEWSPAPERS AND MAGAZINES

For many years slow-speed facsimile service has been available. This service has most commonly made use of voice-grade telephone circuits, and has provided medium-definition (about 100 lines per inch) copy at rates of about one page per ten minutes. More recently, higher-speed equipment has been designed to work with telpak circuits. The definition provided by all of this equipment is acceptable for such things as typewritten messages, weather maps, and photographs for subsequent reproduction in newspapers. However, it is nowhere near good enough for more demanding applications, such as transmission of photo-masters for use in generating plates in a remote high-quality printing operation.

Recent developments in the military electronics and laser fields have made possible the introduction of a new generation of high-definition facsimile equipment based on pinpoint light sources or electron beams. Rather than 100 lines/inch, resolution of over 2000 lines/inch is now offered. This is easily able to resolve the dots from which a half-tone image, black-and-white or color, is formed.

There is already one well-known commercial application of high definition facsimile equipment in this country, in which the Wall Street Journal is transmitted to second-tier printing plants from the first-tier plants in which the basic type setting and composing operation is performed. In addition, weekly news magazines have expressed interest in using facsimile to reduce their dependence on air transportation for photographs, to reduce the lead time required between press time and the deadline on editorial changes, and to centralize the scattered operations now associated with putting together regional editions.

One factor militating against quick adoption of high-definition facsimile is the high cost of the wide bandwidth transmissions which are required. Fig. C-15 shows the relationship between bandwidth, resolution, and speed of transmission. It can be seen that the bandwidth required is comparable to TV. It is important to note, however, that the signal-to-noise ratio requirements are completely different. For network TV, a peak-to-peak video/weighted noise

RESOLUTION

SPINNER SPEED	Bandwidth (MHz) / Time/Frame (min)	750 LPI	1500 LPI	2250 LPI
	705 RPM	.5 / 2.5	1.0 / 5.0	1.5 / 7.5
	1410 RPM	1.0 / 1.25	2.0 / 2.5	3.0 / 3.75
	2820 RPM	2.0 / .63	4.0 / 1.25	6.0 / 1.87

Figure C-15 BANDWIDTH VERSUS RESOLUTION MATRIX FOR 14 x 18 FORMAT

4

ratio of 53 db is generally specified, corresponding to 40 db for unweighted noise out of an FM demodulator. For the facsimile case, the ~~noise~~ signal has only two levels, black or white, so that a much lower signal-to-noise ratio, of the order of 20db, can be used. One would then expect that a satellite link could handle more facsimile transmissions than TV transmissions, for a given video bandwidth.

At this point it is important to note that no such tradeoff is possible between signal-to-noise ratio and the number of transmissions when using conventional terrestrial radio-relay facilities.* Thus the facsimile user <u>must</u> now be charged the same as the TV user. By contrast, satellite service would offer the facsimile user the possibility of much lower charges relative to TV. One manufacturer of facsimile equipment has expressed the opinion that if charges could be lowered by a factor of two or three times, cross-country facsimile transmissions would be considered economically feasible by the publishing community.

A comparison of TV and FAX transmission requirements is given in Appendices A and B, the results of which are summarized below:

	$\frac{C}{nf_b}$	Spectrum Required	Modulation Method
TV	23.2db	$7.6f_b$	FM
FAX	15.5db	$1.5f_b$	4ϕ PSK

It can be seen that, for equal video bandwidth, five FAX signals are the equivalent of one TV signal. There is thus reason to believe that the cost reduction desired by the publishers can, in fact, be achieved.

It is possible to postulate a FAX distribution system, based on satellites, which would serve the needs of a typical publishing operation, such as a weekly news magazine. The purpose of such a distribution system would be to transmit copy from a central point, such as New York, to a number of outlying printing plants, located for example at Boston, Chicago, Atlanta, Dallas, Los Angeles and Denver. The material to be transmitted

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* Theoretically such a tradeoff would be possible by going to multi-level, rather than two-level transmission of the facsimile signals. Practically, this is extremely unlikely because of the cost and complexity of the added equipment that would be required.

will be assumed to consist of 100 pages, of which 50 percent require a 4-color process. Six separate regional editions (East, South, Mid-west, Southwest, Mountain, Far West) would be transmitted. Re-runs and changes would add 20 percent to the total. Total pages to be transmitted would therefore come to 300 for each of the six editions.* If a resolution of 1500 lines/inch is chosen, and a 14 x 18 inch format assumed, a page can be transmitted in 1.25 minutes, using a 4.0 MHz video bandwidth, i.e., the same as for TV. Total transmission time is therfore 6 1/4 hours for each edition if a single FAX channel is used, or 1 1/4 hours if multiple FAX transmitting equipment is used to load up a single TV equivalent channel.

An estimate of the weekly satellite load attributable to news magazines may be made by counting the total number of such magazines (e.g. Time, Newsweek, U.S. News, Business Week, Sports Illustrated, Life, Look). If nine such magazines are assumed, the total weekly load is 67.5 hours of equivalent TV channels. If this load were concentrated in two and one-half hours in each of three days, nine simultaneous equivalent TV channels would have to be made available during each period of activity. Such peak loads are to be expected, since many news magazines are printed on Sunday, for example. The transmission time must also be minimized in order to remain competitive with physical transport of material by air. One saving factor would be that the peaks could probably be scheduled for slack hours of TV network operation, such as Sunday AM or after midnight.

Characteristics of a hypothetical facsimile transmission system shared by nine national magazines are summarized in Table C-14 While the system characteristics are obviously oversimplified, the key requirements of such users as national magazines are identified, and this should permit a rough evaluation to be made of the costs associated with transmission of information via satellite.

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* Time has seven regional editions, plus metropolitan editions for the major cities, plus separate editions for specialized readers, such as educators.

Number of Simultaneous 40 MHz Channels	9
Hours of Operation (EST)	Tues. 00:00 - 02:30 Thurs. 00:00 - 02:30 Sun. 08:00 - 10:30
C/n Required at Earth Terminal	89.4 db-cps
Baseband Width	4.2 MHz
Transmit Earth Terminal Location	New York
Receive Earth Terminal Locations	Boston, Chicago, Atlanta — First 1¼ hours Denver, Dallas, Los Angeles — Second 1¼ hours
Simultaneous FAX Transmissions from Transmit Terminal	45
Simultaneous FAX Carriers Received at each Receive Terminal	15

Table C-14 Facsimile Transmission System Shared by Nine National Magazines

4 ④

1. TRANSMISSION PARAMETERS FOR TV

Here the transmission parameters are typically defined by spectrum limitations. For example, in the domestic pilot system proposed by Comsat, nominal 40 MHz channels are provided. After allowance for guard bands, the maximum permissible modulation index for TV is 2.8.

For network quality TV, the signal quality required is $\frac{Spp}{Nw} = 53$db, where Spp is peak-peak video signal power including sync, and Nw is weighted noise power. The allocation ATT makes to local video systems is 57db. This leaves 55 db for the long-distance transmission link.

Since the effect of preemphasis and weighting in a satellite line is generally assumed to be 13 db, the signal-to-unweighted noise ratio,

$$\frac{Spp}{Nu} = 55 - 13 = 42 \text{ db} = 1.6 \times 10^4.$$

From standard FM theory we have

$$\frac{Spp}{Nu} = 24\, M^2\,(M+1)\,\frac{C}{N_{IF}}$$

or

$$\frac{C}{N_{IF}} = \frac{1.6 \times 10^4}{24 \times (2.8)^2 \times 3.8} = 22.4 = 13.4\text{db}$$

but

$$\frac{C}{N_{IF}} = \frac{C}{2\, nf_b\,(M+1)}$$

therefore

$$\frac{C}{nf_b} = 2\,(M+1)\,\frac{C}{N_{IF}} = 2\,(3.8)\,(22.4) = 22.2 \text{ db}$$

To this must be added any margin that is required in the system. The margin need not be large, since the nominal operating point is already 3 db or so above FM threshold. Under these conditions, the delivered signal is about 3 db below transmission objectives and is still of high quality for al practical purposes. A added margin of 1 db providing a total margin of 4 db above FM threshold, would therefore appear adequate. Accordingly,

$$\frac{c}{nf_b} = 23.2 \text{ db}$$

2. TRANSMISSION PARAMETERS FOR FACSIMILE

Facsimile transmissions are most conveniently considered as a digital bit stream, the bit rate F_b being twice the highest video frequency f_b. The key quantity to be determined for a digital transmission is the maximum permissible bit error rate. For high definition facsimile systems, the size of a picture element is substantially smaller than that of the smallest dot found in a half-tone reproduction. Thus any single error is of no consequence. There are only two effects of any importance. The first, significant darkening of an all-white area (or probably more important, lightening of an all-black area), would require an extremely high error rate, say in excess of 10^{-2}. The second effect would be due to groups of contiguous errors which total up to a line or spot big enough to be noticeable. At normal reading distances, the smallest spot visible against a contrasting background is about 0.002 inch in diameter. At least two contiguous errors would have to occur in order to make an erroneous spot of this size. An approximate calculation indicates that for an error rate of 10^{-4}, there should be no more than a few such spots on a page. Thus an error rate of 10^{-4} would appear to be a conservative value for facsimile transmission.

Of the variety of methods that may be used to modulate a radio link used for digital signals, two will be considered here. Phase-shift keying requires less power and bandwidth than other methods in common use, but uses ~~xxxxxxxxx~~ equipment that can be somewhat expensive. Frequency-shift keying requires no special radio equipment at the satellite earth terminal, since it can employ the same type of FM exciters and receivers used for TV. It therefore involves the lowest implementation costs.

Phase-Shift Keying

For ideal coherent PSK with a bit error rate of 10^{-4}, the required energy-to-noise density ratio is 8.5db. From this we have

$$\frac{C}{nf_b} = \frac{2C}{nF_b} = 2 \frac{E}{n} = 11.5\text{db}$$

To this must be added a threshold margin. Since the TV system was assumed to have a 4 db margin above demodulator threshold, the same figure will be assumed,* so that the nominal condition is:

$$\frac{C}{nf_b} = 15.5 \text{ db}$$

This is 7.7 db less than for the TV case.

For four-phase PSK, the required spectrum width is generally taken as about 0.75 F_b, which in turn is equal to 1.5 f_b.

The Carson's Rule spectrum width required for TV with modulation index of 2.8 is 7.6 f_b.

Frequency Shift Keying

For ideal non-coherent FSK with a bit error rate of 10^{-4}, the required energy-to-noise density ratio is 12.2 db, or 3.7 db more than for PSK. If the same margin is assumed as previously,

$$\frac{C}{nf_b} = 19.2 \text{ db}$$

---

* It might be argued that the digital FAX system requires more margin since its performance degrades much more rapidly than the FM TV system below threshold.

This is 4 db less than for the TV case.

The spectrum width required for FSK is four times that for 4-phase PSK, or $6f_b$.

The following table summarizes the results of the preceding calculations:

		$\frac{C}{nf_b}$	Spectrum Width
TV		23.2db	7.6 f_b
	4-PSK	15.5db	1.5 f_b
FAX	2-PSK	15.5db	3.0 f_b
	FSK	19.2db	6 f_b

It can be seen that with 4-PSK, five facsimile transmissions can be sent through the same satellite repeater as one TV transmission of the same video bandwidth. FSK is less advantageous in that it has about the same spectrum requirement as TV, so that only one FAX channel could be accomodated in a satellite repeater specifically designed for TV. With a broad-band repeater, however, and no other limitations on spectrum occupancy, two FAX transmissions could be made using the same satellite power as for one TV transmission.

APPENDIX D

PARAMETRIC DATA

D.1 Ground Facility Building Cost

Figure D-1 shows the building cost relationship per facility as a function of the number of transmitters and/or receivers. This parametric relationship is constructed from data found in the DCA Cost Manual.* The costs represent the terminal costs only, i.e., no studio facilities are included. Table D-1 itemizes the cost elements. The terminal is assumed to have 900 square feet for offices and 600 square feet per transmitter.

D.2 Terminal Equipment

Figure D-2 illustrates the parametric cost relationship for the audio multiplex equipment (duplex service). The curve is derived using data from the DCA Cost Manual. The rate for the acquisition cost is $2000/audio circuit and the annual maintenance cost is at a rate of 10% of the acquisition cost.

Figure D-3 illustrates the cost curve for the video terminal equipment. The data reference is given as the publication, ITFS: What It Is...How To Plan.** The costs reflect one video tape recorder (VTR) and film and slide chain per channel. Table D-2 gives the cost breakdown per item.

Installation cost is taken to be 20 percent of the acquisition cost, while annual operation and maintenance costs are 15 and 10 percent, respectively.

* Defense Communications Agency Cost Manual, Volume I, "Communications Cost," January, 1967 Instruction 600-60-2.

** "ITFS, Instructional Television Fixed Service (2500 Megahertz), What It Is .. How To Plan," The Division of Educational Technology, National Education Association, 1967

<u>Required Facility Size:</u>

$1500\ ft^2$ for first transmitter/receiver

$600\ ft^2$ for each additional transmitter/receiver

ACQUISITION COST*

Item	Description	Cost/ft^2
Site Acquisition	2 Acres/1000 ft^2 of bldg. @ $3000/acre	$ 6.00
Site Preparation	1 Acre/1000 ft^2 of bldg. @ $1500/acre	1.50
Bldg. Construction	Typical quantity of 3300 ft^2	25.00
Air Conditioning	1 ton/250 ft^2 @ #1000/ton	4.00
Q-Flooring		2.50
	TOTAL	$39 .00

Maintenance cost is at 2% of acquisition.

Table D-1. Cost Breakdown-Ground Facility Building Cost

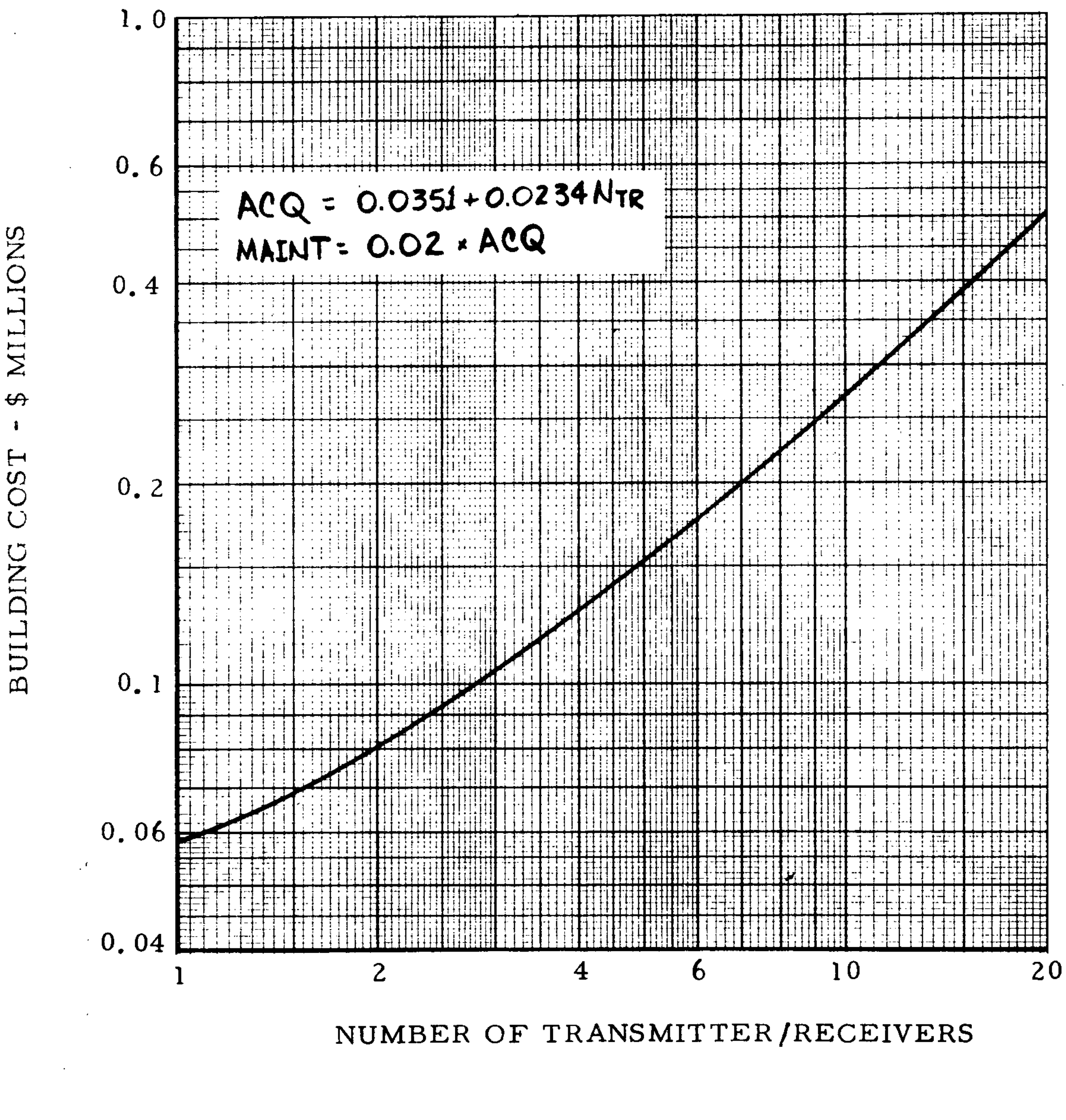


FIGURE D-1. GROUND FACILITY BUILDING COST

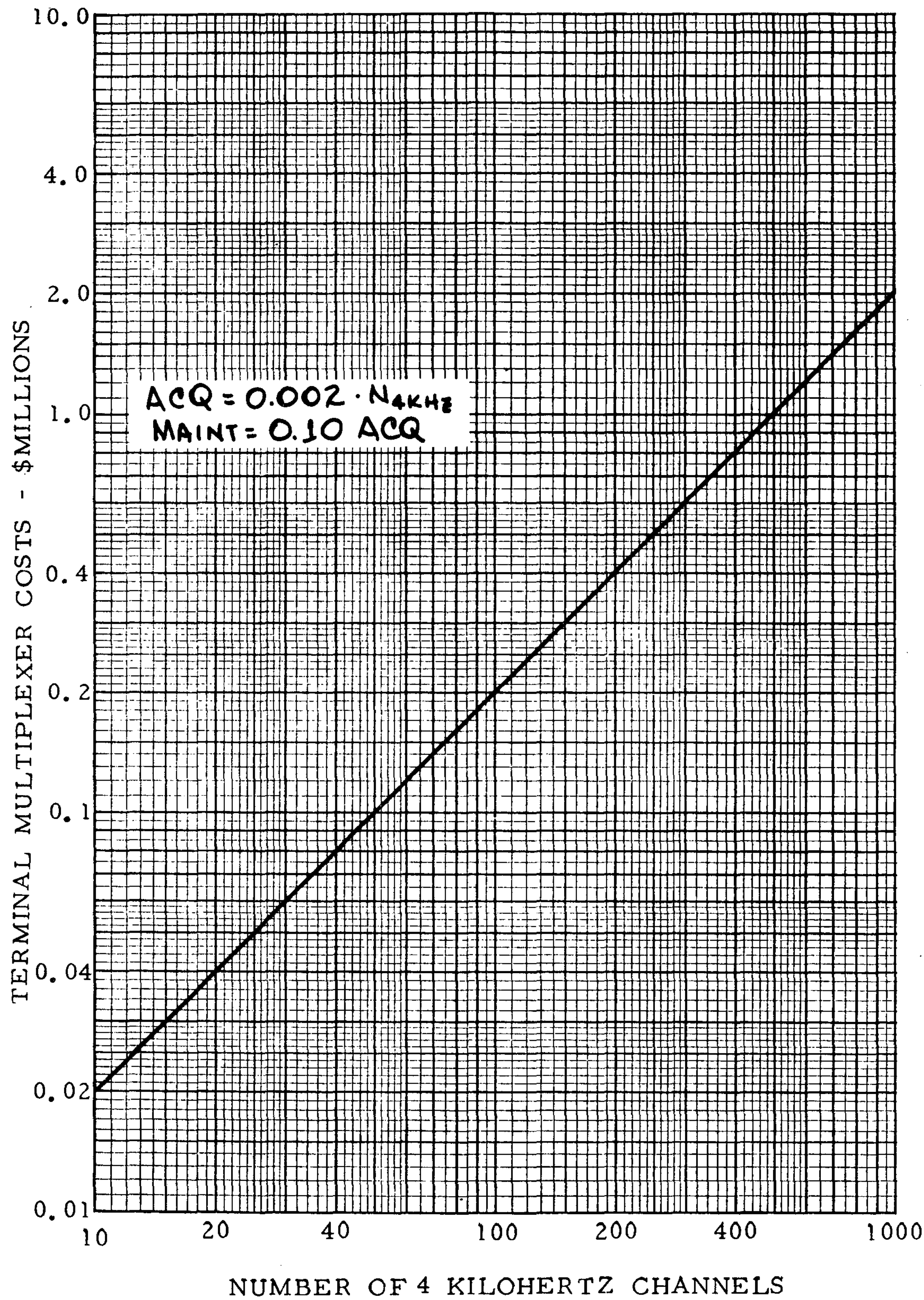


FIGURE D-2. AUDIO-TERMINAL EQUIPMENT COST

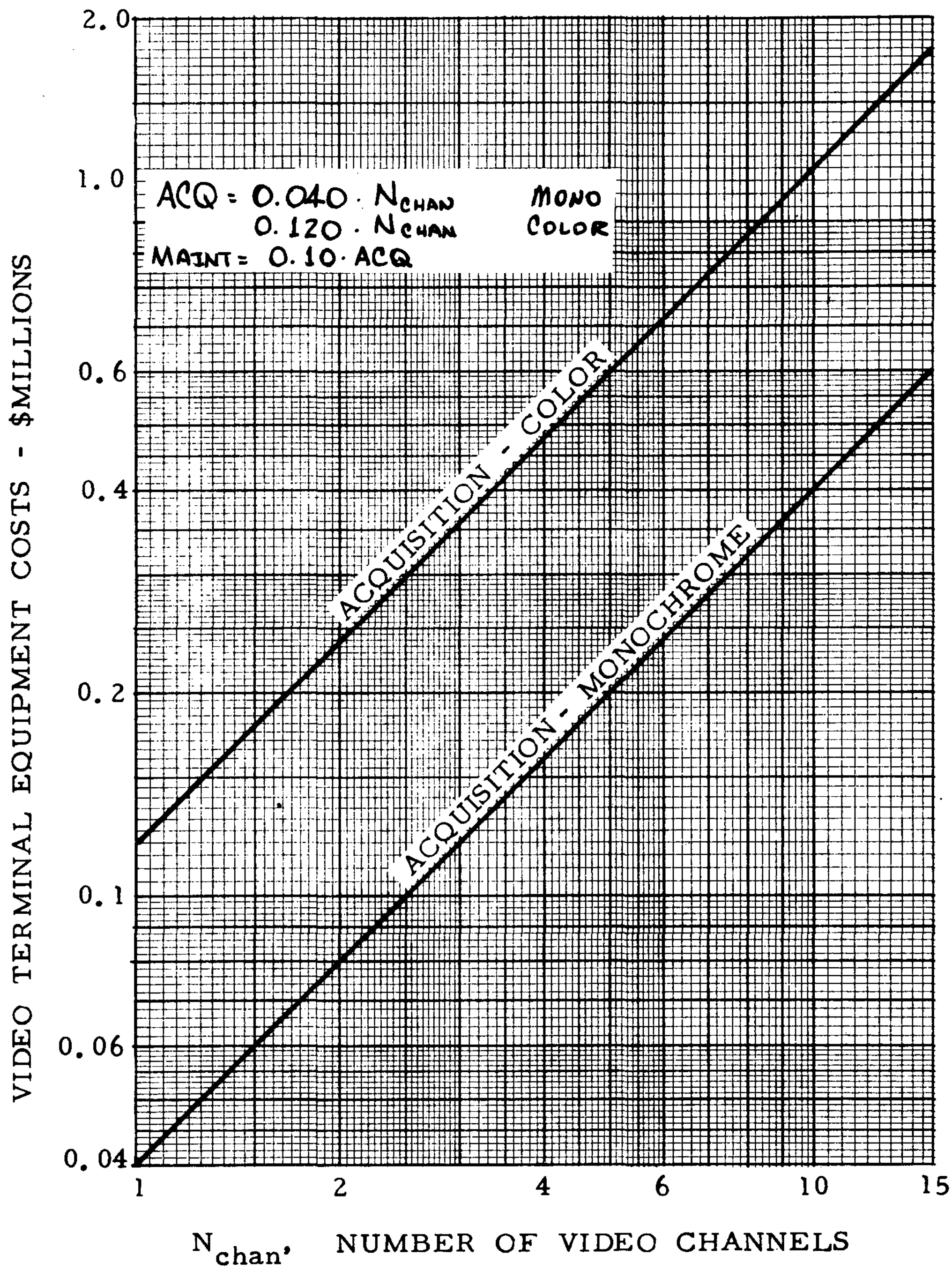


FIGURE D-3. VIDEO TERMINAL EQUIPMENT COST

Video Terminal Equipment Cost

Item	Monochrome	Color
VTR (Quadruplex)	$20,000	$ 70,000
Film/Slide Chain	20,000	50,000
TOTAL	$40,000	$120,000

Table D-2. Cost Breakdown-Video Terminal Equipment

D.3 Ground Transmitter Costs

The transmitter parametric acquisition cost data for a power output of up to 10 kilowatts is developed from information supplied by Hughes Aircraft. The costs reflect the initial cost including FM modulators ($5000). For power output greater than the 10 kilowatts, the curve is extended using the DCA reference. Figure D-4 illustrates the acquisition cost curve. Also shown is the operations cost curve. The cost curve indicated as G.E. source is taken from the G.E. Multi-Kilowatt Transmitter Study NAS8-21886.* The Hughes figures are used in preference to these since they are considered to be more recent. Annual maintenance cost is assumed to be 10 percent of the acquisition cost while installation cost is given as 20 percent.

* General Electric Report No. 68SD4268, 10 June 1968 "Multikilowatt Transmitter Study for Space Communications Satellites", for NASA-MSFC Contract NAS8-21886.

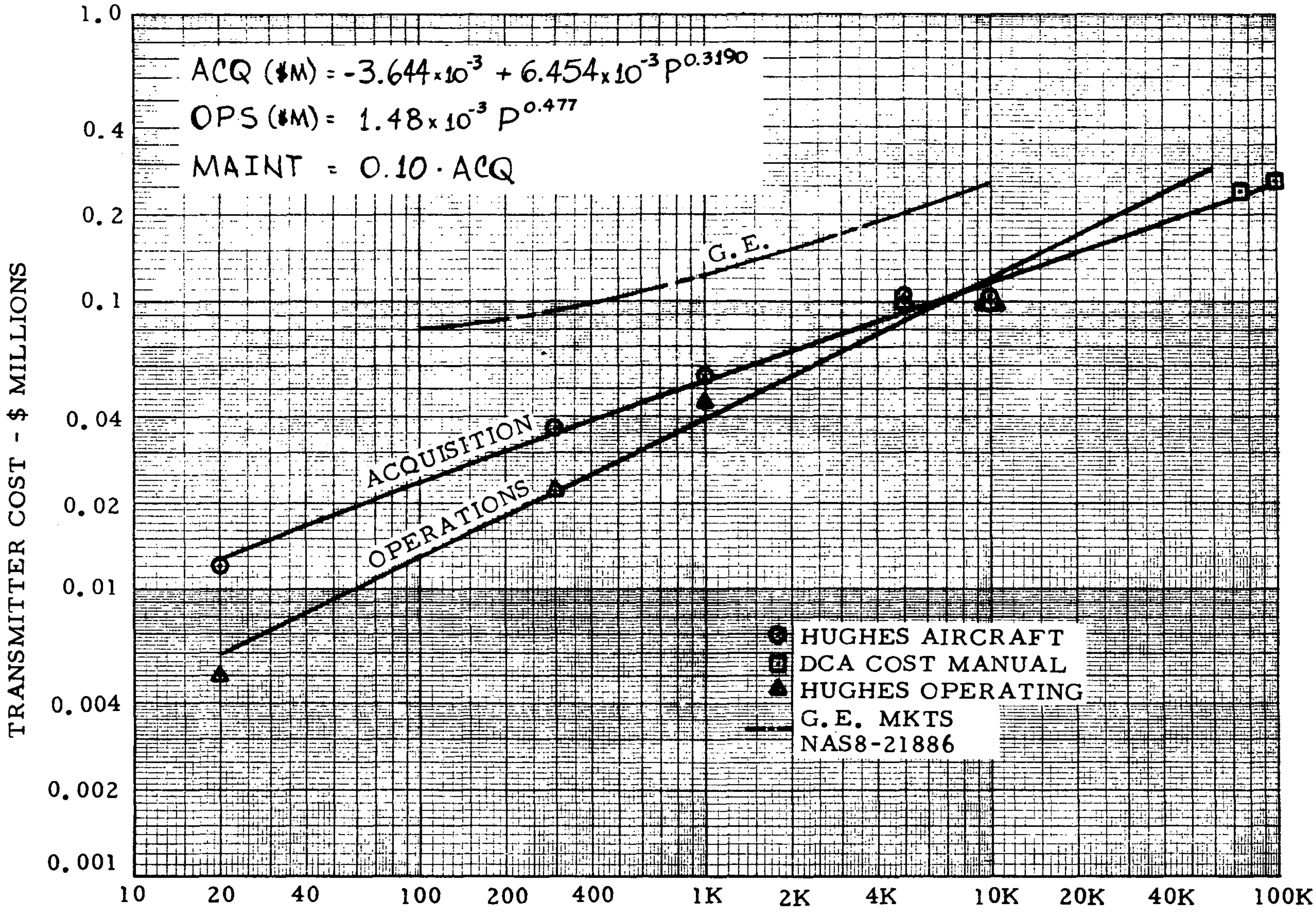


FIGURE D-4. GROUND TRANSMITTER COST

D.4 Manufacturing Learning Curves

The manufacturing learning curves are derived on the basis of Convair experience. The choice of the 85, 89, and 95 percent curves are based on the Jansky and Bailey Report* which suggests that these are typical for multi-unit production of electronic equipment. Figure D-5 illustrates the learning curve relationship.

D.5 Ground Antenna Cost

Figure D-6 illustrates the parametric cost relationship for a steerable parabolic ground antenna with circular polarization. The curve used in the synthesis is the Hughes Aircraft. The cost includes installation, feed, drive motors, and mechanisms, but does not include the servo electronics for antenna pointing. The supplied data indicates that the curve does change shape after a diameter of 42 feet (as depicted). Annual maintenance cost is 10 percent of the acquisition cost. Operations costs are considered negligible.

Figure D-7 shows the acquisition and installation cost relationships for a nontracking parabolic ground antenna with linear polarization. Also shown is the acquisition cost for a ground UHF wideband antenna. Figure D-8 illustrates the various data collected to determine these relationships from two sources: 1) the G.E. MKTS study, and 2) the Jansky and Bailey Report. The G.E. data is used since it is considered to be more recent and reliable. For quantities greater than one, a 95 percent learning curve is employed in determining the cost per unit. Installation costs do not vary with demand. Maintenance is 10 percent of the acquisition.

D.6 Ground Receiver Costs

Figure D-9 and D-10 illustrate the cost relationships for the AM and FM commercial ground receivers, respectively. Data is taken from the Jansky and Bailey Report and the Jansky and Bailey computer program. Discrepancies

*Final Report, "Technical and Cost Factors That Affect Television Reception from a Synchronous Satellite", NASW-1305, 30 June 1966

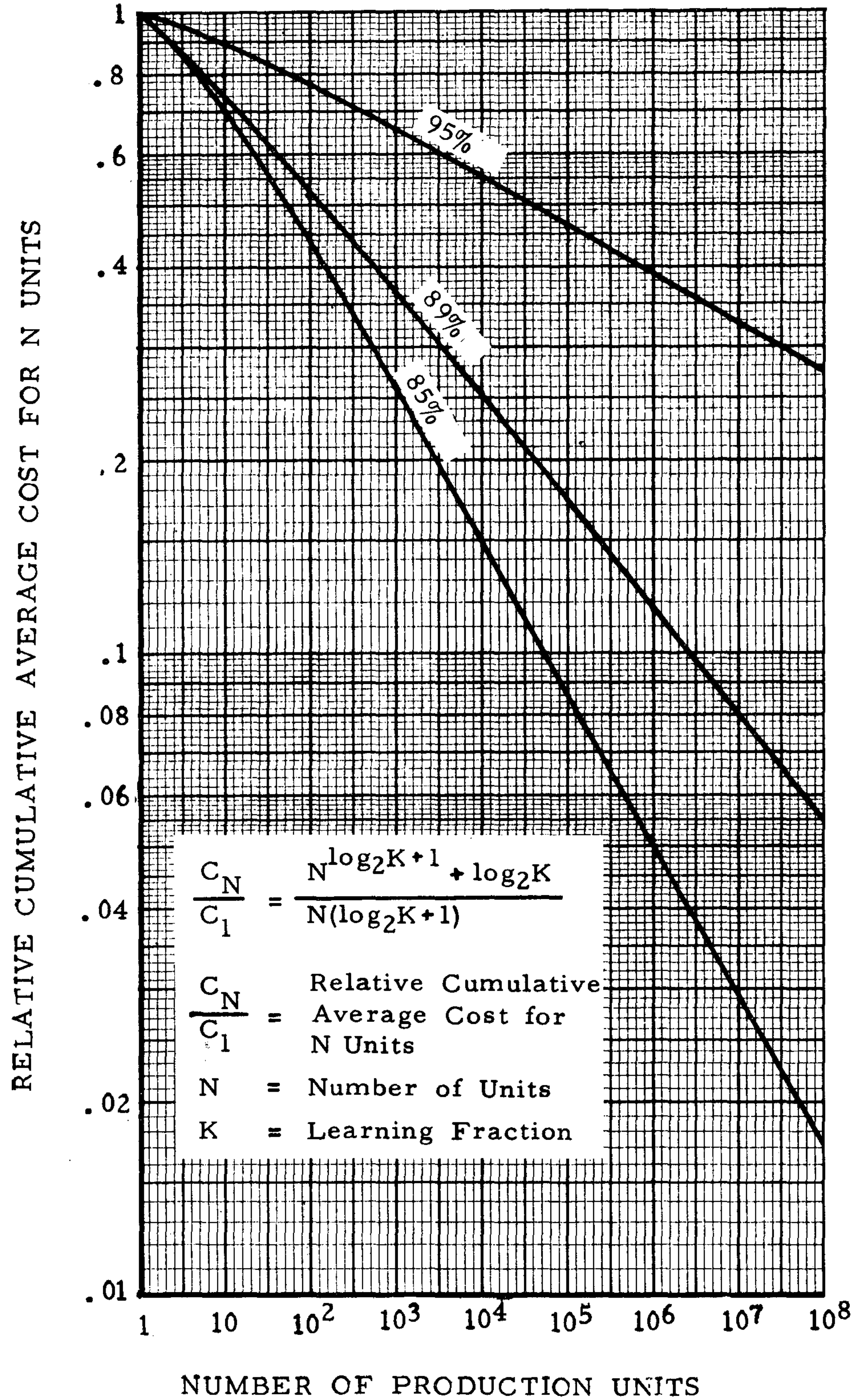


FIGURE D-5. MANUFACTURING LEARNING CURVES

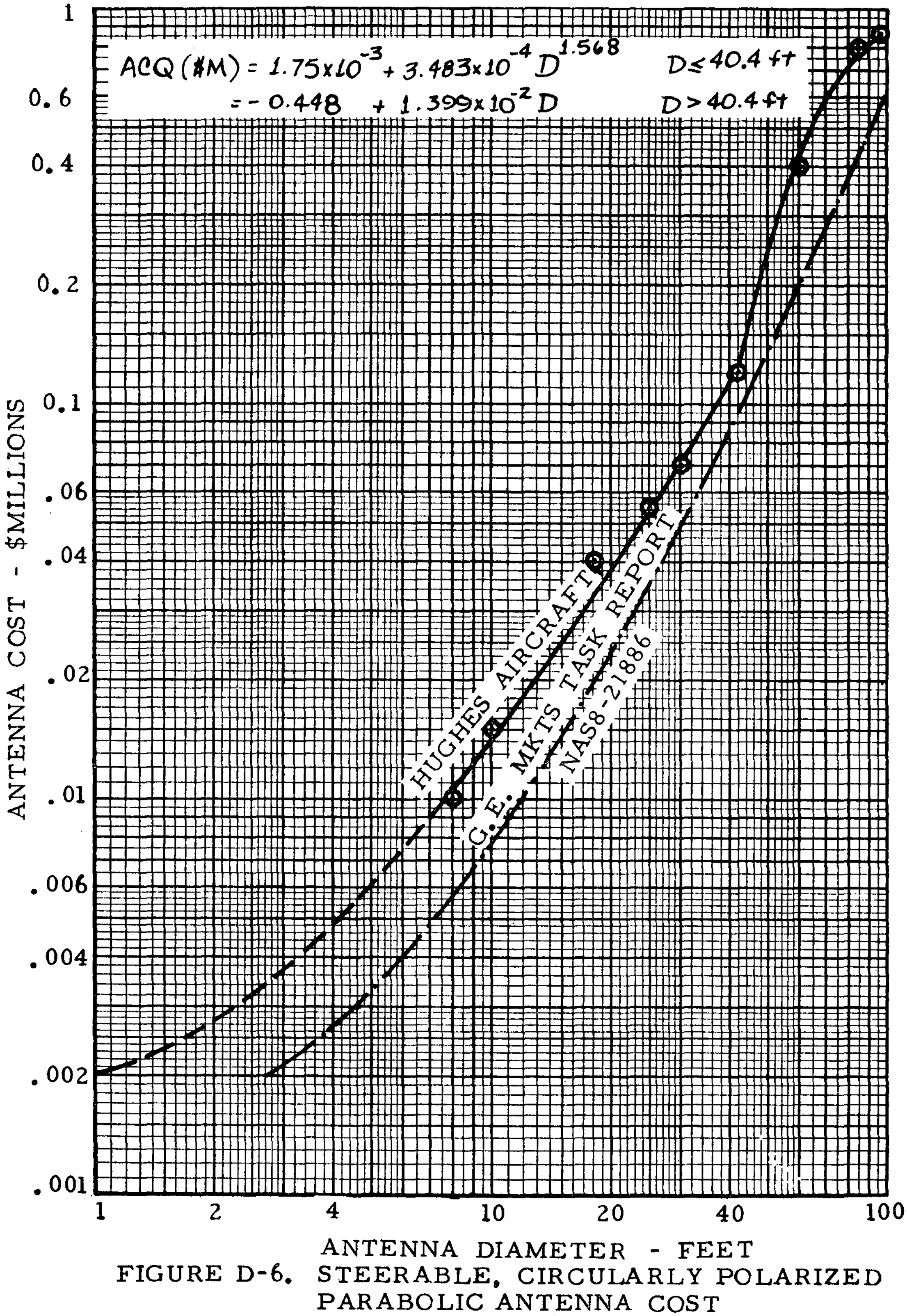


FIGURE D-6. STEERABLE, CIRCULARLY POLARIZED PARABOLIC ANTENNA COST

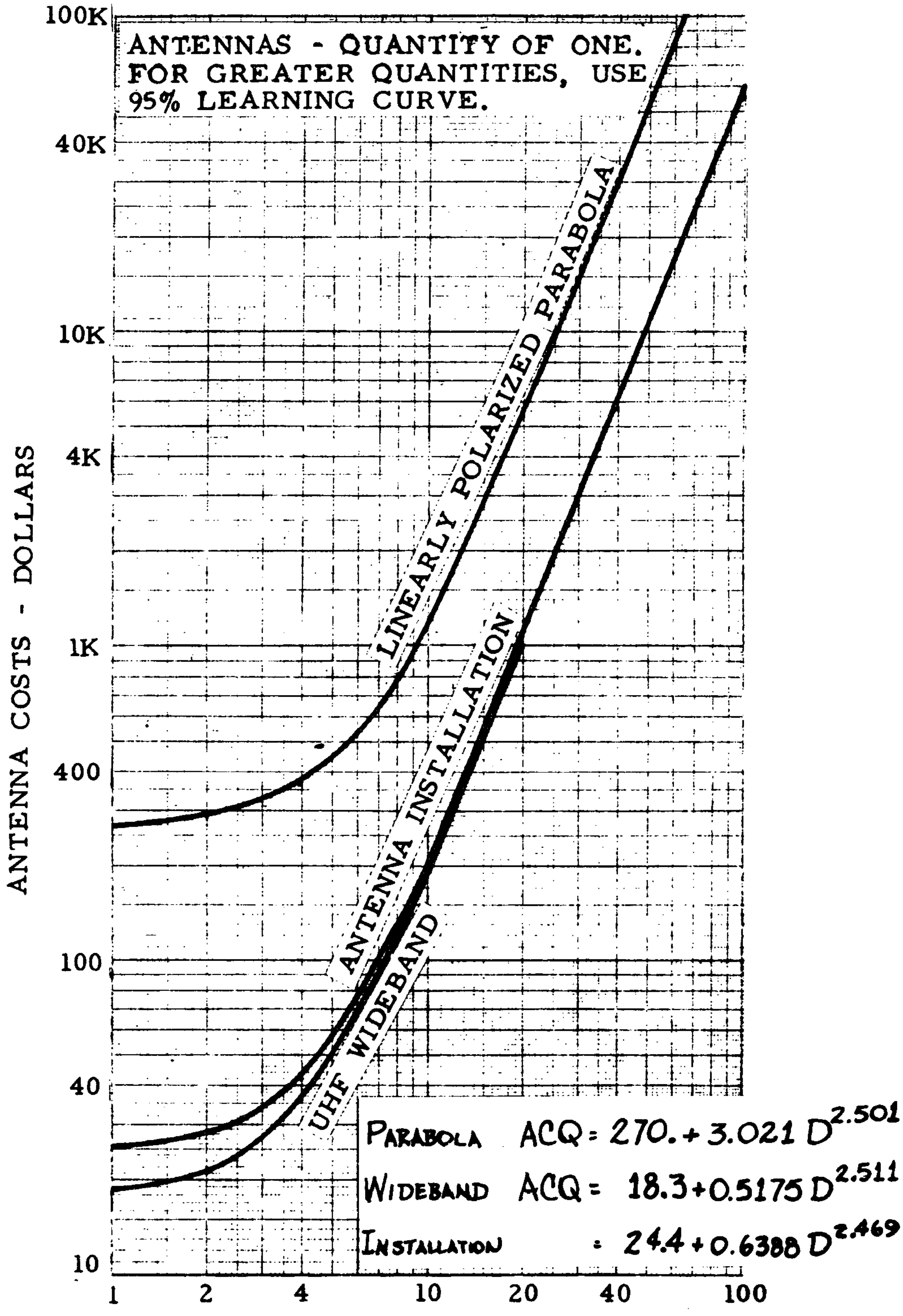


FIGURE D-7. NON-TRACKING, LINEARLY POLARIZED PARABOLIC ANTENNA COST

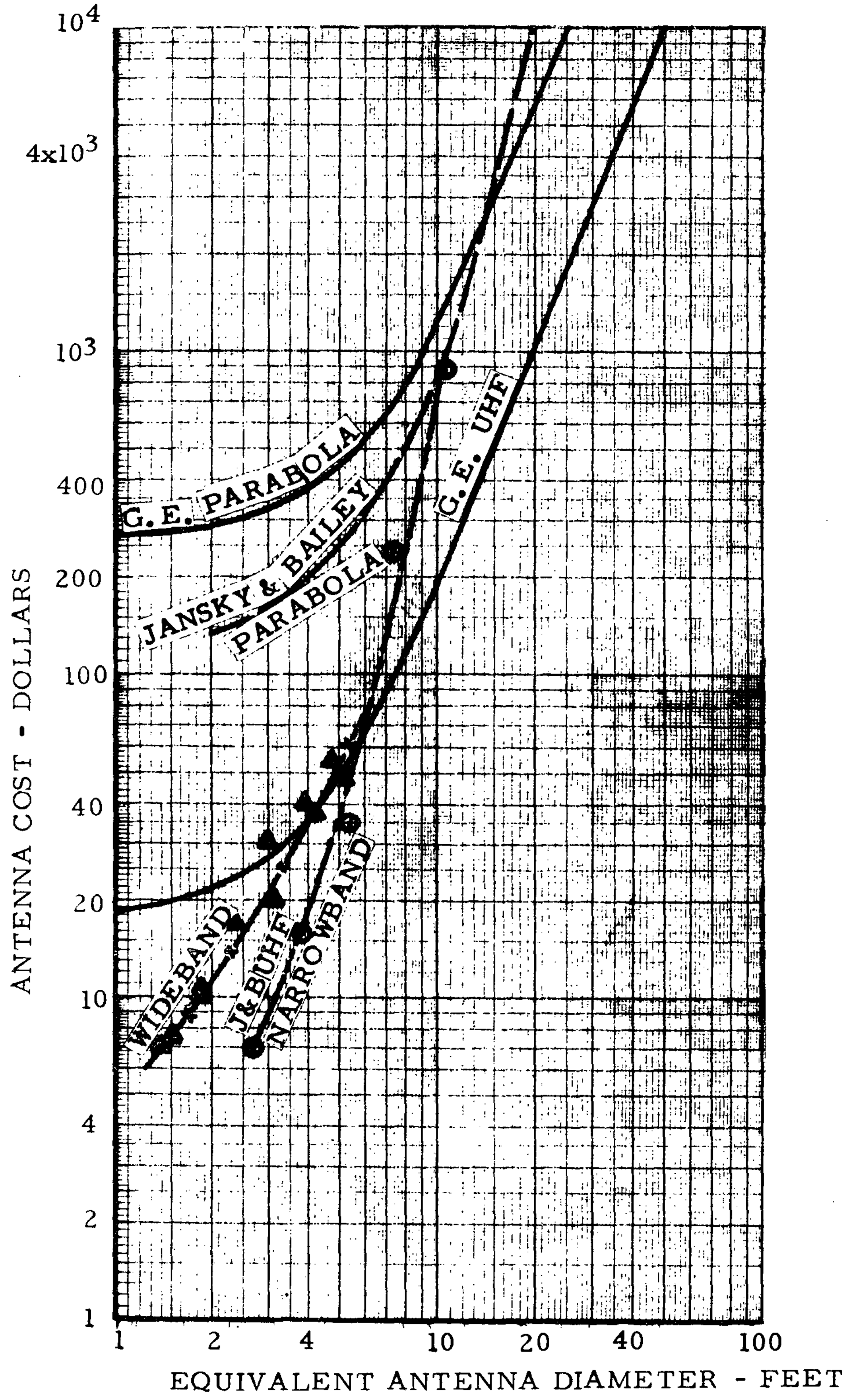


FIGURE D-8. GROUND ANTENNA COSTS

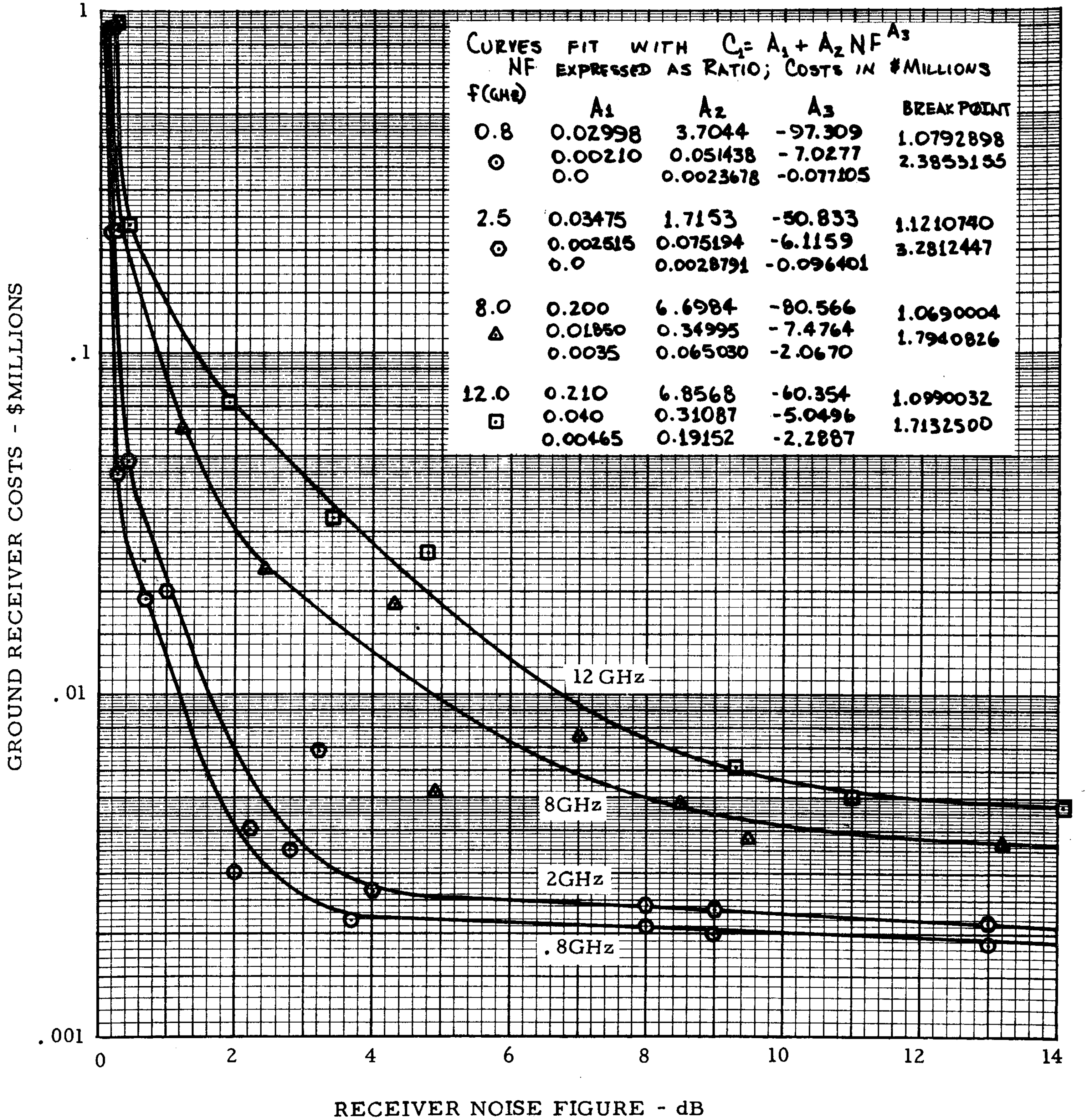


FIGURE D-9. AM COMMERCIAL GROUND RECEIVER COST

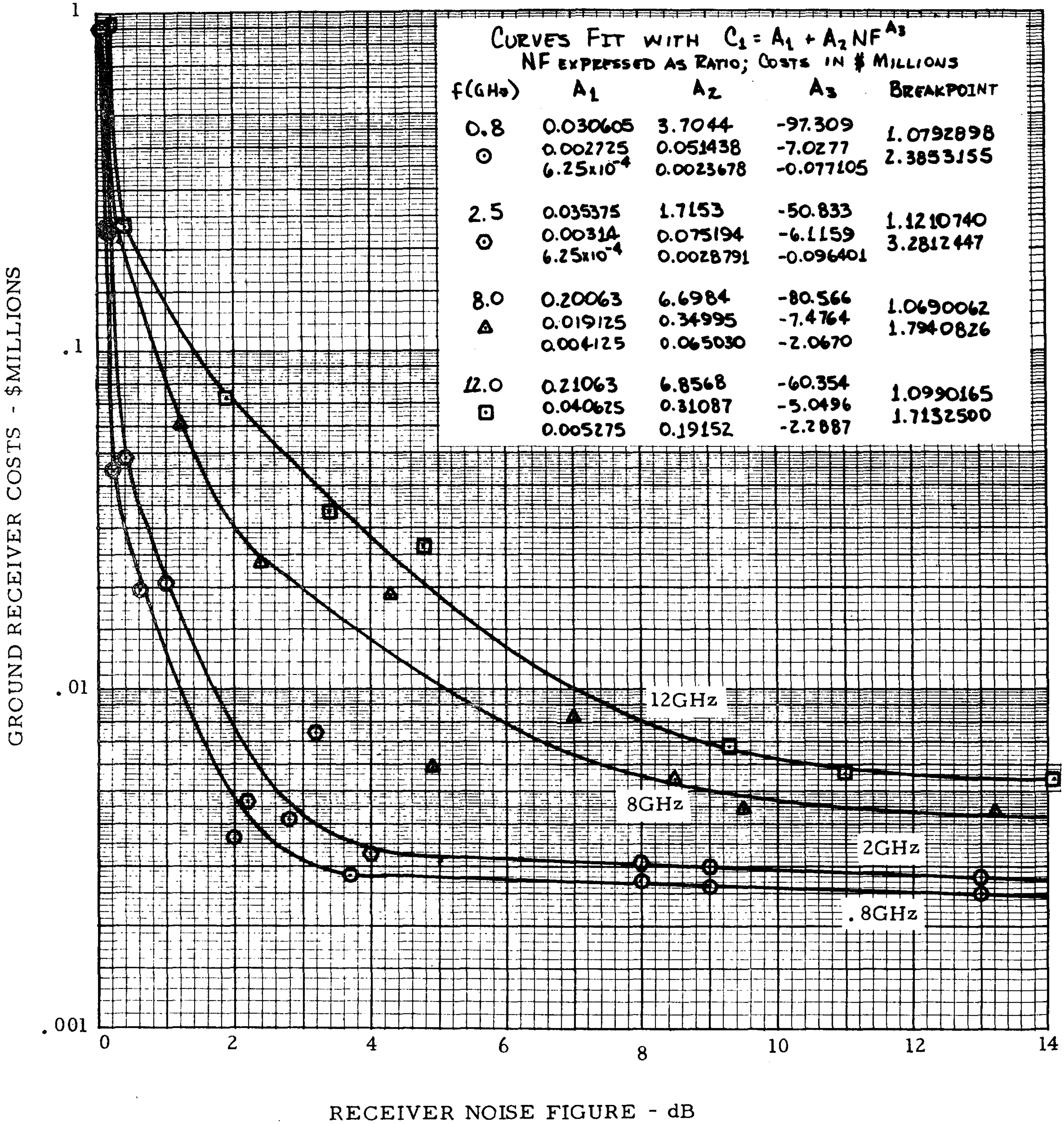


FIGURE D-10. FM COMMERCIAL GROUND RECEIVER COST have been found and corrected (e.g., the wrong learning curve was used for projections to a unit quantity cost). Vendors were contacted to spot check the Jansky and Bailey data. The resulting parametric data is shown in the figures mentioned above. Since the quoted prices were projected back to a quantity of one, small errors may have been included. The costs do, however, tend to agree with the Jansky and Bailey numbers. Other observed data for costing AM and FM receiver/preamplifier/converters for use in reception from a geostationary satellite included G.E. TVBS derived data for 8 and 12 GHz. These figures were considered to be inconsistent, i.e., either too high or too low. The Jansky and Bailey figures appeared more reasonable. Installation cost, annual operating cost, and annual maintenance cost are assumed to be 15, 5, and 10 percent of the acquisition cost, respectively.

Figures D-11, D-12, and D-13 illustrate the final results depicting the cost relationships for mass-produced consumer quality (direct-to-home) ground receivers. These results are based on data found in G.E. and CCIR studies. The derivation of these results and the utilization of the G.E. and CCIR data is fully documented in the final report, Television Broadcast Satellite Study, Volume II submitted by GD/Convair Aerospace to MSFC upon completion of the TVBS study in December 1970.*

Mass produced receiver cost data was obtained at a Phase I briefing of a NASA funded study by G.E.** The base data employed is primarily a result of that review together with data listed in a report by the CCIR Study Group, USSG IV.

Installation cost is 50 percent of the acquisition cost, while annual maintenance cost is taken to be 10 percent.

* "Television Broadcast Study,"Volume II, 31 December 1970, NAS 8-21036

** "Ground Signal Processing Systems" NAS 3-11520

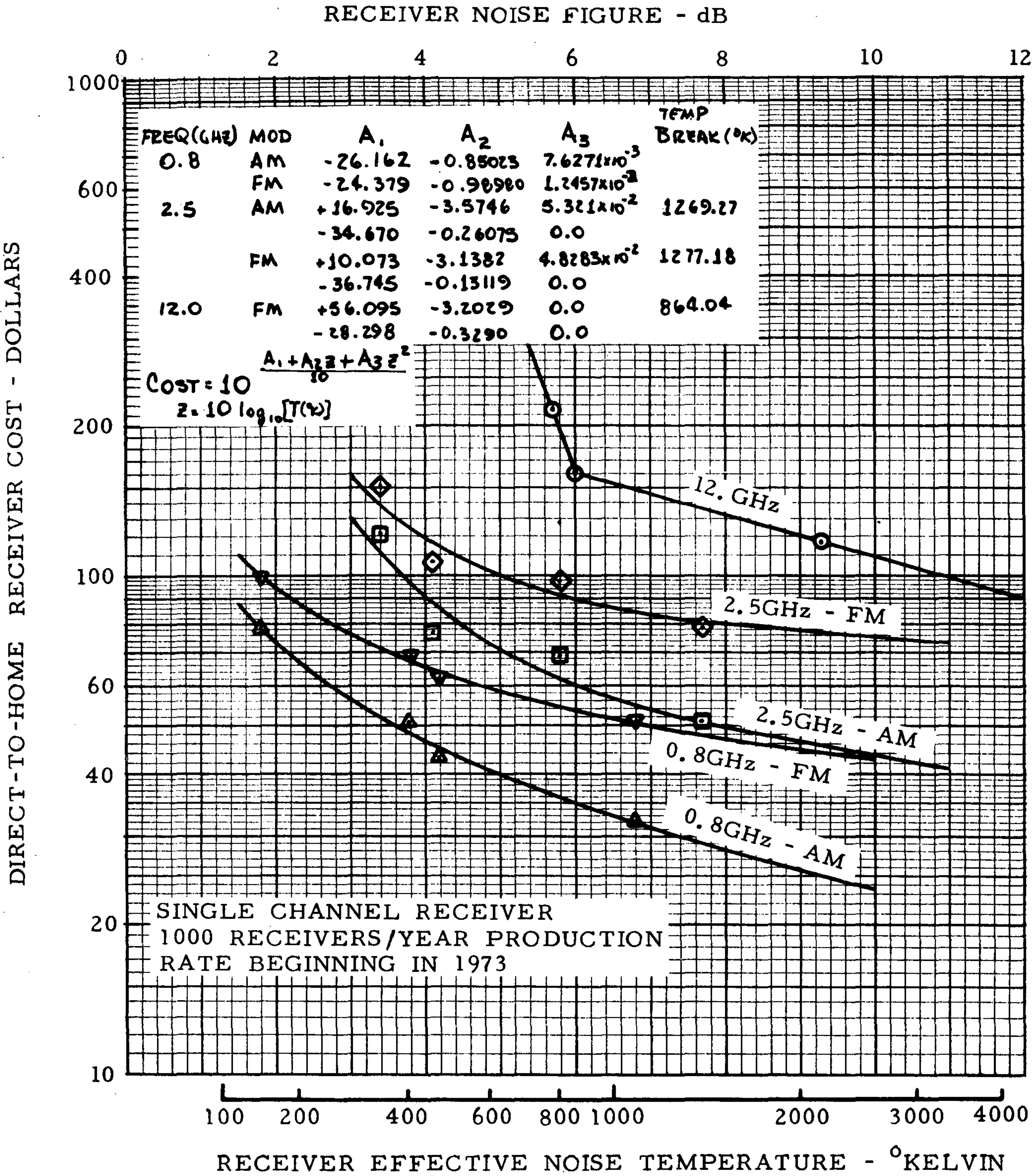
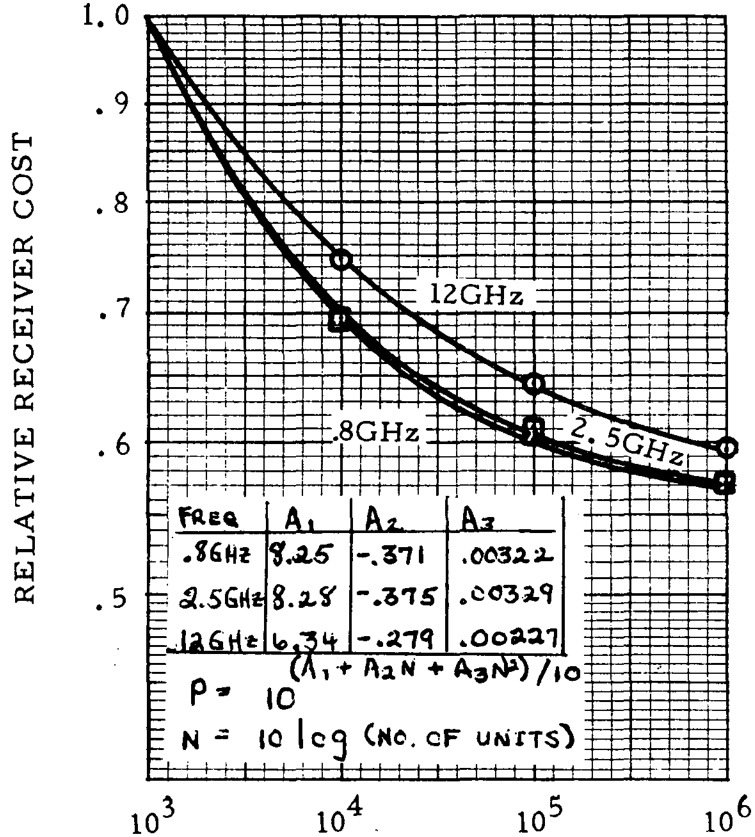
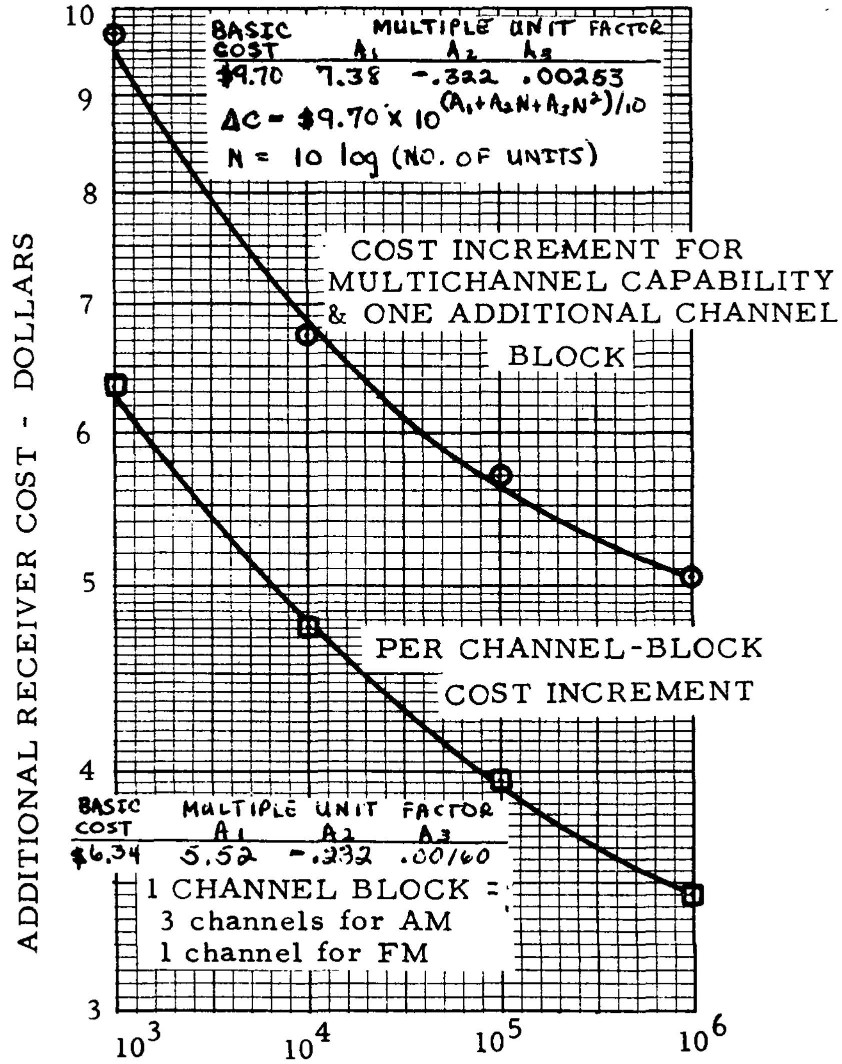


FIGURE D-11. CONSUMER GROUND RECEIVER COST



ANNUAL PRODUCTION VOLUME

FIGURE D-12. COST REDUCTION FOR MASS PRODUCED COMPONENTS



ANNUAL PRODUCTION VOLUME

FIGURE D-13. MULTIPLE CHANNEL COST INCREMENTS

D.7 Standby Power Source

Figure D-14 shows the cost relationships of the standby power source cost versus the generator rating. The curves are generated from data found in the DCA Cost Manual and data supplied by NASA/AMES.* The annual maintenance cost is 5 percent of the acquisition cost while installation is 2 percent.

D.8 Annual Personnel Costs

The annual personnel cost data was generated internally at GD/Convair Aerospace. The results are depicted in Figure D-15. It is assumed that required manpower corresponds to the number of carriers as follows:

1 transmitter/receiver pair - 2 men
4 transmitter/receiver pairs - 4 men
9 transmitter/receiver pairs - 6 men
⋮
$N_{t/r}$ transmitter/receiver pairs - $2 \cdot (N_{t/r})^{0.5}$

Also assumed is a rate of $15,000 annual salary per man with a 10 and 20 percent differential for second and third shift, respectively.

D.9 Telemetry and Command

The cost items for the T, T, & C ground equipment is based on Hughes Aircraft data and is illustrated in Table D-3.

D.10 Test Equipment

Necessary test equipment is required by the Class 1 and Class 2 stations. These are taken to be as follows:

Class 1 - $50,000

Class 2 - $25,000

* Mr. E. Van Vleck, ITS Study Contract Monitor

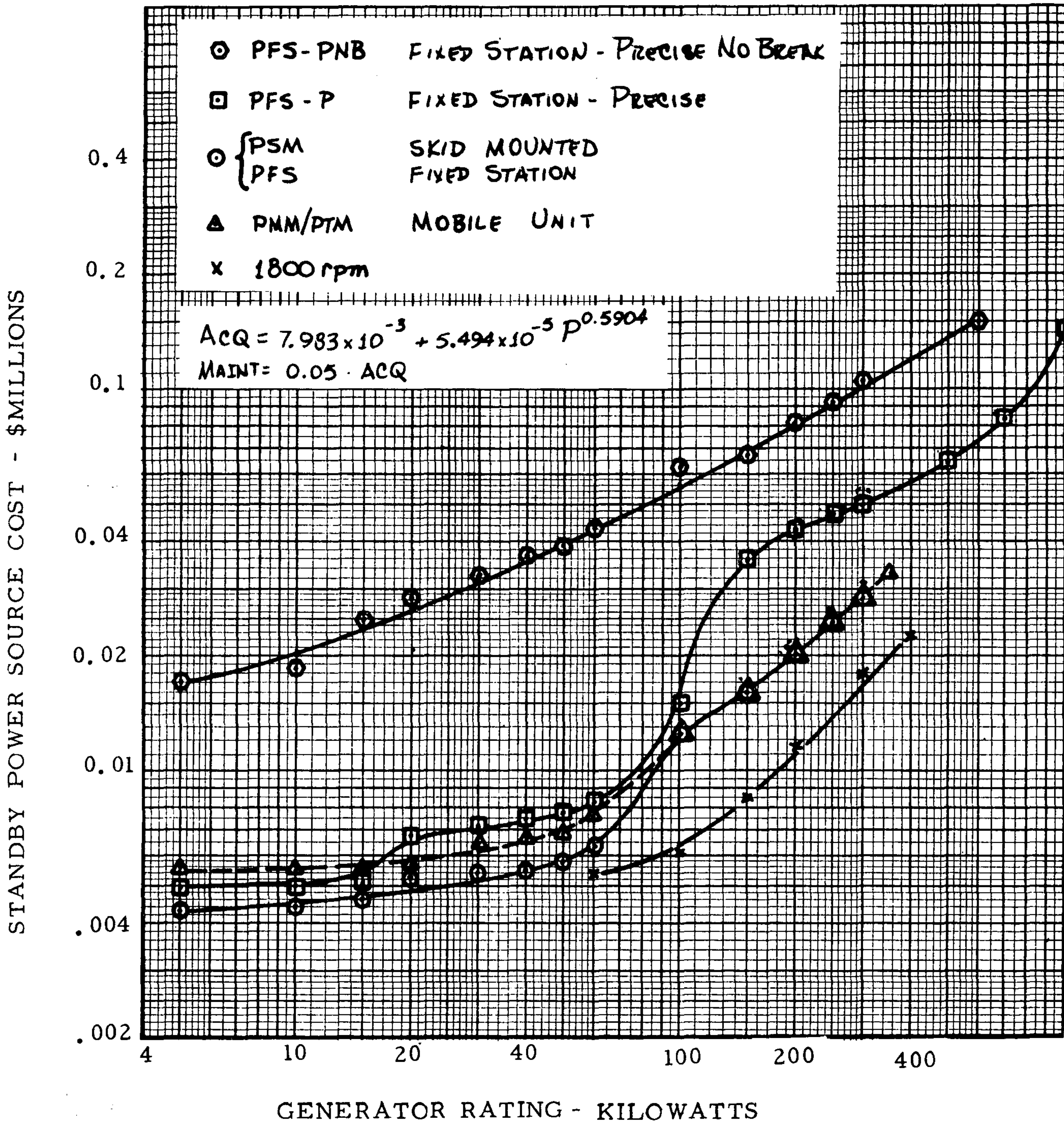


FIGURE D-14. STANDBY POWER COST

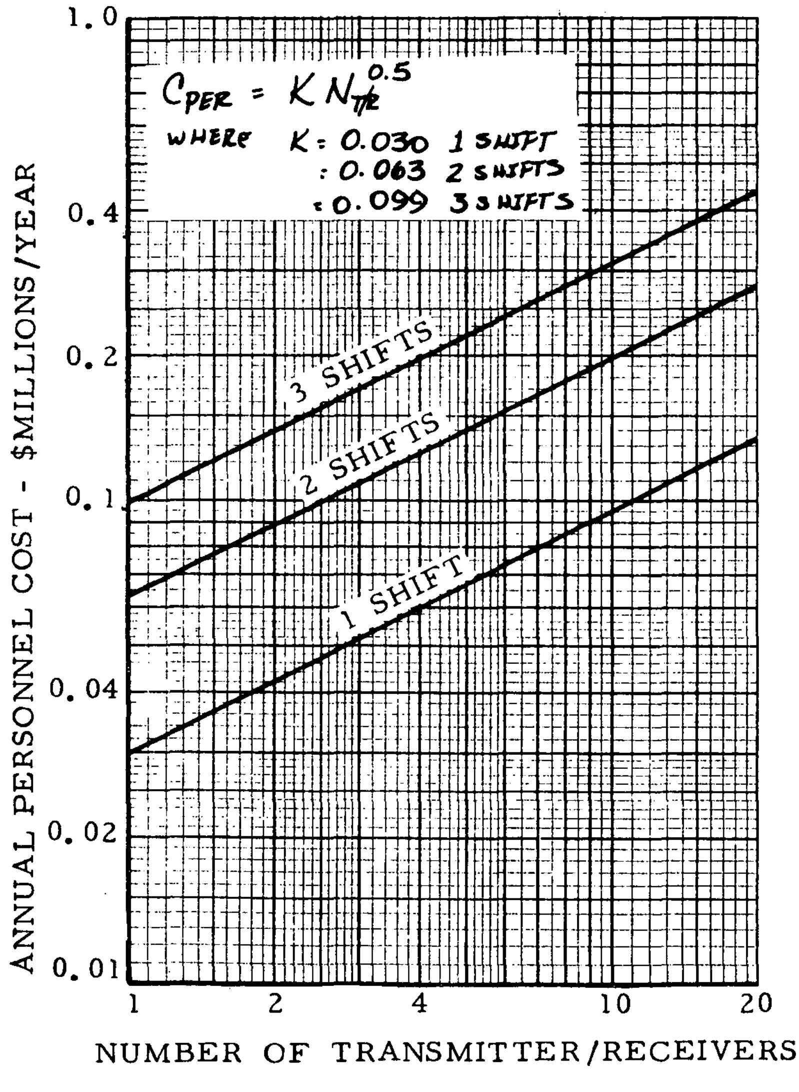


FIGURE D-15. ANNUAL PERSONNEL COST

Item	Cost - $Millions For 1 Unit	For 2 Units	ACQ Cost	R&D Cost
Antenna	.06	.105	.045	.015
Command Xmtr	.047	.094	.047	-
Telemetry Rcvr *	.330	.480	.150	.180
TOTAL			.242	.195

* Includes tape recorders, displays, readout

Table D-3. Telemetry and Command Cost Items

D.11 Power Subsystem

The subsystem is divided into four parts: 1) a long life prime source, 2) a secondary storage source, 3) conditioning, and 4) distribution.

D.11.1 Prime Power

Figures D-16 and D-17 illustrate the parametric cost relationships for the prime power supply (nuclear reactor and solar array types). The numbered cost points refer to the list of numbered references (see paragraph D.11.5.1). The two bands indicated for the solar array on Figure D-16 have the following baselines:

Baseline for upper band -

1. substrate design, parts procurement, and fabrication;
2. array sizing, design, parts procurement, and fabrication;

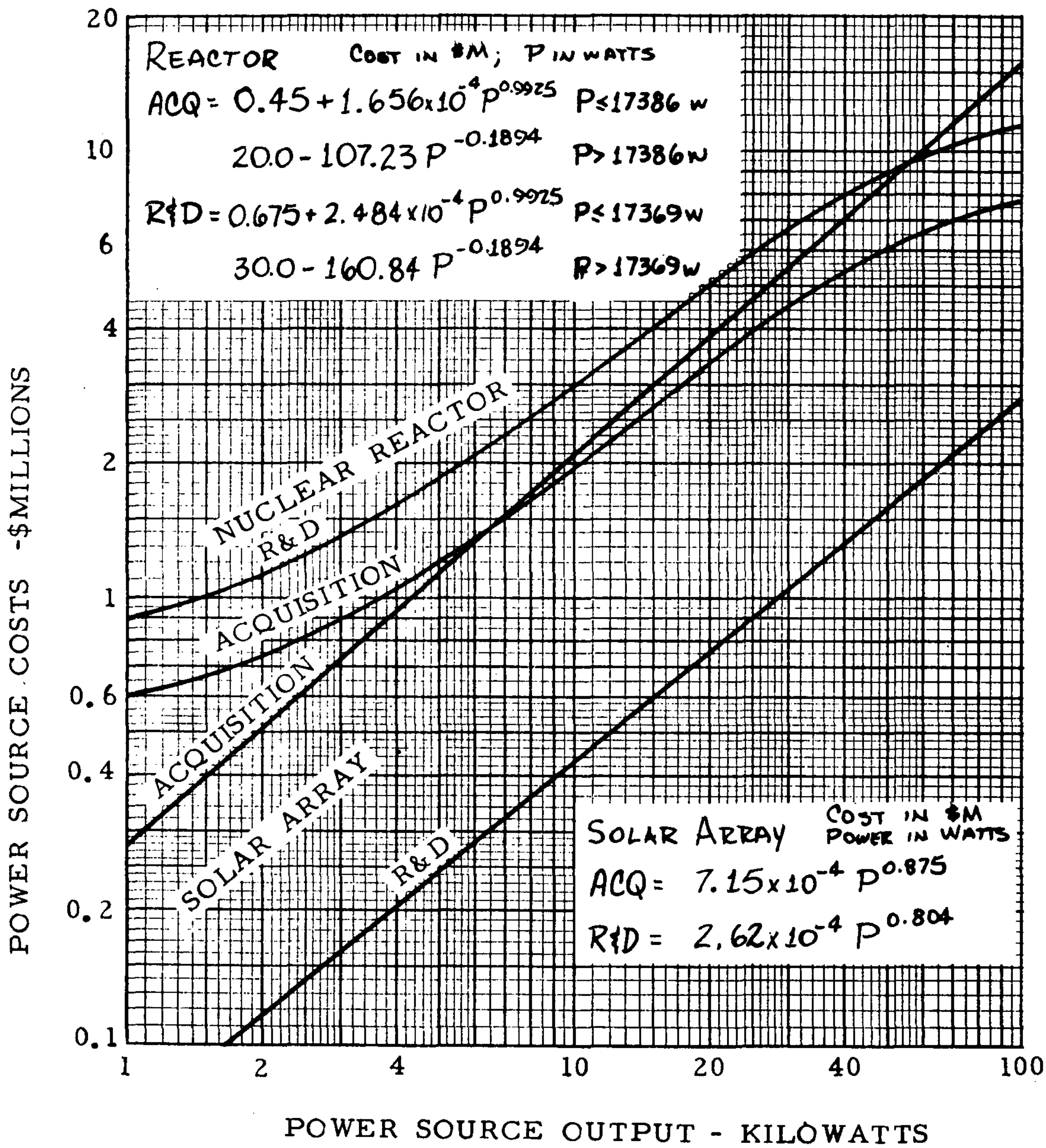


FIGURE D-16. PRIME POWER SOURCE COST

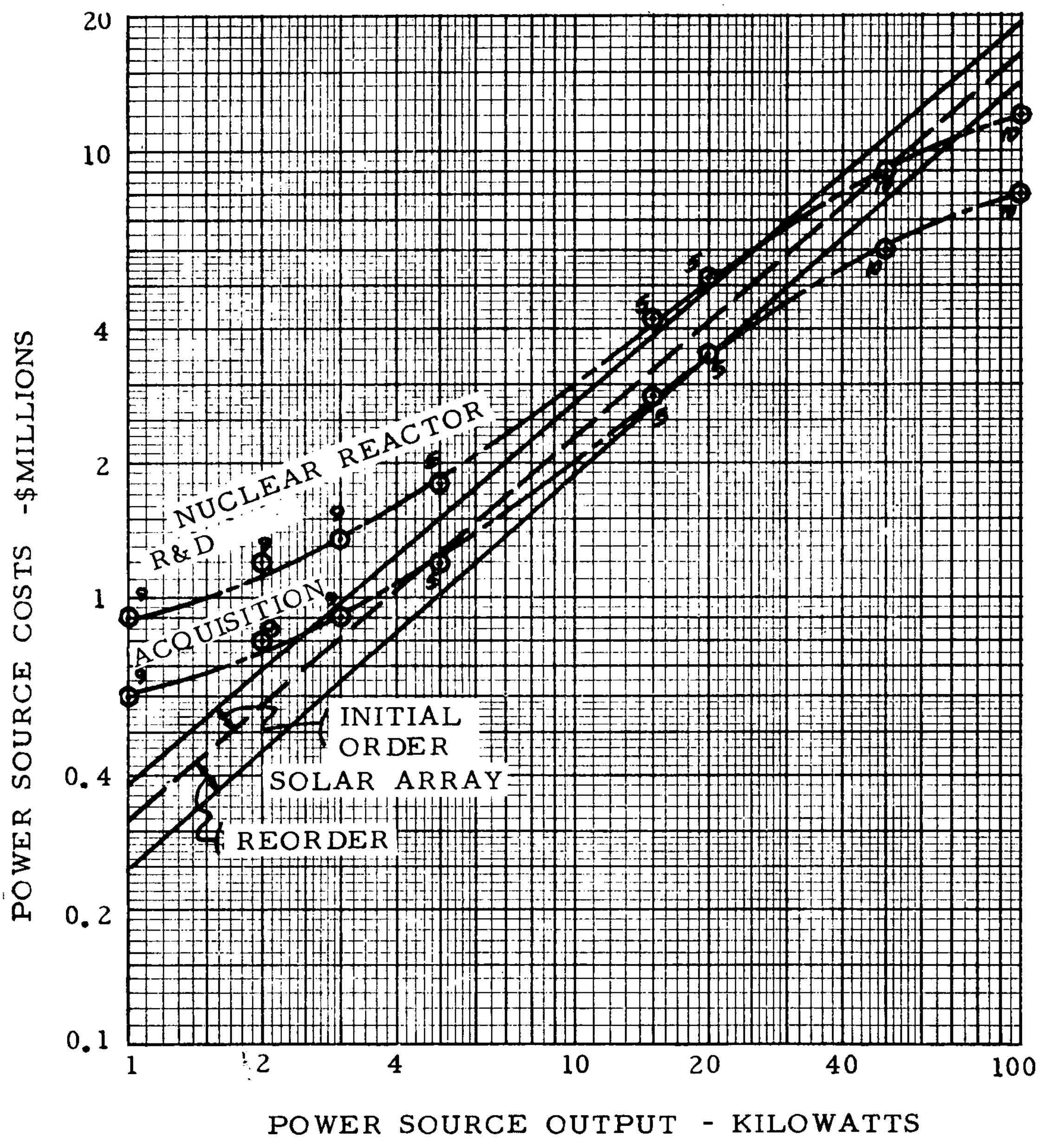


FIGURE D-17. PRIME POWER SOURCE COST DATA

3. array and substrate flight qualification testing, and
4. array flight acceptance testing.

Baseline for lower band -

1. does not include design and qualification costs,
2. does include parts procurement, fabrication, and acceptance testing.

Therefore, the fabrication (acquisition) cost is taken as the median of the lower band. Engineering (R&D) cost is the difference between the upper band median and fabrication cost.

The cost of solar cells was developed from Figure D-17, the enclosure to reference 1 of paragraph D.11.5.2. Solar cell lifetime, weight and volume were developed from reference 2. See Figures D-18 and D-19. Lifetime of the solar cell array is an important consideration. Figure D-20 shows relative degradation of N/P and P/N types of solar cells with long time usage.

D.11.2 Secondary Power

Figures D-21, D-22, and D-23 give the cost, weight and volume of three types of batteries with respect to capacity in watt-hours power usage. The functional expressions for synthesis of the battery parameters in terms of watt-hours are inset in the figures. The information presented on batteries is based upon cost and battery characteristic quotations supplied to Convair by battery vendors.

D.11.3 Power Conditioning

Power conditioning equipment consists of several types of operations. The equipment to perform these operations may be segregated into numerous small modules or grouped. The grouping used for the system synthesis is power conditioning (including inverter, converter and regulator), power control and charge control and an L/C filter (for AM system only).

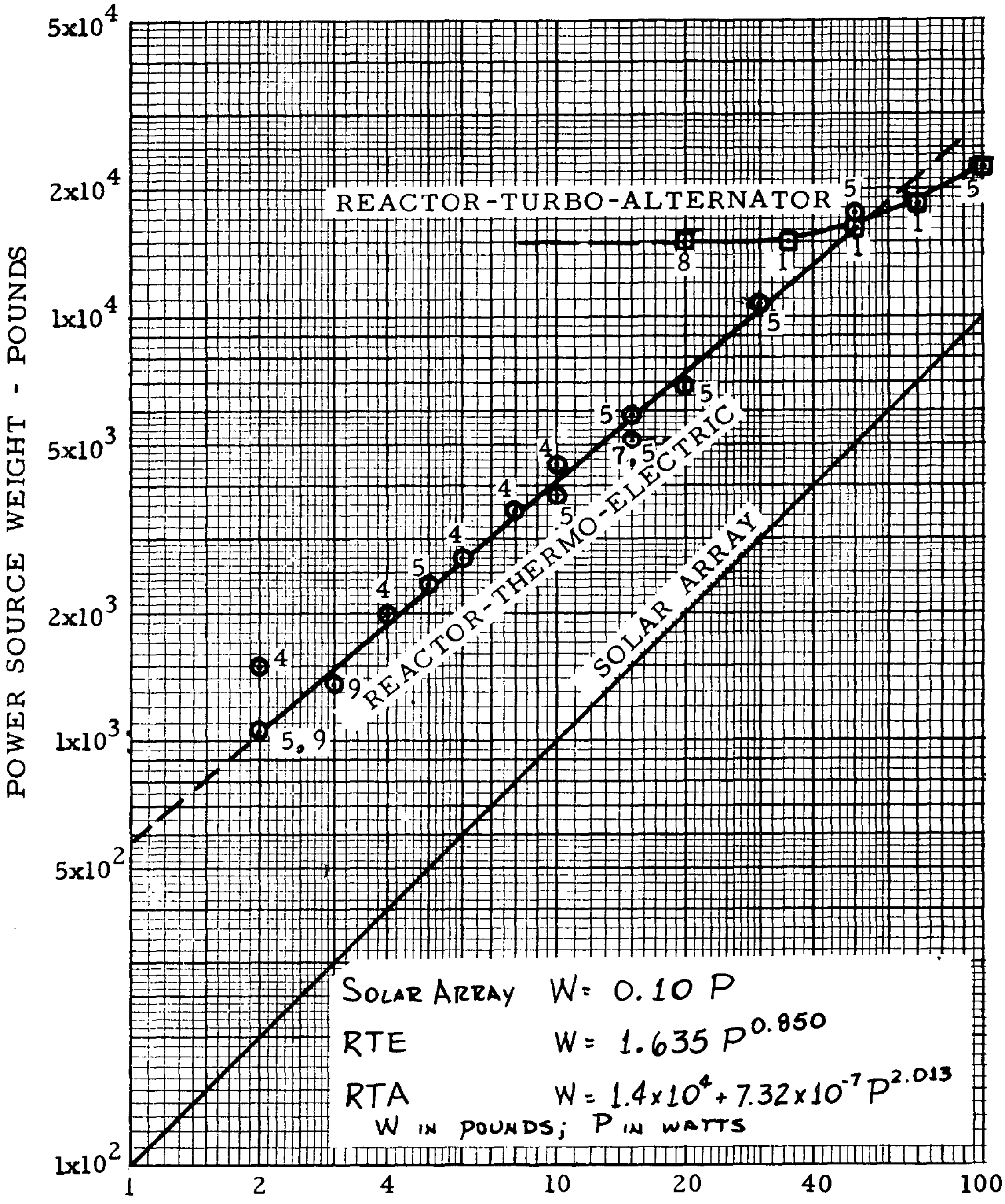


FIGURE D-18. POWER SOURCE WEIGHT

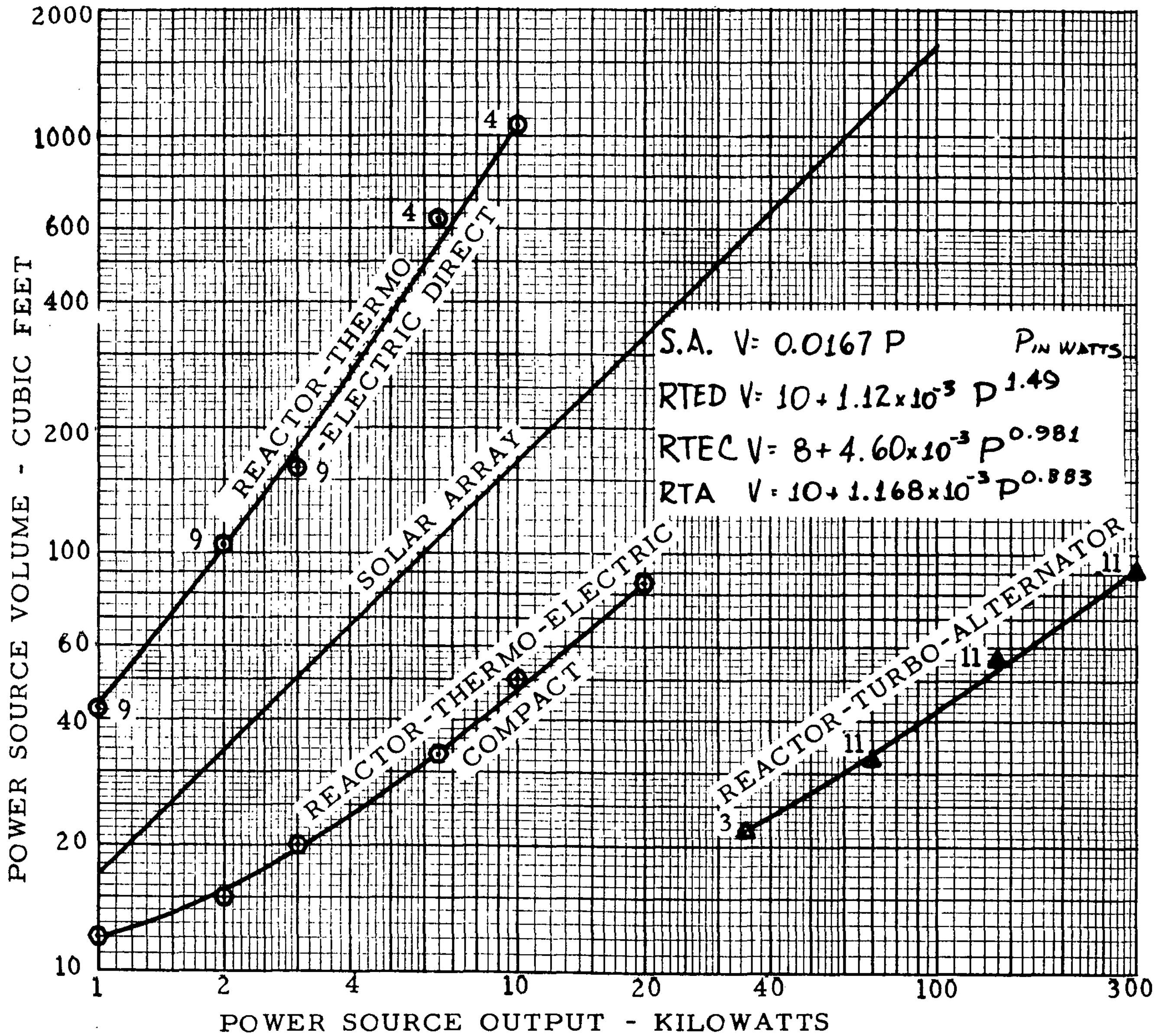


FIGURE D-19. POWER SOURCE VOLUME

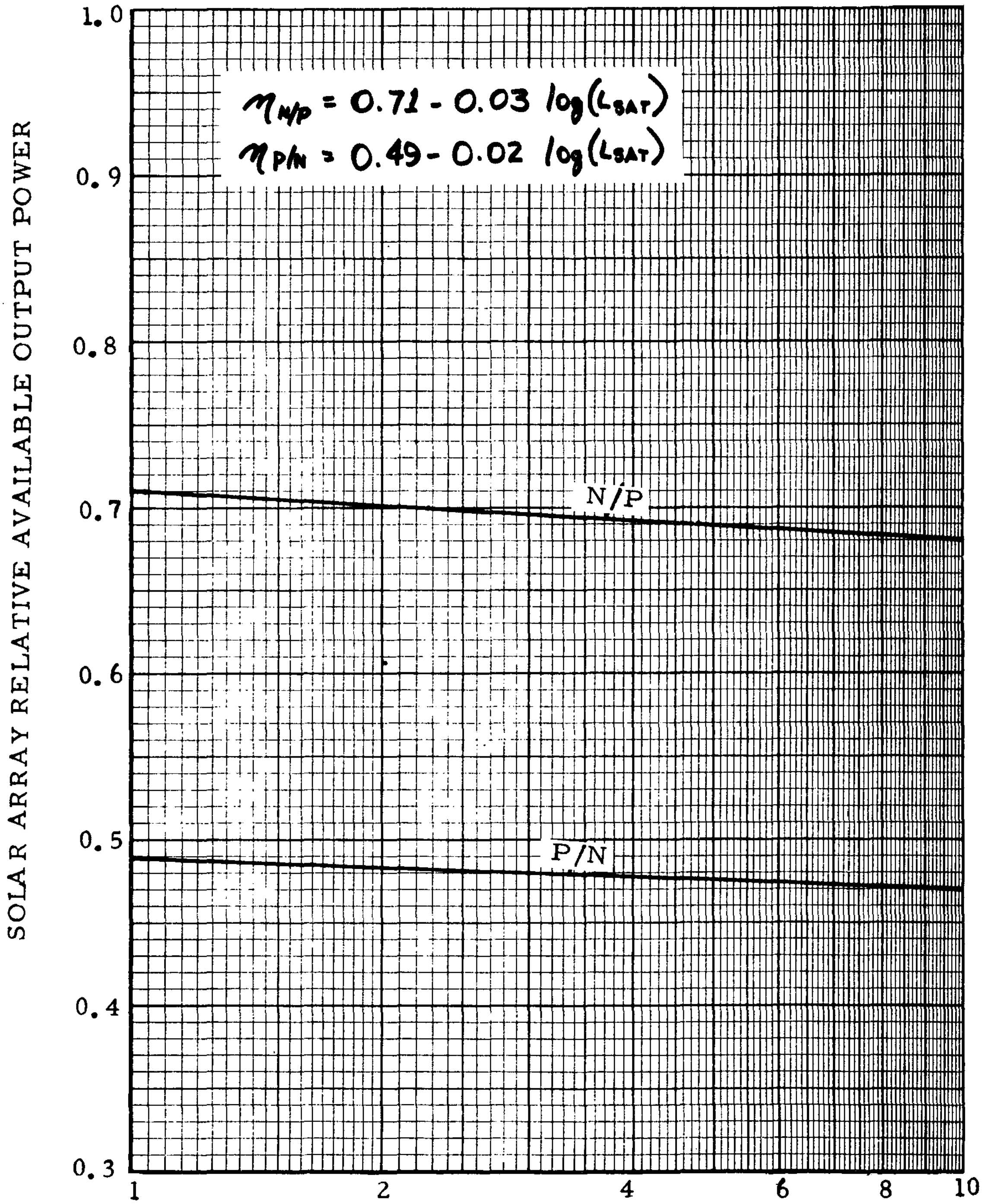


FIGURE D-20. SOLAR ARRAY RELATIVE DEGRADATION

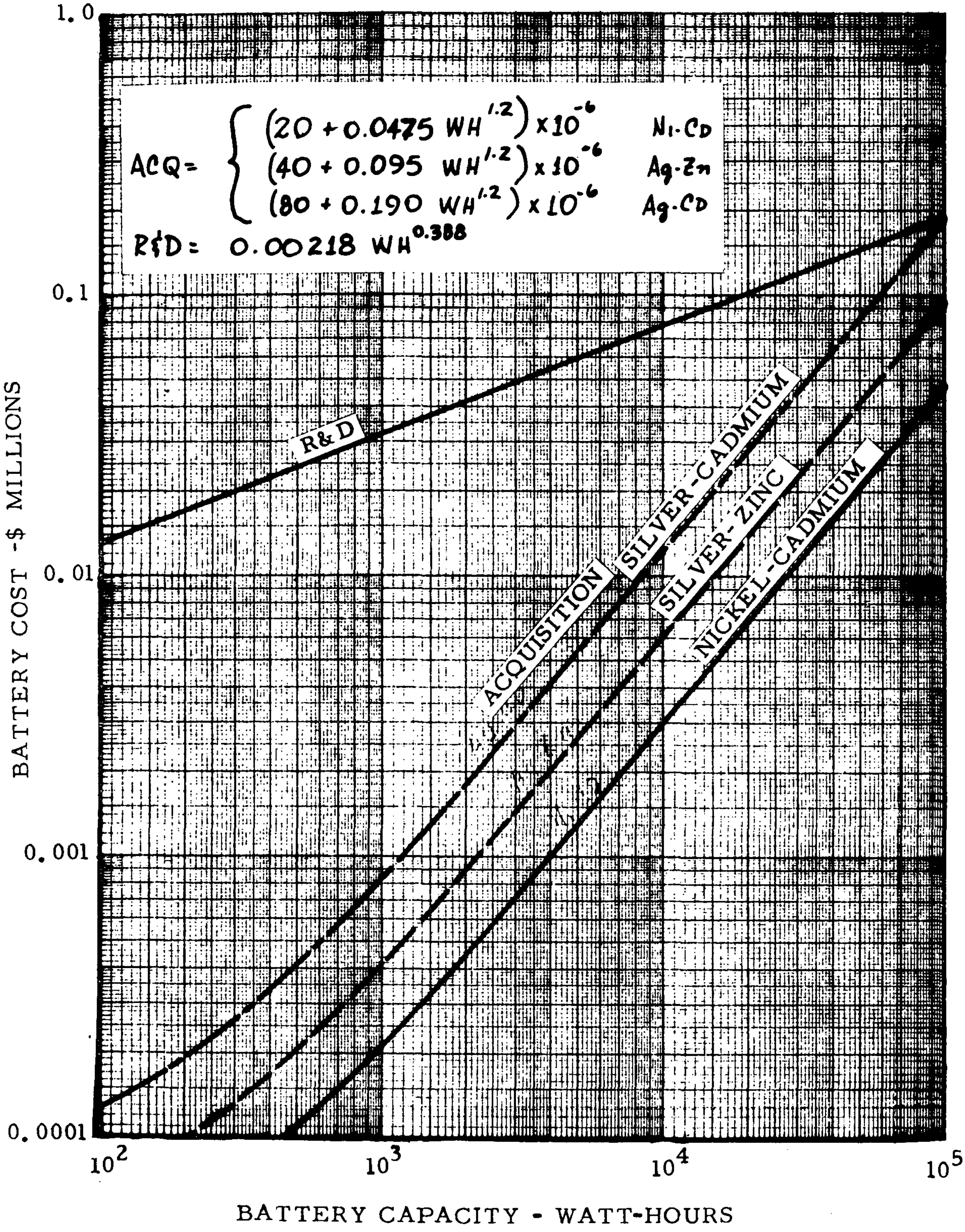


FIGURE D-21. BATTERY COST

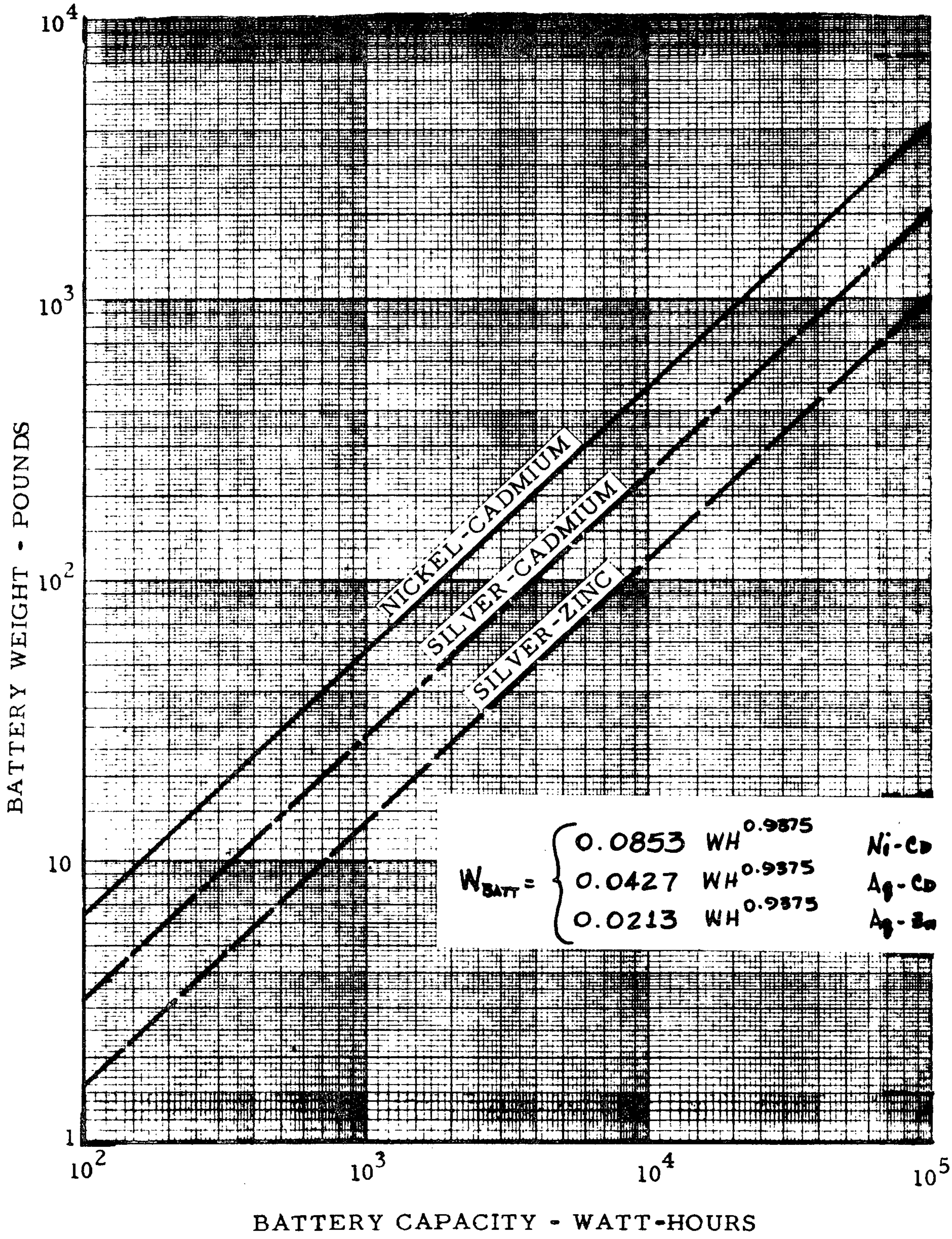


FIGURE D-22. BATTERY WEIGHT

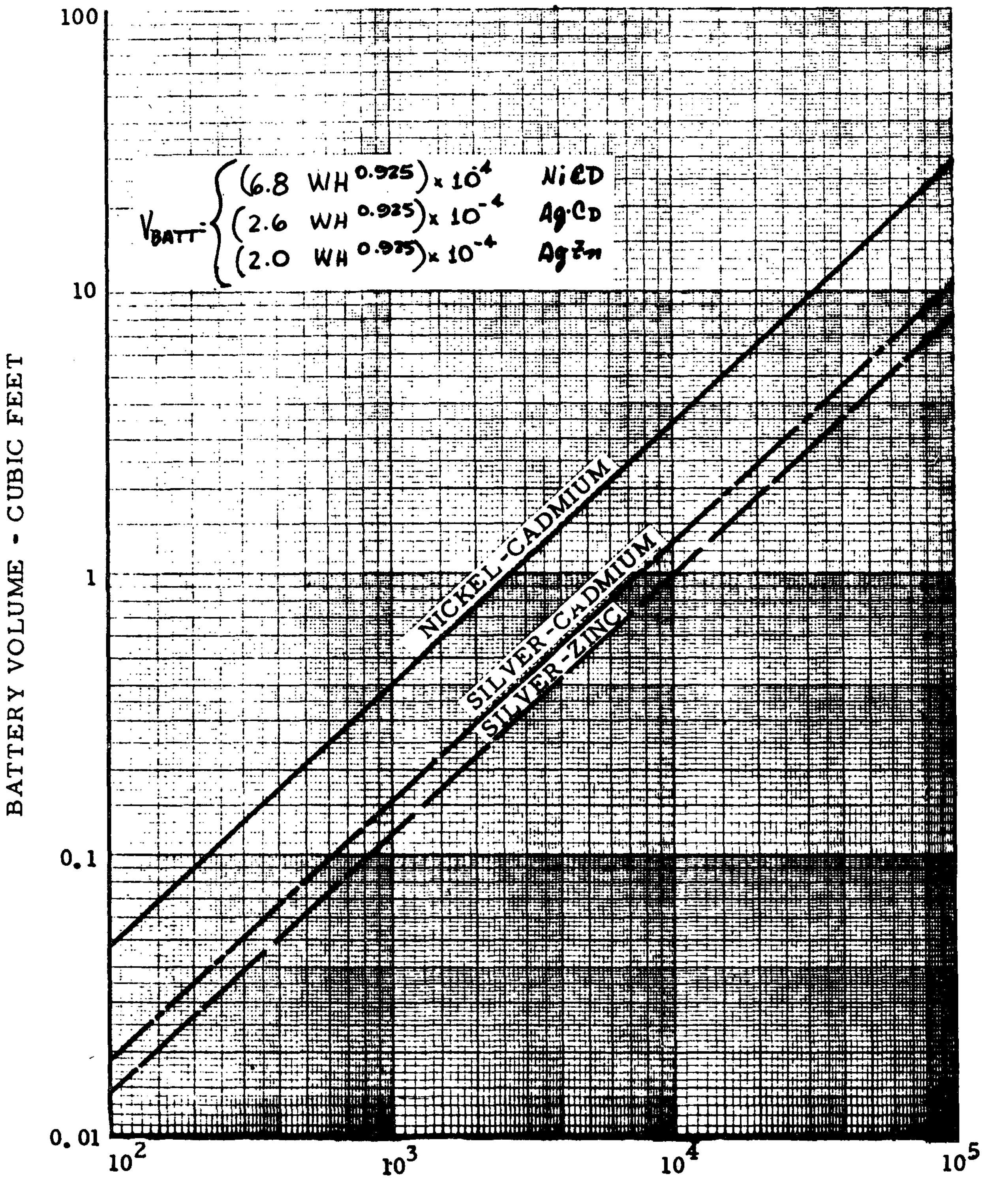


FIGURE D-23. BATTERY VOLUME

Figure D-24 illustrates the general power subsystem cost versus power rating. The elements of the power subsystem costs are divided as follows, based on Convair experience*:

Power Conditioning (Inverter, converter, regulator)	-	75% of R&D 75% of Acquisition
Power Control Unit	-	33% of R&D 33% of Acquisition
Power Transfer	-	75% of R&D 75% of Acquisition
Charge Control Unit	-	25% of R&D 25% of Acquisition
Harnessing and Connectors	-	75% of R&D 33% of Acquisition

* The indicated percentages are taken of the power subsystem cost curves.

The data establishing costs, weights, and volume of power conditioning submodules came from various sources located by Convair and from Hughes Aircraft Company support to the TV Broadcast Study.* These sources of information are listed in paragraph D.11.5.3. The reference numbers and letters relate to the data points on the curves.

The data mentioned above was used to determine the parametric curves (when combined as noted above). When fitted by the least squares method these curves yield the functional relationships used in the system synthesis (inset into respective curves). The parametric data are presented as:

*Appendix A, Fourth Monthly Report, "Television Broadcast Satellite Task Review", 4/16/69 to 5/15/69, NASA contract NAS8-21036, MSFC with Convair Division of General Dynamics.

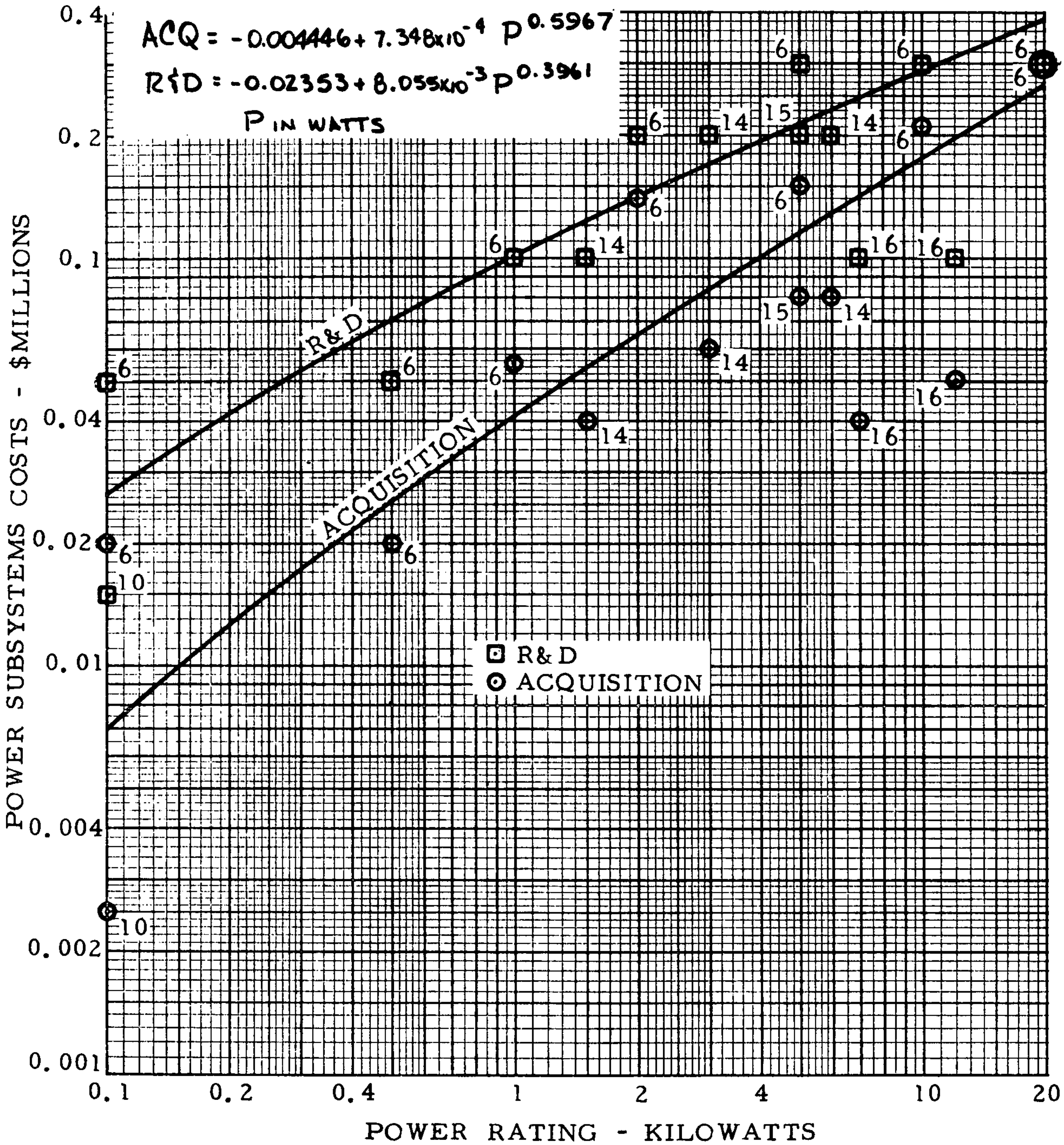


FIGURE D-24. POWER SUBSYSTEMS COST

1. Figure D-25. Power conditioning and control unit costs in millions of dollars per watt (R&D and flight article acquisition).
2. Figure D-26. Power conditioning unit weight in pounds per watt.
3. Figure D-27. Power conditioning unit volume in cubic feet.
4. Figure D-28. Power control unit weight and volume in pounds and cubic feet per watt, respectively.
5. Figure D-29. Charge control unit cost in millions of dollars per watt.
6. Figure D-30. Charge control unit weight in pounds per watt and charge control unit volume in cubic feet per watt.
7. Figure D-31. L/C Filter Cost in millions of dollars per watt (R&D and flight article acquisition).
8. Figure D-32. L/C Filter Weight in pounds per watt and L/C Filter Volume in cubic feet per watt.

The L/C Filter is based upon the G.E. MKTS Report.*

D.11.4 Power Distribution

This subsystem consists of a transfer unit to direct the solar cell output directly to power conditioning or by way of charge control and battery storage. The harnessing and associated connectors, slip rings and switches accomplish the distribution. In the case of power distribution, the source of information is Convair's own experience in missiles (Atlas), space launch vehicles and boosters (SLV and Centaur) and satellites (OV-1 series). Figures D-33 and D-34 give respectively power transfer and harnessing costs in millions of dollars per watt (both R&D and flight article acquisition) and weight in pounds per watt and volume in cubic feet per watt. The parametric equations are inset into the figures.

* General Electric Report No. 68SD4268, 10 June 1968, "Multikilowatt Transmitter Study for Space Communications Satellites", for NASA MSFC, contract NAS8-21866.

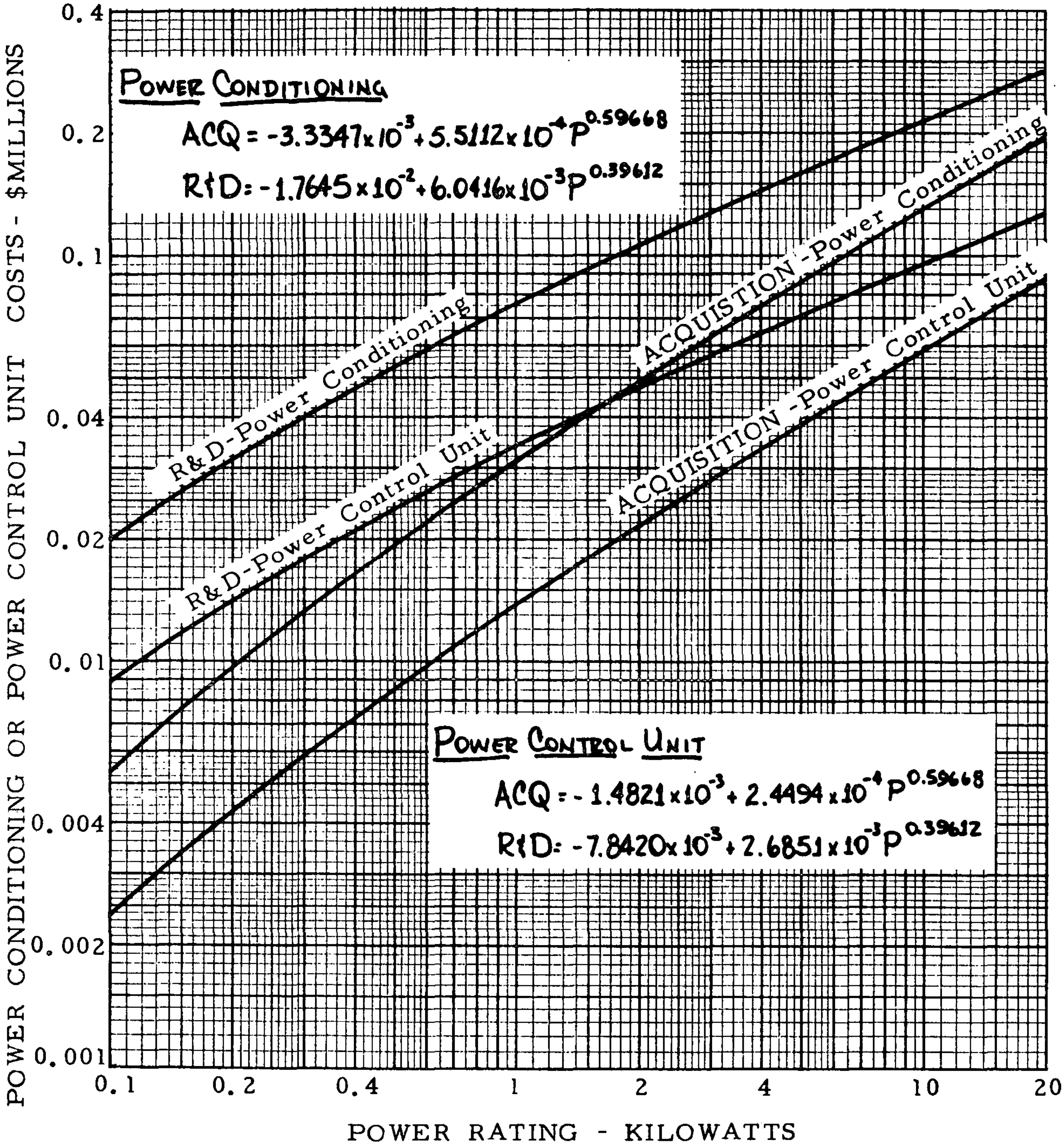


FIGURE D-25. POWER CONDITIONING AND CONTROL UNIT COST

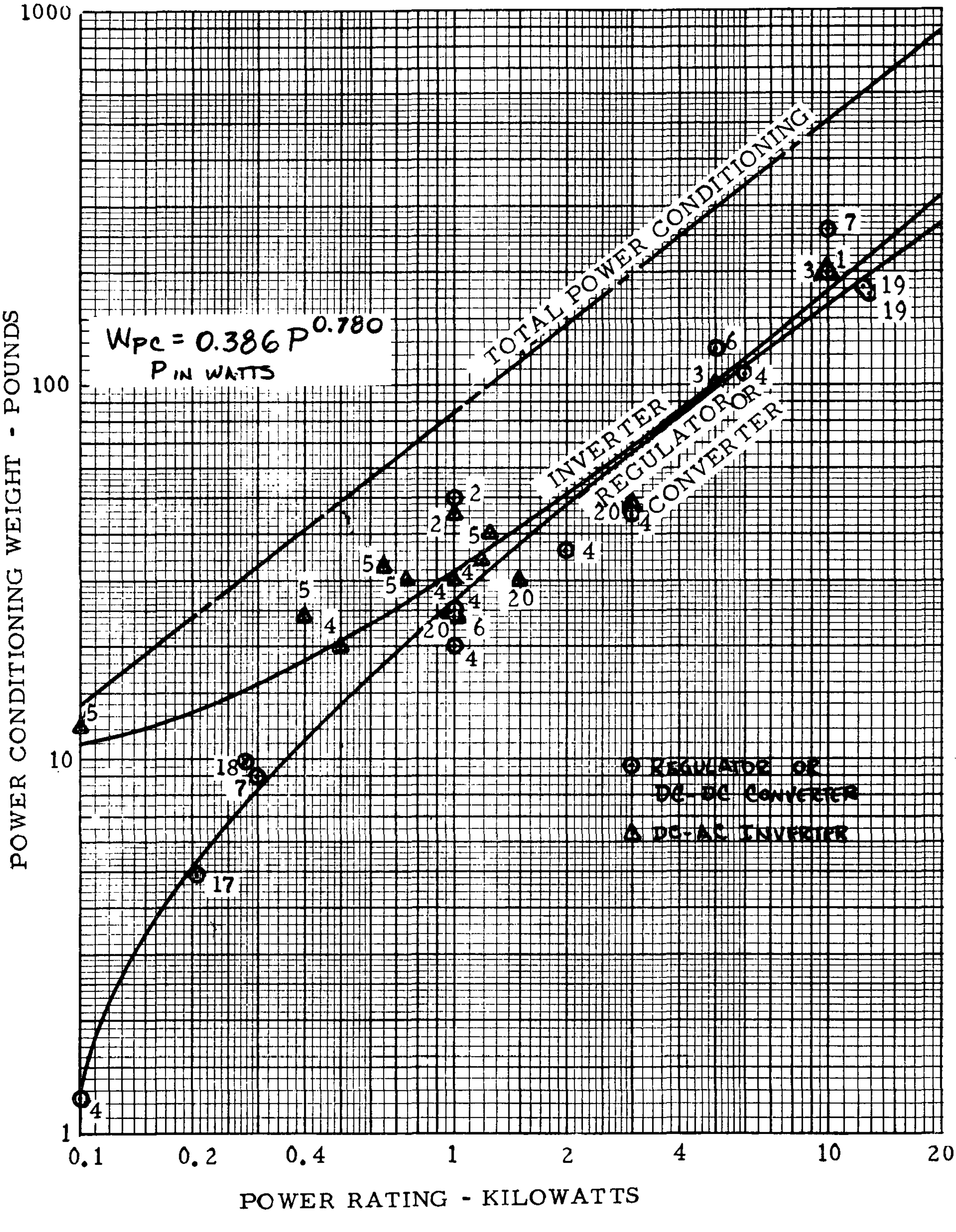


FIGURE D-26. POWER CONDITIONING WEIGHT

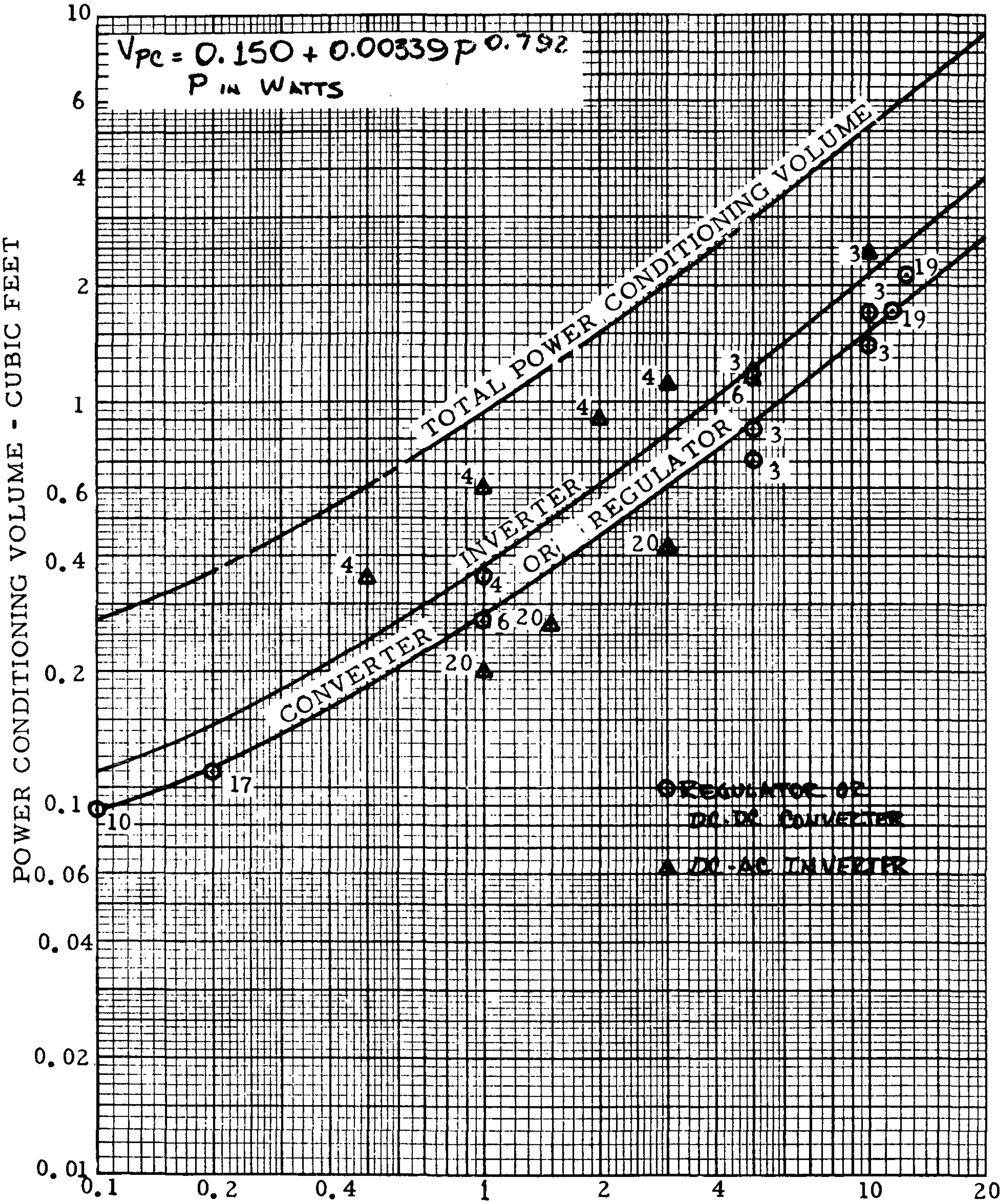


FIGURE D-27. POWER CONDITIONING VOLUME

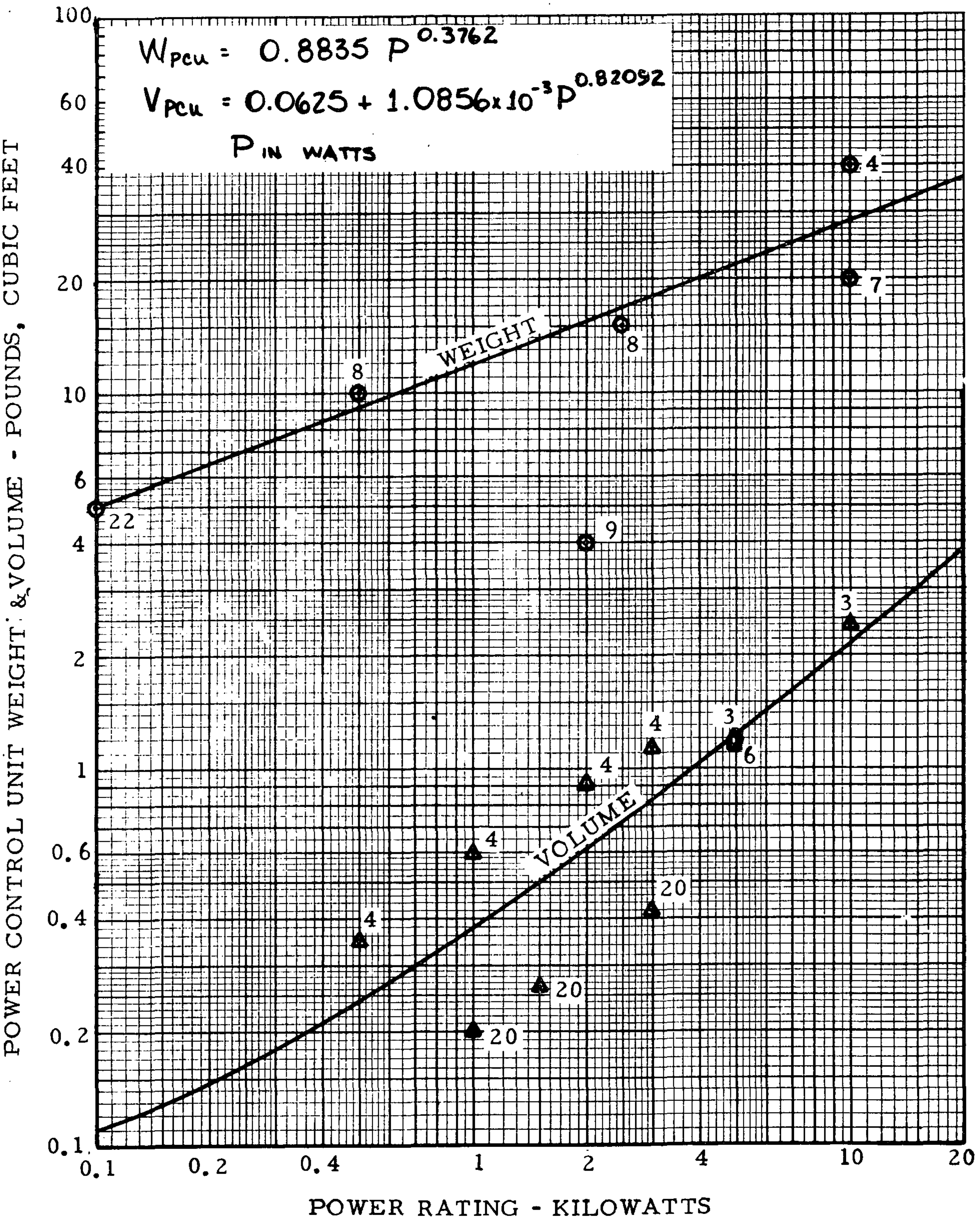


FIGURE D-28. POWER CONTROL UNIT WEIGHT AND VOLUME

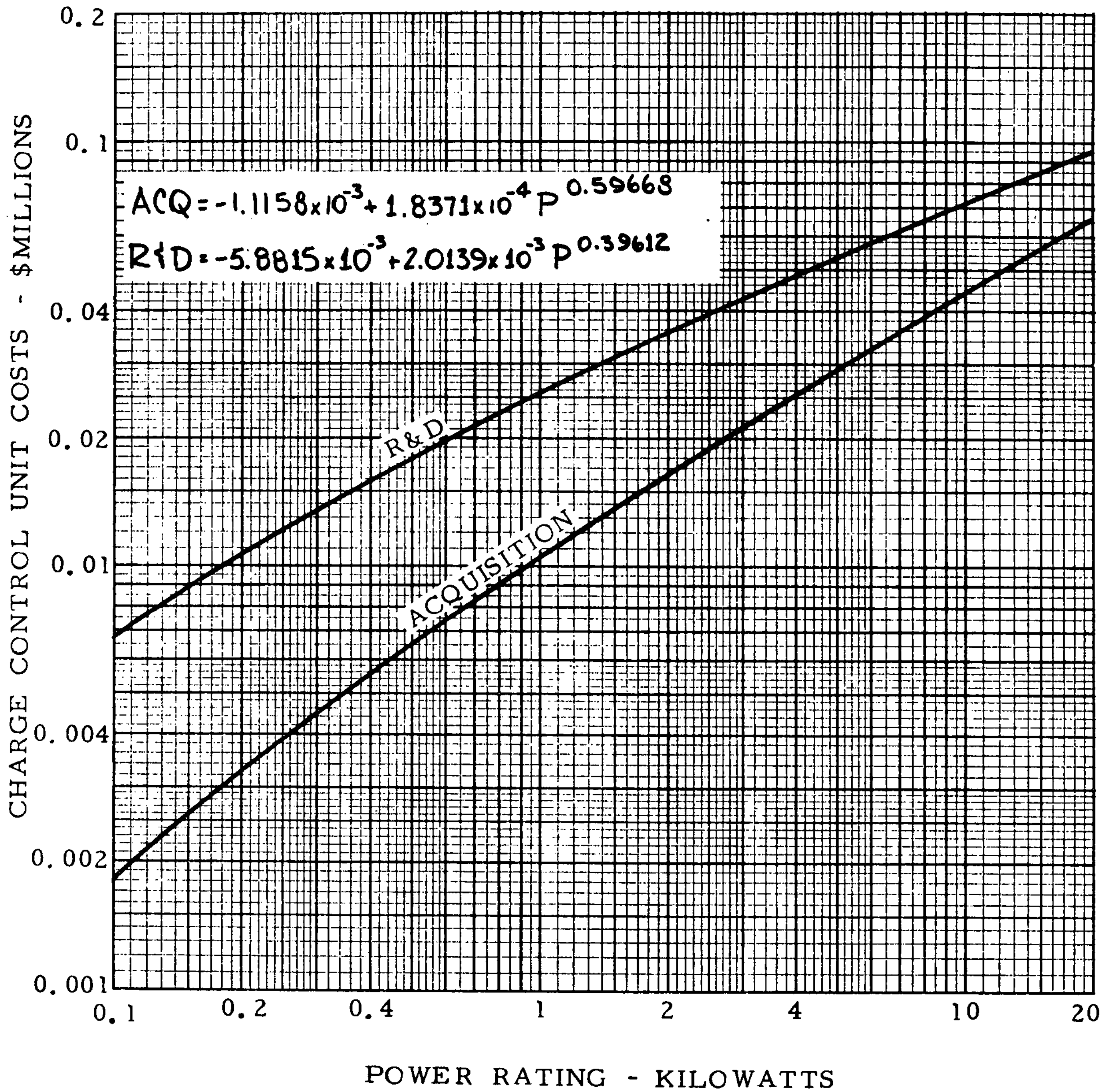


FIGURE D-29. CHARGE CONROL CONTROL UNIT COST

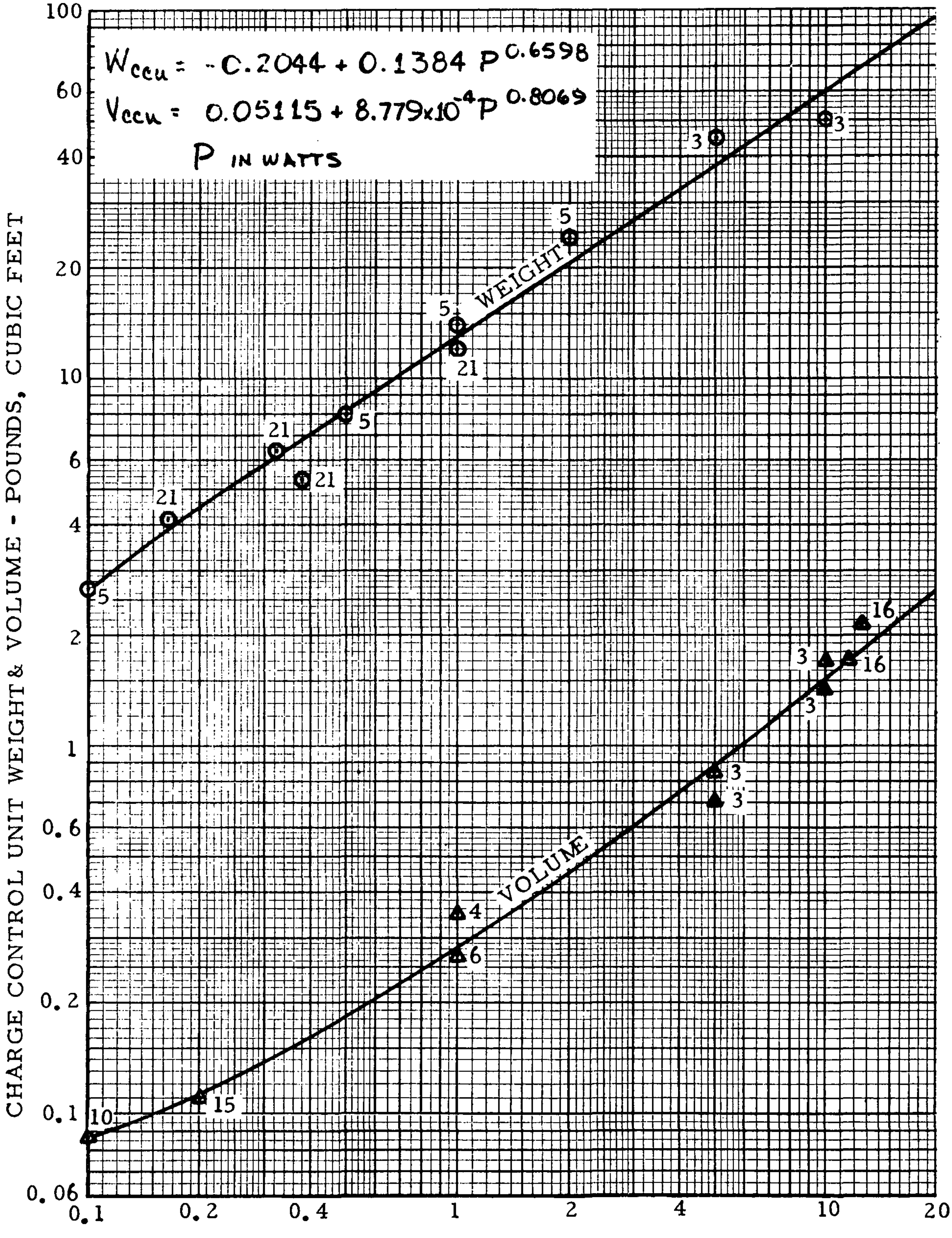


FIGURE D-30. CHARGE CONTROL UNIT WEIGHT AND VOLUME

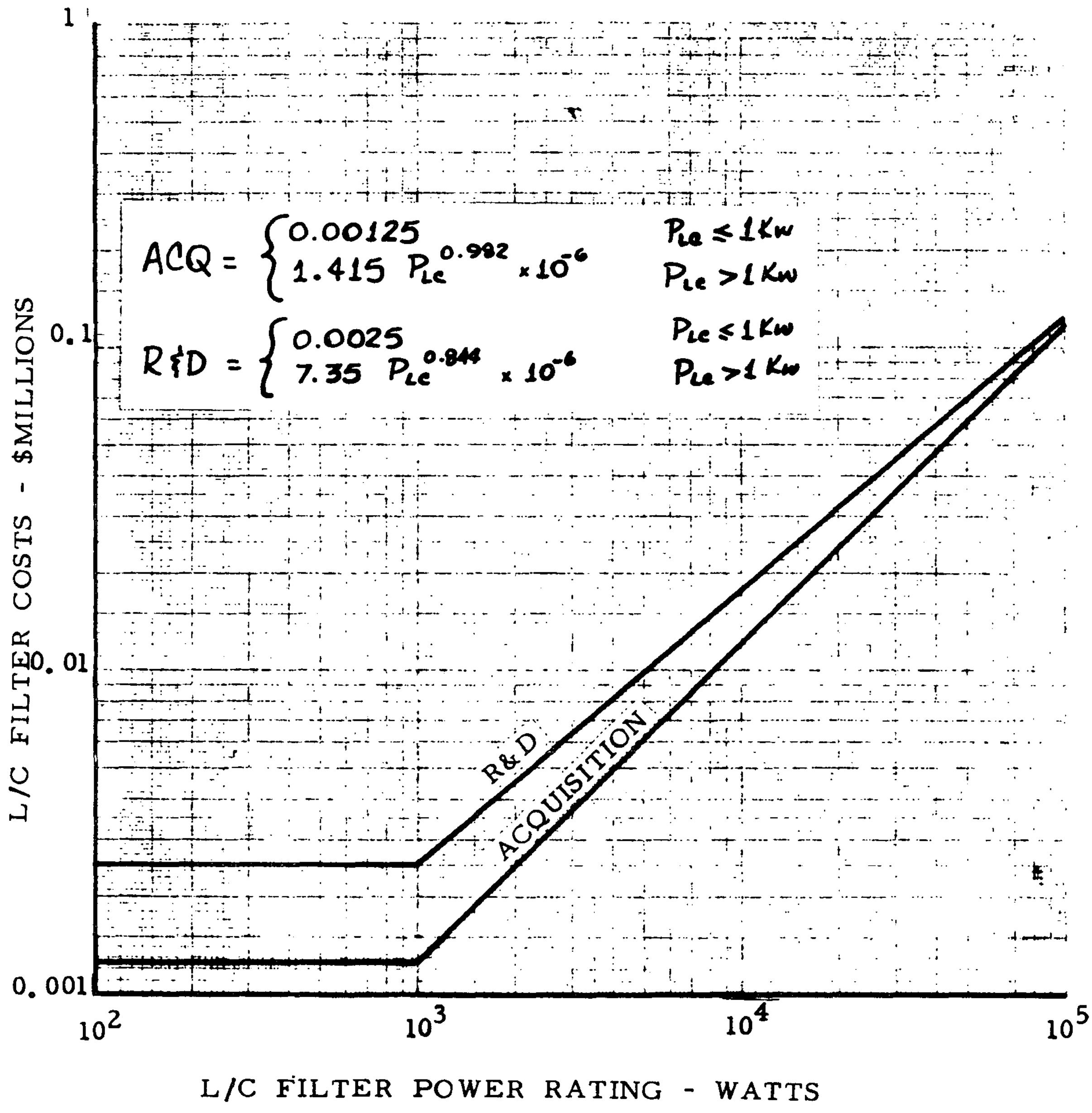


FIGURE D-31. L/C FILTER COST

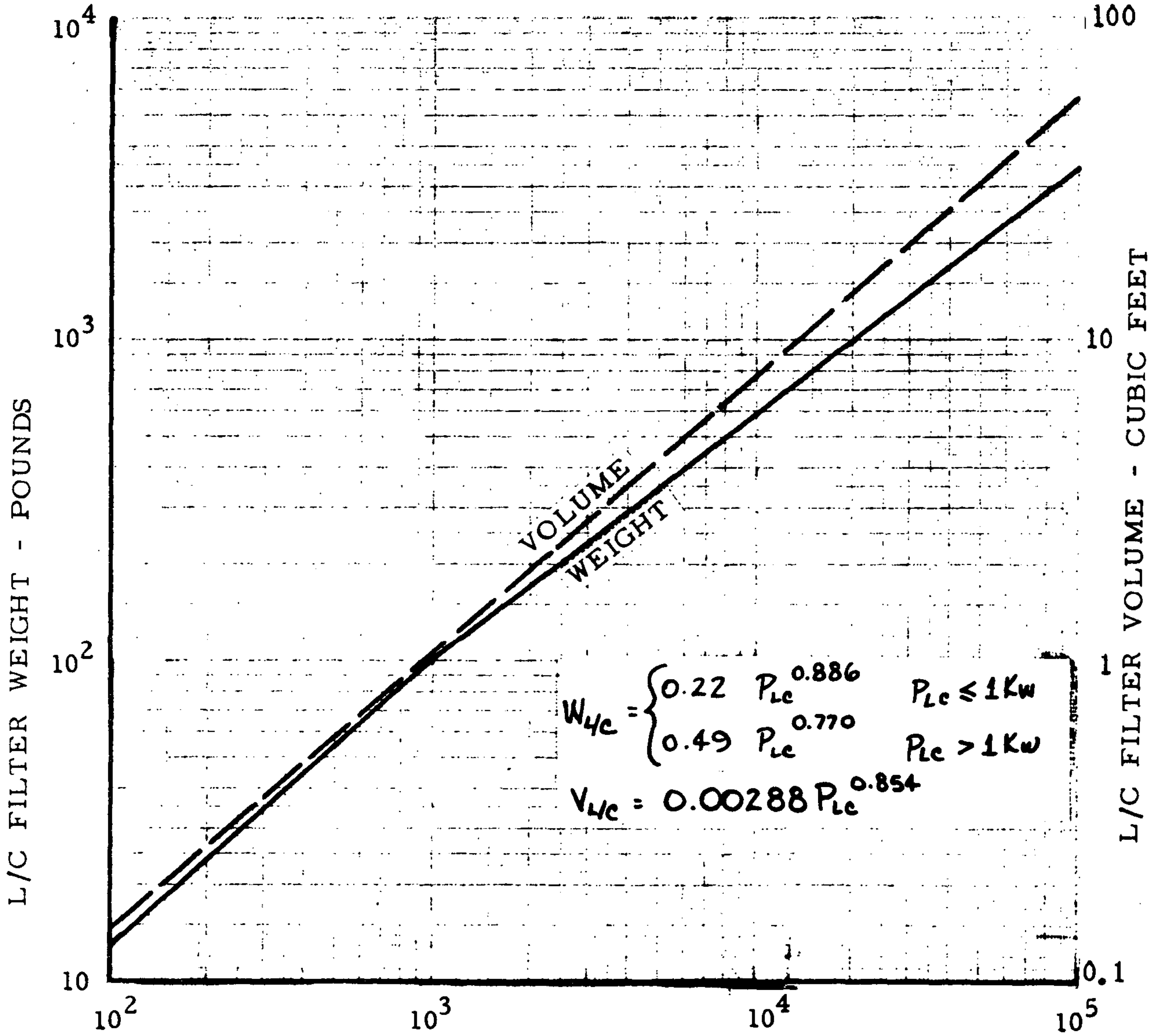


FIGURE D-32. L/C FILTER WEIGHT

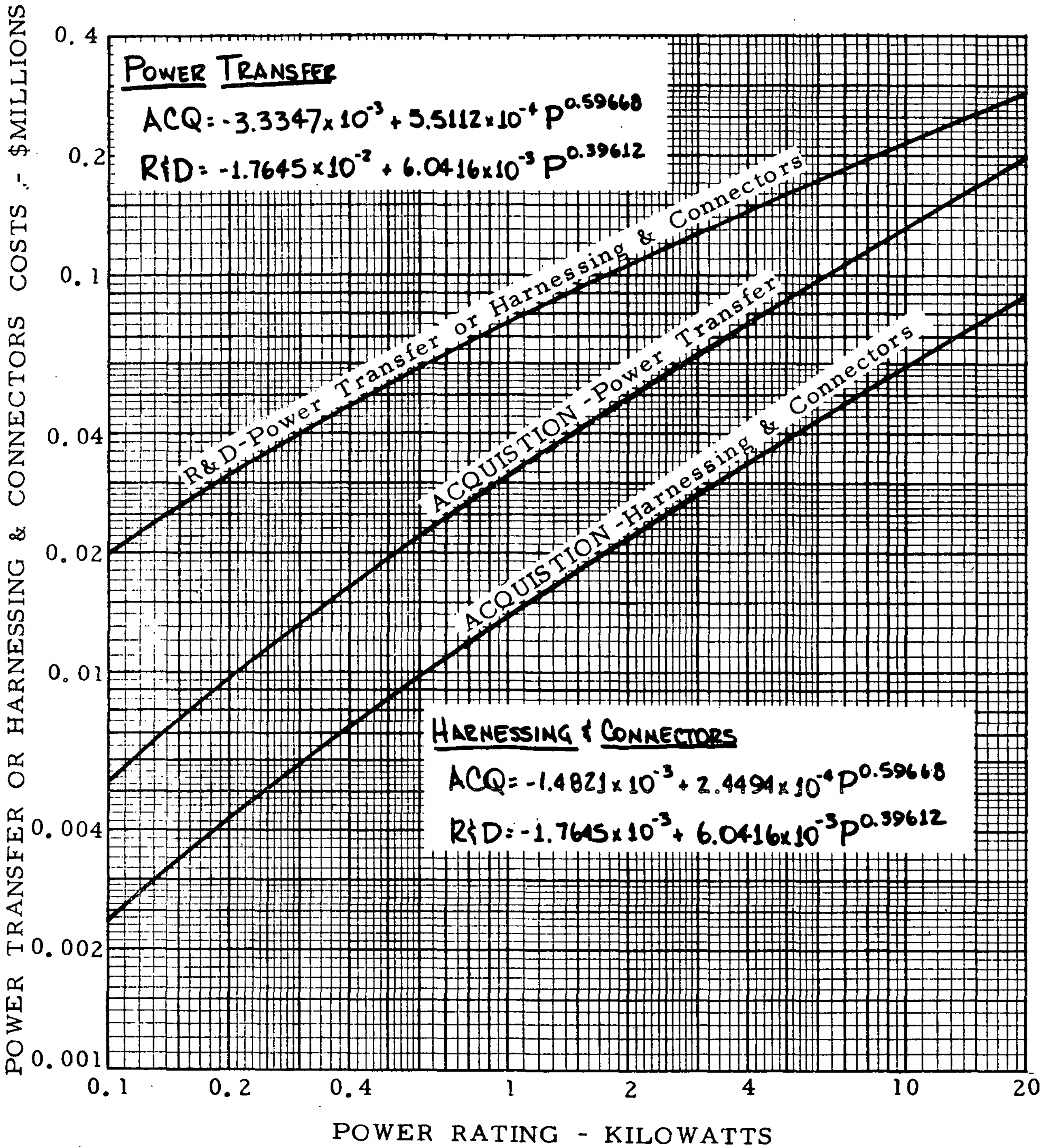


FIGURE D-33. POWER TRANSFER AND HARNESSING COST

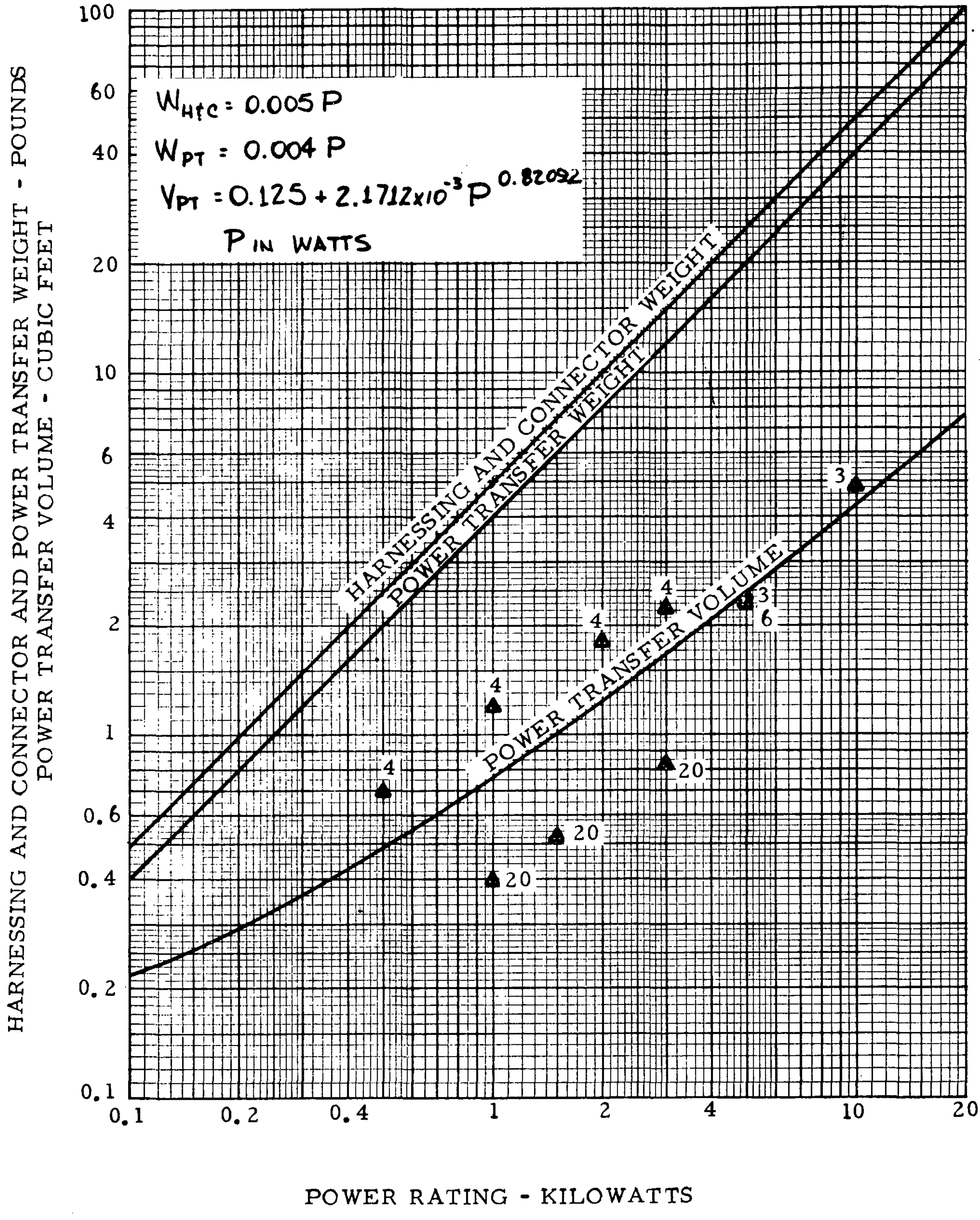


FIGURE D-34. POWER DISTRIBUTION WEIGHT AND VOLUME

D.11.5 References

D.11.5.1 Nuclear Reactor References

1. George M. Thur, NASA/LeRC "SNAP-9 Power Conversion System Assessment," IECEC, 1968.
2. J. N. Hodgson, Aerojet-General Corp, R. P. Macosko, NASA/LeRC "A SNAP-8 Breadboard System - Operating Experience", IECEC, 1968.
3. H. O. Slone "SNAP-8 Development Status" NASA SP-131, 24 Aug. 1966.
4. "Reactor Thermoelectric System Design Studies (0.5 to 10 KWe)" Atomics International, AI-66-MEMO-154, 1966.
5. "Proposal for Nuclear Power Systems Application Study for TV Broadcast Satellites", Atomics International, AI-67-30, 1967.
6. P. Duchon, R. W. Barret, L. K. Petersen, Aerojet-General "Nuclear Power Systems For Hard Sites", IECEC 1968.
7. "Study of Conceptual Deep Space Monitor Communications Systems Using A Single Earth Satellite", Space General Corp., SGC 920FR-1, 1966.
8. J. E. Boretz, TRW, "Large Space Station Power Systems", AIAA 68-1034.
9. "Nuclear Powered Communication S tellites", AI folder.
10. "Proposal for NASA Television Broadcast Satellite Study", HAC, March 1967.

D.11.5.2 Solar Arrays

1. Letter and enclosure from P. E. Beaumont, Electro-Optical Systems Division of Xerox Corp., to R. Bradley, Convair Division of General Dynamics, dated 5 February 1969.
2. "Study for Basic Subsystem Module Preliminary Definition", Volume VIII Electrical Power Systems, Prepared for National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, Contract NAS 9-6796, October 1967.

D.11.5.3 Power Conditioning References

1. John G. Krisilas and H. J. Killian, "An Evaluation and Comparison of Power Systems for Long Duration Manned Space Vehicles," Aerospace Corporation, IECEC, 1966.
2. George Barna and Richard Newell, "Design of a Multi-kilowatt Photovoltaic Power System for Manned Space Stations, RCA Astro-Electronics Division, IECEC, 1967.
3. "Study for Basic Subsystem Module, Preliminary Definition: Electrical Power Systems", GDC-DAB67-003, Convair Aerospace Division of General Dynamics, 1967.
4. "Power Conditioning Subsystems for Space," TIF No. 2552, Westinghouse, 1966.
5. E. F. Schraith, "Electrical Power Conditioning", GDA-ERR-AN-511-1, Convair Aerospace, 1964.
6. "Multikilowatt Transmitter Study for Space Communications Satellites: Vol. II," 68SD4268, GE Space Systems, 1968.
7. EDUSAT - W.V.U.
8. ASCEND - Stanford University
9. STRIDE - W.V.U.
10. ITT, PR - 1045-A High Efficiency Regulator.
11. SAINT - Stanford University
12. R. B. Beltz, et al., "OGO Solar Array Design, Fabrication and Flight Performance, IECEC, TRW Systems, 1967.
13. A. D. Tonelli, "Design and Comparison of Secondary Power Systems for Advanced Space Vehicles," IECEC, Douglas MSSD, 1968.
14. Extrapolated from present-day ion engine cost data.
15. Extrapolated from present-day missile electronics cost data.
16. Extrapolated from present-day airborne electronics cost data.
17. Extrapolated from existing missile electronics technology.
18. Extrapolated from existing deep space probe technology.
19. Extrapolated from existing airborne electronics technology.

20. Extrapolated from existing ion engine power conditioning technology.

21. Extrapolated from existing communication satellite battery controller technology.

22. OV1 Experience

D.12. Antenna Subsystem

Satellite antennas will vary considerably according to coverage pattern required on earth. They will usually be of a reflector type (Dipole arrays and spirals will probably be used below S-band and horns may be used above X-band if high gain is not required). Satellite antennas may be assumed to be rigid if small and expandable if large (like Convair's PETA, "Parabolic Expandable Truss Antenna"). The line of demarcation between rigid and expandable can be set only when a specific booster payload volume is given. Convair has supplied the cost, weight and volume characteristics since the space application of antennas has been a continuing company interest. Figures D-35, D-36, and D-37 display antenna costs, rigid and expandable (R&D and flight article acquisition), weight and volume as a function of effective antenna diameter.

D.13. Transmitter Subsystem

Transmitter parametric relationships are greater in number than most other subsystems. Transmitters are differentiated into AM and FM classes. Each class may employ grid tube, TWT, cross field or solid state amplifiers. The cost of each of the above is dependent both upon frequency and power output level. The requirement for satellite operation results in different costs than would be the case for a similar transmitter at a ground facility. The information presented in the following curves is from the G.E. MKTS Report. The parametric data are presented in:

a. Figure D-38 AM Transmitter efficiency per watt.

b. Figure D-39 AM Transmitter costs in millions of dollars per watt.

c. Figure D-40 AM Transmitter weights in pounds per watt.

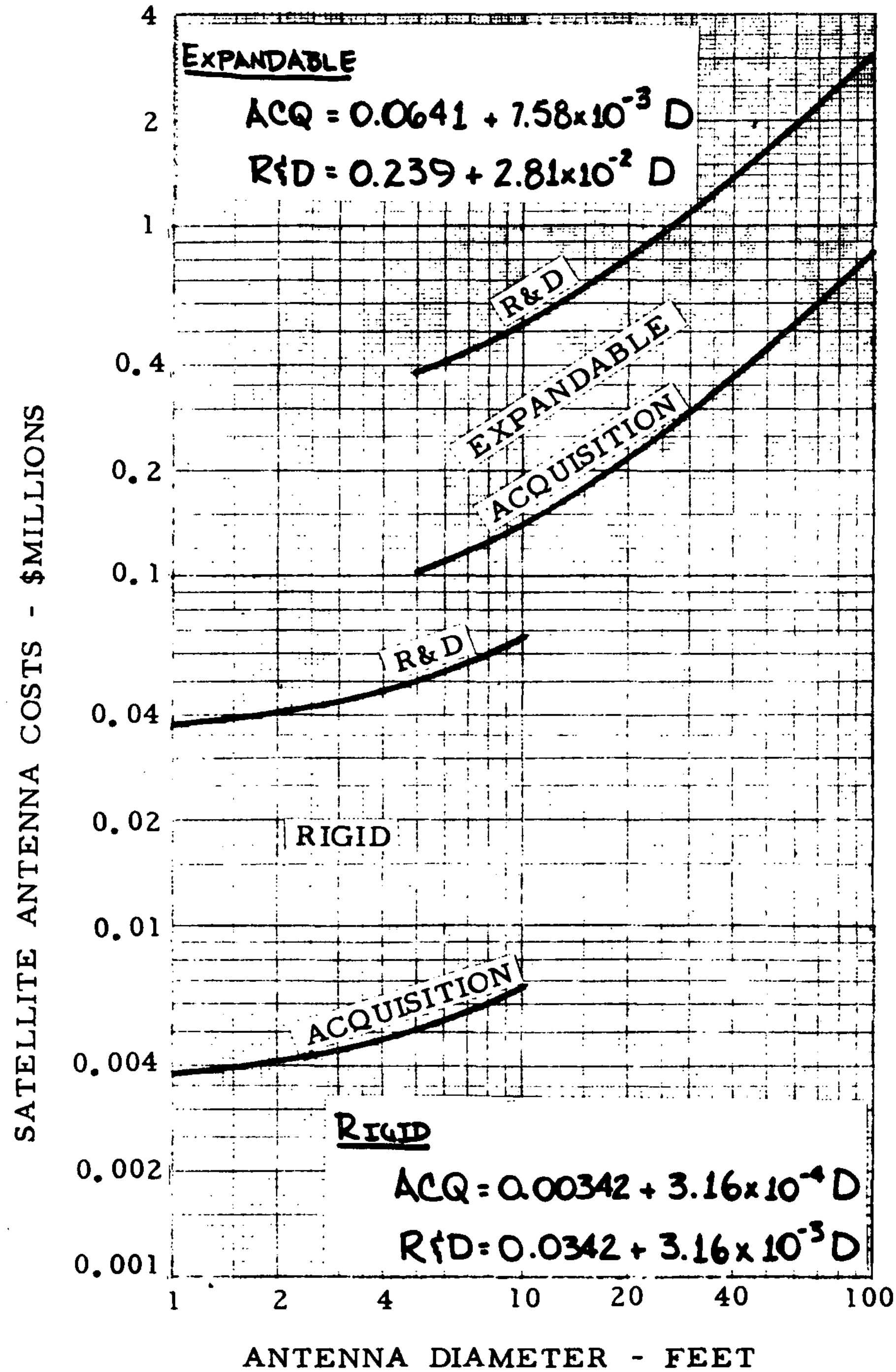


FIGURE D-35. SATELLITE ANTENNA COST

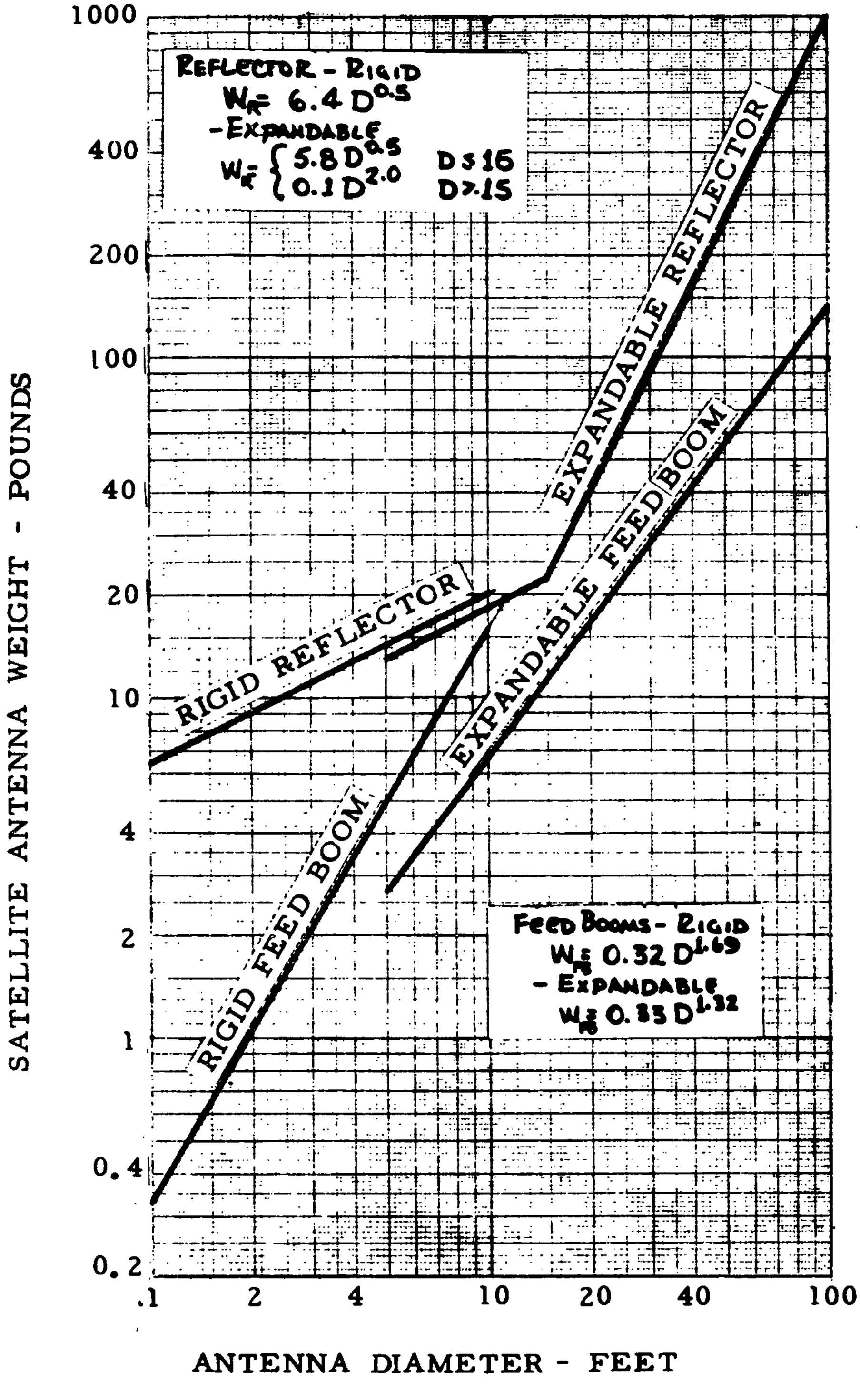


FIGURE D-36. SATELLITE ANTENNA WEIGHT

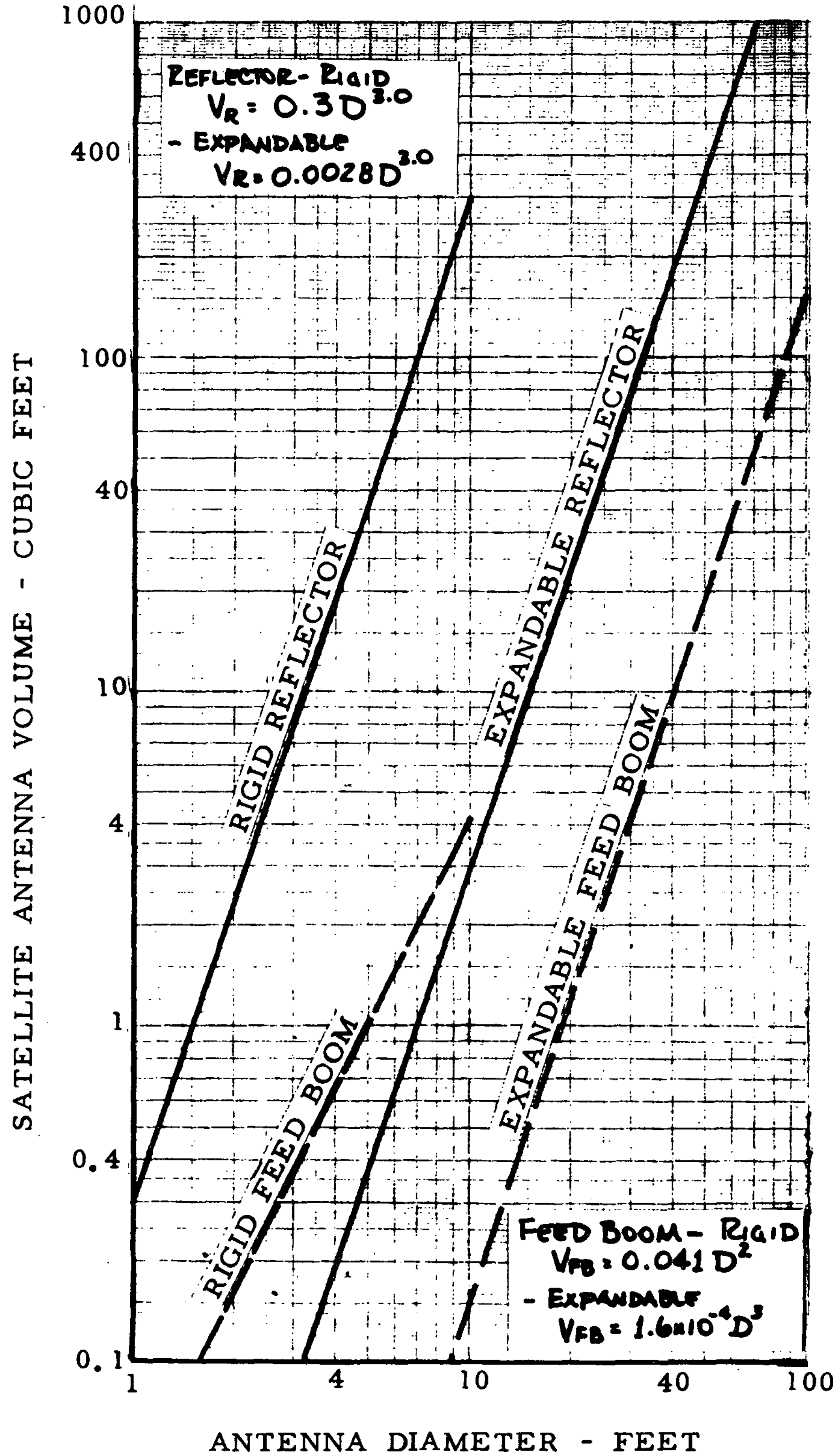


FIGURE D-37. SATELLITE ANTENNA VOLUME

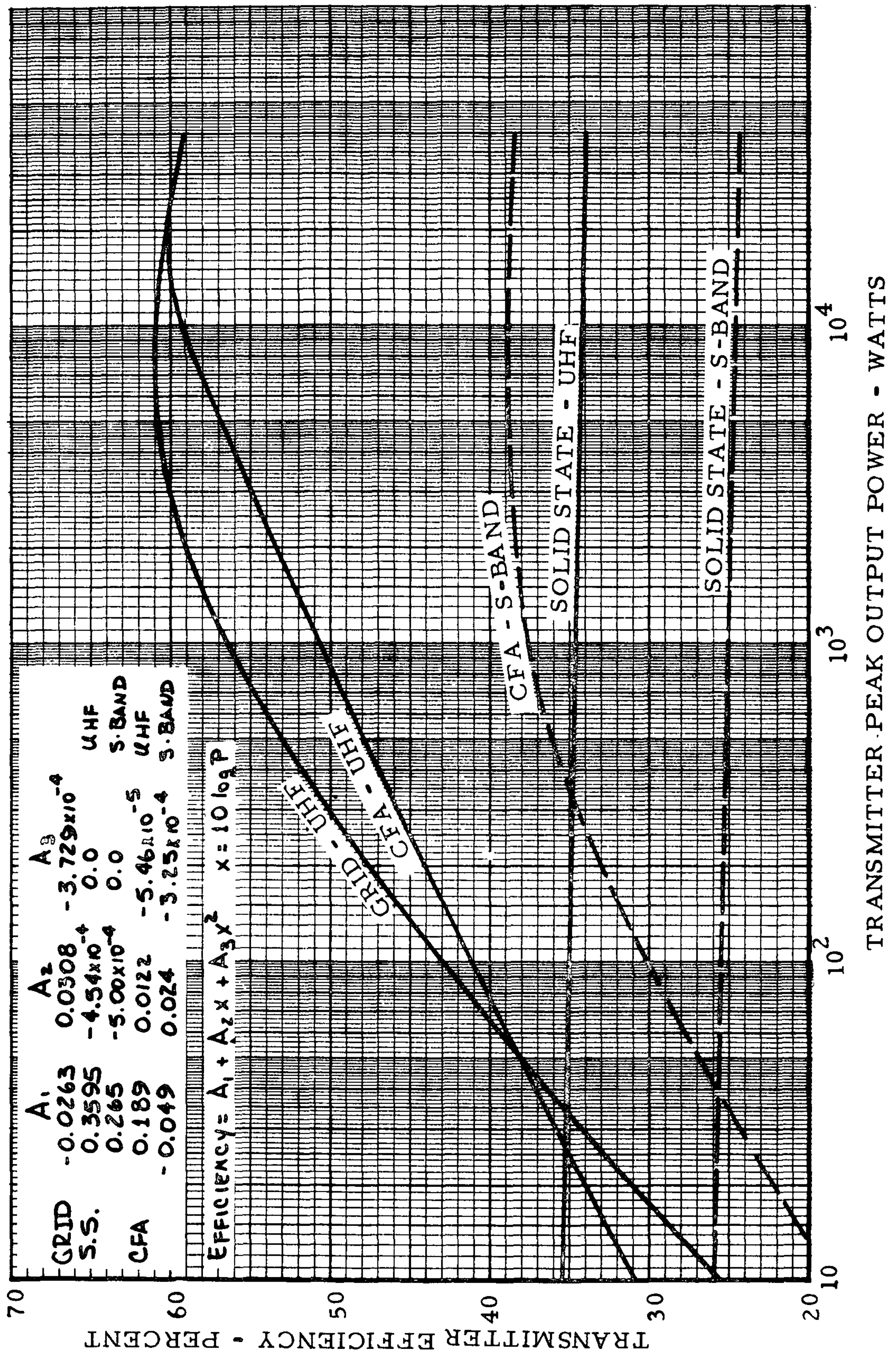


FIGURE D-38. AM TRANSMITTER EFFICIENCY

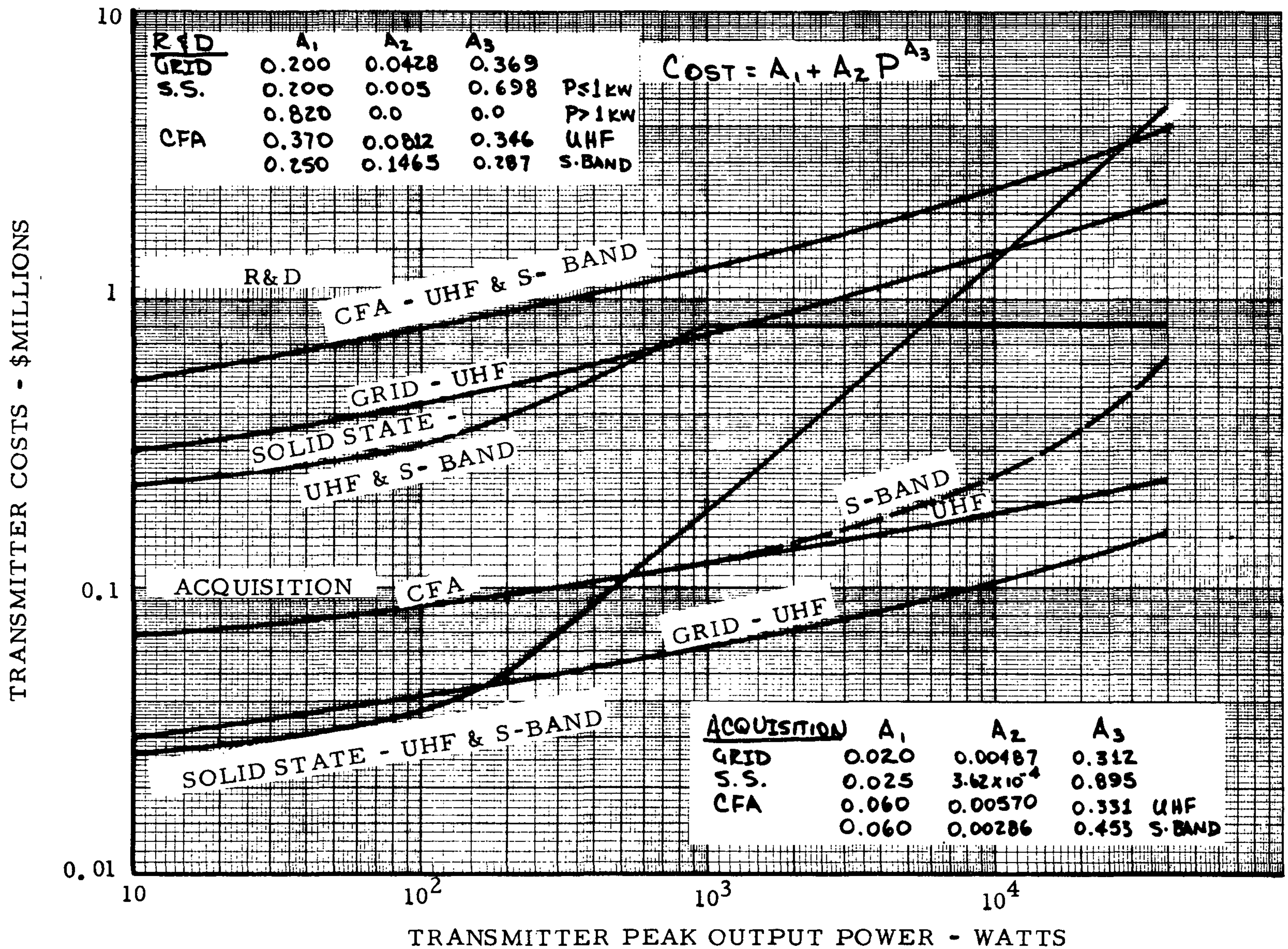


FIGURE D-39. AM TRANSMITTER COST

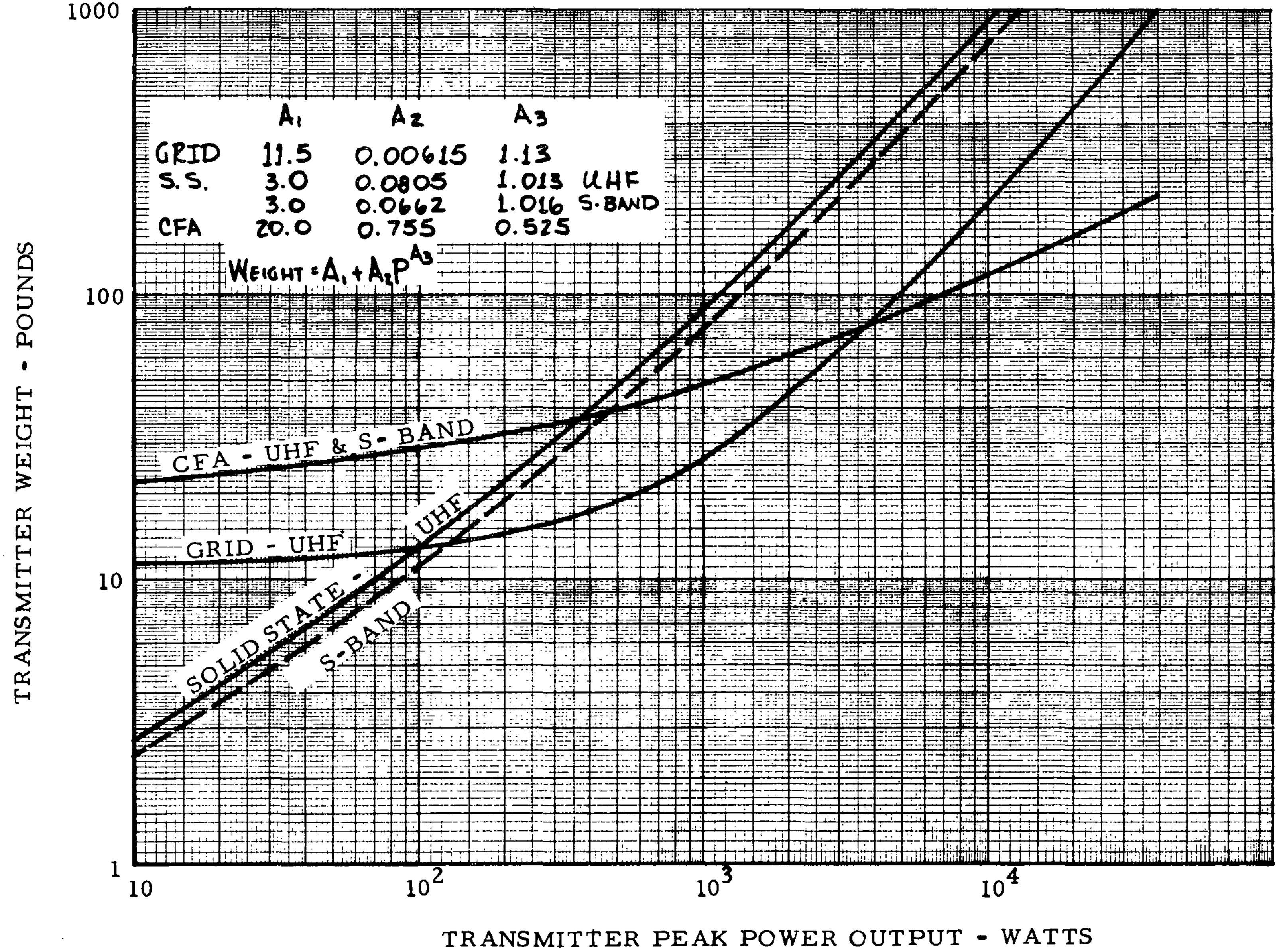


FIGURE D-40. AM TRANSMITTER WEIGHT

d. Figure D-41 Transmitter (AM & FM) volumes in cubic feet per watt.

e. Figure D-42 FM Transmitter efficiency per watt.

f. Figure D-43 FM Transmitter costs in millions of dollars per watt.

g. Figure D-44 FM Transmitter weights in pounds per watt.

D.14 Multiplexer Subsystem

The multiplexer as used in this discussion refers to the r.f. power distribution whether combining the output of several transmitters to one antenna or the reverse process of distribution of a transmitter output to more than one antenna. Thus the multiplexer is an assembly of hybrids and coax or waveguide. The physical parameters and cost are related to number of channels and frequency. The information presented is from the G.E. MKTS Report. Figures D-45, D-46, D-47, and D-48 give insertion loss in dB, cost in millions of dollars, weight in pounds, and volume in cubic feet.

D.15 Receiver Subsystem

The receiver characteristics are presented in terms of the number of receivers (G.E. MKTS Report). Figure D-49 shows receiver costs in millions of dollars for quantities up to 16 units. Both R&D and flight article acquisition costs are shown. There is additional breakdown according to receiver types. Weight, power, and volume are given on Figure D-50.

D.16 Thermal Control Subsystem

Whenever feasible heat generating sources would be so mounted to permit passive radiation at the satellite surface. The large number of sources, however, does not permit exclusively this type of heat dissipation. In addition, heat pipes are planned to conduct heat from larger sources to the radiating surface. Figure D-51 gives thermal control cost in millions of dollars for passive and heat pipe methods in terms of heat dissipation in watts (for both R&D and flight article). Figures D-52 and D-53 give weight in pounds and volume in cubic feet for the two cooling methods as functions of heat to be dissipated in kilowatts. This information was obtained from Convair's study of cooling and direct experience in thermal control on various space applications.

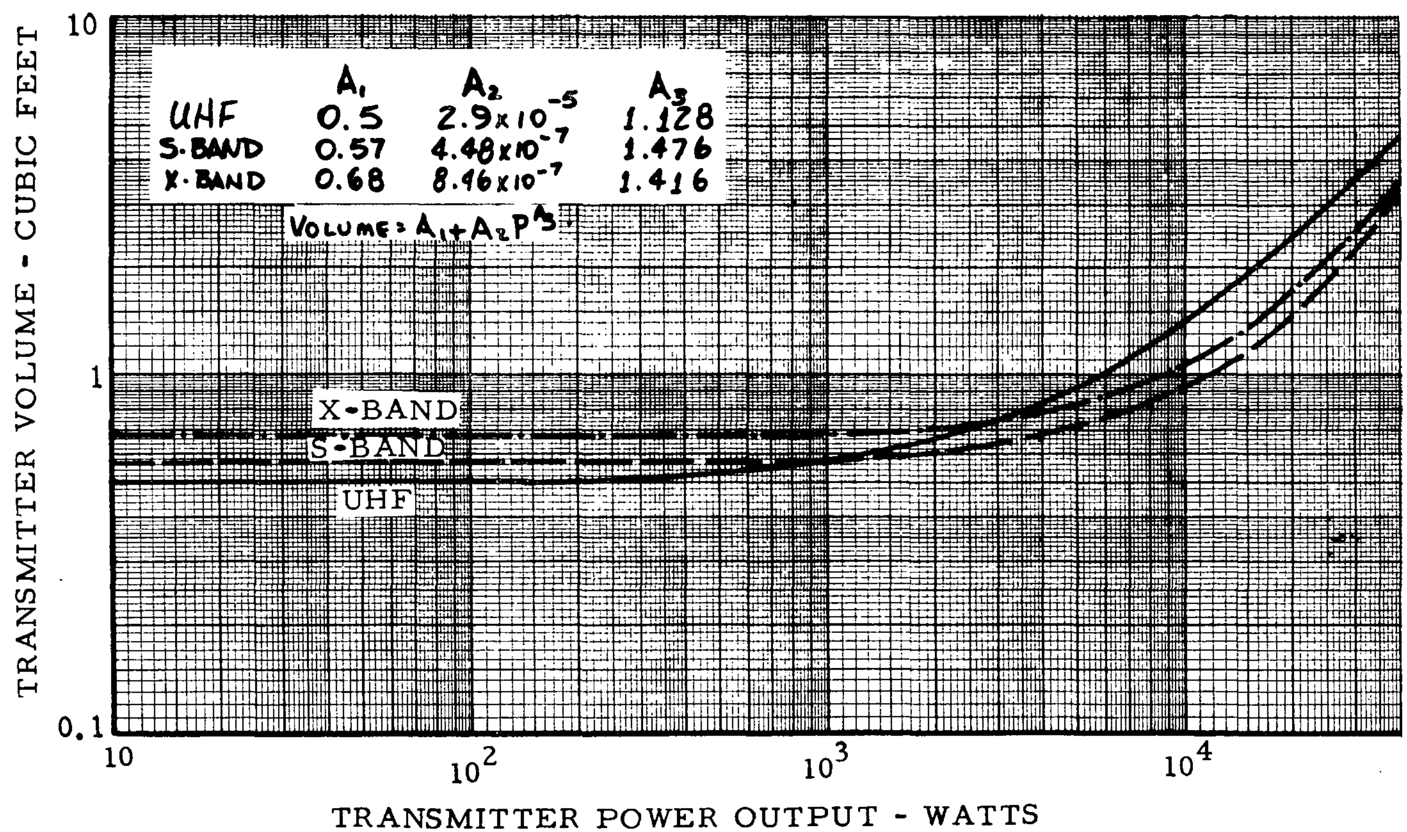


FIGURE D-41. TRANSMITTER (AM & FM) VOLUME

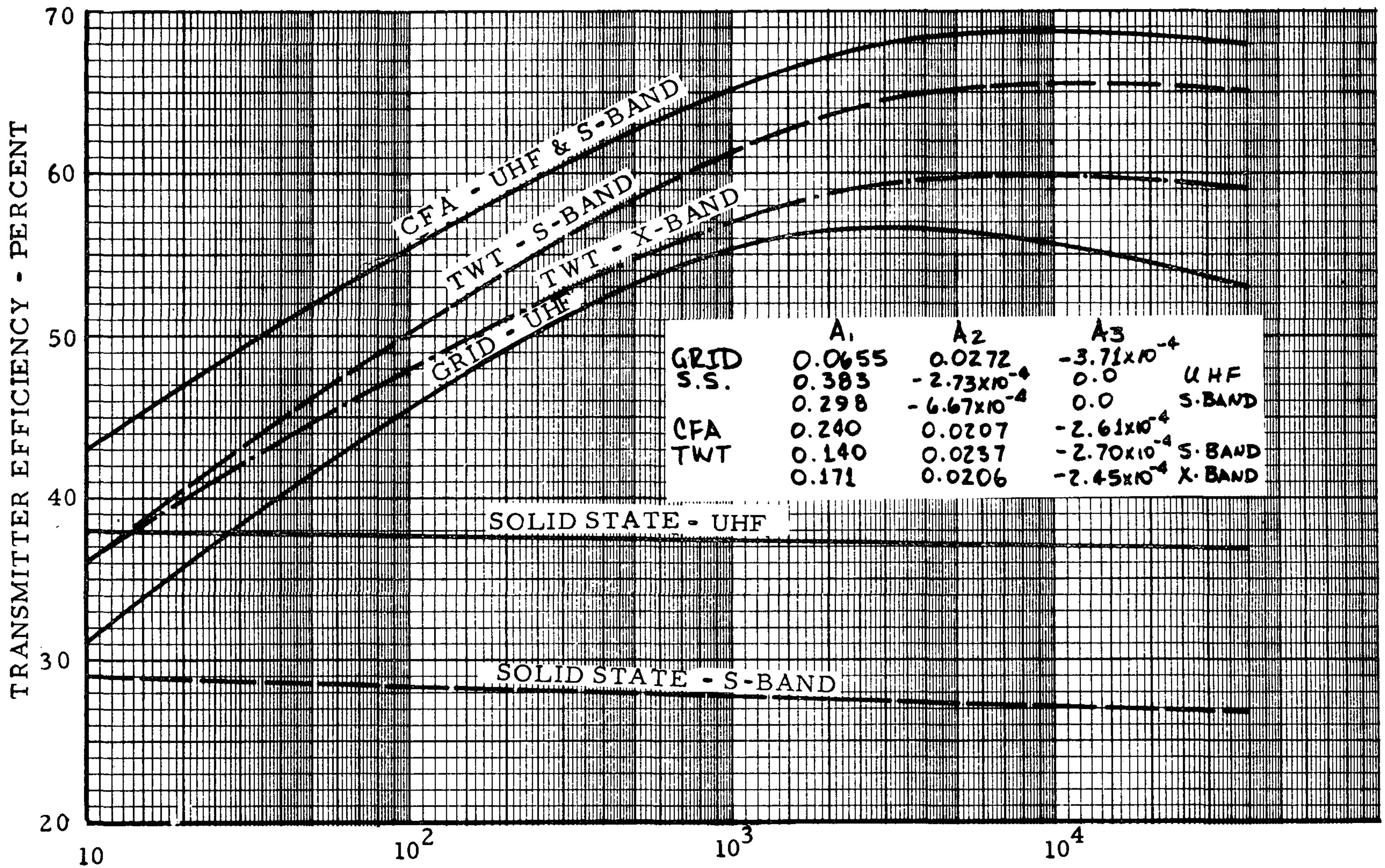


FIGURE D-42. FM TRANSMITTER EFFICIENCY

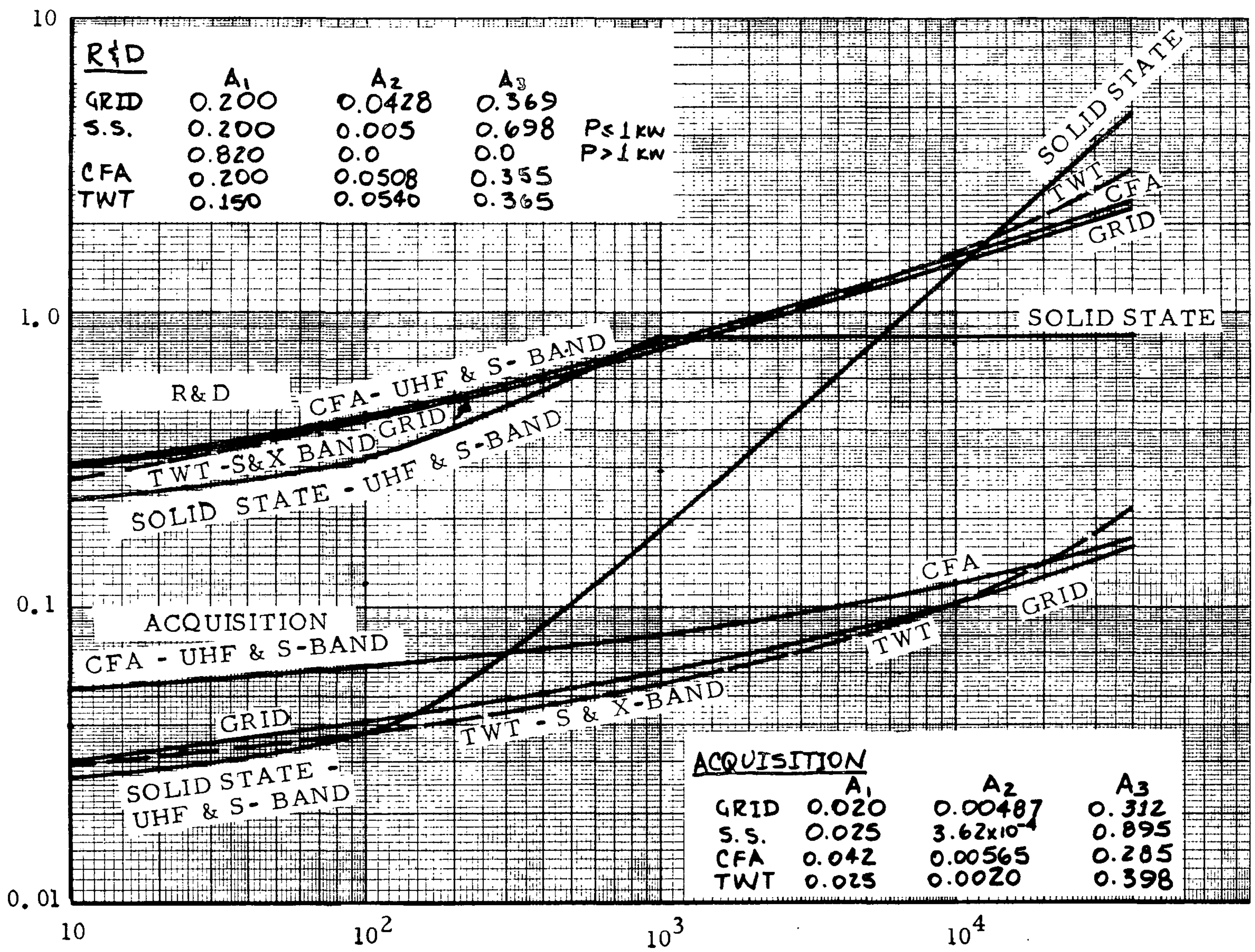


FIGURE D-43. FM TRANSMITTER COST

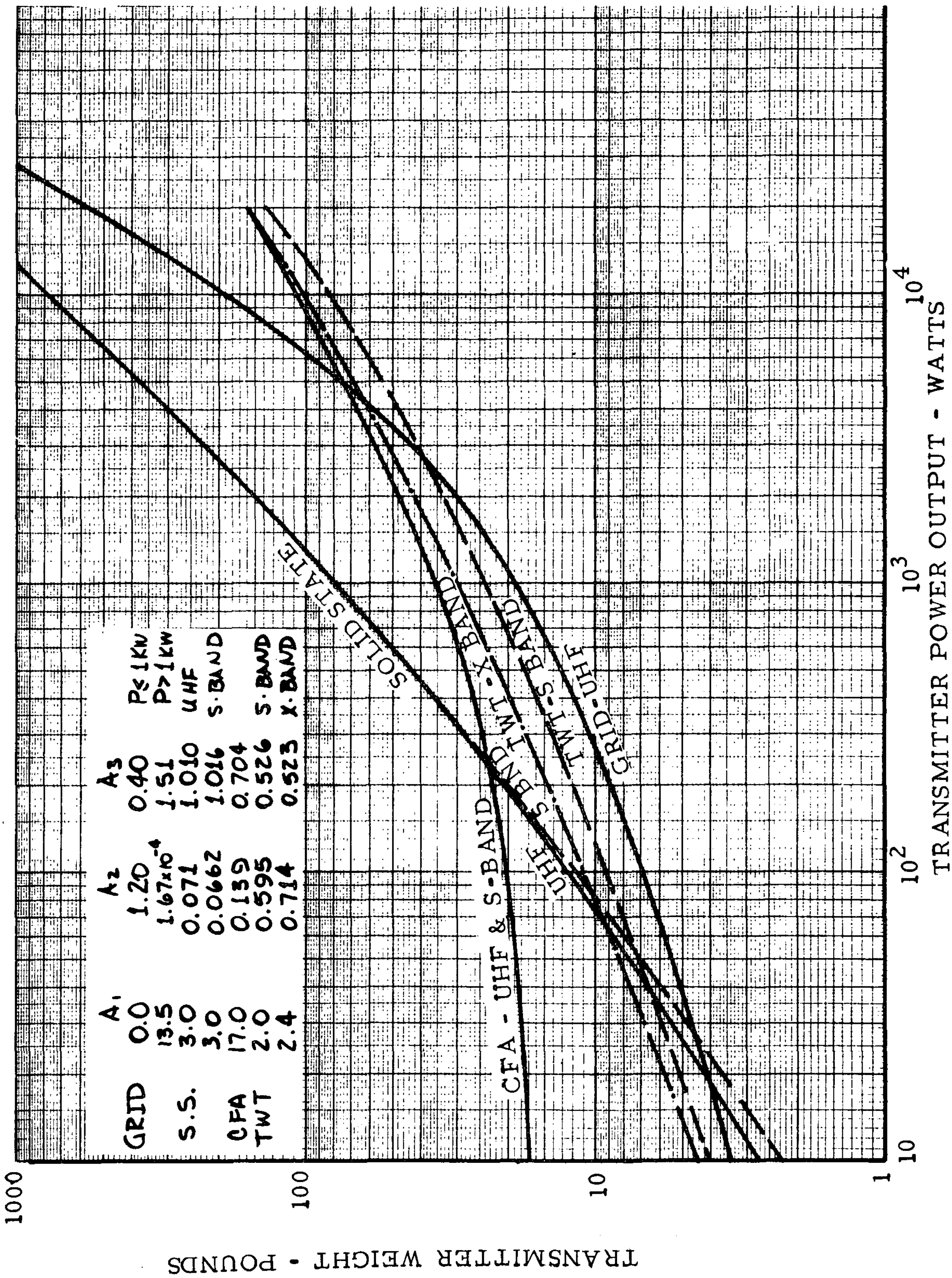


FIGURE D-44. FM TRANSMITTER WEIGHT

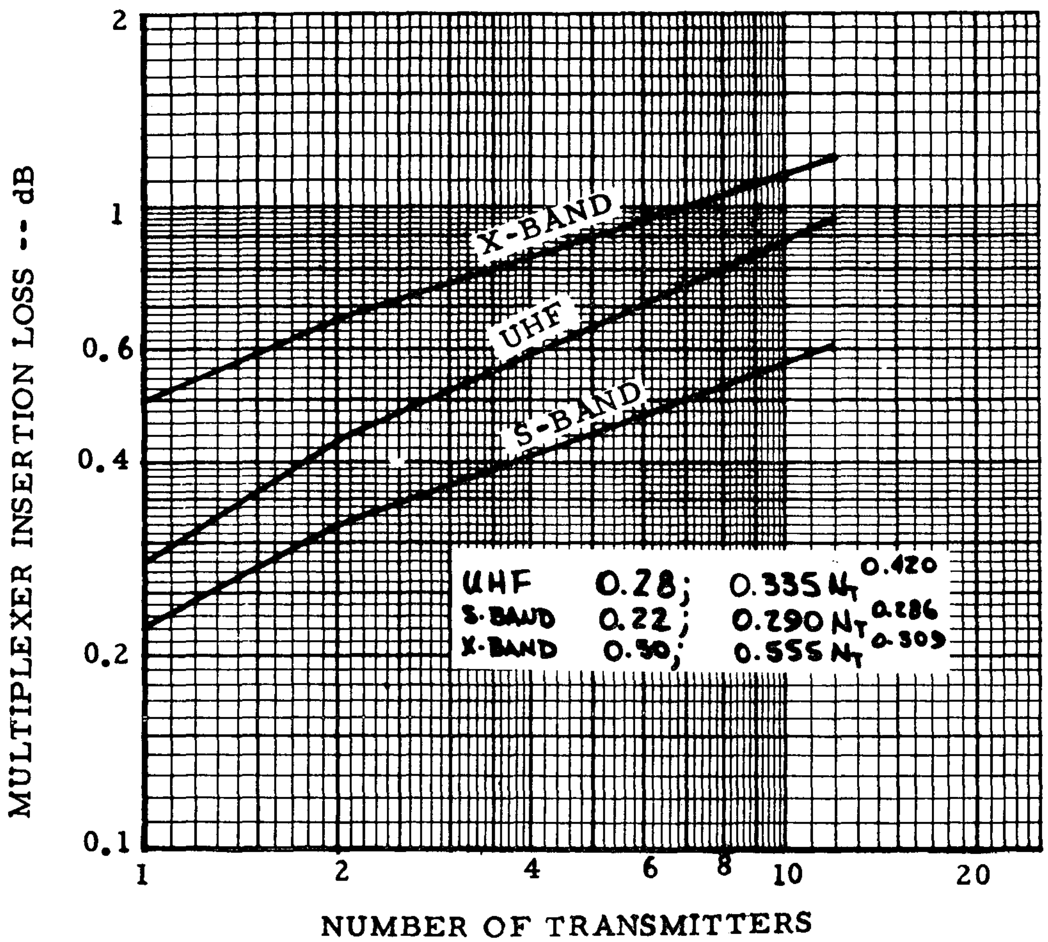


FIGURE D-45. MULTIPLEXER INSERTION LOSS

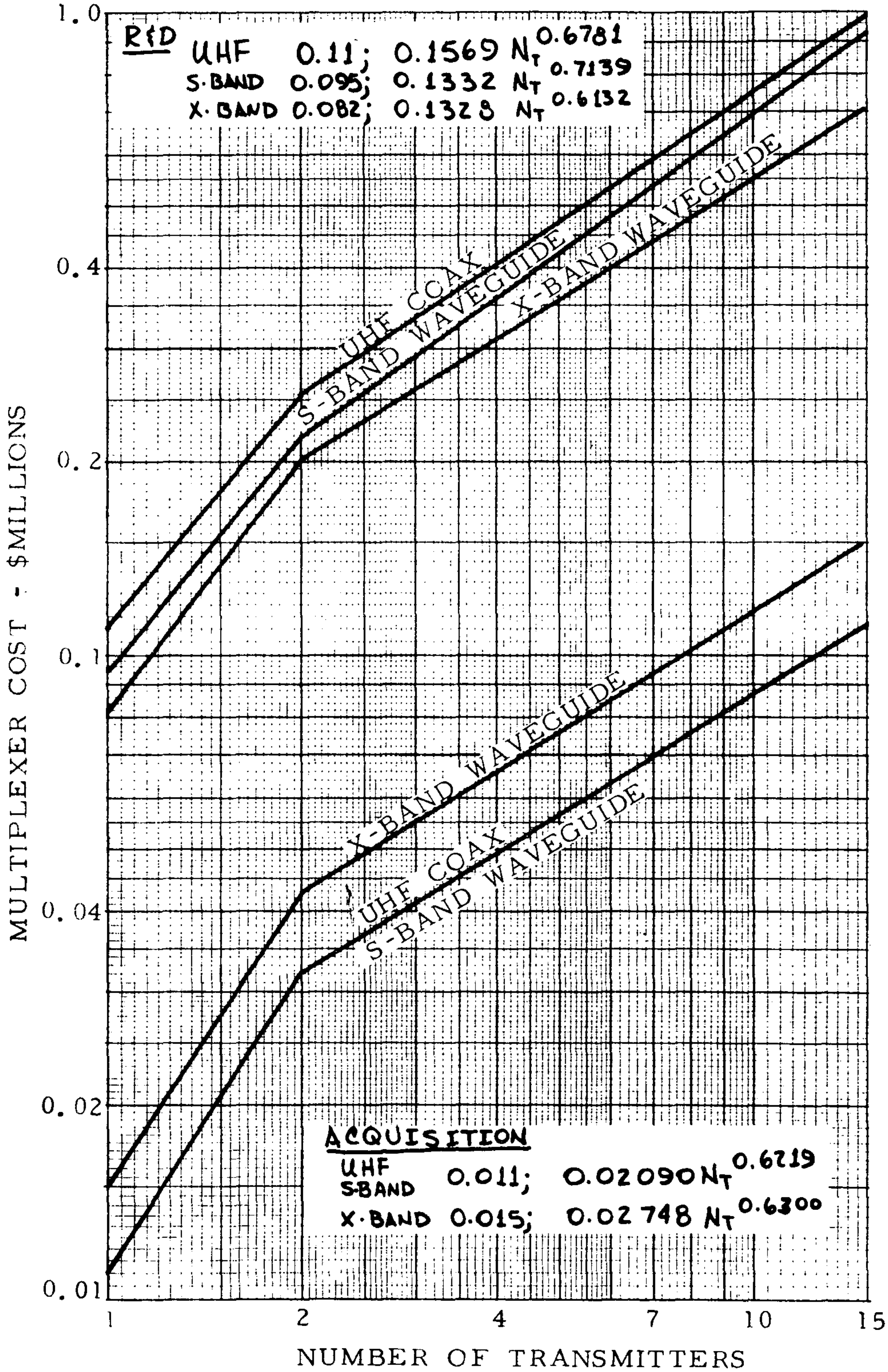


FIGURE D-46. MULTIPLEXER COST

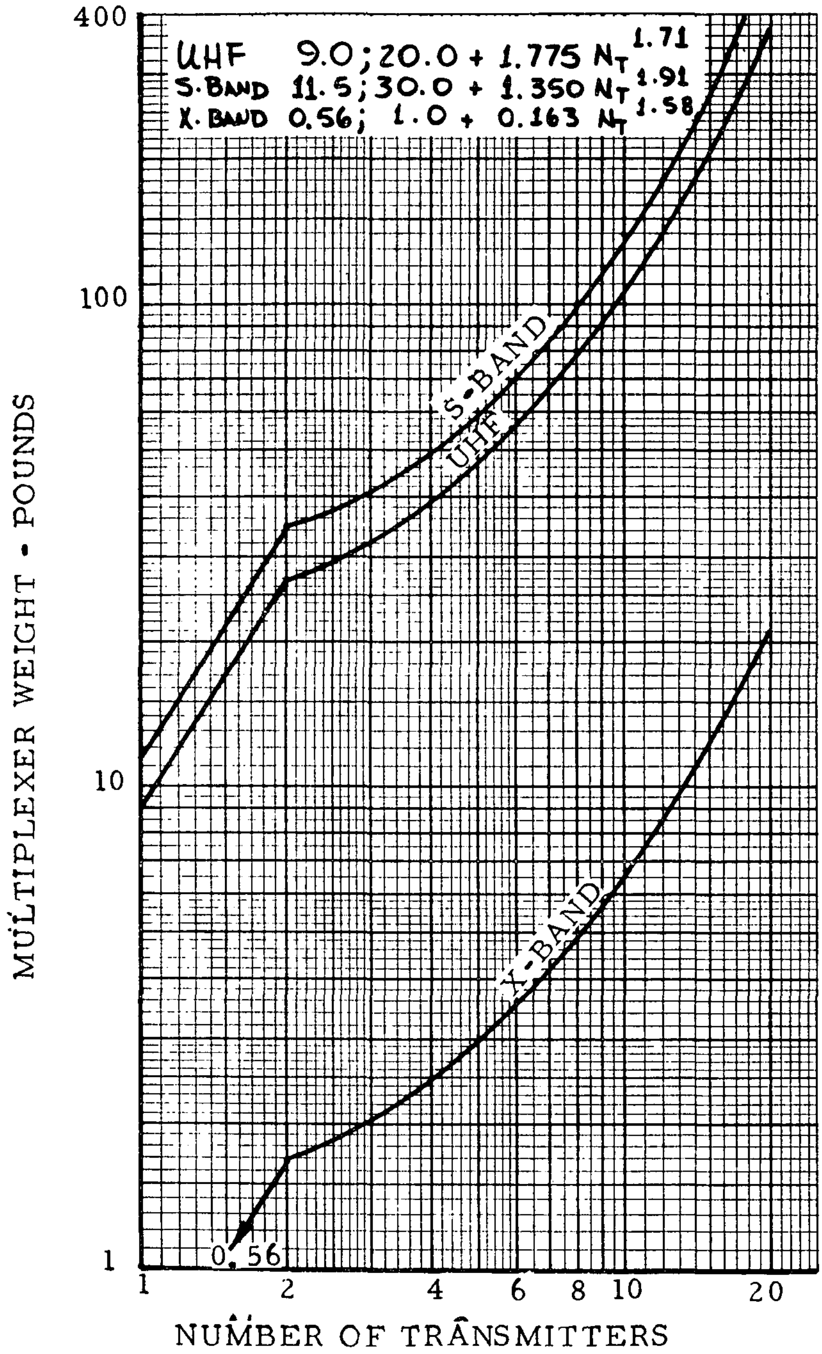


FIGURE D-47. MULTIPLEXER WEIGHT

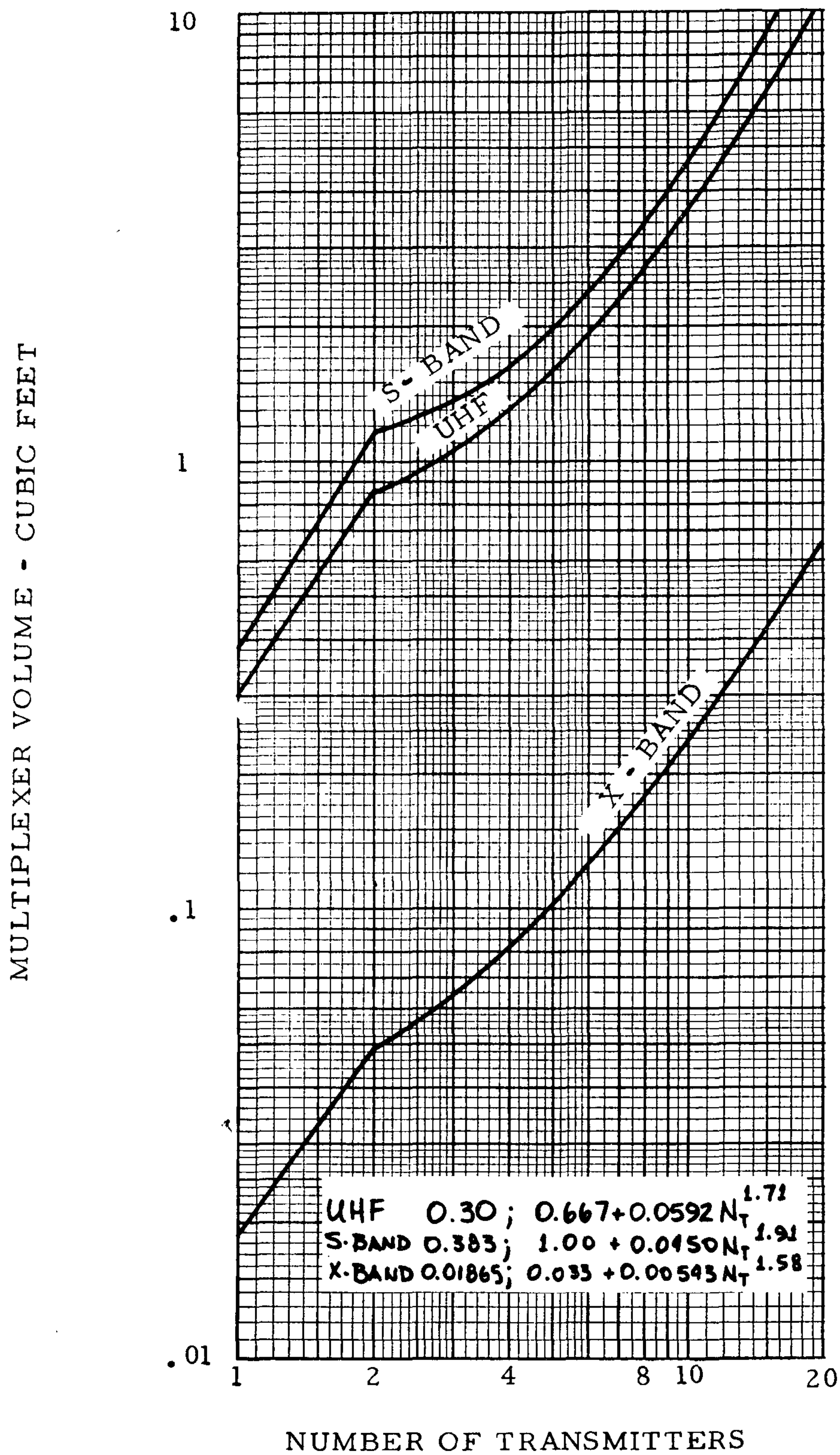


FIGURE D-48. MULTIPLEXER VOLUME

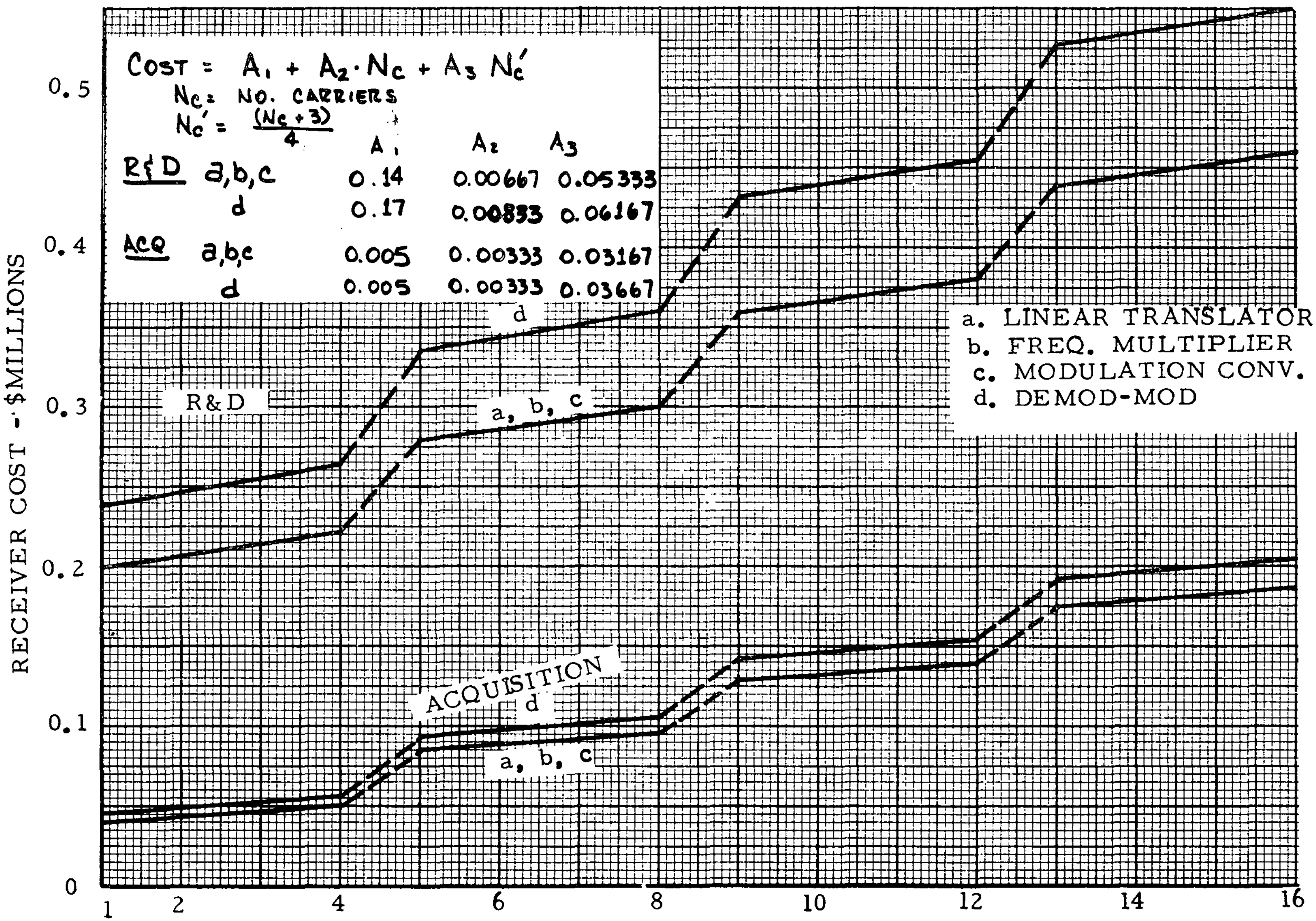


FIGURE D-49. RECEIVER COST

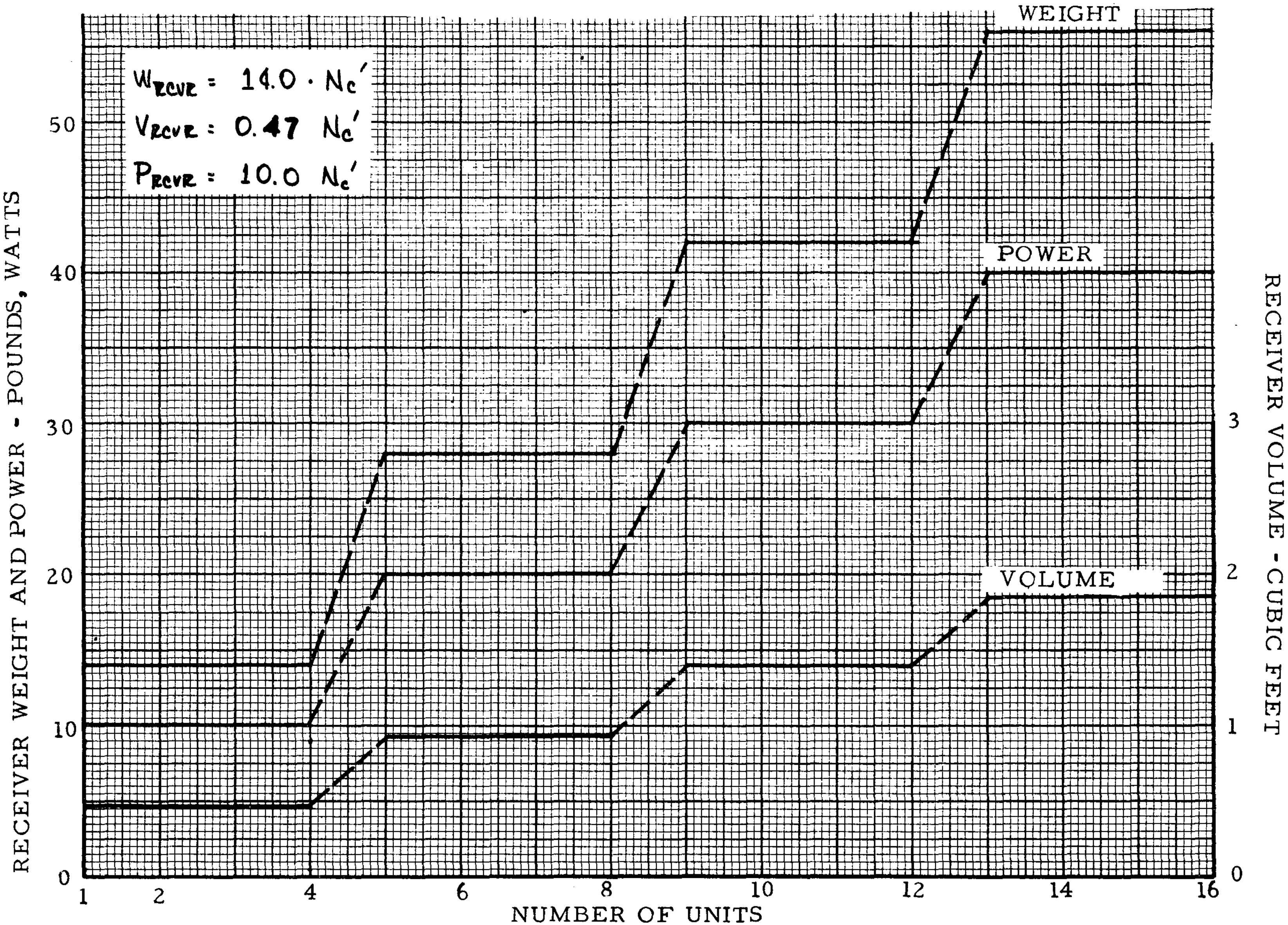


FIGURE D-50. RECEIVER WEIGHT, POWER, AND VOLUME

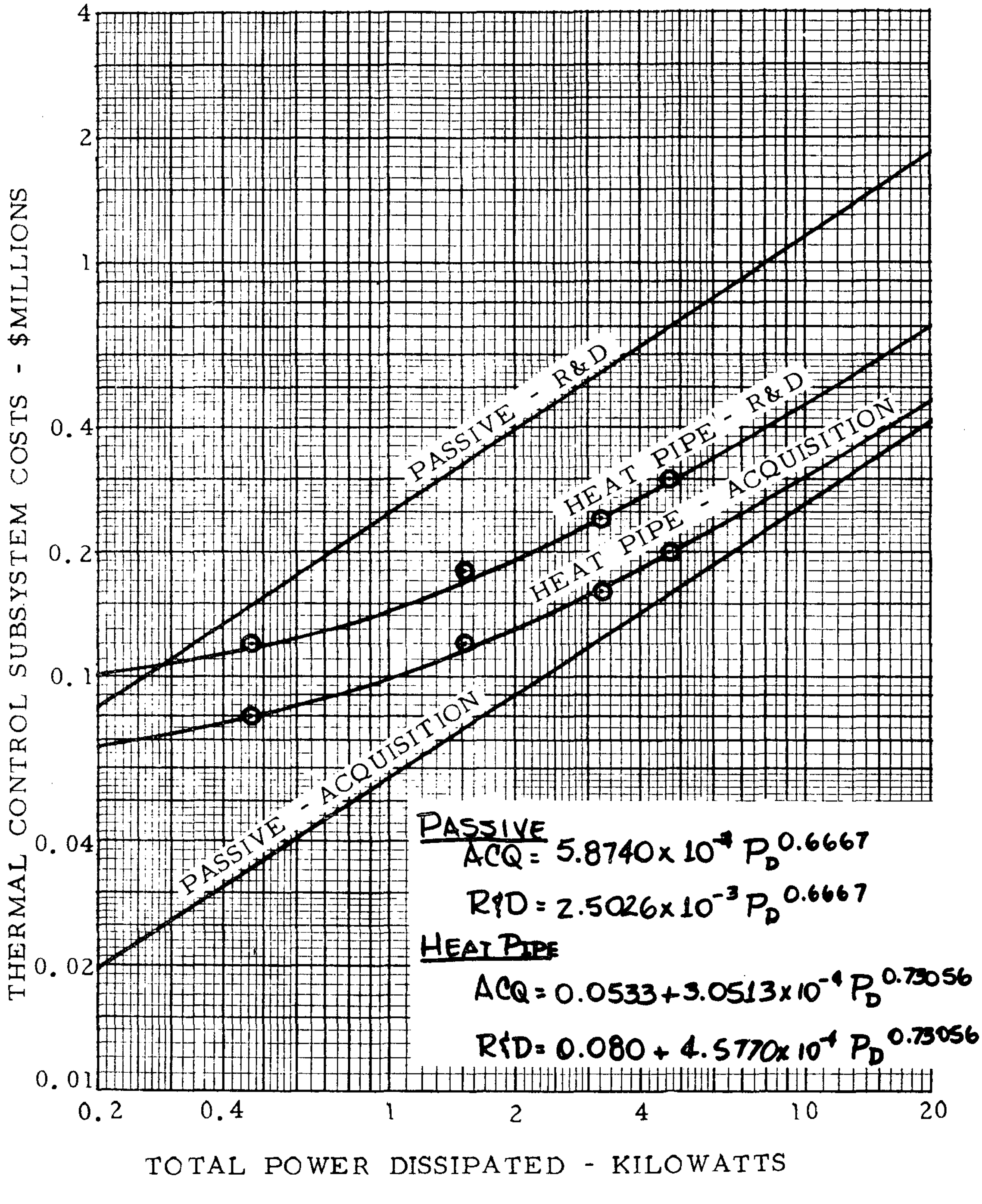


FIGURE D-51. THERMAL CONTROL SYSTEM COST

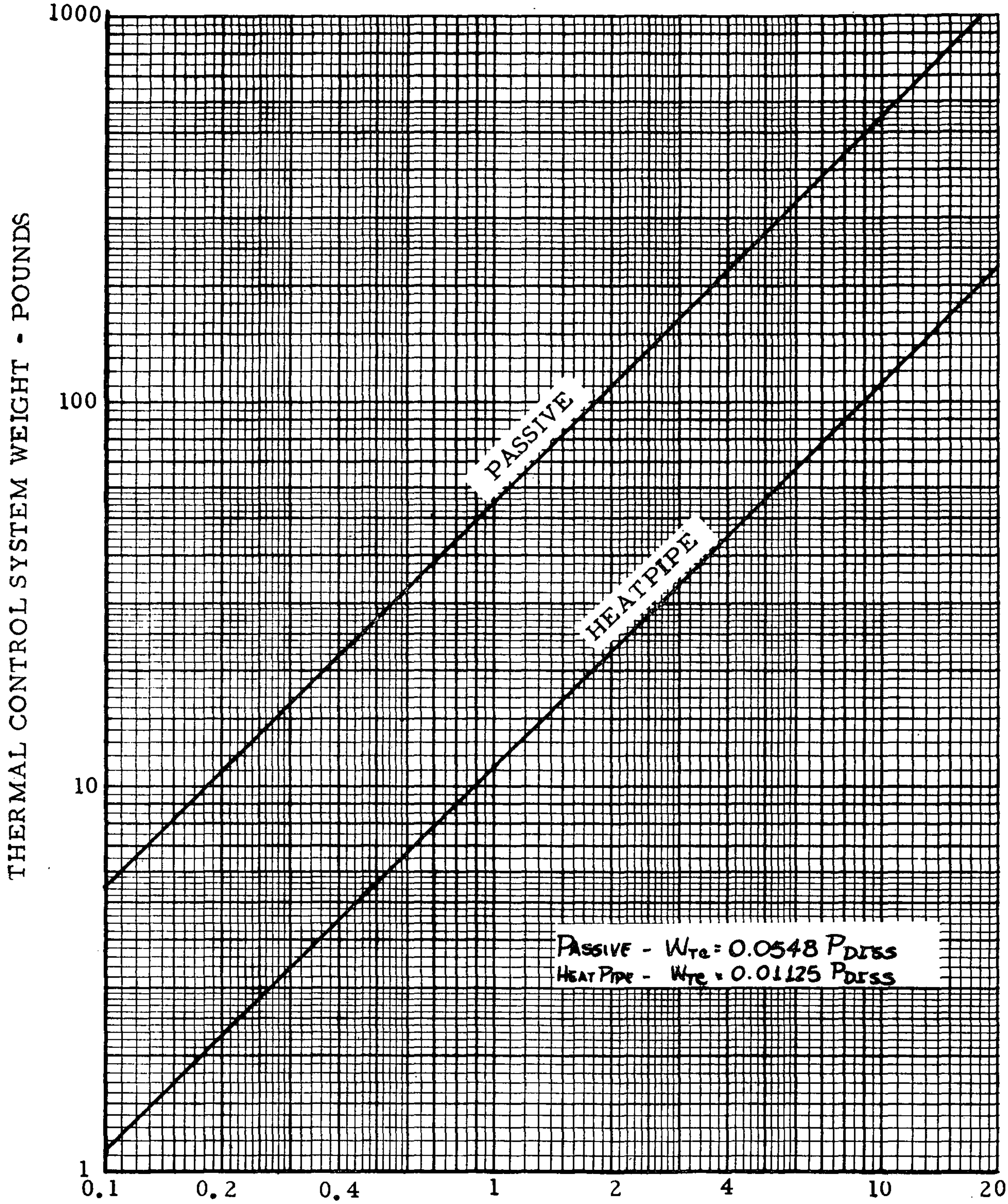


FIGURE D-52. THERMAL CONTROL SYSTEM WEIGHT

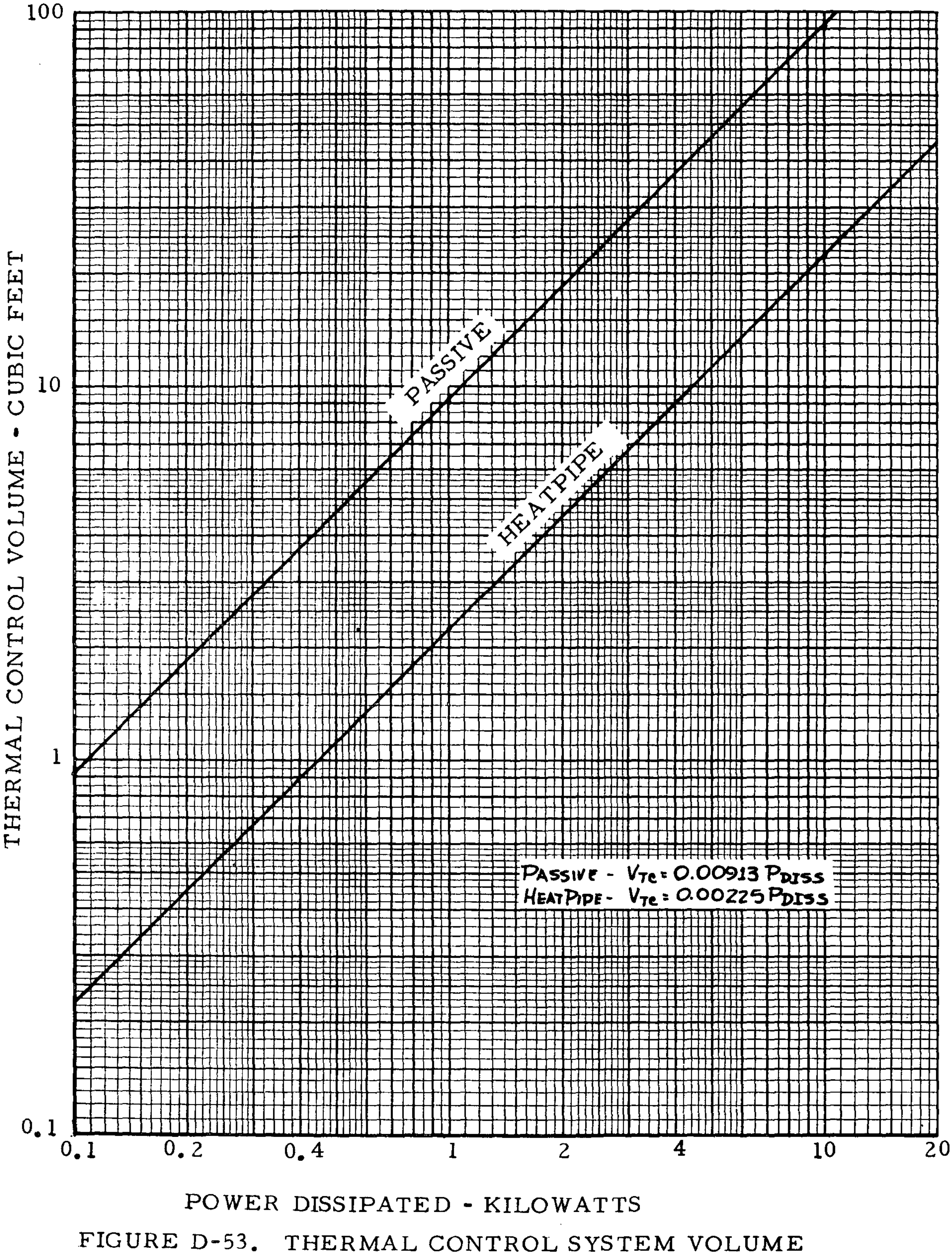


FIGURE D-53. THERMAL CONTROL SYSTEM VOLUME

D.17 Attitude Control

The attitude control data is derived on the basis of Convair experience. Figure D-54 illustrates the parametric cost curves for ion engine and resistojet system as a function of the moment to jet arm ratio and expected lifetime. Figures D-55 and D-56, respectively, give the results for the weight and volume. Required power is shown in Figure D-57.

D.18 Station Keeping

Station keeping data is generated by Convair. Figure D-58 gives the parametric cost relationship for ion engine and resistojet systems as a function of total weight (minus station keeping) and expected lifetime. Figures D-59 and D-60 illustrate the weight and volume, respectively. Figure D-61 gives the power requirement curves.

D.19 Structure Subsystem

Structure costs were readily estimated in view of the extent of experience with aerospace structures. The structure size is determined by the communications system elements it must carry. Size and availability of launch vehicles, of course, impose an upper bound upon weight and volume of the equipment module (EM). Figures D-62 and D-63 give structure cost(R&D and flight acquisition) in millions of dollars per pound and the structure weight in pounds as a function of volume in cubic feet.

D.20 Manned Provisions

A satellite may be unmanned or provide for a life supporting environment permitting man to board for performance of service work. Several manned configurations have been considered in Convair's space module studies. The MDA (multiple docking adapter) provides a "shirt sleeve" environment up to 14 days duration. The BSM (basic submodule) is combining a living environment with the satellite permitting manning for an extended period. Table D-4 gives the inputs to the total system synthesis to provide for either of the two alternatives for lift support. These are constants and do not have parametric expression.

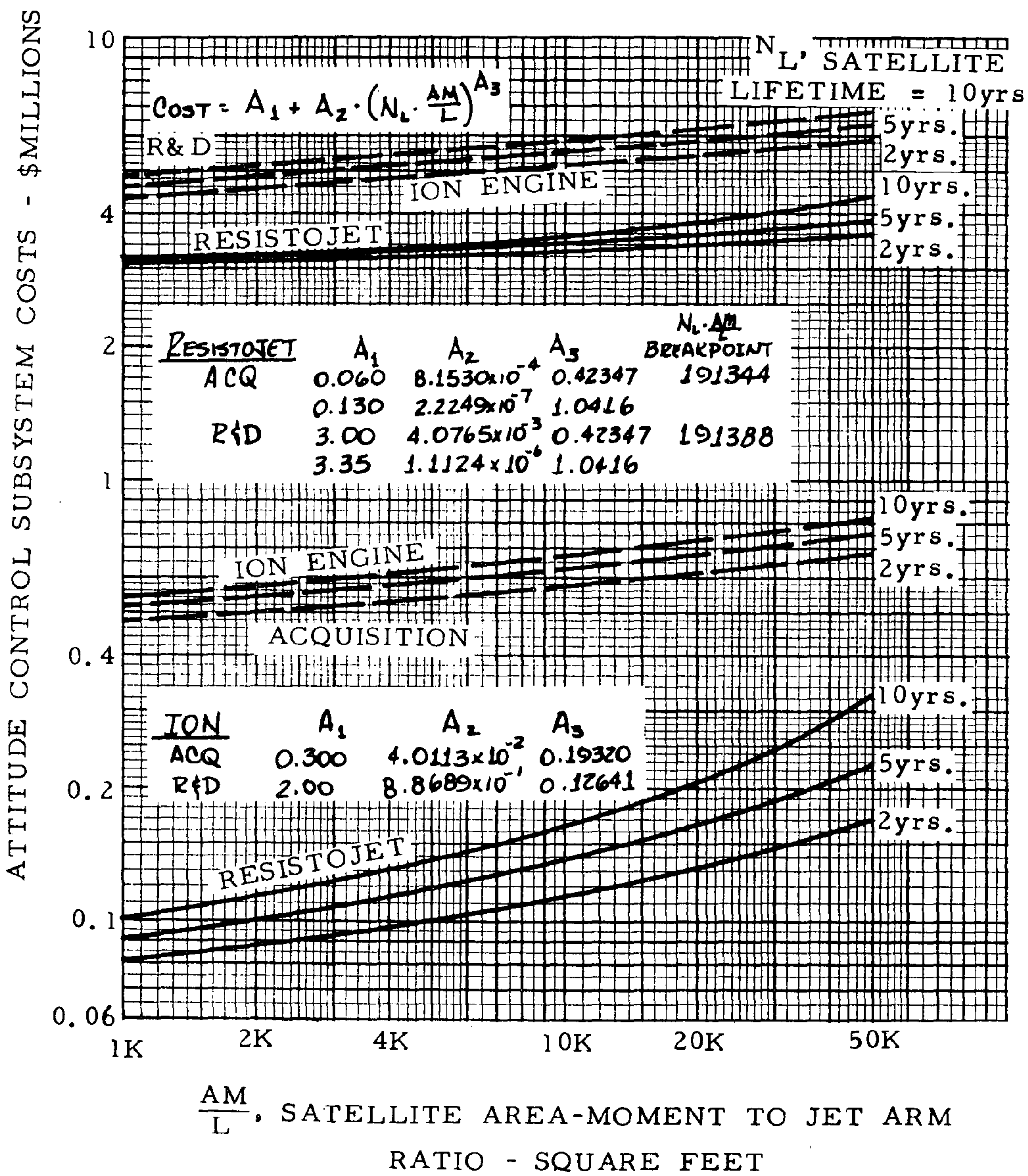


FIGURE D-54. ATTITUDE CONTROL SUBSYSTEM COST

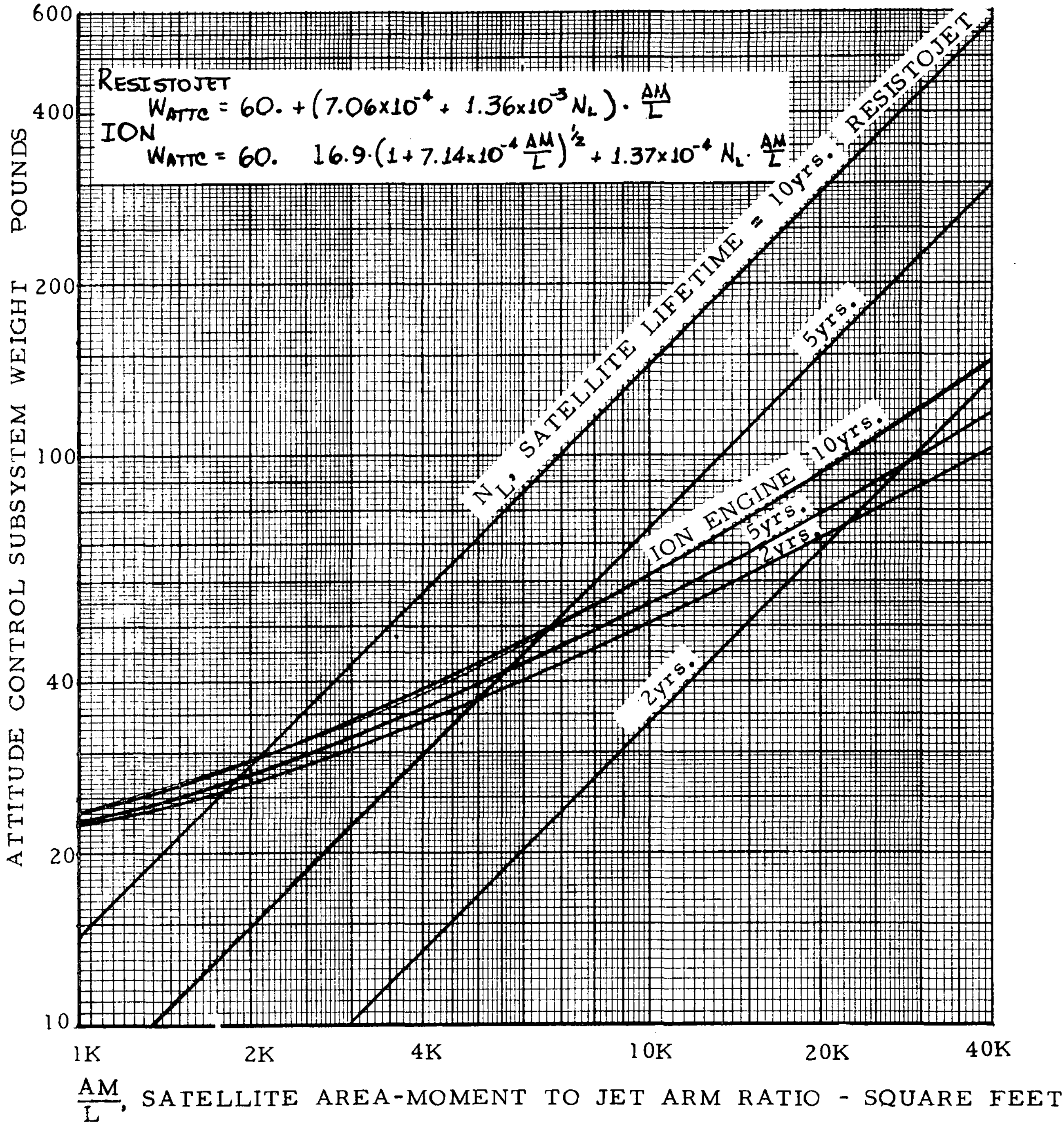
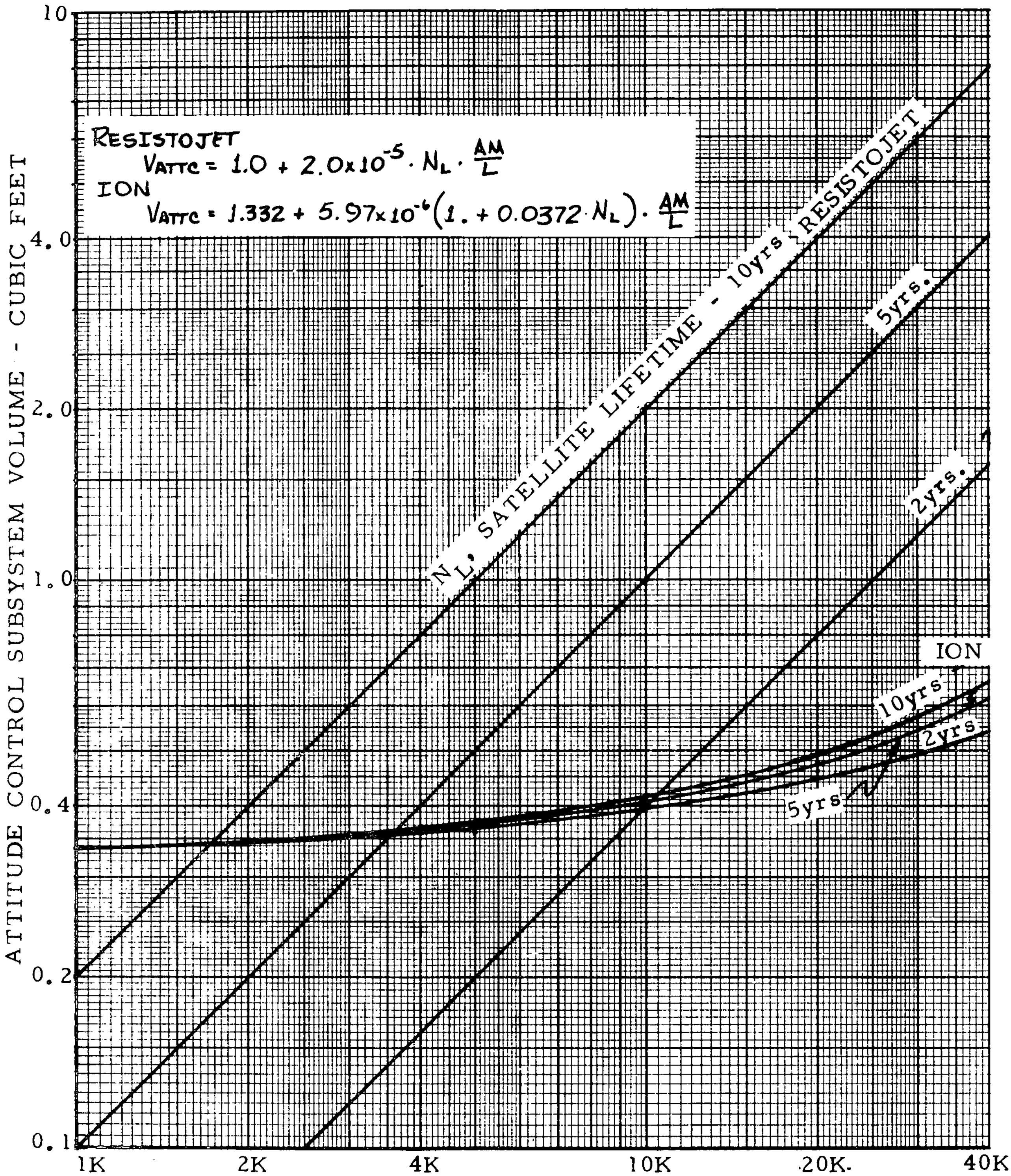


FIGURE D-55. ATTITUDE CONTROL SUBSYSTEM WEIGHT



$\frac{AM}{L}$, AREA-MOMENT TO JET ARM RATIO - SQUARE FEET

FIGURE D-56. ATTITUDE CONTROL SUBSYSTEM VOLUME

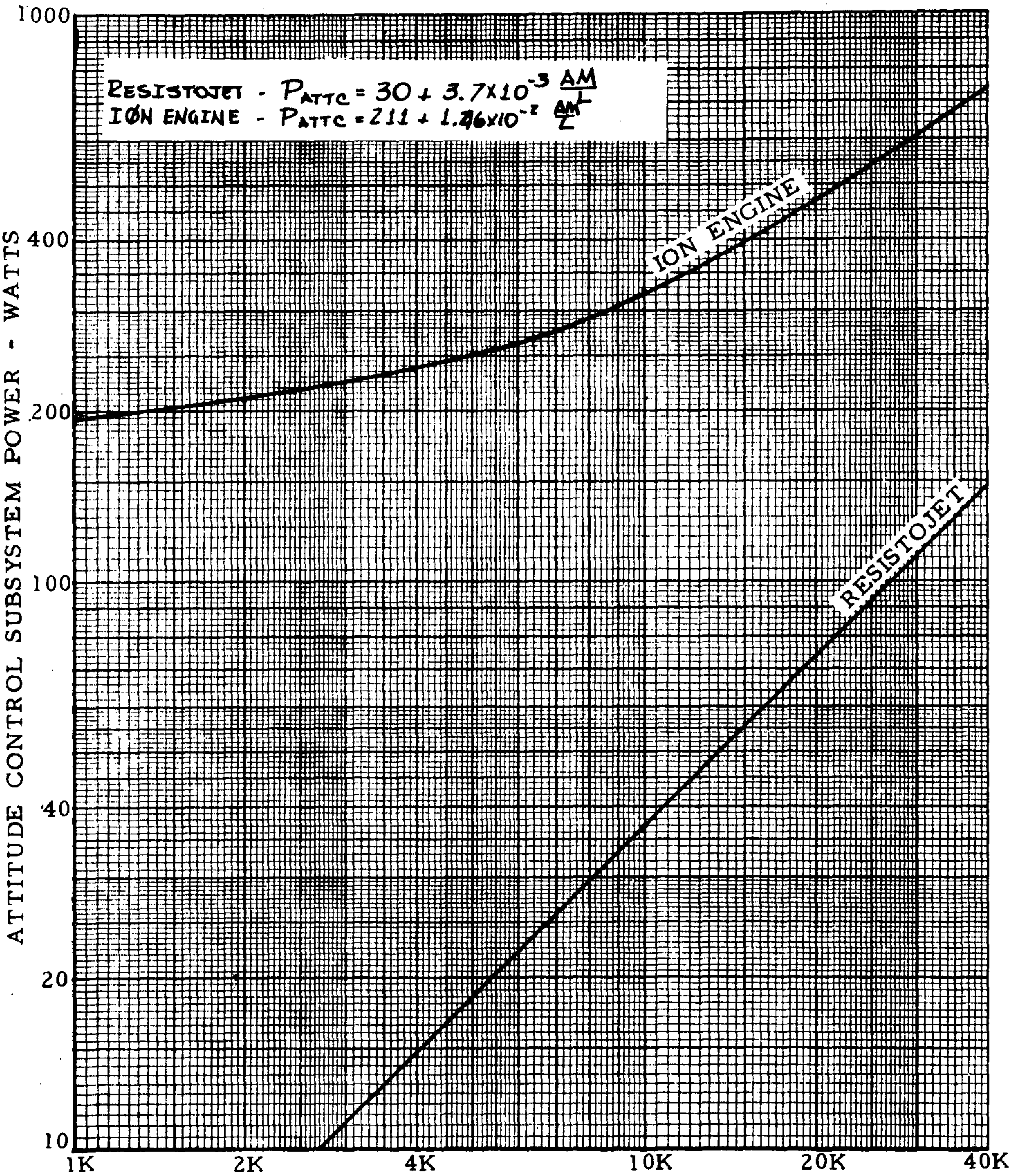


FIGURE D-57. ATTITUDE CONTROL SUBSYSTEM POWER

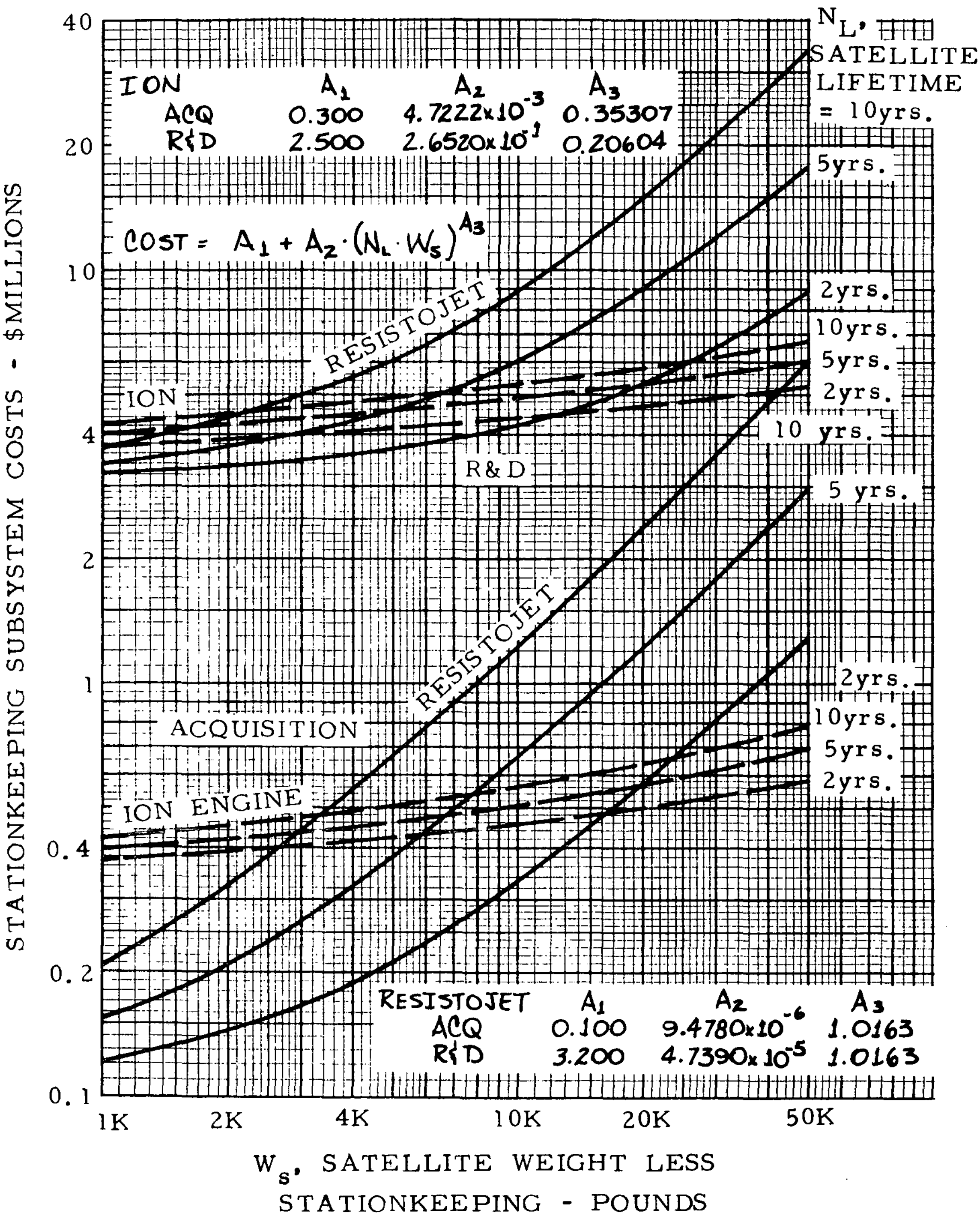


FIGURE D-58. STATION KEEPING SUBSYSTEM COST

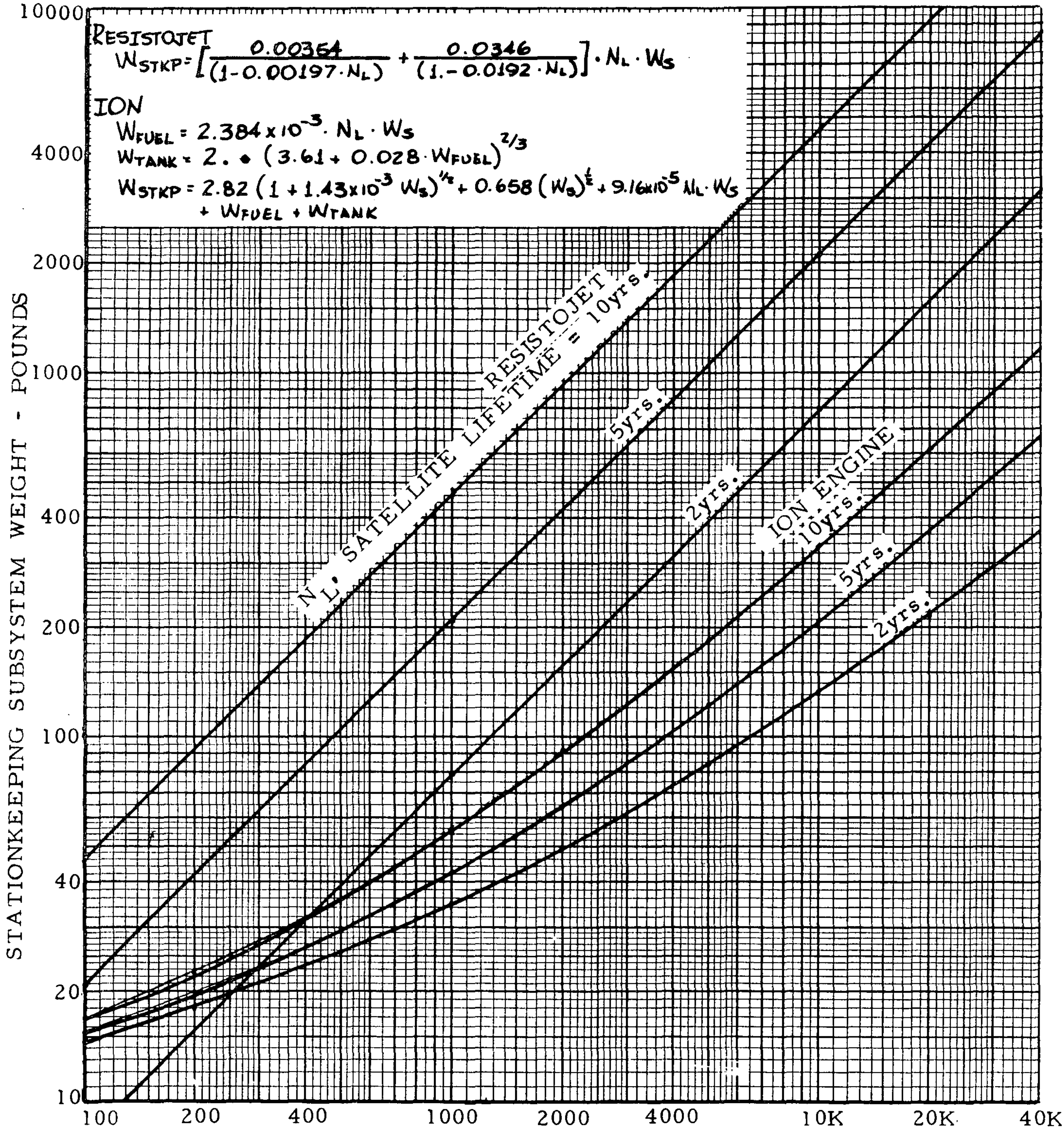


FIGURE D-59. STATIONKEEPING SUBSYSTEM WEIGHT

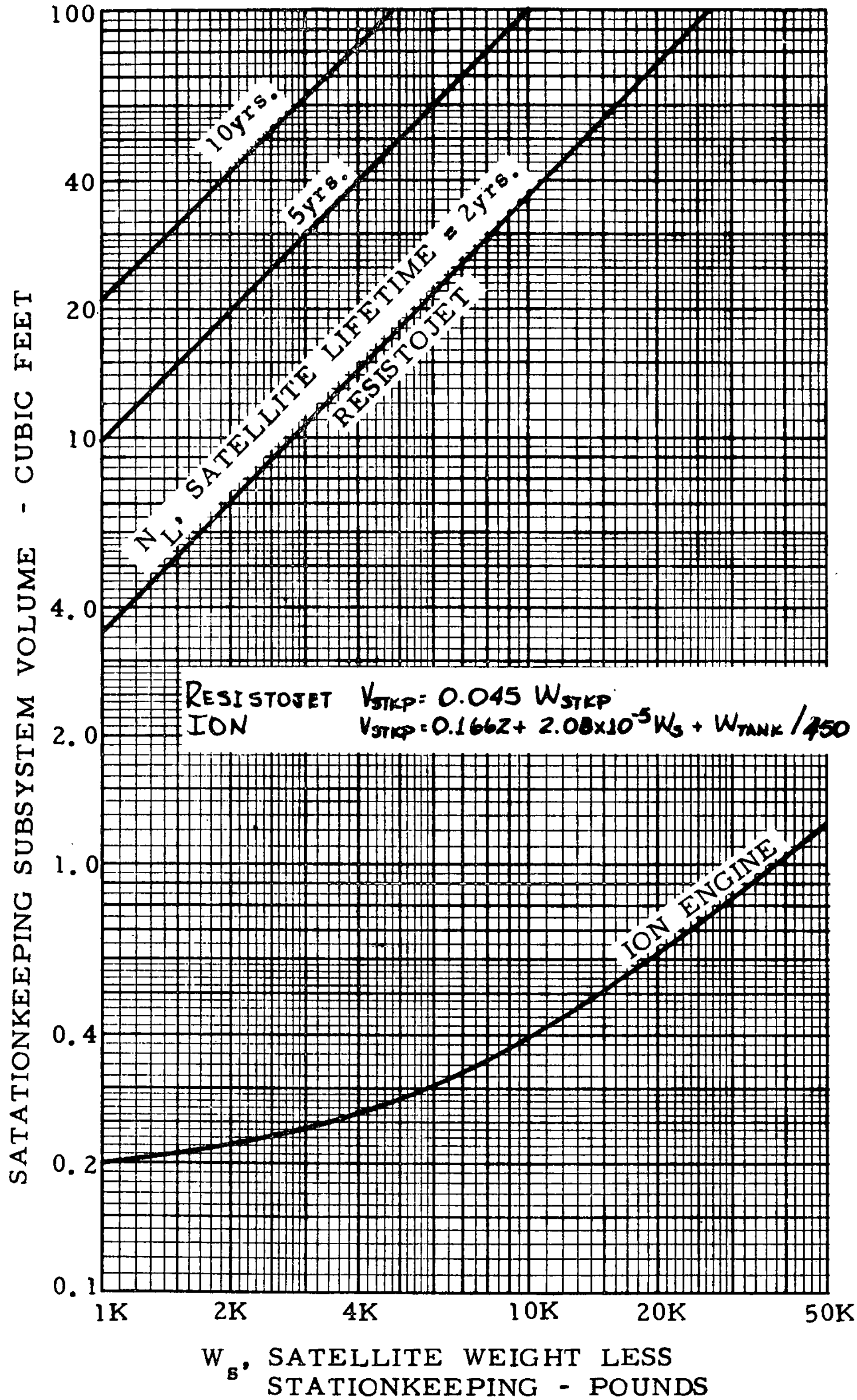


FIGURE D-60. STATIONKEEPING SUBSYSTEM VOLUME

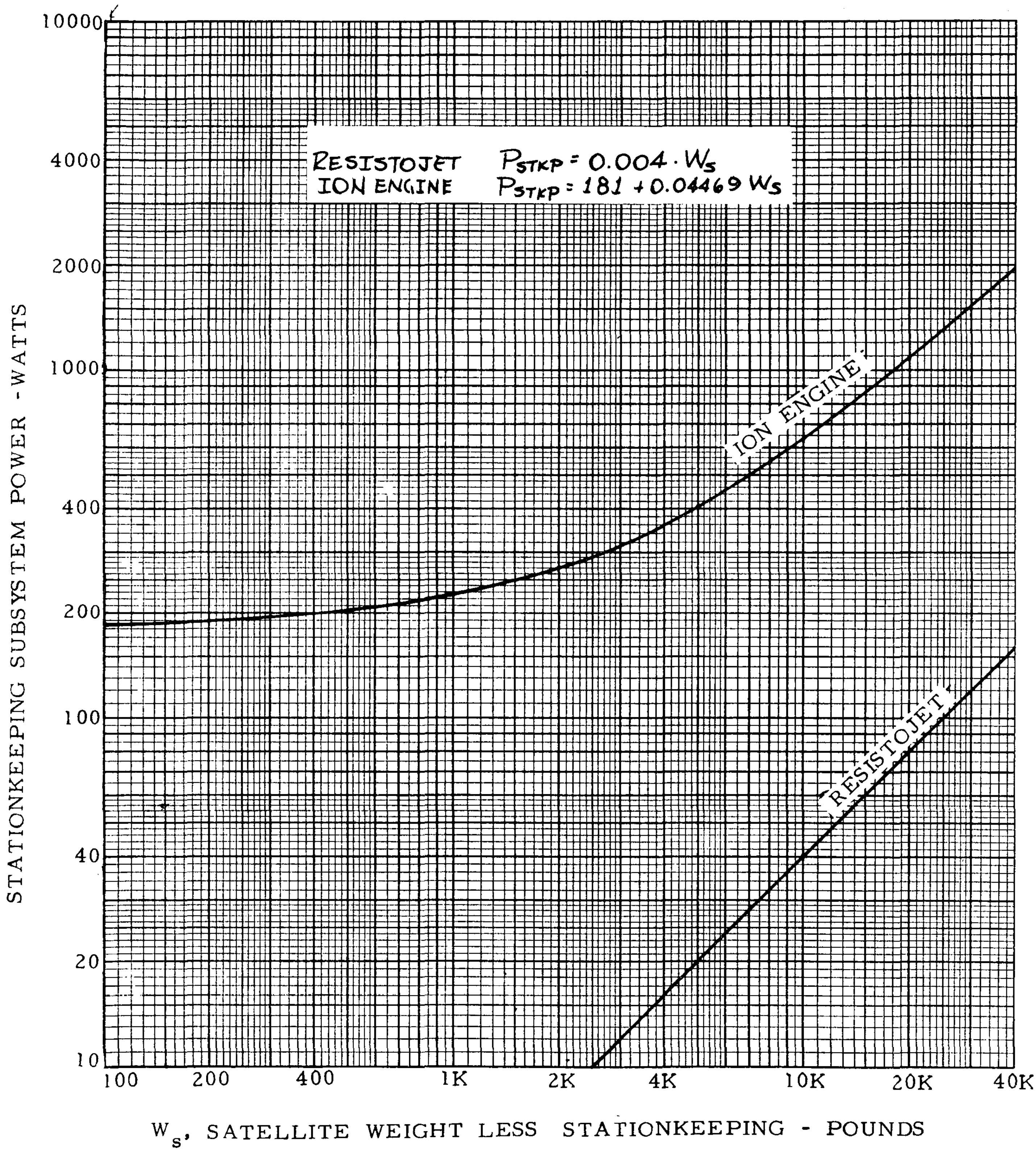


FIGURE D-61. STATIONKEEPING SUBSYSTEM POWER

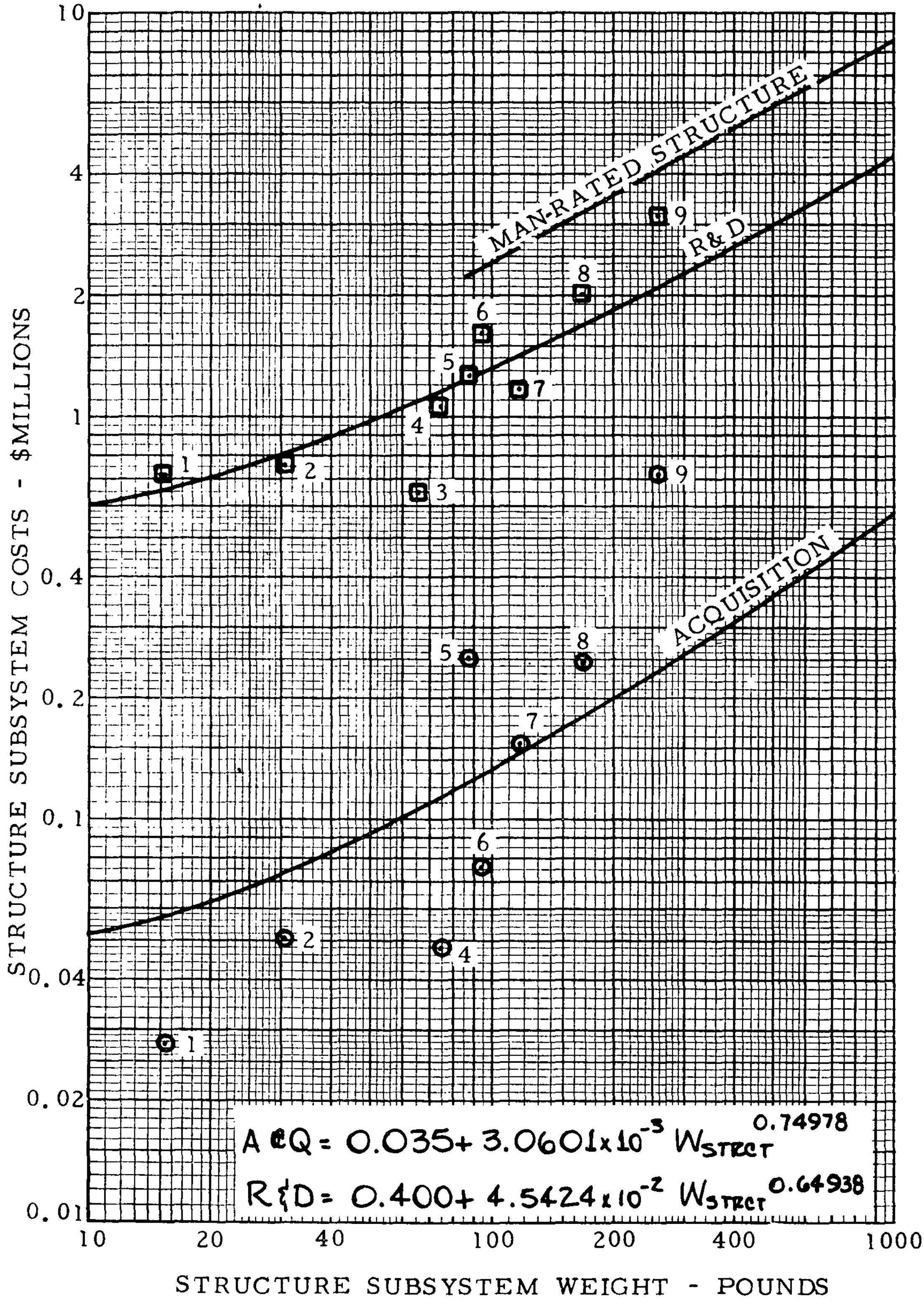


FIGURE D-62. STRUCTURE COST

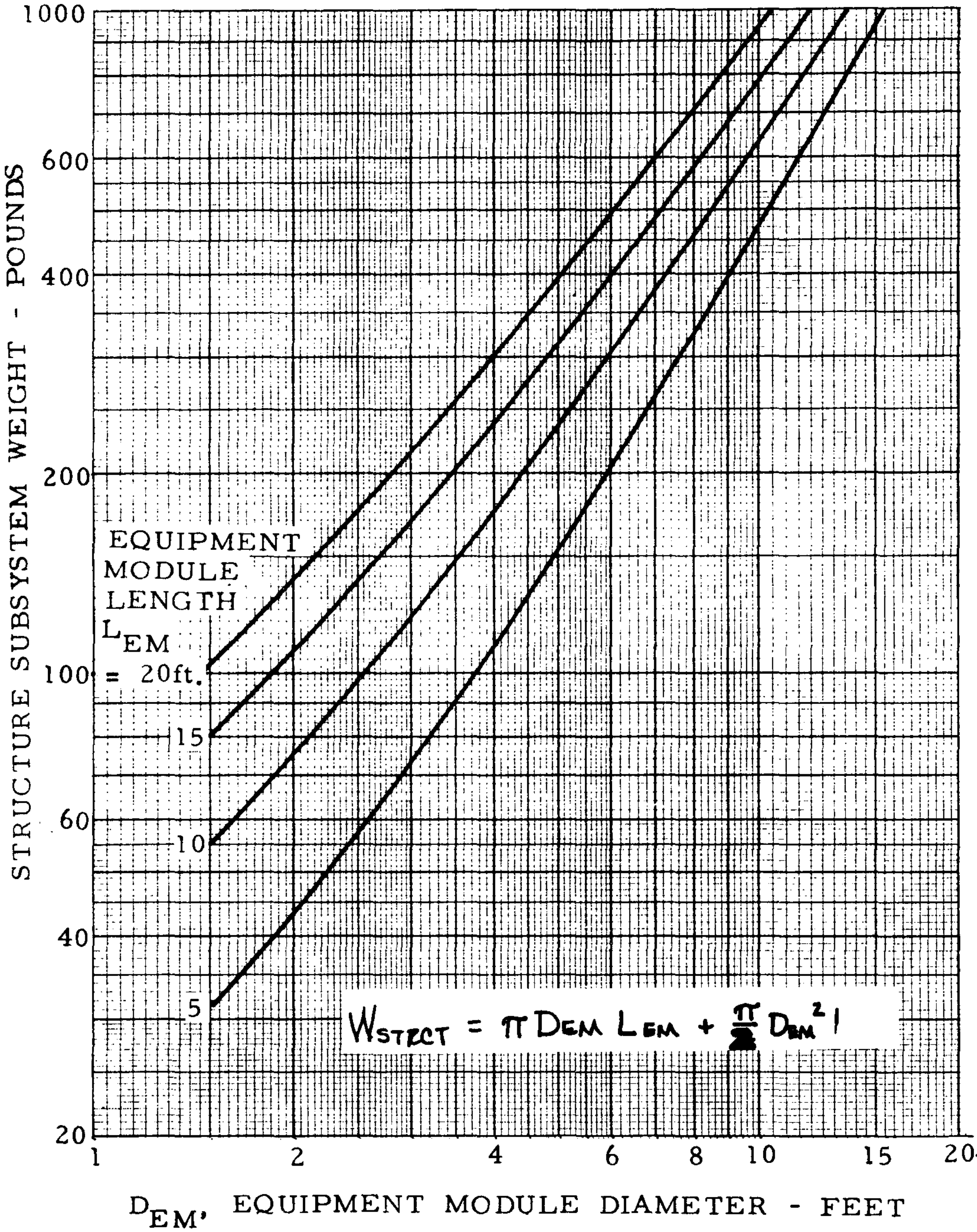


FIGURE D-63. STRUCTURE WEIGHT

Table D-4 Manned Provisions

Method	Cost, Missions Recurring	Nonrecurring	Power, watts	Weight, pounds	Volume, cu. ft.
MDA	1.8	24.9	3,000	6983	740
BSM	1.8	24.9	3,000	5500	740
Conventional	1.8	24.9	3,000	3200	740

This data is based on Convair experience.

D.21 Telemetry and Command Subsystem

The telemetry and command subsystems are required to meet a specific performance specification and not submitted to parametric analysis. The cost, weight, and volume contributions carried as constants ("through puts") in the total system. The information summarized briefly here is from Hughes Aircraft Company support to the television Broadcast Satellite Study.*

d.21.1 Telemetry Subsystem

A representative telemetry group consists of a redundant pair of central encoders and a number (approximately 70) of redundant remote multiplexers. The central encoder addresses each of the remote multiplexers in sequence and processes the telemetry data returning from them. The remote multiplexers are located near the TM data sources thereby reducing the system harness weight.

*Appendix A to Fifth Monthly Report, "Television Broadcast Satellite", June 16 to July 30, 1969, MSFC contract with Convair, NAS8-21036.

D.21.2 Command Subsystem

A representative command group consists of redundant command receivers, redundant demodulator/decoders, and eight sets of redundant remote decoders. The subsystem is capable of accepting a standard NASA Pulse Code Modulation (PCM) Instruction Command. The subsystem is completely redundant and capable of executing 512 pulse commands and 32 8-bit magnitude commands via redundant paths.

D.21.3 Telemetry and Command Input to System Synthesis

The previously described system yielded the values for the communications satellite synthesis given in Table D-5.

Table D-5. Telemetry and Command Subsystems

Subsystem	Cost, millions Recurring	Cost, millions Nonrecurring	Power, watts	Weight, pounds	Volume, cu. ft.
Telemetry			77	52	1.36
Command			11	18	0.43
Total	0.85	0.17	88	70	1.79

D.22 Other Significant Cost Elements

Designating the subsystems of Table D-6 form prime power to manned provisions as items 1-14 successively. The last five items are significant non subsystem cost elements that must be included in the total system cost. These costs are related to the subsystem costs by weighting factors determined by Convair's Economic Analysis Section of the Systems Analysis Group.

D.22.1 Prototype

This nonrecurring cost is taken as the sum of the acquisition costs of subsystem 2 through 14 plus 15% of item 1. This reduction in prime power represents partial implementation of the "high dollar" dolar cell arrays for prototype purposes.

D.22.2 Integration, Assembly and Checkout

This is a recurring cost for each flight article. It is weighted at 7.5% of the sum of the acquisition costs of subsystem items 1-14.

D.22.3 Design, Integration and Management

This is a nonrecurring cost taken as 50% of the sum of the engineering (R&D) costs for subsystem items 1-14.

D.22.4 Center Support

This cost is both recurring and nonrecurring. The recurring cost is used as 15% of the sum of the acquisition costs for subsystem items 1-14 and item 15.

D.22.5 Ground Support Equipment

This cost though related to item 15 for each spacecraft is provided for as nonrecurring cost item. It is weighted as 50% of the sum of the acquisition costs for subsystem items 1-14.

Table D-6. Satellite Subsystem Itemization

Satellite Subsystems	
Power Subsystem	Receivers
Prime Power	Structure
Secondary Power	Thermal Control
Conditioning	Station Keeping
Distribution	Attitude
Antenna	Telemetry and Command
Transmitter	Manned Provisions
Multiplexer	

D.23 Attenuation Model

The following attenuation model curves have been generated by Convair from various sources.*

D.24 Satellite Configuration Constraints

Each launch vehicle imposes constraints upon the physical characteristics of the payload. In addition to the weight and volume limitations, the diameter of the stowed payload and the selection of type of satellite antennas are dictated by the type of launch vehicle. These characteristics affect the selection of deployable or rigid antennas, the available moment arm for attitude control as well as the mounting for the solar array, i.e., the solar array may be mounted on booms if a large antenna cannot support an edge mounted array. The satellite constraints are given in the following table, D-7.

Table D-7. Satellite Configuration Constraints

Vehicle Type	Weight lbs	Volume ft^3	Diameter ft
SLV-3A/AGENA	550	250	5
SLV-3C/CENTAUR D-1/B-II	1650	1200	9
SLV-3X/CENTAUR D-1/B-II	2700	3000**	13
SLV-3X/CENTAUR 93 BURN)	1800	3000 **	13
TITAN IIIC	2600	4000	9
TITAN IIID/CENTAUR D-1T	7100	2800	9
SATURN V	52500	6000	20

*One major source is given as "Lectures on Communication System Theory", Elie J. Baghdady, 1961.

** With Proposed Viking Nose Fairing.

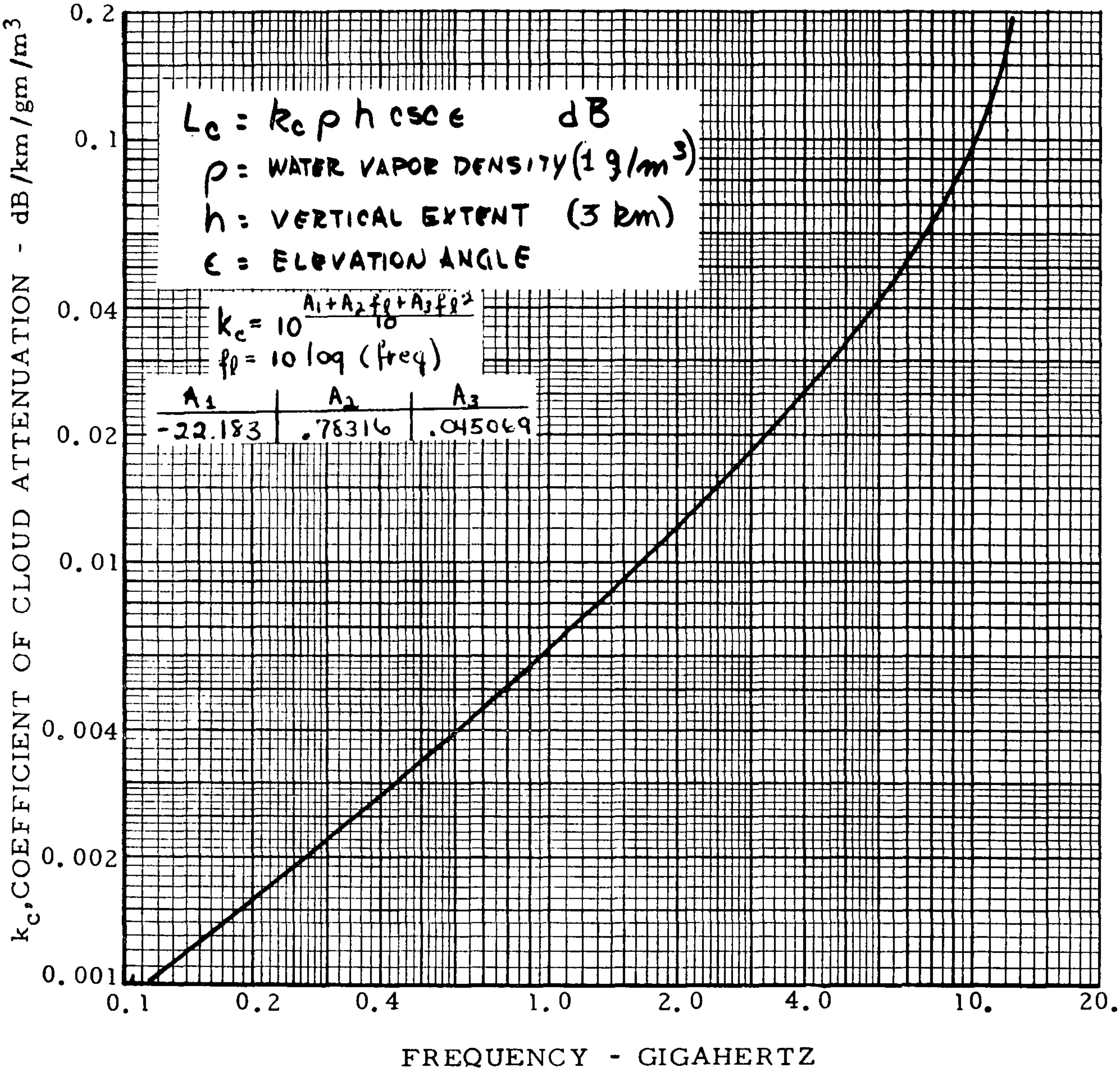


FIGURE D-64. ATTENUATION DUE TO CLOUDS

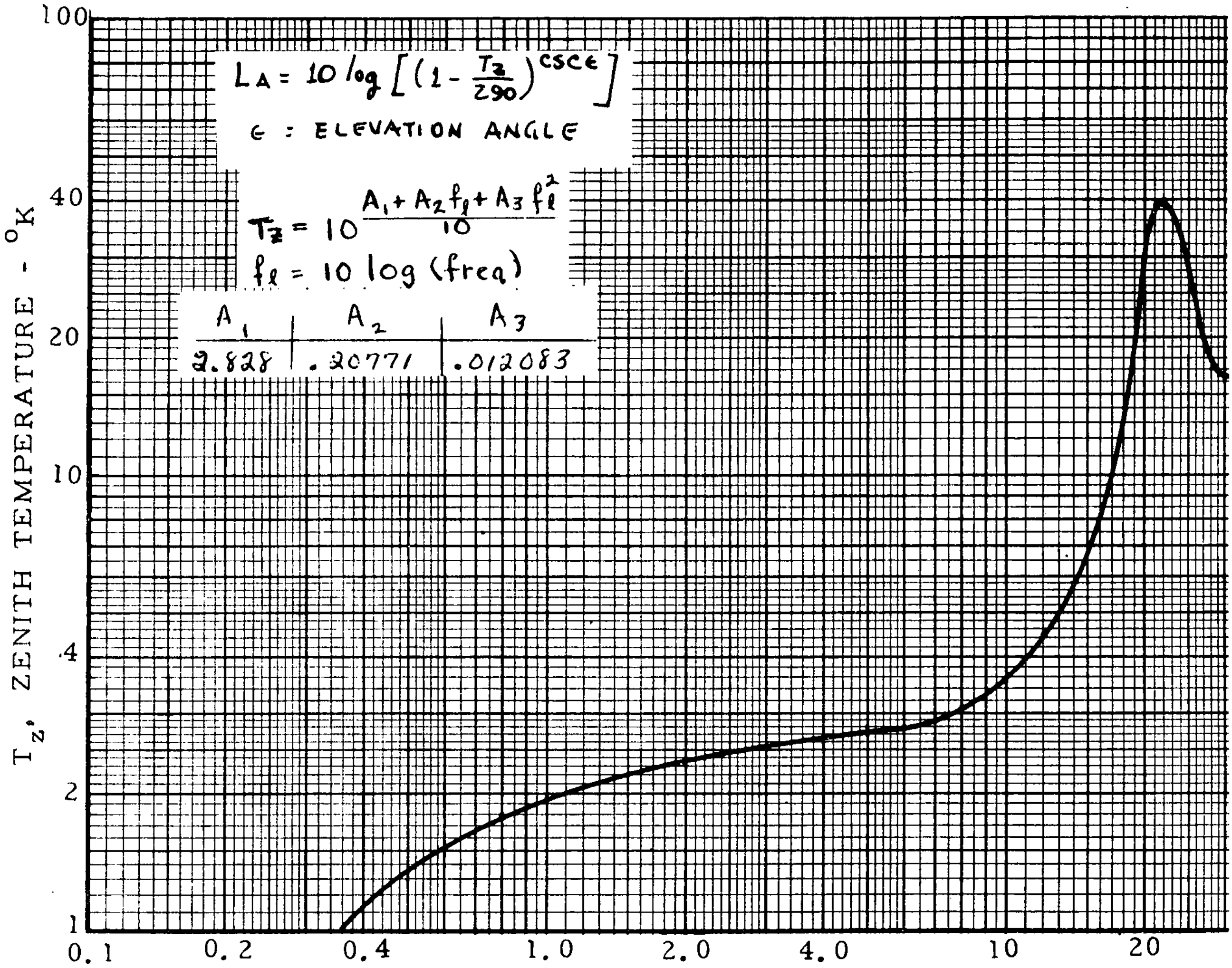


FIGURE D-65. ZENITH NOISE TEMPERATURE FOR ATMOSPHERE DUE TO WATER VAPOR AND OXYGEN

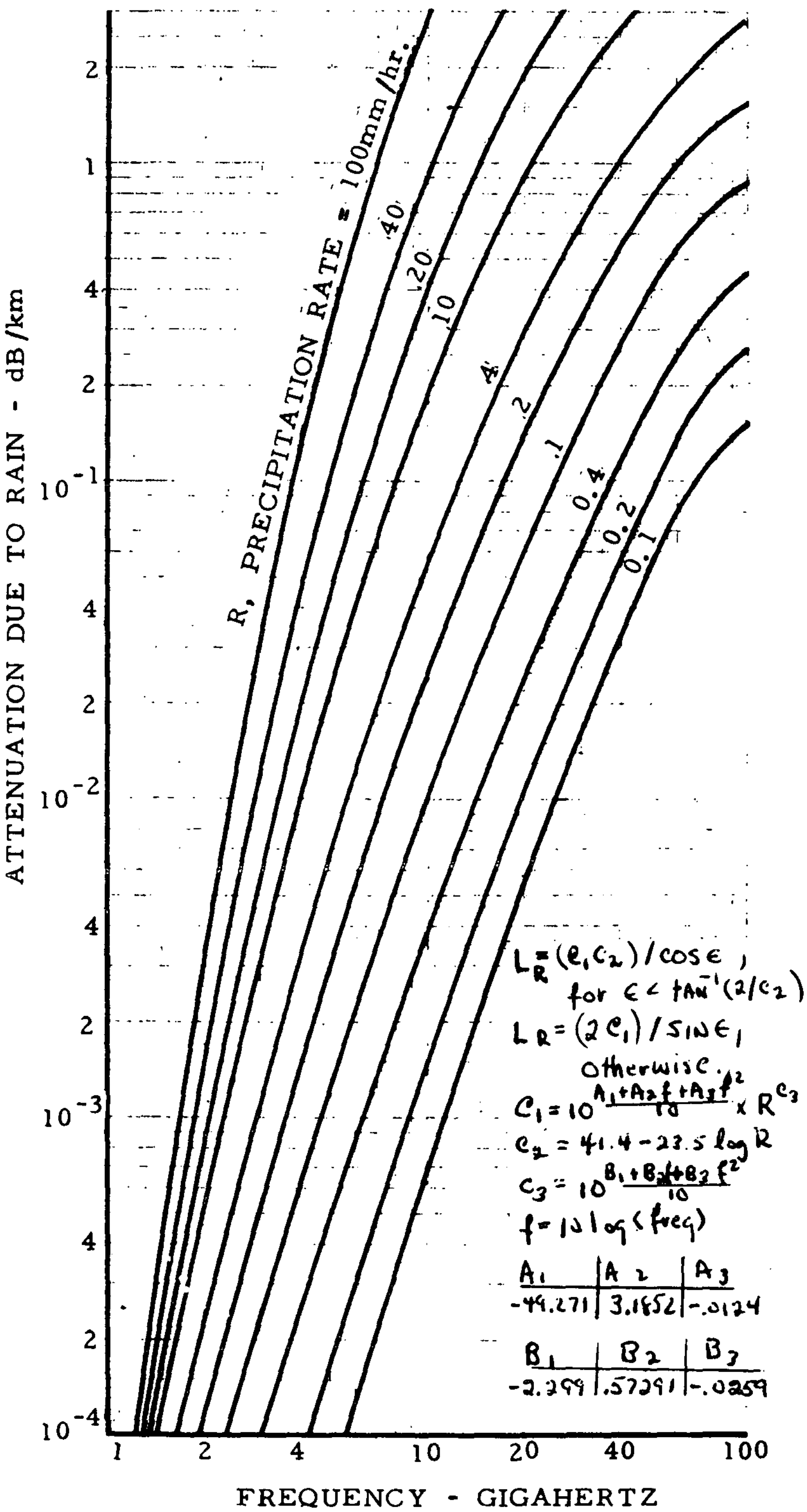


FIGURE D-66. ATTENUATION DUE TO RAIN

APPENDIX E

USER SYSTEM DEFINITIONS

E.1 TELECOMMUNICATIONS SYSTEM FOR ALASKA

The expansion of a terrestrial communications system within the state of Alaska has been hampered due to the extremes in topography and climate and the sparse population. Three rugged mountain ranges divide a state that spans over 2000 miles. Roughly one-third of its area is above the Arctic Circle.

The distribution of the population is shown in Fig. E-1. The southeastern one-fourth of the state has over three-fourths of the population. Of the roughly 450 communities only 24 have populations greater than 1000 as shown in the table of Fig. E-2. Of these 24 only 10 are larger than 2000.

The distribution of communities smaller than 1000 is also shown in Fig. E-2. A large portion of the population lives along the coast -- a coastline longer that that of the lower 48 states -- resulting in a shortage of communications within the interior.

The 7 commercial television stations serve the high population areas -- Anchorage, Fairbanks, Juneau and Sitka. Due to the absence of wideband channels to Alaska and the low population density, the only real-time television reception from outside the state was the Apollo XI mission and an demonstration transmission -- both via satellite. All outside programming is via film or video tape flown from the south 48.

A satellite system to fulfill the the telecommunications requirements for Alaska offers the advantages of short implementation time and uniform coverage regardless of geographic location within the state.

The following paragraphs represent three basic iterations system synthesis and analysis approach to define economical and feasible satellite configurations to satisfy the telecommunications requirements for Alaska.

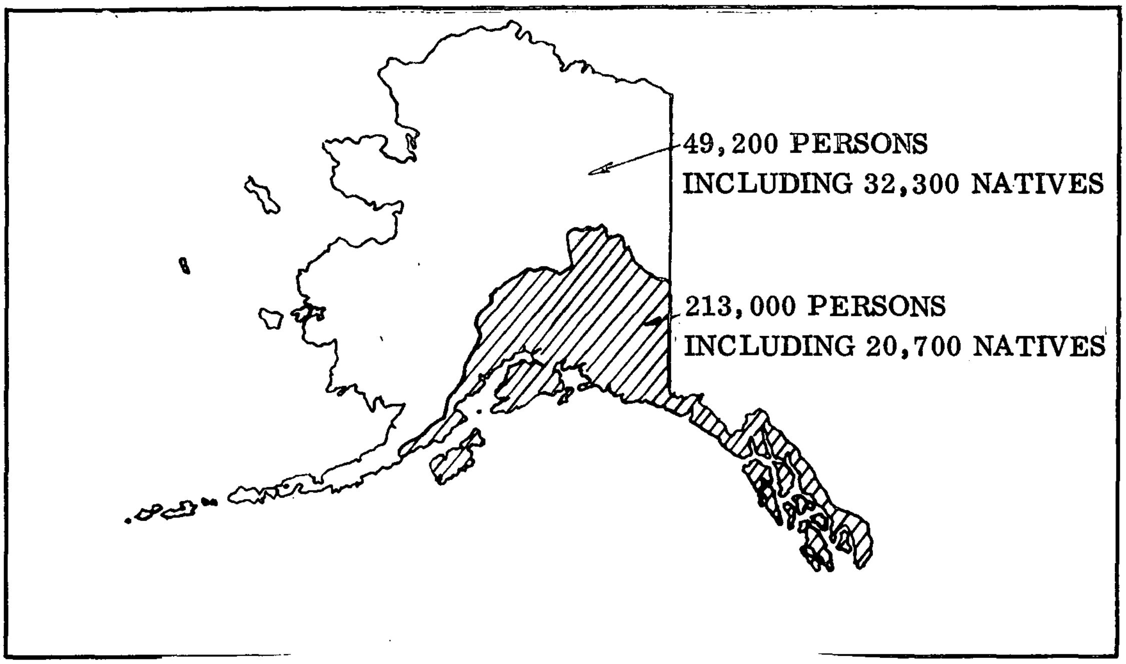


Figure E-1. Population Distribution for Alaska.

ANCHORAGE	45,000
SPENARD	17,000
FAIRBANKS	16,500
JUNEAU	5,900
KETCHIKAN	5,600
SITKA	3,800
KODIAK	3,500
COLLEGE	3,000
NUNAKA VALLEY	2,400
NOME	2,316
BETHEL	1,900
SEWARD	1,891
MT. EDGECUMBE	1,884
EAGLE RIVER	1,600
PALMER	1,600
DELTA JUNCTION	1,600
PETERSBURG	1,502
KENAI	1,500
WRANGELL	1,315
BARROW	1,314
LEMETA	1,300
KOTZEBUE	1,290
DOUGLAS	1,152
CARDOVA	1,128

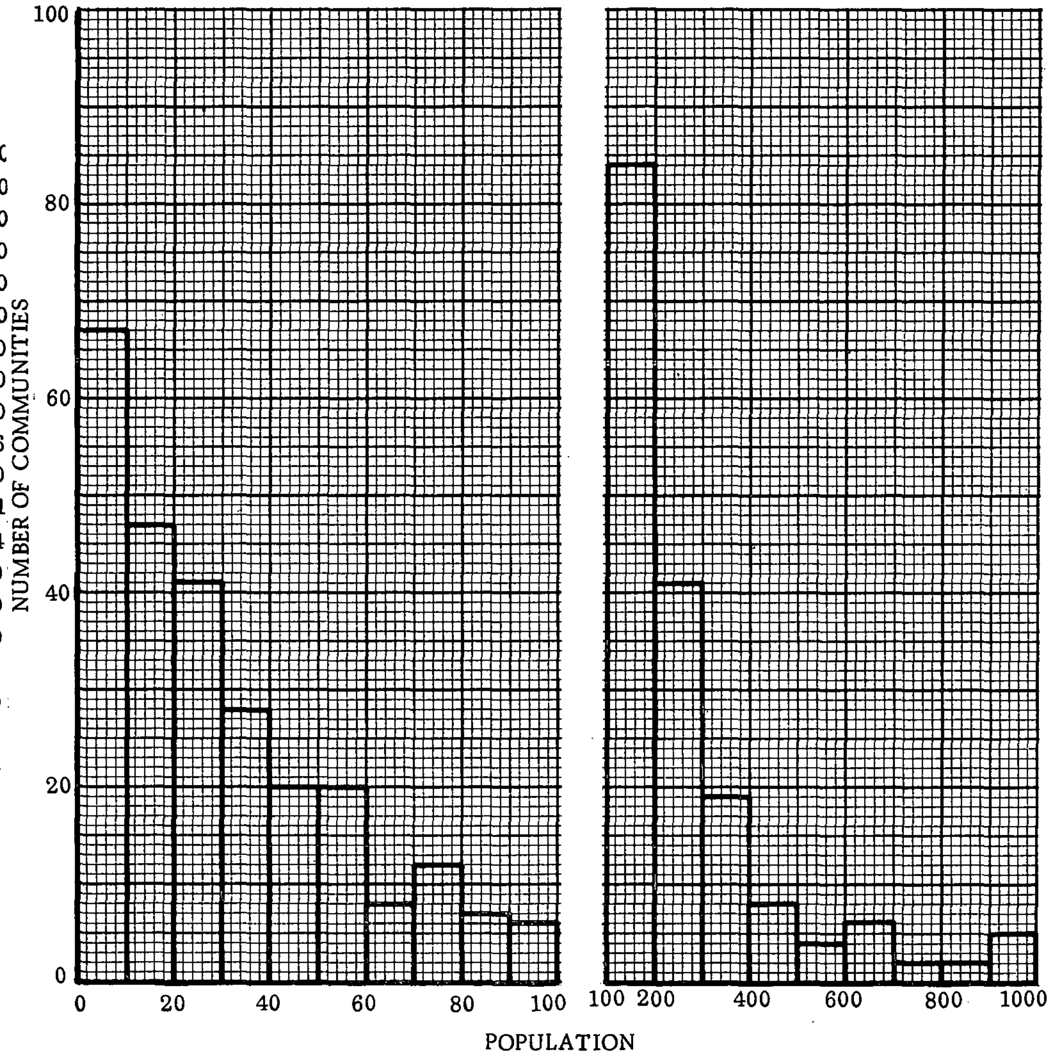


Figure E-2. Distribution of Population in Communities.

FIRST ITERATION:

Since the rocky mountain states of the south 48 have similar requirements and problems as the state of Alaska - i.e., sparse population and rugged terrain - the requirements of the two regions were combined in a first iteration baseline system. This baseline, shown in Tab. E-1 is only an approximation of the requirements and will be refined for further iterations.

Table E-1. Baseline System Description

SOURCE LOCATIONS

- VIDEO - 2 IN ALASKA
  - 8 IN MOUNTAIN STATES
- VOICE - 438 IN ALASKA

DESTINATIONS

- VIDEO - 438 IN ALASKA
  - 2,978 IN MOUNTAIN STATES
- VOICE - 438 IN ALASKA

SYSTEM DESCRIPTION

- 2 DOWNLINK BEAMS
- 11 VIDEO CHANNELS/BEAM
  - 8 INSTRUCTIONAL/EDUCATIONAL
  - 3 ENTERTAINMENT
- 1,200 VOICE CIRCUITS FOR ALASKA
- CCIR RELAY QUALITY
- COMMUNITY RECEIVERS FOR LESS THAN 100 POPULATION
- REDISTRIBUTION FOR GREATER THAN 100

For this system, there are two video uplinks in Alaska and one video uplink per state in the mountain states. In addition, each village in Alaska has telephone transmit/receive capability. The receiving systems are divided into two classes -- community receivers and redistribution systems. The community receivers, for villages of less than 100 in population, are housed in some central location for group viewing. For the larger communities a redistribution system is assumed, such as a CATV header, for distribution to individual households. The cost of the distribution system, however, is not included in this analysis. The division of the system is as follows:

	ALASKA	MOUNTAIN STATES
COMMUNITY	268	1152
REDISTRIBUTION	170	1826
TOTAL	438	2978

The service was synthesized for four frequency bands: 0.8, 2.5, 8.4 and 12.2 GHz (see Fig.E-3). The system shown assumed that each community in Alaska has its own telephony uplink/downlink facility. The major uplink/downlink facilities costs represent Alaskan communities with populations greater than 100 with redistribution capability to individual homes. The minor uplink/downlink facilities offer community receivers with distribution for communities of population less than 100. Similarly, the Mountain States major distribution facilities are for greater than 100 populations and the minor facilities are for community receivers, less than 100. Since the ground transmission/reception facilities are such a large portion of the system cost, the minimum system cost minimizes at the frequency where the ground receivers are least expensive -- 0.8 GHz. The satellite cost at 8.4 and 12.2 GHz levels off at $7 million per year, since the satellite is bounded by the launch vehicle payload capability of 7,100 pounds.

The system was then configured with 3 uplinks in Alaska and an interstate telephone facility in the Mountain States beam to augment Alaska's communications service with the south 48.

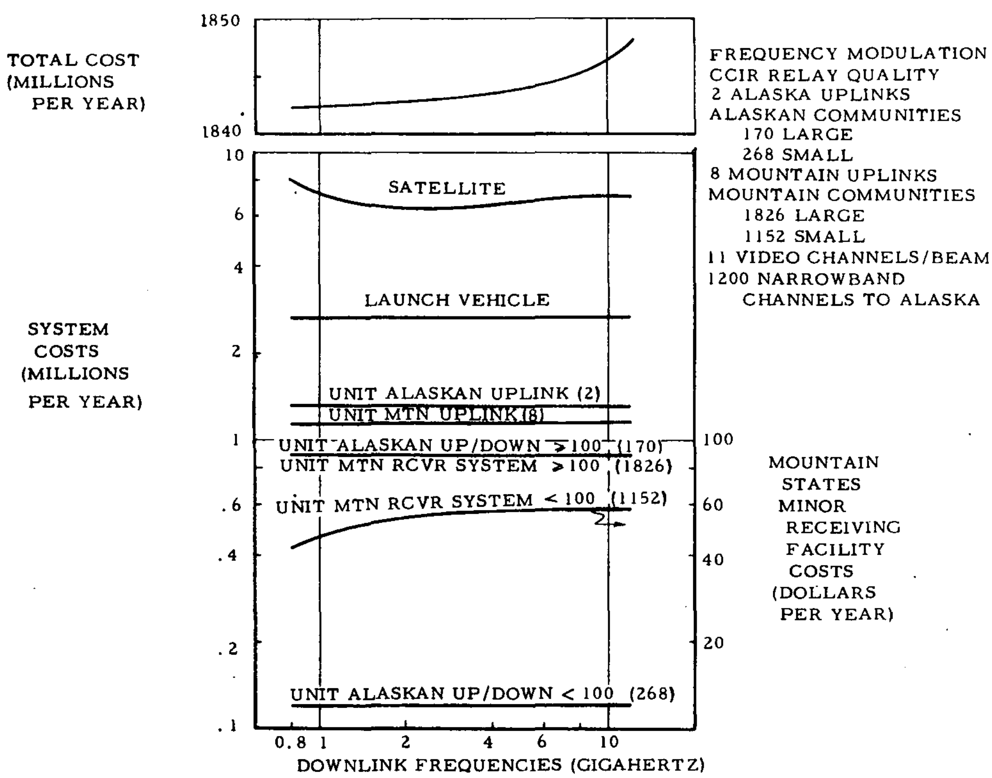


Figure E-3. System Cost Sensitivity to Frequency

The number of video channels was varied for the baseline system of 438 facilities in Alaska and 2978 in the Mountain States while holding the telephony capability constant, as seen in Fig. E-4 As expected, the cost increases more rapidly in the mountain states systems with respect to Alaska cost. This is due to the almost constant costs of the telephone equipment in the Alaskan facilities.

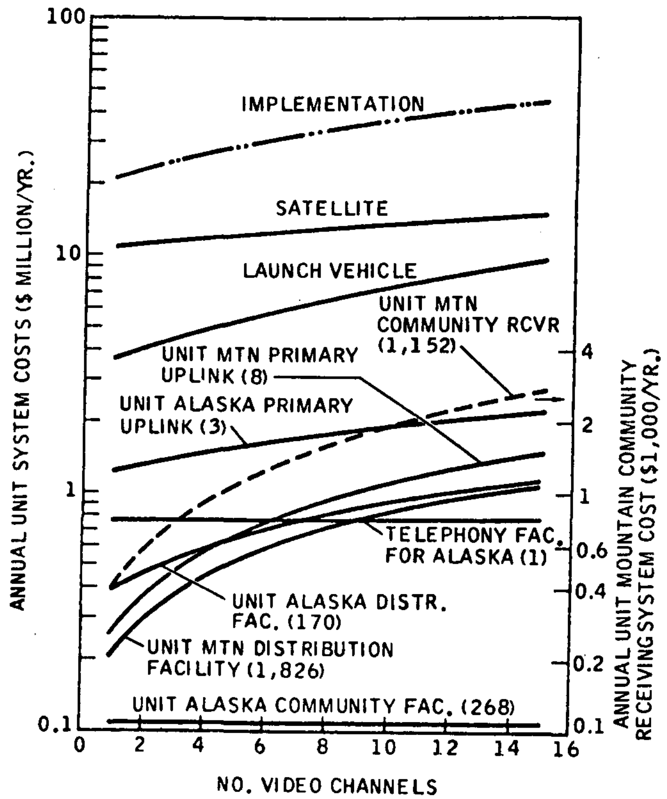


Fig. E-4. Sensitivity of Unit System Costs to Number of Video Channels (complete system)

A distinction should be made between total system cost and implementation cost. Implementation cost refers to the assumed governmental expenses and includes the following cost items: the satellite, the launch vehicle, the primary uplinks, and the interstate telephony facility. Receiver costs would be a function of the local villages or users. Total system cost refers to the cost of the entire communication system.

The sensitivity of the ground facility subsystems to the number of channels can be analyzed in Fig. E-5. For a system of 170 distribution facilities in Alaska the annual total facility cost varies from $0. 6 to $1. 3 millions per year. As can be seen, the personnel and maintenance costs predominate. The miscellaneous costs include the building, stand-by power, installation, integration and checkout.

Fig. E-6 illustrates the variation in unit systems costs as a result of perturbing the number of ground systems. As the number of ground systems are increased in both Alaska and the Mountain States simultaneously, the unit facility cost decreases as expected as a result of production cost reductions and of tradeoffs between the uplinks and downlinks.

The difference in cost in the primary Alaska uplink and the unit mountain uplink is due to the telephone capability in the Alaskan facility.

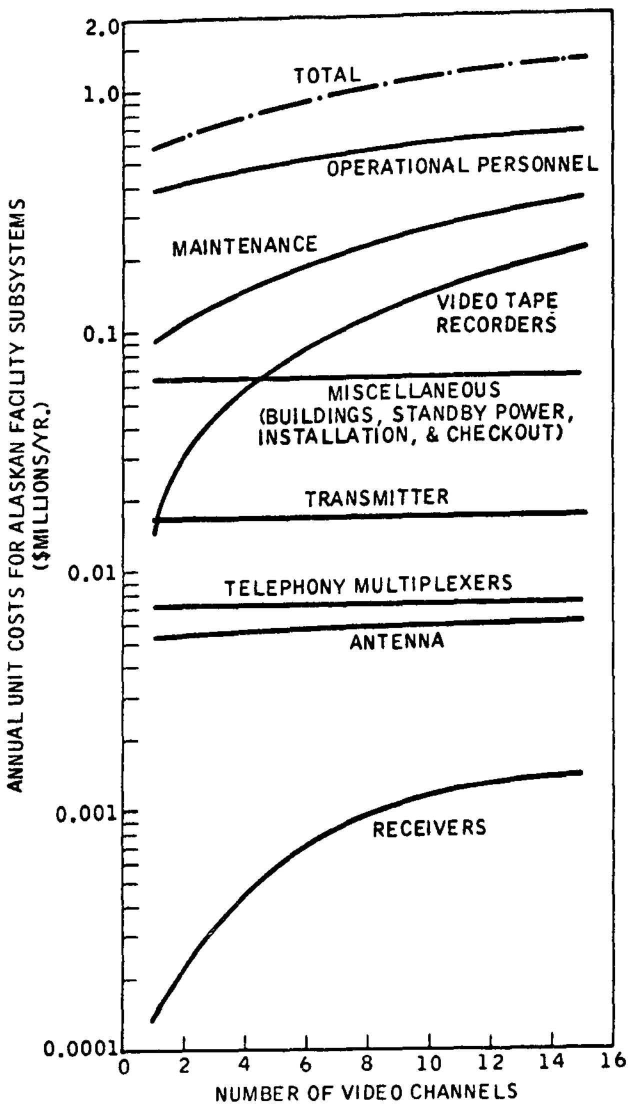


Fig. E-5 Sensitivity of Alaskan Facility Subsystems Unit Costs to Number of Video Channels

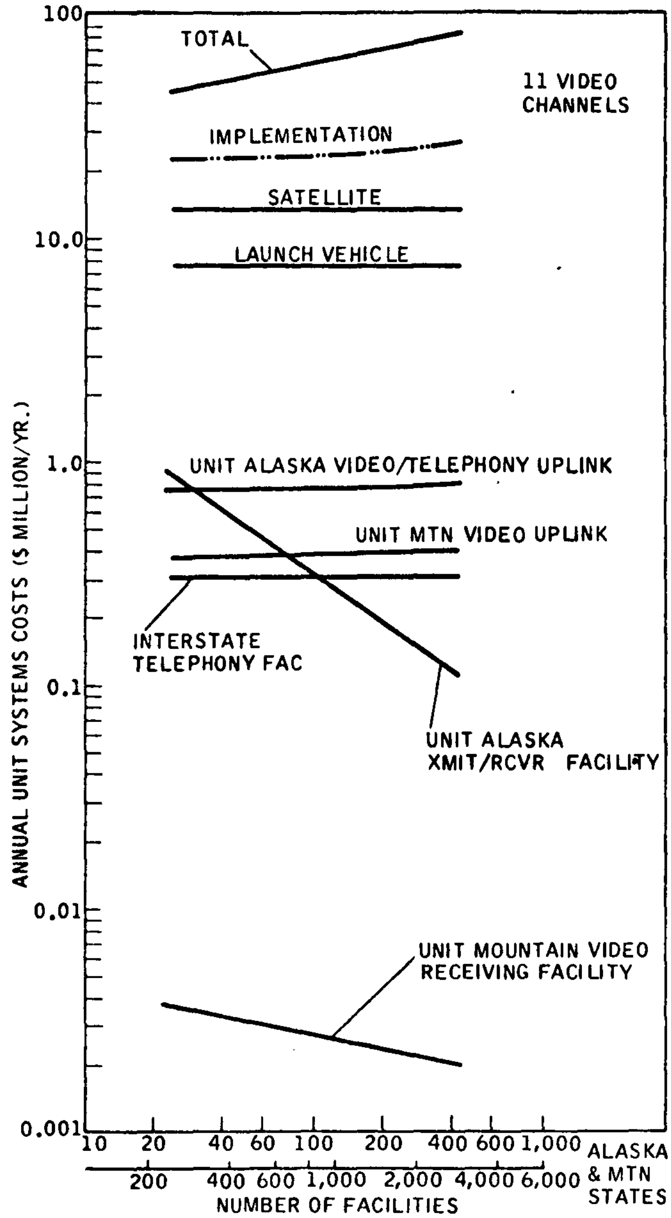


Fig. E-6 Sensitivity of Unit System Costs to Number of Ground Facilities (Considering Only Antenna, Transmitter & Receiver in Ground Facilities)

Additional synthesis runs were performed for an Alaskan Television system. The baseline system is as follows:

SOURCES: 2 ANCHORAGE
JUNEAU

DESTINATIONS: 438

SYSTEM DESCRIPTION:

1 DOWNLINK BEAM

11 VIDEO CHANNELS/BEAM

8 EDUCATIONAL/INSTRUCTIONAL

3 ENTERTAINMENT

C.C.I.R. RELAY QUALITY

As an example of the tradeoffs between the receiving systems and the satellite, the costs are plotted as a function of the number of ground receiver distribution systems, in Fig . E-7. As the number of receiver increases, the tradeoffs among the independent parameters are seen. The receiver facility costs do exhibit a decrease; however, it is overwhelmed by other invariant costs as can be seen in the next figure.

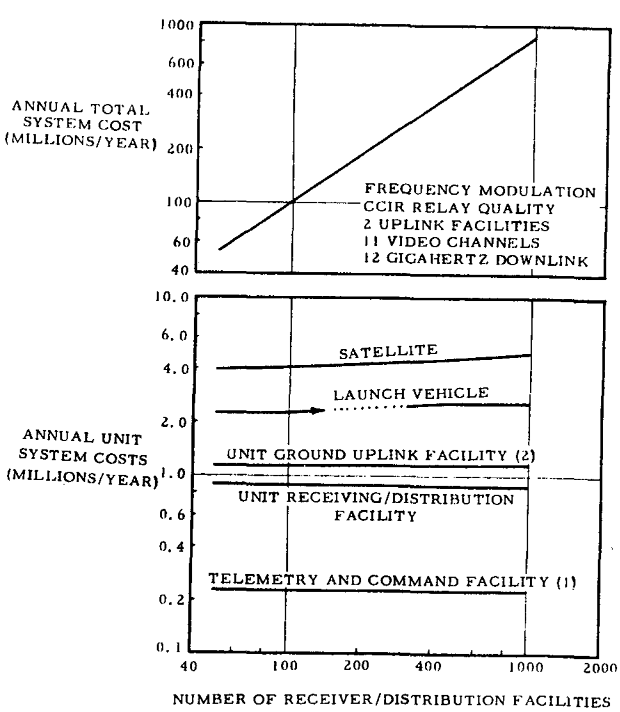


Fig. E-7. System Cost Sensitivity to Number of Facilities

The unit receiving/distribution system costs were broken out as in Fig. E-8. to illustrate the makeup of the system. The operations personnel, maintenance, video tape recorders, and facility costs are not dependent upon the design parameters and do not affect the optimization process. The miscellaneous costs include test equipment and integration, and checkout and management of the facility. The decrease in receiver and antenna costs are due partly to mass production techniques and the tradeoff between design parameters.

The number of downlink channels was perturbed at 12.2 GHz and 438 receiving facilities in Fig. E-9. As expected, the total system cost shows a pronounced increase of $300 million per year. This, of course, is due to the increased receiving system cost. The launch vehicle costs change from Atlas/Agena at one channel to a Titan IIID/Centaur at 11 channels. The dotted lines indicate that somewhere between data points a larger launch vehicle is required.

The distribution costs in the receiving system is shown in Fig. E-10. The increased channel capacity requires increases in all subsystems. The tradeoffs among independent design parameters, however, minimizes the changes in the antenna and the receiver costs. If only the antenna and receivers are required the costs would range from 1 to 2 thousand dollars per year.

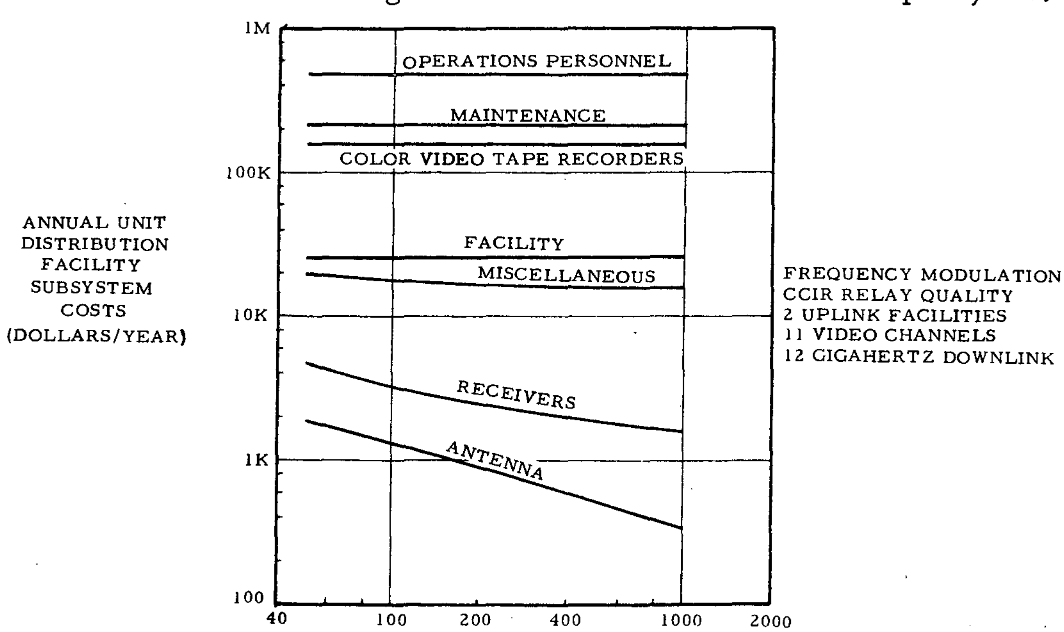


Fig. E-8. Distribution Facility Subsystem Cost Sensitivity to Number of Facilities

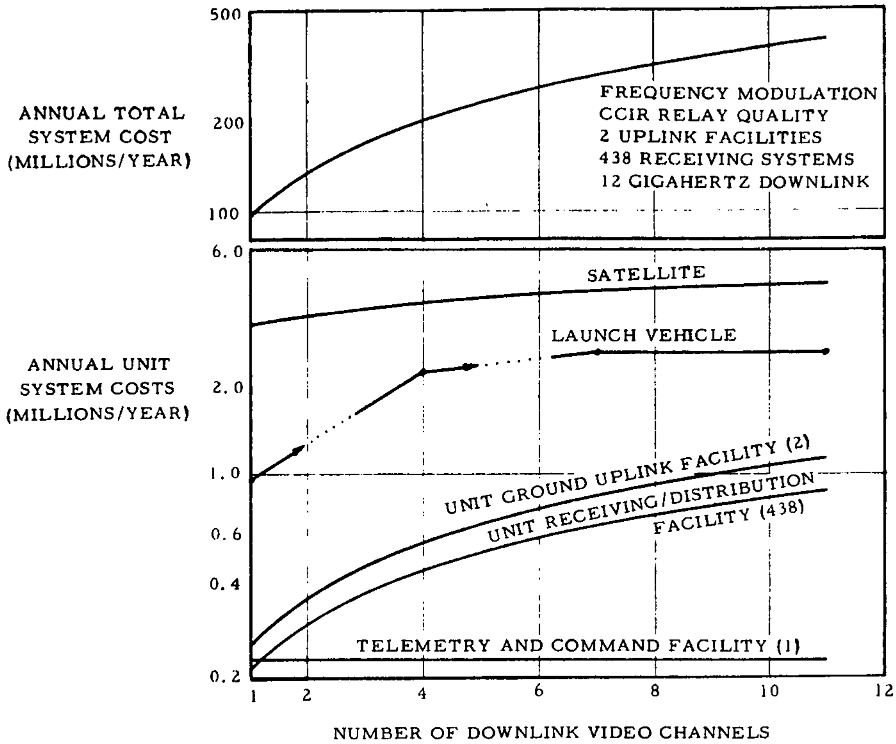


Fig. E-9 System Cost Sensitivity to Number of Video Channels

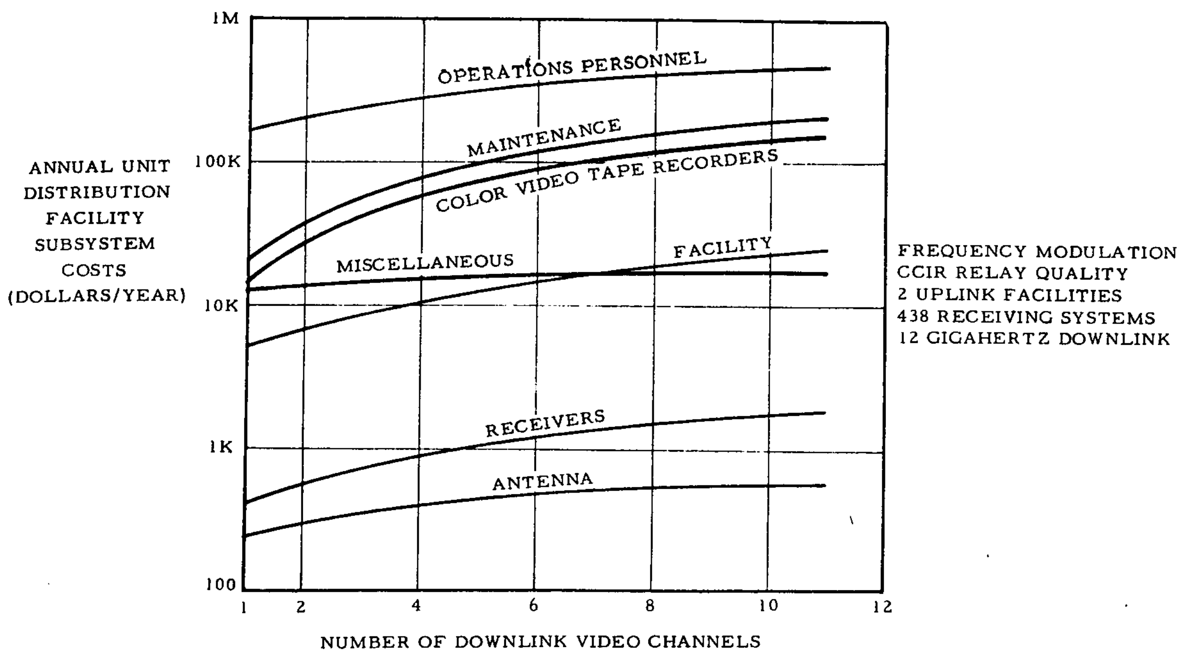


Fig. E-10. Distribution Facility Subsystem Cost Sensitivity to Number of Video Channels

SECOND ITERATION:

In response to a Department of Commerce request, the synthesis program was modified to accommodate 4 classes of ground stations to perform an analysis of a satellite system for Alaska. This analysis was to be a part of the D.O.C. input to the Public Service Commission hearings on Alaskan Telecommunications Requirements scheduled for June 1970.

The communications system is composed of four classes of ground stations whose characteristics are shown in Tab. E-2. The three class 1 stations transmit and receive up to three video channels. The remaining classes have receive-only capability for video but transmit and receive capability for telephony as shown in the table. The system topology requires that all telephony be routed from the lower three classes of stations through a class 1 station where appropriate switching is to be accomplished before traffic is retransmitted through the satellite to the desired destinations. While this increases the RF bandwidth and the channel capacity of the satellite and the class 1 stations, this permits less complexity in the lower classes. However, a received signal-to-noise ratio of 50 dB is required at the class 1 station regardless of source or destination.

Tab. E-3 describes the channel requirements for each class of station and the satellite for implementation of this system.

To investigate sensitivities to total system cost, the number of class 3 and class 4 stations and the number of video channels were perturbed from their nominal values. Fig. E-11 illustrates the results of perturbing the number of stations in the two lower classes, while Fig. E-12 illustrates the effect of increasing the number of video channels.

Tab. E-2 Ground Station Characteristics

Station Class	Station Environment	Number of Stations	Telephony No. of Circuits	Telephony Signal - To-Noise	Video No. of Channels RCV	Video No. of Channels XMIT	Video Signal-To - Noise
1	Max Urban	3	240	50 db	1 to 3	1 to 3	54 db
2	Urban	8	120	50 db	1 to 3	—	54 db
3	Suburban	25 - 50	24	45 db	1 to 3	—	44.5 db
4	Rural	142 - 250	1	30 db	1	—	30.00 db

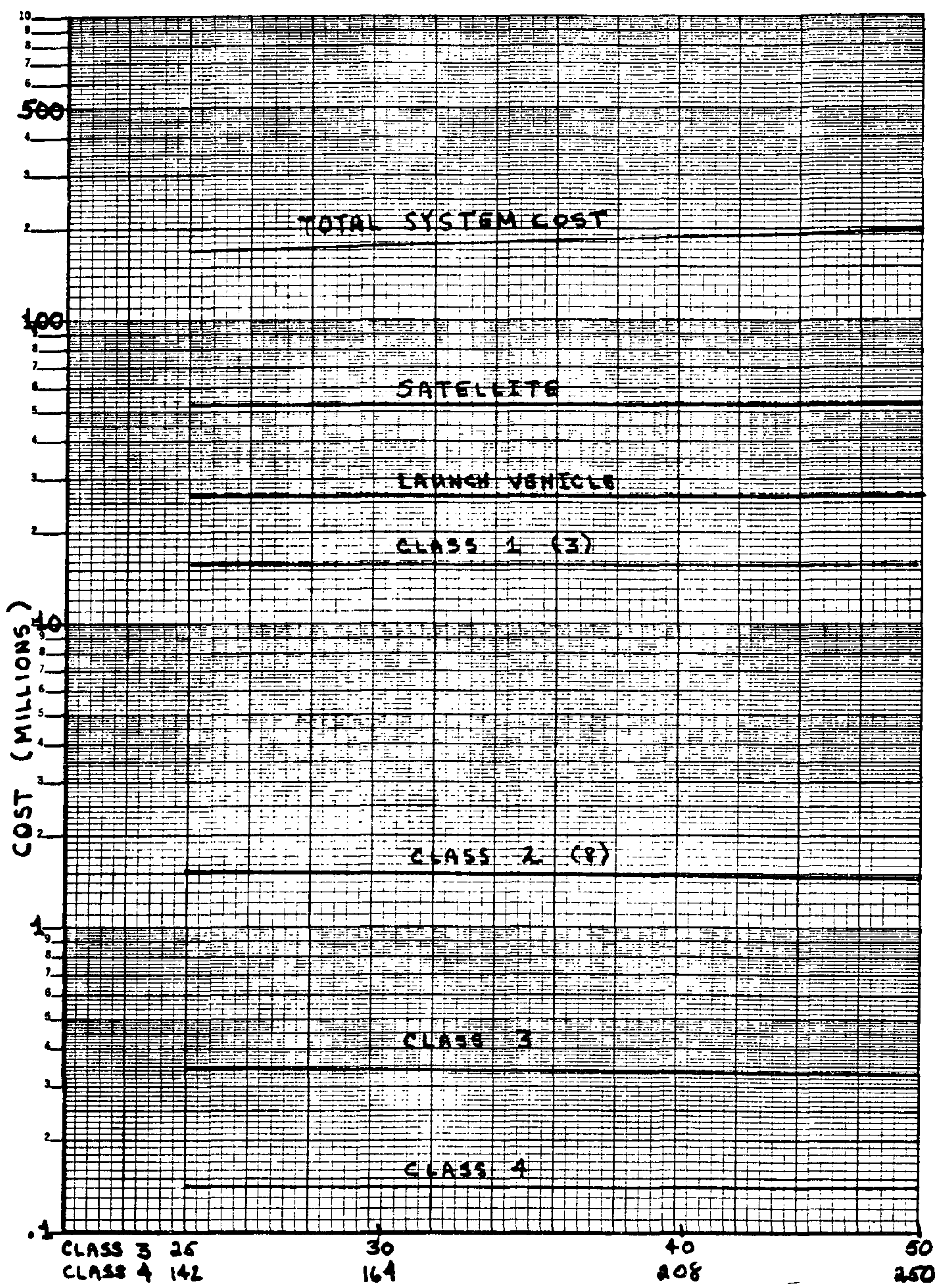


Figure E-11. Cost vs. Number of Stations

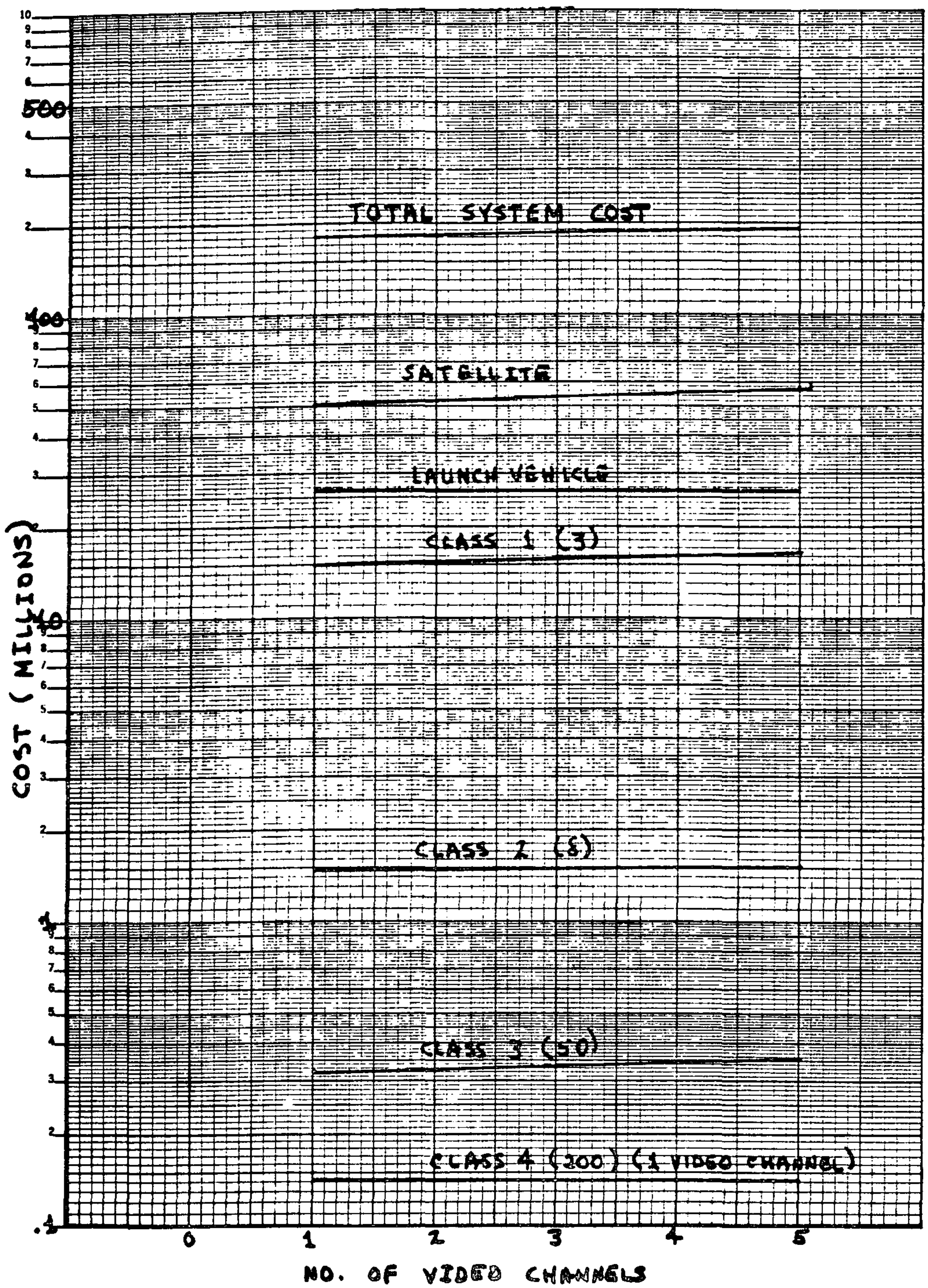


Figure E-12. Cost vs. Number of Video Channels

Tab. E-3. Channel Requirements

Class of Station	No. of Telephony Circuits
1	800
2	120
3	24
4	1
Satellite	2380

The assumed launch vehicle is a Titan 3C/Centaur having a total payload constraint of 7,100 pounds. The minimum cost satellite configuration for implementation of the system results in a weight requirement of approximately 50% of the limit or 3,200 to 3,700 pounds over the range of the perturbed synthesized systems, a large percentage of the weight being due to the number of transmitters required for routing the traffic. This is especially true since transmitter lifetime is assumed to be 2 years requiring redundant blocks of transmitters over the 10 year total system life. An ion propulsion system is employed for station keeping and attitude control. See Fig. E-13.

Signal quality for the two major classes of station is C.C.I.R. (54 db). Signal quality for class 3 and class 4 stations is taso grade 1 and taso grade 3 respectively. Taso grade 1 assumes a S/N of 44.5 db and taso grade 3, a S/N of 30 db.

The minimum cost system, as expected, finds the major unit ground system cost in the class 1 stations, with each of these costing approximatley $15 M/yr. while the class 2 are $1.5 M/yr. and the lowest two are $.3 M/yr. and $.14 M/yr. respectively. This is due to the stated relative complexity of the class 1 station over those in the remaining subclasses. Since the number of class 1 stations and class 2 stations is fixed at 3 and 8 respectively, small perturbations in the quantity of suburban and rural class stations about the nominal of 50 and 200 provide only small changes in total system cost.

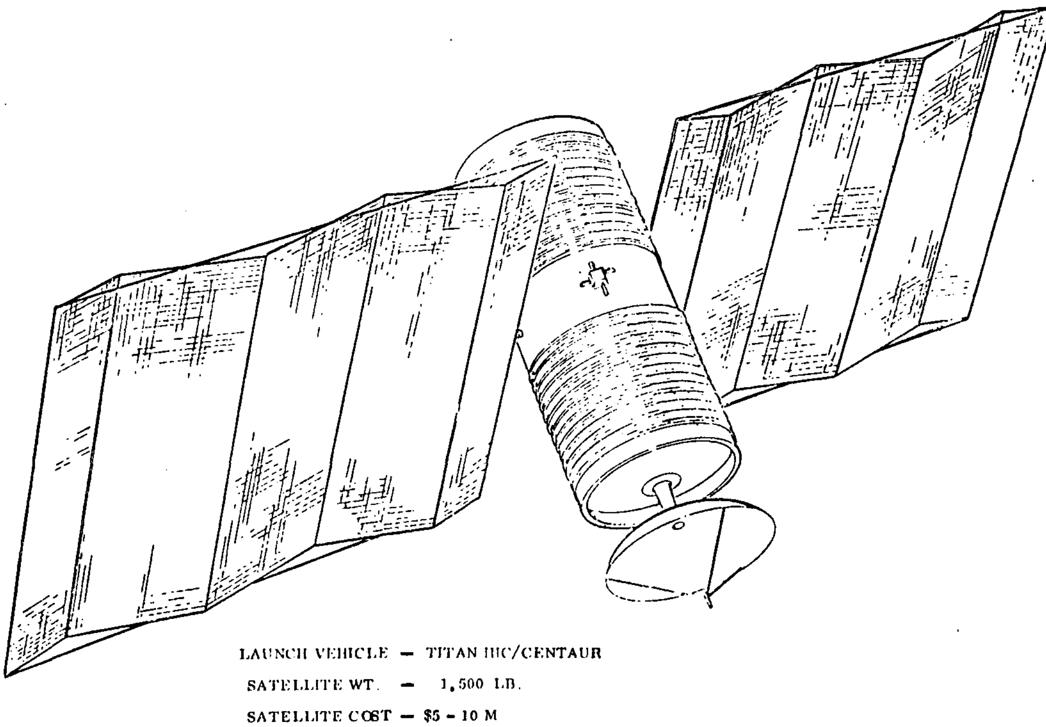


Fig. E-13 Alaska Preliminary Satellite Configuration

Comparing the case of 25 class 3 and 142 class 4 to the case of 50 class 3 and 250 class 4 stations, the increase in total system cost is approximately $2.3 M/yr. relative to a total annual cost of $17 M/yr. The satellite remains essentially the same while the decrease in ground facility cost is slight since the total system cost is in general, insensitive to the perturbation in the number of suburban and rural stations. Even for the maximum case, just mentioned, the cost of the maximum, and suburban stations outweighs that for the lower.

Similar results are obtained by perturbing the number of video channels. The class 1 stations remain the chief contributor to total system cost and therefore reflect the largest change in cost.

The system cost summary for the nominal case of 3 video channels, 50 class 3 stations and 200 class 4 stations is given in Tab. E-4.

Table E-4. System Cost Summary

	Class 1	Class 2	Class 3	Class 4	Satellite	Launch Vehicle	Total
No. of Stations	3	8	50	200			
Unit Costs:							
Initial	\$ 8.43M	\$758K	\$157K	\$ 68K	\$15.6M	\$21.0M	
Annual	.72M	73K	18K	7K	38.1M	5.4M	
Total/Station (10 years)	\$15.64M	\$ 1.49M	\$338K	\$141K	\$53.6M	\$26.4M	
Total System (10 years)	\$46.92M	\$11.78M	\$16.95M	\$28.20M	\$53.6M	\$26.4M	\$186.2M*

*Includes \$2.29M Telemetry/Command Subsystems in one class 1 station.

THIRD ITERATION

Additional runs were performed for the Public Service Commission hearing on the Alaskan Telecommunications Requirements as itemized in Tab. E-5. This configuration was constrained to a two transponder satellite with the four classes of stations. One transponder handles the traffic between classes 1, 2, and 3 while the second transponder carries one video channel and 80 voice circuits for the bush stations. As in the previous iteration all bush communications is routed through the class 1 station. Similarly the signal quality received at the class 1 station is relay quality regardless of source or destination. The system characteristics of the minimum cost station for these requirements are given in Tab. E-6.

The system was then constrained to Intelsat IV parameters of 42 foot antennas and a G/T of approximately 32 dB/°K for the larger three station classes and a G/T of approximately 27 dB/°K for the bush stations. The characteristics of this system are shown in Tab. E-7. A comparison of the two systems illustrates the trade-offs between the ground stations and the satellite. The cost of the satellite for the constrained case is 12% less than the unconstrained case while the ground station cost increases vary from 37% to 160%. The constrained total system cost (excluding the launch vehicle) exhibits an increase in cost of 77% from the unconstrained.

Tab. E-5. Ground Station Characteristics

Station Class	No. of Stations	Telephony		Video		
		Circuits	S/N	XMIT	REC	S/N
Class 1	1	120 from 2, 3 20 from bush	50 dB	1	1	52 dB
Class 2	4	48	50 db	0	1	52 dB
Class 3	5	24	50 dB	0	1	52 dB
Class 4	250	1	45 dB	0	1	47 dB

Table E-6. System Characteristics (Unconstrained)

	Units	Class I	Class II	Class III	Bush	Satellite	Launch Vehicle
EIRP	DBW	54.1 Voice	54.1	54.1	42.4	60.4 (Video + Voice)	
		29.4 Bush 75.4 Video				45.0 (Voice)	
G/T	dB/°K	13.2	13.2	13.2	8.3	5.7	
Antenna Diameter	ft	15.5	15.5	15.5	8.7	6.1	
RCVR Noise Figure	dB	7.1	7.1	7.1	7.1	6.0	
Costs-Initial	$	1.24M	370K	180K	76K	7.0M (Unit Sat)	21.0M
Annual	$/yr	218K	32K	19K	9K	25.7M (R&D)	5.4M
Weight	Lbs	——				1530 /Sat)	
Total Unit Costs (10 Years)	$M	3.42	0.69	0.37	0.16	39.71	26.4
No. of Stations		1	4	5	250	2	1
Total Costs (10 Years)	$M	3.42	2.77	1.86	40.25	39.71	26.40
Total System Costs (10 Years)	$M	114.41					

Table E-7. System Characteristics (Constrained)

	Units	Class I	Class II	Class III	Bush	Satellite	Launch Vehicle
EIRP	dBW	56.6 Voice	56.6	56.6	44.9	41.9 (Video+Voice)	
		47.6 Bush 77.9 Video				26.5 (Voice)	
G/T	dB/^{o}K	31.7	31.7	31.7	26.7	2.5	
Antenna Diameter	Ft	42	42	42	23	3.3	
RCVR Noise Figure	dB	0.7	0.7	0.7	0.7	6.0	
Costs-Initial	$	1.78M	710K	440K	190K	6.2M (/Sat)	11.40M
Annual	$/yr	292K	73K	50K	23K	22,5M (R&D)	18.5M
Weight	Lbs					890 /Sat	
Total Unit Costs (10 Years)	$M	4.70	1.44	0.94	0.42	34.9	29.90M
No. of Stations		1	4	5	250	2	1
Total Costs (10 Years)	$M	4.70	5.74	4.72	105.7	34.9	29.90
Total System Costs (10 Years)	$M	185.7					

E.2 SPACE SYSTEMS SUPPORT

E.2.1 EXPERIMENT MODULE REQUIREMENTS — The following are the NASA guidelines and constraints for the Space Station program that have major impact upon the communications system:

1. A data relay satellite system (DRSS) will be operational.
2. Ground operational support includes Manned Space Flight Network tracking and communications activity.
3. The crew of the space station will be responsible for the evaluation and editing of raw data to delete non-significant information, onboard data processing and data reduction as required, and assignment of transmission priorities and modes.
4. Space Station communication subsystems shall be designed in accordance with:
   a. Provision of transmission paths through data relay satellites to ground.
   b. Multiple voice channels and two-way television.
   c. Broad band experiment data transmission capability.
5. Experiment modules which operate in the free-flying mode and do not require the frequent attention of man for operations should have the capability of command and control by a station or logistics spacecraft and from the ground and of data transmission directly to the ground as well as to the space station.

An over-all systems block diagram, which is consistent with the guidelines and constraints listed, is shown in Figure No. E-14 to show the flow of commands and communications (including data).

Requirements to be satisfied by the relay satellite are represented by the lines connecting to the block representing the DRSS. The solid lines represent the flow of communications and data. The requirement for two-way TV capability (assumed to be of broadcast quality) will require wide-band channels. Also, there is a mass of data generated by the experiments to be conducted in the Space Station Program. The candidateFunctional Program Elements (FPE's) that currently comprise the Experiment Program are listed in Table E-8. In the case of the FPE's marked +,

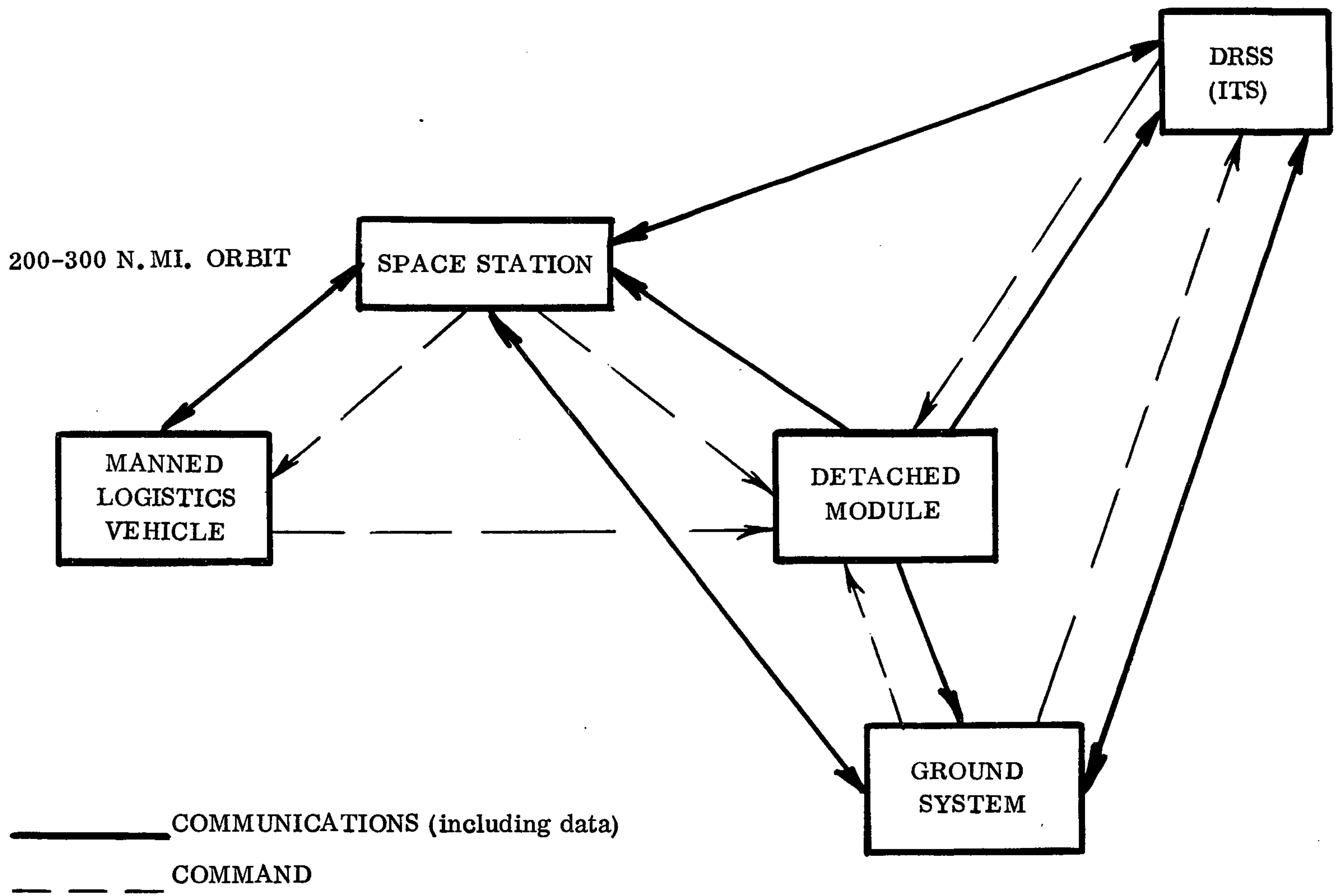


Figure E-14. Space Station communication and command links.

detached modules are involved and the requirement for a capability to communicate directly to the ground will prevent the use of any data management capability aboard the space station. Unless data management capability is provided aboard the module, the DRSS will require the capability of handling the entire experiment data output. The FPE's marked 0 are suitcase experiments meaning that they will be distributed on, or in, the modules provided for other FPE's. At present their allocation to an attached or detached module is not known.

At present the data output characteristics of all the FPE's is being examined and tabulated. The end objective is to construct a time-line vs raw data rate for each FPE. When these are all added, the composite data rate vs time-line will represent the maximum data transmission requirement for the DRSS. Aided by definition studies on the Experiment Modules and the Space Station itself, an evaluation of the data processing to be done in-orbit can be made. This in turn will permit a realistic evaluation of the requirements that the DRSS must satisfy.

The data rates required for commands is negligible compared to the rates required for the experimental data.

Table E-8. Modular Disposition of FPEs for Task II of Experiment Module Study.

FPE NO.		IDENTIFICATION	MODULAR DISPOSITION
5.1	+	X-Ray	Detached
5.2A	+	Stellar	Detached
5.3A	+	Solar	Three Detached Modules
5.5		High Energy Survey	Attached
5.7	0	Plasma	Suitcase
5.8		Cosmic	Attached
(5.9		Bio D) Animal	Attached
(5.26		Bio F) (Combined)	
(5.10	+	Bio E) Plant	Detached) Both modes to be
(5.25	+	Bio C) (Combined)	Attached) considered.
5.11	+	Earth Surveys	Detached & Attached Modes
5.12		BMS Module	Attached
5.13C		Centrifuge	Attached
(5.16	+	Material Science)	Detached (Combined Module)
(5.20	+	Fluid Physics)	
5.17	0	Contamination	Suitcase
5.18	0	Exposure	Suitcase
5.22		Component/Sensor	Attached

Detached Module Concepts	8
Attached Module Concepts	8
Total Module Concepts	16

E.2.2 INTEGRATED SPACE PROGRAM - Option II of the Space Task Group's recommendations is selected for study under the ITS program. The schedule of launches for the program, manned and unmanned, is shown in Figures E-15 through E-18. The unmanned launches are accumulated and shown in Figure E-19. This figure shows a peak of 19 launches in 1974 and 1975, just to support the unmanned portion of the program. Manned launches are considerably less than this in gross terms. However, starting in 1977, the Shuttle (recoverable booster) program comes into being with launches growing from three (3) in 1977 to ninety (90) in 1984.

The primary effect of all of this activity is to generate a large - and continually increasing - demand for information transfer between segments of the systems and between spacecraft and earth terminals. This is illustrated in Table E-9 and Figures E-20, E-21, and E-22. In particular, Figure 3.3-8 shows a growth in the number of narrowband channels from ten (10) in 1970 to an average of thirty-eight (38) from 1980 and on; in wideband channels from five (5) in 1970 to eighteen (18) in 1980 and sixty (60) in 1990. This demand constitutes a major problem for the period under consideration. An over-all Information Management System approach must be identified and implemented to cope with this problem.

It is also clear, in this discussion, that all of the data is not basic telemetry or experimental data. Significant portions are attributable to tracking and ranging; significant portions are also directly attributable to emergency communications. Finally, all forms of information transfer are included - Telemetry (analog and digital), Digital Data, Voice and Television. Much of the transfer is two-way.

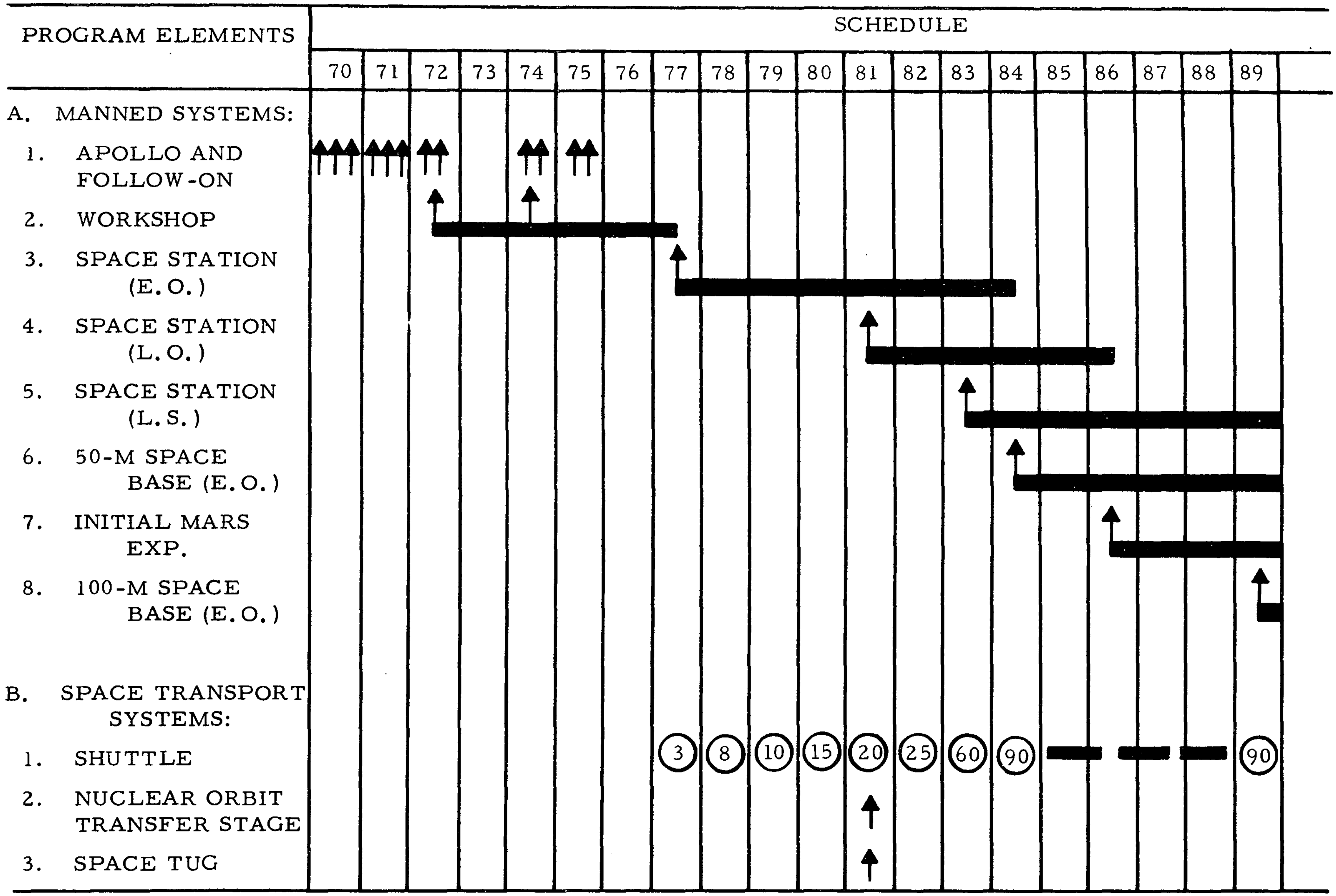


Figure E-15. Integrated Space Program

PROGRAM	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
	CALENDAR YEAR														
<u>ASTRONOMY</u>															
OPTICAL - OAO	▲	▲			△			△	△	△					
SOLAR - OSO		▲		▲	▲	▲				△	△				
HIGH ENERGY AUTO. SURVEY												△			
SMALL SATELLITES	▲▲	▲▲	▲	▲	△△	△△	△△	△△	△△	△△	△△	△△			
<u>SPACE PHYSICS</u>															
ISIS	▲		▲		△										
ATMOSPHERIC EXPLORERS		▲	▲									△△			
SMALL ST'D SATELLITES	▲	▲	▲	▲	△	△	△	△	△	△	△				
INTERPLAN.MONITOR PROBES	▲	▲	▲			△△	△△		△△			△			
HELIOS					▲	▲									
SMALL INTERPLAN. SATS.			▲	▲	▲	▲	▲								
SPACE WEATHER PROBE						△									
CLUSTER SATELLITES								△			△				
OUT-OF-ECLIPTIC PIONEER									△	△					
<u>LIFE SCIENCES</u>															
BIOEXPLORER				△	△	△	△		△		△				
BIOPIONEER						△		△		△					

▲ On-Going Programs
△ Planned Programs

Figure E-16. Unmanned Launch Schedule of Integrated Space Program

PROGRAM	CALENDAR YEAR														
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
UNMANNED PLANETARY PROGRAM															
MARS															
ORBITER		▲▲													
VIKING				▲▲		△△		△							
HIGH DATA RATE ORBITER												△			
EXPLORERS										△		△			
VENUS															
EXPLORERS									△		△	△			
OUTER PLANETS															
JUPITER FLY-BY			▲	△											
JUP-SAT-PLUTO FLYBY								△△							
JUP-URAN-NEPT FLYBY										△△					
ASTEROIDS															
ASTEROID BELT SURVEY												△			

▲ On-Going Programs
△ Planned Programs

Figure E-17. Unmanned Launch Schedule of Integrated Space Program (Continued)

PROGRAM	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
SPACE APPLICATIONS															
METEOROLOGY															
TIROS						△									
NIMBUS	▲		▲	▲		△		△		△					
SYNC. MET SAT		▲	▲												
GARP					▲▲▲▲										
EARTH RESOURCES															
ERTS			▲	▲	△	△									
FILM RECOVERY					△	△									
SMALL ATS				△	△△	△									
EARTH PHYSICS															
DRAG FREE					△			△		△					
GEOS				△											
SAT-TO-SAT						△									
SEA-TO-SAT					△			△		△					
COMMUNICATIONS															
ATS			▲		▲			△			△				
DATA RELAY									△△						
DATA COLLECTION							△								
BROADCAST								△							
COOPERATIVE SAT	▲														
NAVIGATION/TRAFFIC CONTR.															
NAV TRAF SAT							△△								

CALENDAR YEAR

▲ On-Going Programs
△ Planned Programs

Figure E-18. Unmanned Launch Schedule of Integrated Space Program (Continued)

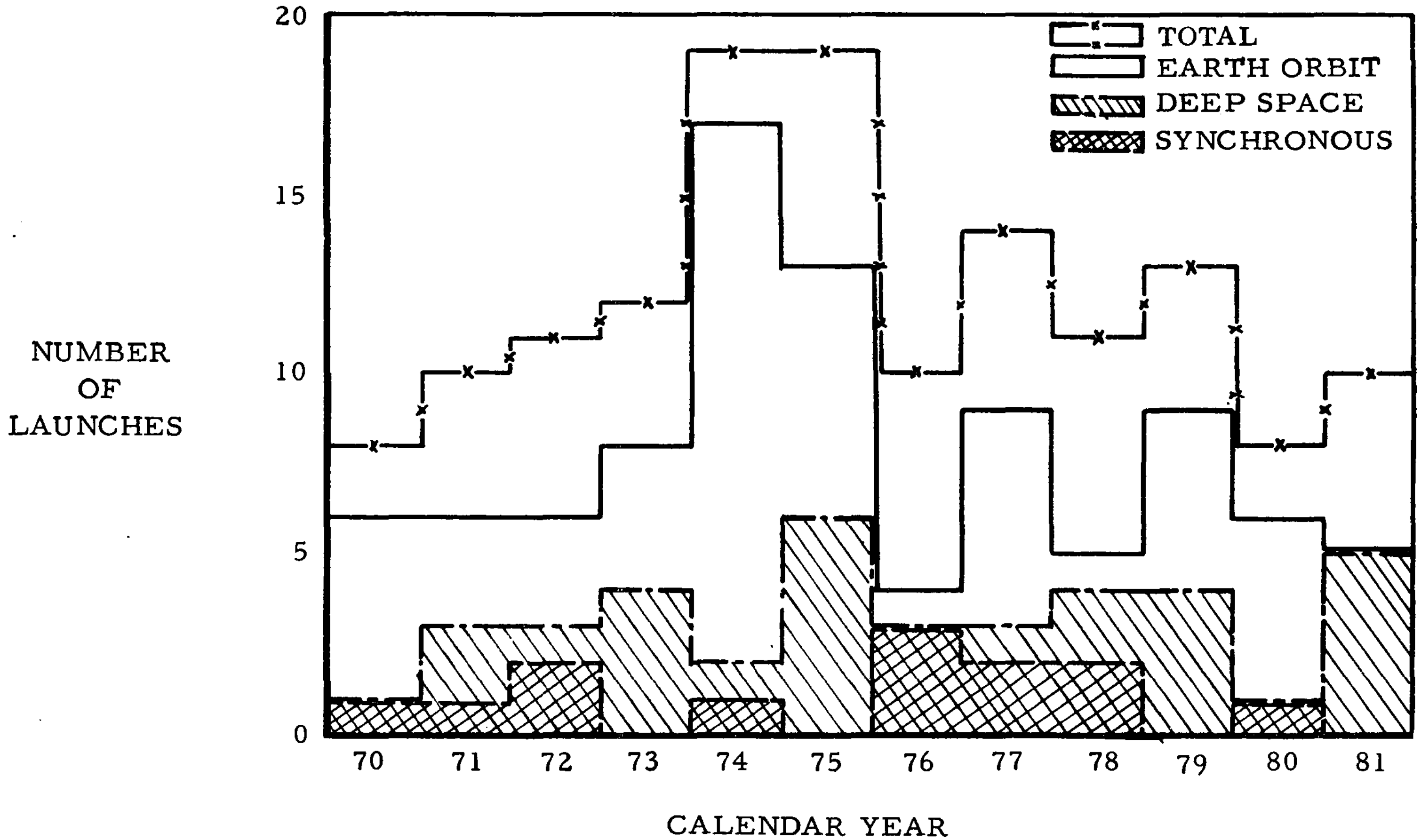


Figure E-19. Launch Profile for Unmanned Integrated Space Program

Table E-9. Manned elements of the integrated space program

ELEMENT	SCHEDULE	PROJECTED INFORMATION TRANSFER REQUIREMENTS
MANNED SYSTEMS;		
1. Apollo, Lunar Exploration	3 in 1970	Each Vehicle:
	3 in 1971	Unified S-band system
	2 in 1972	TLM — 51.2Kbps (2 channels - CSM)(1 channel - LM)
	2 in 1974	Voice — Separate SCO summed with TLM
	2 in 1975	Emergency Voice — Modulated directly on S-band carrier
		Television — FM on carrier.
2. Workshop (Ref. 2)	1 in 1972	Voice — 2 channels
	1 in 1974	TLM — 51.2Kbps
		— 72.0Kbps
		TVTV — Video recorder plus slow-speed playback.
3. Space Station (12-Man/ Earth Orbit)	1977	(1) SS-to-experiment modules and/or shuttle
		Voice — 2 channels
		TLM — (2 channels 2.7 Kbps)
		TV — 2 channels
		PRN Ranging — 1.6Kbps
		(2) SS-to EVA:
		Voice — 2 channels
		TLM — 1.6Kbps
		(3) SS-to-Earth:
		Voice — 4 channels
		TLM — 2 channels, 6 Mbps
		— 2 channels, 72Kbps
		TV — 3 channels
		(4) Emergency Voice — 2 channels.
4. Space Station (6-Man/Lunar Orbit)	1981	(1) SS-to-Lunar Surface and/or Tug:
		Voice — 2 channels
		TLM — 2 channels, 72Kbps
		TV — 2 channels
		PRN — 1.6Kbps
		(2) SS-to-EVA:
		Voice — 2 channels
		TLM — 1.6Kbps

Table E-9. Continued

ELEMENT	SCHEDULE	PROJECTED INFORMATION TRANSFER REQUIREMENTS
		(3) SS-to-Earth: Voice — 3 channels TLM — 2 channels, 6 Mbps — 2 channels, 72 Kbps TV — 4 channels (4) Emergency Voice: 3 channels.
5. Space Station (6-Man/Lunar Surface)	1983	(1) SS-to-EVA and/or Tug: Voice — 2 channels TLM — 2 channels, 72 Kbps TV — 2 channels PRN — 1.6 Kbps (2) SS-to-Earth: Voice — 3 channels TLM — 2 channels, 6 Mpbs TV — 4 channels (3) Emergency Voice: 3 channels.
6. Space Base (50-man/E.O.)	1984	(1) SS-to-Experiment Module, Shuttle and/or Tug: Voice — 4 channels TLM — 3 channels, 6 Mbps — 4 channels, 1.6 Kbps TV — 4 channels (2) SS-to-EVA: Voice — 4 channels TLM — 4 channels, 1.6 Kbps (3) SS-to-Earth: Voice — 12 channels TLM — 6 channels, 6 Mbps — 6 channels, 72 Kbps TV — 6 channels (4) Emergency Voice: 5 channels.
7. Initial Mars Expedition	1986	E.O. & Assembly Communications will be accommodated via Space Base (Item 6). Trans Mars will be an autonomous system. (1) SS-to-EVA: Voice— 2 channels TLM— 2 channels, 1.6 Kbps

Table E-9 Continued

ELEMENT	SCHEDULE	PROJECTED INFORMATION TRANSFER REQUIREMENTS
		(2) SS-to-Earth: Voice — 3 channels TLM — 2 channels, 6 Mbps — 2 channels, 72 Kbps TV — 3 channels (3) Emergency Voice: 2 channels.
8. Space Base (100-Man/E.O)	1989	(1) SS-to-Experiment Module, Shuttle and/or Tug: Voice — 8 channels TLM — 4 channels, 6 Mbps — 8 channels, 1.6 Kbps TV — 8 channels (2) SS-to-EVA: Voice — 8 channels TLM — 8 channels, 1.6 Kbps (3) SS-to-Earth: Voice — 16 channels TLM — 8 channels, 6 Mbps — 8 channels, 72 Kbps TV — 10 channels (4) Emergency Voice: 9 channels.
TRANSPORTATION SYSTEMS:		
1. Shuttle* (Earth-to-Orbit & Return)	Initial Space Flight - 1977 3 in 1977 Build up to 90 in 1984 and on	Vehicle to Space Station and/or Earth Terminal: Voice — 2 channels TLM — 2 channels, 72 Kbps PRN — 1 channel, 1.6 Kbps Emergency Voice — 1 channel.
2. Nuclear Transfer Stage*(Orbit-to-Orbit)	1981 (and on)	Same as Transportation Systems Item 1
3. Space Tug* (Earth Orbit-to-Lunar Orbit & Return)	1981 (and on)	Same as Transportation Systems Item 1

*Additional communications requirements may develop for unmanned operations of these vehicles.

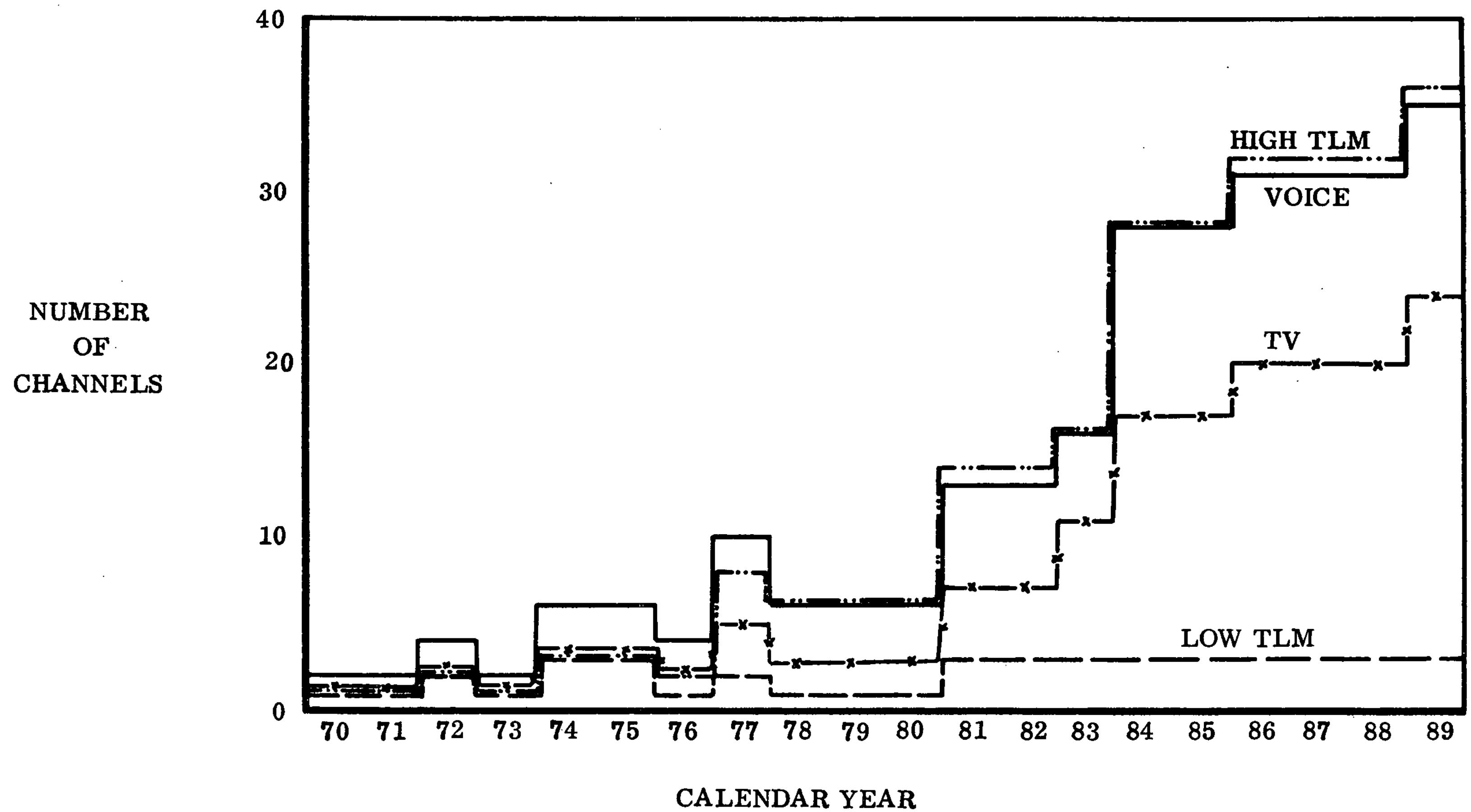


Figure E-20. Data Requirements for Manned Integrated Space Program

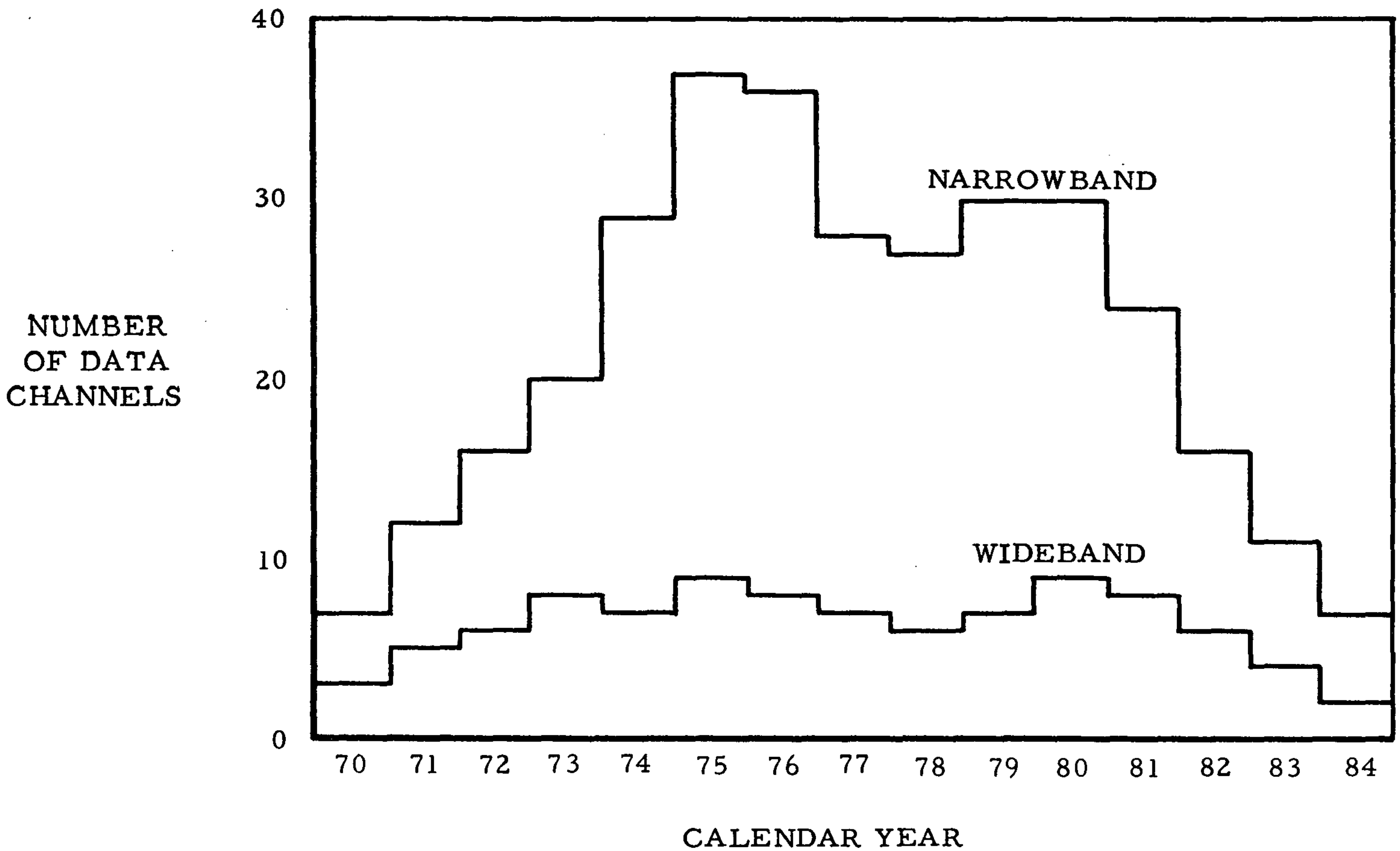


Figure E-21. Data Requirements for Unmanned Earth Orbit Integrated Space Program

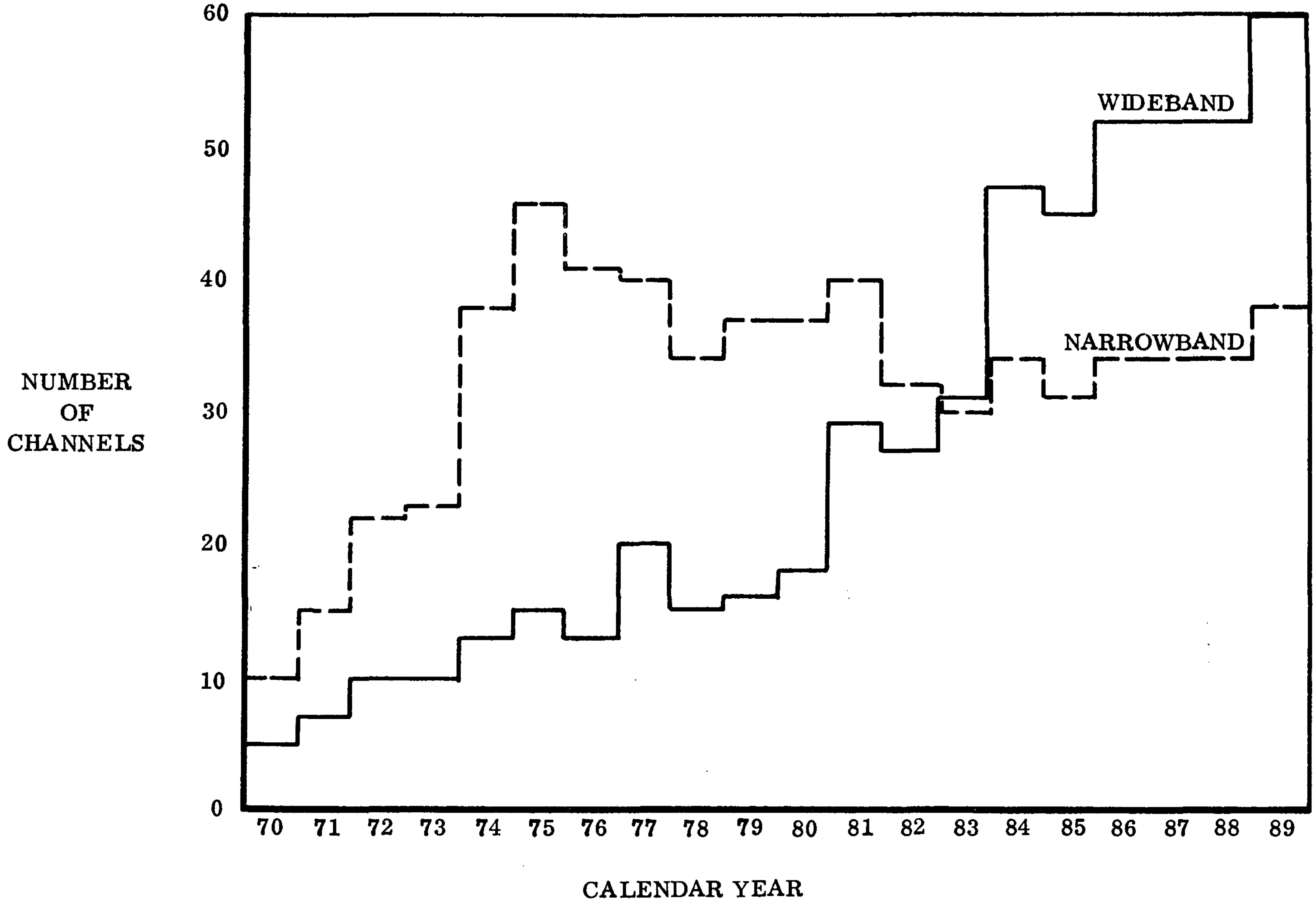


Figure E-22. Data Requirements for Integrated Space Program

E.3 CORPORATE TELEPROCESSING WITHIN THE IBM-ORGANIZATION

INTRODUCTION

In order to gain some idea of the status, scope, volume and future direction of teleprocessing in a typical business situation, a look at a representative system seemed helpful. To this end, a conference was set up with IBM/Los Angeles to discuss their "Advanced Administrative System" (AAS), a teleprocessing system now being installed within IBM for internal corporate purposes. Participants in the meeting were Bob Grant and Don Challed of IBM; H. L. Weinberger and L. P. Reiche of Hughes Aircraft Company.

SYSTEM OBJECTIVES

Objectives of their AAS are to provide access to and processing of administrative records _in real time_, without conventional paperwork, and without large files at multiple locations. There is to be only one data center (in White Plains, New York) which is shared by everybody. A key philosophy is to minimize print-out. Routine items are _not_ printed out. Print-outs _can_ be obtained, but should be resorted to only in very special situations. The data system cuts across corporate organizational lines and territories. Each IBM office has a display-key set for "conversation" with the data center.

SPECIFIC APPLICATIONS

Present (prototype) capability:

1. Management of Accounts Receiveables: Voice-grade lines to 10 locations only, with 120 terminals total. System is now handling about 160K checks per day, with all cash transactions cleared through the New York data center. (Circa 500K-byte* data base, with 500K accesses per day).

* 1 "byte" = 8 bits

The system is currently being extended to do (by the end of 1970):

2. Management of Customer Order Processing: This will include applications engineering, with detailed technical check. Price and delivery quotes will be obtainable within 30 minutes (vs. 3 weeks by conventional means). The order-processing problem got worse as equipment became more complex, with typically 70-percent rejection of initial sales paper work (arising from functional or technical incompatibility of various pieces of equipment). Delivery quotes are based on production load data direct from manufacturing plants (routed over another system to the New York data center).

Ultimately, the system will be extended to do (by 1971):

3. Salesmen's commissions;
4. Installed Inventory Control;
5. Billing of Installed Inventory;

Possible added functions (1972 - 1975):

6. Payroll;
7. Financial File;
8. Communications Support -- Dissemination of sales information (product file);
9. Educational Support -- Scheduling of and enrollment for company courses;
10. Report Data -- Will print out special management reports, on request.

SYSTEM STRUCTURE AND PERFORMANCE

The system is designed for a worst-case response time of five seconds. To process an order, a "conversation" involving numerous responses (punctuated by thoughts periods on the part of the person processing the order) may take about 30 minutes, depending on details and circumstances. During this time, the system runs in data bursts (at 2,400 bps capacity of the voice-grade line), but separated by long pauses. These can be used for time-sharing other accesses to the record center on a party-line basis (provided that the data loads and geographical location of the users fit such an arrangement).

A number of voice-grade lines are gathered into 10 data concentrator locations (Los Angeles, San Francisco, Kansas City, Chicago, Cleveland, Atlanta, Washington, D.C., Philadelphia, Boston, New York City) whence the data is forwarded to White Plains via 40.8-kilobit Telpak links.

The data center has four Model No. 65's on line, plus another 65 for access control to the data file (16 billion bytes capacity), plus two more 65's for backup. (Rental of a Model No. 65 is $120K/Month.)

The rapid access requirement precludes use of any tape storage for active use at the data center --- only for dead file at intervals. The working memory is on disks.

Elaborate security sequences are built into the system to allow access to sensitive company data only to those people holding requisite "clearance" levels.

Voice-grade and Telpak circuits are leased from AT&T under a national contract (at 250K/Month total; this includes WE Data Sets No. 201B3 and concentrators No. 303G). All lines are dedicated to avoid possible problems. AT&T will switch substitute lines rapidly in event of a line failure.

GENERAL REMARKS

The AAS program was started in 1966 as a five-year effort. System cost offsets will be fully paid out by 1975. Its capacity is projected to be adequate until 1981. The overall system is designed to handle 3,000 messages per minute into White Plains, and 6,000 accesses per minute. A message averages 6 to 8 characters in answer to a brief question, such as "What is your office number?" The system is based on a conversational mode; therefore, there are typically many messages per transaction.

It is noteworthy that interrogation to the data center averages roughly an order of magnitude less data load that read-out from the data center. So, instead of a full duplex link, half-duplex links with different capacities in opposite directions could be used. This has not been thought about much at this point in time. During off hours (at night) lower-priority report processing can be done.

Present load-factors (i.e., percent of full load) of the various lines are not known.

Yardsticks of system size and complexity: The system took 800 man-years of development. The largest current teleprocessing system is American Airlines' Sabre (ticket reservation) system; the AAS will be ten times as large.

E.4 TV NETWORK DISTRIBUTION

E.4.1 Background

The TV Network Distribution mission is being examined here in detail. This mission is well defined, has been well studied, and is a likely candidate. Abundant data are available from reliable sources. In particular, the location of traffic sources and destinations, the weekly demand profile, and growth projections are all on hand. Moreover, the amount of traffic involved is substantial, and is likely to exceed the traffic generated by many other types of services.

E.4.2 Notes and Comments

Satellite Relay System SNR (peak-to-peak synch/weighted rms noise)	54 db *
of which emphasis and noise weighting advantage account for	13 db

(* for overall system SNR = 53 db)

The suggested channel SNR is based on a single satellite relay hop between source and destination. (If more satellite hops should be needed -- for greater regional coordination -- the per-hop SNR may have to be raised.)

The TV channels are assumed dedicated for at least 18 hours/day; i.e. the customer will expect instant access to his channels during that time; i.e. no sharing of satellite channels with unrelated services is permissible during that time.

Growth projections (References 3 and 4) relate only to numbers of channels and their utilization (<u>not</u> to the number of metropolitan TV markets).

E.4.3 User Requirements

Total Channel Capacity		48 TV
Typical Services Provided:	Full-Time Channels	28 TV
	Occasional Channels (may also be used for reserve and instructional purposes)	20 TV

Four Major Metropolitan TV markets, each capable of receiving on 18 channels and transmitting on 21 channels.

Market	ARB Net Weekly Circulation	Rank	Total Homes	Rank	Television Households	Rank	Market Area Commercial TV Stations
New York, N.Y.	5,219,200	1	6,841,300	1	6,525,000	1	WABC-TV, WCBS-TV, WNBC-TV, WNEW-TV, WNJU-TV, WOR-TV, WPIX
Los Angeles, Cal.	3,018,500	2	3,792,600	2	3,576,300	2	KABC-TV, KCOP, KHJ-TV, KMEX-TV, KNBC, KNXT, KTLA, KTTV, KWHY-TV
Chicago, Ill.	2,338,700	3	2,746,300	3	2,634,900	3	WBBM-TV, WBKB-TV, WCIU-TV, WFLD, WGN-TV, WMAQ-TV
Philadelphia, Pa.	2,060,400	4	2,692,600	4	2,581,900	4	KYW-TV, WCAU-TV, WFIL-TV, WIBF-TV, WKBS-TV, WPHL-TV

46 Secondary Metropolitan TV Markets, each capable of receiving on 6 channels and transmitting on 3 channels.

Market	Rank
Boston, Mass.	5
Detroit, Mich.	6
San Francisco, Cal.	7
Cleveland, Ohio	8
Pittsburgh, Pa.	9
Washington, D.C.	10
Baltimore, Md.	11
Providence, R.I.	12
St. Louis, Mo.	13
Hartford-New Haven, Conn. .	14
Dallas-Ft. Worth, Tex.	15
Cincinnati, Ohio	16
Minneapolis-St Paul, Minn.	17
Indianapolis, Ind.	18
Atlanta, Ga.	19
Miami, Fla.	20
Seattle-Tacoma, Wash.	21
Buffalo, N.Y.	22
Kansas City, Mo.	23
Milwaukee, Wis.	24
Houston, Tex.	25
Dayton, Ohio	26
Sacramento-Stockton, Cal.	27
Columbus, Ohio ..	28
Harrisburg-Lancaster-York, Pa. ..	29
Charlotte, N.C.	30
Syracuse, N.Y.	31
Tampa-St. Petersburg, Fla. ...	32
Wheeling, W. Va.-Steubenville, Ohio	33
Portland, Ore.	34
Memphis, Tenn.	35
Grand Rapids-Kalamazoo, Mich.	36
Toledo, Ohio	37
Johnstown-Altoona, Pa. .	38
Birmingham, Ala.	39
Albany-Schenectady-Troy, N.Y.	40
Denver, Colo.	41
Greenville-Spartanburg, S.C.-Asheville, N.C. ..	42
New Orleans, La.	43
Nashville, Tenn.	44
Flint-Saginaw-Bay City, Mich.	45
Charleston-Huntington, W. Va. ...	46
Greensboro-Winston Salem-High Point, N.C.	47

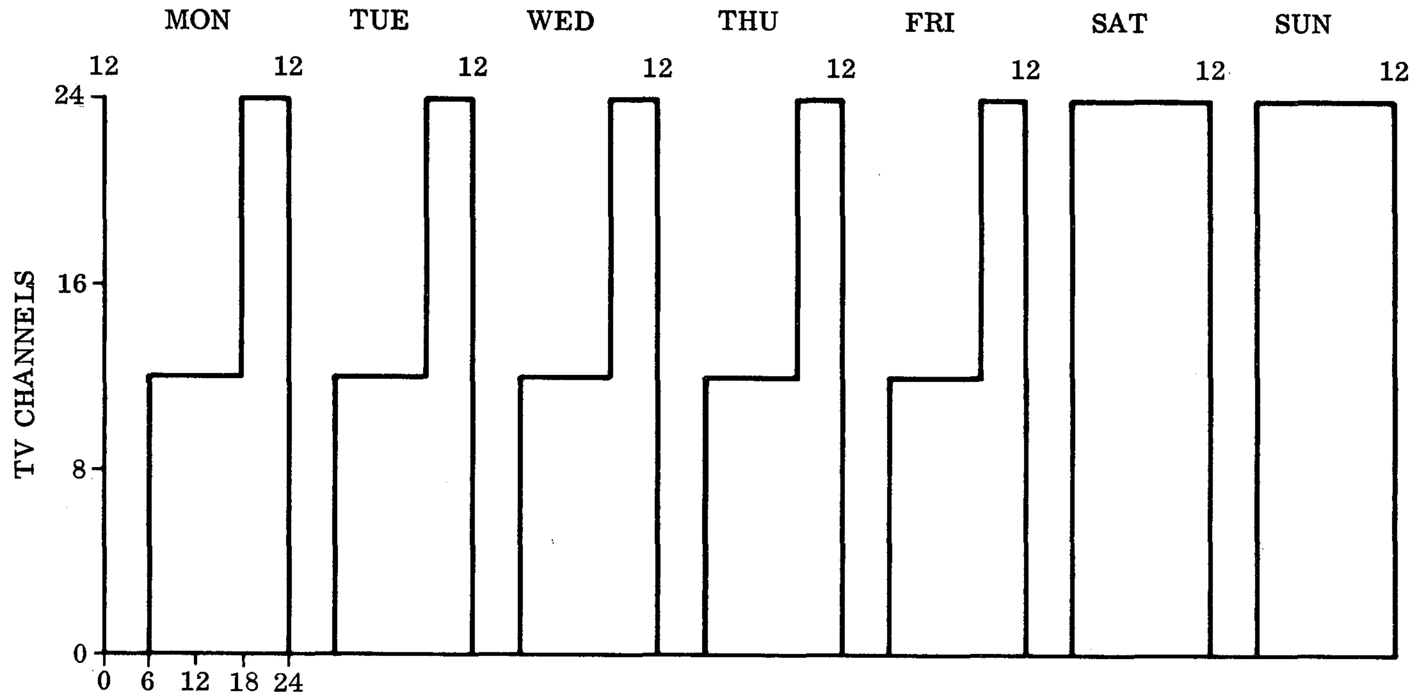
172 Tertiary Metropolitan TV Markets, each capable of receiving on 6 channels.

Market	Rank
Lansing, Mich.	48
Manchester, N.H.	49
Louisville, Ky.	50
Oklahoma City, Okla.	51
Raleigh-Durham, N.C.	52
San Diego, Cal.	53
Norfolk-Portsmouth-Newpo News-Hampton, Va.	54
Salinas-Monterey, Cal.	55
Wichita-Hutchinson, Kan.	56
San Antonio, Tex.	57
Tulsa, Okla.	58
Omaha, Neb.	59
Portland-Poland Spring, Me.	60
Salt Lake City-Ogden-Provo, Utah	61
Phoenix, Ariz.	62
Quad City (Davenport, Ia.-Rock Island-Moline, Ill.)	63
Roanoke, Va.	64
Green Bay, Wis.	65
Orlando-Daytona Beach, Fla.	66
Richmond, Va.	67
Shreveport, La.	68
Wilkes-Barre-Scranton, Pa.	69
Rochester, N.Y.	70
Little Rock, Ark.	71
Jacksonville, Fla.	72
Mobile-Pensacola, Fla.	73
Cedar Rapids-Waterloo, Iowa	74
Champaign-Decatur-Springfield, Ill. (incl. Danville)	75
Spokane, Wash.	76
Des Moines, Iowa	77
Knoxville, Tenn.	78
Cape Girardeau-Paducah-Harrisburg, Ill.	79
Madison, Wis.	80
Columbus, Ga.	81
Baton Rouge, La.	82
Columbia, S.C.	83
Greenville-Washington-New Bern, N.C.	84
Binghamton, N.Y.	85
Jackson, Miss.	86
Chattanooga, Tenn.	87
Fresno, Cal.	88
Youngstown, Ohio	89
Evansville, Ind.	90
Springfield-Holyoke, Mass.	91
Sioux Falls, S.D.	92
Lincoln-Hastings-Kearney, Neb.	93
South Bend-Elkhart, Ind	94
West Palm Beach, Fla.	95
Ft. Wayne, Ind.	96
Peoria, Ill.	97
Augusta, Ga.	98
Rockford, Ill.	99
Albuquerque, N.M.	100
Terre Haute, Ind.	101
Bristol, Va.-Johnson City, Tenn.	102
Lafayette, La.	103
Monroe, La.-El Dorado, Ark.	104
Sioux City, Iowa	105
Erie, Pa.	106
Beaumont-Port Arthur, Tex.	107
Austin-Rochester, Minn.-Mason City, Ia.	108
Burlington, Vt.-Plattsburgh, N.Y.	109
Utica, N.Y.	110
Joplin, Mo.-Pittsburg, Kan.	111
Albany, Ga.	112
Montgomery, Ala.	113
Duluth, Minn.-Superior, Wis.	114
Springfield, Mo.	115
Tallahassee, Fla.-Thomasville, Ga.	116
Charleston, S.C.	117
Hawaii	118
Waco-Temple, Tex.	119
Florence, S.C.	120
Cadillac-Traverse City, Mich.	121
La Crosse-Eau Claire, Wis.	122
Austin, Tex.	123
Amarillo, Tex.	124
Topeka, Kan.	125
St. Joseph, Mo.	126
Wichita Falls, Tex.-Lawton, Okla.	127
Hannibal-Quincy, Ill.	128
Tucson, Ariz.	129
Dothan, Ala.	130
Fargo, N.D.	131
Wilmington, N.C.	132
Chico-Redding, Cal.	133
Alexandria, La.	134
Bluefield, W. Va.	135
El Paso, Tex.	136
Columbia-Jefferson City, Mo.	137
Colorado Springs-Pueblo, Colo.	138
Santa Barbara, Cal.	139
Lubbock, Tex.	140
Wausau-Rhinelander, Wis.	141
Corpus Christi, Tex.	142
Lexington, Ky.	143
Bakersfield, Cal.	144
Macon, Ga.	145
Alexandria, Minn.	146
Yakima, Wash.	147
Odessa-Midland, Tex.	148
Savannah, Ga.	149
Cheyenne, Wyo.	150
Eugene, Ore.	151
Biloxi, Miss.	152
Bismarck, N.D.	153
Bangor, Me.	154
Abilene-Sweetwater, Tex.	155
Panama City, Fla.	156
Huntsville-Decatur-Florence, Ala.	157
Boise, Ida.	158
Tyler, Tex.	159
Mankato, Minn.	160
Meridian, Miss.	161
Las Vegas, Nev.	162
Lower Rio Grande Valley (Harlingen-Weslaco, Tex.)	163
Ottumwa, Ia.-Kirksville, Mo.	164
Oak Hill, W. Va.	165
Ft. Smith, Ark.	166
Harrisonburg, Va.	167
Akron, Ohio	168
Lake Charles, La.	169
Hattiesburg-Laurel, Miss.	170
Ada, Okla.	171
Clarksburg-Fairmont, W. Va.	172
Columbus, Miss.	173
Billings, Mont.	174
Bowling Green, Ky.	175
Watertown-Carthage, N.Y.	176
Lima, Ohio	177
Reno, Nev.	178
Bellingham, Wash.	179
Idaho Falls-Pocatello, Ida.	180
Marquette, Mich.	181
Ardmore, Okla.	181
Roswell, N.M.	183
Jackson, Tenn.	184
Great Falls, Mont.	185
Rapid City, S.D.	186
Casper, Wyo.	187
Eureka, Cal.	188
Butte, Mont.	189
Tupelo, Miss.	190
Jonesboro, Ark.	191
Missoula, Mont.	192
Medford, Ore.	193
Greenwood, Miss.	194
Salisbury, Md.	195
Aberdeen, S.D.	196
Minot, N.D.	197
Hays, Kan.	198
Grand Junction-Montrose, Colo.	199
Ensign, Kan.	200
Ft. Dodge, Ia.	201
Zanesville, Ohio	202
Ft. Myers, Fla.	203
Lufkin, Tex.	204
Twin Falls, Ida.	205
Yuma, Ariz.-El Centro, Cal.	206
San Angelo, Tex.	207
Lafayette, Ind.	208
Mitchell, S.D.	209
Parkersburg, W. Va.	210
Dickinson, N.D.	211
Presque Isle, Me.	212
Muncie, Ind.	213
North Platte, Neb.	214
Pembina, N.D.	215
Klamath Falls, Ore.	216
Laredo, Tex.	217
Marion, Ind.	218
Riverton, Wyo.	219
Selma, Ala.	220
Helena, Mont.	221
Tuscaloosa, Ala.	222
Glendive, Mont.	223

TOTAL CHANNEL CAPACITY REQUIRED

Time Zones	4(7)*
Network Channels/Time Zone	6
Instructional Channels/Time Zone	4
Cultural/Informational/Time Zone	1
Total/Time Zone	11
Total Required	44
Reserve/Time Zone	1
Design Capacity/Time Zone	12
Total Design Capacity	48
Coverage	All US

*with switching



TV NETWORK DISTRIBUTION.
TYPICAL DEMAND PROFILE FOR DEDICATED TV CHANNELS.
(SOURCE: HAC ESTIMATE, BASED ON DATA FROM CBS AND AT&T)

Sources and References

1. Television Market Rankings, 1967 Television Factbook, Television Digest Inc., Washington, D.C.

2. Broadcasters' Non-Profit Satellite System (BNS-3), Estimate for Early 1970's, Ford Foundation Comments, 3 April 1967, FCC Docket 16495.

3. Estimated Channel Requirements, Ford Foundation Comments, 3 April 1967, FCC Docket 16495.

4. Network Television Transmission, SRI

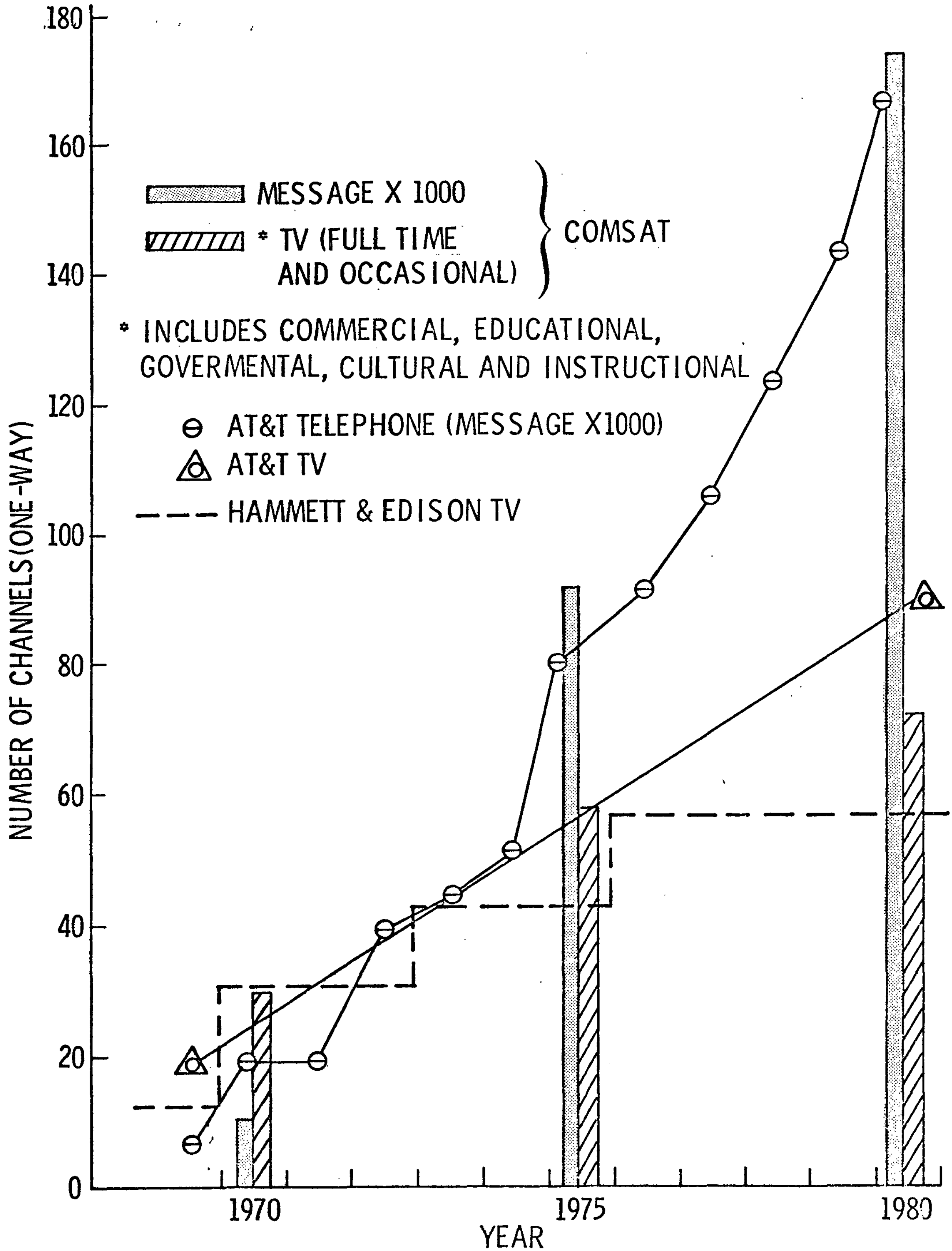
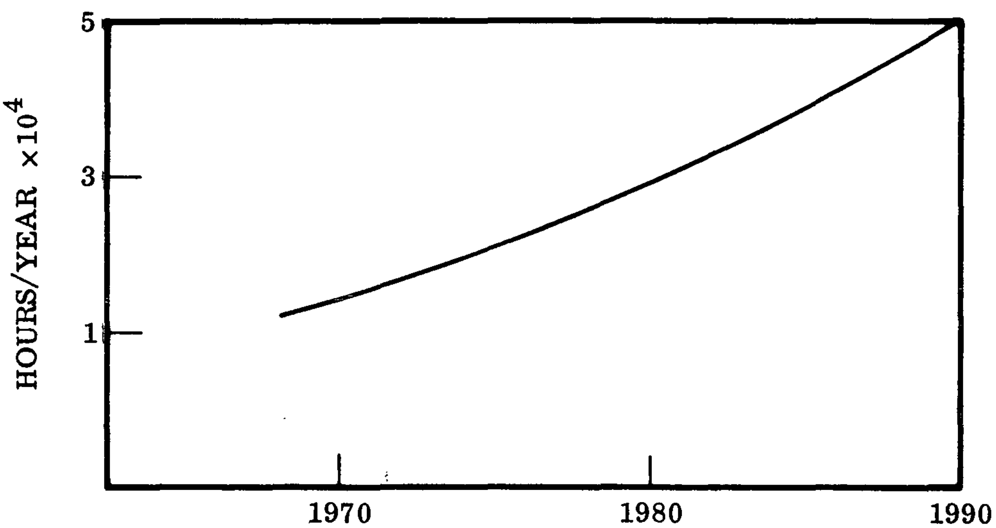


Figure E-23. Total Estimated Channel Requirements



5×10^4 HOURS/YEAR * 3600 SECONDS/
HOUR * 92 MILLION BITS/SECOND
$= 1.7 \times 10^{16}$ BITS/YEAR
(ASSUMPTIONS: 10 NETWORKS, EACH BROAD-
CASTING 12 HRS PER DAY BY 1990)

Figure E-24. Network Television Transmission

E.4.4 ANALYSIS OF TV NETWORK DISTRIBUTION SYSTEM - The Television Network Distribution system outlined in the October Progress Report (GD/C Report No. 581-6-ITS-4) was encoded for analysis using the synthesis program. The system will consist of four uplink facilities (New York, Chicago, Los Angeles, and Philadelphia), one 10 year spacecraft with four downlink beams corresponding to the four time zones, and one downlink facility in each of the 224 metropolitan markets. The system will require 12 downlink channels per time zone allotted as follows:

Commercial Network	6
ETV/ITV	4
Informational	1
Reserve	1

The user requirements as encoded into the computer are given in Table E-10.

Table E-10. TV Network User Requirements

Downlink Modulation	FM
Modulation Index	3
Uplink Frequency	8.2 GHz
Downlink Frequencies	0.8, 2.5, 12.2 GHz
Signal Quality	54 dB (Relay Quality)
Satellite Lifetime	10 years
Total System Lifetime	10 years
Transmitter Types	CFA @ 0.8 GHz TWT @ 2.5, 12.2 GHz

The results of the synthesis program are shown in Figure E-25. The top curve, total cost shows a minimum cost at 2.5 GHz with a slight increase in cost at the other frequencies. This is due to the reduced satellite power requirement for operation in the microwave window. This is also illustrated in the network cost curve of Figure E-25. This curve is the sum of the ground uplink facilities, the satellite, and the launch vehicle costs. Since the launch vehicle and uplink facilities are not a function of the downlink frequency, the change in network cost is due only to the satellite. The ground receiving system curve is the cost of one of the 224 systems consisting of the antenna and the preamplifier/demodulator. The actual distribution system has been excluded in this analysis. The increase in the cost is expected, since low noise receivers are more expensive at the higher frequencies.

It is interesting to examine the uniqueness of the solutions to determine the impact of parameter perturbations. The two of the independent parameters in the program are the noise figure of the downlink receiver and the downlink antenna diameter. The value of these parameters at the minimum cost solution for 0.8 GHz are

$$NF = 1.4 \text{ dB},$$
$$D_a = 18.5 \text{ feet}$$

The curves in Figures E-26 and E-27 were generated by varying one independent parameter about the nominal while holding the other fixed at its nominal value. The systems dependent parameters were recomputed by the program still satisfies the user requirements. Figure E-26 illustrates the shallow sensitivity of system cost to receiver noise figure. As would be expected, the network cost (specifically, the satellite cost) increase and the receiving system cost decreases as the receiver becomes noiser. Figure E-27 shows the sensitivities of costs to downlink antenna diameter. With increasing diameter, the receiving system cost increases ($400/year at 25 ft) resulting in a decrease in cost to the networks. The net effect is, however, increased total cost on either side of nominal.

This system was designed to handle the channel during the 1980's, The impact of a lighter channel requirement is shown in Figure E-28. There is very little network cost reduction as the number of channels is reduced from 12. However, the receiving system cost decreases with decreasing channel requirements due to the lower requirement for preamp/demodulators per station. This curve would be expected to be linear with respect to number of channels, however as the channel requirement increases the number of preamp/demodulators increases resulting in a "learning process" cost reduction.

This "learning process" also reflected in Figure E-29. As the number of receiving systems is increased from 224, the per unit receiving system cost is reduced with a slight increase in cost to the networks. As the receiving system becomes a more significant portion of the total cost, more power is required of the satellite driving the cost to the networks higher. As Figure E-30 shows at 224 receiving systems the receiver cpmprises less than 1 percent of the total cost. At 4000 systems, it rises to 3 percent. At higher receiver populations, its cost will become even more significant. This condition will exist in analysis of direct-to-home systems.

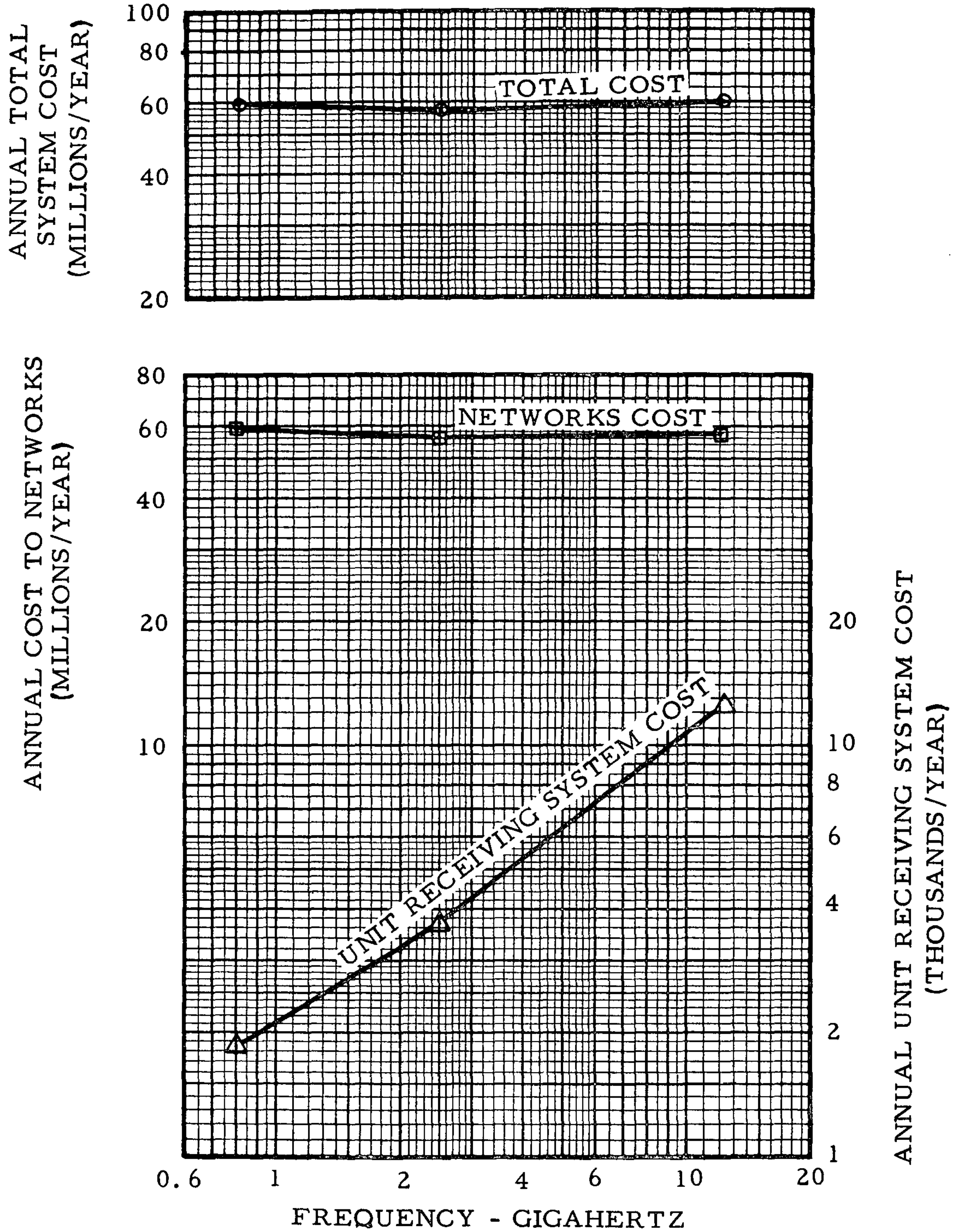


Figure E-25. Cost Sensitivity to Frequency

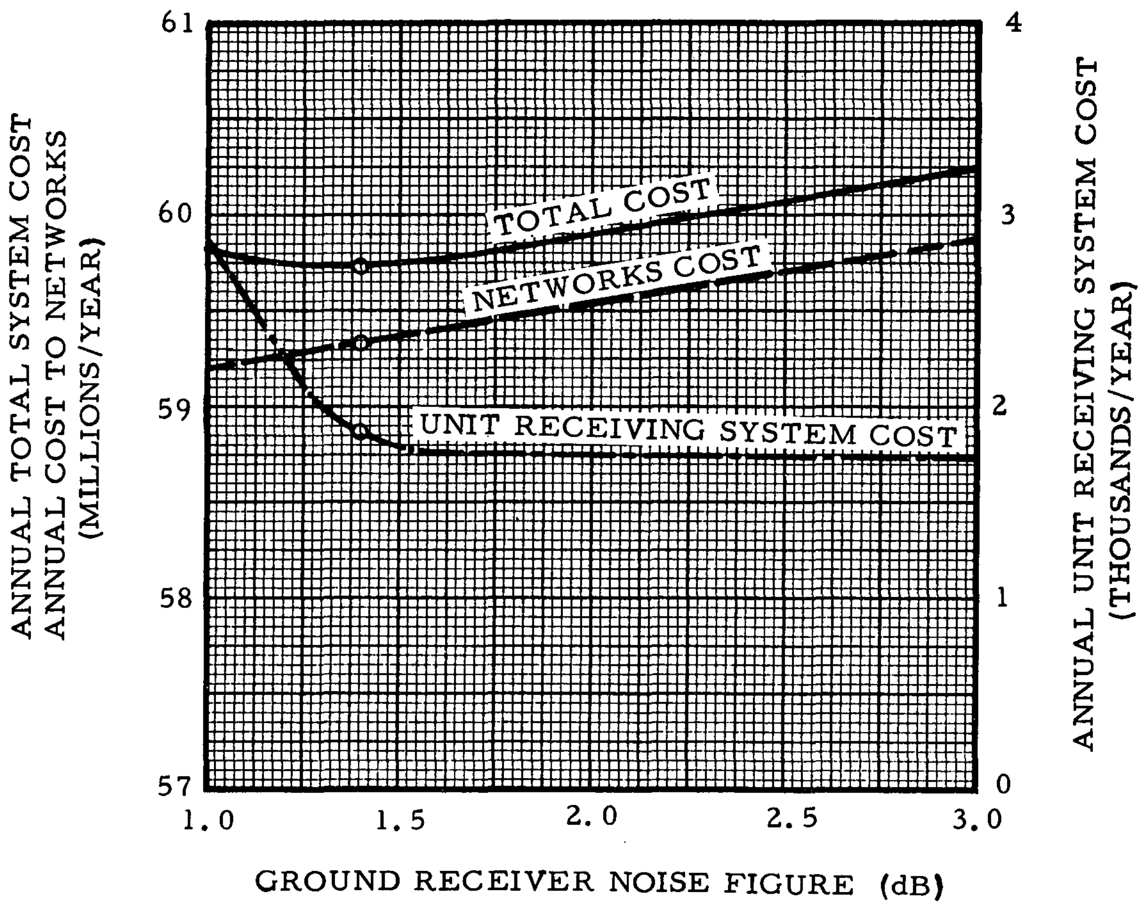


Figure E-26. Cost Sensitivity to Receiver Noise Figure

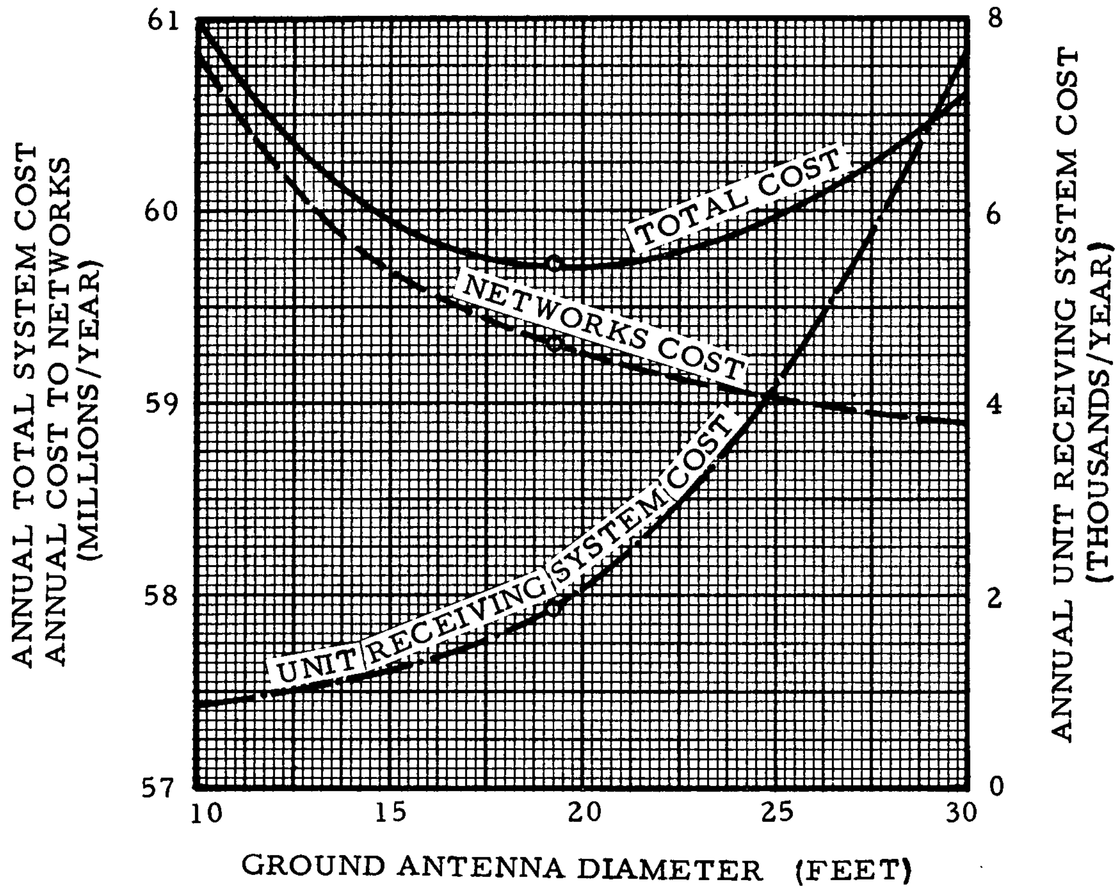


Figure E-27. Cost Sensitivity to Downlink Antenna Diameter

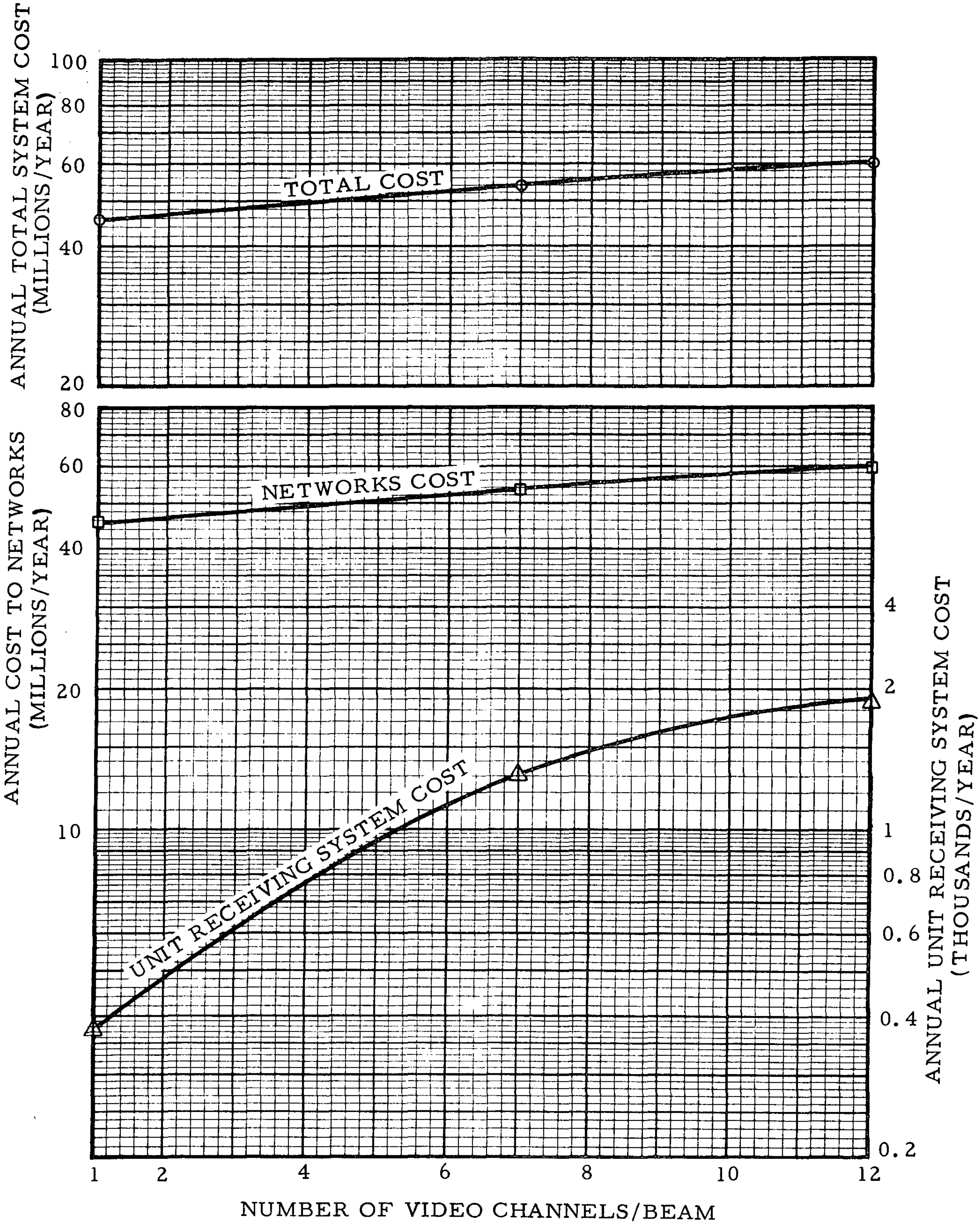


Figure E-28. Cost Sensitivity to Number of Video Channels per Beam

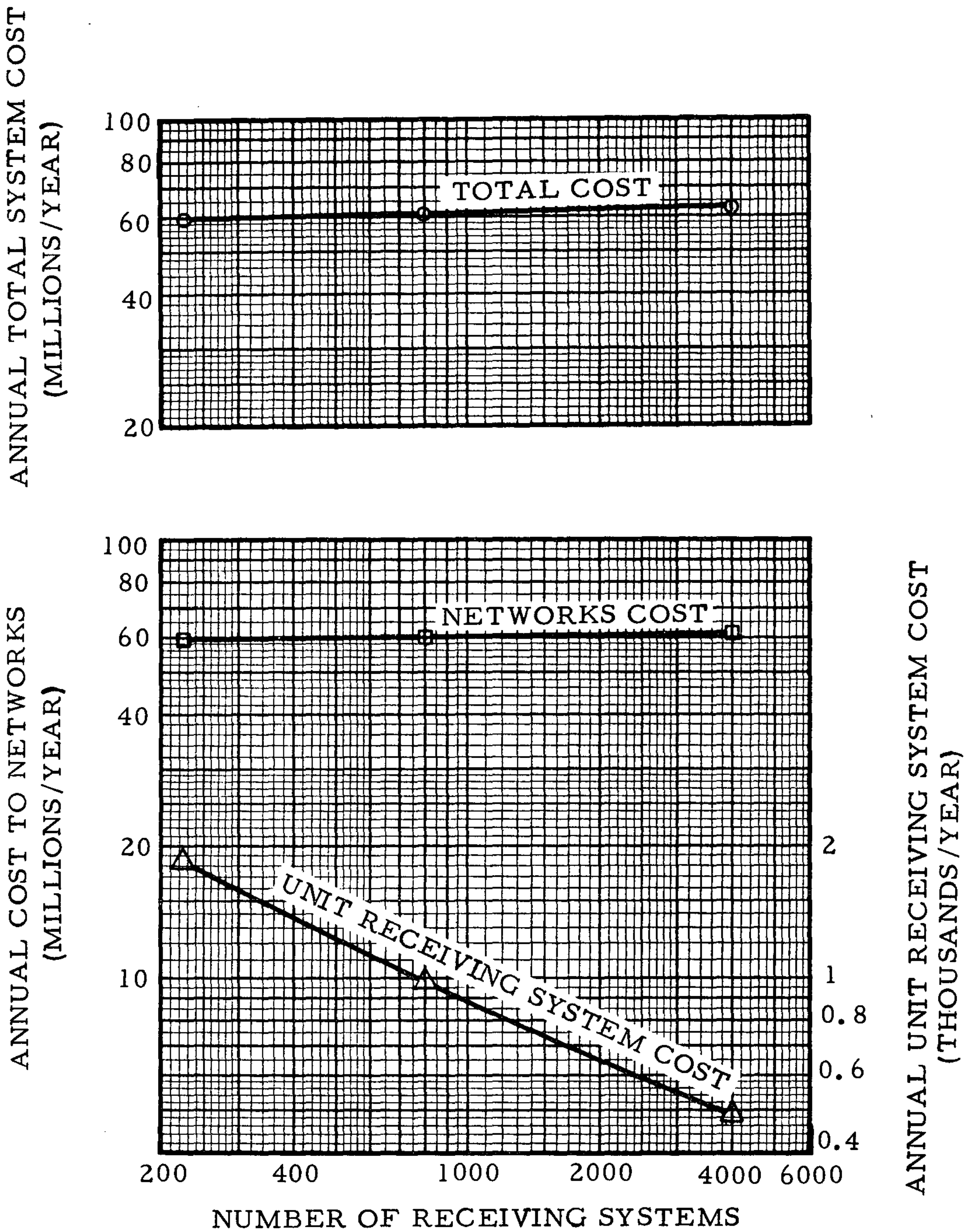


Figure E-29. Cost Sensitivity to Number of Receiving Systems

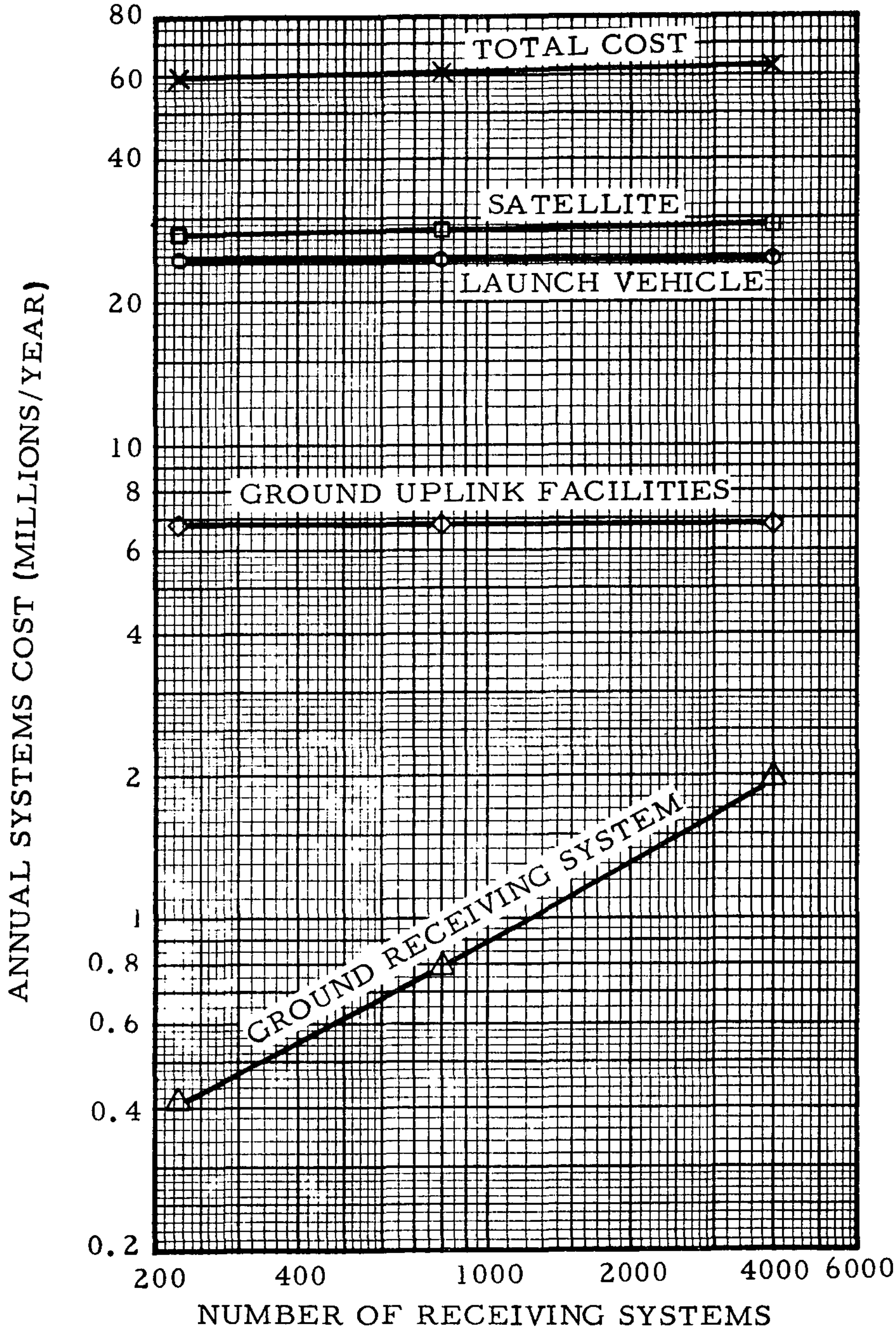


Figure E-30. Systems Cost Sensitivity to Number of Receiving Systems

Lawrence Norwood
9 November 1969

E.5 DATA COLLECTION

INFORMATION TRANSFER SATELLITE CONCEPT STUDY

E.5.1 EARTH RESOURCES AND METEOROLOGICAL APPLICATIONS AND USERS

1.0 INTRODUCTION

In order for us to utilize better the natural resources of the earth and for us to be able to effect better long (temporal) range, medium range and very short range weather forecasts on the macro-, meso-, and micro scales, it is essential that we comprehend better the atmospheric and terrestrial environment.

In order that we be able to predict better the future of the environment and the near future of the ecology, it becomes necessary to transfer large amounts of information (data), acquired at frequent spatial and temporal intervals.

One technique for acquiring these data is by remote sensing of the earth and its atmosphere, either from aircraft or from satellites. This technique is limited by the capability of remote sensors to utilize electromagnetic radiation to infer the properties of the atmosphere and of the earth.

A more direct technique for acquiring these data is by utilizing "in place" sensors which are located on the surface and at various levels within the atmosphere, and which sense the environment directly. At present, more than 14,000 of these remote sensing platforms (RSP's) are deployed, and current plans require the deployment of 26,000 RSP's by 1975.

In order to utilize the RSP's effectively, it is imperative that their data be collected in a timely manner since in many instances- especially meteorology- the information is highly perishable. Hence, rapid data collection and relay are very important attributes of the information transfer function.

In this study it will be demonstrated that a satellite system is particularly appropriate for the function of collection of earth resources information and for meteorological information. The ultimate system discussed will be referred to as an Information Transfer Satellite System (ITSS).

In order to evaluate the feasibility and potential benefits of the ITSS, we have postulated the pertinent parameters for the era of 1975. The number of RSP's and their message traffic have been estimated, based largely upon three existing systems, and upon projections of present plans.

2.0 DESCRIPTION OF CURRENT SYSTEMS

The systems under current consideration are:

* The International Applications Satellite - A (IAS-A), also formerly known as the Fr-2 Program, and still formally known as the EOLE experiment. The system is sponsored by Le Centre National d'Études Spatiales (CNES) in Bretigny.
* The Interrogation, Recording and Location System (IRLS), which is sponsored by NASA/GSFC.
* The OMEGA Position Position Location Experiment (OPLE), which also is sponsored by NASA/GSFC.

The objectives of these systems are similar: to establish the feasibility of measuring meteorological parameters on a global scale utilizing satellites to process, store and transfer information rapidly. The block diagrams for all three systems are similar, as illustrated in Figure E-31.

The basic elements are:

* Remote Sensing Platforms, equipped with sensors to measure the environmental parameters,
* An Information Transfer Satellite (ITS) to interrogate periodically the RSP's, to determine their location and to collect their measurements,
* A ground control and data acquisition station (CDA), to retrieve the results of the satellite interrogations and to command the satellite interrogation schedule.

As a consequence, four communications links must be established.

* From the CDA to the satellite for command and interrogation instruction,
* From the satellite to the RSP for interrogation of the sensor platform,
* From the RSP to the satellite for the transmission of measured data and position location information, and
* From the satellite to the CDA to transfer the RSP information (measurement data and position location information).

The three systems represent two basically different types of approaches to the location and interrogation of the RSP's. The IAS-A and IRLS systems will use medium altitude satellites (between 800 and 1200 km altitude). These satellites will be the IAS-A and the Nimbus, respectively. The ATS-1 and ATS-3 satellites are equipped to perform OPLE experiments at synchronous altitude (37,000 km).

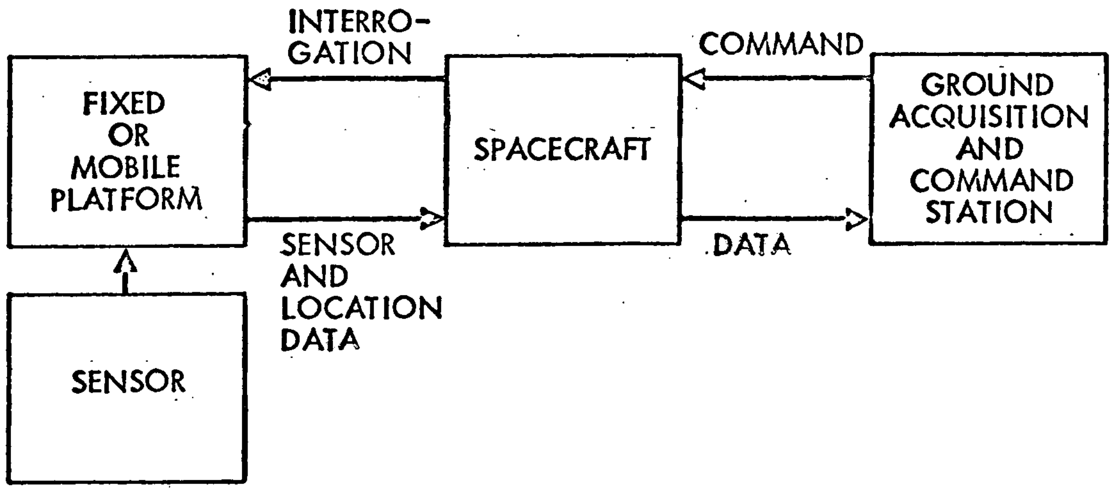


Figure 3-31. SYSTEMIC BLOCK DIAGRAM

2.1 The IAS-A System

The principal objective of the IAS-A system is, according to CNES, "to yield meteorological information from the observation of the general circulation of the troposphere." The RSP's reply to a satellite interrogation by relaying meteorological data back to the satellite. The satellite records the RSP information and also computes range and range-rate measurements from the returned signal. A sequence of such satellite interrogations, RSP responses and recording and ranging functions is made in order to establish by triangulation the exact location of the RSP, especially if it is a balloon, i.e., not absolutely fixed in position. When within communication range, the ground station commands the satellite to transfer its stored information, and the interrogation schedules and addresses are stored in the satellite by ground command. The ground to satellite command up-link and the satellite to ground telemetry down-link are at VHF, while the satellite to RSP interrogation and response links are at UHF.

Figure E-32. illustrates the operational sequence.

2.2 The IRLS System

The IRLS system is designed to provide experimental data for qualitative measurements of meteorological and geophysical phenomena on a global scale. A principal objective of the program is the automatic

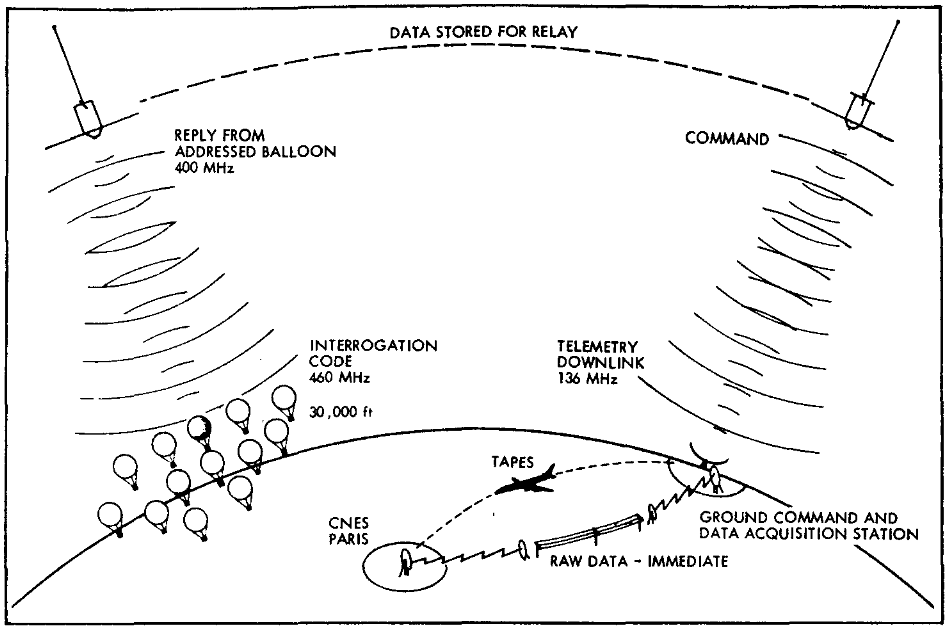


Figure E-32. IAS-A Operational Sequence

transfer of position location and meteorological information utilizing horizontal sounding balloons (HSB's) at altitudes of 55,000 and 80,000 feet. In addition, the IRLS will have a capability to interrogate automatically both fixed and floating RSP's, which will have diverse information transfer ability. As in the case of the IAS-A, a medium altitude satellite will be employed.

When the Nimbus passes over the ground stations at Rosman, N.C., and/or over Alaska, the information stored in the satellite memory will be transferred to the IRLS ground acquisition and command station, and thence will be relayed to the data processing facility at NASA/GSFC. At that time, an updated interrogation schedule may be transmitted to the IRLS satellite command memory.

Figure E-33 depicts the IRLS operational procedure. All IRLS links are at UHF.

2.3 The OPLE System

The purpose of OPLE is to demonstrate the feasibility of using the OMEGA navigational system in conjunction with geostationary satellites to establish a global location and meteorological data collection system. This system differs substantially from the IAS-A and IRLS systems. Position information is obtained through the Navy VLF navigation system, OMEGA. In the operational OMEGA system, a total of eight VLF stations will be operative. Signals will be received from at least three of these stations at any point on the earth. The VLF signals are propagated with very small phase shift for more than 5000 miles. Two lines of position (isophase contours) are generated by the phase difference between each of two pairs of OMEGA transmitters and the RSP positions established by the interception of the isophase contours. Hence, the basic ranging information is obtained in the RSP and is then relayed through the satellite. Figure E-34 depicts the operational sequence for OPLE.

The OPLE control center (OCC) located at GSFC originates the RSP interrogations which are then relayed through the ATS. Several RSP's may be interrogated simultaneously by frequency division multiplexing of the ATS transponder. Those platforms which identify correctly their respective addresses will respond by transmitting tones through the ATS satellite acquisition link to the OCC, to allow phase locked loops to acquire the RSP signal. After the acquisition period, the relayed signals will be translated in frequency from VLF to VHF, compressed into a 2500 Hz BW and transmitted through the ATS to the OCC.

A summary of the basic charistics of IAS-A, IRLS and OPLE are presented in Table E-11.

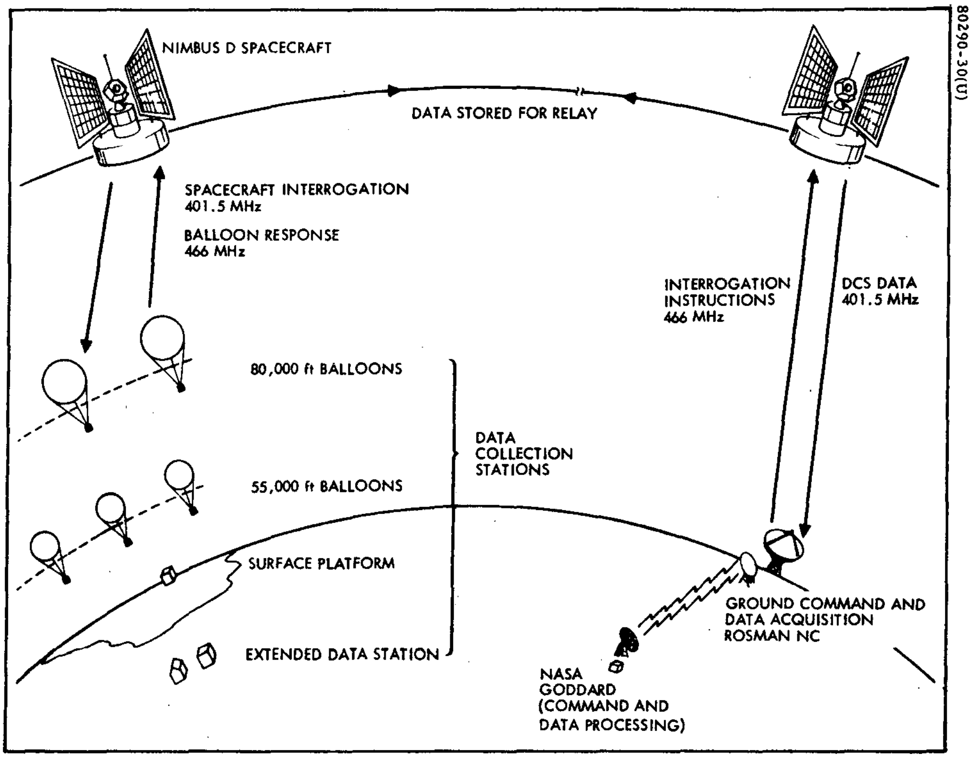


Figure E-33. IRLS Operational Sequence.

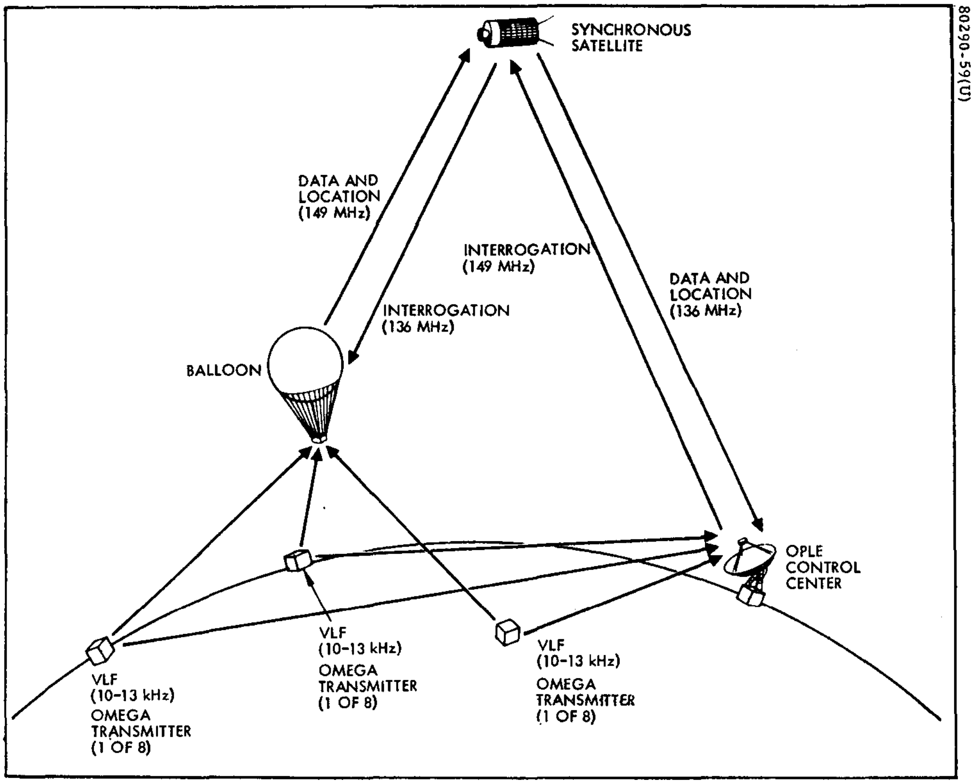


Figure E-34. OPLE Operational Sequence

Table E-11

SUMMARY OF IAS-A/IRLS/OPLE FEATURES

	IAS-A	IRLS	OPLE
Satellite Orbit:			
Altitude	800 KM	800 KM	19323 n.m.
Inclination	50^{o}		Equatorial
Satellite:			
Telem. Transmit Freq.	148 MHz	401.5 MHz	135.6 MHz
Command Receive Freq.	136 MHz	466.0 MHz	149.2 MHz
Interrog. Transmit Freq.	460 MHz	401.5 MHz	135.6 MHz
Interrog. Receive Freq.	400 MHz	466.0 MHz	149.2 MHz
Transmitter Power	4w	21 w	40 w
Antenna Gain	3 db (Max.)	3 db (Max.)	8.5 db
Polarization	Circ.	Circ.	Linear
Receiver Thresh.	-128 dbm	-120 dbm	
Freq. Stab.	0.2 ppm/year	1 ppm	
Noise BW	200 Hz	100 KHz	100 KHz
Equipment Weight	24.8 Kgs	28.5 lbs	31 lbs
Total Power Req.	23 watts	128 watts	96 watts
Balloon:			
Altitude	30,000 ft (300 mb)	55,000 ft (100 mb) 80,000 ft (30 mb)	Variable
Transmit Freq.	400 MHz	466.0 MHz	149.2 MHz
Receive Freq.	460 MHz	401.5 MHz	135.6 MHz; 10-13 KH
Transmit Power	4 watts	6 watts	5 watts
Antenna Gain	3 db (max.)	3 db (max.)	3 db (max)
Polarization	Circ.	Circ.	Linear
Receiver Thresh.	-129 dbm	-112 dbm	-126 dbm
Acq. Time	16 seconds	50 msec.	
Freq. Stab.	3ppm	10 ppm	1ppm
Noise BW	300 Hz	100KHz	7.5 KHz
Thermal Control	Yes	No	No
Power	5 mw (standby) 350 mw (detection) 18 watts (transmit)	65 mw (standby) 360 mw (detection) 25 watts (transmit)	1.1 watts (standby 35 watts (peak)
Lifetime	6 mos.	6 mos.	1 day
Frangibility	Yes	No	No
Equipment Weight	4 lbs	9 lbs	44 lbs
Estimate Cost	$3 to 10,000	$15,000	

Table E-11 continued)

	IAS-A	IRLS	OPLE
Interrogation Command Message Stored in Satellite Command Memory			
Number	64	370	Satellite does not have command memory. All interrogations are in real time
Length	22-bit message	32-bit message	
Composition			
Time —	(9 bits)	(11 bits)	
DCS Address	(9 bits)	(16 bits)	
Format		(3 bits)	
Mode	(4 bits)		
DCS Type		(2 bits)	
Types of Interrogation Command Instructions to Data Collection Stations (DCS)			
Programmed in command memory	Start sequential call End sequential call Destroy sequential called DCS Start nonsequential call Destroy nonsequentially called DCS Turn off satellite transmitter Turn on satellite transmitter (sync signals only)	Call balloon Destroy balloon Call surface platform (up to 30 data frames)	
Nonprogrammed commands (real time)	Turn off transmitter Start sequential call		Call DCS Destroy DCS Turn off DCS electronics until next day/night transition Transmit sensor data only
Interrogation Signal from Satellite to Data Collection Station			
Transmitter frequency	460 MHz	401.5 MHz	135.6 MHz
Modulation	Burst-blank PM	PCM/FM	FSK
Index	$\pi/4$ radians		
Deviation	± 20 KHz	± 2.4 KHz	
Transmitter power	4 watts	21 watts	40 watts
Polarization	Circular	Circular	Linear
Bit rate	48 bits/sec (RZ)	12,500 bits/sec (NRZ)	48 bits/sec (RZ)

Table E-11 (continued)

	IAS-A	IRLS	OPLE
Interrogation sequence	30 bits	16 bits = 192 binits	16 bits
Sequences transmitted	One per DCS	Repeated continuously	45 (one per DCS)
Duration of interrogation	0.625 sec	3.8 sec (if no response) 14.6 sec. (max.)	15 sec
Sequence composition	18 PN bits, 6 zeros, 6 ones 9 last bits of PN = DCS address 2304-Hz burst tone= zero 2688-Hz burst tone= one	16 bits=DCS address or DCS address complement 1 bit=M-word (8 binits) + N-word (4 binits) M-word=bit one or zero N-word=sync	16 bits=DCS address +command+parity First five 16 bit sequences for DCS synchronization. Next forty 16 bit sequences to address DCSs
Same DCS interrogations/pass	Sequential	Instructed by program	One
Maximum DCSs interrogated/orbit			
Sequential	511	370	
Nonsequential	64		
Signal between interrogations			
Normal	Sync signal (24 zeroes, 6 ones)	Satellite transmitter turned Off	Satellite transmitter turned off
By command	Transmitter turned off		
	Signal Transmitted from DCS		
Transmitter power	4 watts	6 watts	5 watts
Carrier frequency	400 MHz	466 MHz	149.2 MHz
Polarization	Circular	Circular	Linear
Modulation	Burst-blank PM FSK/PM	PCM/FM	(Sensor data) PSK
Index	±π/4 radians		±1 radian
Deviation		±20 KHz	
Satellite received signal			
Level	-128 dbm	-133 dbm	-126 dbm
Bit rate	48 bits/sec (RZ) 24 bits/sec	12,500 bits/sec (NRZ)	56 bits/sec Omega tones
Response sequence	Carrier only (0.1 seconds) 12 bits (at 48 bit sec) 4 tones (24/sec) (transmitted once)	192 binit lines repeated continuously until sync verified; 10,192 binit lines after sync verified	Carrier only (11 seconds) Sensor data (3.9 seconds) Omega (180 seconds)

Table E-11 (continued)

	IAS-A	IRLS	OPLE
Signal Transmitted from DCS (continued)			
Duration of response	0.625 sec	3.8 sec (max. if balloon) 14.6 sec (max. if surface platform)	194.9 sec
Sequence composition	Carrier only (0.1 sec) 6 zeroes, 6 ones (distance measured) Zero=2304 MHz, one=2688 MHz 4 data tones	16 bit lines corresponding to DCS address or two 7-bit data words 1 bit encoded into M-word (8 binits+N-word (4 binits) M-word=bit one or zero N-word=sync	Carrier only (11 sec) Sensor data (7-bit words) Omega tones retran mitted for 3 min.
Data transmitted	4 data tones	7 data words (balloon) 21 to 126 data words (platform) 630 data words maximum (extended data platform)	8 data words Omega tones
DCS signals transmitted simultaneously	1	1	40
	Satellite Measurements		
Measurement Doppler frequency shift	Phase lock carrier Count zero crossings in Time T Measure T by reference with stable clock (4.6 MHz) 0.2 ppm stability		All data processin is performed at OPLE Control Center. Satellite only relays DCS signals
Accuracy*	0.2 Hz		
Distance	Phase lock carrier Determine phase of 3 tones by measuring quadriture components. Compute from them distance	Synchronize digital data Measure time between receiving and transmitting same signal by reference with stable clock (1.6 MHz) 1 ppm stability	Phase lock Omega signals relayed by balloon Phase lock signals received directly from Omega station Compare
Accuracy*	0.1 radian (0.5 kilometer)	1 kilometer	1 kilometer

*Accuracy based only on instrument performance

Table E-11 (continued)

	IAS-A	IRLS	OPLE
	Data Recording		
Data memory capacity	121072 bits	100640 bits	No data is stored on satellite
Data memory format			
Bits/line	103	16	
Lines/frame	1	10 (balloon) 17 (balloon)	
Frames/DCS	1	1 (balloon) 1 to 6 (platform) 30 (extended data)	

E.5.2 HYDROLOGICAL DATA GATHERING AND TRANSFER

1. BACKGROUND

The gathering and transfer of hydrological data appears to be a valid contender for the "Data Collection" user category. The collection, management and sales of water constitute an astonishingly large monetary base as shown by the following data:

a. National consumption has reached a level of over 500 million gallons a day. This represents daily sales of about $10 million dollars.

b. A mere one percent increase in hydroelectric power generation efficiency is worth $100 million annually.

c. Yearly damage from floods range from $500 million to $900 million. Some estimates project that flood losses may go as high as $1.3 billion by 1980 if present trends in landscape modification of watershed go unchecked. No monetary estimate has been placed on loss of human life due to floods.

d. Years of severe drought have resulted in hundreds of millions of dollars of agricultural losses, and have more recently caused crises in urban areas and in industry.

The economic management of the nation's water resources is shared by many agencies both state and federal. Most of the data required for research and management of water resources is gathered, processed and published by the U.S. Geological Survey. Some significant users of hydrological data are:

a. U.S. Government Agencies

   1. Corps of Engineers

   2. Bureau of Reclamation

   3. Forrestry Service

   4. Weather Bureau

5. Public Health Service

6. Department of Agriculture

b. State Agencies

c. Power Utilities

d. Insurance Underwriters

e. Industry

Probably the most significant role of a satellite in a hydrological data system is the timely collection of reports from sensors. A national data collection system would employ at least 10,000 sensors which measure and report on such quantities as:

a. Reservoir stage

b. Streamflow

c. Water quality

Dissolved oxygen content
pH
Turbidity
Conductivity
Dissolved chlorides
Water temperature

d. Other

Solar radiation
Atmosphere radiation
Ground water measures
Precipitation
    Snow pack depth and water content
    Rainfall
Meteorologic
    Wind direction and velocity
    Air direction and velocity
    Relative humidity
    Evaporation

Data from sensors is distributed to collection centers where it is processed. A secondary role of the satellite is the distribution of processed data. Some research is being made into the feasibility of collecting hydrological data from sensors aboard a satellite. Whether or not this is an appropriate role for Information Transfer Satellite has not yet been considered in this study.

As a first step in determining user requirements, a visit was made to the U. S. Geological Survey, Water Resources Division, Menlo Park, California. Mr. Warren W. Hastings, Chief Hydrologist and members of his staff gave a general description of the present-day status of hydrological data gathering and provided a number of basic documents and brochures on hydrology, much of which was used in this report. Mr. Hastings also offered to write a letter of introduction to Mr. Charles Robinove, Office of the Director, U. S. G. S., Washington. A visit to Mr. Robinove's office will be made during the July visit to the Washington area.

One very interesting document provided by Mr. Hastings was an advance copy of Satellite (ERTS-A) Network of Ground Data Sensors: A User-Oriented Experiment by James F. Daniel, U. S. G. S., St. Louis. Mr. Daniel will deliver this paper at the National Symposium on Data and Instrumentation for Water Quality Management, University of Wisconsin, July 21 – 23, 1970.

Copies have been obtained of the final report of MevA Corporation' study, Pilot Program for Pilot River Basin, performed for U. S. G. S. in 1966. This study concentrated on the communications problems of a single river basin. A number of approaches were considered including one synchronous satellite system. The MevA study will be reported on in more detail in the next period.

The balance of this report will be devoted to details of the U. S. G. S. operations and a broad introduction to the field of hydrology.

2. U. S. GEOLOGICAL SURVEY

The Geological Survey is a scientific agency of the U. S. Department of the Interior, with headquarters in Washington, D. C.

The work of the Survey is divided among four operating Divisions: Topographic, Geologic, Water Resources, and Conservation; and three staff Divisions: Computer Center, Publications, and Administrative.

The activities of the operating divisions include fact-finding and research concerning the earth and man's attempts to understand its surface and subsurface resources. The Topographic Division takes the necessary first steps in earth studies by preparing precise maps on which the physical characteristics of the terrain are graphically recorded. The Geologic Division studies the structure and composition of the earth and the location and origin of its useful materials. The Water Resources Division collects basic information on the quantity, quality, availability, and behavior of water. From field offices situated near operations, the Conservation Division classifies the mineral, water storage, and waterpower potential of Federal lands.

2.1 Water Resources Activities

The Geological Survey carries out investigations on the quantity, quality, availability, and movement of both the surface and underground water throughout the Nation. Results of these studies provide a basis for development, conservation, and management of water resources. Research is aimed at determining the physical and chemical laws that govern the behavior of water on and within the earth.

2.2 Water Resources Activities in the Western States

To facilitate its work in the Western States, the Survey maintains a regional Pacific Coast Center located at Menlo Park, California, about 30 miles southeast of San Franciso. The regional administrative office of the Water Resources Division is headquartered at the Center, directing all water-resources investigations and research studies in Alaska, California, Hawaii, Idaho, Nevada, Oregon, and Washington. A wide range of water-resources research is undertaken at the Center. Most of the hydrologic investigations throughout the region are conducted in cooperation with other agencies of the Federal, State, or local government. This work is carried out at the state level from seven district offices--one in each state.

One main objective is to provide a continuing inventory of the Nation's water resources. A hydrologic data network is used for measurements of stream-flow, water levels in wells, chemical quality, water temperature, and sediment content of surface and ground waters. In the seven states of the Pacific Coast region there are about 2,000 data-recording instrument stations on streams, lakes, canals, and reservoirs--800 of them are in California. Many of the stations are fully automated, using digital recorders and other devices which record data on punched or magnetic tape for rapid processing by computer. Water-level measurements are made continuously or periodically at about 2,100 sites in the Pacific Coast region, half of them in California. Quality-of-water observations are made at more than 300 stations on streams, canals, and reservoirs, and for about 500 ground-water observation wells. Again, about half are in California. The water data from the networks are made available promptly to all who need them.

Hydrologic studies and aerial appraisals of water resources of specific localities are conducted by scientists at the Center and from field offices in the Pacific Coast region. Some of these studies are made to find solutions to particular problems, such as contamination of ground water in an area. Other studies seek answers to a broadening understanding of the physical and hydrologic framework of an entire watershed or other large hydrologic system. The following are representative of studies recently completed or in progress:

a. The magnitude, frequency, and duration of floods in the principal river basins of the several states in the Pacific Coast region.

b. Comprehensive study of the water resources of the Pacific Northwest region to establish supply-demand relationships.

c. Water-supply evaluation for nuclear-power development and disposal of radioactive wastes at sites in Idaho and other states.

d. Studies leading to estimates of sustained yield of groundwater systems based on annual recharge or discharge from the underground reservoir.

Other studies include appraisals of the availability, quality, and use of surface water problems that exist or may develop; flood-plain mapping of areas that have critical flow problems; investigations of deficiencies in streamflow; and local and regional reconnaissances of the chemical quality and sediment characteristics of surface waters.

2.3 Research Activities

Research forms an integral part of the many hydrologic studies conducted in the Pacific Coast Region. The land-subsidence study in the San Joaquin Valley is an example of a study where extensive investigation of effects of pumping, compaction from flooding, and other factors were involved. In addition, an organized research effort covering a broad range of hydrologic problems is underway at the Pacific Coast Center and several field locations in the Pacific Coast region. Examples are:

a. Measurements and identification of organic waste products and natural organic substances found in ground and surface waters. Special attention is being given to pesticides in this study.

b. Potential applications of nuclear explosives in development and management of water resources.

c. The occurrence, transport, and disposition of radio-nuclides in the Lower Columbia River, including the estuary.

d. Phreatophytes (water-loving plants) and their effects on water resources.

e. Factors affecting the movement of underground water.

f. The source of dissolved minerals in water and their chemical effects.

Other research studies in progress are concerned with the dispersion of flows in open channels, biological alteration of water properties, erosion and sediment movement in stream systems, glaciology, and hydrologic modeling techniques.

2.4 Computer Center

The Computer Center at Menlo Park is part of a modern "state-of-the-art" nationwide computing system which links remote smaller computers by telecommunication circuits to a large-scale general purpose computer in Washington, D. C. Scientists and engineers in the Pacific Coast area are able to use the speed and power of the central computer even though they enter problems into the system at Menlo Park. Within minutes the printed results are returned to the originator by telecommunications.

3. SCOPE OF THE HYDROLOGICAL PROBLEM

3.1 Hydrologic Cycle

The Hydrologic Cycle comprises a constantly running distillation and pumping system. The sun supplies heat energy, and this together with the force of gravity keeps the water moving; from the earth to the atmosphere as evaporation and transpiration, from the atmosphere to the earth as condensation and precipitation, and between points on the earth as a stream-flow and ground-water movement. In this system, there is no water lost or gained, but the amount of water available to the user may fluctuate because of variations at the source, or more usually, in the delivering agent. In the geologic past, large alterations in the cyclic roles of the atmosphere and the oceans have produced deserts and ice ages across entire continents. Small alterations of the local patterns of the Hydrologic Cycle produce floods and droughts.

Every second, millions of sun-heated molecules are evaporated into the air to help supply the water for the Hydrologic Cycle. The total water supply of the world is 326 million cubic miles (a cubic mile of water equals more than one trillion gallons). At any instant, only about 5 gallons of every 100,000 gallons is in motion. Most of the water is stored in the oceans, frozen in glaciers, held in lakes, or detained underground.

The counterminous United States receives a total volume of about 1,430 cubic miles of precipitation each year. Only about 3,100 cubic miles of water, chiefly in the form of invisible vapor, is contained in the atmosphere at any given time. Once fallen, water may run swiftly to the sea in rivers, or may be held in a glacier for 40 years, in a lake for 100 years, or in the ground for thousands of years. Or, it may evaporate immediately. Regardless of how long the water may be delayed, it is eventually released to enter the cycle once more.

Of the 102,000 cubic miles of water that passes into the atmosphere annually, 78,000 cubic miles falls directly back into the oceans. Streams and rivers collect and return to the oceans some 9,000 cubic miles of water, including a large quantity of water which has soaked down into the ground and which, as "ground water," had moved slowly to natural outlets in the beds and banks of streams. The remaining 15,000 cubic miles of water maintain life processes, principally as soil moisture which provides water necessary to vegetation. This water reaches the atmosphere again by the process of evapotranspiration.

More than 2 million cubic miles of fresh water are stored in the earth, about half within a half mile of the surface. This is more than 35 times the amount held on the surface in lakes, rivers, and inland seas, but in turn, is relatively small compared to the 7 million cubic miles stored in glaciers and icecaps. The 317 million cubic miles of water held by the oceans constitutes 97.3 percent of the earth's supply.

3.2 Supply and Demand

Studies by the U.S. Geological Survey show that the U.S. water supply potential of 1,200 billion gallons per day is more than adequate for the Nation's needs. These studies also indicate that there is no nationwide reduction of stream-flow or lowering of the water table. These facts are reassuring and promise that water problems can be solved by intelligent action. Nevertheless, there is little reason for complacency. Almost every part of the United States has at least one major water problem, such as depletion of ground water, floods, droughts, and pollution of surface water. The cost of a clean and ample water supply is also increasing and it is becoming more difficult to meet the expanding and diversified demands for water.

Precipitation is the ultimate source of all water supply. An average of 30 inches of water falls as rain or snow in the United States each year. About 22 inches is evaporated or used by plants, and 8 inches runs off into the oceans after traveling over or through the ground. The amount of water available for use is about 9 inches, several times greater than the amount presently used in the United States.

The distribution of this total U.S. water supply, however, is most uneven. The arid West, where the climate and soil are often highly favorable for agriculture, does not have enough water. In the more humid areas of the country there is a surplus of water, but unfortunately, much of the surplus is of little use to man because it occurs in the form of floods which often do great damage. And even the humid areas are subject to occasional severe droughts, as in the 1930s, in 1949, and again in the 1960s.

Much available surface water is unusable for more purposes because it is badly polluted. Treatment of water to make it drinkable is expensive, and the readily available supplies of good quality near the great centers of industry and agriculture are already developed. Development of additional supplies will cost more and more as time goes on.

As shown in Figures E-35and E-36, industry needs water in fantastic quantities and the demand is skyrocketing. It has increased ten fold since 1900, although the population has little more than doubled. Industries in the United States use 700 gallons per person per day; an individual person in his home for drinking, washing, and other household purposes uses an average of only 50 or 60 gallons a day. Ninety-four percent of industrial water is used for cooling, and most of this can be used again. There is a widespread notion that United States industry will soon be faced with a serious permanent water shortage. This is not true, for the overall supply exceeds the demand and will continue to do so in the foreseeable future. However, there may not be enough water at a given place in a given season, at a price that industry is willing to pay. As shown in Figure E-37, the need for industrial water by regions does not necessarily correlate to availability. And this situation will increasingly worsened as the quality of water in some areas continues to decrease because of pollution and ecological imbalance.

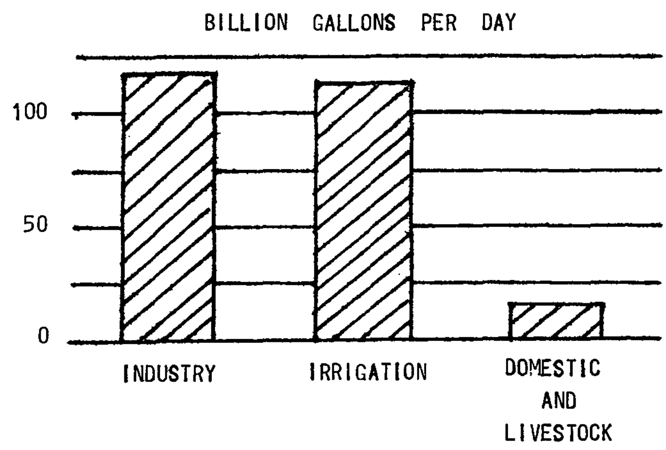


Figure E-35. Consumers of Water

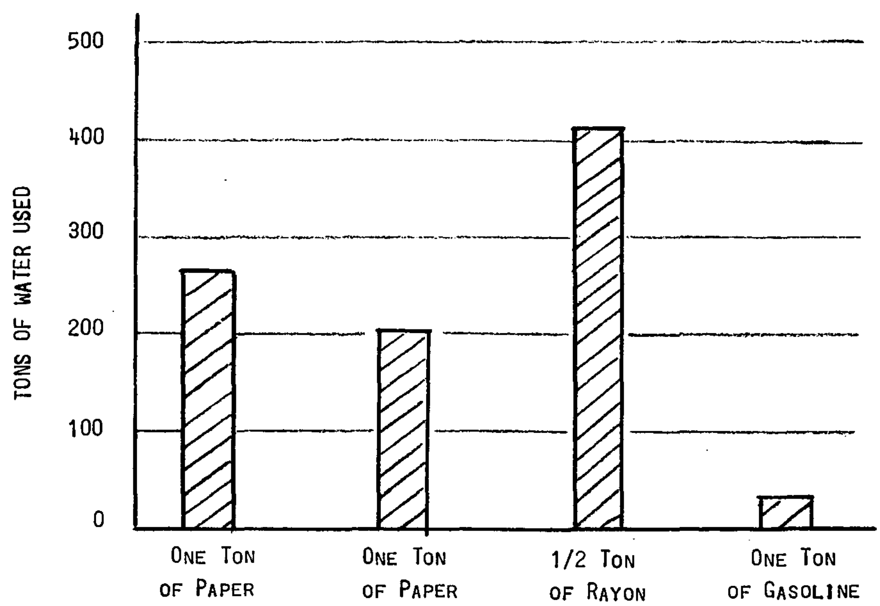


Figure E-36. Water Consumed to Produce Various Materials

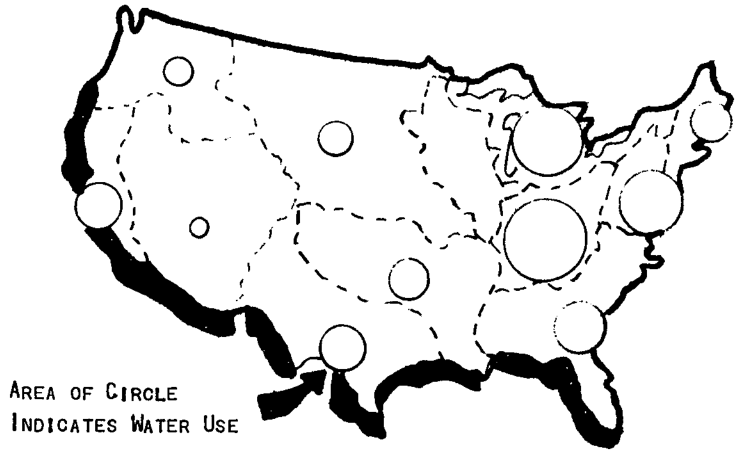


Figure E-37. Use of Industrial Water by Regions

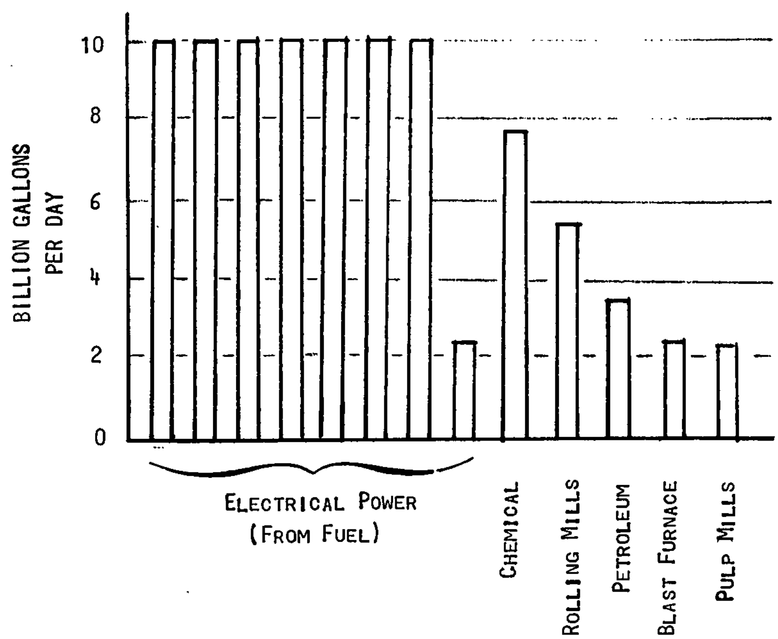


Figure E-38. Major Industrial Users of Water

Some industries use much more water than others. The electric-power industry is the largest user of water. Figure E-38 illustrates that the electric-power industry uses almost ten times as much as the chemical industry, which is the second largest user. The amount of water used depends on the size of the industry and on how the water is used. Industry uses water for cooling, processing, and for sanitation and services.

The electric-power industry cools the steam from turbines with water. The cooled steam condenses, thus reducing the back pressure on the turbines, and increasing the efficiency of the plant. The chemical, petroleum-refining, and steel industries also use large quantities of cooling water. Water for cooling does not usually have to be of high quality.

Water for processing is either incorporated in the product, as in soft drinks or canned fruit, or it comes in contact with the product during manufacture. For certain industries, process water would obviously have to be of very high quality. The pulp-and paper industry uses water for washing the pulpwood, cooking the woodchips, and transporting the pulp to the paper machines. Such water would not have to be quite as pure and free from dissolved solids or bacteria as water used in food-packing plants, or in the making of synthetic textiles.

Some industries require a high standard of quality of water, but others can use water of poor to medium quality. In general, calcium and magnesium compounds are undesirable in process water, especially if the water is used hot, because a scale will be deposited in the machinery. Certain minerals are likely to stain the product and are therefore undesirable. If the product is a synthetic fiber such as rayon or acetate, iron and manganese interfere with bleaching and dyeing. Synthetic fibers require a very high quality water--soft, and low in mineral content. Figure E-39 contrasts the water quality limitations for some representative user processes.

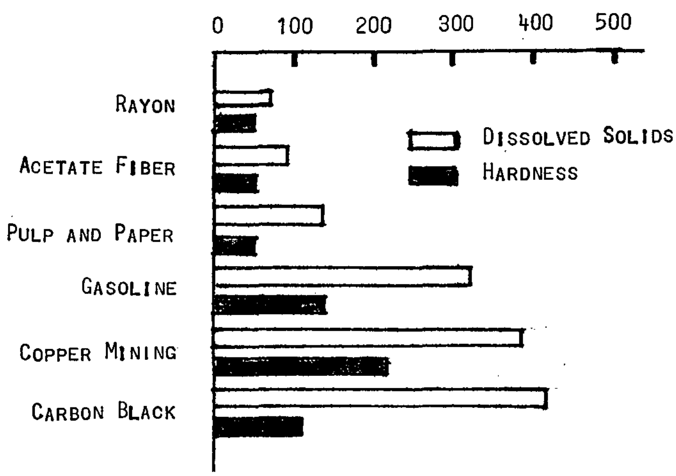


Figure E-39. Water Quality Limitations for Various User Processes

4. NEXT EFFORTS

a. Visit Washington office of U. S. G. S.

b. Extract parametric data from the MevA study.

c. Examine more closely the paper Satellite (ERTS-A) Network Ground Data Sensors; contact the author for more details. Gather information about this program from other sources.

5. SOURCES AND REFERENCES

a. U. S. G. S. Brochures:

1. Reports on Public Water Supplies
2. Water Conservation
3. Pacific Coast Center
4. Water Conservation
5. The Hydrologic Cycle
6. Water and Industry

b. James F. Daniel, U. S. G. S., St. Louis: Satellite (ERTS-A) Network of Ground Data Sensors: A User Oriented Experiment.

c. MevA Corporation: Final Report, Pilot Program for Pilot River Basin, January 15, 1967.

E.6 POST OFFICES SERVICES

E.6.1 MAIL DELIVERY CONCEPT

1. Status of Postal Mail Delivery

Almost everyone is aware of the gradual worsening of mail service accompanied by an increase in postal rates. As the mail volume increases, the present antiquated methods of mail handling and delivery are shown to be more inadequate. Unless something drastic is done, a complete breakdown in service is felt by authorities to be inevitable. Tables E-12 andE-13 reveal not only the magnitude of the problem but the rate at which this problem is accelerating.

Table E-12. Increase in Mail Volume

BILLION PIECES					
1965	71.3	1967	77.7	1969	82.0
1966	75.0	1968	78.7	1970	84.3

Table E-13. Post Office Operating Deficits

FISCAL YEAR	TOTAL OPERATING DEFICIT (MILLIONS)	FISCAL YEAR	TOTAL OPERATING DEFICIT (MILLIONS)
1965	$ 729.5	1968	$1,020.9
1966	942.3	1969 (Est)	1,021.5
1967	1,147.0	1970 (Est)	1,310.4

Because of the seriousness of the problem, President Johnson appointed a Commission on Postal Organization which made as its recommendation an immediate and complete reform of the Post Office Department. It was recommended that a Federal Postal Corporation be created. This recommendation was adopted by the present administration and a detailed corporation plan has been drawn up and submitted to congress. The result of this reorganization would be that the present post office would be transferred to a corporation known as the United States Postal Service to be operated similar to a private business corporation removed from politics. One of the advantages of this reorganization would be that the corporation could, by issuing bonds, borrow up to ten billion dollars to help finance improvements of facilities and equipment. Also as a private corporation it would have more freedom in negotiating contracts with transportation companies for carrying the mail. Although this proposed legislation is receiving much opposition in congress and from the postal workers unions, it is inevitable that far-reaching changes will eventually be made to the post office system to cope with the existing problems.

2. Private Mail Systems

Although the increasing glut of mail is posing many problems, it could be worse if there were not private postal systems providing mail service that would otherwise be supplied by the Post Office Department. Briefly there are these services that are presently available:

a) IPSA, Independent Postal Service of America — This firm delivers third class or junk mail in 37 cities and is expanding. It makes money in spite of the fact that its rates are less than that of the Post Office Department. It is operated by franchised operators who hang deliveries on doorknobs in plastic bags since it is forbidden by law to use residential mailboxes. IPSA has applications for franchises from about 2000 towns and cities and is preparing to deliver mail on a selective list basis.

b) UPS, United Parcel Service — UPS delivers parcels within cities as well having intercity and interstate delivery service. It also makes a profit with rates that are in many instances lower than that charged by the P.O.D. As with IPSA it deals with business firms not individuals. UPS is preferred by many businesses because of its reliability and predictability of delivery. In addition, it provides services not available from the P.O.D. such as automatic daily pick-up at a flat charge, delivery direct to the addressee in person, obtaining addressee's signature for every parcel delivered, three attempts at delivery if addresses isn't home and automatic protection up to $100 on every parcel against loss or damage.

In addition, air freight is increasing and becoming cheaper as the jumbo jets go into service. Also buses carry parcels.

3. Existing Electronic Transfer Techniques

Post Office Department financed and independent studies are investigating the application of electronics to handling and transfer of mail. In the meantime advanced techniques are being applied to the transmission of newspapers and documents.

a) Facsimile Transmission of Wall Street Journel — Since 1962 an exact duplicate of each page of the Pacific Coast Edition of the Wall Street Journal has been transmitted from Palo Alto, California to Riverside, California, a distance of 400 miles. Transmission by pressfax facsimile equipment produces a full page-size negative in 4.5 minutes. Photography and photo-engraving etching produces a master plate used directly on rotary printing presses. Excellent quality is achieved by using a 1000 per inch scanning line density. The entire newspaper is transmitted in less than two hours via a television channel furnished by Pacific Telephone and Telegraph Co. Facsimile is the medium for distributing newspapers to printing plants in Texas and Arkansas by means of a 600 KHz private microwave system. Where economically feasible, facsimile transmission will expand to other newspapers and magazines in the future.

b) Message Facsimile — The introduction of low cost fool-proof facsimile systems that send and receive documents over voice grade telephone lines has made this service available to low-volume users. The availability of these low cost facsimile systems has resulted in the organization of at least four networks to provide facsimile transmission between major U.S. cities. Rates vary from $2.50 to $9 per 8-1/2 × 11-inch page, in addition to telephone charges of 6 minutes per page. Western Union has been providing facsimile service, Info-Fax, between 5 major cities for several years. Design improvements claimed by some manufacturers will reduce transmission times of from 3 to 6 minutes to less than a minute over a voice grade line and thus reduce telephone charges.

4. Proposed Satellite Mail Delivery Systems

Several means have been suggested as a means of providing improved mail service. On a trial basis is a joint effort between the Post Office Department and Western Union whereby the post office patron may for an additional charge have a message transmitted via the Western Union microwave system to a post office at the destination and then delivered as regular letter mail to the addressee. Recent studies have resulted in proposals for mail delivery systems utilizing satellite radio links.

a) General Electric "Telemail" — In a special filing before the FCC in February 1969, General Electric proposed a system whereby one of the features would be to transmit mail from business firm to business firm at a cost of 33 cents for a 600 word message in 1975, eventually decreasing by 1990 to 10 cents for the same length message. Terminals similar to teletypewriters would be linked by a satellite repeater using time division multiple access (TDMA) modulation techniques. Assuming a 100% penetration of this business-to-business market the projected volume predicts 16 billion messages by 1975 and 20 billion messages by 1980. This system would operate completely independent of the P.O.D. but would presumably supplant the P.O.D. in servicing business-to-business mail requirements.

b) Lockheed Advanced Satellite Applications Study — This study titled "Relay Satellite Facsimile Postal System Concept" would augment the present postal system to provide next day delivery of preferential mail posted anywhere in the United States. The system would consist of a single satellite with antenna coverage of the entire CONUS, a master traffic control station and 100 post office substations. A high speed facsimile system is proposed that would transmit at a rate of 70 sheets per second.

E.6.2 MAIL SYSTEM PARAMETER DETERMINATION

Purpose and Objectives

The purpose of this study is to develop a model of an electronic mail distribution network so that the ITS computer synthesis program can be used to optimize the parameters of the network with the objective of defining a minimum cost system. Electronic mail distribution to households via CATV networks is assumed. The time base year is 1985.

Based on various proposals for mail transmission and the trend towards private mail delivery firms, it is difficult to predict what proportions of the total mail volume will be allocated to the various private services and the U.S. Postal Department. However, the study should yield parametric data on which the cost effectiveness of electronic mail delivery can be based.

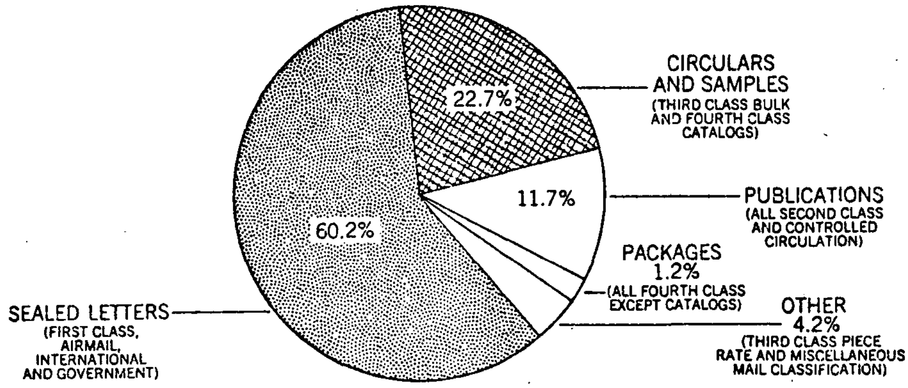
Review of Postal Mail Service

Some of the principle functions of the postal system have changed since the early years of this country. Originally the mails were the only means of communications. Now there are many available means of communications so that consequently there is not as great a dependency upon the post office to provide this type of service. In the early years it was necessary for the post office to establish post roads to serve as a network for mail delivery via stage coach. Each new mode of transportation such as railroads, canals and eventually airlines were supported by government subsidies and mail contracts. The post office was used as a means of dispensing patronage so that top management selection has been based on political considerations with continuity only for the duration of the political party in power. Special rates were given to newspaper and magazine publishers because a free flow of information was considered necessary to maintain and preserve the democratic process. An absolute sanctity for the contents of the mails has been maintained by the P.O.D. since its inception and has been accepted by the public as a fundamental characteristic of the postal service.

As a result of these established precedents, traditions have developed that exert a strong influence both on how the post office is operated and what is expected by the public. A postal deficit is considered necessary because the post office has subsidized transportation and given preferred rates to publishers. The post office is expected to continue to operate as a politically influenced branch of the government with top administrative posts filled by political appointment. The public feels strongly that a privacy and security of letter mail will always be maintained.

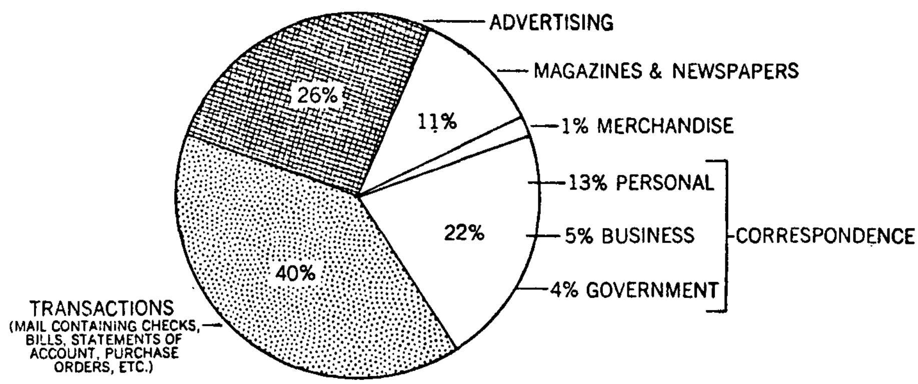
Today's Composition of the Mail

In the early days of the postal service correspondence between individuals undoubtedly dominated the mail flow. Gradually there has been a transition in mail usage so that today this type of mail represents only 7% of the mail volume, 14% if greeting cards are included. The mail has today become a principle means by which the nation's business is conducted. It is a primary vehicle for exchange of bills, orders, account statements and checks. Approximately 70% of all magazines are delivered by mail. Figure E-40 illustrating percentage of mail volume by various classes indicates that there are four principle classes of mail as defined by post office statutes. Arthur D. Little, Inc. in a special study for the P.O.D. has revealed the actual uses to which the mails are put. This is illustrated in Figure E-41.



Source: Compiled from Post Office Department data.

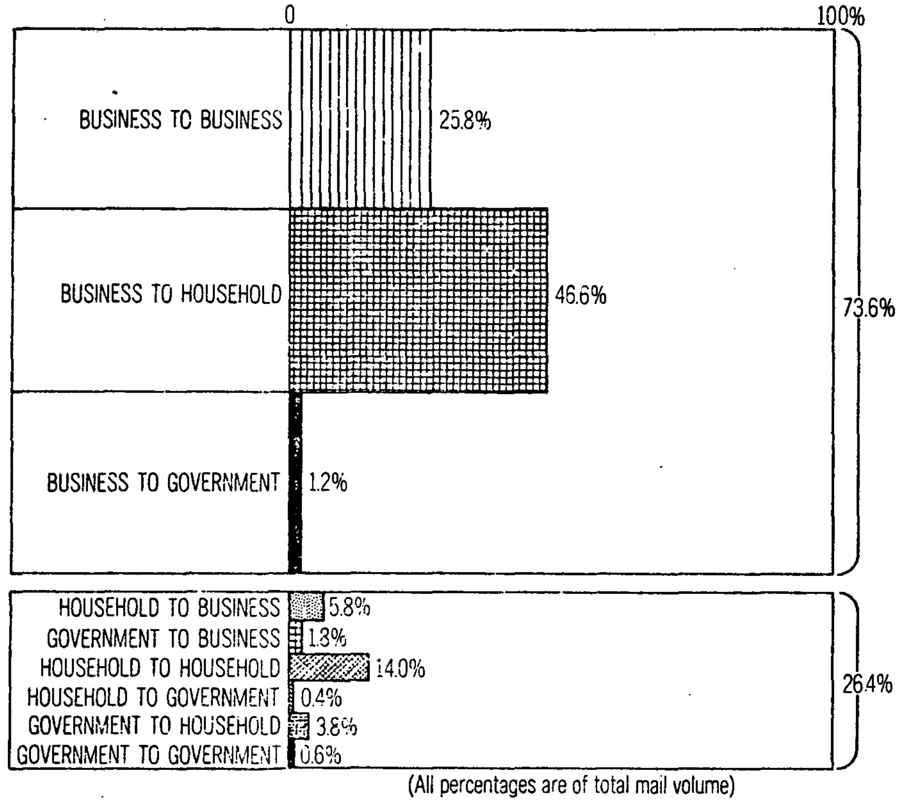
Figure E-40. What is the mail?



Source: Compiled from Arthur D. Little, Inc.; details in Special Study on Services.

Figure E-41. What's in the mail?

Thus it may be noted the extent to which business mail predominates with 40% of the mail consisting of transactions and advertising making up 26% of the total mail volume. Figure E-42 from the same special study shows that business (including non-profit institutions) originate 74% of the mail, households 20% and government 6%.



Source: Compiled from Arthur D. Little, Inc.; details in Special Study on Services, Part II.

Figure E-42. Most mail is sent by business.

Transactions - Transactions comprise the greatest percentage of the total volume of mail. Table E-14 is a breakdown of transactions mail. Flow shows that 80% of all transaction mail consists of business to business and business to household.

The volume of transactions that involve transmission of money is particularly significant since in the future electronic means will undoubtedly be utilized for transferring funds. Table E-15 shows the breakdown of mail flow for transactions involving money transfer.

Table E-14. Flow of transactions.

		Percent of All Transaction Mail	Percent of All Mail
From *business*	to business	43	17
	to households	37	15
	to government	1	*
From *households*	to business	13	5
	to households	1	1
	to government	*	*
From *government*	to business	1	*
	to households	4	2
	to government	*	*
		100	40

*Less than 0.5%.
Note: This table and those which follow are drawn from the Commission's Study of the Market for Postal Services by Arthur D. Little, Inc.

Table E-15. Transactions containing money

		Percent of all Monetary Transfers	Percent of all Transactions	Percent of all Mail
From *business*	to business	29	7	3
	to households	8	2	1
	to government	4	1	*
From *households*	to business	43	10	4
	to households	6	1	*
	to government	1	*	*
From *government*	to business	*	*	*
	to households	9	2	1
	to government	*	*	*
		100	23	9

*Less than 0.5%.

2. <u>Advertising</u> — Fig. E-41 indicates that 26% of all mail volume is made up of advertising matter with 5% sent from business to business and 21% from business to households.

3. <u>General Correspondence</u> — Tab. E-16shows the flow of general correspondence mail. It may be noted that in spite of the fact that business-to-business messages have been considered to be a promising candidate for electronic mail transfer it consists of only 2% of the total mail volume.

Table E-16. General correspondence mail.

	Percent of All General Correspondence	Percent of All Mail	
Business to:			
Business	9	2	Business Correspondence (5%)*
Households	4	1	
Government	4	1	
Households to:			
Business	3	1	
Households	60	13	Personal Correspondence*
Government	1	**	Government Correspondence (4%)*
Government to:			
Business	6	1	
Households	10	2	
Government	3	1	
	100	22	

*Corresponds to terms used in Figure 13, p. 48.
**Less than 0.5%.

4. <u>Proximity of User to Sender</u> — Of importance in determining the percentage of mail that might be transmitted via satellite is the proximity of business senders to household recipients. Tab. E-17 provides this type of information.

Table E-17. Proximity of business senders to recipients.

Kind of mail	Percent Local*	Percent Same State	Percent Out-of-State
Letters:			
From a bank or Savings & Loan Association	50	78	22
From a store or about a charge account or credit card	42	70	30
From an insurance company	19	56	44
From electric, gas or telephone company	37	88	12
From a nonbusiness association	44	70	30
Other	25	46	54
Postcards: **			
Bills	54	80	20
Other	46	75	25
Parcels	8	32	68
Total	33	60	40

*Local mail is not necessarily in-state, *e.g.*, St. Louis, Missouri, and East St. Louis, Illinois.

**The allocation of postcards by location of sender is based on a very small sample—27% of the total number of postcards in the study.

5. Urgency of Mail — Electronic transmission of mail provides a means of reducing the transmission time between distant points. Tab. E-18 contains the results of a questionnaire to determine how great a demand there is for more rapid mail service if it requires higher cost or a trip to the post office. A recent test of length of time required to deliver letters reported in Life Magazine for 28 November 1969 indicated that short distance mail delivery is often slower than mail transmitted from coast to coast. Therefore electronic transmission across country would not necessarily speed mail delivery without a parallel effort to expedite intercity mail delivery between the postal terminal and the recipient.

Table E-18 Relationship of type item mailed to urgency required.

Item: \ Type of action:	Mail at the Post Office	Pay an Extra Penny	Pay an Extra Dime	Do None of These Things
All letters and postcards to business (45%)	35	14	4	61
containing money (31%)	36	14	3	60
not containing money (14%)	35	15	5	62
All letters and postcards to individuals (52%)	40	24	6	53
containing money (7%)	34	21	5	57
not containing money (45%)	41	24	6	53
All letters and postcards to government (3%)	36	16	8	58
containing money (1%)	40	15	11	53
not containing money (2%)	32	17	7	63
Total letters and post-cards (100%)	38	19	5	58
containing money (40%)	36	15	4	59
not containing money (60%)	39	22	6	55

Notes: Figures in parentheses beside each item show percentage of all household-generated letters and postcards represented by item.
Figures in table show percentage of total items for which respondent said he was willing to take the action shown.
Money is defined to include checks, money orders, drafts, etc.

There is no service at present that can be purchased from the P.O.D. that will assure next day mail delivery. Special delivery service comes into play only after a letter has reached its city of destination and is sometimes slower than regular service. Apparently a need does exist for an expedited service for the mail willing to pay a premium for assured next day delivery. Arthur D. Little, Inc. in its market analysis for the P.O.D. recommends two types of service:

1) Assured same day or next day service for mail users regarded as urgent.

2) Normal dependable delivery for remainder.

<u>Efficiency of Information Transmission</u>

Since the cost of information transfer can ultimately be expressed in terms of cost per bit it is desirable to minimize the number of bits required to transmit a given message. Shannon has defined methods of calculating the information content or entropy, H, of the written language. If the language is translated into binary digits in the most efficient way, the entropy H is the average number of binary digits required per letter of the original language. The average information per word of a message with n possible words of probability P_1 to P_n, respectively, is

$$H_{\Delta V} = -\sum_{j=1}^{n} P_j \log P_j \text{ bits/word}$$

Based on tabulations of word frequencies Shannon has plotted logarithmically word probability against frequency rank, yielding a resultant slope of -1 such that if P_n is the probability of the nth most frequency word, then roughly $P_n = \frac{0.1}{n}$. The total probability becomes unity for $n = 8,727$; therefore

$$H_{\Delta V} = -\sum_{1}^{8727} P_n \log_2 P_n = 11.82 \text{ bits/word}$$

or 2.14 bits/letter based on an average of 5.5 letters per word.

The information content of a typewritten 8-1/2 × 11" page of English text, assuming a 300 word average is $11.82 \times 300 = 3550$ bits. Converting each character of a 8-1/2 × 11" typewritten page to a 7 bit binary word results in $300 \times 5.5 \times 7 =$ 11,550 bits per page. If the same typewritten page were to be transmitted by facsimile at a density of 100 lines per inch the number of bits required would be $8.5 \times 11 \times 100^2 =$ 935,000 bits. Due to the predominance of white areas in a document containing typewritten text, significant data compression is possible. One data reduction technique that can be used is run length coding which is based upon transmitting one data word for each group of consecutive white elements and one data bit for each black element. A data compression ratio of about 4:1 can be achieved using this technique, thus reducing the number of bits per page to $935{,}000/4 = 233{,}750$ bits, which is still 20 times greater than the number of bits required to represent the characters of printed text digitally. Therefore, if there is a choice, English text messages should be generated and transmitted by teletypewriters or similar devices rather than by facsimile if efficiency of information transfer is to be achieved.

Determination of Mail Volume Requirements for a Satellite Network

If one were to make a summation of all the following categories of transaction mail and correspondence mail it would amount to 40% of total mail volume.

Transaction Mail	% of Total
business to business	17
business to household	15
Correspondence Mail	
business to business	2
business to household	1
business to government	1
government to business	2
government to household	2
government to government	1
Total	40

According to Tab. E-15 the average percentage of business to household mail that is mailed out of state is 34%. Assuming this as a valid percentage for all the above categories, this figure will be used to determine the ratio of mail volume that is amenable to transmission by satellite.

Fig. E-43 projects a total mail volume in 1985 of 125 billion pieces based on a linear extrapolation of data points from Tab. E-12. It may be noted that a projection for 1980 from a recent magazine article is slightly above the projected line in Fig. E-43

According to Fig. E-44 it may be noted that 56% of mail volume is handled by the 75 largest post offices. Due to the cost of satellite ground facilities it would not be cost effective to provide electronic mail service via satellite to all post offices. Therefore the 75 largest post offices are arbitrarily chosen to receive this service.

Assuming a 90% saturation of the potential market based on the above assumptions and projections the 1985 yearly mail volume applicable to satellite transmission would be,

$$125 \times 0.4 \times 0.34 \times 0.9 \times 0.56 = 8.5 \text{ billion pieces.}$$

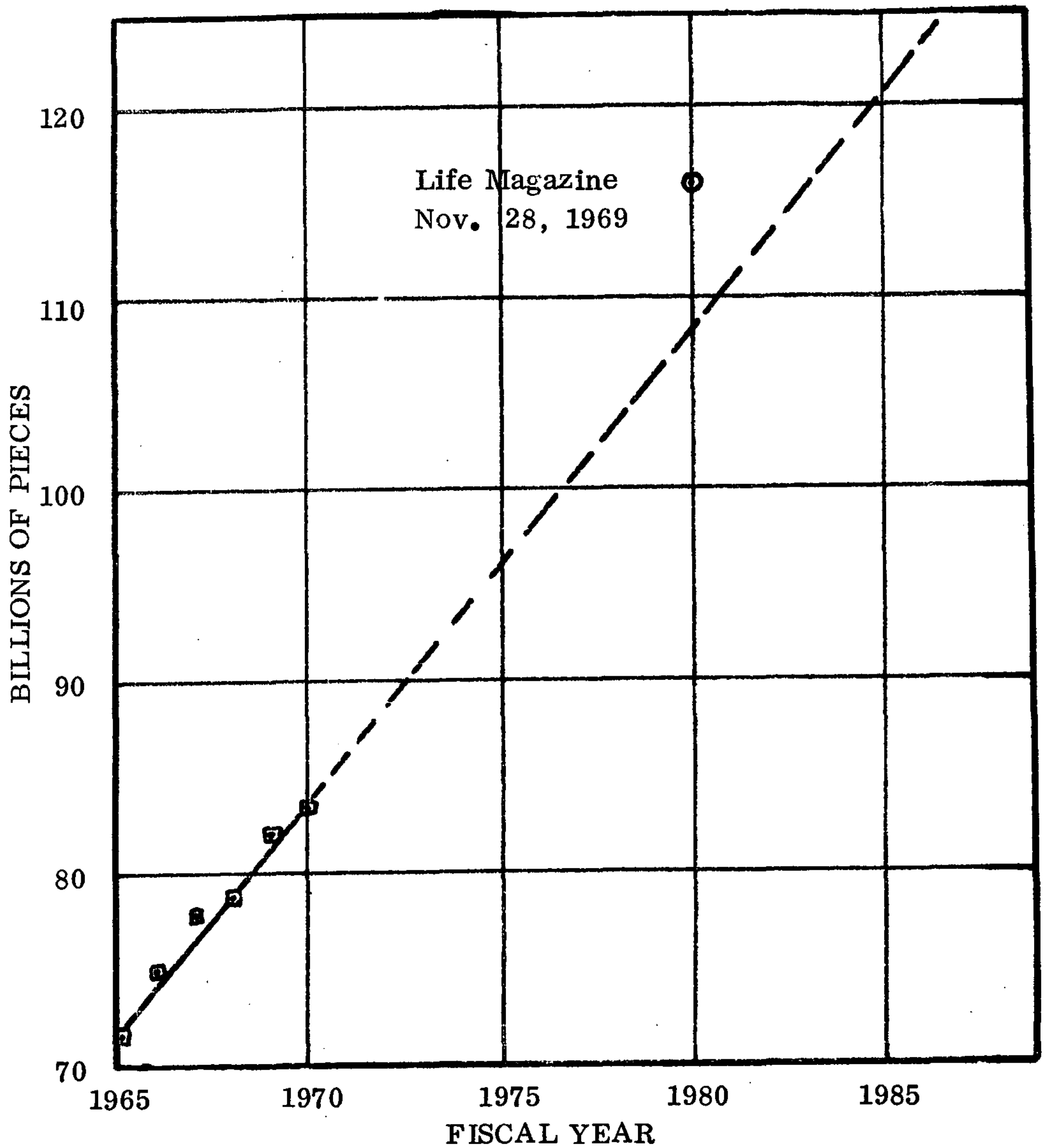
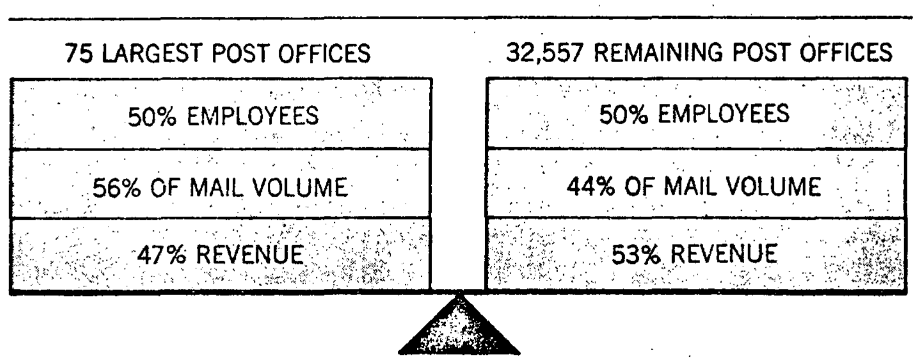


Fig. E-43. Total mail volume projections.



Source: Prepared from Post Office Department data.

Fig. E-44. Importance of large metropolitan post offices.

This is 6.8% of total mail volume and 17% of all transaction and correspondence mail.

There are other factors that might be considered in estimating the volume of mail to be transmitted electronically via satellite. Depending upon competitive cost it can be anticipated that a portion of TWX, TELEX and private wire service market might become attracted to electronic mail service. There may be effects resulting from post office reorganization, modernization and subsequent changes to the postal rate structure. With an accessible communications system linking most of the nation's largest post offices a portion of the message traffic will pertain to official post office business. Independent communications networks may provide money transfer betweem banks and businesses.

E.6.3 Mail Transfer Network Model

1. Basic Design Constraints & Requirements — In substituting electronic mail transmission for traditional mail handling and delivery it is important that there is not an accompanying compromise of those characteristics of the postal service that the public has traditionally expected and demanded, namely message privacy and dependability of mail delivery. To prevent unauthorized reception and decoding of messages, encryption techniques are generally included in a communication system design. Dependable and accurate message transmission and delivery requires that there be means to prevent (1) loss and misdirection of messages, and (2) additions or deletions of any part of a message due to a noisy channel. Solutions to these

problems requires that error detection and correction techniques be included in the communications system design.

The communications system model shall be an all digital system because (1) message data is most easily handled digitally, (2) encryption and error correction techniques are more adaptable to digital data, (3) a digital system provides greater flexibility through ease of multiplexing and formatting a variety of messages, and (4) a digital channel is more efficient than an analog channel in the tradeoff of power and bandwidth versus channel capacity.

The network model will include 75 stations sharing a single satellite relay to communicate with each other. Because of the uncertainty and variation of the message duty cycle of the stations making up the network, a demand assigned time division multiple access, TDMA, system is proposed for the all digital system.

The satellite model is in synchronous orbit with an antenna beam covering the continental United States. To accommodate the TDMA modulation technique, a frequency translation repeater is proposed with phase shift keying of the signals making access and no modulation translation within the satellite.

2. Calculation of System Parameters — The TDMA system is based on an experimental system developed by Comsat that includes the following parameters:

COMSAT EXPERIMENTAL TDMA SYSTEM	
Number of Stations	10
Bit Rate	50 megabits/sec
Preamble Word	57 bits (PSK) 47 bits (DPSK)
Capacity	782 voice channels
Guard Time	100 nanoseconds

To allow additional capacity for internal post office communications and the possible encroachment on TWX, TELEX and private-wire message service the 1985 projected mail volume is increased to 10 billion pieces per year. Assume the average message contains 26,000 bits and a 8-1/2 × 11 FAX transmission with redundancy reduction contains 260,000 bits. At an assumed message/FAX ratio of 10 to 1 the number of data bits transmitted per year is $260,000 \times 10^{9} + 26,000 \times 9 \times 10^{9} = 4.94 \times 10^{14}$ bits. Assuming a TDMA efficiency of 0.9, the total number of bits transmitted per year is 5.49×10^{14}. At a system duty cycle of 0.75 the system bit rate is $\dfrac{5.49 \times 10^{14}}{365 \times 24 \times 3600 \times .75} = 23.1$ megabits/sec. (Table E-19)

Assume a bit rate of 23 megabits/sec. the guard time should be greater than 100 nanoseconds per burst. The bit period $= \dfrac{1}{23 \times 10^{6}}$ seconds or 43.5 nanoseconds. Thus 3 guard bits per burst and $3 \times 75 = 225$ guard bits per frame are required.

To accommodate a 75 station network the preamble is increased to 60 bits to allocate more bits for the station address code. All 75 stations can be active simultaneously; therefore, the frame consists of 75 data bursts at a 0.9 TDMA efficiency the number of message bits per burst can be obtained from,

$$\frac{\text{MESSAGE BITS}}{\text{MESSAGE BITS + PREAMBLE + GUARD BITS}} = 0.9$$

$$= 567 \text{ (where PREAMBLE + GUARD = 63)}$$

The average message is based on the following:

two 300 word pages of text

7 bits per character

5-1/2 letters per word

1 parity bit

bits per message = 2 × (words/page) (letters/word) (bits/character + parity)

$= 2 \times 300 \times 5.5\ (7 + 1) = 26,000$

Tab. E-19. TDMA satellite network parameters

No. of Ground Stations	75
System Bit Rate	23 megabits/sec.
System Message Capacity	5325
Preamble Bits Per Data Burst	60
Guard Bits Per Burst	3
Frame Rate	485 frames/sec.
Message Word Length	8 bits (7+1 parity)

The messages are thus formatted into 8 bit words so that the average number of messages per burst is 568/8 = 71 (567 is increased to 568 to be evenly divisable by 8). The number of messages per frame is 75 × 71 = 5325. The total number of bits per frame is 75 (568 + 60 + 3) = 47,325 and the frame rate is $\frac{23 \times 10^6}{47,325}$ = 485 frames per second.

The length of time required to transmit the average message, assuming 8 bits of a given message is transmitted during each frame

$$t = \frac{\text{bits per message}}{\text{(bits per message word) (frames per second)}}$$

$$= \frac{26,000}{8 \times 485} = 6.7 \text{ seconds.}$$

An 8" × 11" facsimile requires 10 t or 67 seconds.

The average number of message channels assigned to each station is 71. However, this number varies depending on the relative traffic volume of each station. Included within the preamble that precedes the data burst transmitted from each station is an automatic signalling channel that conveys switching and channel assignment information between all stations in the network. At each ground station control circuitry would be required to control message flow according to circuit availability and message priority. Spare channel capacity would be continuously assigned to stations as it becomes available on a demand basis.

Facsimile data would be in digital form so that it can be time multiplexed with message data for transmission. The facsimile data would be formatted into 8 bit words to provide uniformity with message data and simplify demultiplexing. The transmission time for a 8-1/2" × 11" document would be approximately 10 times that required for an average message so that during the period of a single facsimile transmission, ten messages can be sequentially transmitted.

This basic network model has sufficient flexibility so that it can accommodate a variety of system requirements. The bit rate essentially establishes the system capacity. If it is necessary to increase capacity the bit rate can be increased. The number of stations in the network could be decreased and thus channels would be distributed between fewer stations. Also the average message length and the message/facsimile ratio can be varied. If the number of message channels assigned to each station were fixed the system design would be simpler but would not be as adaptable to variations in load requirements of the individual stations.

E.6.4 Network Ground Station

1. Overall Ground Station Configuration — A simplified block diagram of one of the network ground stations is shown in Fig. E-45. If a terrestrial data transmission network were to be substituted for the TDMA satellite network, modems would replace that part of the diagram within the dashed line. The TDMA control equipment includes a burst synchronizer, preamble generator, preamble detector and bit timing recovery. The TDMA reference station equipment can be located at one or more of the network stations. However, at a given time only one station operates as the reference station. The function of the reference station is to distribute demand assigned channels to all the stations in the network and supply a reference signal for the other stations.

The PSK modulator and demodulator are operated in synchronism with the bursts. It is necessary for the demodulator to serially acquire each burst's carrier and clock signal. Receive message control subsystem strips all but the address information from the incoming messages and forwards them to the post office, business firms, or a CATV distribution network. The transmit message control subsystem inserts format, control and error checking data on the message and performs store and forward switching.

2. Conversion Devices and Message Control — The messages are assumed to originate within postal stations and business firms. Conversion of messages to digital signals would be generated by computers, teletypewriters and facsimile. For keyboard generated messages a device similar to a line concentrator would be required to store all characters as they are typed. When operator has verified that message is correct,

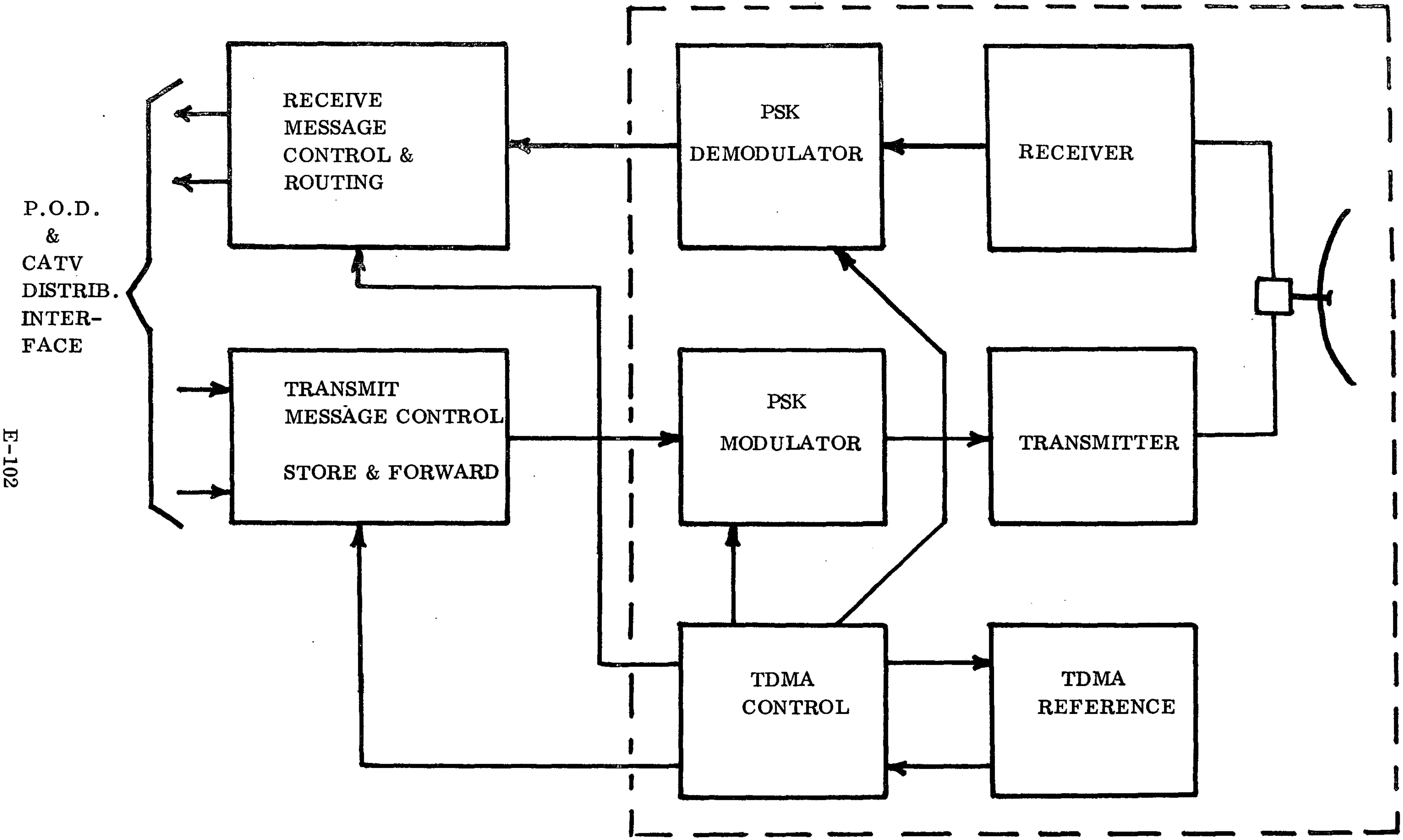


Fig. E-45. Network ground station.

a special key would be depressed transmitting the message to the data transmission system. In a communications system the concentrator inserts format, address control and checking data. The formatted message is then ready for transmission. The concentrator delivers the message at the bit rate compatible with the transmission link. The control of message composition formatting and flow requires in some cases the use of a store and forward switch similar to that used in the Autodin data transmission system. Store and forward switching in simple form consists of the component blocks shown in Figure E-46.

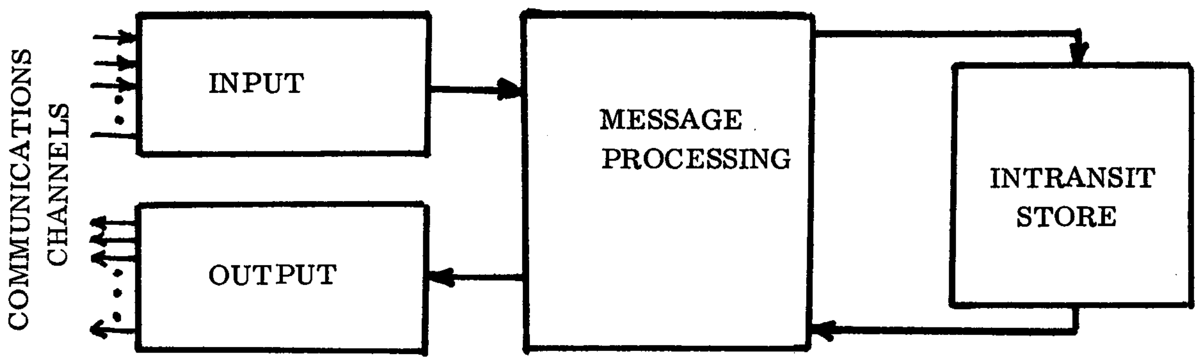


Fig. E-46. Store and forward switch.

Message processing is computer controlled. The Autodin store and forward switch provides:

- Automatic error detection and correction
- Automatic alternate routing
- Message accounting and delivery protection
- Encryption
- Automatic processing of single, collective and multiple address messages
- Automatic message processing by assigned procedence
- Automatic format, speed and code conversion.

Not all of these features would be required in a mail delivery system. However, to maintain efficient and reliable message flow a certain degree of computer controlled message processing would be required.

3. Encryption and Error Correction — The privacy to be expected from electronic mail transmission would be comparable to that normally experienced with TELEX or TWX service. If a sender requires secrecy of message transmission he perhaps would use some service other than the post office depending upon the level of secrecy required. In military data communications systems encryption takes place after the message is formatted and prior to modulating the transmitter. At the destination the message is decrypted after demodulation. The sender could supply an encrypted message to the post office and the recipient would then do the decryption after receipt of the printed message.

Error detection and correction is generally considered a necessity in most data transmission systems. Errors occur prior to transmission by the operator and during transmission due to a noisy channel. Operator errors are corrected by human checking. When an error is made the typewriter is back spaced and the correct character is inserted. A final verification is made prior to pressing the key that transfers the message to the data transmission system.

To detect and correct data transmission errors, ARQ or retransmission is a method which provides a high degree of error detection and correction capability. The message is sent as blocks of a fixed number of characters. A parity bit is added to each 7 bit character. At the end of the block a message parity character (MPS) is transmitted (block parity). At the end of transmission of a block a modulo - 2 sum of the transmitted bits is compared with the MPC and an acknowledge character is sent back to the transmit terminal. The next block is sent unless there is no response or if the incorrect response code is received.

In a synchronous satellite data transmission system the extremely long propagation delay of nearly one half second makes conventional retransmission techniques very inefficient. In this case continuous block transmission might be required whereby the first transmitted block is stored until an acknowledge message is received. However, the transmission of the second block immediately follows the first block. Two output buffers are required that toggle back and forth on the line for this type of system. ARQ for error correction may not be too efficient for a TDMA system even if continuous block transmission is employed. It is possible to achieve some degree of error protection without using a return path by use of forward-acting error correcting codes. The degree of error correction required must be decided before designing a system. Essentially the higher the order of correction required the higher the cost in terms of dollars and reduced information flow.

E-6.5 CATV Distribution Net

Cable TV has been seriously considered as a vehicle for bringing mail directly to the home. Proponents of cable TV predict that in five years 30 million homes (half the households in the U.S.) will be wired for cable TV. Some systems will provide as many as 68 separate selectable channels. There will therefore be adequate bandwidth for services to be provided to the CATV subscriber.

Fig. E-47 is a simplified block diagram showing the basic components of a CATV network. It should be feasible for CATV network of the future to serve business firms as well as households. Companies are developing printers and facsimile machines at costs that will be attractive to the home market. The implementation of electronic mail distribution via CATV, if it fulfills a definite need at an attractive cost, only requires that the mechanics be worked out, such as:

1) Tolling and billing of subscriber
2) Prevent unauthorized interception of mail
3) Mail forwarding, handling mis-addressed mail
4) Prevent receipt of unwanted mail
5) Household origination of messages
6) Develop design for low cost polling system that can interface with CATV/ satellite network.

E.6.6 SYSTEM COSTS

Having identified the basic system configuration and parameters an analysis of system costs is possible. The basic elements of system are the space or satellite segment and the ground stations. The Convair computer synthesis program can exercise the variable of the space or satellite segment and the receiver/transmitter portion of the ground stations to arrive at a minimum cost solution. Accurate cost estimates for time division multiple access equipment is difficult because it is still in an experimental stage of development. In estimating costs for a competing terrestrial system, digital

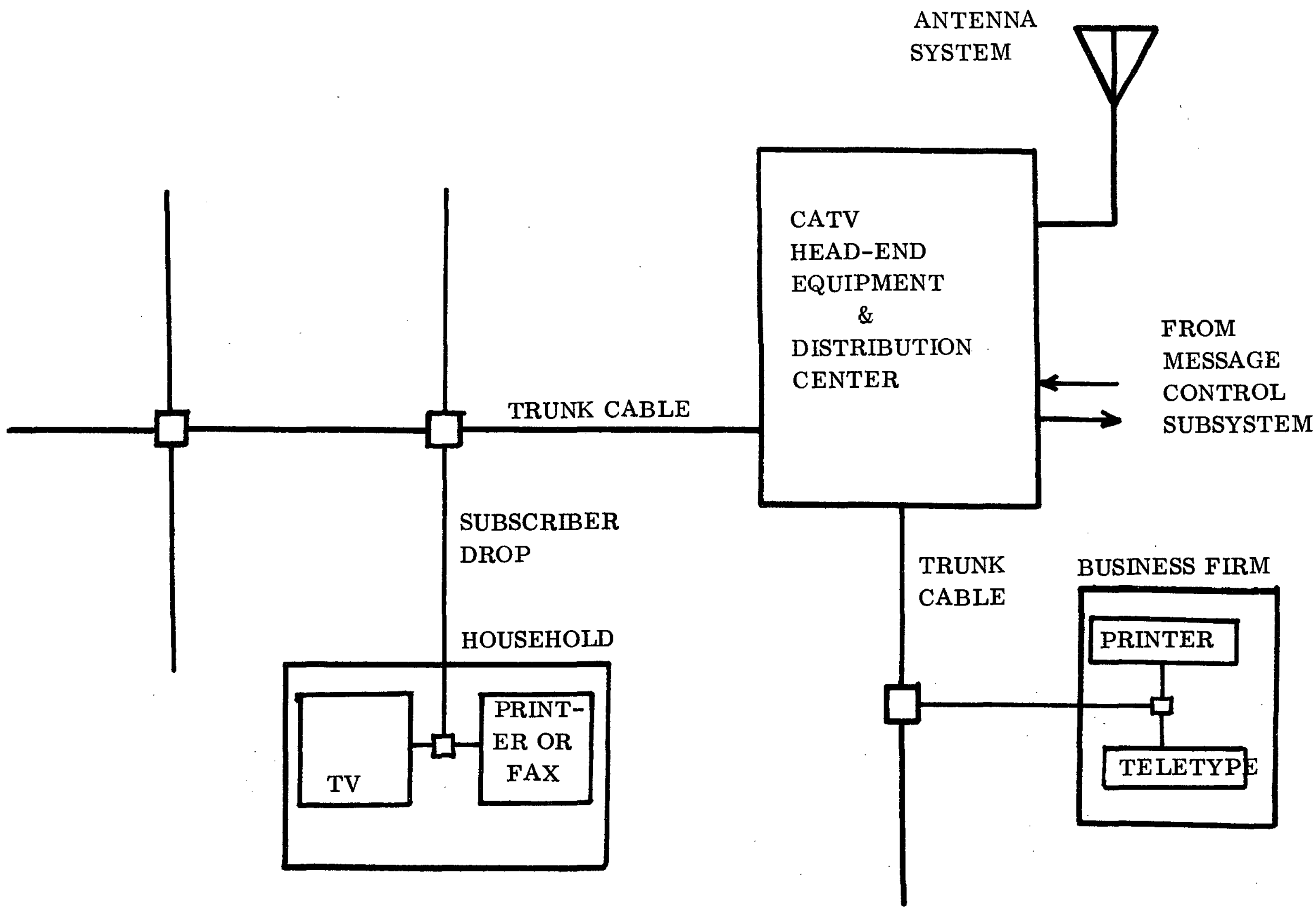


Figure E-47. CATV distribution network.

data modems would replace the portion of the ground station shown included within the dashed lines in Fig. E-45. Terrestrial data transmission costs would be based on a terrestrial data transmission line network linking the 75 post office stations. Since the messages originating from each station are now transmitted over separate links to each of the other terminals instead of being sequentially routed through a single satellite repeater, the average bit rate would be reduced accordingly to about 4 kilobits/sec. The average bit rate is based on the same message density. However, instead of all the messages being time multiplexed each message is transmitted as a continuous sequence until completed. Based on an average message length of 26,000 bits and 6.7 seconds required to transmit an average message and allowing an additional 5% for error correction and message routing information bits, the average bit rate would be

$\frac{26,000\ (1.05)}{6.7} \cong 4.0$ kilobits/sec. In other words, all stations are transmitting data to every other station at a 4 kilobit/sec rate. A network model would next be required to ascertain the transmission line cost requirements.

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E.7 MEDICAL SERVICES COMMUNICATIONS NETWORK

E.7.1 GENERAL

Factors Contributing to the Need for Medical Services Communications — Good health, a fundamental need of mankind, is achieved by advancing all forms of preventive and curative medicine via the medium of health services. Electronics and electrical engineering are assuming an increasingly important role in medical services. In a recently completed study of Information Transfer Requirements,[1] medical service, specifically diagnosis, was assigned number one ranking based on the criteria of (1) providing high benefit to the United States, and (2) exhibiting characteristics that require advancement of communications beyond the normal projection of conventional terrestrial services. The provision for adequate and efficient medical services depend upon communications. Communications provide the following essential services:

1. Means by which doctors can be informed of events, products, research and procedures.
2. A continuing medical education to members of the medical profession.
3. Dissemination of medical information to non-medical audiences.
4. Bring medical care to people in isolated communities that cannot be reached by the limited supply of doctors.
5. Supply a quick response to specialized information requests.

Information Transfer Categories for Medical Services — The following categories of information transfer have been identified:

1. Distribution of Library Information — This service is specifically for the medical community. The libraries would be located at a few regional centers as well as the National Library of Medicine. Types of circuits required would be teletype, telephone and television channels for remote viewing. The primary destinations for the library data would be hospitals. Other receiving points would be medical schools and clinics.

2. Specialized Information Requests — This service is also specifically for the medical community whereby inquiries can be directed to centrally located data banks. The requests and responses are by means of digital data links.
3. Public Health Information Dissemination — This service is primarily for the medically uninformed segment of the public. Information is conveyed by commercial quality television. Use would be made of existing educational TV broadcast stations eventually augmented and possibly superseded by a medical TV network covering the CONUS.
4. Record Transmission and Inventory Control — This service pertains to the transfer of information about patient's records and transfer of information necessary to maintain inventory control of vital medical supplies such as blood banks and banks for organ transplants. Digital data links are required initially in metropolitan and regional areas with the ultimate use of a national network.
5. Remote Area Medical and Diagnostic Services — This service would extend the service of a remote area by transmitting visual information via one-way or two-way TV and diagnostic monitoring data via telemetry from a remote site to a central location. Initially on a sectional basis and within states, this service could extend to regional and national areas.
6. Dial Access Systems — Selectable tape recorded 4-6 minute lectures on current medical problems available by dial telephone by doctors in a state or regional area.
7. Telelecture system for doctor education that uses 2-way radio for lecture followed by Q & A period. A variation uses radio for transmission only with questions from audience received via telephone.

In summary, information transfer requirements on which to base a national medical services network include teletype, video, voice and digital data links.

E.7.2 REVIEW OF PROPOSED AND OPERATING SYSTEMS

1. Communications Links for a Biomedical Communications Network — A study pertaining to this subject was performed by Aerospace Corporation for the National

Library of Medicine.[2] The development of this network was undertaken on the recommendation of the House and Senate Appropriations Committee and the House Special Subcommittee on the Investigation of the Department of Health, Education and Welfare (1966). Responsibility for the development of this network has been assigned to the Lister Hill National Center for Biomedical Communications, an element of the National Library of Medicine.[3]

This study surveyed the location and distribution of the "biomedical community", the approximately four million primary users of the network. This included people and institutions devoted to providing medical services. Physicians, dentists, and nurses constitute the core of the community. Table E-20 shows how these groups are distributed among the 10 most populous states along with distribution of population, hospitals, hospital beds, and health related professional schools.

The geographical distribution of biomedical personnel and facilities in general tends to follow the distribution of population in the United States with the heaviest concentration of medical practicioners and facilities in the heavily populated areas. Also, large metropolitan areas serve as the sites for most medical, dental and other professional schools, research institutes, large hospitals and medical societies. Figure E-48 shows this cluster pattern and that these metropolitan areas are largely in the Northwest, Midwest and in California. Table E-21 shows distribution of personnel and facilities in principal metropolitan areas. It was found that the same pattern of distribution holds for the scientific, engineering, educational, and other professional communities as it does for the biomedical community. Because of similarity of geographic distribution, need for dissemination of scientific and technical information and provision for continuing education, it is quite probable that the engineering and scientific community can share a dedicated satellite communications system with the biomedical community.

It is probable that during the early development of BCN medical education television will make extensive use of, or share existing and planned ETV broadcast stations, various kinds of intra-state distribution systems and television facilities at higher

Table E-20 Distribution of population, medical personnel, and hospitals of the ten most populated states.

Rank Order	State	1967 Population (in thousands)	1975 Population (in thousands)	Number of Physicians	Number of Dentists	Number of Nurses	Hospitals	
							Number	Beds
1	California	19,153	24,129	33,604	11,573	55,240	638	140,020
2	New York	18,336	20,450	39,806	14,342	67,830	440	210,038
3	Pennsylvania	11,629	12,482	18,358	6,597	42,222	322	120,771
4	Illinois	10,893	12,141	14,810	6,285	29,371	325	106,906
5	Texas	10,869	11,840	12,284	3,890	17,448	565	72,459
6	Ohio	10,458	11,461	14,536	5,058	29,569	255	81,456
7	Michigan	8,584	9,259	12,462	4,334	21,322	260	73,702
8	New Jersey	7,003	8,156	9,808	4,268	22,101	141	54,933
9	Florida	5,995	7,720	9,042	2,941	16,432	179	39,053
10	Massachusetts	5,421	5,842	10,989	3,816	26,032	201	64,524
	TOTAL	108,341	123,480	175,699	63,104	327,567	3,326	963,862
	U.S. TOTAL	197,863	222,802	283,680	103,400	549,007	7,160	1,678,658
	Percentage	54.76	55.42	62	61	59.5	46.5	58

Tab . E-21. Distribution of health personnel and facilities of 28 metropolitan areas.

	Metropolitan Area	Projected 1980 Pop. (thousands)	Number of Physicians (thousands)	Number of Dentists (thousands)	Hospitals		Number of Medical and Dental Schools and Medical Research Centers
					Number	Beds	
1.	N.Y.-Newark	19,950	35.2	13.3	220	66.6	15
2.	L.A.-San Bernardino	13,350	15.4	5.4	223	30.4	8
3.	Chicago	9,300	11.7	5.0	119	31.1	10
4.	Phil-Trent-Wil	6,650	11.3	3.7	103	26.3	9
5.	S.F.-Oak-San Jose	5,850	9.6	3.1	80	15.6	7
6.	Detroit	5,125	6.8	2.5	70	15.9	5
7.	Boston	4,200	9.0	2.9	101	18.6	9
8.	Washington	3,500	5.3	1.6	31	7.4	6
9.	Dallas-Ft. Worth	2,760	2.8	0.9	64	7.1	2
10.	St. Louis	2,775	3.4	1.3	43	10.8	4
11.	Houston	2,620	3.2	0.9	53	9.6	2
12.	Cleveland-Akron-Warren	2,715	6.0	2.3	53	14.6	2
13.	Miami-Ft. Lauderdale	2,350	3.4	1.0	31	6.8	2
14.	Baltimore	2,400	4.4	0.9	23	7.9	3
15.	Pittsburgh	2,500	3.4	1.5	45	13.9	2
16.	Minneapolis-St. Paul	2,150	2.8	1.3	35	9.4	3
17.	Seattle-Tacoma	1,975	3.0	2.2	40	5.4	2
18.	San Diego	1,815	1.9	0.7	27	3.4	2
19.	Atlanta	1,800	2.0	0.6	17	4.1	2
20.	Hartford-Springfield	1,725	2.2	0.8	22	5.4	1
21.	Cincinnati	1,690	2.1	0.5	18	5.0	3
22.	Buffalo-Niagra Falls	1,690	2.3	0.9	26	6.6	2
23.	Denver	1,525	2.5	0.8	21	4.8	1
24.	Milwaukee	1,540	2.3	1.1	29	6.4	2
25.	Kansas City	1,525	2.2	0.9	32	6.6	1
26.	New Orleans	1,420	2.4	0.6	23	6.1	3
27.	Tampa-St. Petersburg	1,350	1.2	0.5	17	3.1	--
28.	Phoenix	1,300	1.3	0.4	19	2.9	1
		107,050	159.1	58.3	1,585	251.7	106
	Total USA	242,307	283.7	103.4	7,160	1,678.6	173
	Percentage	44	56	57	22.2	15	62

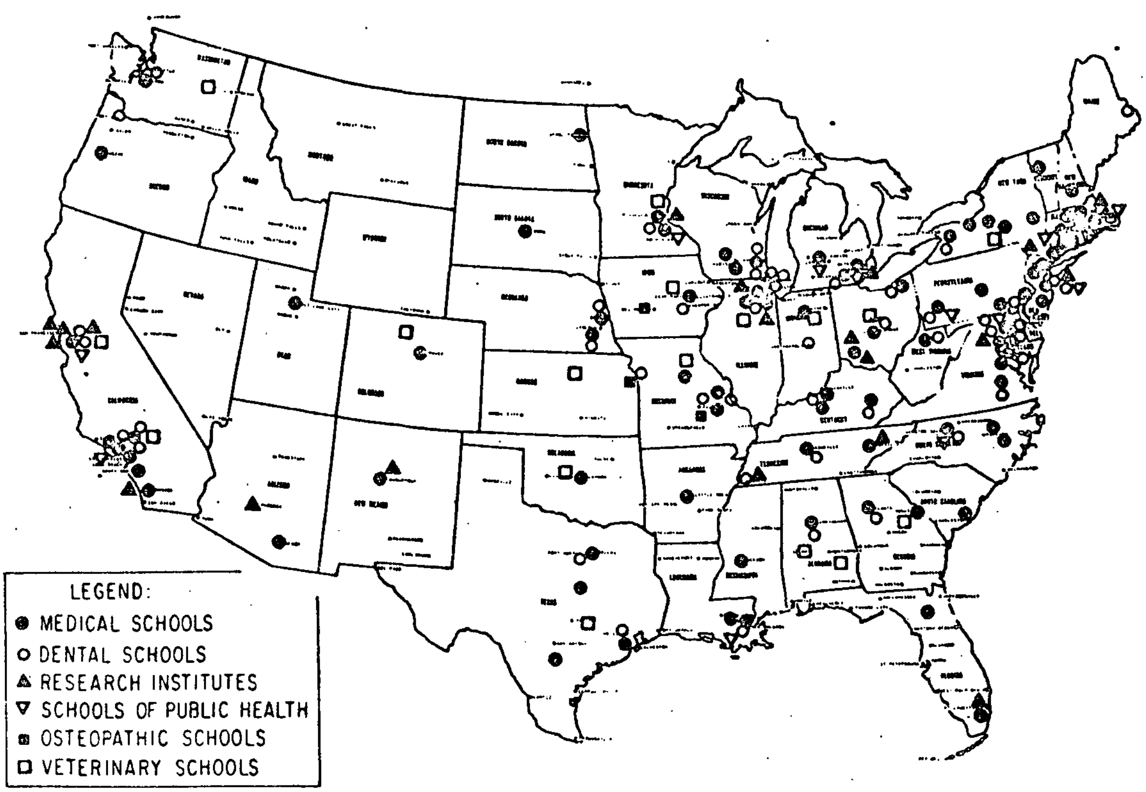

Fig. E-48. Medical educational institutions.

institutions of learning. The above has been taken into consideration in the development of the BCN model. Fig. E-49 and Table E-22 show the ETV station locations and existing biomedical network locations. Four models were configured for the BCN with no attempt to optimize a network because of the lack of sufficient communications requirements. Table E-23 compares the four models and Figures E-50 and E-51 show the smallest and largest models that were configured.

Because of the wide bandwidth required, television is considered the pacing requirement for the network. Real-time communications types such as telephone, teletype, facsimile and digital data are also required. Television standards similar to those used in present commercial television in the United States were assumed. The network would originate in Washington, D. C. and in perhaps three or four other major medical centers. The network would link most or all of these centers to the biomedical community.

A major emphasis of the BCN study dealt with an analysis of the types of transmission systems that could be considered for intercity connections and local distribution. The local distribution links, typically less than 10 miles, were considered "short haul" and the intercity links were classified as "long haul" with distances ranging from a few tenths of miles to a few thousand miles. The types of systems considered for intercity links were microwave relay, common carrier and communications satellites. The choices considered for local distribution were utilization of ETV broadcast stations, broad-band coaxial transmission systems, microwave links, common carrier services, and direct reception from satellites. For intercity communications links an interesting and attractive method considered was a dedicated satellite to serve the communications needs of medical, scientific, engineering, educational, and other professional groups. It is proposed as a non-profit cooperative venture handling no commercial traffic in competition with commercial carriers. The system consists of a synchronous satellite located at 128°W longitude with one antenna beam covering the CONUS and three narrow beams illuminating three local areas of high user density — the East Coast, the Midwest and California. The proposed frequency plan was 15 GHz

Table E-22 **Geographical distribution of regional medical program biomedical networks.**

Location	Type of Network				
	1	2	3	4	5
Albany, New York	X				
Albuquerque, New Mexico		X			
Atlanta, Georgia		X	X		
Buffalo, New York	X				
Columbia, Missouri	X			X	X
Durham, North Carolina	X				X
East Lansing, Michigan				X	
Kansas City, Kansas				X	
Los Angeles, California			X		
Memphis, Tennessee		X			X
Milwaukee, Wisconsin		X			
Nashville, Tennessee		X			X
Rochester, New York					X
Salt Lake City, Utah	X	X	X		X
Seattle, Washington	X		X	X	X

Legend:
1. Continuing Education Networks, Radio or Telephone
2. Health Service Networks, Radio or Telephone
3. Continuing Education Networks, Television
4. Continuing Education Networks, Computer-Based Systems
5. Health Service Networks, Computer-Based Systems

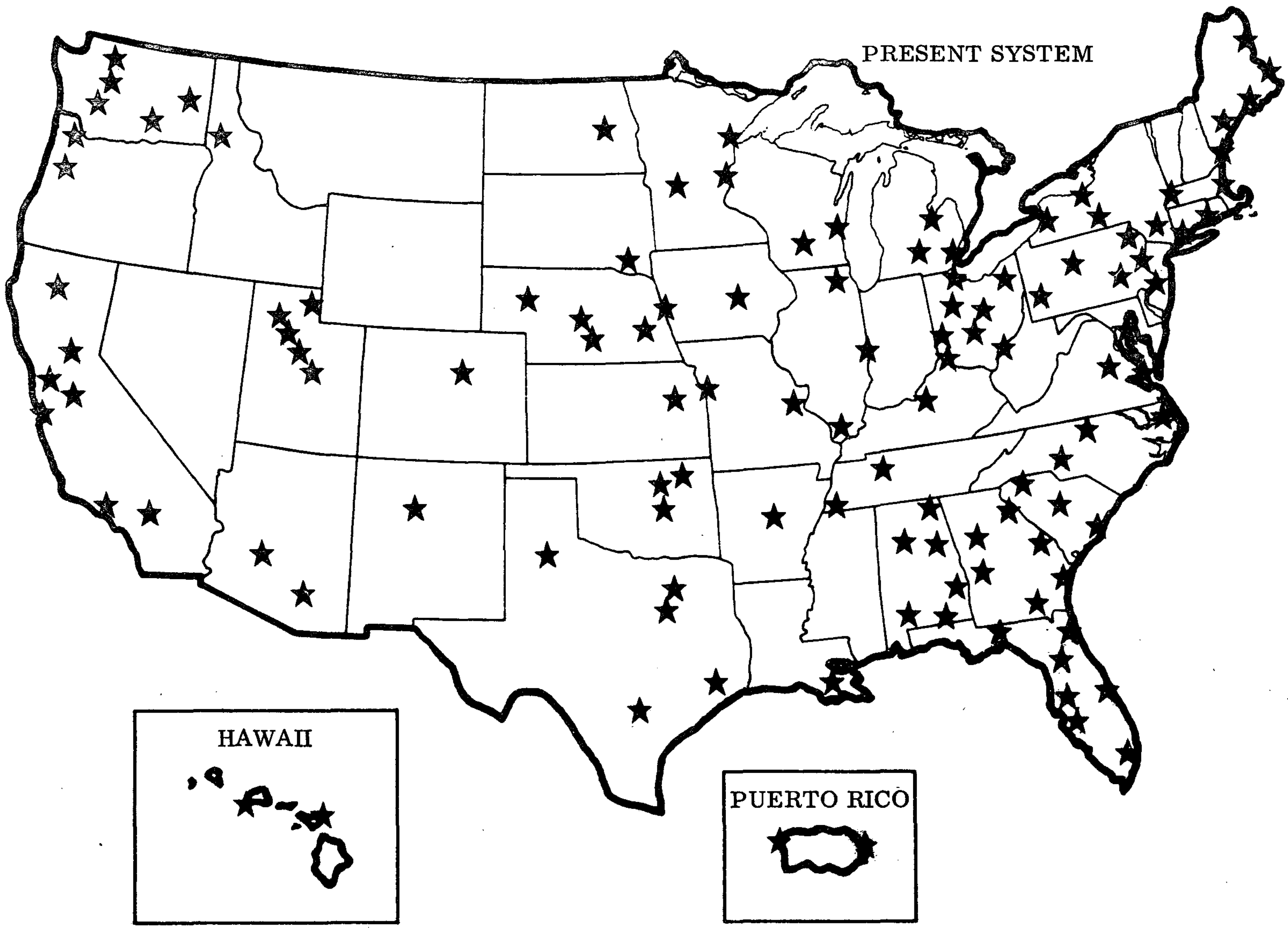

Figure E-49. Locations of Operating Non-commercial ETV Broadcast Stations.

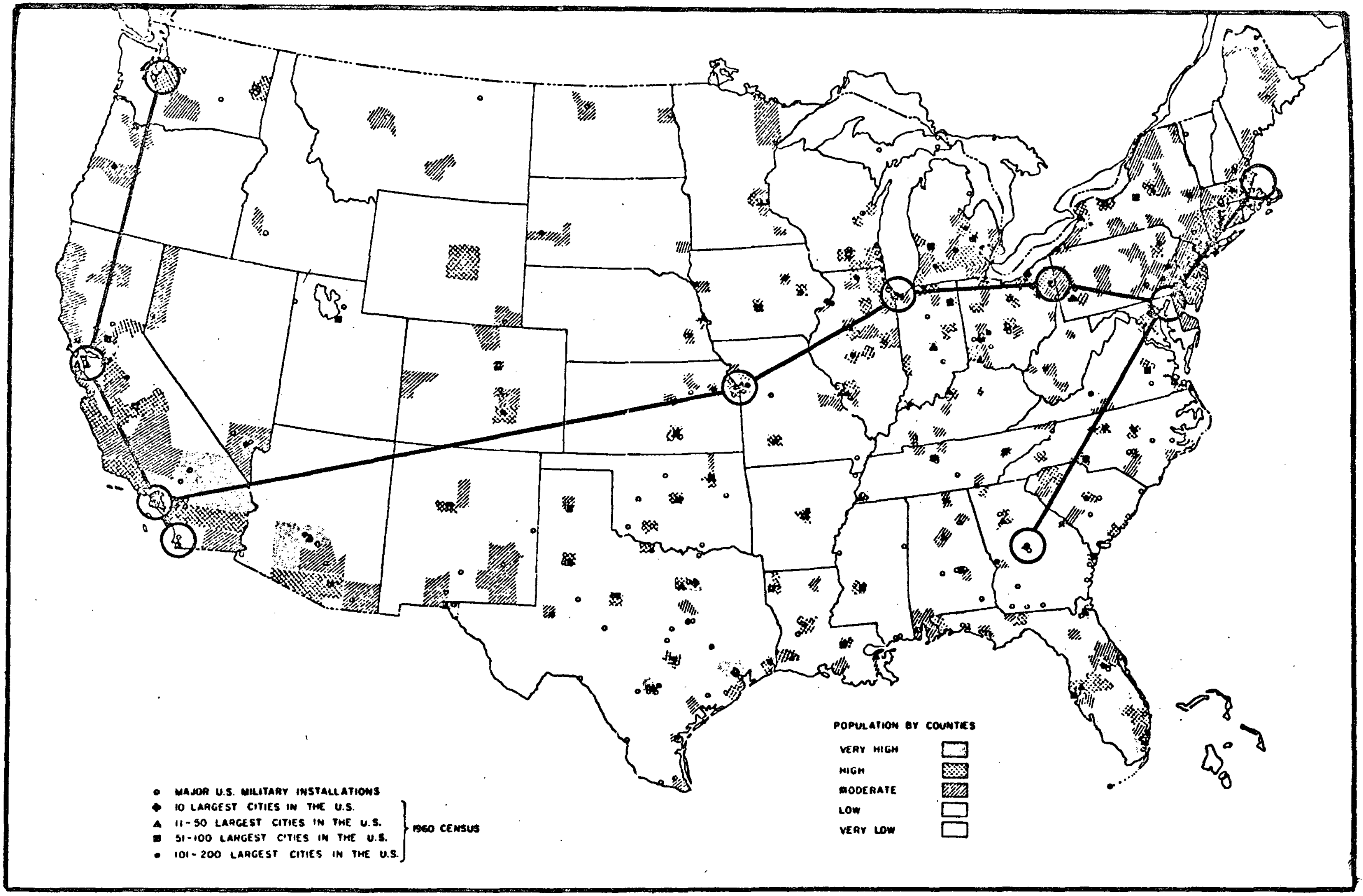

Figure E-50. Small network connecting only some of the major centers.

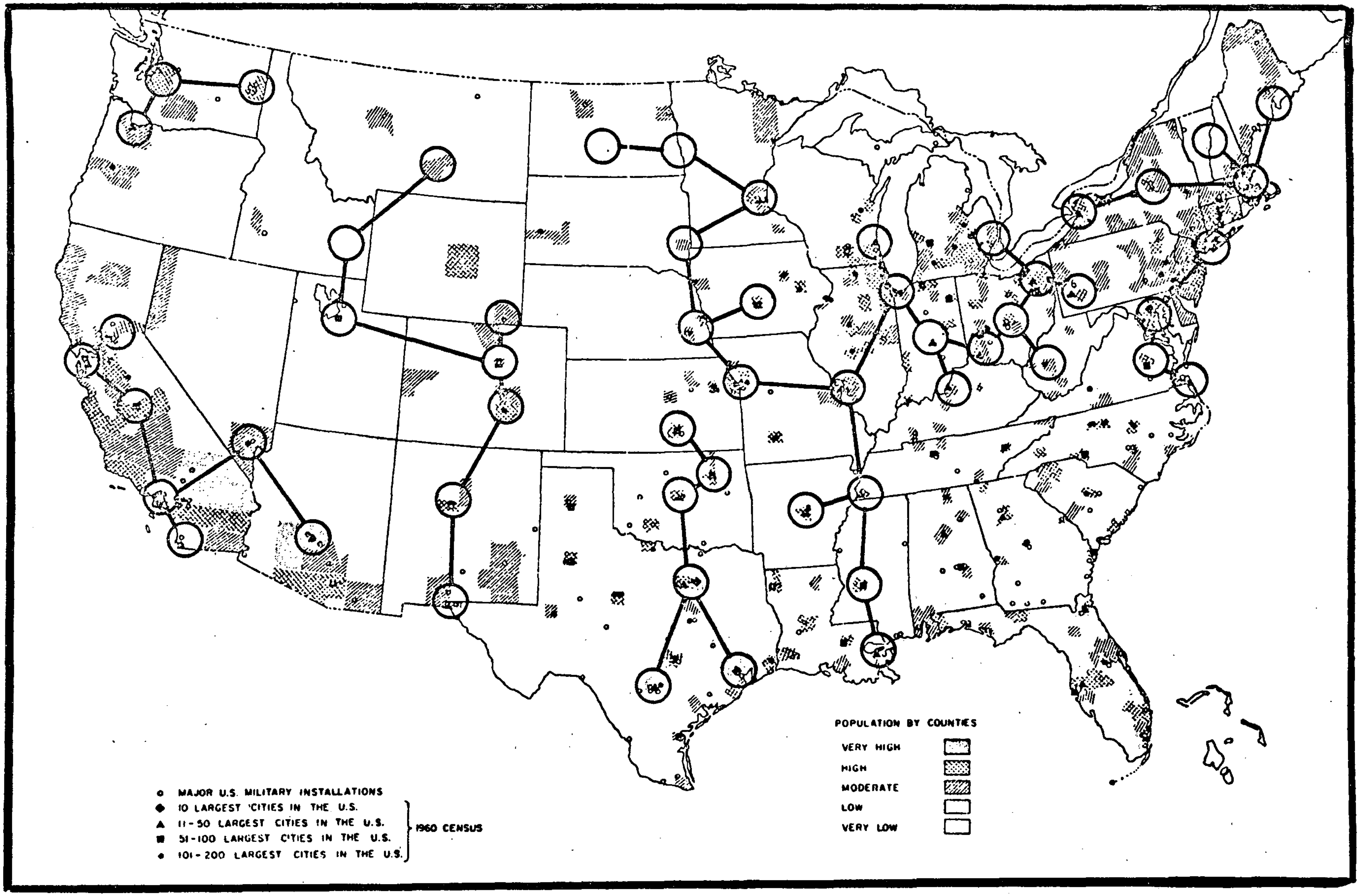

Figure E-51. Regional network.

Table E-23. Comparison of various model networks.

NETWORK	TOTAL ONE-WAY LINK MILEAGE	NUMBER OF CITIES SERVED
SMALL	4,400	11
NOMINAL	13,400	70
REGIONAL PLUS BACKBONE	21,000	70
EXTENDED REGIONAL PLUS BACKBONE	34,900	340

for the downlink and 12 GHz for the uplink, although these are not frequencies allocated for communication satellite service.

A major portion of the study was devoted to investigating satellite systems that could be received direct by individual users. Four principal designs developed, each with several highly-directional beams covering 3 to 5 regions of the United States. Power levels were sufficiently high to allow reception of television signals using an 8-foot diameter ground antenna.

2 Medical Applications of Remote Electronic Browsing — This study was performed by Stanford Research Institute for the National Library of Medicine.[4] The ultimate purpose of this study was to define some of the parameters and requirements for the BCN. The main emphasis of the study was in the areas of: (1) remote viewing of page material; and (2) remote interrogation of fact banks with question-answering abilities.

Some of the main features of the proposed remote browsing design concept are:

1.) The material to be remotely viewed is assumed to exist primarily in the form of microfiche.

2.) Remote viewing images will be transmitted via the pre-existing TV broadcast channels of the BCN.

3.) Actual picture transmission will be by frame-addressed or line-addressed units of video, so that one channel can at one time serve many different users responsively. Also the TV channel can be time shared by other educational functions.

4.) The remote viewing display will have capability for storage of a full frame and therefore will not have to be refreshed via the TV channel.

One of the main requirements was that the system be economical for a low-density population of users. Cable TV was considered to be the best suited form of transmission for the requirements. It could provide the basis of reducing the unit cost of a terminal in a doctor's office. It was estimated that there would be 60,000 usages per day with approximately 300 users on an average searching the master index simultaneously during a peak hour. At the same time, 200 users would be in the remote viewing mode simultaneously (possibly 400 during a peak minute). To serve the usage density, a minimum of 3 regional centers would be needed in addition to the NLM center. A separate computer would be required at each center, each equipped with a large amount of rapid access memory. This was needed because each center must be capable of conducting a search of the master index every second during peak periods. Each separate TV broadcast circuit would support 250 users simultaneously in the remote viewing mode with one or several of these circuits originating at each regional center.

The communications requirements for a question-answering service can be accommodated either by a teletype link or a digital link via a voice-grade channel using data sets or modems to accommodate transmission of digital data. The data bank would require a computer with storage capability depending upon the information requirements.

3 Physician Monitored Remote Areas[5] — This proposed system is considered of significance because of its potential for providing medical service to remote areas and because it is the type of link that might be supplied by a satellite system. The purpose of the system is to provide for monitoring of patients at remote sites by a physician located at a centrally located medical center. The system would "combine existing technology in biomedical instrumentation, telemetry, data handling, and communications developed for

Aerospace applications, with new techniques in public health screening, prevention, and emergency medical treatment, to establish an integrated system of health care for people living in remote areas."

The system would consist of:

1.) A physician-monitored operation center (see Figure E-52) to provide:

   a. A TV display of patient at remote site.

   b. A display of medical data from instrumentation at a remote site.

   c. A display of patient history data.

   d. A computer to determine priorities of emergency among various remote stations.

2.) A report facility (see Figure E-53).

   a. Equipped to conduct health examinations of multiphasic medical screening.

   b. A color TV for viewing patient with controls operated remotely from Operation Center.

   c. A means of dispensing drugs at remote site with controls at Operation Center.

The communications link requirements would include:

1.) Several TV channels linking the Operation Center with a number of remote sites.

2.) Voice channels from Operation Center to each remote site.

3.) Control channels for remotely operating TV controls.

4.) For dispensing drugs at remote sites.

It is proposed that there will also be mobile units in addition to the fixed remote facilities. The study did not investigate the means of providing data links but assumed microwave links either leased or owned by the system.

4. Biomedical Communications Programs of U. S. Medical Schools — A number of medical schools provide various educational services that require communications links and therefore might be future candidates for services of a dedicated domestic satellite communications system. A compilation of descriptions of these facilities and programs has been prepared for the National Library of Medicine by Educom.[6] A brief description of a few of the more significant of these programs follows:

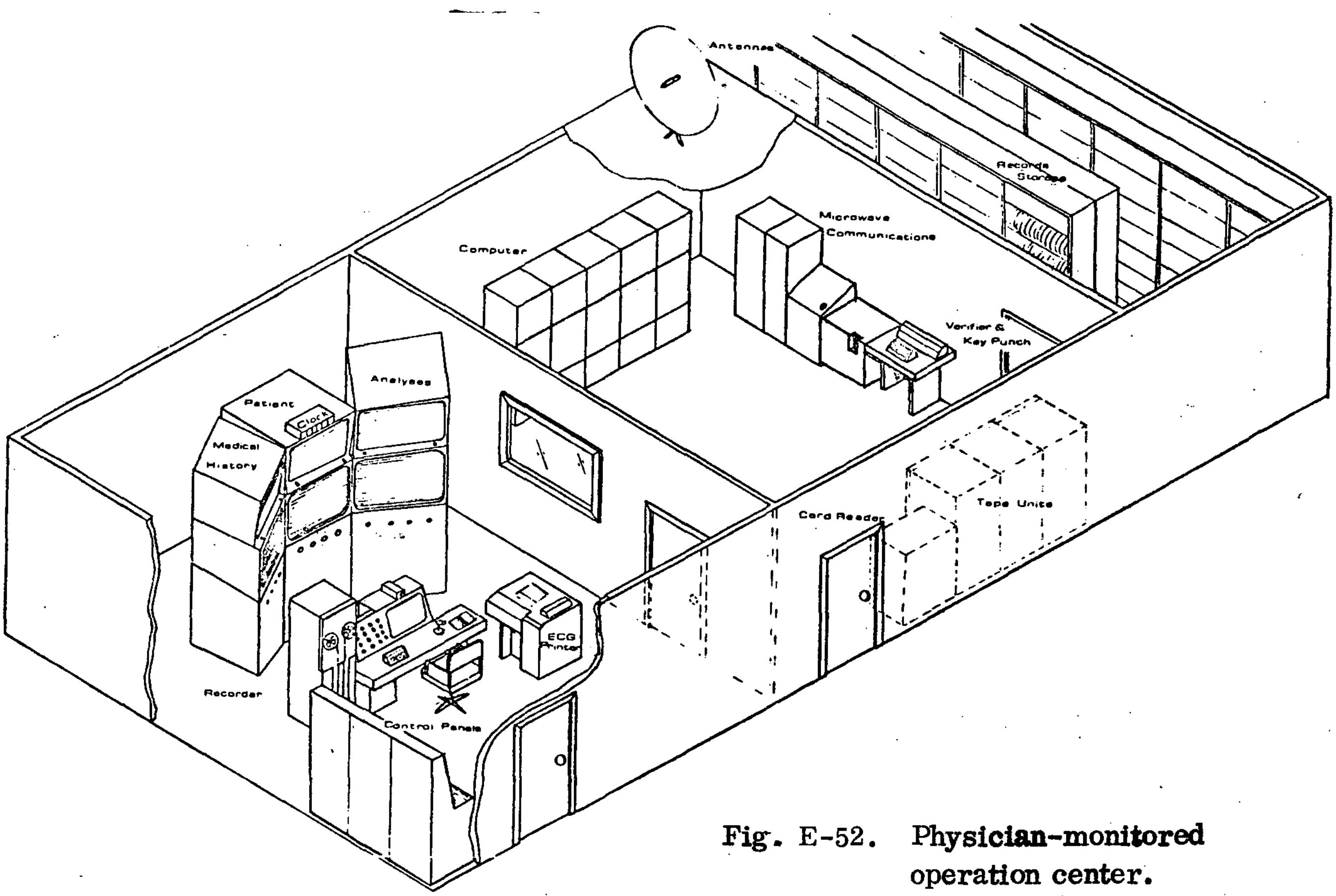

Fig. E-52. **Physician-monitored operation center.**

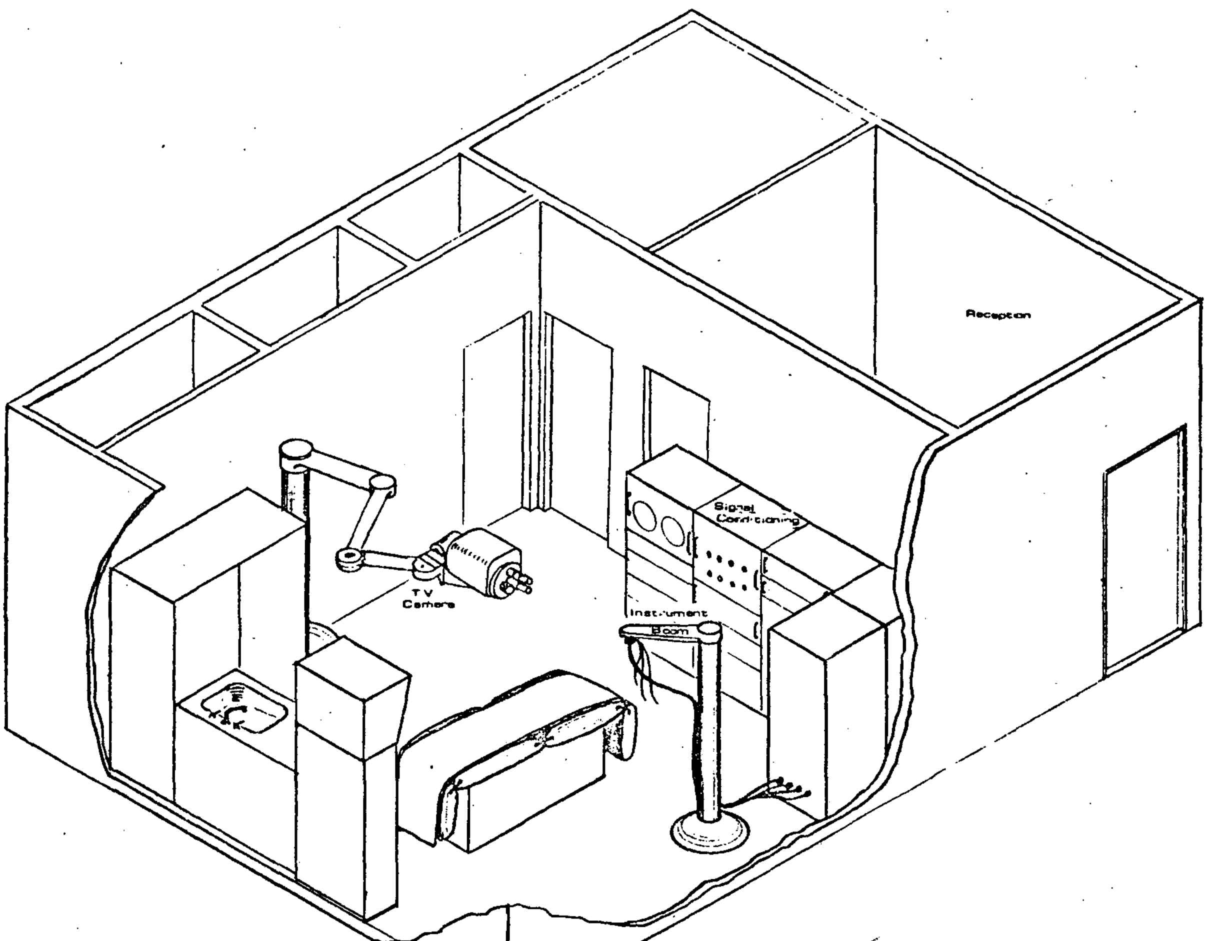

Fig. E-53. **Typical remote facility.**

1.) The California Medical Television Network (CMTN) — This network will be used to disseminate medical information to urban and rural communities in the Southwestern U. S. In addition to UCLA, six other institutions will participate in the program. KCET will be the central broadcasting facility. No information is available on the network.

2.) Medical lectures for physicians in the San Francisco area — sponsored by the University of California School of Medicine, San Francisco, California. Transmission is via radio.

3.) Microwave links transmitting TV from University of Colorado School of Medicine; Boulder, Colorado. The medical school in Denver will be one of terminals of a microwave link to allow instructors in Boulder to present basic science courses to the students in the medical school.

4.) Feasibility study to transmit EKGs via commercial telephone lines — Medical College of Georgia and three other institutions will be interconnected by rented telephone lines.

5.) Indiana University School of Medicine — A statewide medical communication system will include live and pre-recorded video via a 2,500 MHz distribution system.

6.) "Louisiana Hospital TV Network" (LHTN) — a joint CCTV full-time network television broadcasting system linking medical schools and hospitals statewide.

7.) University of Missouri School of Medicine — Experimentation with a dial-access system using audiotapes borrowed from the University of Wisconsin. A telelecture system is proposed for continuing education of physicians and health personnel throughout the state. Two intra-state WATS lines and private voice-grade lines are used.

8.) Albany Medical College of Union University — A two-way radio communication system includes hospitals throughout New England, the Eastern third of New York State, the Northern third of New Jersey and metropolitan New York City. A question/answer period during broadcasting allows all parties to hear all questions and answers.

9.) State University of New York at Buffalo School of Medicine — A two-way telephone communication network will link all hospitals in Western New York with the University and the Roswell Park Memorial Institute. The communication network will be used to transmit educational programs, administrative conferences, poison control information, EKGs blood bank information and medical data.

10.) State University of New York Biomedical Communication Network — There are nine participating libraries. A central computer is located at Syracuse. One or more communications terminals are located at each library. Common carrier services provide six full period C-4 grade lines and a Telpak B.

11.) Duke University — A TWX network links medical libraries in three states. This network will eventually be joined by NLM.

12.) The University of North Carolina School of Medicine, Chapel Hill, N.C. — This is one of 8 medical institutions in the U.S. utilizing a two-way radio technique for continuing medical education. Similar to Albany Medical College and University of Wisconsin, radio is used for transmission only and questions from the audience are received via telephone.

13.) Ohio State University College of Medicine — A statewide telelecture system is in use similar to the two-way radio system of Albany Medical College servicing various hospitals in the state.

14.) University of Utah College of Medicine communications activities include:

<u>American Association of Medical Television Broadcasters</u> — Service is provided to 13 medical schools in U.S., 2 medical schools in Canada, 3 medical societies, 2 non-profit organizations and one federal agency.

<u>Inter-Mountain Regional Medical Program</u> — Telephone consultation services are provided to local physicians. Communications services include common carrier private lines and microwaves.

15.) University of Washington School of Medicine — A two-way radio broadcast educational system is being developed for Washington and Alaska. EKG telephone "hot line" service is planned to Alaska and Yakima. TV and audio material are prepared and distributed to the entire Washington-Alaska area.

16.) University of Wisconsin —

a) "Educational Telephone Network" (ETN) links the university with 56 courthouses, 48 hospitals and 11 university centers. It is used mainly to present lectures followed by discussions. This is supplemented by a "piggy-back" communication technique whereby the same signal is superimposed on FM signals emanating from the FM State Broadcasting Network.

b) FM lectures to rural physicians — One hour lectures are provided followed by incoming questions from rural listeners by telephone. The same program includes Albany Medical College and six other U. S. medical colleges.

c) Dial-Access Medical Tape Recording Library — Provides for 4 to 6 minute audio tapes on current medical problems. Physicians are served in Wisconsin, Minnesota and North Dakota by incoming WATS lines. The system will eventually include participation by nine big ten schools and the University of Chicago.

5 Telediagnosis — "Telediagnosis" is an advanced system of medical care operating in embryo form at Massachusetts General Hospital. This system was developed by Dr. Kenneth Bird and utilizes a two-way microwave TV link to enable doctor and patient to be within sight and sound of one another. Also, most physiological analyses such as heartbeat, blood pressure, temperature, respiration, blood count and urin analysis as well as other clinical tests are transmitted. In addition to the main camera, a second camera is used for close-up examinations of inside the mouth, to look into the eye or to examine an injury. A third camera allows the viewing of specimens through a microscope. Two-way high fidelity audio channels with 20 Hz to 15 KHz response and a 15 KHz channel on a second subcarrier is used for transmitting the physiological analyses.

5 Application of Computers in Medical Services

1.) Data Bank Inquiry — Data is stored on specialized subjects such as poisons and drugs. By interrogating a control computer via a data link, the desired information can be received via the same digital data link. One system installed in a hospital uses a Honeywell 200 computer to store information on 5,000 potentially dangerous drugs, household products and chemicals. The computer responds within 4 seconds by teletype with detailed information on the means of control.[9]

2.) Use of Computer in Medical Diagnosis — Research is now going on that will ultimately result in the use of the computer to assist in medical diagnosis and treatment.[10] Making access to the computer from a patient located remotely will require the transmission of symptom and test data from patient to computer and transmission of diagnostic results and treatment plan from computer to attending physician. The computer is considered as an assist to the physician and therefore will only augment the role of the physician.

3.) Patient Scheduling in a Clinic — A questionnaire is mailed to a patient when he gets his initial clinic appointment. After computer processing, the questionnaire output is used for two purposes:

1. To provide a patient-recorded history to the physician, and
2. To schedule the patient to the most applicable specialists. Data transmission requirements are not anticipated for this function although questionnaire processing time could be eliminated by direct entry from patient to computer via terminal device and data link.

4.) Automated Analysis — Computers are used to analyze patient test data received via transmission links from a remotely located patient. Systems in operation receive EEG, EKG and other patient data for analysis by a specialist aided by a computer. One system in operation at the University of Utah receives brain waves transmitted from the patient via six voice grade telephone channels.[11]

5.) Health and Medical Records — Information systems are being implemented to serve large hospitals and groups of interconnected small hospitals. Data links would nominally not exceed 200 miles and would not be applicable for satellite transmission. Predictions resulting from recent studies foresee the transmission and interchange of health and medical records on a national basis. Computerization of individual health data has aroused concern that unauthorized, non-medical persons or agencies might gain access to this data. With the establishment of health data banks, inevitably there will be pressure for the release of medical information on specific individuals. This problem has recently received attention from the medical community.[12]

6.) Use of Computers in Hospital Care — With the recent appearance on the market of low cost minicomputers, it becomes economically desirable to extensively use these computers within hospitals to assist in patient care. In this application sensors would interface the computer with alarm levels set for each patient. Periodic printouts of each patient's readings would provide a hard copy for physician's records. Medication and dosage requirements for individual patients can be fed into the computer to assist in proper treatment. The computer could take over control of some types of therapy whereby temperature or intravenous infusion might be controlled.

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FEDERAL RESERVE BANK COMMUNICATION SYSTEM

1. BACKGROUND

The Federal Reserve System has used electronic communications for some time to transfer financial information between its various member institutions. Recently the Federal Reserve has been constructing a new communications facility in Culpeper, Virginia. This facility will have many innovations and will represent the most modern example of a financial data communications system.

2. THE FEDERAL RESERVE SYSTEM

The Federal Reserve System was established by the Federal Reserve Act of 1913. The System is the central banking authority of the United States and performs the following functions:

a. Acts as fiscal agent of the U.S. Government.

b. Is custodian of the reserve accounts of commercial banks.

c. Makes loan to commercial banks.

d. Is authorized to issue federal reserve notes.

The System is structured into five parts:

a. The Board of Governors

b. The twelve Federal Reserve Banks.

c. The Federal Open Market Committee

d. The Federal Advisory Council

e. The member banks.

The country has been divided into twelve Federal Reserve districts as shown in Fig. E-54. In each district there is a Federal Reserve Bank. A Federal Reserve Bank is a privately owned corporation established pursuant to the Federal Reserve act to serve the public interest. Although it is privately owned by the member banks the stockholders do not have the powers usually held by stockholders in private institutions.

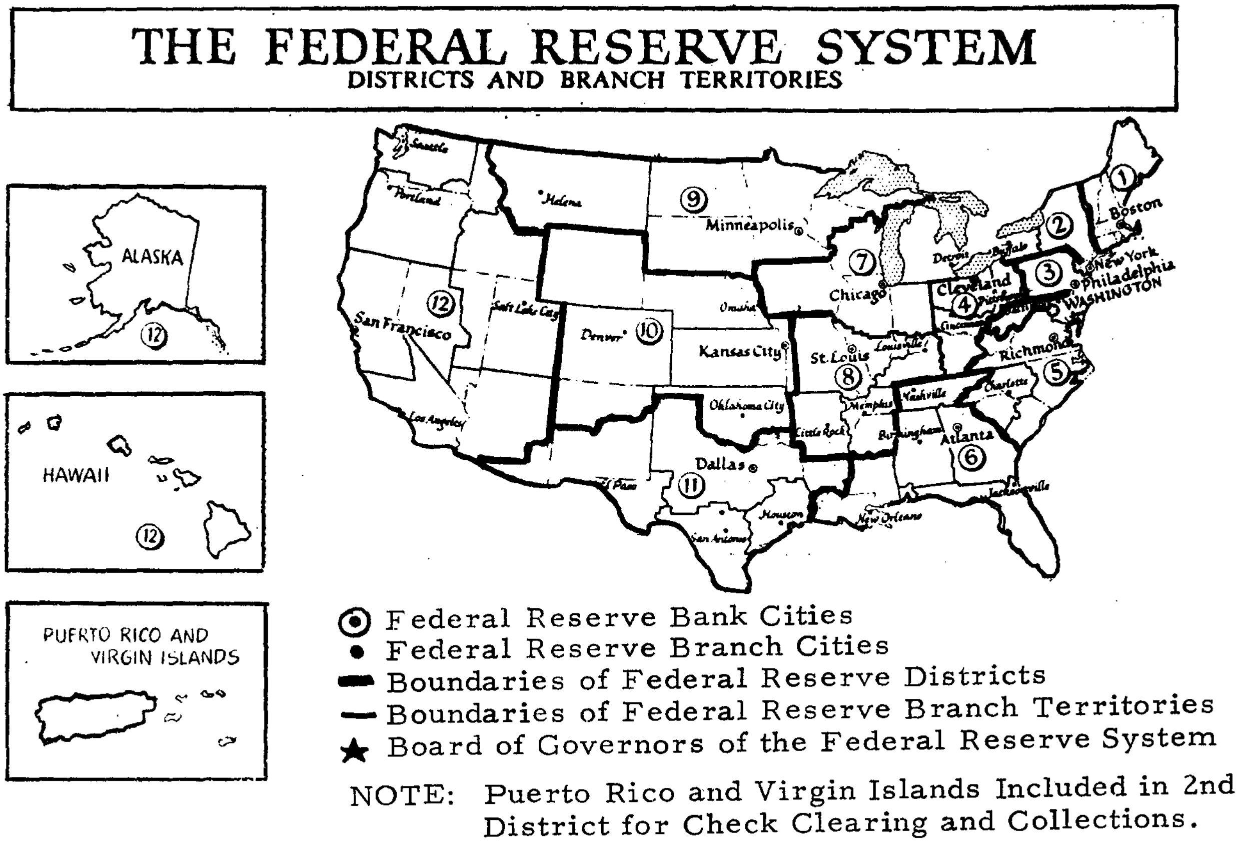


Figure E-54

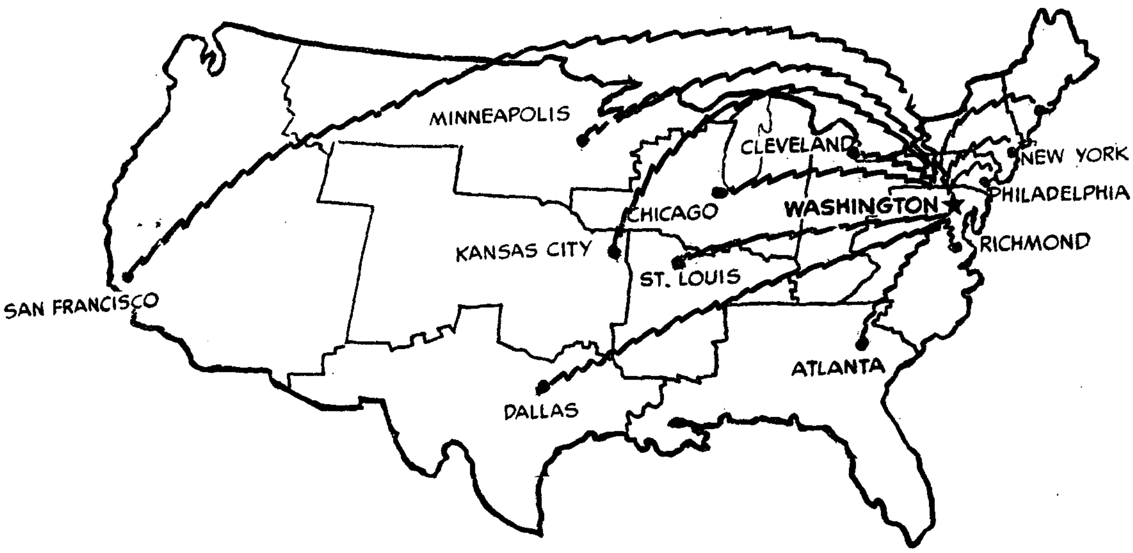


Figure E-55
Telegraphic Wire Transfer System

The Federal Reserve Act provides that each Federal Reserve Bank serve as a check clearing and collection center for the banks in its district that have accounts with it. The system provides a national clearing mechanism that eliminates the lengthy rerouting and exchange charges on checks. A member bank that receives checks payable out of town may now clear the checks through its Federal Reserve Bank or branch or city correspondents. City banks encourage their country bank "cousins" to use their special collection facilities. The correspondent banking network and the Federal Reserve System work hand in hand to process the ever-rising volume of checks that need to be collected.

A huge volume of traffic flows through the system. For example, in 1965 the Federal Reserve System handled more than 5.3 billion checks, amounting to over 1.8 trillion dollars. Also, of course, many other checks were collected by city correspondent banks, or local clearing houses, or by direct presentation from one bank to another.

The central nervous system of the Federal Reserve has been its telegraphic wire transfer system, Fig. E-55. It links the Reserve banks with each other and the interdistrict settlement fund. Through it money is constantly being transferred from one reserve bank to another. Total transfers are greater than $18 billion a day and involve about 44 million checks. Most of this is settlement for collected checks, but it also includes transfers of funds for member banks, their customers, and the U.S. Treasury. The cost of collecting and clearing checks is a major part of Reserve bank expenses. But, consistent with the ideal of a money that circulates at the same value throughout the country, these and other services are rendered free of charge. A diagram of the flow of checks and credits through the system is given in Fig. E-56.

3. FEDERAL RESERVE COMMUNICATION CENTER

Fortunately for the American payments system, the growth of knowledge in the field of information technology has kept pace with the growth of paper generated by the ever expanding volume of economic and financial transactions. While the paper jam has on numerous occasions impaired the orderly flow of economic activity, and probably will again, it is encouraging that steps are being taken which should practically rid the payments system of the future of this costly burden.

The Federal Reserve System's latest step in using technology to combat the problem of information flow is the creation of the new Communications and Records Center at Culpeper, Virginia. The communications aspect of the center is now in the testing stage and is expected to be fully operational in 1970. In view of the Federal Reserve's central role in the handling of economic and financial data – particularly banking statistics – the communications facility is expected to have a significant bearing upon the speed and accuracy with which the payments system operates as well as upon the capacity of the system to handle the increased volume of information.

The Communications and Records Center was officially dedicated in December 1969. It is built largely underground and serves several roles. It provides vault space for storage of money and duplicate records for use in the event of a national emergency. Also, it will house a computer to serve the data processing needs of the Federal Reserve Board, and to supplement the Board's existing computer located in Washington.

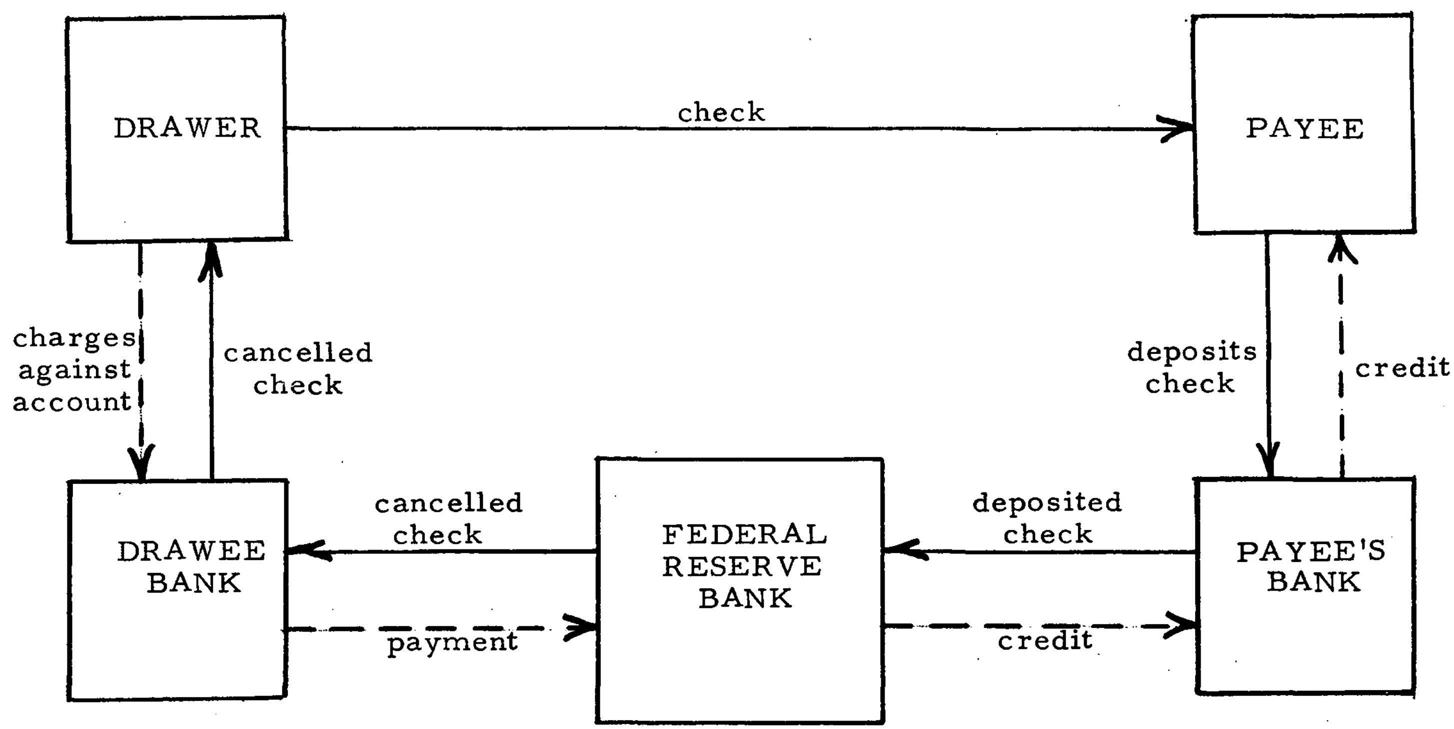


Figure E-56
Money Moves by Transfer of Credit from One Bank Account to Another

Of most significance to the payments mechanism, however, is the fact that the Culpeper facility contains the Federal Reserve System's new communications center, consisting of four large, high-speed, special-purpose, communications switching computers. The Culpeper facility, including the communications center, is operated by the staff of the Federal Reserve Bank of Richmond for the entire Federal Reserve System. When it goes into full operation, the new communications system will replace the existing Telegraph and Switching Center, which has been in operation at the Richmond Bank's head office since 1953. The Federal Reserve System has operated a wire transfer system since 1922, but the Board of Governors decided to move the center which handled this operation from Washington to Richmond in 1953, to make it less vulnerable to nuclear attack. The decision to move to Culpeper was predicated partially on the same motive, but of equal importance was the desire to establish a modern facility with a capability for growth commensurate with that expected in the Federal Reserve System's communications needs.

4. TECHNICAL DESCRIPTION OF THE CENTER

Marshall Communications Division of Control Data Corporation was awarded a $2 1/2 million contract for the installation of a M-1000 Quad Communications Switching System at Culpeper. This system is actually four M-1000 computers which are designed to handle in very rapid fashion the receiving and relaying of messages among the 12 Federal Reserve Banks, their 24 branches, the Federal Reserve Board, and the U.S. Treasury. The system operates as a message exchange or switch, and it communicates with the 38 locations, each of which has one or more terminal units, by means of telephone lines capable of high speed data transmission. Any type of message, whether quantitative or narrative, can be transmitted by the system.

An important feature of the system is that the kinds of terminal units located at each of the Federal Reserve offices can vary considerably. Standardization is achieved through the use of a universally adopted code in which all messages are phrased and transmitted. This code, which can be handled by several types of terminal gear, is ASCII, American Standard Code for Information Interchange, known as "asky". The code is a communications language which, in addition to actually transmitted information, executes its own internal check on the accuracy of the information transmitted.

Most Federal Reserve offices have been equipped with Model 37 terminal units — slightly modernized versions of conventional teletype equipment. Each office has the capability to send and receive messages, although specialized equipment to receive or send only is provided additionally at some locations. These units handle the frequent and important low-content messages involving transfers of funds and administrative transmissions, but usually not those messages transmitting large quantities of data.

Since the Culpeper message exchange is capable of communicating with a wide viariety of terminal equipment, the use of the Model 37 terminals, is regarded as temperary at several of the Federal Reserve offices. A number of Reserve Banks and branches are in the process of upgrading their data processing and research computer equipment. In doing this, they have taken into consideration the coming potential of the Culpeper center. Thus, some of them intend to use large third-generation computers as terminals to communicate with the Culpeper exchange in addition to performing other data processing or research functions for the Reserve Banks. The Federal Reserve Bank of New York has planned from the outset to do this, and will therefore begin its communication with the Culpeper exchange via a computer.

The Federal Reserve Banks of Chicago and San Francisco have plans to follow a similar approach in the near future, and will probably replace or at least supplement their existing terminal gear with computer-to-computer communications. Other Reserve Banks, including the Federal Reserve Bank of Richmond, have similar plans under consideration. The advantages of this approach are considerable in that all messages flowing to or from the Culpeper exchange at a given Reserve Bank can be examined by that Bank's computer for informational content relevent to other computer related functions - accounting, reserve accounting, research and statistics, fiscal agency operations, discount and credit, etc. The terminal computer can thus automatically update files or perform necessary processing of the data it receives from the message flows.

Several Reserve Banks have further plans to establish computer-to-computer communications with member commercial banks in their districts. Such arrangements will make possible direct electronic communication via the Culpeper exchange of commerical banks throughout the nation. Messages involving funds transfers, for example, will be completed almost instantaneously. Human intervention in the transaction will be minimized thus reducing the possibility of error, and automatic updating of all relevant reserve accounts will be achieved as a by-product of the communication.

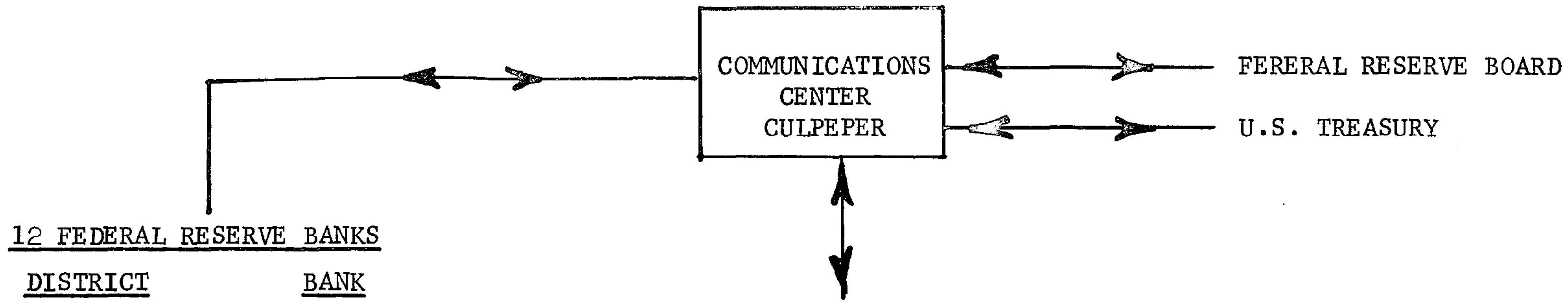
The technical capability exists for still other communications linkages, of a bank or non-bank nature, either directly to the Culpeper exchange or to it via a computer-type terminal at a Reserve Bank or branch. The existence of the Culpeper facility makes feasible, for example, the sharing among Federal Reserve offices of a large centralized data bank of national economic information.

5. COMMUNICATIONS NETWORK

As described in the July report the system operates as a message exchange and as such connects together 38 locations through a sophisticated switching system located at the Communications and Record Center. Fig. E-57 identifies the 12 Federal Reserve Banks and the 24 Federal Reserve Branches tied into the network. Also connected are the Federal Reserve Board and the U. S. Treasury in Washington, D. C.

5.1 Communications Center Equipment

The switching system is designated M-1000 Protected Message Exchange and is configured around four-type M-1000 exchange units manufactured by the MDM Division of Control Data Corporation of Santa Ana, California. Other significant equipment items are 4 Discpacks and Discpack Controls, Fast-Access Disc (part of each M-1000 unit), 5 Magnetic Tape Storage Equipment, Line Termination Units, Power Conversion Equipment (60 Hz to 400 Hz), and 2 Inktronic Printers. Each M-1000 Exchange Unit has a core storage function with a storage capacity of 60 bytes for the combined 4 units. The Fast Access and Discpack storage capacity is 12, 000, 000 bits. The data storage devices are all built in modular form to provide growth capability.



12 FEDERAL RESERVE BANKS

DISTRICT	BANK
1	Boston
2	New York
3	Philadelphia
4	Cleveland
5	Richmond
6	Atlanta
7	Chicago
8	St. Louis
9	Minneapolis
10	Kansas City
11	Dallas
12	San Francisco

24 FEDERAL RESERVE BRANCHES

DISTRICT	BRANCHES
2	Buffalo
4	Cincinnati, Pittsburgh
5	Baltimore, Charlotte
6	Birmingham, Jacksonville, Nashville, New Orleans
7	Detroit
8	Little Rock, Louisville, Memphis
9	Helena
10	Denver, Oklahoma City, Omaha
11	El Paso, Houston, San Antonio
12	Los Angeles, Portland, Salt Lake City, Seattle

FIGURE E-57 The Culpeper Center Communicates
With 38 Locations

Four M-37 ASR Teletype Terminals are included with the equipment. These are used principally for maintenance, supervisory, and control functions.

5.2 Terminals

Most of the Federal Reserve offices are equipped with Western Electric type 37 terminal units. These are modernized versions of conventional teletype equipment and are used to handle the frequent low-content messages involving fund transfers and administrative data. Specialized equipment is used in some locations to handle messages involving large quantities of data. Full duplex lines are used with the Model 37 terminals. This allows messages to be sent and received simultaneously.

In addition to the Model 37 terminals, the 12 Federal Reserve head offices and the Federal Reserve Board are being equipped with IBM Model 2968 tape units for transmitting and receiving large quantities of data through the Culpeper exchange. These units utilize magnetic tape which is readable by the data processing computers at each of the locations. With this equipment, tapes of economic information generated by the Banks' computers can be immediately transmitted to other Reserve Banks or to the Board through the Culpeper exchange, or conversely, can be received by a given Reserve Bank for immediate processing on its own computer. Lines available for transmission by this method are 2400 baud operating at approximately 2400 words per minute. These lines are half-duplex. This means that a terminal can either receive or send at a given time, but not both.

5.3 Network Interconnections

The geographical arrangement of the network is shown in Figure . Except for 4 locations which are relayed, lines connect directly to all of the Federal Reserve Banks, Federal Reserve Branches, and to the Federal Reserve Board and the U.S. Treasury. Most of the lines are TELPAK and are leased through GSA because of FRB's status as a quasi-governmental organization. Some of the heavy traffic routes use more than one line.

6 SYSTEM CHARACTERISTICS

6.1 System Operations

The full duplex lines connecting the Model 37 terminals to the Center allow simultaneous reception and transmission of messages. The fact that a terminal is in the process of sending a message does not preclude its receiving another message at the same time. Whether this is done is determined by the message exchange computers at Culpeper. The Culpeper computers continuously poll all terminals to determine whether a message is waiting to be transmitted. The complete polling cycle takes only a few seconds at the present loading of each trunk. For a trunk loaded to full capacity (26 lines) the polling time would be about 45 seconds.

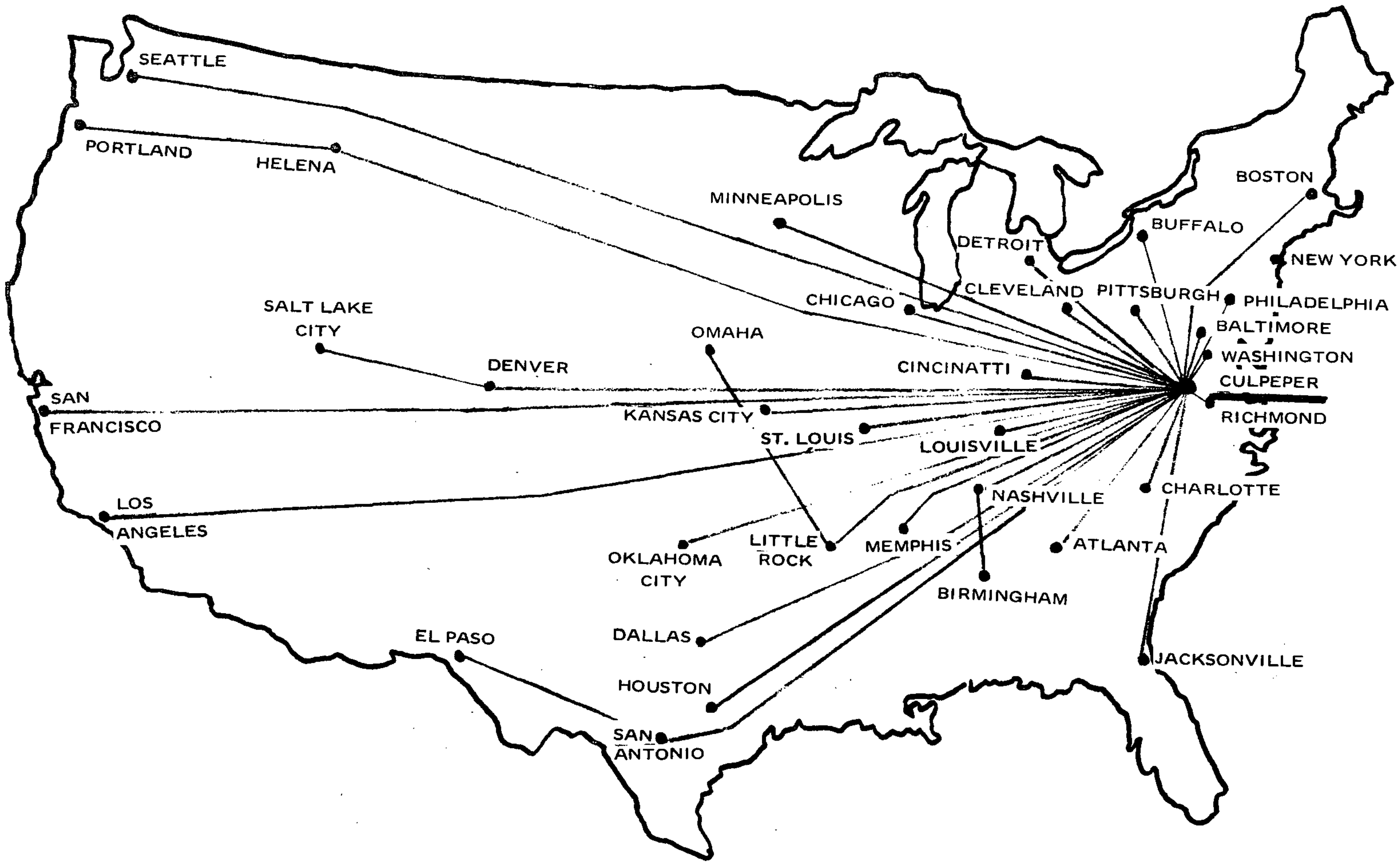


Figure E-58. Federal Reserve System Communications Network

If when polled a positive signal is indicated by a waiting terminal, the Culpeper exchange receives the message and notifies the terminal of the message's arrival. In a similar fashion, if a message has been received by the Culpeper exchange for delivery elsewhere, the Culpeper exchange notifies the terminal at the destination (or destinations) that a message is to be delivered. Upon receipt of the proper signal, the message is sent to its destination, and the Culpeper computer awaits a signal from the terminal that the message was received. All messages are then stored at the Culpeper Center on discs or tapes for a predetermined period of time.

6.2 Message Categories

There are three basic types of messages:

a. Wire Transfers - These are used to transfer funds between Federal Reserve District Banks. Every interdistrict transfer must go through the FRB's fund transfer system. A significant amount of each message constitutes message protection. In this instance protection refers to the use of accounting procedures and repetition for assurance of freedom from errors, rather than the use of security or secrecy procedures. Additional protection is provided by the equipment, which has parity techniques inherent in its mode of operation.

   Timely processing and delivery of wire transfers is extremely important because of "float." Float is a phenomenon which occurs because the time actually taken to collect checks is often longer than that allowed in the schedules. This crediting frequently occurs before the account of the bank on which the check is drawn is debited. The difference between the asset account (cash items in process of collection) and the liability account (deferred availability cash items) represents checks that, although not yet collected by the Reserve Banks, have already been credited, in accordance with a specified time schedule, to the reserve accounts of the banks that deposit them. This difference is termed float. It is sometimes sizable and serves as a measure of the amount of Federal Reserve Credit generated by the national check collection process and available to the member banks.

b. Security Transfers - Security Transfers are transacted between Member Banks and Between Federal Reserve Banks. In addition to these usual Security Transfers the Federal Reserve system also buys and sells securities in the open market as it accommodates seasonal demands for money and credit, attempts to offset cyclical economic swings, and supplies the bank reserves needed for long-term growth. The net change in its securities portfolio tends to be comparatively small over, say, a year, but over the same period the system undertakes a large volume of transactions--purchases and sales together--in response to seasonal and other temporary variations in reserve availability.

Timely processing of security transfers is extremely important because of the fluctuation in value of the securities. The same system of message protection used for wire transfers is also used for security transfers.

c. General Administrative Correspondence - These messages are principally narrative in nature. For this type of traffic, message protection procedures are usually not applicable (except for the equipment's inherent characteristics previously described).

6.3 Message Format

In the ASCII code used for transmission there are eight bits per character and six characters per word. In a typical wire transfer the message would contain:

Addressee

Originator

Message Text

Message Identification

Message Acknowledgement

The message identification and acknowledgement portions of the message form an important part of the transaction and contain the following categories of information:

a. Sending

ISI - Input Station Identification

IDTG - Input Data Time Group

IMSN - Input Message Sequence Number

b. Receiving

MFN - Message File Number

ODTG - Output Date Time Group

ISI - (Same as above)

IDTG - (Same as above)

IMSN - (Same as above)

OSI - Output Station Identification

OMSN - Output Message Sequence Number

6.4 Data Rate

At present, the system is equipped to handle messages to or from the Model 37 terminals at the speed of 150 words per minute. The lines presently available for use with the Model 37 terminals are 150 "baud," where "baud" is defined as a unit of signalling speed. The term is, for practical purposes, almost synonymous with "bits per second." With the ASCII code, there are eight bits per character, and six characters per word. Allowing for additional characters that are transmitted in order to check the internal accuracy of the message, the term "baud" becomes approximately synonymous with words per minute.

In considering the data rate potential of the system it should be noted that the message exchange computers at Culpeper are capable of transmitting messages to distant points at speeds of 9,600 bits per second. At present, therefore, constraints are imposed by the lines as well as by the types of terminals in use at the various end locations. Present needs, however, do not require the maximum utilization of the capacity available at the Culpeper message exhange.

6.5 Traffic

At the present time the peak traffic load is about 3,500 transactions per hour (3,500 in, 3,500 out). The average message length is 125 characters for wire transfers or security transfers. General administration traffic averages 225 characters per message. The breakdown according to categories is:

Wire transfers	65 percent
Security transfers	10 percent
General administrative	25 percent

The variation in traffic volume throughout the day is illustrated in Figure E-59.

6.6 Growth

The System's traffic has experienced a linear growth rate of approximately 7.3 percent per year as shown in Figure E-60. This rate of growth is expected to continue.

7. ANTICIPATED TRENDS

While some of the additional load of the projected growth will be accommodated by a corresponding increase in facilities, plans must be made to increase the efficiency of the transfer system. To some extent efficiency will be increased simply by increasing the speed of transactions. However, many constraints are imposed by the complexity of the economy and its institutions, as well as by the distances which separate individuals and organizations--not to mention many other natural barriers. There is

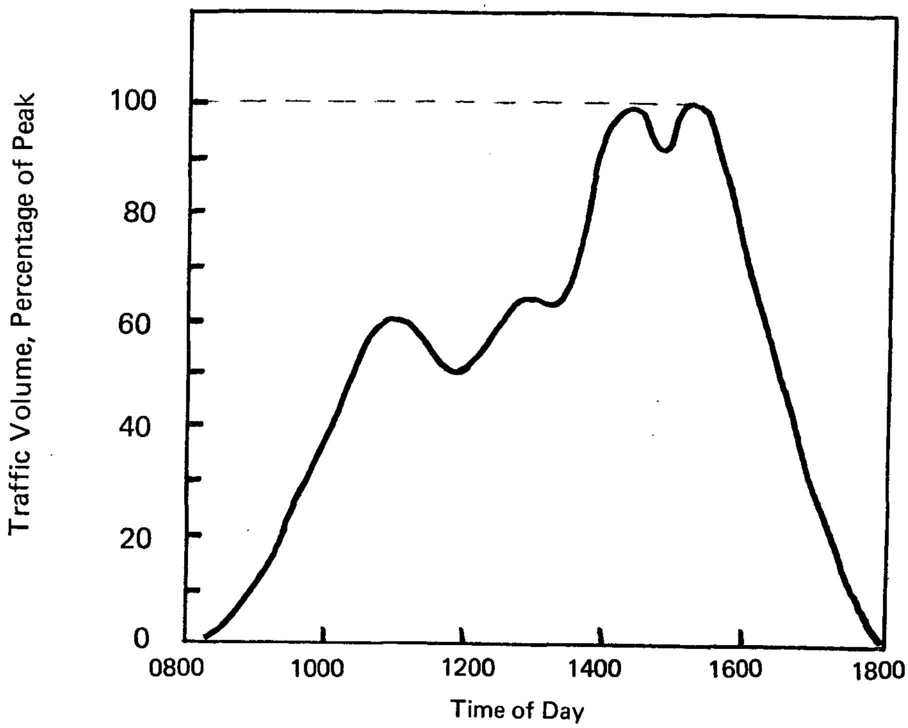


Figure E-59. Variation in traffic Volume Throughout Day

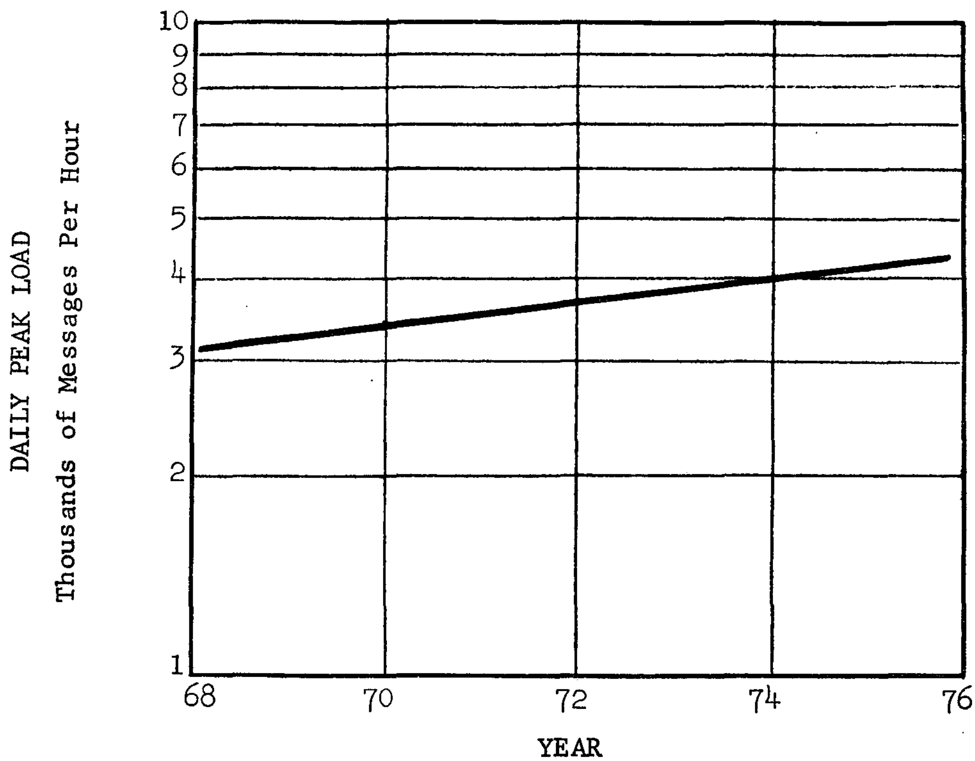


Figure E-60. Traffic Growth Pattern of Low Speed Circuits presumably some maximum speed at which it is physically possible to sort checks, to move pieces of paper from one location to another, or to ship currency and coin. While numerous advances have been made in all these areas, progress to date is still considered far short of adequate. Modern technology does not seem to promise an ultimate solution whereby maximum efficiency of the payments system can be achieved. Since all economic units are not electronically interfaced with one another, it is not feasible to consider this kind of efficiency--nor would such a system necessarily be desirable. Nevertheless, the limits of feasibility have been greatly expanded expanded. The establishment of the Culpeper exchange is an example of the technological possibility of alternative payments systems, which might feasibly include an economy without checks (the "cashless society") or at least an economy with fewer checks (the "less check society").

Banks play an obviously critical role in the American payments system as it presently exists. They provide the mechanism through which the overwhelming preponderance of payments are made. Therefore the efficiency of communications among banks largely determines the efficiency with which the payments system operates. The Federal Reserve, as the central bank, in turn plays a critical role in the settling of payments among banks, both member and nonmember. The Federal Reserve's communications center at Culpeper will unquestionably become a core element in the nation's payments mechanism.

The significance of the Culpeper center is yet to be seen, since its contribution to the Federal Reserve and to the payments system has only just begun. Its potential impact, however, is more clearly revealed by its technical characteristics than by the nature of the jobs that it will be required to perform in its initial stages. Most of the work that will be put through the Culpeper exchange at the outset are conventional tasks that will be transferred from the existing Telegraph and Switching Center--e. g., funds transfers among banks, administrative messages, transmissions of economic information among Reserve Banks, etc. However, as the Federal Reserve Banks and branches begin to install more sophisticated terminal equipment, as communications via computers are established with commercial banks, and as rapid data transmission among Reserve Banks get underway, the impact of the center upon the operations of these institutions should be striking. Significant departures from existing customs of communication will be quick to follow. Technological progress in the communications field has exceeded present levels of ability and readiness to take maximum advantage of its potential. There is little doubt that the Culpeper center represents one of the early steps leading invariably to an electronic payments system.

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E.9 DATRAN SYSTEM

The Bottleneck in Data Transportation

The past decade has presented us with a dynamic new technological medium, a new force with the potential to influence every area of our present and future - computerized data. Viewed at first as an investment in time-saving for corporations dealing in large amounts of detail-traffic, it has evolved today into the basic tool for the organization and conduct of commerce, government, health and education, and virtually every sphere of modern socio-economic activity.

What we have before us, in effect, is an invaluable new language and energy source, with immediate positive application to all areas of problem solving and day-to-day living. However, the techniques and facilities for the transportation of data have fallen dangerously behind our needs, depriving countless individuals and organizations of the substantial benefits which can be realized.

America is faced today with a crisis in data distribution comparable to the nation's transportation tieups. Almost everyone is familiar with some of the more obvious bottlenecks. In the streets of our cities, cars and trucks move bumper-to-bumper and as more vehicles join the long lines, they move slower and slower, to a standstill. Circling over the nation's busiest airports are giant jets carrying thousands of passengers, descending in gradual stages to the runways, even as other jets join the circling, waiting to land.

Less known, because it is less visible, is similar congestion in data traffic, which is causing increasingly critical bottlenecks.

At its simplest level, a data bottleneck exists whenever a caller receives a busy signal on the telephone. Data bottlenecks exist in schools and libraries where the constant flow of new materials cannot be rapidly assimilated and distributed; data bottlenecks exist in hospitals where vital patient statistics and medical information are not immediately available to doctors and research scientists; data bottlenecks exist today along the breadth of the nation's highways where on-the-spot traffic intelligence could effectively reduce the growing numbers of accidents; they exist critically in business operations in the absence of essential facts and guidelines for profitable decision-making; they exist in government agencies that need to gauge the resources of an entire nation or any of its communities at a given moment, to aid in allocating funds, levying taxes and planning new legislation.

Modern man is geared to an environment of change -- sudden, dynamic and sweeping change. Growth, progress, even survival in such an environment call for immediate and reliable communications. We differ greatly from our forebears of pony express days, of transatlantic cable days, of pre-direct dialing days. There are more people in the world today, engaged in more activities, and there are more urgent things to communicate than at any time in our history. Projections for the next fifty years are staggering to comprehend. Already in 1970, society is refined for speed, demanding virtually errorless performance and total instantaneous communications.

As a nation, we are only beginning to realize that a product of such broad dimensions as computerized data requires its own specialized processing and distribution techniques and channels. Somewhere along the way, we have neglected to apply America's most pragmatic success formula - specialization - to the wholesale transmission of computerized data.

Confronted with a continuing data explosion -- signifying immeasurable universal potential for progress -- we are foundering in outmoded and overworked methods of making data available, for the broad benefit of industry and our citizenry. Billions of dollars have been spent for advanced data transmission systems in military and space applications. But the advantages of the technology thus achieved has yet to be felt among the general public.

As bottlenecks in data transportation continue to grow in America, they directly affect every sector of the economy, every government program, every citizen.

Data - A New Wealth

At the heart of civilization, according to one penetrating analysis, is Man's relentless drive to convert his inventions, which started out as luxuries, into absolute necessities in his day-to-day activities. Certainly this is true of fire, the wheel, electricity, the automobile, the telephone, and so many other features of contemporary living that we take for granted. The most recent of these is computerized data, modern Man's dramatic new energy resource.

Computer-generated data is making possible solutions to problems which were once considered beyond Man's comprehension, and the potential is virtually limitless. Thus, we have the phenomenon of data banks. Here, vast quantities of information are stored for immediate application to specific needs and problems. A data bank is a "captured" body of highly specialized information, processed and compressed into an incredibly tiny space, yet generally available to large numbers of users over great distances via computerized communications networks.

The computer, despite its awesome image in the minds of many people, is basically Man's most elaborate tool. Very likely it is his biggest workhorse, as it performs a spectrum of chores that includes operating an oil refinery, translating design formulas into complete instructions for automated factory processes, predicting the course of hurricanes, calculating and controlling the distribution flow of auto parts, processing bills, and so on. The computers of the world are busy all day and night, serving Man in various ways, generating vital new data that are deposited in special banks.

There are growing numbers of these data banks in government, finance, industry, health and education, science and engineering, transportation, communications and countless other areas. Insurance companies, for example, are among the greatest users of data banks containing vital birth, death, health and accident statistics. Banks use data banks for instantaneous processing of the large volume of transactions taking place every day in our "check-less" society.

By far the most dramatic use of a data bank was in the Apollo space program. Critical data support came from NASA's Houston facility, to help guide astronauts and their spacecraft to a successful Moon landing and return. Even now, as data is being transmitted from scientific instruments left on the Moon's surface, the world's most advanced space data bank is being updated and expanded many times.

Over the past decade, the American public has made a substantial investment in advancing data banks and computerized communications. We are at the stage now where tangible returns for the average citizen are within reach, to meet the mounting sociological needs and pressures in such areas as employment, education, health, law enforcement, traffic convenience and safety, housing, pollution, distribution of goods, and many others.

In every area, we are learning that data, in order to be useful, must be suitable for use at the precise moment it is needed. In medicine, a vital serum cannot save a life unless it is located and administered to a victim in time. In retailing, last week's inventory records do not give a true accounting of orders that can be fulfilled. Trucks and ships, as well as spacecraft, must be apprised of the latest weather conditions; available manpower resources and equipment must be immediately calculable and communicable to combat floods, forest fires, riots and other emergencies. The longer data is delayed in transmission from a data bank or other source, the less effective it becomes. Unused data, in short, is useless data; in a very real sense, old data is false data. We know today that inadequate communications leads to social disintegration.

Analog and Digital Communication

To understand adequately the communications problem currently facing the nation, one should be aware of the different requirements of traditional telecommunications, which is based on the analog system, and computerized data transmission, which is based on the digital system.

Very simply, the former primarily measures and translates the various components of sound, such as the human voice, into signals which are reconverted to sound and words at the receiving end. Digital transmission, on the other hand, counts and transmits data in direct unit impulses. The analog system is ingeniously structured to accommodate extremely complex combinations of sound, involving myriad flowing variations in tone, volume, timbre and pitch. The digital system, oriented to communicating pure data, incorporates only two variations in its signals, a key feature which enables it to service the tremendous data flow of computers with remarkable speed and accuracy.

The problem clearly focuses on the inadequacy of existing means to transmit the great mass of data that is being produced by increasing numbers of computers. It is one thing for a businessman in New York to talk to another in Los Angeles, but there is a completely different communications pattern when computers "talk" to one another. A different language comes into play with a rate of "speech" that is unbelievably rapid. Computers, moreover, are capable of communicating to virtually unlimited numbers of other computers simultaneously.

The traditional analog-based common carriers of the communications field--the telephone and telegraph companies--are acutely aware of the inadequacy of analog systems to service the huge output of modern computerized data. In attempting to fill the communications gap, they have developed and are developing intricate mechanisms and procedures by which digital data is translated into analog impulses, and then converted again back to digital data. Common carrier networks today do indeed transport digital data, but they are only partially meeting the growing needs of digital data transmission. The result is that neither the most sophisticated user of computers nor the average citizen is receiving the full social and economic benefits of our advanced technology.

For the traditional common carriers to assume this additional communication chore at a time when their facilities are already straining to keep up with the mounting demands of established telecommunications is a tremendous burden on the networks themselves and also on business, government and private interests throughout America. The problem is compounded by the growing stockpiles of digital data that must be transported without delay for maximum effectiveness. Digital data today is multiplying at such a rate that it is expected to exceed the volume of voice communications in a few years.

America is at the brink of a communications crisis. Specialization has long been a major factor in the advancement of traditional telecommunications. The abandonment of this approach is gradually producing communications chaos. Digital technology has rushed far ahead of the ability of a "multi-purpose" system to respond to the nation's specialized commmunications needs. There is great urgency for telephone/telegraph companies to resume concentrating solely on their historic services to America, while a new communications carrier implements a pure digital data transmission operation, for the benefit of all.

The Need for an Additional Communications Carrier

Scattered throughout the country are a number of private-channel communications systems for transporting specialized digital data. However, privately-owned networks are economically feasible only for such users as pipelines, railroads and airlines. Most corporations, academic and health institutions, as well as government agencies, are forced to use the conventional common carriers, the established telephone and telegraph companies. For those requiring rapid, reliable and economic digital communications, there is no economic alternative at the present time.

Among the disadvantages of superimposing a mounting load of digital data on the existing common carrier networks is the inadequate speed levels which result in transmission. A typical voice channel operates at 75-200 bits per second (bps), although more expensive terminals can boost these speeds to about 2,000 bps. However, a user requiring a reliable rate of 4,800 bps, for example, even for short periods, has to resort to very costly specially "conditioned" private line circuits. It should also be noted that a speed requirement of 9,600 bps is not uncommon among computer users today, and that many computerized data systems ideally should be utilizing even faster speeds.

Moreover, the analog system that becomes a "hybrid" digital transmitter is obliged to utilize costly and complex equipment to safeguard against errors. Suspected errors are then retransmitted while valuable time is lost, still without any reassurance of absolute accuracy. In addition, noise or static, acceptable to some degree in voice communications, tends to cause displacement or even complete loss of bits of vital digital data. Interference, also, between the voice communications and "computer talk" is another detracting element.

A further disadvantage is the minimum three-minute call rate currently in use via telephone systems. Computers rarely take more than 6 to 12 seconds to send or receive an entire message, yet the user may still be charged for the remaining two minutes, fifty or so seconds. There is some movement underway today toward a one-minute minimum, a goal which does have some advantages, but still represents a time strait-jacket.

Still another factor is the average 20-second delay in making a connection, which represents irretrievable time lost for the transmission of crucial information. In addition, there is a disturbing 4-5% proportion of busy signals.

Probably the greatest disadvantage of a merged analog-digital system is the compromises which inevitably follow in the areas of voice communications services. There is nowadays an unprecedented demand for such services. Equally serious are the delays in achieving the vast potential benefits of digital data transmission. The bottleneck not only exists in rising established communications requirements, but also with regard to the flow of computer answers to the many problems facing the nation.

As they are today, America's communications resources are roughly comparable to a house with dubious wiring facilities. To add some convenient electrical appliances to a system barely able to meet present capacity demands is to invite frustration, failure and danger. Similarly, our present national policy of encouraging overloading and hybridization of an excellent voice-based communication network is a highly questionable expedient. The time has arrived when we have to gauge very accurately what can and cannot be done with our present communications systems, and explore the alternative of adding a third type of communications carrier to accommodate pure data transmission.

Pure Data Transmission

A completely new, entirely separate network--designed, engineered and dedicated to the transportation of digital data--is the only logical answer to America's mounting communications crisis. Such a network could be based on truly advanced technology, unhampered by the need to accommodate analog signals.

Digital transmission, via the time division multiplex system (TDMS), which has been used for years by NASA to monitor and control ground stations and spacecraft -- including Apollo 12 -- is entirely practical and economical for national data communications. A digital transmission system could also incorporate such space-age innovations as computer-controlled circuit switching and automatic store-and-forward message switching. Moreover, an all-digital communications network could be entirely compatible with proposed domestic satellite communications systems.

The time division multiplex system assigns each data channel to a specific time slot, so that each channel receives the benefit of the full power of the transmitter. This avoids the common problems of varying loads and power dispersion encountered when channels are added to conventional systems.

In a sense, computer-controlled circuit switching -- between any two points in a digital transmission network -- is to present voice systems what the present systems are to the old telephone system, which effected cross-country "connections" through cascades of human operators located at far-flung individual switchboards. Computer-controlled switching is capable of slashing the present average 20-second circuit connection time to a maximum of three seconds, and to reduce the rising busy signal rate to just 1%. Clearly, the cost of integrating such near-instantaneous switching into the present voice-based phone network is prohibitive.

Store-and-forward switching, as the phrase implies, involves one or more switching centers equipped to accept a message whenever it is offered, then physically store the message, and instantly retrieve and forward it to a receiver whenever he is able to accept it. This is comparable to instructing a telephone operator to "keep trying" to put through a call when initial attempts result in busy signals.

Through these and other proven, state-of-the-art technologies, a nationwide, subscriber-to-subscriber network could be set up, operated and maintained by what would amount to a new communications common carrier, regulated by State and Federal agencies to serve the public's interest. Envisioned is a coast-to-coast trunk and tail circuit network, providing "door-to-door" service through more than 250 microwave stations and ten district offices. The backbone of the trunk system would follow a route generally from San Francisco to Los Angeles to Phoenix, Albuquerque, Dallas, north to Minneapolis, southeast to Atlanta, then up the eastern seaboard to include the major metropolitan centers.

By specializing in meeting the needs of digital data communications, such a network could provide subscribers with superior service and, at the same time, free the nation's established common carriers to concentrate on most efficiently meeting the challenges of voice communications at the lowest possible cost to the public.

Communications Advances of the Future

A digital data transmission system would remove present restraints on far ranging computer applications. For example, an education and knowledge resource network could be established via "digitized" microfilmed books, periodicals, research reports, and other vital information materials. These could be made available to anyone in the country. A college student in Anaheim, California would have swift access to Harvard's great store of books; a detective in Denver could inspect police files in Miami; a family doctor in a small Ohio town could tap the finest medical research centers and libraries in the nation without leaving his office. Teachers, engineers, executives, scientists, elected officials would be able to keep instantly informed on latest developments in their areas of performance.

A digital data transmission system could set up a national highway communications network for motorists. Such a network - versatile, effective and invisible - is entirely within the reach of modern technology. Network communications would provide motorists with routing, traffic, paging, emergency lodging and entertainment information via car radios. Easier, safer and more comfortable motoring would result.

Analog-dedicated networks could not possibly absorb the voluminous data such networks would generate. However, through 4,000 channels of communications operating simultaneously over a single radio path and supported by cable as necessary, specialized digital data systems could easily accommodate the loads -- with speed and accuracy. Digital transmission is inherently much less error prone than analog transmission and has built-in error checks. Moreover, a digital transmission system employs repeaters spaced along the line to regenerate clean, perfect pulses, or bits. Also, computer-controlled switching reduces impulse noise to negligible levels.

Digital transmission achieves speeds over 100 times greater than those of analog networks, along with dramatically heightened reliability. A specialized digital transmission system would offer the benefit of economy with subscribers paying only for the actual time they use the system.

A specialized system dedicated to the specific requirements of data transmission would begin to resolve the worsening bottlenecks in many areas of the nation's communications. From another point of view, a pure digital system would go a long way toward conserving a national resource already in critically short supply -- existing wire and cable facilities. The continued use of voice channels to carry data is not only wasteful, it is also a threat to the growth and improvement of the highly developed nationwide voice system on which the entire economy relies so heavily.

Volume alone demands immediate action in the direction of a digital system. It is expected that ordinary digital traffic will grow 50% annually, with additional volume coming from increasingly popular low-cost, remote access computer terminals for banking, insurance, airline, hotel, car rental, retail and similar businesses.

Furthermore, once the current communications traffic jam is under some semblance of control, there will be dramatic computer-based advances, each contributing huge volumes of new digital data. For example, there is a large market for dynamic load sharing, whereby massive computational and processing tasks are broken into segments and distributed among several remote computer complexes. Universities and giant industrial organizations are ready for this type of service, which is not practicable under the present analog-oriented transmission system.

Computer-aided graphic design will also come of age through digital transmisison. Design engineers, armed with TV-like consoles, will be able to summon needed images from the memories of remote computers and modify and manipulate them to quickly produce fully-coordinated, complex designs. The computer can also test the designs for such factors as stress and feasibility, while producing finished engineering drawings and instructions for automated factory processes.

A further advance of enormous potential is envisioned through computer-aided instruction. Audio and visual material stored in computers could adjust to the learning rates and specific responses and needs of individual students. A large number of students could be reached simultaneously, with each one proceeding at his own pace on subject matter of his own choice.

The growing demand for low-cost, high-speed facsimile transmission is still another market that could be serviced by a dependable, specialized data transmission carrier. Today, a page of facsimile can be sent from

New York to San Francisco in about six minutes. An all-digital network could cut the time to about 30 seconds. Interface would be effected with Teletype-type machines and digital Xerographic-type equipment, as well as computers. Applications might include transmitting materials from a central composing room to several satellite newspaper printing plants, sending engineering drawings to a manufacturing facility, distributing illustrated management reports, and automatic dissemination of scientific and technical papers, based on "interest profiles" of individual subscribers and stored in a computer.

The broad benefits of a pure data transmission system would filter down to the nation's small businessman as well as its great corporations, local doctors as well as hospital complexes, villages and townships as well as federal government agencies, farmers as well as urban planning/ghetto improvement programs.

So enormous are the advantages and the progress that would result from an additional communications carrier, specializing in transmitting pure data, that it would appear self-destructive for our national system to proceed as is. To be sure, rigid requirements and qualifications should be ascribed to any organization undertaking this vast urgent responsibility. A deep exposure to digital transmission technology with considerable specific space communications experience, is mandatory. It is for the government, industry, and the public to invite the most professional group operating in America today to initiate such a system, for the ultimate benefit of all interests.

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Tuesday, Nov. 25, 1969

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FCC ASKED TO OKAY NEW NATIONAL NETWORK

WASHINGTON, Nov. 25 -- Data Transmission Company (DATRAN) today filed an application with the Federal Communications Commission for Authority to construct and operate a common carrier system for transmitting data to 35 major metropolitan areas (map of cities attached). DATRAN is a wholly-owned subsidiary of University Computing Company of Dallas.

The nationwide system, estimated to cost approximately 375 million dollars, is designed solely to provide door-to-door communications service in digital form, the language of computers and data processing equipment. DATRAN told the Commission that by eliminating the necessity of translating to and from analog (voice-type) circuits that are already congested, its proposed system would offer business, government, and education faster, more reliable and more economical transmission service.

DATRAN's application is based on studies prepared with the assistance of Keystone Computer Associates, showing a broad potential market for its services, including leading companies in the banking, insurance, manufacturing, petro-chemical, food retailing, securities, and transportation fields.

Engineering data, developed over the last 15 months by DATRAN personnel and Page Communications Engineers, showed how customers would be served initially by a combination of 244 microwave repeater stations, ten district offices for computerized switching, and tail-circuits to customer locations. The Company told the FCC that its proposed system would offer users the following advantages over methods today available to serve public need:

Speed - The DATRAN network would connect subscribers in less than 3 seconds, compared to the 20 seconds normally required by today's systems. Since the typical data transmission, as in a reservations inquiry and reply, lasts only 15 to 20 seconds, this time-saving factor is significant to network users. Also speeding service, only one per cent of "calls" in the new system would get busy signals on the average, against the 4 to 5 per cent average by present systems. Messages sent via the DATRAN system can move at the fastest speed that most customers' communicating terminals can generate. It may be as high as 14,400 "bits" per second, and need not be slowed down to 2,400 "bits" -- the present practical limit on most voice-type facilities.

Reliability - By eliminating the need for translating the data from computer language to voice-type signals and back again, the DATRAN system is designed to reduce system-induced transmission errors to no more than one in ten million bits. It also provides a unique capability for automatic detection of an outage, making possible the scheduling of repair before the subscriber is even aware that the outage has occurred.

Economy - The customer would be billed only for the actual time used, which may be 6 to 12 seconds, rather than the standard minimum rate for a 3-minute call on present facilities or the rent for a private line which he may not be able to utilize economically.

Flexibility - The DATRAN system would interface not only with computers and Teletype-type machines, but also would provide ready access to and from digital Xerographic-type machines, thus permitting the transmission of facsimile and other types of graphic information at speeds 6 times or more faster than can today's conventional network voice circuits. Thus, DATRAN will for the first time provide low-cost network graphic transmission services for the medical profession, educators, and researchers, as well as for the other scientific and engineering disciplines on which America's well-being and economy are based.

Although UCC is expected to be one of the users of the DATRAN system, services will be offered to all customers on an equal tariff basis.

Officials of DATRAN stated that the application for FCC authority would undoubtedly be under consideration by that agency for at least a year and possibly longer, and there is no assurance that the requisite authority would be forthcoming from the FCC.

Construction of the system is planned to begin as soon as legal authorization has been secured and appropriate financing arranged, and completion of the system would be expected within four years thereafter. Funding for the proposed project would be expected to be supplied by UCC and other sources now under consideration. Officials of UCC and DATRAN emphasized that no firm commitments have been obtained from the financing sources which have been contacted.

Officers of DATRAN include Seymour Joffe, president, who was with Univac for 12 years until he joined UCC as vice president in 1967; Edward A. Berg, vice president for operations, an engineer who has been with the New York Telephone Company, Univac and the Veteran's Administration, where he was chief of communications research and development; and David H. Foster, vice president for administration, who was formerly a vice president and director of Collins Radio Company.

2.0 DATRAN Network

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FCC ASKED TO OKAY NEW NATIONAL NETWORK

WASHINGTON, Nov. 25 -- Thirty-five metropolitan areas, ranging from Boston to San Diego and Atlanta to Minneapolis, would be served by a new common carrier data transmission system, which Data Transmission Company today asked the Federal Communications Commission to authorize. The application asks permission to contruct and operate 244 microwave repeater stations, 10 district offices for computerized switching, and tail circuits to locations of an estimated 160,000 prospective customers. It says the $375 million system is designed to provide speedier, more reliable, and more economical transmission of digital data than is possible over present voice-type circuits. (Figure E-61).

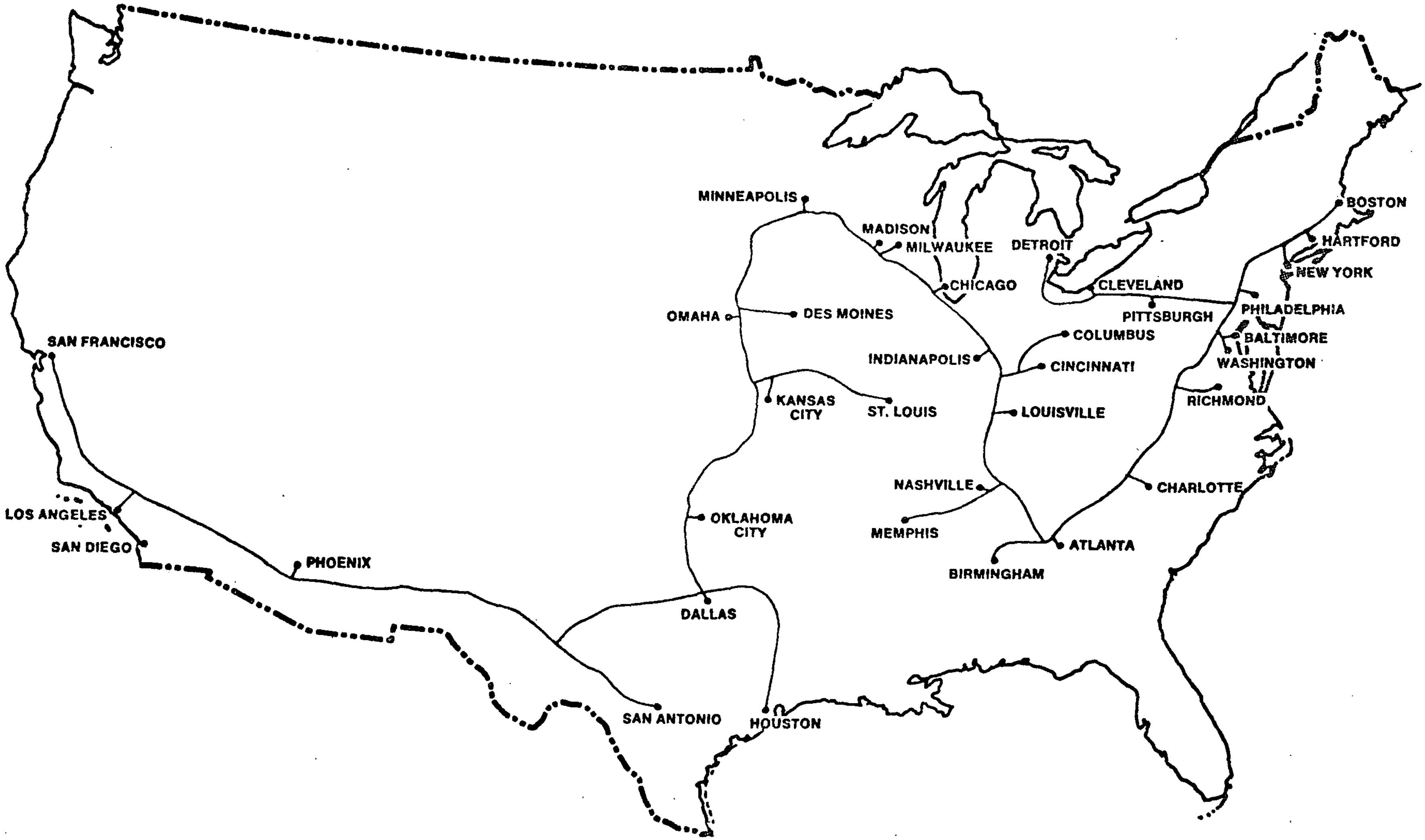


Fig. E- 61. **DATRAN NATIONAL NETWORK**

E.10 LAW ENFORCEMENT

E.10.1 FBI NATIONAL CRIME INFORMATION CENTER

On Monday, July 27, 1970 a visit was made to the NCIC in Washington, D.C. The operations and facilities of the Center were described by Mr. Norman F. Stultz who also provided numerous brochures and other information.

2.1 Concept of the NCIC

2.1.1 Inception

In September, 1965 the FBI embarked on the development of a national electronic information system to be known as the National Crime Information Center. The NCIC was set up by the FBI to complement the development of electronic information systems — metropolitan or statewide in nature — and to coordinate the setting of standards which would enable all systems to readily inter-change information.

The System planners visualized an information network encompassing the entire United States which would make available to each law enforcement agency, in a matter of seconds, the facilities of an information file national in scope. Thus, the criminal is deprived of mobility as a sanctuary because information is readily available to any participant in the system concerning any criminal or criminal act regardless of geographic boundaries.

The prospect of such a system has excited the imagination of the law enforcement community since it enables local officers, through coast-to-coast and border-to-border cooperation, to close ranks against the criminal element.

2.1.2 Need for State-Local Systems

The logical development of electronic information systems proceeds from local metropolitan systems to statewide systems and then to a national system. In effect, each succeeding system would afford greater geographical coverage. The information stored at each level depends on actual need, with local metropolitan systems naturally having a data base much broader than that of either the statewide or national system. By the same token, State systems should store information of statewide interest which would not properly be stored within a national system. It was considered important to avoid any concept that the implementation of a national system eliminates the need for systems of lesser geographical scope - metropolitan and statewide systems must develop to serve local needs which could not possibly be met by any national system. The ultimate nationwide network cannot be achieved until such systems develop in each State and in the larger metropolitan population centers.

2.1.3 Establishing Requirements

As a first major step to establishing a nationwide system, the FBI contracted with the Institute for Telecommunications Sciences and Aeronomy (ITSA), Environmental Science Services Administration, Department of Commerce, to survey all existing telecommunications networks throughout the United States and to recommend a network that would best support a nationwide computerized system. This effort covered the following points:

a. A study of National Crime Information Center computer characteristics.

b. A study of existing information systems.

c. A study of existing and planned telecommunications networks.

d. Determination of data transmission requirements for the National Crime Information Center system.

e. Development of telecommunications operations to fulfill National Crime Information Center requirements.

Initially the FBI's National Crime Information Center included stolen automobiles unrecovered after a specified time, stolen property in certain categories, and some wanted persons. The information stored in the national system was largely entered directly into it by participants and was immediately available to local users throughout the United States on direct inquiry. This step-by-step approach was adopted as the most practical means of establishing the nucleus of a nationwide network and of putting such a network into operation. Other applications as described herein were later added as the system developed.

2.1.4 Financing

Financial assistance which materially aided the rapid development of the network was received from the Office of Law Enforcement Assistance, Department of Justice. Additional funds were made available for the communications study, advisory group meeting, and communication line costs and terminal equipment costs for the initial local and State agencies participating in the system. None of these funds were applied to the costs of the center itself; all hardware and development costs in that regard are borne by the FBI. Similarly, each of the initial participants has contributed substantially from its own resources in the form of personnel and other development costs, thus enabling it to tie into the system.

2.2 System Description

2.2.1 Use of Computers

The FBI has long made use of computer technology and currently uses the computer to process over 800 programmed tasks. These tasks range in scope from the preparation of FBI payrolls to the analyzing of evidence in accounting cases, crime analysis, recidivism studies, and the breaking of codes. All work assigned to computers has necessarily been limited to that which could be processed sequentially due to constraints imposed by available equipment. However, with the developing of computers having random-access storage and the resultant adaptation to operational use through communications advances, it became apparent that the computer would play a new and vital role in FBI activities.

2.2.2 The NCIC Network

The NCIC Network is shown in Fig. E-62. At the present time the network consists of 89 150-baud dedicated circuits, 26 150-baud multipoint circuits and 5 2400-baud dedicated circuits. Through connections to state and local systems about 3000 terminals are tied into the computers at NCIC. The incoming traffic is now approximately 55,000 transactions a day.

2.2.3 NCIC Files

2.2.3.2 File Details

a. Stolen, Missing or Recovered Guns

This file contains a listing of stolen or missing guns identified by make, caliber, type and serial number. To enter these guns in file, it is essential to have the date of theft, the identity of the agency holding the theft report, and that agency's case number, in addition to the identifying data. To search the gun file, the serial number and the make of the gun is furnished to the computer.

If a gun has been recovered and an NCIC inquiry reveals there is no theft report, the weapon can still be entered into file as a recovered gun. In the event a theft report is later made, a search will immediately reveal that the weapon has already been recovered.

b. Stolen Articles

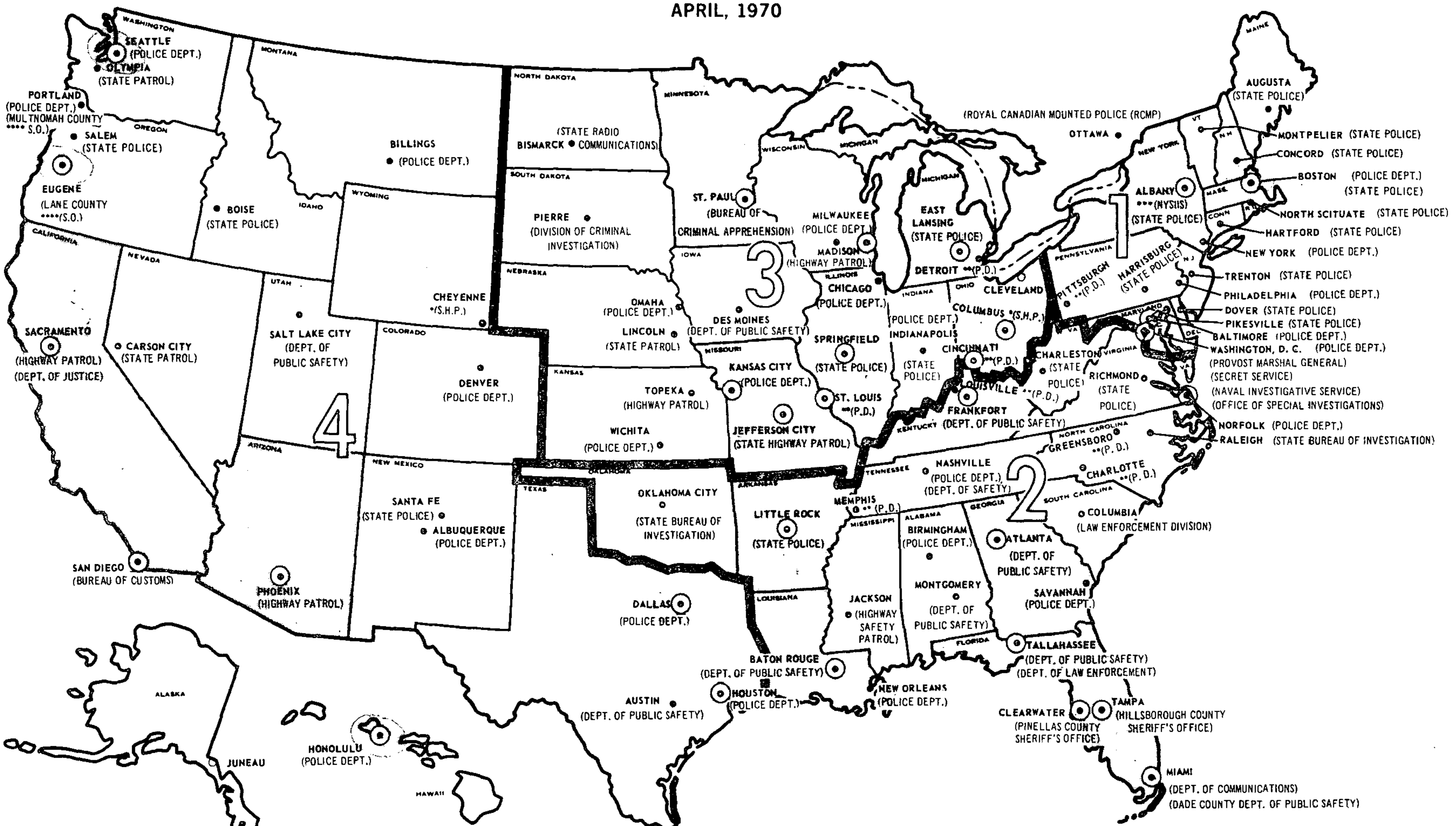
A listing is contained in this file of items of property not designated under the other classifications. Articles are described in terms of types, brand names, serial numbers, and models. The date of theft, the identity of the police agency holding the theft report and that agency's case number are also included in an article entry. Such a file is useful because of the wide variety

FEDERAL BUREAU OF INVESTIGATION
UNITED STATES DEPARTMENT OF JUSTICE
JOHN EDGAR HOOVER, DIRECTOR

Figure E-62

NCIC NETWORK

APRIL, 1970



NCIC POLICY BOARD REGIONS

1 11 NORTHEASTERN STATES AND DISTRICT OF COLUMBIA – Population: 53,414,000

2 13 SOUTHERN STATES – Population: 46,352,000

3 12 NORTH CENTRAL STATES – Population: 55,628,000

4 14 WESTERN STATES – Population: 44,467,000

*(S.H.P.) — (STATE HIGHWAY PATROL)

**(P.D.) — (POLICE DEPT.)

***(NYSIIS) — (NEW YORK STATE IDENTIFICATION AND INTELLIGENCE SYSTEM)

****(S.O.) — (SHERIFF'S OFFICE)

◉ Operational Terminal -- Computer
● Operational Terminal -- Manual
○ Planned Terminal (to be added)

(Shaded portions represent areas having immediate access to NCIC through local or state computers.)

of stolen property listed. A value criterion exists for entering stolen property in this file; however, local discretion based on investigative experience and sound police judgment is the controlling factor in making entries of articles regardless of the value. In making inquiries of this file, the computer should be furnished with the serial number and the type of article.

c. Wanted Persons

Included in this file are the names of persons with identifying data against whom charges are outstanding and warrants issued for extraditable offenses. To make an inquiry it is essential to furnish a person's name and date of birth or some other numerical descriptor peculiar to him. It is helpful to furnish his social security number, military serial number, or similar identification known. Information such as height, weight, and hair color cannot be searched in this file, but in entering the record of a wanter person, these items must be set forth. In addition, it is essential to furnish the offense for which an individual is wanted, the date of the arrest warrant, the identity of the law enforcement agency holding the warrant for this person, and that agency's case number. If he owns a vehicle and is known to be using it while a fugitive, the identifying number of the vehicle and the license plate number should be entered into his record. In the event inquiry is made concerning this vehicle, the wanted person's record will be revealed.

d. Stolen/Wanted Vehicle and Stolen License Plate Files

These two files are closely related to each other with the only difference being separate methods by which NCIC receives data to be placed in storage. For entry into the stolen vehicle file, the information needed is the automobile make and model, the vehicle identification number, the license plate number, the state of registration of the license number, the type of license plate where pertinent (truck-trailer-taxi-dealer), the color of the automobile, the car's date of theft, the identity of the agency holding the theft report along with that agency's case number. The license plate file requires the same information; however, no vehicle is involved. To search these files all that is needed is the vehicle identification number or the license number and state of registration.

e. Stolen/Embezzled/Missing Securities

This file contains serially numbered identifiable securities which have been stolen, embezzled, or are otherwise missing. Securities, for the purpose of this file, include currency (both real and counterfeit) and those documents which are of the types traded in securities exchanges (stocks, bonds, etc.). Also included in the file are warehouse receipts, traveler's checks, and money orders. Personal notes and checks, cashier's checks, officer's checks and certified checks are not included in this file.

Securities are basically described in terms of type, serial number, denomination, issuer and owner (and social security number if owner is a person). Other descriptive expressions which are helpful to identify securities are readily available from observation of the security and are termed "sinking fund", "series A", "collateral trust", "cumulative", "convertible", etc. The date of theft, the identity of the police agency holding the theft report and that agency's case number are also included in a security entry.

This file is useful because of the mobility of security thieves and the speed with which NCIC can advise on the receipt of an inquiry whether a questionable security has been entered in NCIC as having been stolen or embezzled or as missing. To make an inquiry it is essential to furnish type, serial number and denomination. A special provision makes it possible to obtain information concerning securities taken from one person by inquiring by type and owner and/or social security number of the owner.

2.2.3.3 Access to Files

The initial step to having pertinent information entered or searched through the computer occurs at the terminal of a local agency. Data may apply to a wanted person, stolen/wanted vehicle, stolen license plate, stolen, embezzled, missing security, as well as stolen, missing, or recovered weapons and stolen articles. The actions of the terminal operator (who might also be a radio dispatcher) "talking" to the computer require a few seconds, and a prescribed method must be followed. This is called a format.

The operator first furnishes the computer a standarized coded description of what he wants done – an entry or an inquiry – and indicates the file he wishes to communicate with. He then types the agency identifier, a pre-determined number, which identifies the agency to the computer. Then he furnishes pertinent information in an established order concerning the substance of the entry or inquiry. With the last piece of identifying data into the computer, he indicates there is no further information being submitted. From that point on, the computer takes over. If the transaction is the entry of a record, the computer automatically stores this information in its memory and acknowledges that it has been recorded. Should the transaction be a request for a search of a particular file, the computer will conduct the search necessary and furnish a printed record of any information found to the operator. When there is no record located, the computer will print out the fact there is no record. It takes a few seconds to make an entry or an inquiry and only a few more seconds to receive an answer.

2.3 System Operations

On July 1, 1970 the operations report showed the following statistics:

Records on File

Wanted Persons	60,902
Vehicles	487,780
License Plates	160,220
Securities	619,077
Articles	385,156
Guns	317,507
Boats	1,508
Total Records on File	2,032,150
Total Transactions for June	1,587,000
Daily Average Transactions	52,900

Tab. E-24 shows the daily average total of all messages to NCIC to be 50,197 during the month of May 1970. There were 136 users of the network during the month categorized as follows:

State Agencies	49
City and County	38
FBI	39
Military	8
Secret Service	1
R. C. M. P.	1
	136

It is interesting to note that just four users--all state police agencies--accounted for over 25 percent of the total. Approximately 50 percent of the total traffic was shared by 12 users--6 state and 6 municipal. The average message length both in and out is 50 characters. In addition to the usual NCIC formated traffic there is also some administrative traffic. This is usually involved with announcements or with operational problems, outages, editing, etc. All messages received at NCIC are addressed to NCIC. There is no switching system for forwarding of inter-terminal traffic.

At the present time there are about 3,000 terminals tied in to the system. The communications network consists of:

89 - 150 baud dedicated circuits

26 - 150 baud multipoint circuits

5 - 2400 baud dedicated circuits

Honolulu is connected to the NCIC via a 150 baud Intelsat Satellite circuit which is relayed through the California Highway Patrol circuit. Of the above circuits, 39 have computer interfaces. All lines operate in half-duplex mode.

TABLE E-24. NCIC TOTAL DAILY USAGE FOR MAY 1970

NOTE: The number in parenthesis after certain users indicates the number of communication lines to that user where more than one line is involved. An asterisk indicates that agency is a new user (connected to NCIC during May, 1970).

RANK	TERMINAL	DAILY AVERAGE OF ALL MESSAGES	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
1	Michigan State Police (3)	4,263	8.5	8.5
2	New York State Police (3)	3,162	6.3	14.8
3	Illinois State Police (3)	2,807	5.6	20.4
4	Cal. Highway Patrol (3)	2,590	5.2	25.6
5	Kansas City Police Department	2,370	4.7	30.3
6	Dallas Police Department (2)	1,658	3.3	33.6
7	New York City Police Department (2)	1,560	3.1	36.7
8	Arizona Highway Patrol (2)	1,476	2.9	39.6
9	Memphis Police Department	1,340	2.7	42.3
10	Chicago Police Department (2)	1,320	2.6	44.9
11	Ohio State Patrol	1,301	2.6	47.5
12	D. C. Police Department (2)	1,213	2.4	49.9
13	St. Louis Police Department (2)	1,138	2.3	52.2
14	Dade County, Florida	1,082	2.2	54.4
15	New Jersey State Police	1,029	2.1	56.5
16	Philadelphia Police Department	956	1.9	58.4
17	FBI-UCR (3)	814	1.6	60.0
18	California Department of Justice (2)	765	1.5	61.5
19	New Hampshire State Police	748	1.5	63.0
20	Pennsylvania State Police	702	1.4	64.4
21	Baltimore Police Department	676	1.3	65.7
22	Massachusetts Department Safety (2)	666	1.3	67.0
23	North Dakota State Comm.	593	1.2	68.2
24	Secret Service	521	1.0	69.2
25	Wichita Police Department	517	1.0	70.2

Table E-24. NCIC TOTAL DAILY USAGE - MAY 1970 (Cont'd)

RANK	TERMINAL	DAILY AVERAGE OF ALL MESSAGES	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
26	Texas Department of Safety (2)	503	1.0	71.2
27	Miami, Florida Department Com.	501	1.0	72.2
28	Georgia Department of Safety	429	0.9	73.1
29	King County, Seattle, Washington	418	0.8	73.9
30	Kentucky State Police (2)	378	0.8	74.7
31	FBI - Voucher- Stat. (2)	374	0.7	75.4
32	Indiana State Police	362	0.7	76.1
33	R.C.M.P.	358	0.7	76.8
34	Maryland State Police (2)	354	0.7	77.5
35	Louisiana State Police	350	0.7	78.2
36	Missouri Highway Patrol (2)	345	0.7	78.9
37	Detroit Police Department	345	0.7	79.6
38	West Virginia State Police	328	0.7	80.3
39	Florida Department of Safety	328	0.7	81.0
40	Utah Department of Safety	321	0.6	81.6
41	Boston Police Department	320	0.6	82.2
42	Louisville Police Department	318	0.6	82.8
43	Norfolk Police Department	311	0.6	83.4
44	New Orleans Police Department	309	0.6	84.0
45	Alburquerque Police Department	298	0.6	84.6
46	Houston Police Department	295	0.6	85.2
47	Portland Police Department	278	0.6	85.8
48	Nashville Police Department	240	0.5	86.3
49	Washington State Patrol	238	0.5	86.8
50	Nebraska State Patrol	235	0.5	87.3
51	New Mexico State Police	231	0.5	87.8
52	Cincinnati Police Department	231	0.5	88.3
53	Oklahoma Bureau of Investigation	214	0.4	88.7
54	Pittsburgh Police Department	212	0.4	89.1
55	Kansas Highway Patrol	209	0.4	89.5
56	Delaware State Police	205	0.4	89.9
57	Conn. State Police	202	0.4	90.3
58	Oregon State Police	198	0.4	90.7
59	Birmingham Police Department	196	0.4	91.1
60	Pinellas County, Florida S.O.	193	0.4	91.5
61	Denver Police Department	191	0.4	91.9
62	Minnesota Bureau Crime Appr.	189	0.4	92.3
63	Omaha Police Department	188	0.4	92.7
64	Iowa Department of Safety	185	0.4	93.1

Table E-24. NCIC TOTAL DAILY USAGE - MAY 1970 (Cont'd)

RANK	TERMINAL	DAILY AVERAGE OF ALL MESSAGES	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
65	FBI-Denver	174	0.3	93.4
66	South Dakota Division of Ident.	160	0.3	93.7
67	Rhode Island State Police	153	0.3	94.0
68	NYSIIS	144	0.3	94.3
69	Arkansas State Police	135	0.3	94.6
70	Alabama Department of Safety	127	0.3	94.9
71	FBI - New York City	124	0.2	95.1
72	Hillsborough County, Florida	116	0.2	95.3
73	Virginia State Police	113	0.2	95.5
74	Milwaukee Police Department	96	0.2	95.7
75	North Carolina Bureau of Investigation	95	0.2	95.9
76	Lane County, Oregon	93	0.2	96.1
77	Wisconsin Highway Patrol	87	0.2	96.3
78	Nevada Highway Patrol	84	0.2	96.5
79	FBI-Chicago	80	0.2	96.7
80	Wyoming Highway Patrol	80	0.2	96.9
81	Tennessee Department of Safety	77	0.2	97.1
82	Idaho State Police	76	0.2	97.3
83	Billings, Montana Police Department	76	0.2	97.5
84	Charlotte Police Department	68	0.1	97.6
85	South Carolina Division of Ident.	64	0.1	97.7
86	Maine State Police	63	0.1	97.8
87	Savannah Police Department	61	0.1	97.9
88	Naval Investigation Service	57	0.1	98.0
89	Mississippi Highway Patrol	56	0.1	98.1
90	Indianapolis Police Department	54	0.1	98.2
91	Multnomah County, Oregon	53	0.1	98.3
92	FBI-Charlotte	48	0.1	98.4
93	Fort McPherson, Georgia	46	0.1	98.5
94	FBI-El Paso	44	0.1	98.6
95	FBI- Boston	42	0.1	98.7
96	FBI-Oklahoma City	41	0.1	98.8
97	FBI-Philadelphia	40	0.1	98.9
98	FBI-Louisville	33	0.1	99.0
99	FBI-Newark	33	0.1	99.1
100	FBI-Portland	32	0.1	99.2

Table E-24. NCIC TOTAL DAILY USAGE - MAY 1970 (Cont'd)

RANK	TERMINAL	DAILY AVERAGE OF ALL MESSAGES	PERCENT OF TOTAL	CUMULATIVE PERCENTAGE
101	FBI-Springfield	32	0.1	99.2
102	FBI-Pittsburgh	30	0.1	99.4
103	FBI-Jackson	28	0.1	99.5
104	FBI-Jacksonville	28	0.1	99.6
105	FBI-Richmond	28	0.1	99.7
106	FBI-Houston	27	0.1	99.8
107	FBI-Columbia	27	0.1	99.9
108	FBI-Baltimore	26	0.1	100.0
109	Vermont State Police	25	0.0	100.0
110	FBI-Atlanta	24	0.0	100.0
111	FBI-New Haven	24	0.0	100.0
112	FBI-Indianapolis	23	0.0	100.0
113	FBI-Birmingham	22	0.0	100.0
114	FBI-Memphis	22	0.0	100.0
115	FBI-Knoxville	21	0.0	100.0
116	FBI-Butte	20	0.0	100.0
117	FBI-Alburquerque	20	0.0	100.0
118	FBI-Seattle	19	0.0	100.0
119	FBI-Milwaukee	17	0.0	100.0
120	FBI-San Antonio	17	0.0	100.0
121	FBI-Salt Lake City	15	0.0	100.0
122	FBI-Mobile	14	0.0	100.0
123	FBI-Savannah	14	0.0	100.0
124	Department of Army	14	0.0	100.0
125	FBI-Omaha	13	0.0	100.0
126	FBI-Las Vegas	12	0.0	100.0
127	Florida Bureau of Law Enforcement (2)	12	0.0	100.0
128	FBI-Little Rock	10	0.0	100.0
129	FBI-Norfolk	10	0.0	100.0
130	O.S.I. - Air Force	10	0.0	100.0
131	Fort Sam Houston, Texas	9	0.0	100.0
132	*Fort Sheridan, Illinois	8	0.0	100.0
133	Greensboro Police Department	2	0.0	100.0
134	Fort Meade, Maryland	1	0.0	100.0
135	Fort Myer, Virginia	1	0.0	100.0
136	*Allegheny County, Pennsylvania	0	0.0	100.0
	TOTAL DAILY AVERAGE	50,197		

E.10.2 LOS ANGELES COUNTY SHERIFF'S DEPARTMENT MICROWAVE SYSTEM

The microwave interconnection used in the Los Angeles County Sheriff's Department ORACLE (Optimum Record Automation for Court and Law Enforcement) system will perform functions closely analogous to those of an information transfer satellite. The information presented in this part was condensed from Los Angeles County Specification No. 1607 for Design, Fabrication and Installation of Videofile* Microwave System.

3.1 Purpose

The microwave system's primary role is to provide the communications link for the various elements and terminals of the Sheriff's Department Videofile portion of the ORACLE system. A secondary use of the microwave network will be to provide CCTV programming on a time shared basis.

3.2 System Configuration

The configuration of the system is shown in block diagram form in Fig. E-63. The initial systemwill connect the Central File located at the Los Angeles Country Hall of Justice to 15 remote terminals of the ORACLE network.

*Videofile is a trademark of the Ampex Corporation.

Expansion of the Videofile system is contemplated beyond the initial requirement. Additional Sheriff's stations are planned for Pico Rivera, Montrose, Carson, and Lomita. It is also anticipated that other police agencies and some courts will seriously consider connecting to the central Videofile terminal.

3.3 System Geography

The geographical arrangement of the system is shown in Figure E-64. Exact locations and heights of the Central File and Remote Terminal locations are given in Tab. E-25. Similar data for the Microwave Station locations is listed in Tab. E-26.

3.4 System Requirements

3.4.1 General

The equipment will be type approved by the F.C.C. for the Operational Fixed Radio Service. It will operate in the 12.2 to 12.7 GHz band. The primary power source is 117V $\pm$ 5 percent, 60 Hz with 48 volt dc being available in some locations. Emergency standby power facilities capable of 8 hours operation are required.

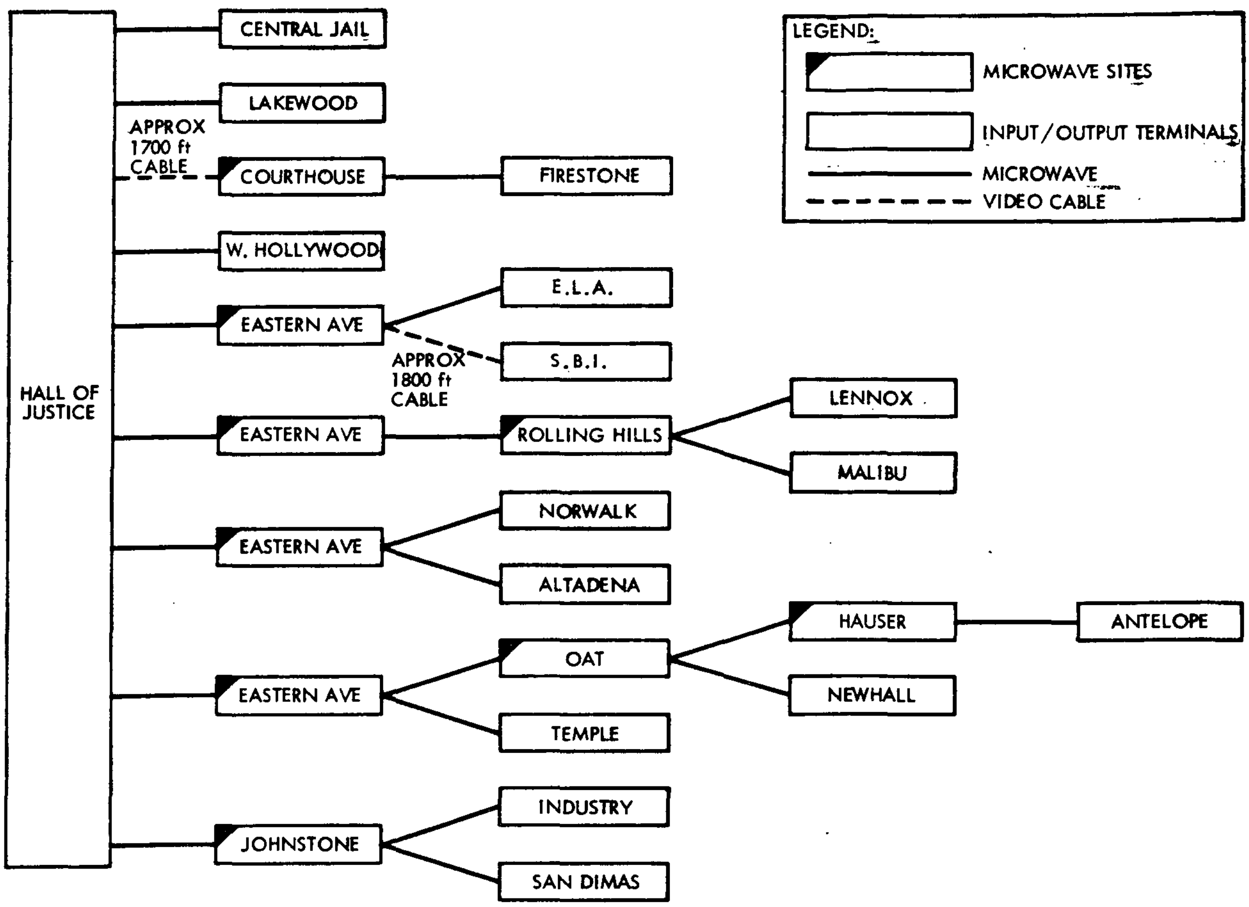


Figure E-63. Microwave Link Diagram (22 Links Total)

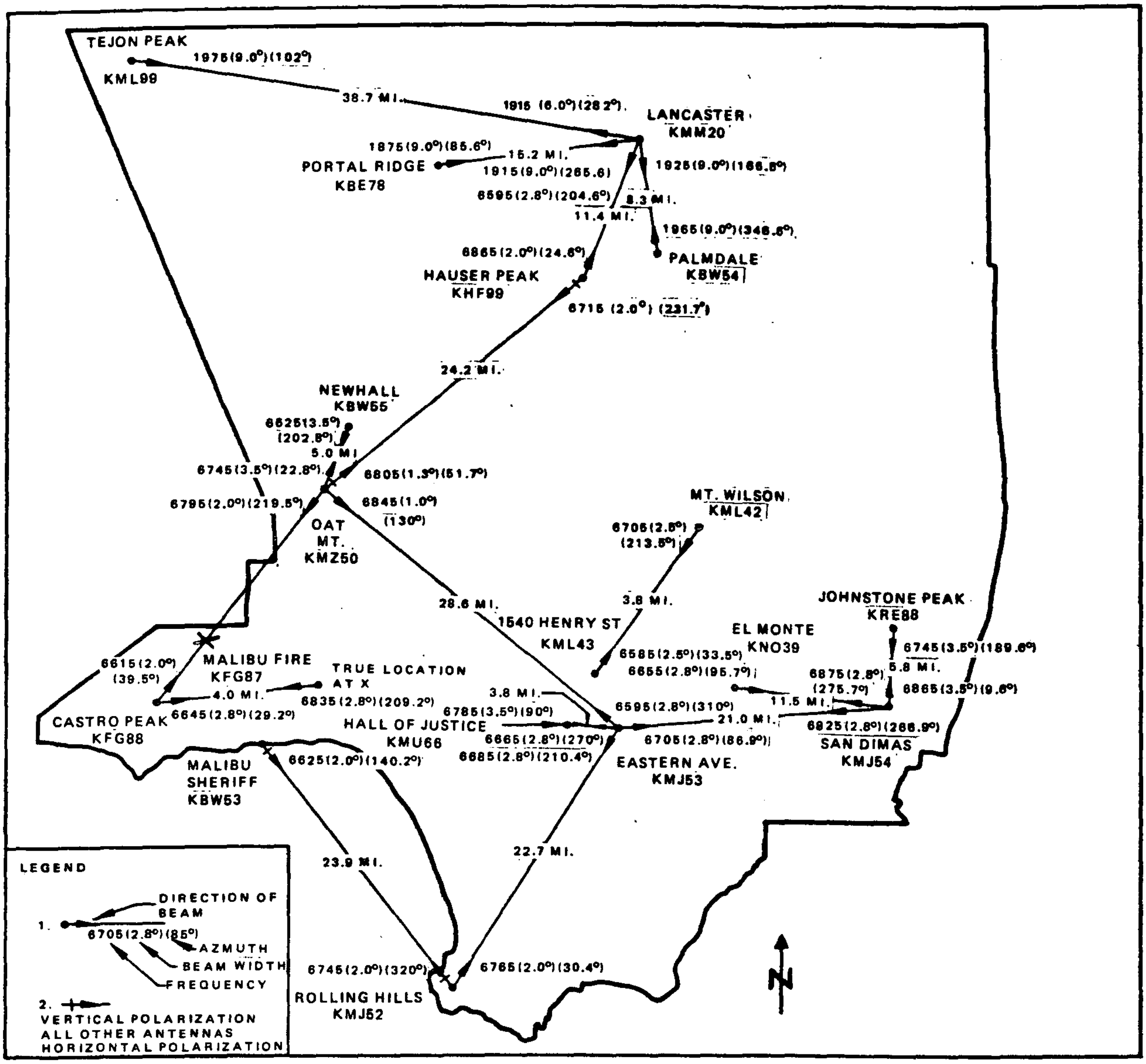


Figure E-64. Geographical Arrangement of System

TABLE E-25
CENTRAL FILE AND REMOTE TERMINAL LOCATIONS

Sheriff's Stations and Locations	Latitude and Longitude	Estimated Antenna Height	Ground Elevation
Altadena 780 East Altadena Drive, Altadena	34° 11' 23" 118° 07' 56"	20'	1340'
Antelope Valley 1010 West Avenue J, Lancaster	34° 41' 18" 118° 08' 54"	30'	2360' +150' tower
East Los Angeles 5010 East 3rd Street, Los Angeles	34° 02' 01" 118° 09' 15"	25'	250'
Firestone 7901 South Compton Avenue Los Angeles	33° 58' 04" 118° 14' 49"	20'	140'
Industry 150 North Hudson, City of Industry	34° 01' 33" 117° 57' 25"	20'	320'
Lakewood 5130 North Clark Avenue Lakewood	33° 51' 06" 118° 07' 57"	20'	50'
Lennox 4331 Lennox Blvd., Inglewood	34° 56' 18" 118° 21' 03"	30'	70'
Malibu 23519 West Stuart Ranch Road Malibu	34° 02' 14" 118° 41' 18"	20'	20'
Newhall Valencia and Henry Mayo Drive Newhall	34° 24' 58" 118° 33' 04"	20'	1149'
Norwalk 11801 East Firestone Blvd. Norwalk	33° 54' 46" 118° 04' 50"	20'	100'
San Dimas 122 North San Dimas Avenue San Dimas	34° 06' 27" 117° 48' 21"	20'	960'
Temple City 8838 East Las Tunas Drive Temple City	34° 06' 11" 118° 04' 33"	20'	410'
West Hollywood 720 North San Vicente Blvd. Los Angeles	34° 05' 01" 118° 22' 58"	20'	200'
Central Jail 441 Bauchet Street, Los Angeles	34° 03' 37" 118° 13' 47"	Roof height	+85' building
Sybil Brand Institute 4500 East City Terrace Drive Los Angeles	34° 03' 23" 118° 10' 01"	--	550' +65' building
Hall of Justice 211 West Temple Street Los Angeles	34° 03' 21" 118° 14' 28"	Roof height	325' +200' building

TABLE E-26
MICROWAVE STATION LOCATIONS

	Latitude and Longitude	Ground Elevation	Estimated Antenna Height
Courthouse 111 North Hill Street, Los Angeles	34° 03' 20" 118° 14' 47"	380' +125' building	Roof Height
Eastern Avenue 1320 North Eastern Avenue, Los Angeles	34° 03' 12" 118° 10' 10"	590' +180' tower	Various
Hauser, near Palmdale	34° 32' 48" 118° 13' 00"	5170'	15' (all)
Oat Mountain, near Chatsworth	34° 19' 12" 118° 33' 53"	3332'	15' (all)
Johnstone Peak, near San Dimas	34° 09' 38" 117° 47' 48"	3201'	15' (all)
Rolling Hills 5741 West Crestridge Road Palos Verdes Peninsula	33° 46' 07" 118° 22' 32"	1195' +150' tower	15' (Lennox) 150' (Malibu) 15' (E. Ave.)

3.4.2 RF Bandwidth

The characteristics of the Videofile system are such that the occupied bandwidth will be 30,000 kHz F9. This will require a waiver from the F.C.C.'s normal limitation of 20,000 kHz F9.

3.4.3 Baseband

3.4.3.1 Video

The video signal specifications for the Videofile are listed below. These are "end to end" specifications, i.e., from input/output of the remote terminals to the input/output of the Central File at the Hall of Justice.

a. Frequency response: 60 Hz to 7.2 MHz, within $\pm$.5 dB.

b. Group delay: 200 KHz to 7.2 MHz, no greater than $\pm$15 nanoseconds.

c. Differential gain: Less than 3.0 percent.

d. Tilt on 30 Hz square wave: Less than 20 percent.

e. Signal to noise: Greater than 46 dB, peak-to-peak/RMS, referenced to one volt peak-to-peak in the 200 Hz to 7.2 MHz bandwidth with a 30 dB RF signal fade.

f. Input signal level, video composite: One volt peak-to-peak into 75 ohms, negative synch -.3 $\pm$ .05 volt.

g. Output signal level, video composite: One volt (-.3 to +.7) peak-to-peak from 75 ohms: negative synch -.3 $\pm$ .05 volt.

h. Frame rate: 15 FPS

In addition to the primary system requirement for the Videofile System, the System will be capable of carrying standard momochrome video signals for CCTV programming on an alternate time-shared basis with the Videofile System, and will meet the following specifications which are also "end to end".

a. Differential gain: $\pm$1.0 dB. 10-90 percent APL.

b. Differential phase: Less than 2 degrees, 10-90 percent APL.

c. Tilt: Less than 2 percent at 50 Hz.

3.4.3.2 Audio Channels

In addition to the video transmission capability specified above, an audio channel is required between each remote terminal and the Central File at the Hall of Justice. These channels are to be full duplex 4-wire and while maintaining cognizance of the "end to end" specifications, stipulated below, will be placed as close as possible on the baseband above the 7.2 MHz video. These audio channels are to be utilized for digital control channels and for the audio portion of CCTV programming on an alternately time-shared basis. Tab. E-27 defines the number of required audio channels for each microwave link. The specifications for these channels are listed below:

a. Frequency response: 300 to 3000 Hz, +1, -3 dB, 1000 Hz reference.

b. Input impedance: 600 ohms.

c. Output impedance: 600 ohms.

d. Input level: 0 dBm.

e. Output level: 0 dBm.

f. Harmonic distortion: Less than 500 microseconds, 650 to 2650 Hz.

h. Frequency error: Less than ±3 Hz.

3.4.3.3 Spare Audio Channels

In addition to the audio channels described in para. 3.4.3.2, one additional channel will be furnished between the Central File and the following locations: Lakewood, Firestone, East Los Angeles, Rolling Hills, Norwalk, Eastern Avenue, Johnstone Peak. These channels are for contemplated expansion of the system.

TABLE E-27
Proposed Videofile Microwave System
AUDIO CHANNEL CONFIGURATION
- Per Link -

Hall of Justice to	Audio Channels Required Reference Paragraph 3.4.3.2	Spare Audio Channels Required Reference Paragraph 3.4.3.3	Digital Channels Required Reference Paragraph 3.4.3.4	Service Channels Required Reference Paragraph 3.4.3.5	Total Number Audio Channels Required Per Link
Central Jail	1		7	1	2
Lakewood	1	1	7	1	3
Eastern Avenue		1*			1
Firestone	1	1	7	1	3
West Hollywood	1		5	1	2
East L. A. SBI	2	1 (ELA)	7 (ELA) 2 (SBI)	1	4
Altadena Norwalk	2	1 (Nrwlk)	2 (Altdna) 7 (Nrwlk)	1	4
Lennox Malibu	2		7 (Lennox) 5 (Malibu)	1	3
Temple Newhall Antelope	3		7 (Temple) 5 (Newhll) 5 (Ant.)	1	4
Industry San Dimas	2		7 (Ind.) 5 (S. D.)	1	3
Johnstone Peak		1			1
Rolling Hills		1			1

3.4.3.4 Digital Control Channels

The digital control channels are to utilize the audio channels on an alternately time-shared basis with the audio portion of CCTV programming. The number of digital control channels to be supplied will vary with the different categories of remote terminals. These are listed below:

Remote Terminals	Number of Digital Channels Required
Firestone	7
East Los Angeles	7
Lennox	7
Norwalk	7
Temple	7
Lakewood	7
Industry	7
Central Jail	7
Newhall	5
San Dimas	5
Hollywood	5
Malibu	5
Antelope Valley	5
Altadena	2
Sybil Brand Institute	2

The technical characteristics of these digital control channels are as follows:

a. Each channel will be capable of full duplex operation with a data rate of 200 bits per second.

b. The signal to noise ratio must be high enough to ensure data transmission with a bit probability of error not in excess of 10^{-6} during a 30 dB RF fade.

c. The Central File and the remote terminal ends of these channels will furnish a transmit interface as specified by EIA Standard RS-232-B interface with AA, AB, BA, CA, CB, and CC leads and a receive interface as specified by EIA Standard RA-232-B interface with AA, AB, BB, and CF leads.

d. RS-232-B, Part 1, Section 1.4 and Part 3, Section 3.1 restricting total length of extension cables to "less than approximately 50 feet" is amended to permit cable lengths in excess of 50 feet to be installed in stations where the physical requirements so require.

3.4.3.5 Service Channel Specification

Each microwave terminal will include a service channel. The Hall of Justice and Eastern Avenue will each incorporate a single service channel and be provided with a switching or patch arrangement for individual link selection. These channels will conform to the following specifications:

a. Power Input: 110 VAC at 110 VAC terminals, 48 VDC at 48 VDC terminals.

b. Operation: Full duplex, handset with speaker monitoring with handset on hook, jacks to be provided for headset operation.

c. Frequency Response: 300-3000 Hz, +1 -3 dB, 1000 Hz reference.

d. Distortion: Less than 5 percent at 1000 Hz.

e. Signaling: In band tone, coded OFF-ON operating bell or buzzer.

f. Impedance: Input and output, 600 ohms balanced.

g. Sing Margin: At least 24 dB, one loop.

3.5 Status and Schedules

After receiving and evaluating competitive bids the County has issued a letter of intent to Collins Radio Company. Final contract negotiations with Collins are not complete at this time. The tentative schedule for implementation of the system indicates that completion is required by the latter part of 1971.

5.0 SOURCES AND REFERENCES

a. FBI Law Enforcement Bulletin, May 1966: A National Crime Information Center.

b. FBI Law Enforcement Bulletin, September 1967: NCIC Progress Report.

c. FBI Pamphlet: Now-Instant Crime Control in Your Town.

d. NCIC Newsletter, July 1970.

e. Los Angeles County Specification No. 1607: Design, Fabrication and Installation of Videofile Microwave System for Sheriff's Department.

f. Ampex Corporation Brochure F005-5-69: Videofile Information System.

a. Ampex Corporation Brochure F005-5-69: Videofile Information System

b. Papers presented at the Society of Photographic Scientists and Engineers, April 13-15, 1970 Symposium:

   1. An overview of Videofile Information Systems by R. A. Miner, Ampex Corporation.

   2. Videofile — A Dynamic Information Storage and Retrieval System by M. O. Felix, Ampex Corporation.

   3. A High Resolution Vidicon Camera and Optical System for a Document Storage and Retrieval System by E. Benedetti and K. F. Wallace, Ampex, Corporation.

   4. An Electrofax Printer for Reproduction of Unusually High Resolution Television Images.

c. Federal Bureau of Investigation: NCIC Total Daily Usage, May 1970.

d. Federal Bureau of Investigation: Uniform Crime Reports for the United States, August 1970.

3.3.1 ITFS/ARCHDIOCESE OF SAN FRANCISCO - This system is currently being implemented with its central studios and transmitter located at St. Patrick's Seminary. A four-channel system is planned each providing eight hours of instruction per day. Investments are:

1.	Transmission System	$180,000
2.	Studio Equipment	$150,000
3.	Installation	$150,000
		$480,000
4.	Receiving System (at each school)	$ 1,500

A total of 140 schools will ultimately be served by the system representing a total capital investment of approximately $700,000.

George Sitts has investigated annual operational costs with the following results:

1.	100% Leased Programming	$160,000
2.	50-50% Leased & Produced Programming	$240,000
3.	100% Produced Programming	$385,000

They have selected the third option and are emphasizing high quality programs. Their experience (New York, Brooklyn and Milwaukee) shows that a series has an average life of three years. They offer such incentives as increased residuals to the producer for continued use beyond the average three years.

Revenue will be extracted from the system on the basis of a per-student tax to the parish schools. Starting with 20 schools in the Fall of 1970, and up to 60% (of 140 schools) by 1974, the following revenue is anticipated:

1.	1970	-	-$261,000
2.	1971	-	-$122,000
3.	1972	-	+$174,000
4.	1973	-	+$423,000
5.	Thereafter	-	+10%

This system is being implemented for the specific purpose of reducing the cost of parochial education at a diocesan (total system) level. Because of increased costs more and more schools have relied on subsidies from the Bishops to carry them through. This is a practical approach to serving the diocese as a total system. As can be seen from the above quoted revenues, it is expected that the system will be self-supporting after three years. Savings to a small (single-section) school will range from $2,000/yr. for an elementary school to $8,000/yr. for a high school; for a large school (multi-section) from $7,000/yr. for an elementary school to $20,000/yr. for a high school.

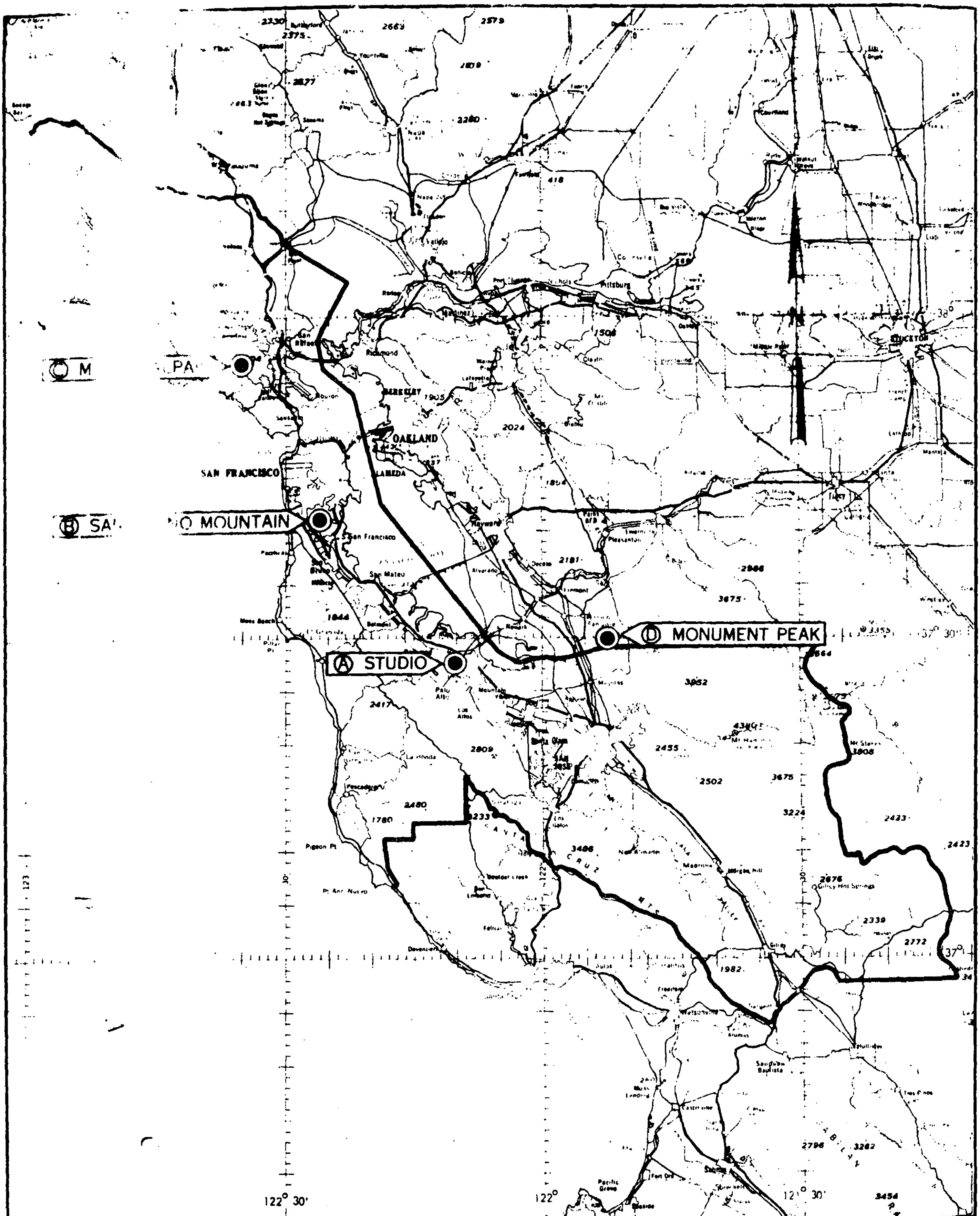
The system, mostly covering the peninsula side of the bay from Gilroy in the south to San Anselmo in the north, will be on the air in February 1970.

Figures E-65 through E-76 and Table E-28 contain a technical description of the system, as prepared by Hammett and Edison, Consulting Engineers, San Francisco, California.

Table E-128. Roman Catholic Welfare Corporation of San Francisco - Engineering Specifications of Proposed Transmitting System

Site	A		B		C (No change)		D (No change)
Description	Studio		San Bruno Mountain		Mt. Tamalpais		Monument Peak
North Latitude	37° 27' 37" *		37° 41' 23" *		37° 55' 44"		37° 29' 23"
West Longitude	122° 10' 03" *		122° 26' 12" *		122° 35' 11"		121° 51' 54"
Location	St. Patrick's Seminary * Menlo Park		Rural San Mateo County 2 miles S of San Francisco		Rural Marin County 10 miles NW of San Francisco		Rural Alameda County 31 miles SW of San Francisco
File no. and call sign	BMPIF-218/KZB-22		BMPIF-219/KZB-23		BMPIF-193/KZB-24		BMPIF-194/KZB-25
Transmitters							
Quantity	Four *		Four		Four		Four
Manufacturer	Jerrold *		Jerrold *		Adler		Jerrold
Type	SRT-1 *		SRH-1 *		EST-10A		SRT-1
Rated power	10 watts *		10 watts		10 watts		10 watts
Operating power	2.9 watts *		10 watts		10 watts		10 watts
Channels	G-1, G-2, G-3, G-4		B-1, B-2, B-3, B-4		D-1, D-2, D-3, D-4		D-1, D-2, D-3, D-4
Transmitting Antennas							
Manufacturer	Andrew *	Andrew *	Andrew *	Taco	Taco	Taco	Taco
Type	Custom *	Custom *	57368 *	Two EPA-1T	ESA-H1x2	Two EPA-1T	ESA-H2x2
Description	6 ft dish	6 ft dish	Cylindrical paraboloid *	1 ft. dishes	Zigzag	1 ft. dishes	Zigzag
Orientation	N 79° E *	N 325° E *	N 0° E	N 148° E	N 25° E	N 143° E	N 230° E
Maximum power gain	30 db	30 db	16 db	19 db	18 db	19 db	16 db
Half-power beam width	4.3°	4.3°	156°	24.5°	65°	20.5°	156°
Polarization	Vertical *	Horizontal	Horizontal	Horizontal	Horizontal	Vertical	Horizontal
Transmission line input power per channel	1.45 w *	1.45 w *	7.5 watts	2.5 watts	1.0 watts	9.0 watts	10.0 watts

* Denotes change from existing authorization



10 0 MILES 20 30

ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO

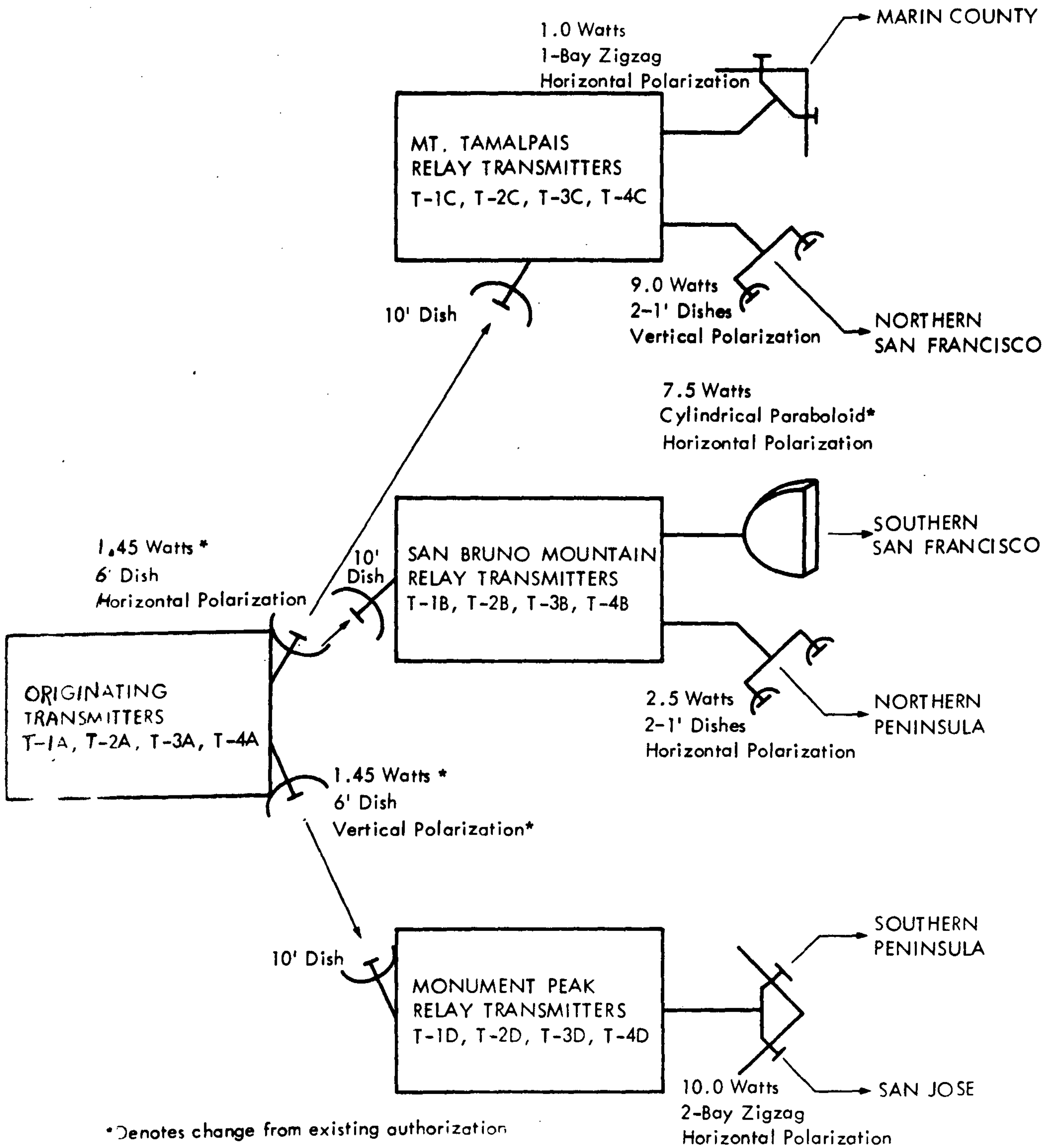
OUTLINE OF SCHOOL DISTRICT
LOCATIONS OF TRANSMITTERS

Figure E-65

690801

ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO

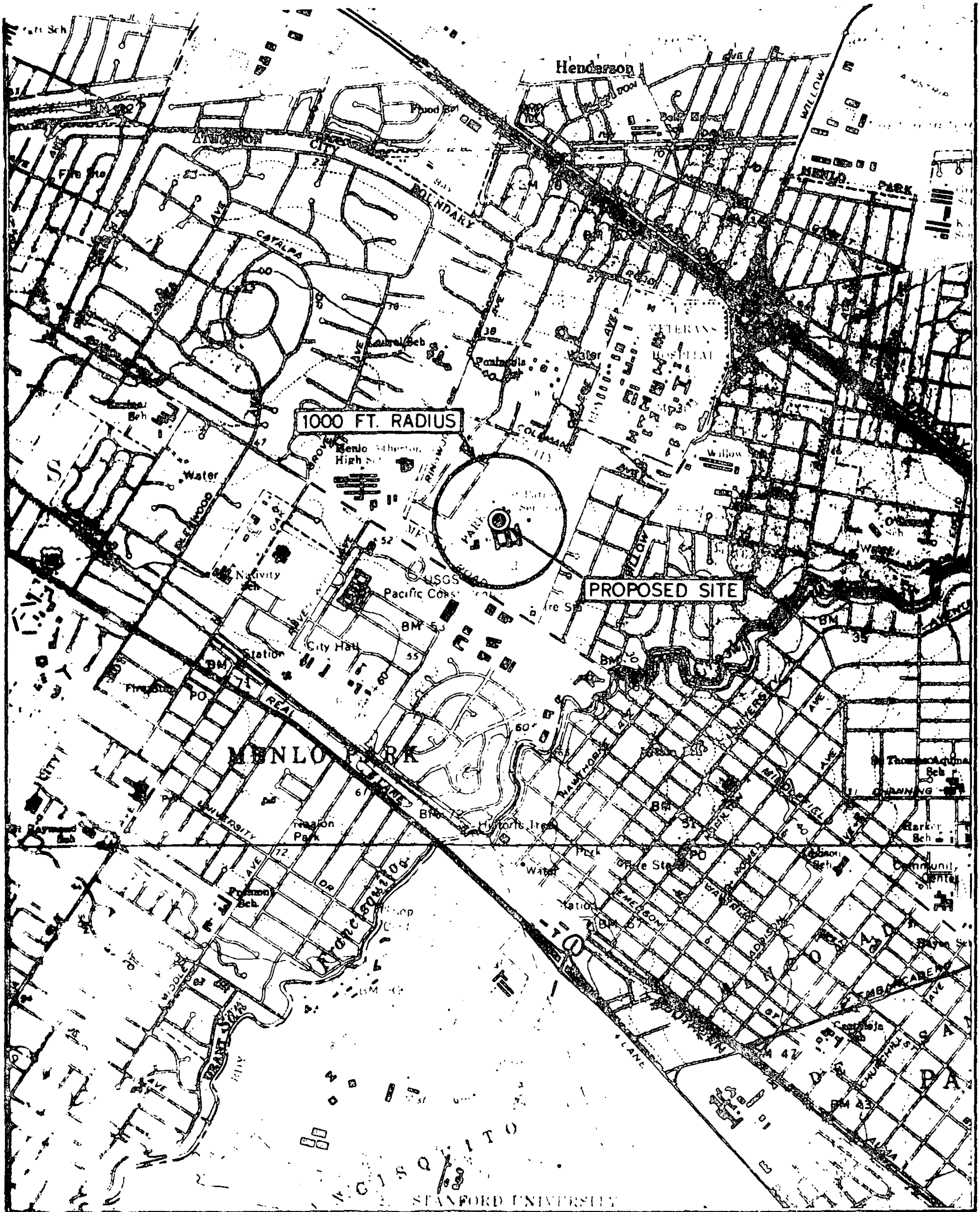
SYSTEM FUNCTIONAL DIAGRAM



*Denotes change from existing authorization

Hammett & Edison
Consulting Engineers

Figure E-66



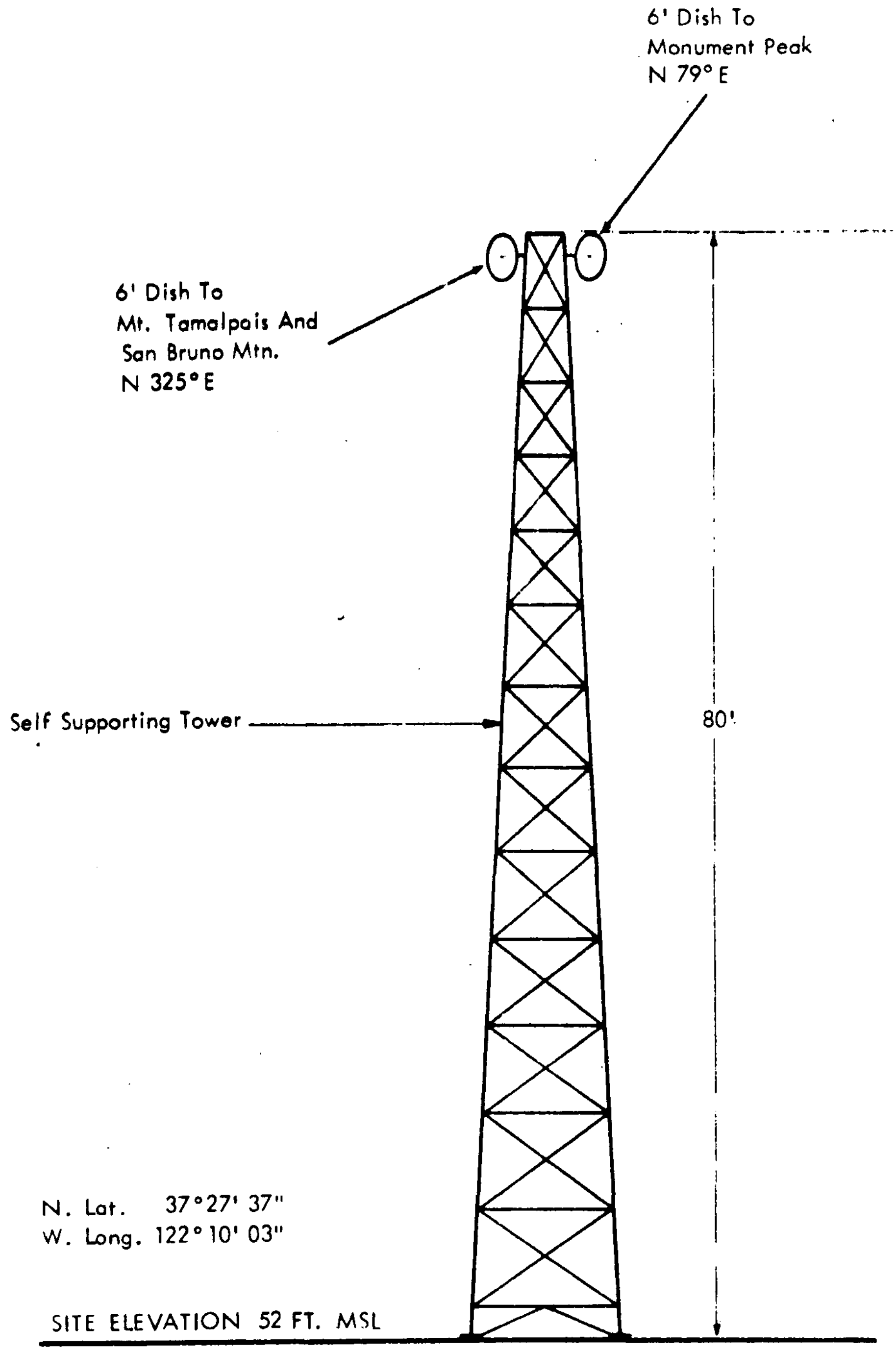
0 — 1 MILE

ROMAN CATHOLIC WELFARE CORPORATION OF SAN FRANCISCO

VICINITY OF TRANSMITTERS
T-1A, T-2A, T-3A, T-4A
STUDIO SITE

690801

Figure E-67

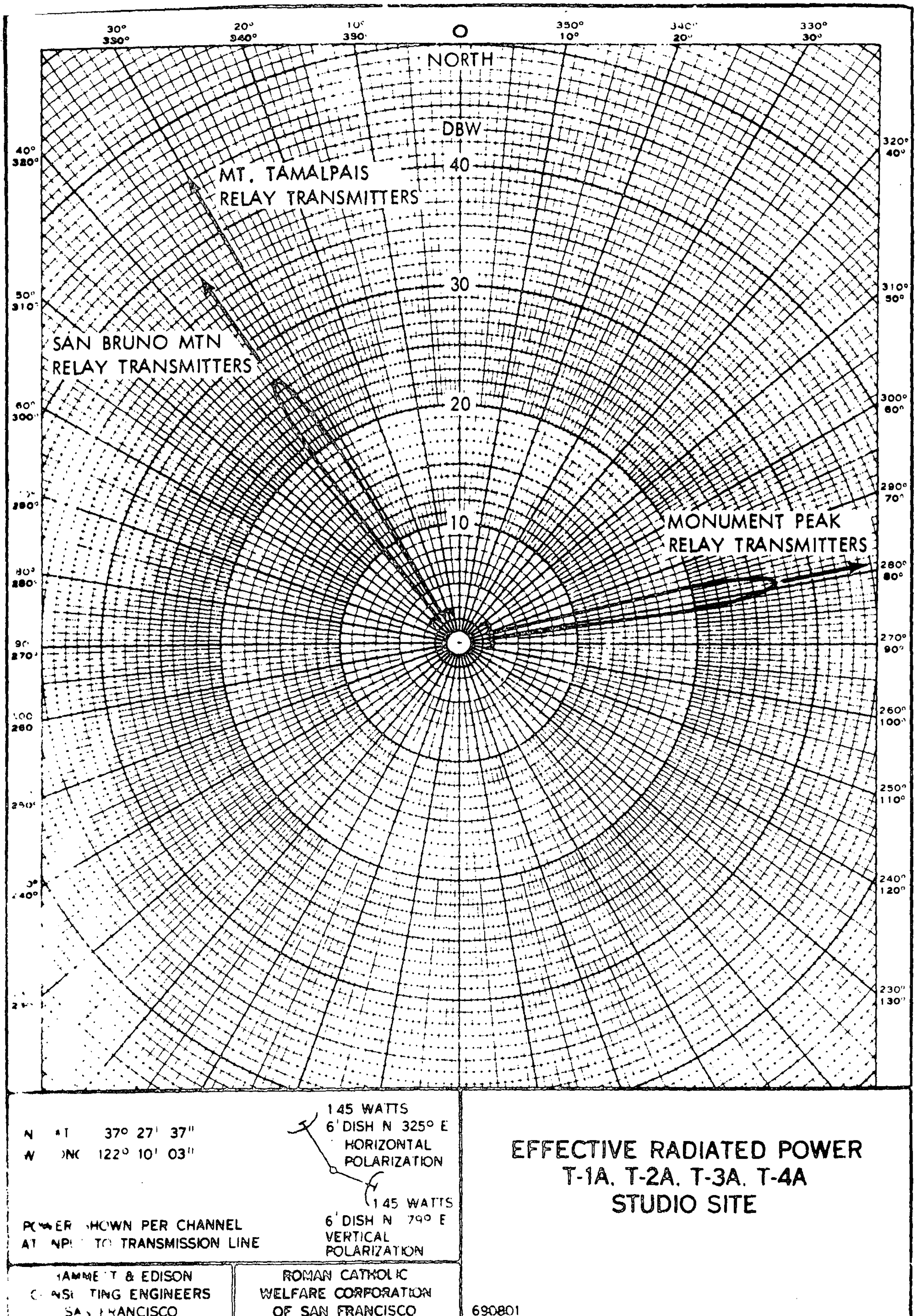


ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO

690801

ANTENNA ELEVATION
T-1A, T-2A, T-3A, T-4A
STUDIO SITE

Figure E-68



NORTH
DBW
40
30
20
10
MT. TAMALPAIS
RELAY TRANSMITTERS
SAN BRUNO MTN
RELAY TRANSMITTERS
MONUMENT PEAK
RELAY TRANSMITTERS
37° 27' 37"
122° 10' 03"
145 WATTS
6' DISH N 325° E
HORIZONTAL
POLARIZATION
145 WATTS
6' DISH N
VERTICAL
POLARIZATION
PER CHANNEL
TRANSMISSION LINE
& EDISON
TING ENGINEERS
ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO
EFFECTIVE RADIATED POWER
T-1A, T-2A, T-3A, T-4A
STUDIO SITE
690801

Figure E-69

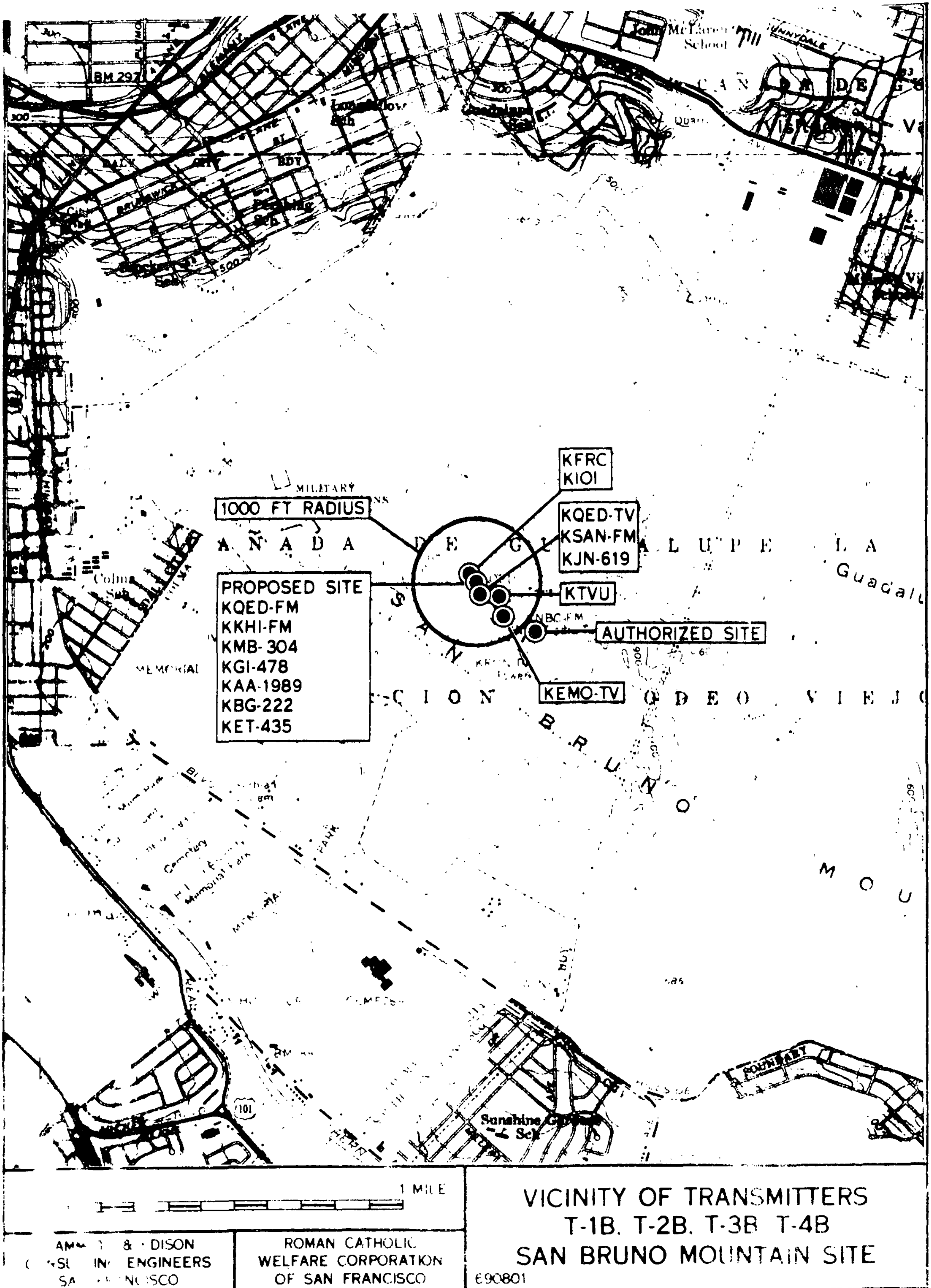
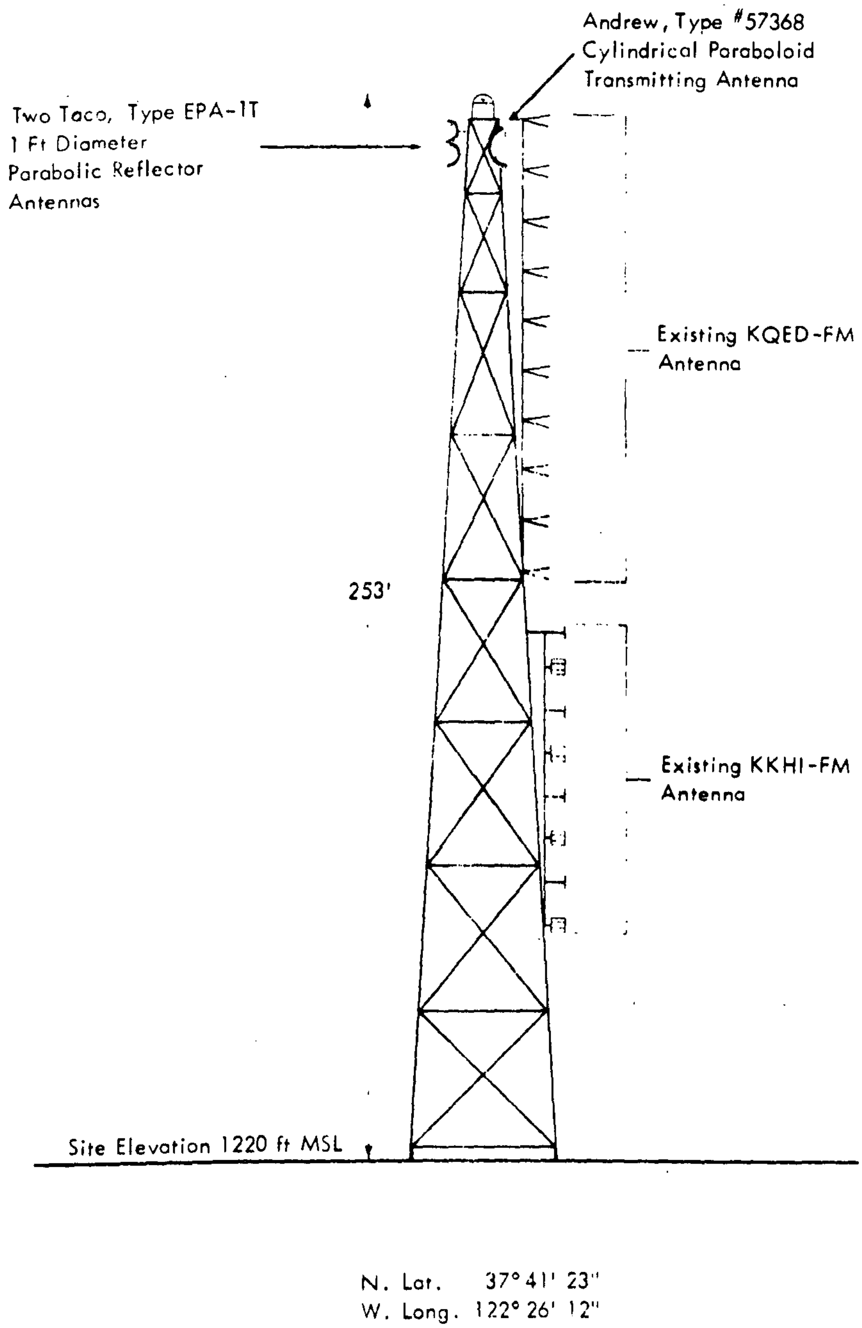
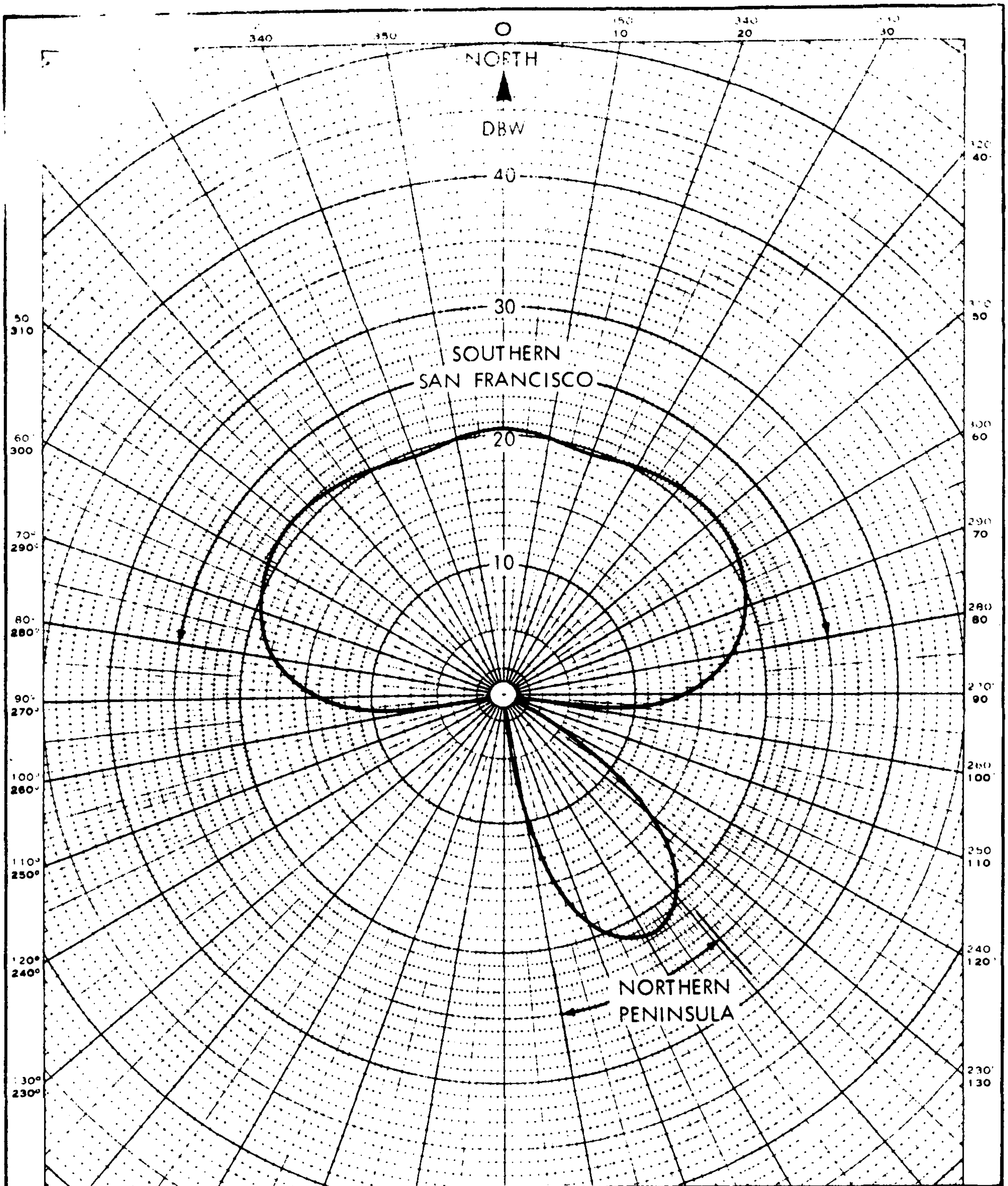

KFRC
KIOI
KQED-TV
KSAN-FM
KJN-619
1000 FT RADIUS
PROPOSED SITE
KQED-FM
KKHI-FM
KMB-304
KGI-478
KAA-1989
KBG-222
KET-435
KTVU
AUTHORIZED SITE
KEMO-TV
1 MILE
ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO
VICINITY OF TRANSMITTERS
T-1B. T-2B. T-3B T-4B
SAN BRUNO MOUNTAIN SITE
E90801

Figure E-70



[illegible]	ROMAN CATHOLIC WELFARE CORPORATION OF SAN FRANCISCO	ANTENNA ELEVATION T-1B. T-2B. T-3B. T-4B SAN BRUNO MOUNTAIN SITE 690801

Figure E-71



N LAT. 37° 41 14"
W LONG. 122° 26 01"

7.5 WATTS
ESA-H2X2 ZIGZAG

POWER SHOWN PER CHANNEL
AT INPUT TO TRANSMISSION LINE

2.5 WATTS
2-EPA-1T 1' DISHES

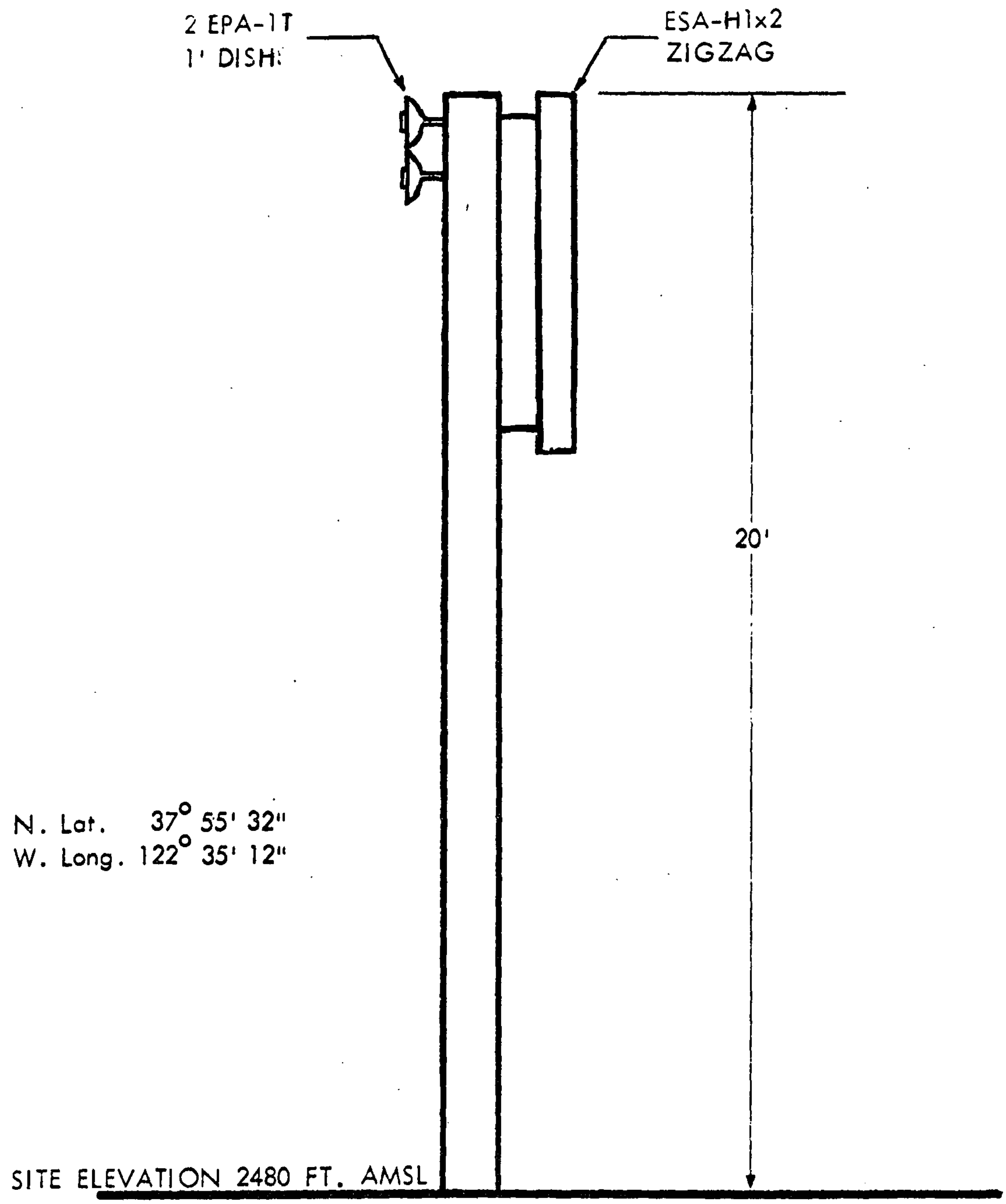
EFFECTIVE RADIATED POWER
T-1B, T-2B, T-3B, T-4B
SAN BRUNO MOUNTAIN SITE

HAMMETT & EDISON
CONSULTING ENGINEERS
SAN FRANCISCO

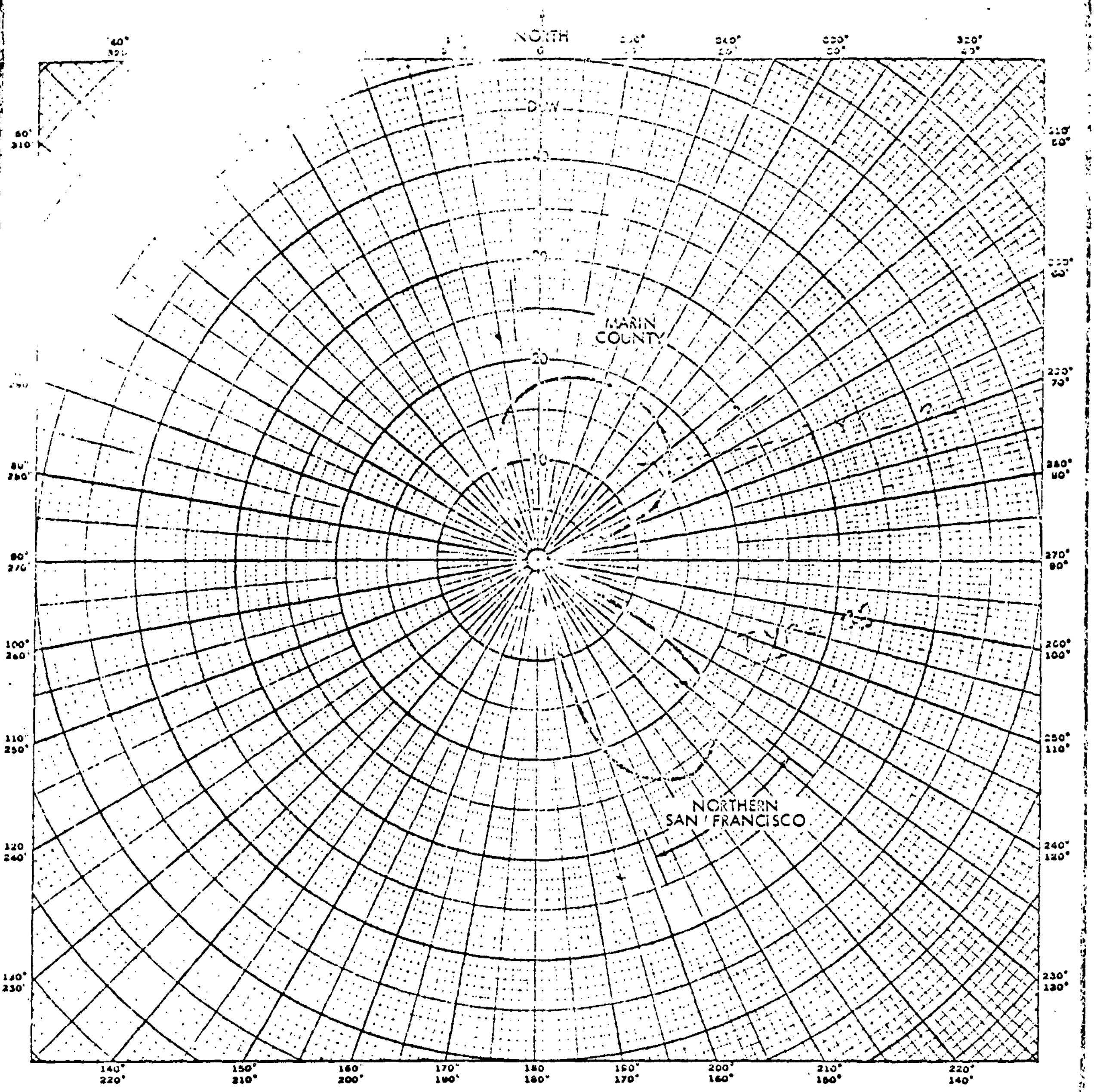
ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO

681007

Figure E-72



HAMMETT & EDISON CONSULTING RADIO ENGINEERS SAN FRANCISCO	ROMAN CATHOLIC WELFARE CORPORATION OF SAN FRANCISCO	ANTENNA ELEVATION T-1C, T-2C, T-3C, T-4C MT. TAMALPAIS SITE 660228 **Figure E-73**



N. LAT. 37°55' 32" W. LONG. 122°35' 12" POWER SHOWN PER CHANNEL AT INPUT TO TRANSMISSION LINE	1.0 WATTS ESA-H1X2 ZIGZAG 9.0 WATTS 2-EPA-1T 1' DISHES
HAMMETT & EDISON CONSULTING RADIO ENGINEERS SAN FRANCISCO	ROMAN CATHOLIC WELFARE CORPORATION OF SAN FRANCISCO

EFFECTIVE RADIATED POWER
T-1C, T-2C, T-3C, T-4C
MT. TAMALPAIS SITE

Figure E-74

660223

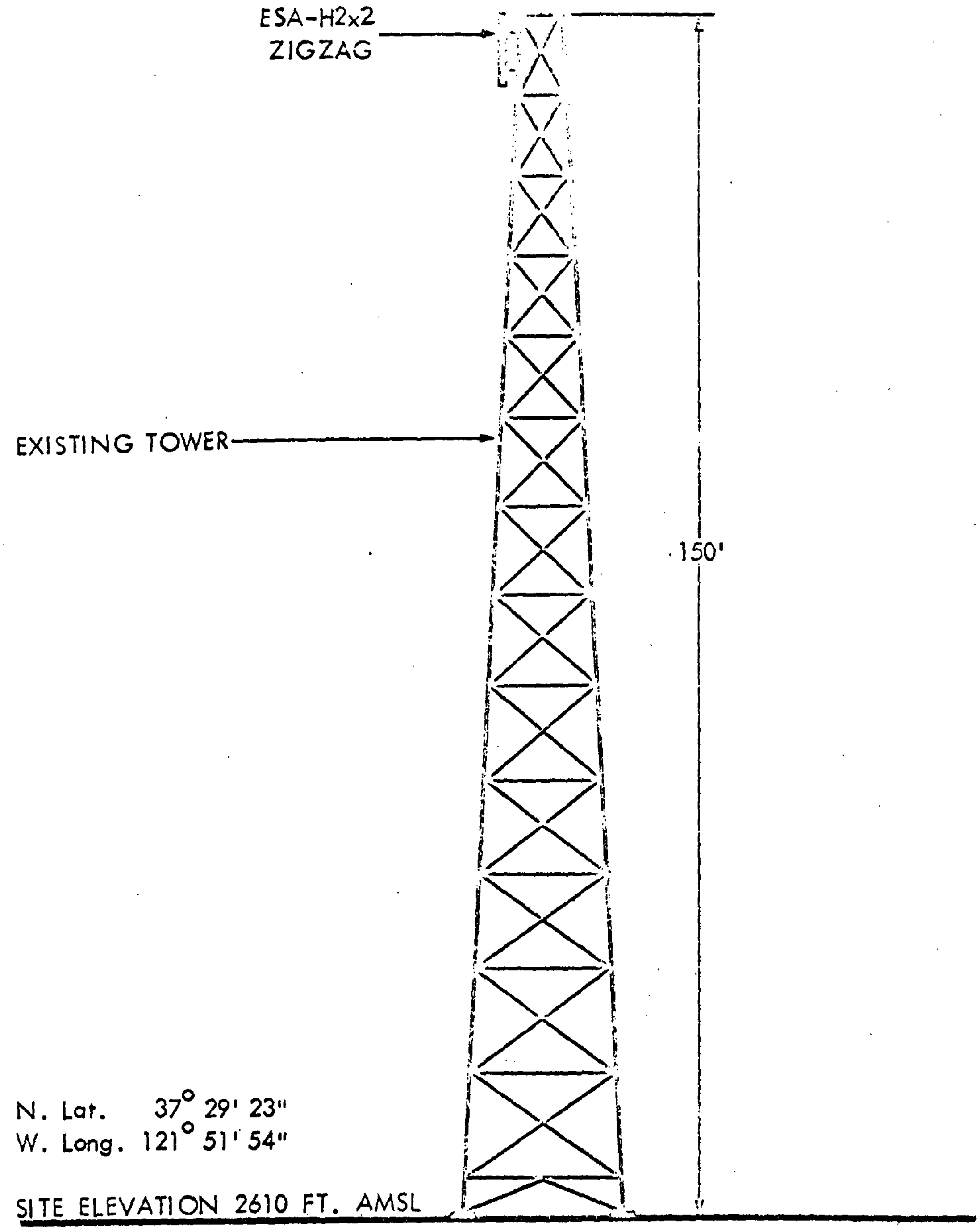
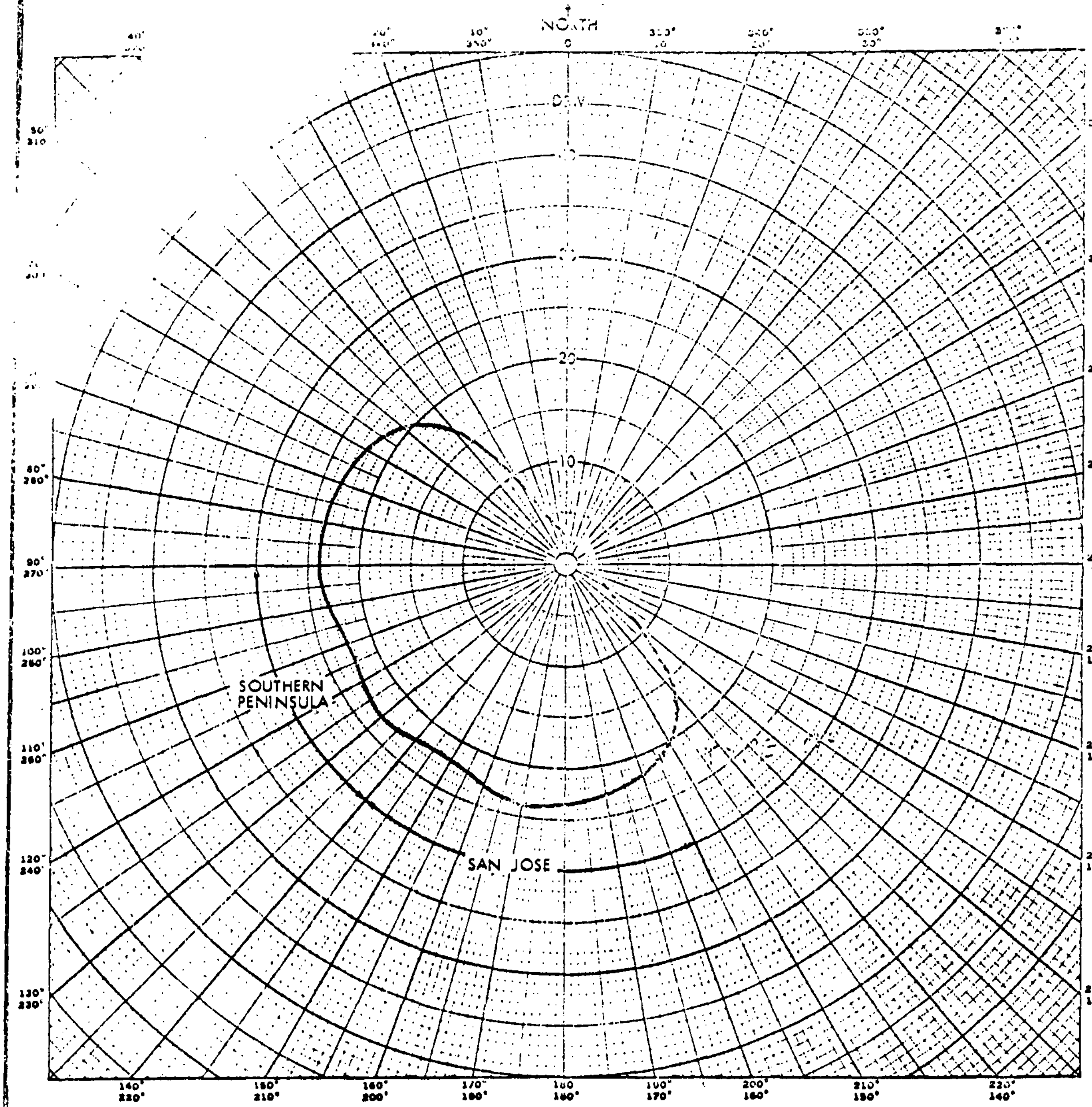


Figure E-75

HAMMETT & EDISON CONSULTING RADIO ENGINEERS SAN FRANCISCO	ROMAN CATHOLIC WELFARE CORPORATION OF SAN FRANCISCO

ANTENNA ELEVATION
T-1D, T-2D, T-3D, T-4D
MONUMENT PEAK SITE



N. LAT. 37°29'23"
W. LONG. 121°51'54"

10.0 WATTS
ESA-H2X2
ZIGZAG

POWER SHOWN
PER CHANNEL
AT INPUT TO
TRANSMISSION LINE

EFFECTIVE RADIATED POWER
T-1D, T-2D, T-3D, T-4D
MONUMENT PEAK SITE

HAMMETT & EDISON
CONSULTING RADIO ENGINEERS
SAN FRANCISCO

ROMAN CATHOLIC
WELFARE CORPORATION
OF SAN FRANCISCO

Figure E-76

660228

E.12 WINGSPREAD CONFERENCE

CONFERENCE ON MODERN COMMUNICATION TECHNOLOGY AND EDUCATION - As can be seen from the list of participants (Table E-29) the title for this conference was "Modern Communications Technology and Education". The stated objectives for the conference were:

1. ....Note specific ways in which prototype projects can assist national educational communications development. The result as an tentative national agenda, or list of possible specifications, for prototype projects.
2. Relate this national prototype agenda to the characteristics and requirements of the individual prototype locations.
3. For each prototype location, determine desirable and reasonable next steps for development.
4. Determine whether the participant locations should form a national telecommunication prototype group, and if so, agree on:
   a. A simple but reliable mechanism for continuing liaison;
   b. A preliminary strategy for support.

The prototype locations selected for this study were:

1. The State of Alaska
2. San Diego and surroundings
3. Cleveland
4. Maryland Center for Public Broadcasting.

Overall methodology for the conference followed this sequence:

Table E-29

MODERN COMMUNICATION TECHNOLOGY AND EDUCATION

December 3-5, 1969

List of Participants

Patrick Bergin
Convair Division of General Dynamics
San Diego, California

Frederick Breitenfeld, Jr.
The Maryland Center for Public Broadcasting
Owings Mills, Maryland

Wally Briscoe
Managing Director
National Cable Television Association
Washington, D.C.

Herbert B. Cahan
Chairman of the Board, The Maryland Center for Public Broadcasting
Owings Mills, Maryland

C. Ray Carpenter
President
Joint Council on Educational Telecommunications
Washington, D.C.

Dr. Martin Chamberlain
Director
University of California at San Diego
LaJolla, California

X Ward B. Chamberlin, Jr.
Corporation for Public Broadcasting
New York, New York

Frank Darnell
Executive Secretary of the Association of Alaska School Boards
College, Alaska

Dr. M. Ted Dixon
Superintendent of Schools
San Diego County
San Diego, California

E. L. Estes
Real Estate Manager
S. C. Johnson & Son., Inc.
Racine, Wisconsin

Dr. Quentin L. Earhart
Deputy State Superintendent of Schools
Baltimore, Maryland

Winston O. Franklin
C. F. Kettering Foundation
Dayton, Ohio

William G. Harley
President
National Association of Educational Broadcasters
Washington, D.C.

Albert Horley
Consultant
Department of Health, Education and Welfare
Washington, D.C.

George Hohman
Bethel, Alaska

90

William J. Kessler
W. J. Kessler Associates
Consulting Telecommunications Engineers
Gainesville, Florida

Robert Mosher
Architect
Mosher, Drew, Watson & Associates
LaJolla, California

Samuel L. Myers
President
Bowie State College
Bowie, Maryland

Dr. Charles M. Northrip
Executive Director
Alaska Educational/Public Broadcasting Commission
University of Alaska
College, Alaska

Frank Norwood
Executive Secretary
Joint Council on Educational Telecommunications
Washington, D.C.

Fr. John Leahy
Cleveland, Ohio

Dr. Ernest B. O'Byrne
Vice President for Administration
San Diego State College
San Diego, California

William H. Stegeman
Assistant Superintendent
Curriculum Services Division
San Diego City Schools
San Diego, California

Dr. Alan R. Stephenson
Director of Educational Services
WVIZ-TV
Cleveland, Ohio

Dr. Donald B. Swegan
Executive Director
Cleveland Commission on Higher Education
Cleveland, Ohio

Donald V. Taverner
Station WQED-TV
Pittsburgh, Pennsylvania

x Lionel Van Deerlin
Congressman, 37th District, California
Washington, D.C.

Dr. Harold Wigren
National Education Association
Washington, D.C.

John P. Witherspoon
General Manager
KEBS-TV-FM
San Diego State College
San Diego, California

<u>The Johnson Foundation Staff</u>

Leslie Paffrath
President

George Goss
Senior Program Associate

Sister Rosita Uhen
Senior Program Associate for Urban Affairs

Rita Goodman
Program Associate

Kenneth Kautzer
Administrative Assistant

Jayne Bogard
Program Assistant

12/2/69

1. Exposure of all the groups to the new and developing technologies that apparently have some benefits to offer to education.
2. Discussion within each group of their basic problems and objectives in regard to education.
3. Discussion within each group of the relation of the technologies to these problems and objectives.
4. Finally, definition by each group of a prototype system that represents a solution to their problems.
5. Interspersed throughout these individual group sessions were collective summary sessions and free time for splinter-group conferences and consultations.

The conference got off to a good start in an excellent facility and environment. The vignettes on new technologies were each short (15 minutes) and generalized. They covered studio techniques, communications satellites, CATV, radio, classrooms and teachers of the 1970's, and computers and computer-assisted instruction. In general, nothing startling or revolutionary was presented but sufficient interest was generated to maintain a considerable question and answer period. This appeared to be particularly true about satellite systems. The main difficulty seemed to center around the various demonstration experiments previously conducted and planned in the ATS series. As an example, the previous TV transmission experiment with ATS-1 was written off as a "disaster"; however, discussion did bring out that the "disaster" - a very noisy picture - was exactly what was expected within the limitations of the instrumentalities used for the experiment. As a further example, and much more critical to the cause of satellites, is the expectation of great performance by ATS-F&G in similar demonstrations. Dr. H. Wigren was under the impression that he could interconnect a large group of teachers and administrators in one location with several other locations under the following conditions:

1. Direct mode of transmission.
2. Excellent picture quality.
3. Small ground terminals costing not more than $1,500 each.

The responsibility for these mistaken impressions of capability seem to stem from two sources:

1. An inadequate articulation of both the ATS performance capabilities and the experiment requirements.
2. An inadequate dialogue between the principals which prevented the deficiencies from being exposed.

Discussions in the Alaska group lead to the following general conclusions:

1. The only real educational problems in Alaska relate to rural areas.
2. The cities are adequately supported now.
3. Full recognition of the native cultures (Aleute, Eskimo and Indian) must be maintained in all program materials in order to maintain their personal dignity.
4. This same recognition is required in the city programs to foster understanding and acceptance of the natives.
5. In order of preference for near-term dissemination of educational programs the following solutions were selected:
   a. AM radio centers interconnected by FM radio links.
   b. Direct FM radio transmission from satellites.
   c. TV transmission from satellites.

JOINT COUNCIL ON EDUCATIONAL TELECOMMUNICATIONS
1126 Sixteenth Street N.W., Washington, D.C. 20036 202 / 659-9740

December 9,1969

Mr. Patrick A. Bergin
5505 Laurel Street
San Diego, California 92105

Dear Pat:

On behalf of the Joint Council on Educational Telecommunications, I want to extend to you our thanks for your participation in the recent Wingspread Conference on Communications Technology and American Education.

The outstanding hospitality of the Johnson Foundation, and the beauties of Wingspread provide the environment for creative thinking and a successful conference. That is borne out, I think you will agree, by our own experience.

Each of the groups reported a series of exciting ideas, and the concept of four independent but interrelated Communications Prototypes is well begun. As soon as the tapes of the final session are transcribed and duplicated, we shall send them along to all the participants.

As Ray Carpenter said, the JCET will be happy to provide appropriate coordination among the groups as our initial plans are developed in more detail.

We look forward to seeing you all again, perhaps, eventually, at Wingspread, but in the meantime, here in Washington at some future meeting in our own conference room, or at the JCET office whenever you are in the neighborhood.

Cordially,

Frank

Frank W. Norwood
Executive Secretary

JCET

JOINT COUNCIL ON EDUCATIONAL TELECOMMUNICATIONS
1126 Sixteenth Street N.W., Washington, D.C. 20036 202 659-9740

December 15,1969

MEMORANDUM

TO: Wingspread Participants
FROM: Frank W. Norwood, JCET

SUBJECT: DIGEST OF FINAL WINGSPREAD SESSION

Enclosed is a copy of my summary of the plans outlined by each group at our Friday morning meeting. It was prepared primarily for the JCET Board, but may be useful to you until I can get out the complete transcript of the tape recording.

The secretarial service which has done tape transcription for us in the past was solidly booked until December 18, but the tape is now in their hands. I expect to have copies of the transcript in the mail to you shortly after the holidays. Speaking of which. . .

Best wishes for a Merry Christmas and a Happy New Year.

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WINGSPREAD CONFERENCE ON COMMUNICATIONS TECHNOLOGY AND AMERICAN EDUCATION

Introduction: On December 3, 4, and 5, the Johnson Foundation, with the cooperation of the Joint Council on Educational Telecommunications, held a Wingspread Conference on Communications Technology and American Education, bringing together representatives from four geographic locations (the State of Alaska, the region of Southern California centering around San Diego, Metropolitan Cleveland, and the State of Maryland) plus selected consultants and observers. The four objectives of the meeting were:

1. With the assistance of conference consultants, plus material furnished in advance and at Wingspread, to review briefly the state of the art in educational communications and some of the advances just ahead. Note specific ways in which prototype projects can assist national educational communications development.

2. Relate this national prototype agenda to the characteristics and requirements of the individual prototype locations.

3. For each prototype location, determine desirable and reasonable next steps for development.

4. Determine whether the participant locations should form a national telecommunications prototype group, and if so, agree on:

    A. A simple but reliable mechanism for continuing liaison;

    B. A preliminary strategy for support.

At the final session of the conference on the morning of the 5th, the participants gathered to outline the plans which had been developed during the meeting. Each group was asked to summarize the problem, the proposal developed to meet the identified needs, and the way in which the proposal might be a national prototype offering potential application in other areas.

Alaska: The delegation from Alaska identified the problem to be attacked as the near-total lack of communications in Alaska's rural areas. By definition, "rural" was taken to mean the communities of fewer than 300 people. Three-quarters of the state falls within that definition. Information needs include not only traditional education but such areas as fish and game, sanitation, personal hygiene, and problems of mental health. In addition, the problem is complicated by significant linguistic and cultural differences. In most rural Alaskan schools, first graders arrive without functional ability in English, but their teachers are likely to be from the lower forty-eight states. The proposed solution would, for the first time, attempt to involve the native people in an attack on their problems.

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The proposal involved the establishment of a series of regional AM radio stations of 5 to 10 KW in power. In Alaska, AM frequencies are available. Wide-area coverage would be provided, and self-powered transistorized receivers are cheap. Stations would be located to provide coverage fitting the linguistic-cultural regions and would broadcast common programs in English plus local originations in the native language.

As an alternative, satellite communications was considered. The State of Alaska has already proposed experimental satellite communications via NASA's ATS-I. While the satellite can provide television and FM radio, television reception requires ground terminals costing $250,000, and FM radio could only be received on special receivers. The most appropriate interface between ATS-I and the proposed AM radio stations might be to use the satellite's FM capacity to network English language programming among the stations.

Looking to the future, the group discussed the eventual use of direct FM beams to regions of Alaska, with multiple up-links. Such FM broadcasting would escape the present barrier to FM development (Alaska's many high mountain ranges) and would allow members of cultural minorities to be served even if no longer living in their native areas.

One of the chief advantages foreseen for the proposed AM system is its ability to make possible the reshaping of the educational curriculum in rural Alaska.

The application of the idea to other areas might be possible in the rural Southwest (particularly for American Indian groups), in the Canadian North, and perhaps in Appalachia. One possible source of funding for the hardware segment would be the Educational Broadcasting Facilities Program which now makes grants for radio as well as television. An administrative context for such a prototype might be the newly organized Alaskan Educational Broadcasting Commission, on which the university and the statewide Natives' Association are represented, and which is chaired by the State Superintendent of Schools.

Cleveland: Representatives from Cleveland pointed out the fact that that city's situation is one common to most urban areas in the United States. Its citizens span a wide economic range; there are ethnic pockets within the community; much heavy industry and a substantial blue-collar population; 40% of the residents are black, and there are also substantial Spanish-speaking and Appalachian groups.

Unlike most other cities, Cleveland already has an educational consortium, which includes the Cleveland Commission on Higher Education, the community ETV station, the parochial schools, the medical society, an association of local school superintendents, the Cleveland schools, and a school system in neighboring Parma. This group was originally organized to activate and use the 16 available ITFS channels in the 2500 MHz band. Out of the Wingspread conference came the idea that the consortium should extend its concerns beyond questions of television and hardware and move toward becoming an educational agency which might provide concerted attack on local problems.

The Cleveland proposal envisions three major projects, and suggests other projects which might be mounted at a later date. The first project would have as its purpose information dissemination for parents and adults in the minority communities via the ITFS channels. Once a week or twice a month, broadcasts would be scheduled to adult viewing centers in neighborhood schools. Subject matter might include such areas as nutrition, consumer education, and child psychology. A "parents council advisory group" and the use of a paid discussion leader at each viewing center would provide feedback into the system.

The second project is designed to improve student teaching and would involve the creation of a council on Improvement of Field Experiences which would bring together both the school systems and the local colleges. The council would lead to the creation of a Center with the nucleus staff concerned with both student teaching and in-service education. Among the functions of the Center would be the preparation of useful materials, including film and other non-television media for student teachers, for supervisors, principals and parents, including materials on teaching techniques which would enable the "host" teachers to keep abreast of the new methods and ideas in which their student teachers are trained.

The third major project concerns vocational education in Cleveland's parochial schools. While the demand for vocational education increases, the parochial system's ability to fund certificated teachers in this area has not kept pace. The project proposes sharing the teaching resources by television. Presentation of vocational lessons would take place by television with the schools providing "hands on" or laboratory experiences which could be staffed by non-professionals from industry. The Ohio state law specifies the maximum number of contact hours which can be staffed by non-certificated teachers. The staff differentiation proposed here would allow maximum impact for trained vocational teachers and provide a sound means by which the talents of vocational practitioners could be utilized.

Time did not permit the exploration of other potential projects, including providing supplementary educational services for the gifted, and administrative services via television.

Maryland: The problem to which the group directed its attention lies in the fact that an increasing number of students with sub-marginal preparation are being admitted to higher education. Clearly, this trend will increase. Most important is the problem of keeping such students from flunking out or dropping out after their appetites have been whetted. In many of Maryland's six state colleges, the clientele is rapidly becoming a rural-suburban mix in which some students arrive on campus ill-prepared for college, while others from suburban high schools are very well prepared.

The objectives of the proposal are to create a "community of educational endeavor" to attack the problem synergistically, to increase unity among the six institutions in the state college system, and to use college faculty, student teachers, and students themselves in discovering new approaches and new media by which improved articulation between the high school and the college experience may be accomplished.

The project will begin by organizing a formal or informal "community of educational endeavor" the members of which will include

The six State Colleges
The State Board of Education
The School of Education of the University of Maryland

The Maryland Council of Higher Education
Specific school systems with which the pilot project might be undertaken (including Maryland's Eastern Shore and the City of Baltimore)
The Maryland Public Broadcasting Center.

The basic approach to the problem is to minimize disagreement over where blame should be placed and to mount a multi-institutional attack involving cooperation between secondary and higher education, and among the members of the institutions of the higher education community. Likely areas for attack include reading improvement, vocabulary development, and study skills. Remedial help would be provided students from the 10th grade of high school through the freshman and sophomore years of college with appropriate carry-over, so that programs begun in secondary education could be built upon during the student's college years. Techniques suggested include the preparation of video tapes for playback on inexpensive machines in the high school or on the college campus, tutorial sessions using college-prepared student teachers, and broadcast programs for students, cooperating faculty, and parents.

The Maryland group made plain that final definitions and decisions regarding curricula and technique would properly be left to the "educational community," after it is organized.

The prototype nature of the project is found in the fact that the problems identified are present in every state of the Union, and that the Maryland proposal would organize a state-wide cooperative effort to deal with them.

San Diego: The San Diego group addressed itself to the problem of attempting to orchestrate the area's technical and human resources, looking toward the development of a community communications center. The initial partners in the venture will be the county schools, the San Diego city schools, the State College, and the University of California at San Diego. As plans develop, it is expected that the group will broaden to encompass the private colleges of the area, the parochial schools, training and education in the industrial and military communities, and local and state government.

The first step will be the preparation of a preliminary study by the staff of the county schools. The study to be completed by the end of January,1970, will

1. Identify the purposes of such a prototype center
2. Suggest organizational structure
3. Examine the legal aspects
4. Review funding possibilities for a more comprehensive study for the establishment of a center and for the identification of users and consumers.
5. Recommend staff and consultant requirements.

The communications resources available to the San Diego community include 2500 MHz ITFS, non-commercial television, several large CATV systems, non-commercial radio and, potentially, interconnection with NASA satellites via hardware supplied by Convair/General Dynamics.

The meeting concluded with an agreement that no published report of the Wingspread conference would be undertaken until the participants have had the opportunity for further work at home. The JCET agreed to undertake a transcription of the recordings of the final session, and offered its services as a coordinating agency in the development of the four inter-related Communications Prototypes.

SAN DIEGO: OFFICE OF THE ASSISTANT CHANCELLOR
LA JOLLA, CALIFORNIA

UNIVERSITY OF CALIFORNIA, SAN DIEGO
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LA JOLLA, CALIFORNIA 92037

December 16, 1969

CHANCELLOR WILLIAM J. McGILL

This is a report on the Communication Technology and American Education Conference sponsored by the Joint Council on Educational Telecommunications in cooperation with The Johnson Foundation held at the Wingspread Conference Center of The Johnson Foundation at Racine, Wisconsin, December 3-5, 1969.

The purpose of the meeting was to review the state of the art in communication technology and its relation to education and to consider the possibility of forming four prototype organizations which might typify the problems of coordinating activities among the segments of education. Selected for this purpose were the states of Arizona, Maryland, the greater Cleveland metropolitan area, and San Diego County. Much of the meeting was devoted to efforts on the part of the representatives of these four constituencies to determine whether it would be possible to create prototype community communications centers.

Though no committments were made on the part of the participating organizations in San Diego, clearly there was a willingness to explore the possibility of coordinated effort based on the belief that it would be impossible to find money to fund separate communications centers for all of the educational institutions in the community.

Following is the report I gave for the San Diego group at the Wingspread meeting. This report calls for action on our part and a committment to the general idea which should be explored through normal channels for this campus:

> We have agreed to attempt to "orchestrate" our presently available and possible future resources into something that could be considered a community communications center.
>
> Involved, initially, are the City and County Schools and the State College and University. Ultimately, there will be others - notably the junior colleges, private schools and

colleges, the military (Navy and Marine Recruit Training Centers, Fleet Training Center, and Naval Air Training Center), industry (i.e., General Dynamics), and local and state government.

To put this into motion we have agreed to the preparation of an initial study which, in a preliminary way, will inventory and identify present resources in San Diego County, enabling us to spot the gaps to be filled. The County schools will provide a competent staff man to conduct this study. He will be assisted by a committee representing the other three institutions. (I am proposing Chuck Bridgman as the University's representative.) The study will:

1) Examine purposes for a prototype center.

2) Suggest a permanent organizational structure.

3) Sirce public funds will be involved from several sources, it will be necessary to review the legal aspects of a coordinated effort.

4) Review funding possibilities for a comprehensive feasibility study and for establishing a prototype center.

5) Recommend the involvement of users and consumers of the services of a center.

6) Recommend staff and consultant requirements.

This report will be ready for review in late January by the participants of our San Diego group at an all day meeting at a remote center. At this meeting we will determine next steps, including a feasibility study, an enlarged organization with a steering committee or some executive group, and funding efforts. Consultants probably will be needed. For

> this meeting each of the elements will prepare a brief paper concerning the implications of the communications center for his agency, answering such questions as: What do we want from such a center? What do we hope to obtain? What can be our contribution? We will review the model of an ideal prototype center, to be constructed by John Witherspoon and Bob Mosher. We are aware that we are in (or we are entering into) the "accountability era." Thus, we will be cognizant of dollar efficiency in reaching our goals and will hope to provide more educational service by acting jointly than all of us could do separately.

After discussing this matter with Chuck Bridgman, I will endeavor to find others from this campus whose interests are involved and have a meeting with them. Meanwhile, I assume that I have your support in the desirability of pursuing this possibility for coordinated effort.

Martin

Martin N. Chamberlain

Enclosure

cc: Charles F. Bridgman
Patrick Bergin
M. Ted Dixon
Robert Mosher
Ernest B. O'Byrne
William H. Stegeman
Harold Wigren
John P. Witherspoon