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TECHNICAL REPORT NO. 2

TELEVISION BROADCAST RELAY SYSTEM

Prepared by

SATELLITE COMMUNICATIONS LABORATORY
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FOREWORD

This is a technical report of a study conducted by the Electrical Engineering Department under the auspices of the Engineering Experiment Station toward the fulfillment of the requirements prescribed in NASA Contract NAS8-24818. A method of handling data pertaining to the design of a satellite television broadcast system is discussed in depth.

ABSTRACT

A method of handling data pertaining to the design of a satellite television broadcast system is discussed in depth. Sample data is analyzed and plotted by computer techniques.

ACKNOWLEDGEMENT

The authors wish to express their appreciation to the many members of the group from the Auburn University Electrical Engineering Department, both student and faculty, who contributed to the overall preparation of the study.

TABLE OF CONTENTS

LIST OF FIGURES

TELEVISION BROADCAST RELAY SYSTEM

R. F. McKinney, Jr., and E. R. Graf

I. INTRODUCTION

In the next few years the probability of using television broadcasting from synchronous satellites for educational and commercial purposes is great. Several advantages over land-based television transmitters are offered by the satellite stations. One big advantage of satellite television is that the satellite station can cover many times the area that a land-based transmitter can serve. Television stations in present use can cover a circular area with a radius of about fifty miles, whereas a satellite transmitter could possibly cover an area with a radius of five hundred miles, or one hundred times the area covered by one land-based station.

Both developed and developing countries could make use of satellite television broadcasting. The requirements and needs of the two types of nation can vary greatly. In a developed country, such as the United States, there are television broadcast systems which have evolved as a result of prior land-based radio stations. Many important specifications such as signal power, frequency allocations and bandwidth, and methods of modulation and demodulation and propagation have long since been rather rigidly fixed by government agencies. Existing receivers and antennas must also be considered. This consumer equipment represents a huge investment on the national scale.

In a developing country, requirements may be much more relaxed. Since home receivers are few and far between, a satellite transmitter may be built with receivers designed to be used with it. This would be a particular advantage where the population is dense or where the transmitter would be used for educational purposes, since many people could benefit directly from each receiver.

Studies covering virtually every facet of interest in satellite station design have been made. Several of the necessary requirements are not yet state of the art, but most of the projected needs are under development and may well be feasible in the next few years.

Because of the enormity of the material about station components, a design study could be long and fruitless unless care is taken in analyzing and presenting the data. Data given in parametric form lends itself well to manipulation and calculations. This presentation is based on methods of presenting data in parametric form, using computers to do the work of calculating and plotting the data. Use is made of the Friis transmission formula as an example of using parametric data with equations to quickly determine possibilities of design.

II. DISCUSSION OF THE BASIC SATELLITE TELEVISION SYSTEM

There has been a considerable amount of work done in the study of the problems of satellite television broadcasting. Work either has been or is being done to advance the state of the art in nearly every area of interest.

Receiving and broadcasting antennas for a satellite have been studied in some detail. Basic design studies have been done by D. W. Power,[1] J. Sauides,[2] and many others.[3,4] Another antenna study area is that of construction materials. Work has been done in this area by J. Jansen.[5]

Satellite transmitters and receivers require considerable research and development. Transmitters which can handle large amounts of power efficiently and be reliable for several years must be developed. Research in this field has been done by W. Neugebauer[6] and G. M. Branch.[7]

Another important area of study is in the energy gathering and conditioning equipment. Arrays of solar cells seem to be the logical choice for energy gathering. R. Wizenick[8] and R. W. Sudbury[9] have studied the problems of solar arrays, as have many others.[10,11,12,13,14]

Two more important study areas are dissipation of wasted power from the transmitter and other equipment, and protection of the station from solar energy. Jansen[15] has presented work on these problems, and also on the area of storage batteries for a satellite.

There are many possible television broadcasting stations, but some features are common to all. A synchronous satellite, on that stays fixed relative to the earth, would have to be stationed above the equator. For a satellite to remain fixed with respect to a point on earth, it must be orbiting at the same angular velocity as the earth. From these restrictions, it can be shown that the satellite must be at a height above the earth of approximately 22,000 miles. At a height of 22,000 miles, a half-power beamwidth of three degrees would cover an area with radius approximately 500 miles, or a circular area of approximately 800,000 square miles. A half-power beamwidth of one and one-half degrees would cover an area of radius approximately 250 miles, or 200,000 square miles.

To obtain an acceptable signal for in-use receivers from a satellite broadcast system, an enormous amount of power would have to be transmitted. It is conceivable that satellite television broadcasting will be used commercially some day, when home receiver sensitivity has been greatly improved. However, the most feasible use in the near future for satellite television is in educational systems. Both developed and developing countries could benefit greatly from the educational possibilities offered by a satellite station.

There are many station design problems that a developed country must solve that differ from the problems of a developing country, mostly because of the already imposed restrictions and requirements of the developed country.

Allowable bandwidths and frequency allocation of stations are designated by government agencies. A change in frequency allocation or bandwidth is not a simple matter, in a developed country, due to the large number of interested parties involved. In a developing country, where there is but a relatively small investment in home receivers, and where existing transmitting stations are few, much greater tolerances in design can be allowed. One can imagine, for example, that the allocation of a most desirable frequency and bandwidth might be readily obtained. Receivers can be designed for use with an educational satellite station which might be economically prohibitive for home use. This would allow consideration of new power levels, bandwidths, frequencies, and modes of modulation and demodulation which cannot be used with present receivers. Antennas are available which meet the requirements of receiving low level signals vertically with circular polarization.

These above considerations make a satellite station much more practical for educational purposes than for home reception.

III. AN APPROACH TO THE SYSTEM REQUIREMENTS

Much research on the problems of synchronous satellite television broadcast stations has been done. Reports are available on nearly every conceivable aspect of interest. Retrieving and evaluating this information is a major problem that faces anyone who attempts a satellite design. Without a firm requirement for a specific design, the research work which has been done is quite general in nature. To determine from this work the optimum design, one needs a method of collecting and presenting the data on a specific component or area, and must have rapid means of comparing the parameters of interest of the same.

There are a number of design parameters of a satellite television station that must be ascertained. Some principal variables that the designer must consider are weight and volume of the communication system, antenna and solar cell weight and area, power transmitted, frequency and bandwidth of transmission, and methods of modulation and demodulation.

Many minor variables determine to a large extent the above principal system parameters. Weight is a major parameter to be considered. Moreover, it depends primarily on the choices made in the other major parameters mentioned above. For instance, the weight of the antenna depends on the choice of construction material as well as upon its configuration and size. The latter is a function of frequency, one of the major variables. The weight of the solar cell array to satisfy a particular power requirement depends on the type of cell used as well as the mechanical array structure. Once a transmitter has been chosen to fit the requirements of power transmitted, frequency, and efficiency, the weights involved are those of the transmitter itself and associated cooling and power conditioning equipment. Some other weight-deciding choices are amount and type of storage battery, type and size of louvers to protect the system from the solar rays, and the choices of stabilizing and positioning fuels and engines. The types of louvers and stabilizing engines depend on the choice of station orientation, whether sun-oriented or earth-oriented.

Due to the complexity of the problem, as well as the assumptions based upon expected state-of-art developments of the near future, it is difficult to determine and isolate the problem areas within any given system design.

In this work, careful study was given to several reports describing a number of television satellite systems. In particular, special attention was given to checking the present and future feasibility of the designs from the most basic points of view possible. An effort has been made to computerize typical parameters which are required to satisfactorily evaluate and compare the systems in question.

As an example of this technique, computations involving a form of the Friis transmission formula were chosen.

An equation that relates the weight of the communications station to other parameters involved is

$$W = \gamma A_T + \tau P A_S \tag{1}$$

where

W = total weight of the communications system (pounds),

γ = antenna weight factor (pounds per square meter),

A_T = area of the transmitting antenna (square meters),

τ = weight factor of the communications system, excluding the antenna (pounds per watt),

P = Poynting vector at the receiver (watts per square meter),

and A_S = serviced area (square meters).

A basic system schematic is shown in Figure 3-1. An equation for the directivity of the transmitting antenna is

$$D_T = \frac{4\pi S^2}{A_S}, \tag{2}$$

where

D_T = directivity of the transmitting antenna,

S = distance between transmitting and receiving antennas (meters),

and A_S = area illuminated by transmitting antenna (square meters).

Then, from (2)

$$\frac{D_T}{4\pi} = \frac{S^2}{A_S}, \tag{3}$$

τ = (satellite weight)/(power transmitted)

γ = (antenna weight)/A_T

$W = \gamma A_T + \tau PA_S$

PA_S = total power transmitted

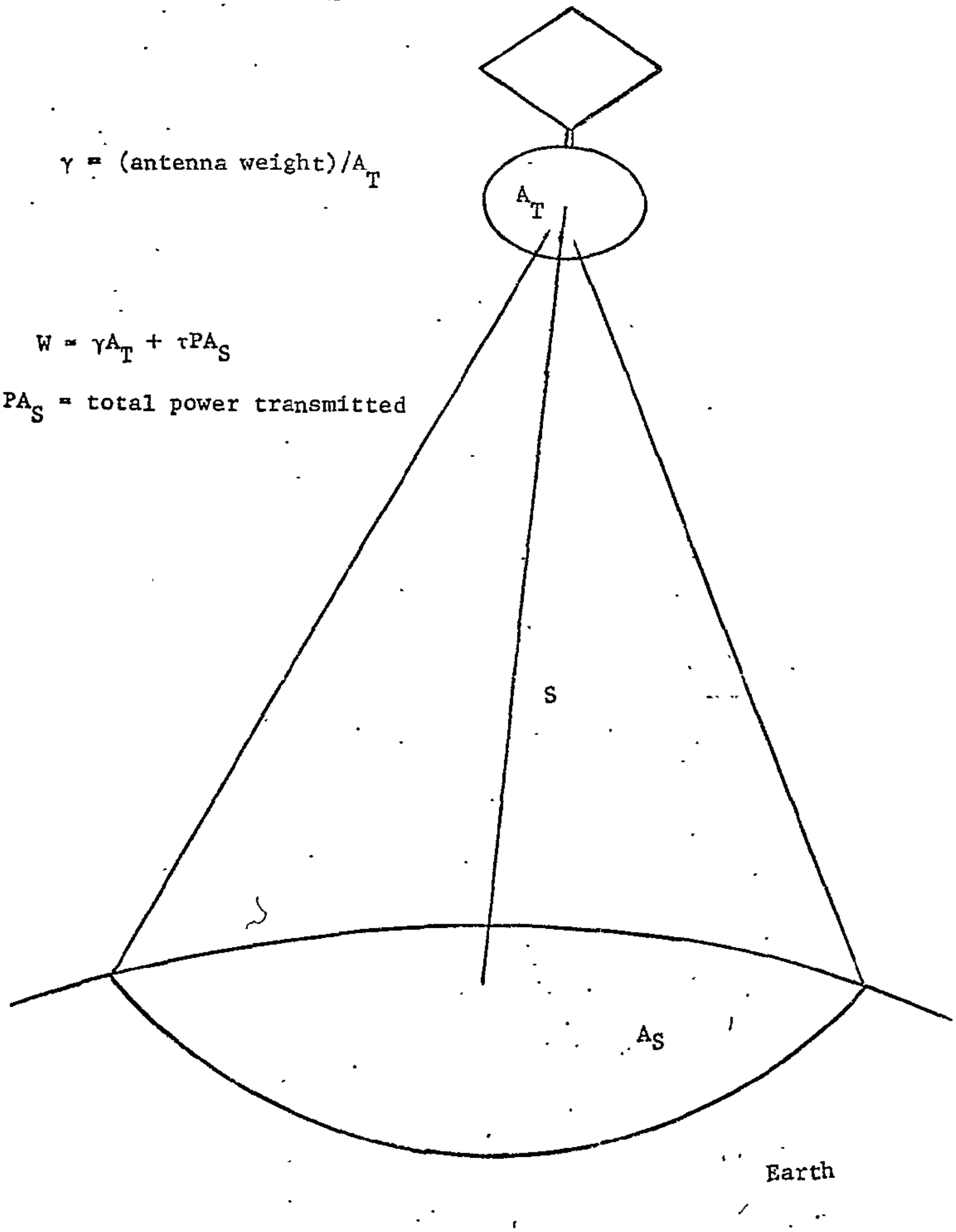


Figure 3-1 -- A basic television satellite schematic and

$$\frac{\lambda^2 D_T}{4\pi} = \frac{\lambda^2 S^2}{A_S} = A_T, \tag{4}$$

where

λ = wavelength of transmitted signal (meters).

Upon substituting equation (4) into equation (1), one obtains

$$W = \gamma \frac{\lambda^2 S^2}{A_S} + \tau P A_S . \tag{5}$$

Solving equation (5) for $\tau P A_S$,

$$\tau P A_S = \frac{W}{2} \pm \sqrt{\left(\frac{W}{2}\right)^2 - S^2 \lambda^2 P \gamma \tau} \tag{6}$$

For a given service area A_S, a required value of Poynting-vector P, and a maximum allowable weight W due to vehicle limitations, the parameters γ and τ are affected only by a change in wavelength λ.

Now, for convenience, make the substitutions

$$b^2 = S^2 \lambda^2 P \gamma \tau \tag{7}$$

and

$$c^2 = (W/2)^2. \tag{8}$$

Then, using (7) and (8) in equation (6), one obtains

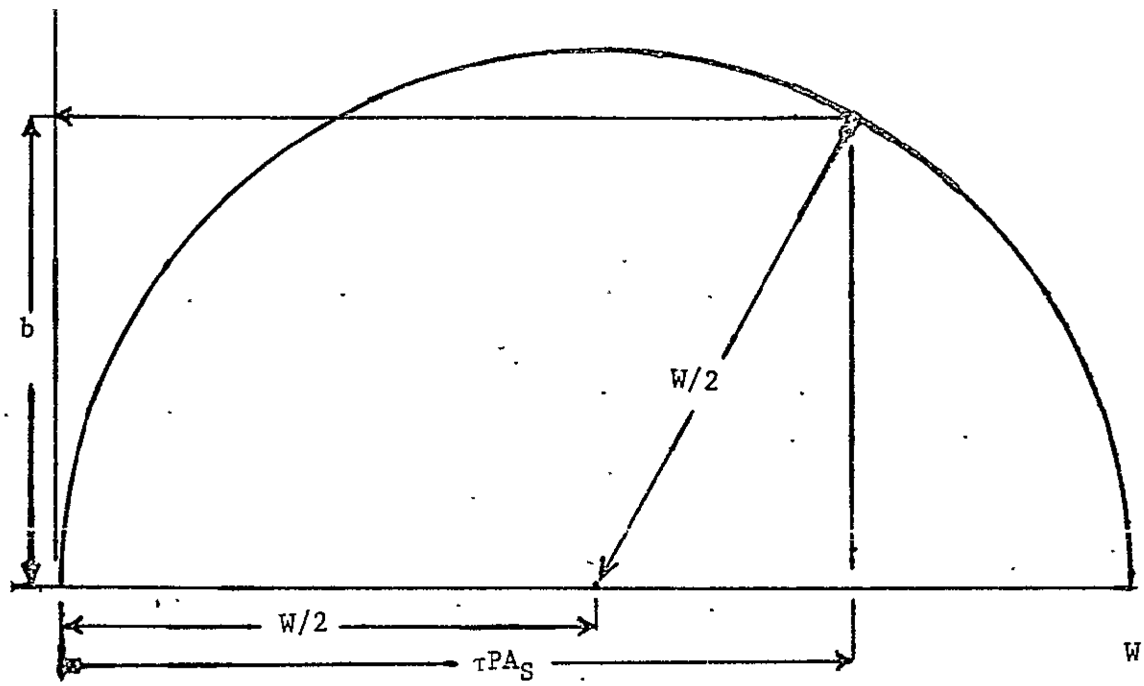
$$\tau PA_S = \frac{W}{2} \pm \sqrt{c^2 - b^2}. \tag{9}$$

Equation (9) can be represented by a graph of a semicircle, with W/2 as center. Figure 3-2 is a graph of equation (9), with τPA_S as abcissa and b as ordinate. Only the quarter circle to the right of W/2 is necessary for the physical situation.

In Figure 3-2, the rightmost point of the semicircle represents W, the weight of the system. τPA_S represents the weight of the system minus the antenna weight, while the distance $(W - \tau PA_S)$ represents the weight of the antenna. The parameter wavelength is the determining factor as to what percentage of the total weight is in the antenna and what percentage is in the rest of the system. As wavelength λ changes, the percentages of weight in each part of the system change.

The graph represented by Figure 3-2 is one of the many possible ways to present the data. Some of the individual component data can be shown as straight line graphs, represented mathematically as $y = mx + b$, while other data is more complicated.

The more simple graphs will be used in conjunction with the more complex ones. For example, in using the graph in Figure 3-2, if a frequency has been selected, then the amount of weight allowed for the communications system can be easily determined. This information can then be applied for use with simpler graphs to determine which materials and components are possible candidates for use in the communications system.



W = total weight of the system

τPA_S = weight of the system without antenna

$(W-\tau PA_S)$ = weight of the antenna

$b = S\lambda\sqrt{P\gamma\tau}$

Figure 3-2 -- The circle diagram

A considerable number of cross correlations between graphs might be required to either design or check a particular system. With the aid of the graphs, rapid evaluations of the feasibility of a system can be accomplished, and the cross-correlations between the graphs makes it possible for the designers to control the design more accurately. Finally, actual numerical checking will be implemented in a computer program.

IV. PRESENTATION AND UTILIZATION OF PLOTTED DATA

In the previous chapter, the Friis transmission formula was chosen to demonstrate the computer-aided presentation of basic parametric data. Inasmuch as the data is in parametric form, obviously one has almost unlimited possibilities for both form and quantity of data which can be presented for any given system.

The utility of plotted data is probably determined most by the ease with which one can choose or check a particular system parameter. In the remainder of this chapter a number of representative curves have been plotted and discussed to exemplify the method of approach taken in this study. The computer programs involved are found in Appendix A.

Figure 4-1 is an example of a straight-line graph. In it, weight is plotted against battery capacity on one set of axes, and load requirement is plotted against battery capacity on the other set of axes. For the battery type that this graph represents, if any of the three variables, battery capacity, weight, or load requirement, is decided, then the other two are immediately determined. Should battery capacity be the decided quantity, then weight and load requirement are ascertained by entering the plot from the abcissa at the correct value, proceeding vertically to intersections with the two curves, and from each intersection to its respective axis. If an

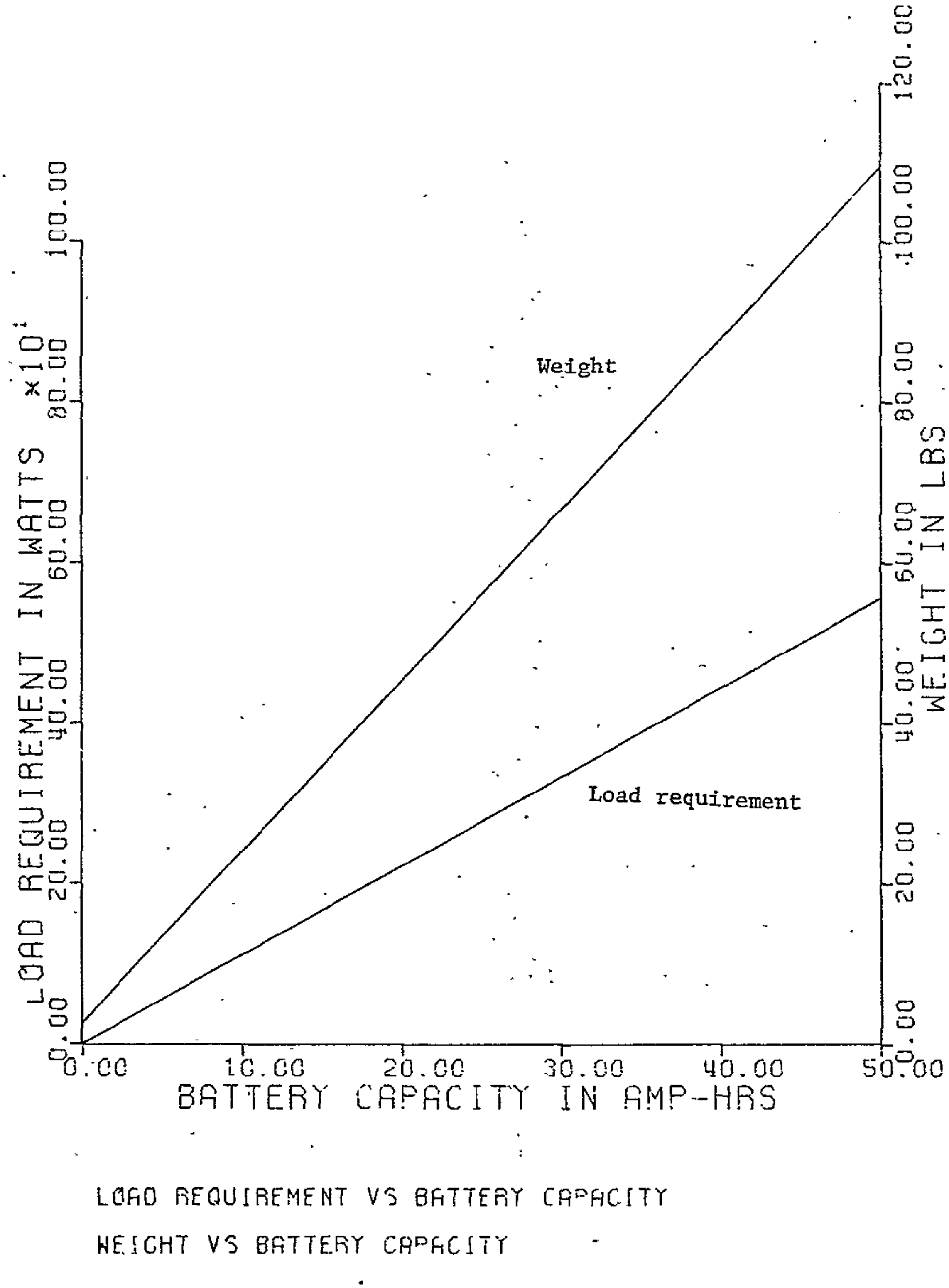


Figure 4-1 -- Load capacity and weight as a function of battery capacity ordinate value is fixed first, then the abcissa value and the other ordinate value are found by entering the plot from the chosen axis at its ordinate value, proceeding horizontally across to the battery capacity curve, and downward to the abcissa for the battery capacity value, while the other ordinate value is found as in the first case.

Figures 4-2 through 4-16 are alike in that each of them offers the same type of information. Each of these curves is a plot of the weight of a communications system as a function of frequency. The equation used to plot the curves is

$$W = (\gamma \times S^2 \times C^2)/(A_S \times F^2) + (\tau \times P) \tag{1}$$

where

W = total weight of the communications system (pounds),

γ = antenna weight factor (pounds per square meter),

S = distance from transmitter to receiver (meters),

C = speed of light (meters per second),

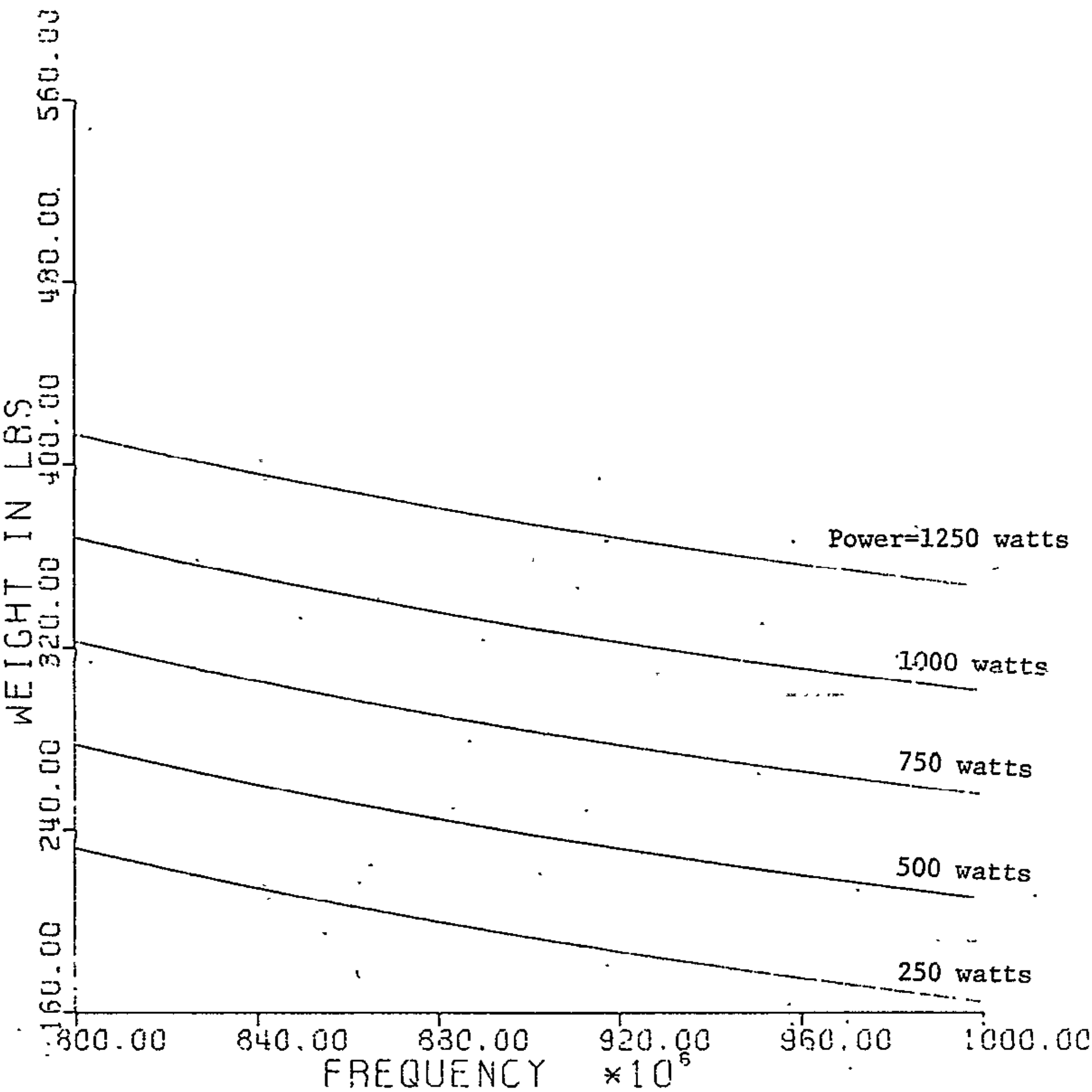
A_S = area of receiving antenna (square meters),

F = frequency (Hertz),

τ = weight factor of the system with the antenna not included (pounds per watt),

and P = transmitted power (watts).

On each plot there are five curves, each representing a different transmitted power, as indicated on the curves. Each plot utilizes a different



COMM SYSTEM WEIGHT VS FREQUENCY

FOR FIVE VALUES OF TRANS POWER

Figure 4-2 -- Communications system weight as a function of frequency from 0.8 GHz to 1.0 GHz with an antenna weight factor of 0.2 pounds per square foot

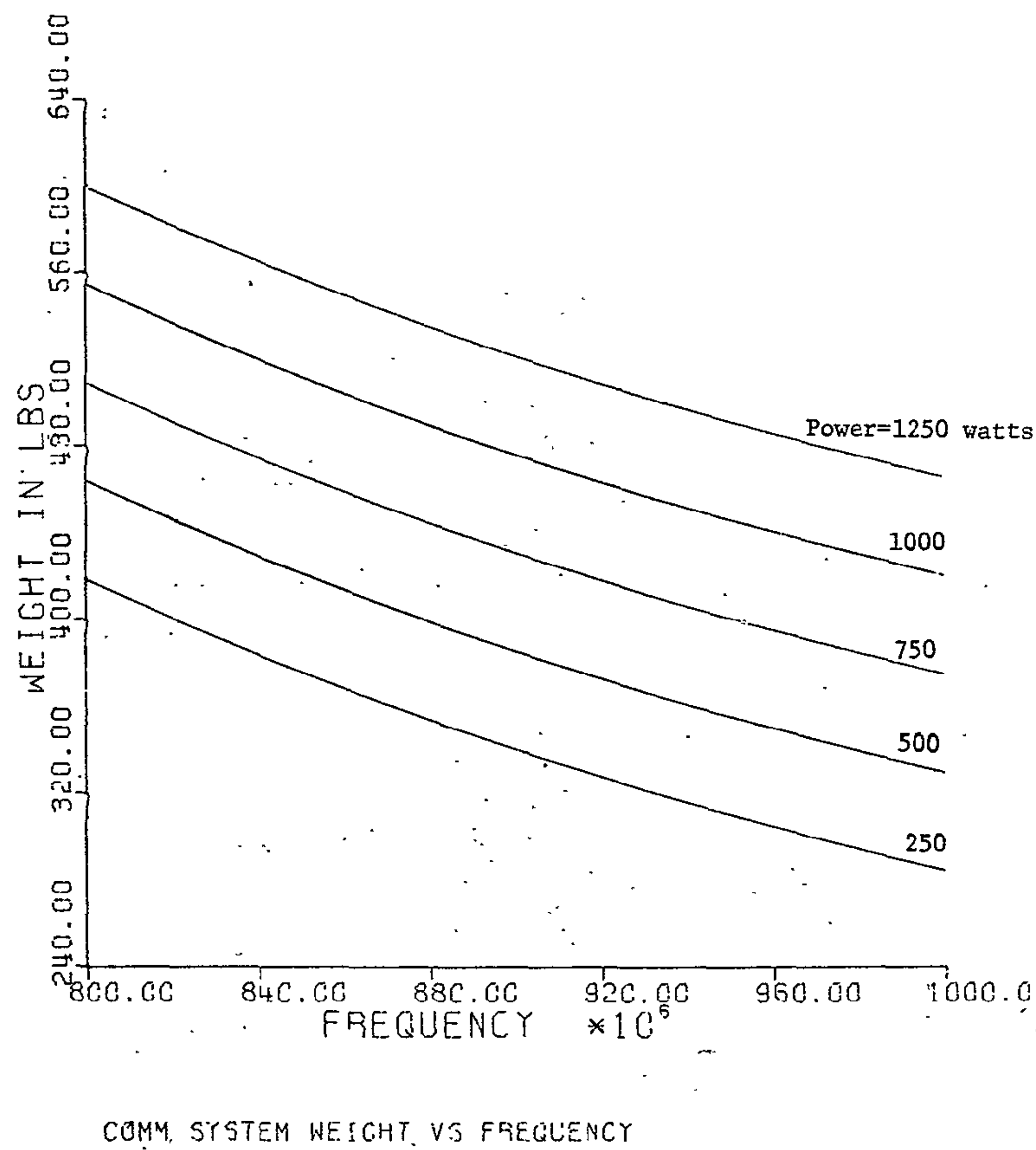


Figure 4-3 -- Communications system weight as a function of frequency from 0.8 GHz to 1.0 GHz with an antenna weight factor of 0.4 pounds per square foot

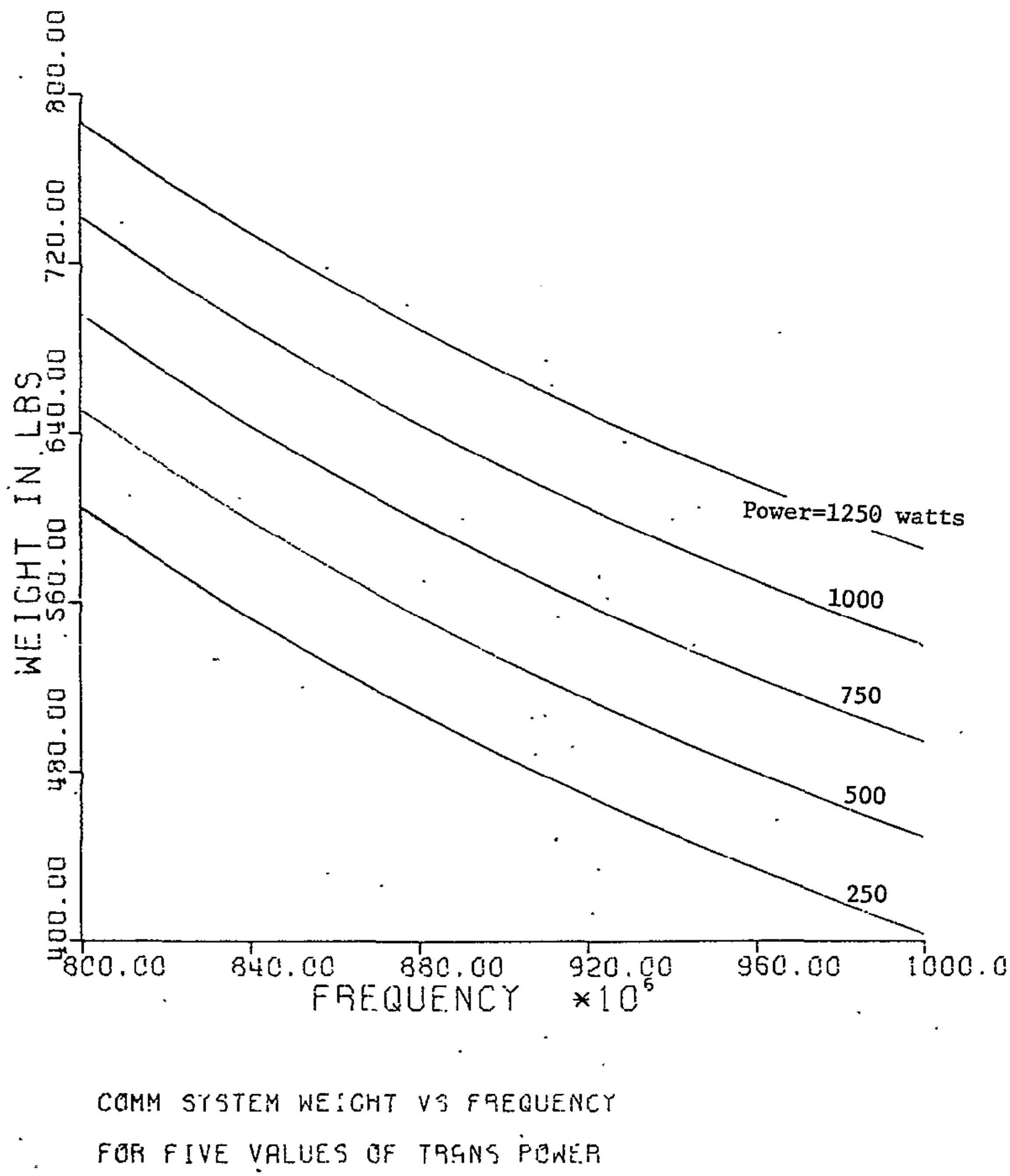


Figure 4-4 -- Communications system weight as a function of frequency from 0.8 GHz to 1.0 GHz with an antenna weight factor of 0.6 pounds per square foot

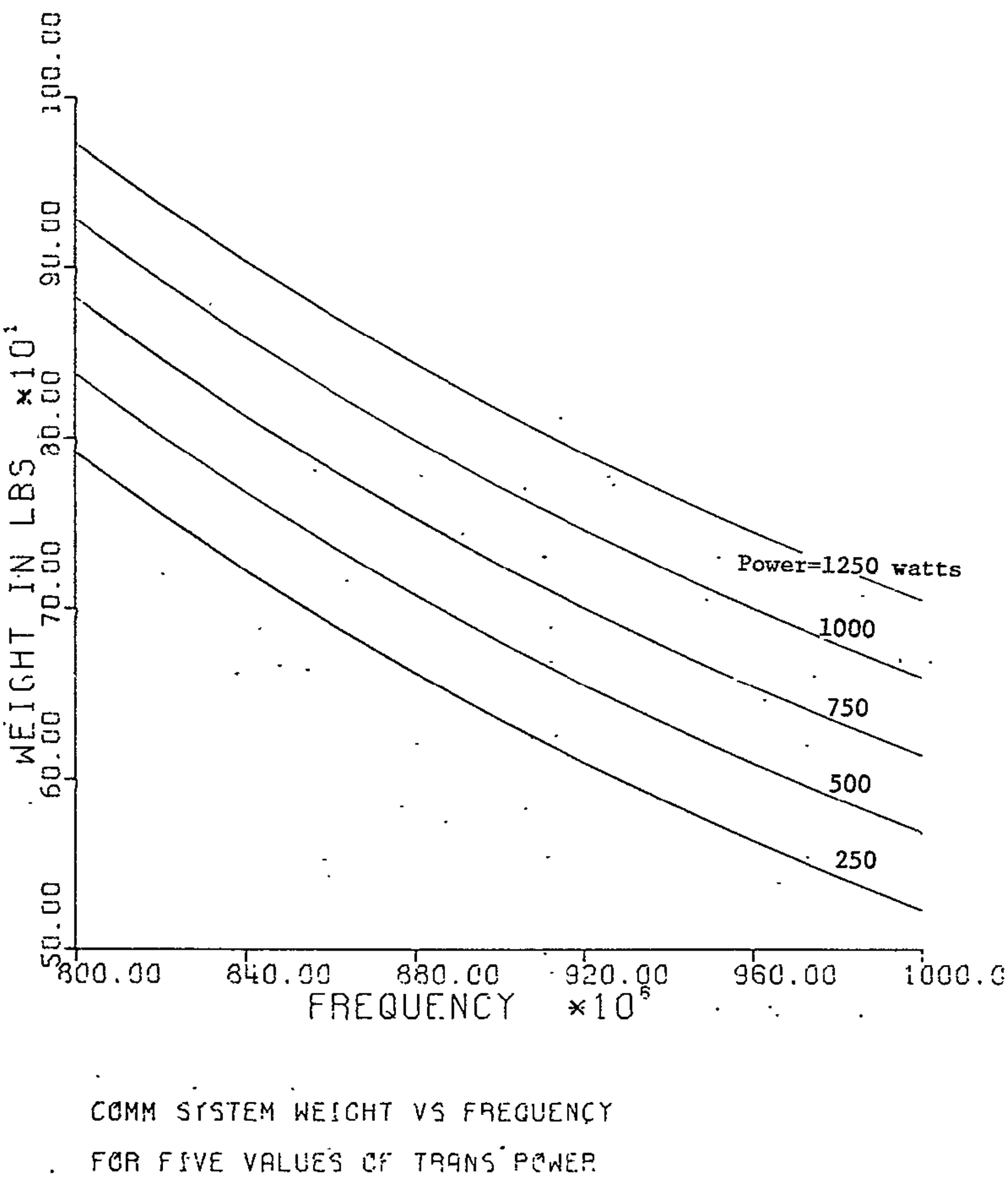


Figure 4-5 -- Communications system weight as a function of frequency from 0.8 GHz to 1.0 GHz with an antenna weight factor of 0.8 pounds per square foot

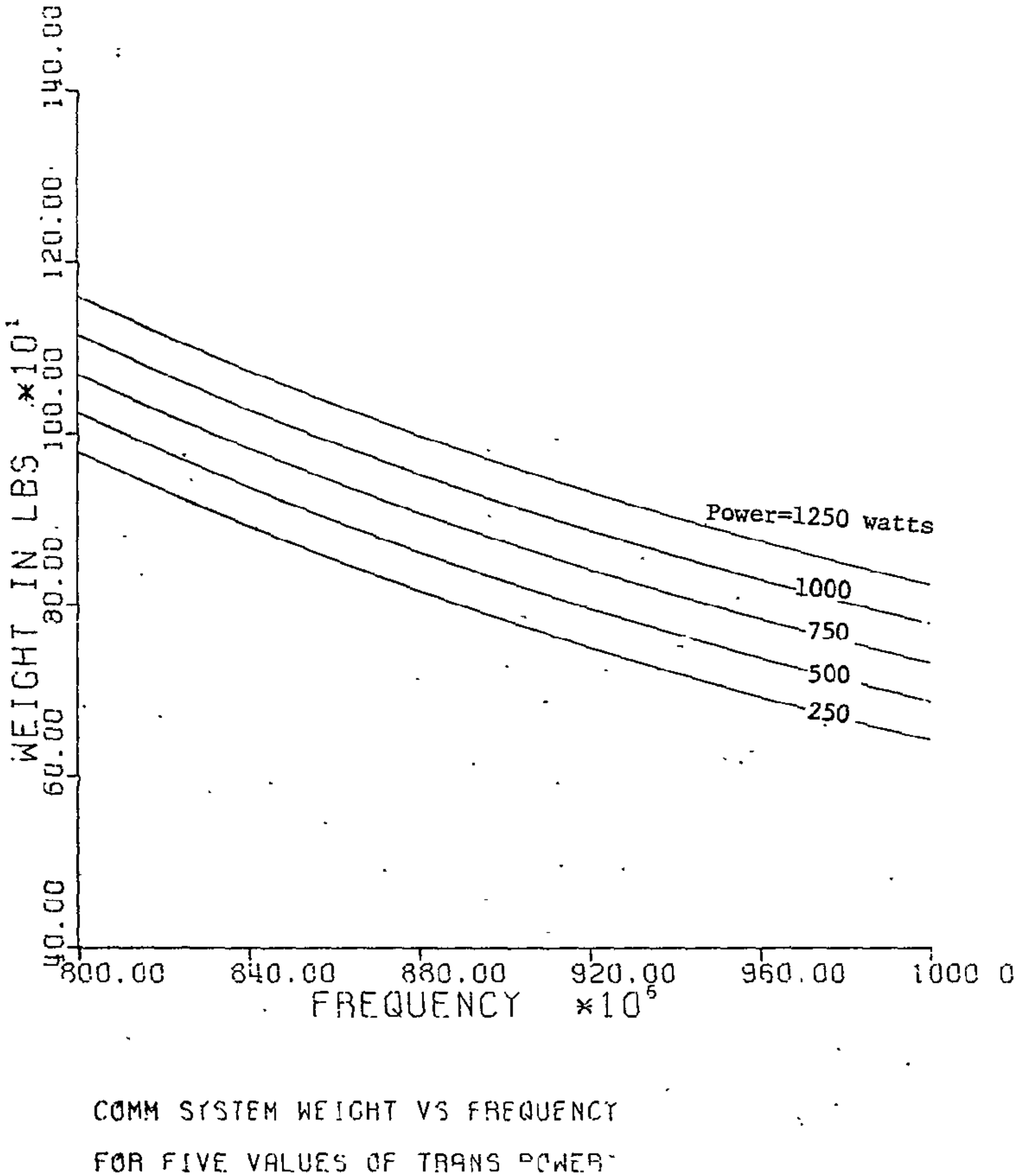


Figure 4-6 -- Communications system weight as a function of frequency from 0.8 GHz to 1.0 GHz with an antenna weight factor of 1.0 pounds per square foot

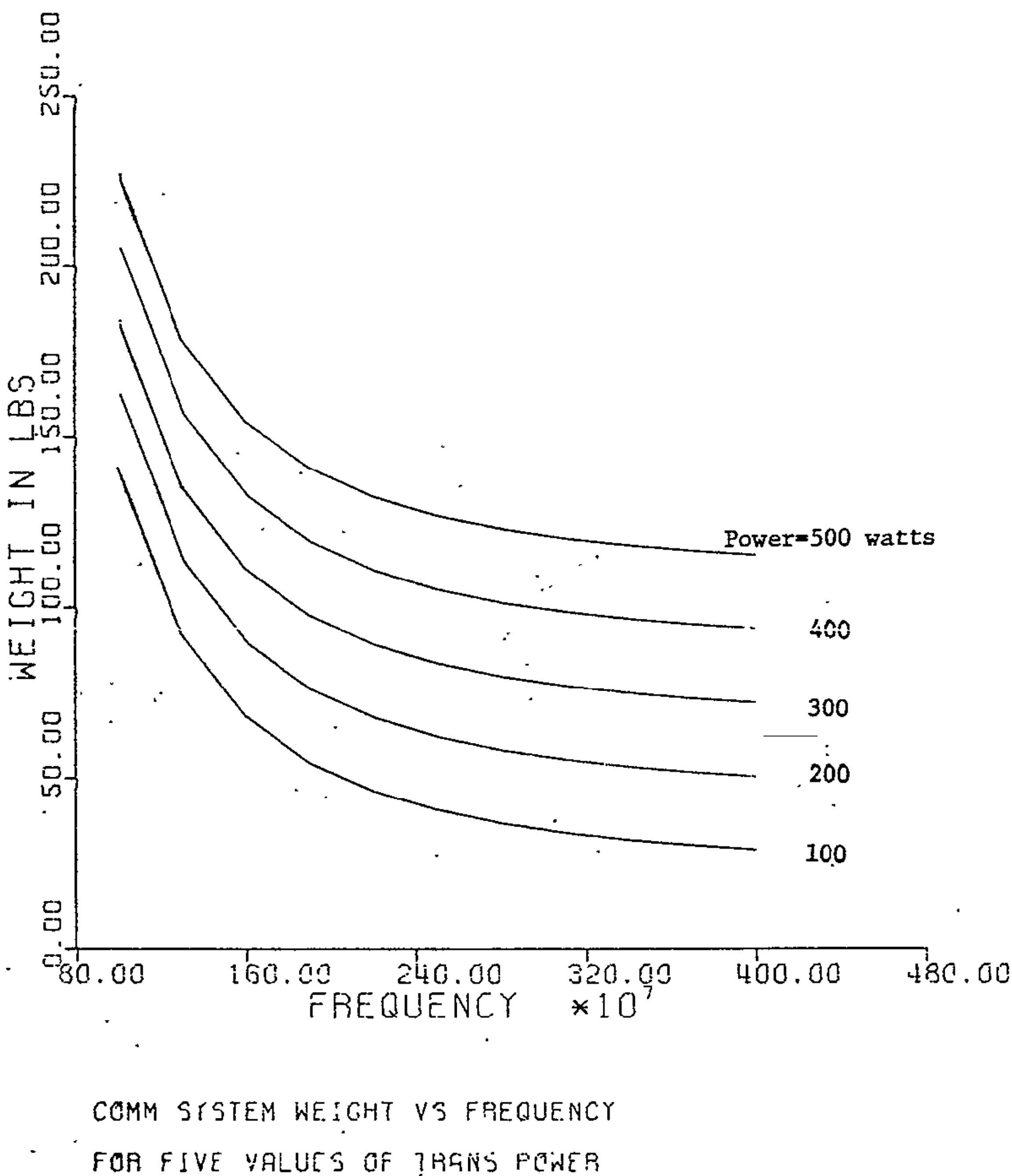
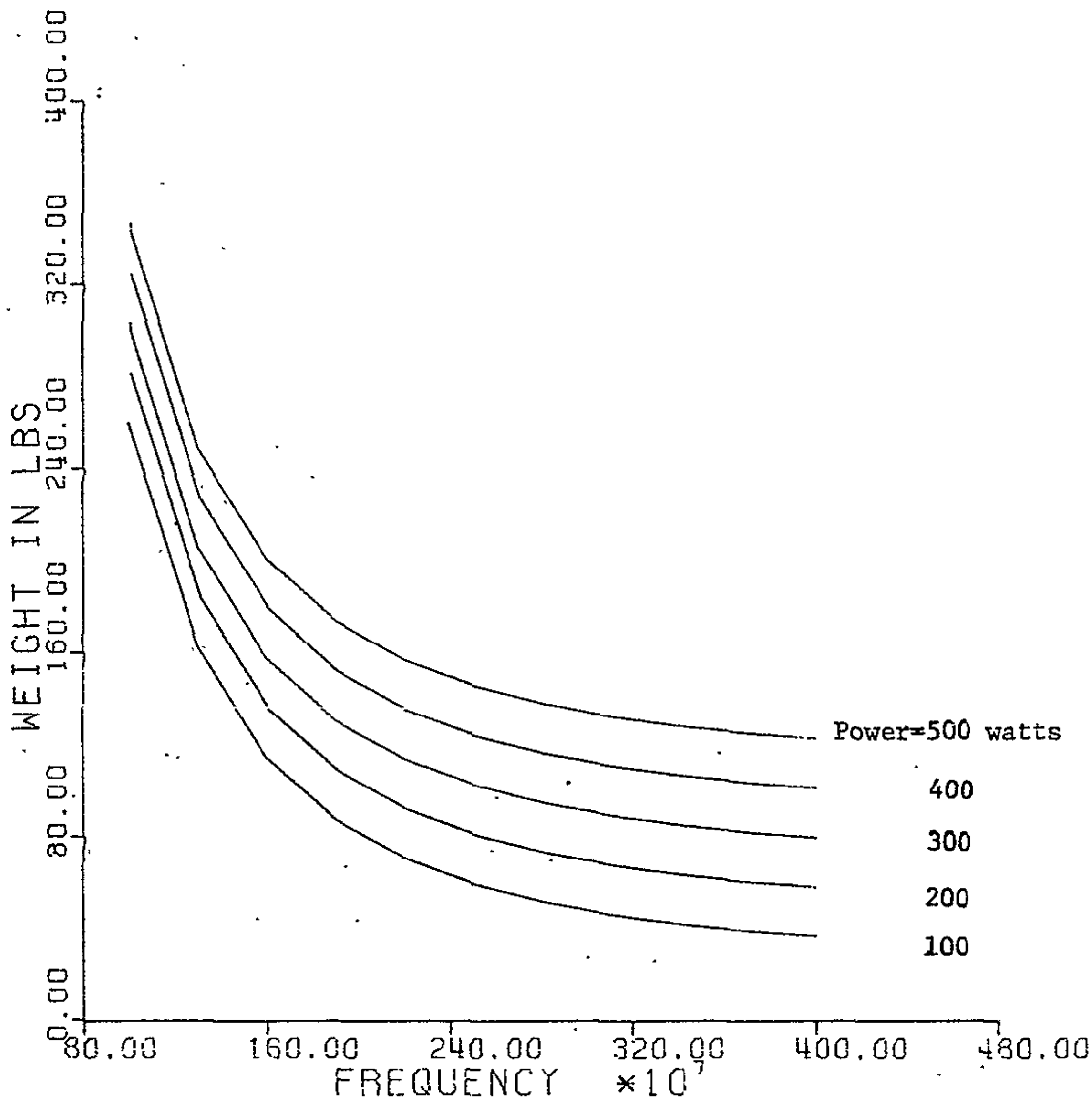


Figure 4-7 -- Communications system weight as a function of frequency from 1.0 GHz to 4.0 GHz with an antenna weight factor of 0.2 pounds per square foot



COMM SYSTEM WEIGHT VS FREQUENCY

FOR FIVE VALUES OF TRANS POWER

Figure 4-8 -- Communications system weight as a function of frequency from 1.0 GHz to 4.0 GHz with an antenna weight factor of 0.4 pounds per square foot

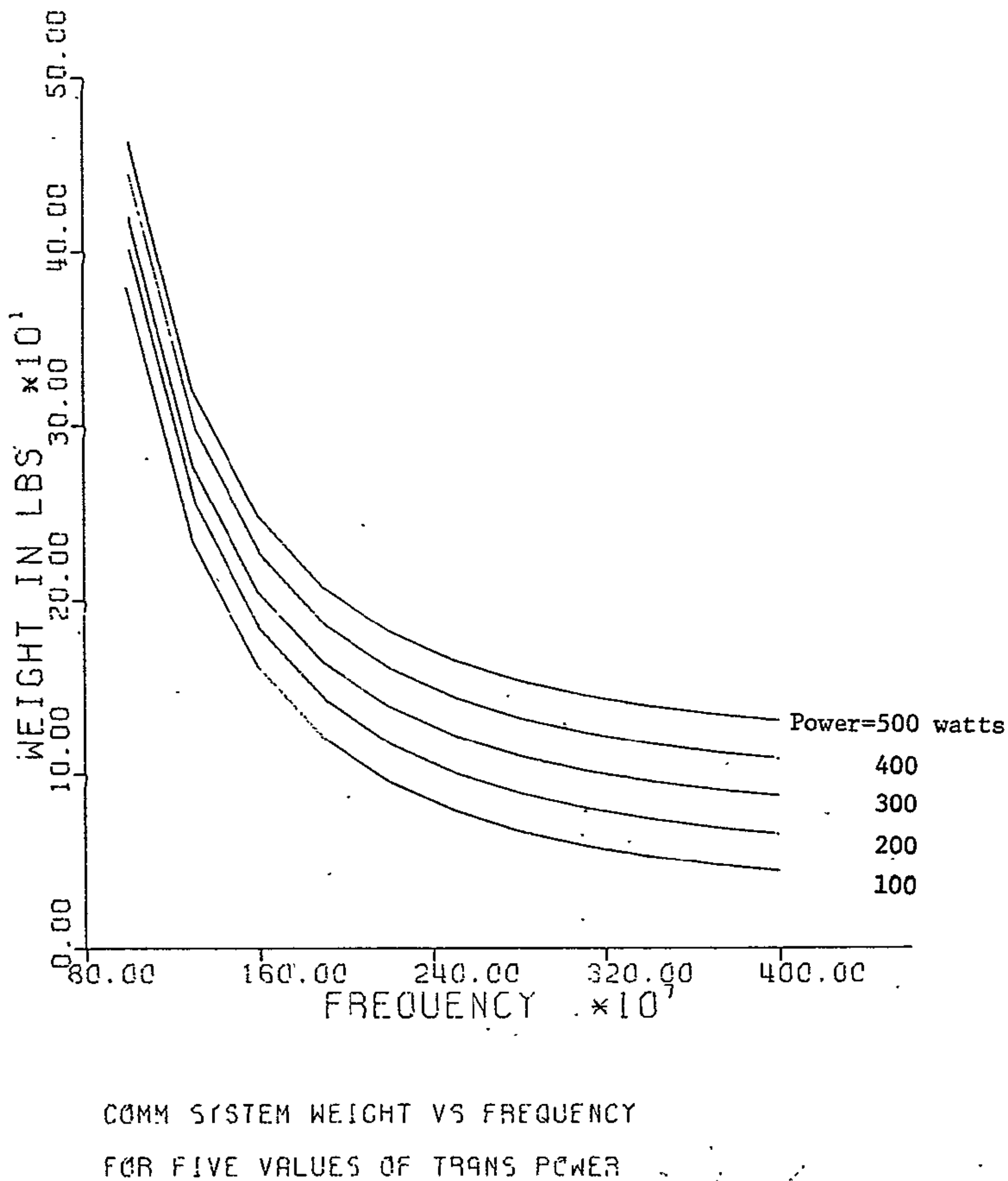


Figure 4-9 -- Communications system weight as a function of frequency from 1.0 GHz to 4.0 GHz with an antenna weight factor of 0.6 pounds per square foot

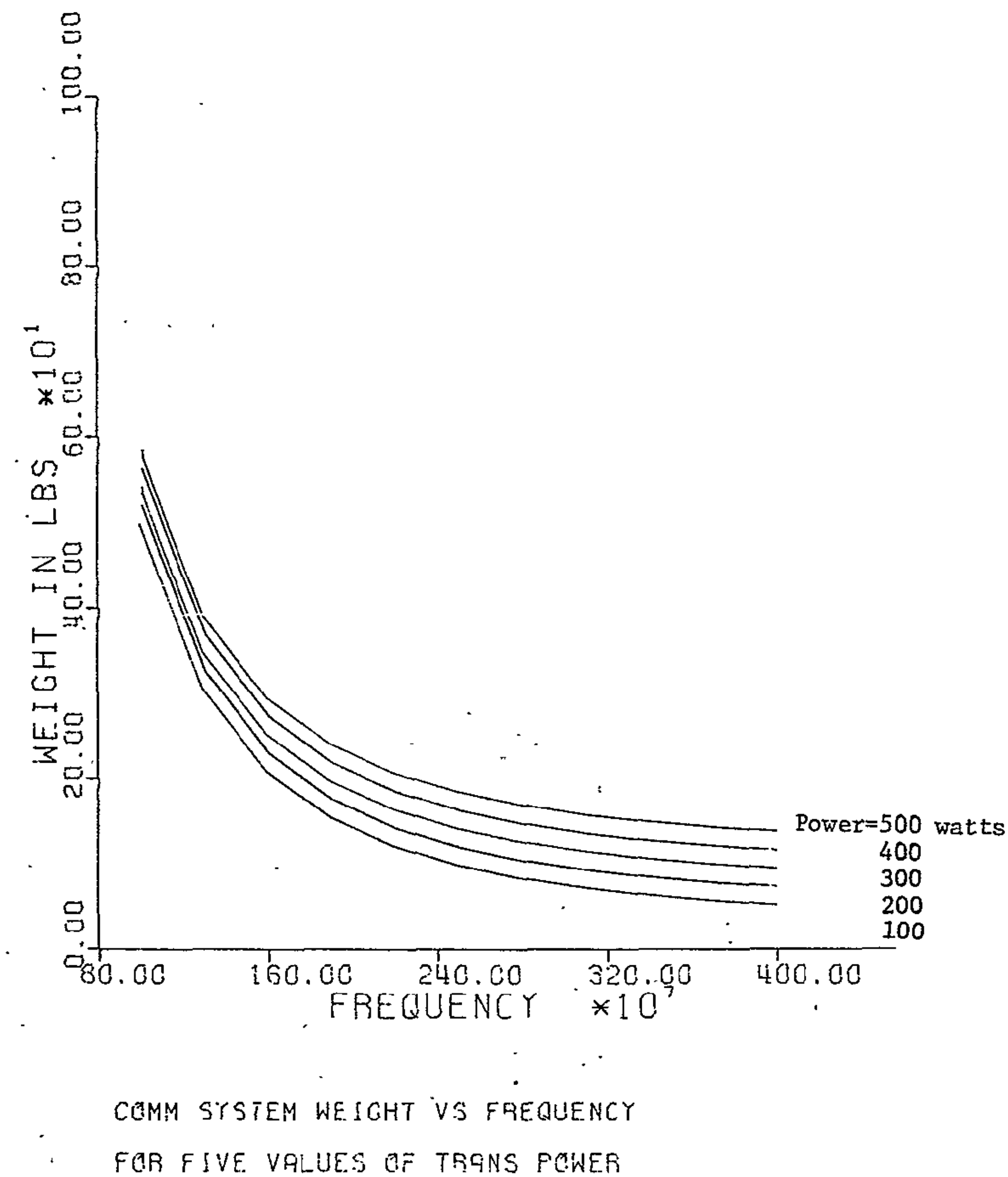
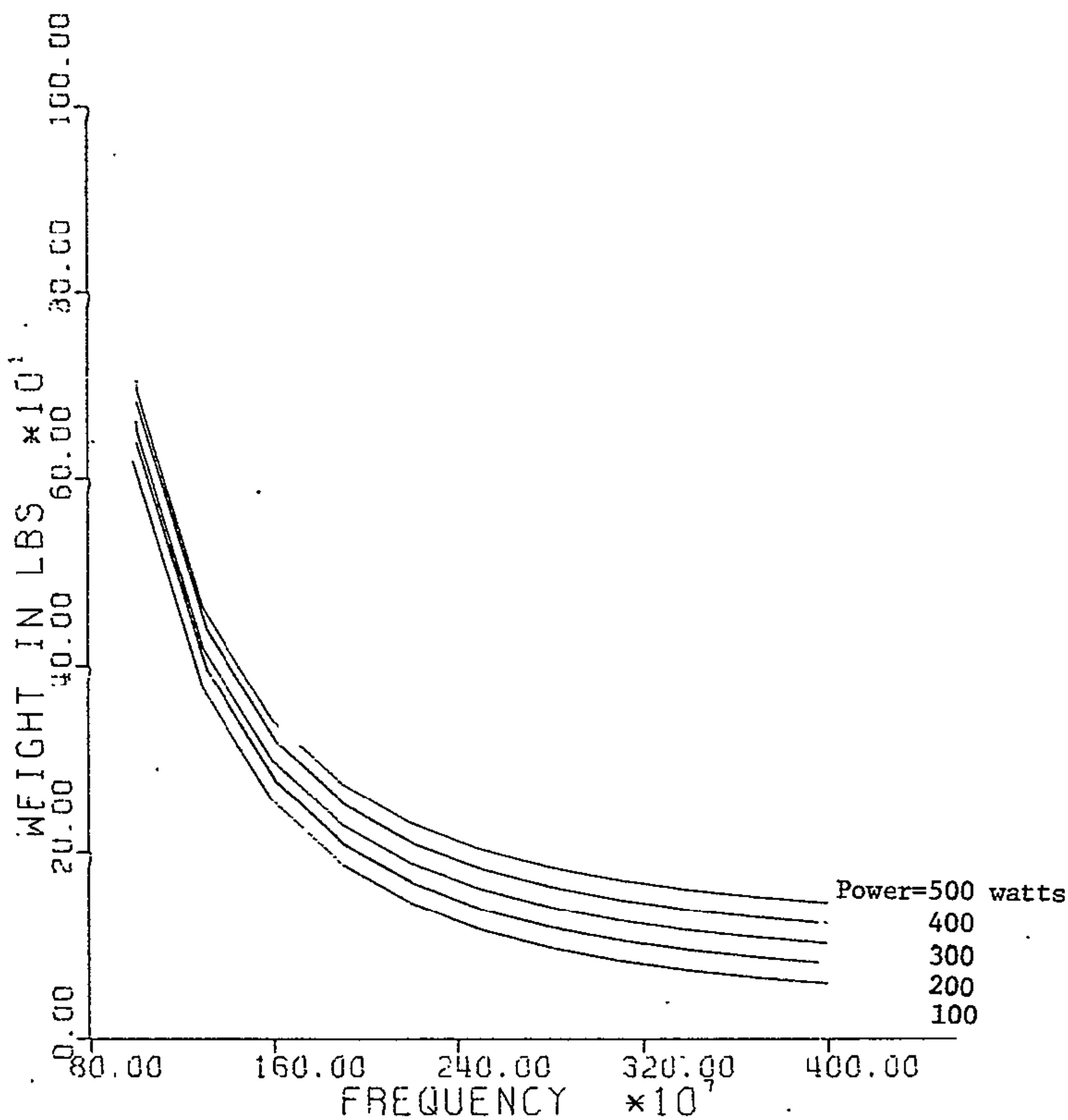


Figure 4-10 -- Communications system weight as a function of frequency from 1.0 GHz to 4.0 GHz with an antenna weight factor of 0.8 pounds per square foot



COMM SYSTEM WEIGHT VS FREQUENCY

FOR FIVE VALUES OF TRANS POWER

Figure 4-11 -- Communications system weight as a function of frequency from 1.0 GHz to 4.0 GHz with an antenna weight factor of 1.0 pounds per square foot

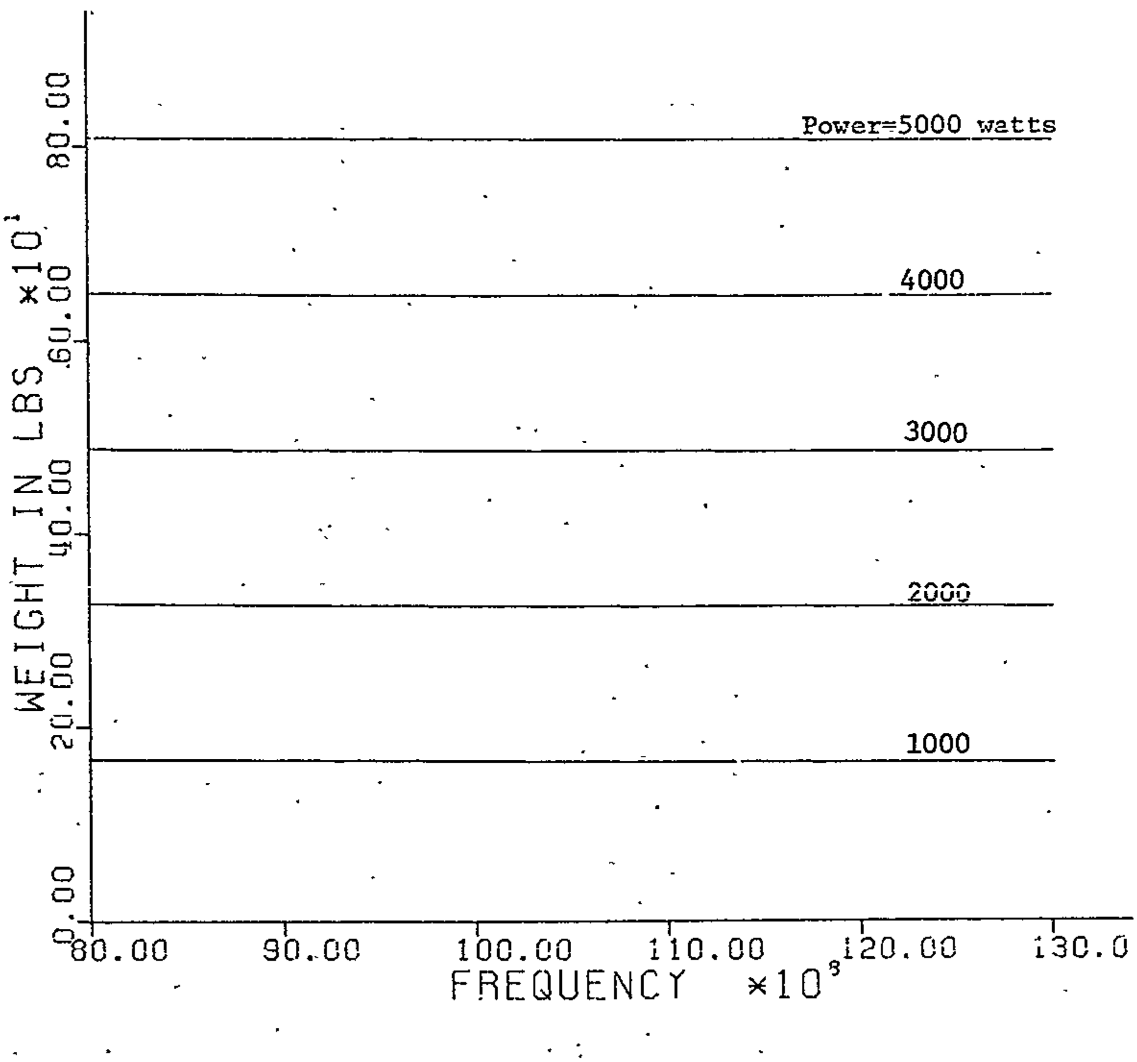
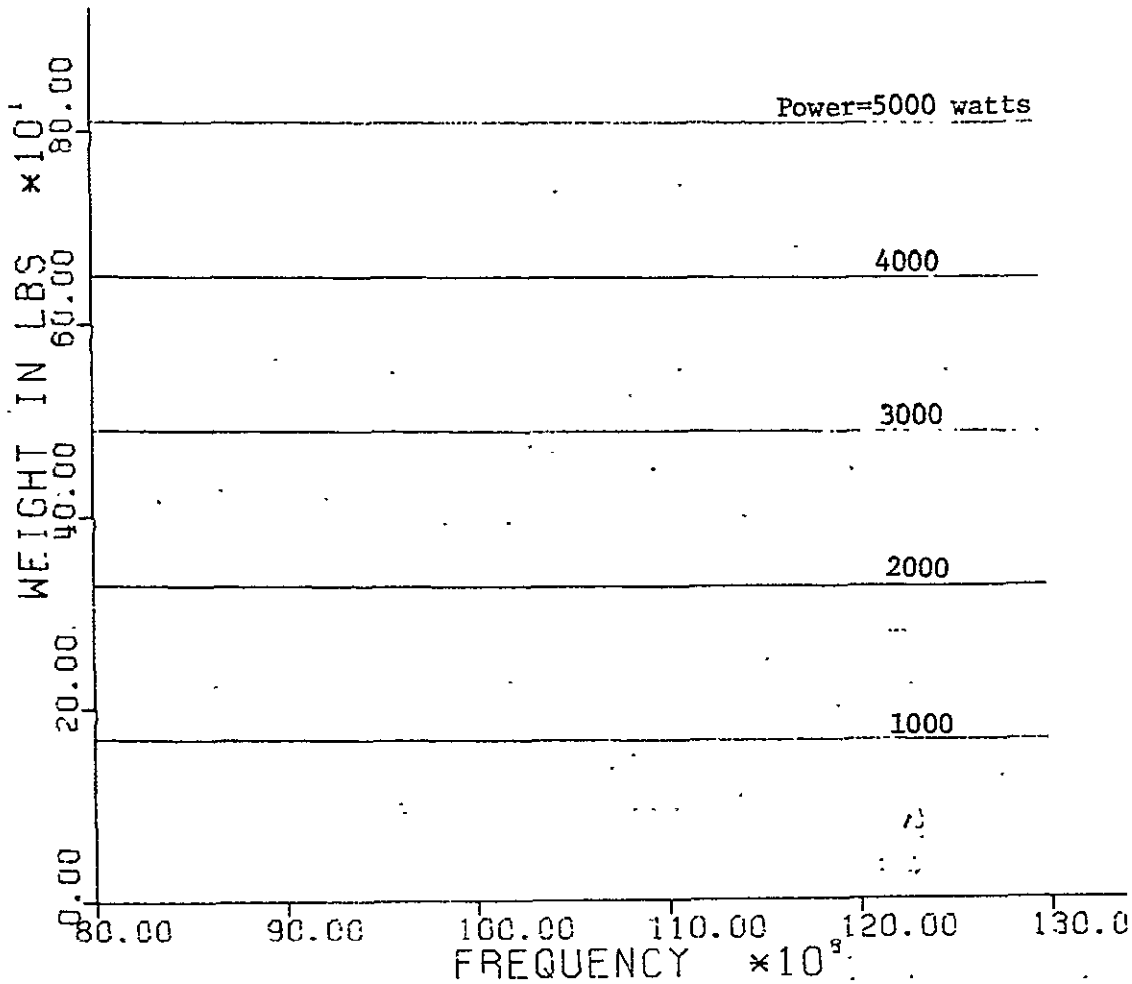


Figure 4-12 -- Communications system weight as a function of frequency from 8.0 GHz to 12.0 GHz with an antenna weight factor of 0.7 pounds per square foot



COMM SYSTEM WEIGHT VS FREQUENCY

FOR SIX VALUES OF TRANSMITTED POWER

Figure 4-13 -- Communications system weight as a function of frequency from 8.0 GHz to 12.0 GHz with an antenna weight factor of 0.9 pounds per square foot

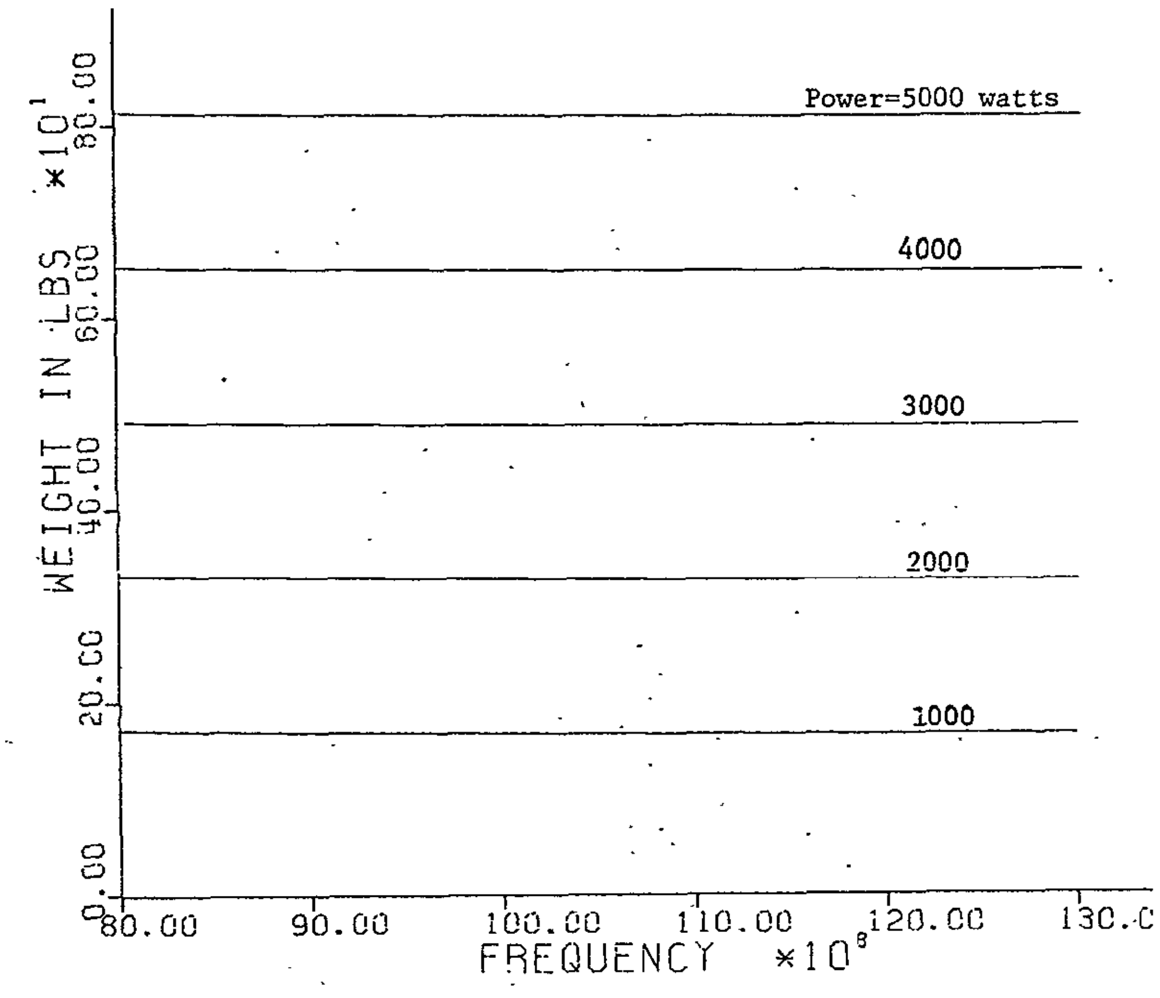
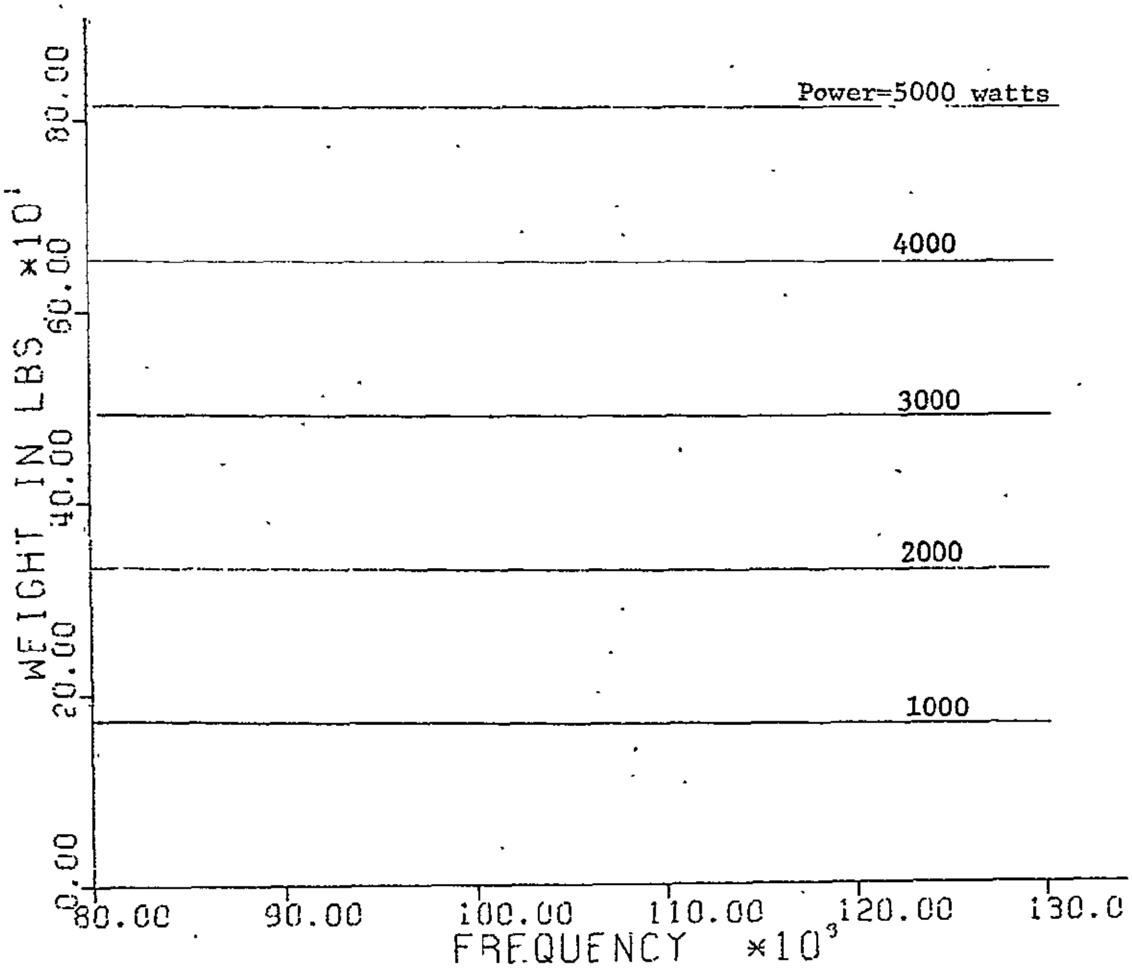


Figure 4-14 -- Communications system weight as a function of frequency from 8.0 GHz to 12.0 GHz with an antenna weight factor of 1.1 pounds per square foot



COMM SYSTEM WEIGHT VS FREQUENCY

FOR SIX VALUES OF TRANSMITTED POWER

Figure 4-15 -- Communications system weight as a function of frequency from 8.0 GHz to 12.0 GHz with an antenna weight factor of 1.3 pounds per square foot

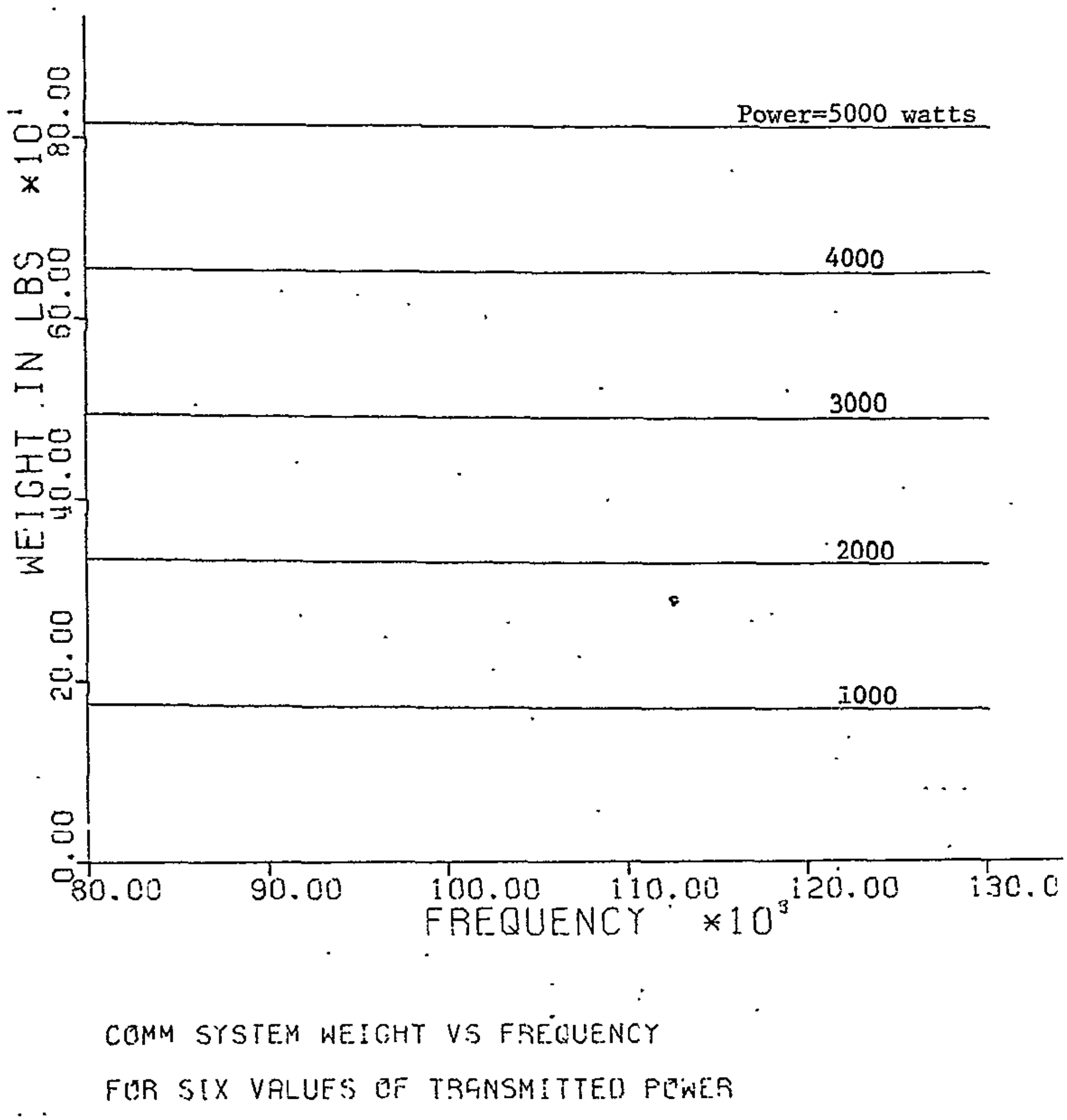


Figure 4-16 -- Communications system weight as a function of frequency from 8.0 GHz to 12.0 GHz with an antenna weight factor of 1.5 pounds per square foot

antenna weight factor. For the frequency bandwidth from 0.8 GHz to 1.0 GHz, there are five plots, Figure 4-2 through Figure 4-6. For the bandwidth from 1.0 GHz to 4.0 GHz, there are five plots, Figures 4-7 through 4-11, and the bandwidth from 8.0 GHz to 12.0 GHz is represented by Figure 4-12 to 4-16. The value of these graphs to system design is that for a given transmitted power and communications system weight factor τ, the variation of the weight of the system with frequency is easily found.

Figure 4-17 is a representation of the same equation with different axes and different variables. In this plot, the total communcations system weight is the ordinate, and the abcissa is parametric antenna weight, pounds per square meter. Each of the curves is for a different wavelength, as indicated on the figure. The value of the graph is that for a given frequency, power, and weight factor τ, total system weight is found as a function of antenna weight factor γ.

The final graph, Figure 4-18, is a plot of the equation 3-9. The derivation of this equation was discussed in Chapter 3. Only the quarter circle to the right of the semicircle midpoint is plotted. Each of the five curves represents a total system weight, shown by the intersection of each curve with the abcissa. The value of a plot of this type is that it can be used to check a system design rapidly.

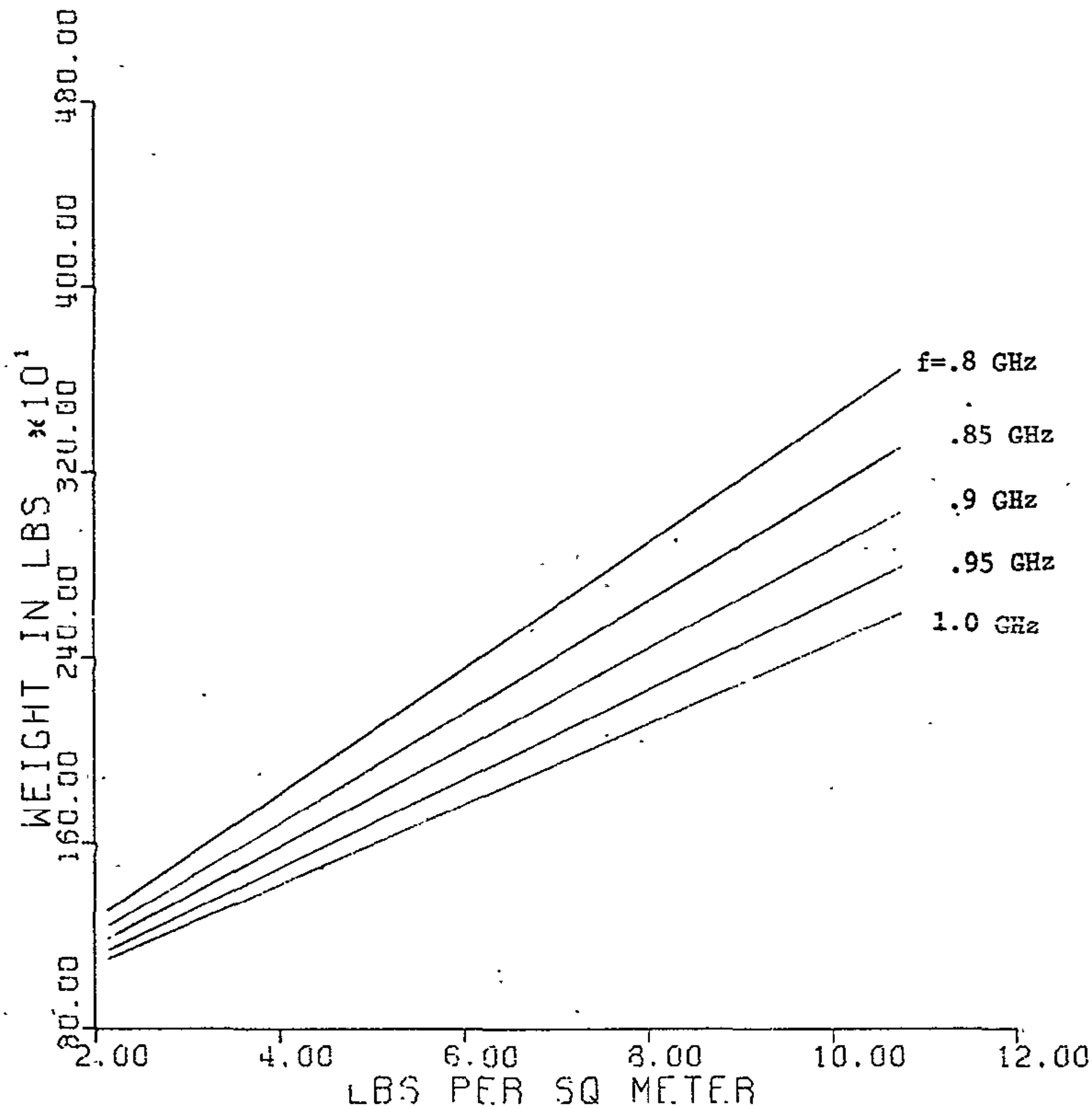
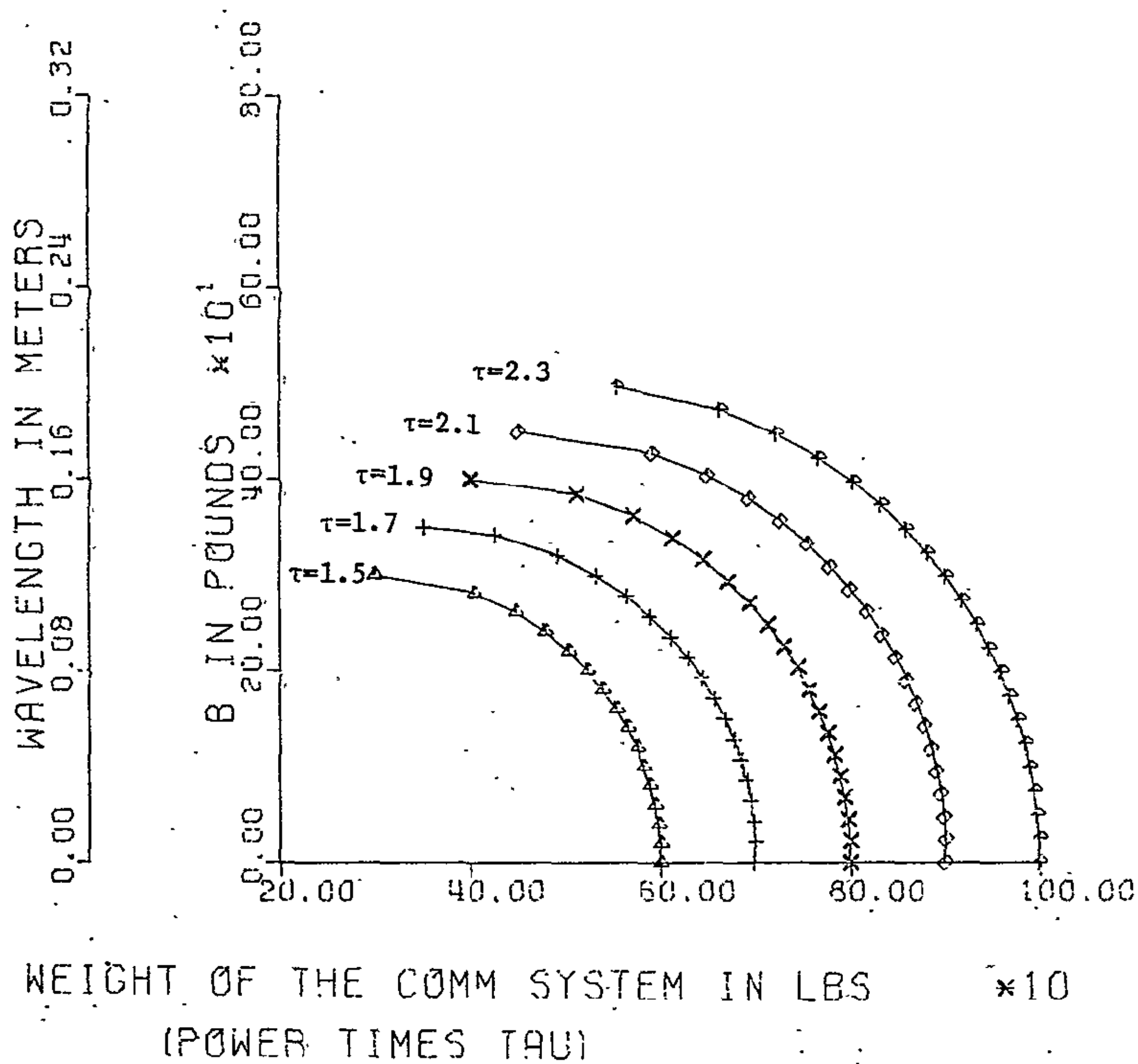


Figure 4-17 -- Total satellite weight as a function of antenna weight factor for five frequencies



B VS WEIGHT OF THE COMM SYSTEM

B EQUALS S*WAVELENGTH*(SQ RT OF (POYNTING VECTOR*G*T)

S=HEIGTH OF SATELLITE, G=ANT WT FACTOR (LBS PER SQ METER),

T=SYSTEM WT FACTOR (LBS PER WATT)

Figure 4-18 -- The circle diagram

V. FUTURE STUDY AND CONCLUSIONS

Although much work has already been done on the problems of designing reliable satellite transmission systems, the state of the art is such that probably certain of the necessary components may not be ready for some time. During this period of development, there is time to fully explore the parametric data. Data may be looked at in depth, using computer methods to analyze and plot the same.

To devise the optimum station, it is advantageous to have access to all pertinent data. To this end it is important to have a continuing comprehensive literature survey with state-of-art information available. To illustrate this point, consider two hypothetical transmitter candidates for a satellite station. Perhaps one transmitter operates most efficiently at 10 GHz, must transmit 10 killowatts to the desired area on earth for an acceptable picture, and requires 50 pounds of cooling equipment for efficient operation. Now, should the second transmitter operate best at 12 GHz with a higher efficiency than that of the first, several points must be considered. Because of the changing absorption rates of the earth's atmosphere for different frequencies, more power might be required to get an acceptable signal to earth from the second transmitter, and the total effect might be that the same amount of cooling equipment is necessary as in the first case. If this was the effect, then additional solar cells would be needed to gather more energy in the second case because of the higher power requirement, adding more weight to the system. If, however, the 12 GHz transmitter is enough lighter than the 10 GHz transmitter to offset the increase in solar cell array weight, then the deciding factor might be the smaller, lighter transmitting antenna that the 12 GHz signal would require. In actual design, the complexity of the problem would be much greater than the example given above.

The time and money spent on the development of a satellite broadcast station would not be justified unless there is reason to believe that such a station is either necessary or less expensive than land-based stations that could cover the same area. For any system design, it is therefore expedient to make a detailed cost analysis on a comparison basis with a comparaible land-based system.

Computer techniques, programs, and methods of data presentations should be continuously examined and up-dated with state-of-art advances. Nonetheless, in checking or designing a particular system, care must be exercised not to allow wishful thinking to affect parametric values which are meant to represent hard data. This is of the greatest necessity, due to the system complexity and the tremendous amount of analysis required to evaluate a complete system with respect to both operation and relative cost.

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12. Shepard, N. F., F. A. Blake, <u>et. al.</u>, "Feasibility Study: 30 Watts Per Pound Roll-Up Solar Array, Final Report," General Electric, JPL Contract No. 951970, June 21, 1968.

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14. Dawson, W. P., L. J. Goldhammer, "Final Report: Solar Cell Radiation Flight Experiment," Hughes Co., JPL Contract No. 952351, May 30, 1969.

15. Jansen, J., P. L. Jordan, et. al. "Television Broadcast Satellite Study," TRW Systems Group, Redono Beach, California, NAS3-9707, October 24, 1969.

APPENDIX

```
DIMENSION BC(103),PR(103),W(103)
CALL PLOT(2.0,2.0,-3)
DO 30 J=1,101
A=J
BC(J)=A*.5-.5
PR(J)=BC(J)*11.11
W(J)=BC(J)*2.133+2.667
WRITE(6,101) BC(J),PR(J),W(J)
FORMAT(5X,F10.6,10X,F10.6,10X,F10.6)
CALL SCALE(BC,5.,101,1)
CALL SCALE(PR,5.,101,1)
CALL AXIS(0.0,0.0,27HBATTERY CAPACITY IN AMP-HRS,-27,5.,0.0,
1BC(102),BC(103))
CALL AXIS(0.0,0.0,25HLOAD REQUIREMENT IN WATTS,25,5.,90.,
1PR(102),PR(103))
CALL LINE(BC,PR,101,1,0,0)
CALL SYMBOL(.1,-1.,.1,36HLOAD REQUIREMENT VS BATTERY CAPACITY
10.0,36)
CALL SYMBOL(.1,-1.3,.1,26HWEIGHT VS BATTERY CAPACITY,0.0,26)
CALL SCALE(W,6.,101,1)
CALL AXIS(5.0,0.0,13HWEIGHT IN LBS,-13,6.,90.0,W(102),W(103))
CALL LINE(BC,W,101,1,0,1)
CALL PLOT(15.,0.0,999)
STOP
END
```

Computer Program for Figure 4-1.

```
 DIMENSION YBUF(65),YLA(13),YLB(13),YLC(13),YLD(13),YLE(13),F(13)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(14),YLB(1)),(YBUF(27),YLC(1)),
1(YBUF(40),YLD(1)),(YBUF(53),YLE(1))
 CALL PLOT(2.0,2.0,-3)
  S=22000.*1760.*36./39.37
 C=3.*(10.**8)
  G=2.1528
  T=2180./12000.
  AS=3.1416*((500.*1760.*36./39.37)**2)
  AS IS APPROX 203*10**10 SQ M
 DO 30 I=1,11
 A=I
  F(I)=(.78+A*.02)*(10**9)
  YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*250.
  YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*500.
  YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*750.
  YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1000.
  YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1250.
 WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I)
 FORMAT(5X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4)
 YLA(12)=YLA(11)
 YLA(13)=YLA(11)
 YLB(12)=YLB(11)
 YLB(13)=YLB(11)
 YLC(12)=YLC(11)
 YLC(13)=YLC(11)
 YLD(12)=YLD(11)
 YLD(13)=YLD(11)
 YLE(12)=YLE(11)
 YLE(13)=YLE(11)
 CALL SCALE(F,5. ,11,1)
 CALL SCALE(YBUF,5.,63,1)
 CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5. ,0.,F(12),F(13))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(64),YBUF(65))
 YLA(12)=YLE(12)
 YLA(13)=YLE(13)
 YLB(12)=YLE(12)
 YLB(13)=YLE(13)
 YLC(12)=YLE(12)
 YLC(13)=YLE(13)
 YLD(12)=YLE(12)
 YLD(13)=YLE(13)
 CALL LINE(F,YLA,11,1,0)
 CALL LINE(F,YLB,11,1,0)
 CALL LINE(F,YLC,11,1,0)
 CALL LINE(F,YLD,11,1,0)
 CALL LINE(F,YLE,11,1,0)
  CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,0.0,31)
  CALL SYMBOL(.1,-1.3,.1,30HFOR FIVE VALUES OF TRANS POWER,0.0,30)
```

Computer Program for Figure 4-2.

```
 DIMENSION YBUF(65),YLA(13),YLB(13),YLC(13),YLD(13),YLE(13),F(13)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(14),YLB(1)),(YBUF(27),YLC(1)),
1(YBUF(40),YLD(1)),(YBUF(53),YLE(1))
 CALL PLOT(2.0,2.0,-3)
  S=22000.*1760.*36./39.37
 C=3.*(10.**8)
 G=6.4583
  T=2180./12000.
  AS=3.1416*((500.*1760.*36./39.37)**2)
  AS IS APPROX 203*10**10 SQ M
 DO 30 I=1,11
 A=I
  F(I)=(.78+A*.02)*(10**9)
  YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*250.
  YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*500.
  YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*750.
  YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1000.
  YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1250.
 WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I)
 FORMAT(5X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4)
 YLA(12)=YLA(11)
 YLA(13)=YLA(11)
 YLB(12)=YLB(11)
 YLB(13)=YLB(11)
 YLC(12)=YLC(11)
 YLC(13)=YLC(11)
 YLD(12)=YLD(11)
 YLD(13)=YLD(11)
 YLE(12)=YLE(11)
 YLE(13)=YLE(11)
 CALL SCALE(F,5. ,11,1)
 CALL SCALE(YBUF,5.,63,1)
 CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5. ,0.,F(12),F(13))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(64),YBUF(65))
 YLA(12)=YLE(12)
 YLA(13)=YLE(13)
 YLB(12)=YLE(12)
 YLB(13)=YLE(13)
 YLC(12)=YLE(12)
 YLC(13)=YLE(13)
 YLD(12)=YLE(12)
 YLD(13)=YLE(13)
 CALL LINE(F,YLA,11,1,0)
 CALL LINE(F,YLB,11,1,0)
 CALL LINE(F,YLC,11,1,0)
 CALL LINE(F,YLD,11,1,0)
 CALL LINE(F,YLE,11,1,0)
  CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,0.0,31)
  CALL SYMBOL(.1,-1.3,.1,30HFOR FIVE VALUES OF TRANS POWER,0.0,30)
```

Computer Program for Figure 4-4.

```
 DIMENSION YBUF(65),YLA(13),YLB(13),YLC(13),YLD(13),YLE(13),F(13)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(14),YLB(1)),(YBUF(27),YLC(1)),
1(YBUF(40),YLD(1)),(YBUF(53),YLE(1))
 CALL PLOT(2.0,2.0,-3)
  S=22000.*1760.*36./39.37
 C=3.*(10.**8)
 G=8.6111
  T=2180./12000.
  AS=3.1416*((500.*1760.*36./39.37)**2)
 DO 30 I=1,11
 A=I
  F(I)=(.78+A*.02)*(10**9)
  YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*250.
  YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*500.
  YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*750.
  YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1000.
  YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1250.
 WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I)
 FORMAT(5X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4)
 YLA(12)=YLA(11)
 YLA(13)=YLA(11)
 YLB(12)=YLB(11)
 YLB(13)=YLB(11)
 YLC(12)=YLC(11)
 YLC(13)=YLC(11)
 YLD(12)=YLD(11)
 YLD(13)=YLD(11)
 YLE(12)=YLE(11)
 YLE(13)=YLE(11)
 CALL SCALE(F,5., 11,1)
 CALL SCALE(YBUF,5.,63,1)
 CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5., 0.,F(12),F(13))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(64),YBUF(65))
 YLA(12)=YLE(12)
 YLA(13)=YLE(13)
 YLB(12)=YLE(12)
 YLB(13)=YLE(13)
 YLC(12)=YLE(12)
 YLC(13)=YLE(13)
 YLD(12)=YLE(12)
 YLD(13)=YLE(13)
 CALL LINE(F,YLA,11,1,0)
 CALL LINE(F,YLB,11,1,0)
 CALL LINE(F,YLC,11,1,0)
 CALL LINE(F,YLD,11,1,0)
 CALL LINE(F,YLE,11,1,0)
  CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,0.0,31)
  CALL SYMBOL(.1,-1.3,.1,30HFOR FIVE VALUES OF TRANS POWER,0.0,30)
```

Computer Program for Figure 4-5.

```
DIMENSION YBUF(65),YLA(13),YLB(13),YLC(13),YLD(13),YLE(13),F(13)
EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(14),YLB(1)),(YBUF(27),YLC(1)),
1(YBUF(40),YLD(1)),(YBUF(53),YLE(1))
CALL PLOT(2.0,2.0,-3)
 S=22000.*1760.*36./39.37
C=3.*(10.**8)
G=2.1528
 T=864./4000.
 AS=3.1416*((500.*1760.*36./39.37)**2)
 S IS THE DISTANCE FROM SAT TO EARTH,P IS POYNTING VECTOR
 AS IS APPROX 203*10**10 SQ M
DO 30 I=1,11
A=I
F(I)=(.7+A*.3)*(10.**9)
 YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*100.
 YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*200.
 YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*300.
 YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*400.
 YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*500.
WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I)
FORMAT(5X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4)
YLA(12)=YLA(11)
YLA(13)=YLA(11)
YLB(12)=YLB(11)
YLB(13)=YLB(11)
YLC(12)=YLC(11)
YLC(13)=YLC(11)
YLD(12)=YLD(11)
YLD(13)=YLD(11)
YLE(12)=YLE(11)
YLE(13)=YLE(11)
CALL SCALE(F,5. ,11,1)
CALL SCALE(YBUF,5.,63,1)
CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5. ,0.,F(12),F(13))
CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(64),YBUF(65))
YLA(12)=YLE(12)
YLA(13)=YLE(13)
YLB(12)=YLE(12)
YLB(13)=YLE(13)
YLC(12)=YLE(12)
YLC(13)=YLE(13)
YLD(12)=YLE(12)
YLD(13)=YLE(13)
CALL LINE(F,YLA,11,1,0)
CALL LINE(F,YLB,11,1,0)
CALL LINE(F,YLC,11,1,0)
CALL LINE(F,YLD,11,1,0)
CALL LINE(F,YLE,11,1,0)
 CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,0.0,31)
 CALL SYMBOL(.1,-1.3,.1,30HFOR FIVE VALUES OF TRANS POWER,0.0,30)
```

Computer Program for Figure 4-7.

```
 DIMENSION YBUF(65),YLA(13),YLB(13),YLC(13),YLD(13),YLE(13),F(13)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(14),YLB(1)),(YBUF(27),YLC(1)),
1(YBUF(40),YLD(1)),(YBUF(53),YLE(1))
 CALL PLOT(2.0,2.0,-3)
  S=22000.*1760.*36./39.37
 C=3.*(10.**8)
 G=8.6111
  T=864./4000.
  AS=3.1416*((500.*1760.*36./39.37)**2)
  S IS THE DISTANCE FROM SAT TO EARTH,P IS POYNTING VECTOR
  AS IS APPROX 203*10**10 SQ M
 DO 30 I=1,11
 A=I
 F(I)=(.7+A*.3)*(10.**9)
  YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*100.
  YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*200.
  YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*300.
  YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*400.
  YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*500.
 WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I)
 FORMAT(5X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4)
 YLA(12)=YLA(11)
 YLA(13)=YLA(11)
 YLB(12)=YLB(11)
 YLB(13)=YLB(11)
 YLC(12)=YLC(11)
 YLC(13)=YLC(11)
 YLD(12)=YLD(11)
 YLD(13)=YLD(11)
 YLE(12)=YLE(11)
 YLE(13)=YLE(11)
 CALL SCALE(F,5., 11,1)
 CALL SCALE(YBUF,5.,63,1)
 CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5., 0.,F(12),F(13))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(64),YBUF(65))
 YLA(12)=YLE(12)
 YLA(13)=YLE(13)
 YLB(12)=YLE(12)
 YLB(13)=YLE(13)
 YLC(12)=YLE(12)
 YLC(13)=YLE(13)
 YLD(12)=YLE(12)
 YLD(13)=YLE(13)
 CALL LINE(F,YLA,11,1,0)
 CALL LINE(F,YLB,11,1,0)
 CALL LINE(F,YLC,11,1,0)
 CALL LINE(F,YLD,11,1,0)
 CALL LINE(F,YLE,11,1,0)
  CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,0.0,31)
  CALL SYMBOL(.1,-1.3,.1,30HFOR FIVE VALUES OF TRANS POWER,0.0,30)
```

Computer Program for Figure 4-10.

```
 DIMENSION YBUF(90),YLA(15),YLB(15),YLC(15),YLD(15),YLE(15),
1YLF(15),F(15)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(16),YLB(1)),(YBUF(31),YLC(1)),
1(YBUF(46),YLD(1)),(YBUF(61),YLE(1)),(YBUF(76),YLF(1))
 CALL PLOT(2.0,2.0,-3)
 C=3.*(10.**8)
 S=22000.*1760.*36./39.37
  G=7.5347
  T=1285./8000.
  AS=3.1416*((500.*1760.*36./39.37)**2)
  S IS THE DISTANCE FROM SAT TO EARTH,P IS POYNTING VECTOR
  AS IS APPROX 203*10**10 SQ M
 DO 30 I=1,13
 A=I
 F(I)=(7.5+A*.5)*(10**9)
  YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1000.
  YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*2000.
  YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*3000.
  YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*4000.
  YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*5000.
  YLF(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*6000.
 WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I),YLF(I)
 FORMAT(2X,F14.1,1X,F14.4,1X,F14.4,1X,F14.4,1X,F14.4,
11X,F14.4,1X,F14.4)
 YLA(14)=YLA(13)
 YLA(15)=YLA(13)
 YLB(14)=YLB(13)
 YLB(15)=YLB(13)
 YLC(14)=YLC(13)
 YLC(15)=YLC(13)
 YLD(14)=YLD(13)
 YLD(15)=YLD(13)
 YLE(14)=YLE(13)
 YLE(15)=YLE(13)
 YLF(14)=YLF(13)
 YLF(15)=YLF(13)
 CALL SCALE(F,5., 13,1)
 CALL SCALE(YBUF,5.,88,1)
 CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5., 0.,F(14),F(15))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(89),YBUF(90))
 YLA(14)=YLF(14)
 YLA(15)=YLF(15)
 YLB(14)=YLF(14)
```

Computer Program for Figure 4-12.

```
YLB(15)=YLF(15)
YLC(14)=YLF(14)
YLC(15)=YLF(15)
YLD(14)=YLF(14)
YLD(15)=YLF(15)
YLE(14)=YLF(14)
YLE(15)=YLF(15)
CALL LINE(F,YLA,13,1,0)
CALL LINE(F,YLB,13,1,0)
CALL LINE(F,YLC,13,1,0)
CALL LINE(F,YLD,13,1,0)
CALL LINE(F,YLE,13,1,0)
CALL LINE(F,YLF,13,1,0)
CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,
0.0,31)
```

Computer program for Figure 4-12 continued.

```
 DIMENSION YRUF(90),YLA(15),YLB(15),YLC(15),YLD(15),YLE(15),
1YLF(15),F(15)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(16),YLB(1)),(YBUF(31),YLC(1)),
1(YPUF(46),YLD(1)),(YRUF(61),YLE(1)),(YBUF(76),YLF(1))
 CALL PLOT(2.0,2.0,-3)
 S=22000.*1760.*36./39.37
 C=3.*10.**8
 G=13.9930
  T=1285./8000.
  AS=3.1416*((500.*1760.*36./39.37)**2)
  S IS THE DISTANCE FROM SAT TO EARTH,P IS POYNTING VECTOR
  AS IS APPROX 203*10**10 SQ M
 DO 30 I=1,13
 A=I
 F(I)=(7.5+A*.5)*(10**9)
  YLA(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*1000.
  YLB(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*2000.
  YLC(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*3000.
  YLD(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*4000.
  YLE(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*5000.
  YLF(I)=G*(S**2)*(C**2)/(AS*(F(I)**2))+T*6000.
 WRITE(6,100) F(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I),YLF(I)
 FORMAT(2X,F14.1,1X,F14.4,1X,F14.4,1X,F14.4,1X,F14.4,
11X,F14.4,1X,F14.4)
 YLA(14)=YLA(13)
 YLA(15)=YLA(13)
 YLB(14)=YLB(13)
 YLB(15)=YLB(13)
 YLC(14)=YLC(13)
 YLC(15)=YLC(13)
 YLD(14)=YLD(13)
 YLD(15)=YLD(13)
 YLE(14)=YLE(13)
 YLE(15)=YLE(13)
 YLF(14)=YLF(13)
 YLF(15)=YLF(13)
 CALL SCALE(F,5., 13,1)
 CALL SCALE(YBUF,5.,88,1)
 CALL AXIS(0.0,0.0,9HFREQUENCY,-9,5., 0.,F(14),F(15))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(89),YBUF(90))
 YLA(14)=YLF(14)
 YLA(15)=YLF(15)
```

Computer Program for Figure 4-15.

```
      YLB(14)=YLF(14)
      YLB(15)=YLF(15)
      YLC(14)=YLF(14)
      YLC(15)=YLF(15)
      YLD(14)=YLF(14)
      YLD(15)=YLF(15)
      YLE(14)=YLF(14)
      YLE(15)=YLF(15)
      CALL LINE(F,YLA,13,1,0)
      CALL LINE(F,YLB,13,1,0)
      CALL LINE(F,YLC,13,1,0)
      CALL LINE(F,YLD,13,1,0)
      CALL LINE(F,YLE,13,1,0)
      CALL LINE(F,YLF,13,1,0)
       CALL SYMBOL(.1,-1.,.1,31HCOMM SYSTEM WEIGHT VS FREQUENCY,0.0,31)
      CALL SYMBOL(.1,-1.3,.1,35HFOR SIX VALUES OF TRANSMITTED POWER,.0,
     135)
      CALL SYMBOL(.1,-1.5,.1,43HWITH ANTENNA WT FACTOR OF 1.3 LBS PER S
     1Q FT,0.0,43)
      CALL PLOT(12.,0.,999)
      STOP
      END
```

Computer program for Figure 4-15 continued.

```
 DIMENSION YBUF(55),YLA(11),YLB(11),YLC(11),YLD(11),YLE(11),G(11)
 EQUIVALENCE(YBUF(1),YLA(1)),(YBUF(12),YLB(1)),(YBUF(23),YLC(1)),
1(YBUF(34),YLD(1)),(YBUF(45),YLE(1))
 CALL PLOT(2.0,2.0,-3)
  R=22000.*1760.*36./39.37
 S=385./10.**12
 PS=250.
 T=2.91
 XLA=3./8.
 XLB=3./8.5
 XLC=3./9.
 XLD=3./9.5
 XLE=3./10.
 DO 30 I=1,9
 A=I
 G(I)=(.1+A*.1)*(39.37**2)/144.
 YLA(I)=T*PS+G(I)*(XLA**2)*(R**2)*S/PS
 YLB(I)=T*PS+G(I)*(XLB**2)*(R**2)*S/PS
 YLC(I)=T*PS+G(I)*(XLC**2)*(R**2)*S/PS
 YLD(I)=T*PS+G(I)*(XLD**2)*(R**2)*S/PS
 YLE(I)=T*PS+G(I)*(XLE**2)*(R**2)*S/PS
 WRITE(6,100) G(I),YLA(I),YLB(I),YLC(I),YLD(I),YLE(I)
 FORMAT(5X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4,2X,F14.4)
 YLA(10)=YLA(9)
 YLA(11)=YLA(9)
 YLB(10)=YLB(9)
 YLB(11)=YLB(9)
 YLC(10)=YLC(9)
 YLC(11)=YLC(9)
 YLD(10)=YLD(9)
 YLD(11)=YLD(9)
 YLE(10)=YLE(9)
 YLE(11)=YLE(9)
 CALL SCALE(G,5., 9,1)
 CALL SCALE(YBUF,5.,53,1)
 CALL AXIS(0.0,0.0,16HLBS PER SQ METER,-16,5., 0.,G(10),G(11))
 CALL AXIS(0.0,0.0,13HWEIGHT IN LBS,13,5.,90.,YBUF(54),YBUF(55))
 YLA(10)=YLE(10)
 YLA(11)=YLE(11)
```

Computer Program for Figure 4-17.

```
 YLB(10)=YLE(10)
 YLB(11)=YLE(11)
 YLC(10)=YLE(10)
 YLC(11)=YLE(11)
 YLD(10)=YLE(10)
 YLD(11)=YLE(11)
 CALL LINE(G,YLA,9,1,0)
 CALL LINE(G,YLB,9,1,0)
 CALL LINE(G,YLC,9,1,0)
 CALL LINE(G,YLD,9,1,0)
 CALL LINE(G,YLE,9,1,0)
 CALL SYMBOL(.1,-1.,.1,51HPARAMETRIC ANTENNA WEIGHT VS TOTAL SATELL
1ITE WEIGHT,0.0,51)
 CALL PLOT(12.,0.,999)
```

Computer program for Figure 4-17 continued.

```
  DIMENSION XBUF(115),X1(23),X2(23),X3(23),X4(23),X5(23),
1 XLAMB(23),B1(23),B2(23),B3(23),B4(23),B5(23),BBUF(115)
 EQUIVALENCE(XBUF(1),X1(1)),(XBUF(24),X2(1)),(XBUF(47),X3(1)),
1(XBUF(70),X4(1)),(XBUF(93),X5(1)),
2(BBUF(1),B1(1)),(BBUF(24),B2(1)),
3(BBUF(47),B3(1)),(BBUF(70),B4(1)),(BBUF(93),B5(1))
 CALL PLOT(4.,3.,-3)
  AS=3.1416*((500.*1760.*36./39.37)**2)
  P=300./AS
  S=22000.*1760.*36./39.37
 C=3.*(10.**8)
  S IS THE DISTANCE FROM SAT TO EARTH,P IS POYNTING VECTOR
  AS IS APPROX 203*10**10 SQ M
  G=6.4583
  T1=1.5
  T2=1.7
  T3=1.9
  T4=2.1
  T5=2.3
  YLA=600.
  YLB=700.
  YLC=800.
  YLD=900.
  YLE=1000.
 DO 30 I=1,21
  A=I
  XLAMB(I)=A*.015-.015
  B1(I)=S*XLAMB(I)*((P*G*T1)**.5)
  B2(I)=S*XLAMB(I)*((P*G*T2)**.5)
  B3(I)=S*XLAMB(I)*((P*G*T3)**.5)
  B4(I)=S*XLAMB(I)*((P*G*T4)**.5)
  B5(I)=S*XLAMB(I)*((P*G*T5)**.5)
  IF(B1(I).GT.YLA/2.)B1(I)=YLA/2.
  IF(B2(I).GT.YLB/2.)B2(I)=YLB/2.
  IF(B3(I).GT.YLC/2.)B3(I)=YLC/2.
  IF(B4(I).GT.YLD/2.)B4(I)=YLD/2.
  IF(B5(I).GT.YLE/2.)B5(I)=YLE/2.
  X1(I)=YLA/2.+(((YLA/2.)**2-(B1(I)**2))**.5)
  X2(I)=YLB/2.+(((YLB/2.)**2-(B2(I)**2))**.5)
  X3(I)=YLC/2.+(((YLC/2.)**2-(B3(I)**2))**.5)
  X4(I)=YLD/2.+(((YLD/2.)**2-(B4(I)**2))**.5)
  X5(I)=YLE/2.+(((YLE/2.)**2-(B5(I)**2))**.5)
  WRITE(6,100) XLAMB(I),B1(I),
1B2(I),B3(I),B4(I),B5(I),X1(I),X2(I),X3(I),X4(I),X5(I)
  FORMAT(5X,F10.4,2X,F10.4,2X,F10.4,2X,F10.4,2X,F10.4,2X,F10.4,
12X,F10.2,/,2X,F10.2,2X,F10.2,2X,F10.2,2X,F10.2,//)
 X1(22)=X1(21)
 X1(23)=X1(21)
```

Computer Program for Figure 4-18.

```
X2(22)=X2(21)
X2(23)=X2(21)
X3(22)=X3(21)
X3(23)=X3(21)
X4(22)=X4(21)
X4(23)=X4(21)
X5(22)=X5(21)
X5(23)=X5(21)
B1(22)=B1(21)
B1(23)=B1(21)
B2(22)=B2(21)
B2(23)=B2(21)
B3(22)=B3(21)
B3(23)=B3(21)
B4(22)=B4(21)
B4(23)=B4(21)
B5(22)=B5(21)
B5(23)=B5(21)
 CALL SCALE(BBUF,4.,113,1)
 CALL SCALE(XBUF,4.,113,1)
 CALL AXIS(0.0,0.0,11HB IN POUNDS,11,4.,90.,BBUF(114),BBUF(115))
 CALL AXIS(0.0,0.0,50HWEIGHT OF THE COMM SYSTEM IN LBS (POWER TIME
1S TAU),-50,4.,0.,XBUF(114),XBUF(115))
 CALL SCALE(XLAMB,4.,21,1)
CALL AXIS(-1.0,0.0,20HWAVELENGTH IN METERS,20,4.,90.,XLAMB(22),
1 XLAMB(23))
X1(22)=X5(22)
X1(23)=X5(23)
X2(22)=X5(22)
X2(23)=X5(23)
X3(22)=X5(22)
X3(23)=X5(23)
X4(22)=X5(22)
X4(23)=X5(23)
B1(22)=B5(22)
B1(23)=B5(23)
B2(22)=B5(22)
B2(23)=B5(23)
B3(22)=B5(22)
B3(23)=B5(23)
B4(22)=B5(22)
B4(23)=B5(23)
 CALL LINE(X1,B1,21,1,1,2)
```

· Computer for Figure 4-18 continued.

```
      CALL LINE(X2,B2,21,1,1,3)
      CALL LINE(X3,B3,21,1,1,4)
      CALL LINE(X4,B4,21,1,1,5)
      CALL LINE(X5,B5,21,1,1,6)
      CALL SYMBOL(.1,-1.,.1,30HB VS WEIGHT OF THE COMM SYSTEM,0.0,30)
      CALL SYMBOL(.1,-1.3,.1,51HB EQUALS S*WAVELENGTH*SQ RT OF(POYNTING
     1 VECTOR*G*T),0.0,51)
      CALL SYMBOL(.1,-1.6,.1,88HS=HEIGTH OF SATELLITE,G=ANT WT FACTOR(L
     1BS PER SQ METER),T=SYSTEM WT FACTOR(LBS PER WATT),0.0,88)
      CALL PLOT(12.,0.,999)
```

Computer program for Figure 4-18 continued.

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