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Space, Telecommunications And Radioscience Laboratory

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SEMI-ANNUAL REPORT

To: Goddard Space Flight Center
Ms. Genevieve Wiseman
Grant Officer

From: Dr. Peter M. Banks PMB
STAR Laboratory
Stanford University

Subject: REMOTE SCIENCE OPERATION CENTER RESEARCH
SEL 39-85

Date: July 1, 1986

The Stanford University/GSFC Cooperative research program has produced significant and important advances in the task areas specified under the Remote Science Operation Center Research Cooperative Agreement. These tasks include the following three areas: The design, planning and operation of a remote science payload operations control center; design and planning of a data link via satellite; and the design and prototyping of an advanced workstation environment for multi-media (3-D CAD/CAE, voice, video, text) communications and operations. The research progress reported here is the results of the combined and cooperative research efforts of the GSFC and Stanford researchers involved.

DESIGN, PLANNING AND OPERATION OF THE REMOTE SCIENCE PAYLOAD OPERATIONS CENTER

Over the past year the payload operations center became a reality with its first operational mission, Spacelab 2. Stanford designed, engineered and implemented a working control center at Stanford for the control of a Stanford instrument onboard Spacelab 2. This entailed the development of a multi-media communications network between GSFC, MSFC and JSC and a fully developed workstation environment at Stanford. The success of the mission and the Stanford remote operations has prompted the follow on simulation activity. Stanford has just completed the enginnering design work to conduct a high fidelity simulation of part of the Spacelab 2 mission. Instead of the mission being conducted in the centralized manner (all orbiter and payload control originating from JSC) it will be conducted in completely distributed manner. Details of the simulation are given in Attachment 1.

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DESIGN AND PLANNING OF A DATA LINK VIA SATELLITE

The satellite research project has just completed the implementation phase and simulation testing is to begin this summer. This prototype research system will be tested aginst user requirements being developed within the Space Station program. Attachment 2 gives complete details of the research completed at this stage.

DESIGN AND PROTOTYPING OF A MULTI-MEDIA WORKSTATION ENVIRONMENT

Research work has proceeded in the area of multi-media workstation environment for potential use in control centers. True multi-media workstations include capabilities to handle 3-D CAD/CAE graphics, video displays, digital voice, text and high resolution color graphics. No singular system has been developed yet which incorporates all of these capabilities. Primary advances in the CAD/CAE have been seen in the research work done on the software and hardware Silicon Graphics IRIS 2400 system. The joint research work at GSFC and Stanford in this area has been good. Robotic simulation, mission payload simulation, stereo imaging displays and compression research are a few of the research areas that progress has been seen in the past year. In the area of video research, considerable progress has been made in the development of interfaces between the state-of-the-art Bosch FGS 4000 video graphics and animation system and the Evans and Sutherland PS 300 and the IRIS 2400 CAD/CAE systems. Graphic object files have been transferred between the display systems via ethernet connections directed by DEC VAX computers. These systems become the essential display systems for control center operations for Shuttle and Space Station. Work has just begun on voice recognition systems and is being integrated into existing workstation systems. The exchange of software and hardware developments under the research efforts at Stanford or at GSFC has enabled considerable progress to be made in establishing future multi-media systems for Space Station.

Enclosure: Attachment 1
Attachment 2

ATTACHMENT 1

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1 INTRODUCTION

The Shuttle has successfully carried Spacelabs 1, 2, 3 and D1 into space. We now have direct experience with multi-discipline space science operations involving the Shuttle and its Spacelab facility. Since Spacelab 1 in late 1983, considerable discussion has arisen within NASA and in the space science community about this new laboratory in space. In particular, a number of space science advisory groups have reviewed the Spacelab missions for overall science productivity. These reviews, unlike engineering reviews, emphasized such areas as scientific publications produced, number of scientists involved, students trained, research time spent and overall science program cost. Their assessment has indicated that they feel the Shuttle provides an exciting new space science capability but the infrastructure (ground facilities for payload design, integration, flight operations and science analysis) is such that science productivity has been limited. NASA and the science community have concluded that the infrastructure must be modified to make it more responsive to space science productivity goals. A number of committees within NASA (Spacelab Mission Implementation Cost Assessment (SMICA), Spacelab End to End Data System (SEEDS), Shuttle Payloads Working Group) and outside NASA (National Academy of Sciences Space Science Board, Task Force for Scientific Uses of Space Station (TFSUSS)) have examined a number of alternate concepts in terms of their impact on the overall space science program. To evaluate and test these concepts an engineering testbed and simulation is being planned involving personnel at NASA Headquarters, Goddard Space Flight Center, Marshall Space Flight Center, Johnson Space Center and Stanford University.

Before discussing specific simulation test areas, it is instructive to examine the functional aspects of the existing Shuttle science payload operations. This can be divided into five key areas: The Mission Control Center (MCC) which has overall responsibility for orbiter flight operations and control, the Payload Operations Control Center (POCC) which has responsibility for all science payload management, operations and control, the science instrument user area which provides capabilities to scientists for the operations and control of their individual investigations, The Spacelab Data Processing Facility (SLDPF) which has responsibility for coordinating all external interfaces and mission data processing requirements and the Communications and Network Control Center (NCC) which coordinates all NASCOM and TDRSS communications. For Spacelabs 1, 2 & 3, the MCC, POCC and user area functions were carried out at JSC while the SLDPF and network communications functions were managed at GSFC.

A typical scenario for a scientist involved in a Spacelab mission is as follows:

1. The investigation is chosen for flight by OSSA.

2. The experimental equipment is designed and built by the scientific group in close coordination with Spacelab mission management and engineers at MSFC. There are extensive communications about safety, compatability, configuration control and documentation, payload timeline formation and interface requirements. Most activities require frequent visits to MSFC by the science team.

3. The experiment's developers, along with all of the diagnostic and test ground support equipment, travel to KSC for integration and test of the experiment hardware in the Spacelab.

4. The operations ground support equipment (GSE) (computers, displays, recorders, etc) is moved from the sceintist's home institution to the user rooms at JSC. The GSE must conform to user room resource allocations (space, power, heat etc.) and specific data flow interfaces.

5. Mission simulations are performed to train all groups. The simulations are run at various time lengths with relatively high fidelity. The fidelity is limited primarily by budgetary considerations.

6. The mission is flown. Direct interaction between the experimental equipment in Spacelab and the scientists is achieved through the cooperative efforts lllof the MCC, POCC and user room personnel at JSC. Real time and near real time data analysis is limited by the limited GSE that the scientist has at Houston. Discussion with other researchers who are associated with the experiment who remain at the home institution is limited to AT&T voice grade lines.

7. The payload and orbiter data is captured at the SLDPF at GSFC and computer tapes of the investigation data is distributed to the scientist's institutions several months after the mission.

The SEEDS working group was convened to review the lessons learned and identify the problems with the present shuttle payload system in terms of space science usage and suggest solutions. They made several significant reccomendations: 1. remote user facilities should be established at the scientists' home institutions 2. a permanent data network should be established for coordination 3. high speed information links should be established for real time data, voice, and video using common data interface standards. 4. a real time calibrated ancillary data set be extracted from the Orbiter parameters and be made available to all users 5. realistic simulation of the mission should be conducted prior to flight.

Recommendations of the SEEDS Working Group

The Spacelab End-to End Data System (SEEDS) working group was formed in January, 1984. 22 representatives from NASA and the user community in universities and industry gathered to examine some of the problems discovered during Spacelab 1 and to formulate recommendations for future development. The final report was released in October, 1984.

The group presented 21 major recommendations for change. Each recommendation had several major subsections. Among the most important were (the numbers are those of the report):

3.1.4 "A capability should be developed that permits remote user access to voice, command, and data networks during all mission phases."

3.2.2 NASA should "assure the timely, electronic availability of Orbiter-Spacelab ancillary data...whether in a POCC or a remote user room."

3.2.1 "NASA should provide computer network access for investigators to communicate with each other and with Spacelab facilities."

3.2.3 "NASA should provide electronic exchange of Spacelab-related information bases and required mission forms."

3.1.5 "An electronic information system should be implemented for each spacelab mission to facilitate the flow of information among the various mission elements."

3.3.2 "Spacelab users should have direct control of onboard experiment hardware within safe limits."

All of these recommedations lead to a final conclusion:

3.3.1 1) "The POCC should be capable of evolving into a distributed system which can accomodate users who will support mission operations from their home institutions. This requires the remote accessibility of instrument data (including digital and video), ancillary data, voice data, and a capability to initiate commands."

1.1 AN EVOLUTIONARY APPROACH TO THE SPACE STATION

The Task Force for Scientific Uses of Space Station (TFSUSS) has coined the word "Telescience" to provide a functional science goal for the design of the Space Station. The concept of telescience will be the basis for scientists' interaction with experiments aboard the space station. This newly developed concept integrates the use of telecommunications tools to conduct scientific investigations in remote, possibly hostile environments. These tools include digital data, video, and voice communications so that the scientist may directly interact with his or her experiment.

The telescience concept was evaluated in the Telescience for The Space Station Era Conference conducted this summer. Researchers from several different scientific areas defined their requirements for telescience operations with space station based experiments. Several of these were:

"Communication with the Space Station from investigator's home institution" to include "control and command of instruments on the Space Station". The participants agreed that "downlink of digital, video, and voice communications in "near-real-time" was necessary. "The downlink ...data transfer to the home institution must be sufficiently fast that real time command decisions can be made (on the order of seconds)."

The report concluded:

"Steps should be taken immediately to develop telescience for the space station era. ...(It is necessaary that) essential ground-based supporting systems are defined and built up in an evolutionary fashion. We recommend that NASA initiate a program of telescience development including intense involvement of the scientific community and incorporating definition studies, pilot science projects, and the development of the basic computer networking systems."

This need for evolutionary, long-term development was echoed in the Space Station Summer Study Report released in March, 1985. The members of this wide-ranging study group recommended:

"NASA should develop an integrated plan for using the space shuttle as a test-bed for the advanced end-to-end communications and information system to be developed for the Space Station for the improvement of scientific operations in space."

The TFSUSS Summer Study of 1985 made science operations and telescience its major agenda items. A number of the recommendations from the operations panel and the Communications and information systems panel revolved around interactive participation of the science community in the definition, design and development of the space station. This interactive participation was seen to take the form of testbeds in parallel to ongoing space science missions. The Shuttle payloads program was viewed as an ideal environment for studying telescience concepts and new technology.

The proposed simulation activity involving the Spacelab capability would provide the first implementation of the above recommendations. The successful engineering of the simulation capability will enable a number of telescience testbeds, involving many disciplines and institutions, to be carried out over the next few years. Many of the TFSUSS recommendations indicate the need to evolve the Shuttle payload program so that space science transitions gradually to the space station. This will require that many of the SEEDS recommendations be gradually integrated into the Spacelab capability. This can only be accomplished efficiently by creating realistic testbeds which involve NASA engineers and space scientists.

2 SIMULATION IMPLEMENTATION APPROACH

Three NASA field centers, GSFC, JSC, and MSFC will work together with Stanford University to implement a simulation that tests the concept and capabilities of a distributed Shuttle payloads operations capability. Each center will have specific areas of responsiblity for the simulation.

Stanford's SUNSTAR research group will have primary responsibility for coordination of all simulation activities. The SUNSTAR Operations Facility (SOF) will serve as the remote user facility. GSFC will have responsibility for the SPLDF and as the NCC. JSC will manage all MCC functions and interfaces. MSFC will be responsible for all POCC functions. NASA Headquarters and these four groups will all serve on the post-test evaluation.

This simulator can test all of the recommendations of the SEEDS working group that were quoted in the first portion of this documentation. It serves as a safe, low-cost, and effective way to test these concepts. Because it is only a simulation, we can safely test procedures and new technology that are not yet fully developed and/or might be considered risky if used for the first time on an actual mission. This allows more direct interaction of the scientist with the Spacelab experimental equipment.

THE FIRST TEST, JULY 1985

The SUNSTAR group first tested the facility during the flight of Spacelab 2. They supported the JSC-based primary research team on the VCAP experiment. The support operations that SUNSTAR provided VCAP's primary research team in Houston were limited. There were several significant problems. The high-speed satellite data link between Goddard and Stanford was not completed, so the full data set was unavailable. As an alternative, the VCAP experiment computer at Houston was programmed to send a low-rate, selected set of data to Stanford via a telephone line, but there were numerous problems with this link that have since been solved. No audio was available, so the team at Stanford could not hear the communications nor could they talk to the Houston team except by long distance phone. This severely limited the interaction between the two groups.

Nonetheless, the SUNSTAR team still had some success. All video that was relayed by the NASA Select channel was recorded, cataloged, and made available for rapid review and study. Some data from the VCAP experiment was presented via real time graphic and numeric displays. The SUNSTAR group analyzed timelines, planned, and coordinated the VCAP experiment with other scientific groups who were conducting ground radar tests and tests with the Dynamics Explorer satellite.

We learned several important lessons. First, even with those limited capabilities, the remote site can provide significant assistance to the primary team. Second, improved communications for data, video and audio are absolutely necessary for future advancement. Third, two-way video information is important to the conduct of the experiment.

REQUIRED CAPABILITIES

For the simulation, the primary scientific team will use the SOF, so support activities alone will not be adequate. Communications and information handling become critical issues. These challenges be may divided into six significant areas:

1. High-speed, real-time, experimental-data relay to the SOF and real-time analysis and display. The experiment data will be transmitted from Goddard to the SOF by a commercial satellite link. Multiple, inter-networked computers at the SOC will prepare the data for real-time display and store it for future analysis.

2. Low-speed data communications for coordination and forms handling. This will be transmitted via the ground based computer network. In addition to electronic mail, this should be used for the electronic transfer of request and rescheduling forms and updated planning and timeline documents. This computer network is important through all phases of planning, execution, and evaluation of the simulation.

3. Low-speed, secure, error-free relay of command instructions to the Spacelab experimental equipment. This can be performed with the same network as in area 2. Additional software will be required.

4. Multiple-channel voice communications. This will require 4-8 channels of audio to the SOC so that the science team may monitor critical operational channels and 2-4 return channels for verbal coordination and discussion with the control cadre and the simulated Spacelab crew.

5. Video data relay and presentation. This may be handled via the NASA select television link to Ames Research Center and microwave relay to the SOF for real-time viewing and recording. The ability to transmit video from the SOF to the NASA centers must also be evaluated.

6. A multi-media teleconferencing capibility is essential to simulate face to face interactions of scientists, MCC and POCC personnel. Compression techniques should be examined to determine the most efficient means of communications.

TASK RESPONSIBILTIES FOR EACH SITE (Discussion points for engineering study)

Goddard Space Flight Center

Goddard will serve as the SLDPF and NCC. The responsibilities are:

- High speed data transmission
- simulated payload data generation
- initial payload data processing
- cross experiment data archiving and retrieval

Johnson Space Center

Johnson will serve as the MCC. The responsibilities are:

- MCC functional simulation
- Orbiter crew participation simulation
- voice links to the MCC and simulated crew
- video imagery generation, selection. and transmission

- realtime simulated Orbiter parameter data
- online storage and retrieval of Orbiter parameter data
- MCC link to simulated remote uplink commanding

Marshall Space FLight Center

Marshall will serve as the POCC. The responsibilities are:

- POCC functional simulation
- voice links to the POCC
- multimedia teleconferencing capabilities for replanning discussions
- timeline and electronic forms handling via network
- POCC-Spacelab data simulation
- Spacelab crew participation simulation
- POCC control of simulated remote uplink commanding

Stanford University SUNSTAR

SUNSTAR will serve as the remote user facility (SOF). The requirements are:

- science team simulation
- generate replanning and rescheduling requests
- monitor and process all video, voice, and instrument data
- generate remote uplink commands for control of experiment

SCHEDULE OF STUDY

December- pre-visit coordination and discussion via telephone

January- SUNSTAR engineering team visits JSC

January- SUNSTAR engineering team visits GSFC

February- SUNSTAR engineering team visits MSFC

June- full team meeting at MSFC

Late June- presentation to Headquarters, Code EM

ATTACHMENT 2

NASA - SPOCC

Communications Progress Report

Bruce B. Lusignan

16 December 1985

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I. Overview

The purpose of the NASA-SPOCC Communications Project is to demonstrate and implement a high-data-rate satellite network to interconnect major NASA centers and smaller remote science centers. Each center will originate a data rate up to 2.0 Mb/sec, which can be received at all other sites and at the remote centers. The high-data-rate stations will be managed by a lower-data-rate network run through small stations. The small stations will also provide direct low-data-rate services to other centers.

In the first phase of the project, one low-data-rate station and a 5 meter high-data-rate receive-only station have been purchased. The antenna for the high-data-rate station has been received and installed. The electronics has been received and is currently being installed.

Two low-data-rate stations have been delivered to Stanford as part of a National Science Foundation project. These are identical to the NASA stations and have been used for tests for both programs. The high-data-rate station and the two low-data-rate stations are shown in Figures 1 and 2.

The next phase of the project is to review the design, purchase and install the up-link high-data-rate station, purchase the second low-data-rate station and install both low-data-rate stations. Upon completion of the second phase, there will be a two-way low-data-rate station at both Stanford and Goddard Space Flight Center, a high-data-rate transmit station at Goddard and a high-data-rate receive station at Stanford. The low-data-rate stations will transmit at a rate of 1.2 kb/sec and receive up to 19.6 kb/sec. The high-data-rate stations transmit and receive at rates of both 56 kb/sec and at 1.544 Mb/sec. Initial demonstrations will be made at 56 kb/sec. The stations power and antenna size is designed to transmit up to 2 Mb/sec if desired.

The following sections present the background link equations, equipment descriptions and cost information for the second phase.

II. Satellite Link Equations

The high-data-rate network is designed to supply two different data rates as standard capabilities. An initial capability of 56 kb/sec will be installed to provide a basic backbone network. This will be used during the first year of network demonstrations. A 1.544 Mb/s capability will be activated when the data needs expand.

For the initial phase, both 56 kb/sec and 1.544 Mb/sec systems will be demonstrated between Stanford and Goddard. It is not likely that the 1.544 Mb/sec will be used regularly until about the second or third year. However, the ground stations will be built with the power capability to support the higher rate from the start. Table I lists the two target data rates.

Table I: Target Performance Parameters

Data Rate	56 kb/sec	1.544 Mb/sec
Worse Case Bit Error Rate (BER)	1×10^{-7}	1×10^{-7}

The satellite selected for the service is the Galaxy III Satellite. This satellite is being used because its cost per EIRP is competitive with the other satellites available and because its saturation flux density is much better than that of the other satellites. As will be seen, the saturation flux density greatly reduces the cost of the transmitting ground station. Table II gives the basic parameters of the Galaxy III Satellite.

Table II: Characteristics of Galaxy III Satellite

Saturated EIRP	34.5 dBw
Saturation Flux Density	-86 dBw/M^2
Orbit Location	93.5^{o} West Long
Frequency Bands:	
Down-Link	3722-3726 MHz
Up-Link	5947-5951 MHz
Receive G/T:	
G Approximate	25 dB
T Approximate	30 dB^{o}K

In Table II the worse case EIRP and Saturation Flux Density have been used. Similarly, the worse case G/T has been used. The frequencies specified are those recommended by the satellite transponder manager. Actually the full C-Band frequencies of the satellite run from 3.7 to 4.2 GHz for down-link and 5.925 - 6.425 GHz for up-link, and the ground stations are able to work on any of these bands. The satellite saturation flux density together with the sensitivity of the ground stations determines the division of total interference between the up-link and the down-link. This has been worked out and the target up-link and down-link performance is presented in Table III.

Table III: Required Up Link and Down Link Parameters

Data Bit Rate	56 kb/sec	1,544 kb/sec
Transmit Bit Rate	64 kb/sec	1,744 kb/sec
Bandwidth with QPSK (R/W = 0.7)	45 kHz	1,230 kHz
C/N Down Link	10.85 dB	10.85 dB
C/N Up Link	18.2 dB	18.2 dB
Total C/N	10.1 dB	10.1 dB
Eb/No (With R/W = 0.7)	8.6 dB	8.6 dB
Bit Error Rate (With 7/8 Code)	1×10^{-7}	1×10^{-7}

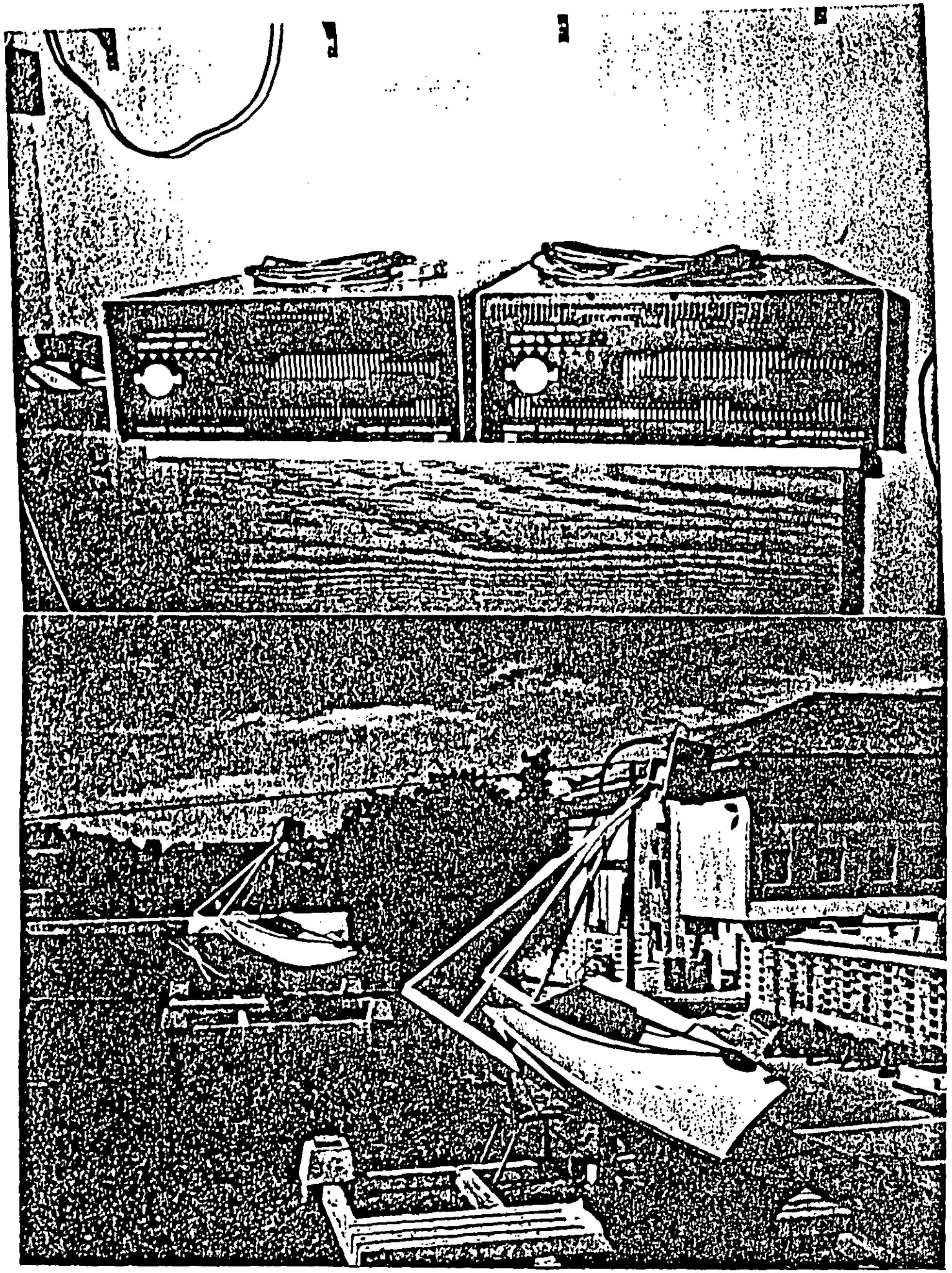

Figure 1. C-200 Ground Stations at Stanford.

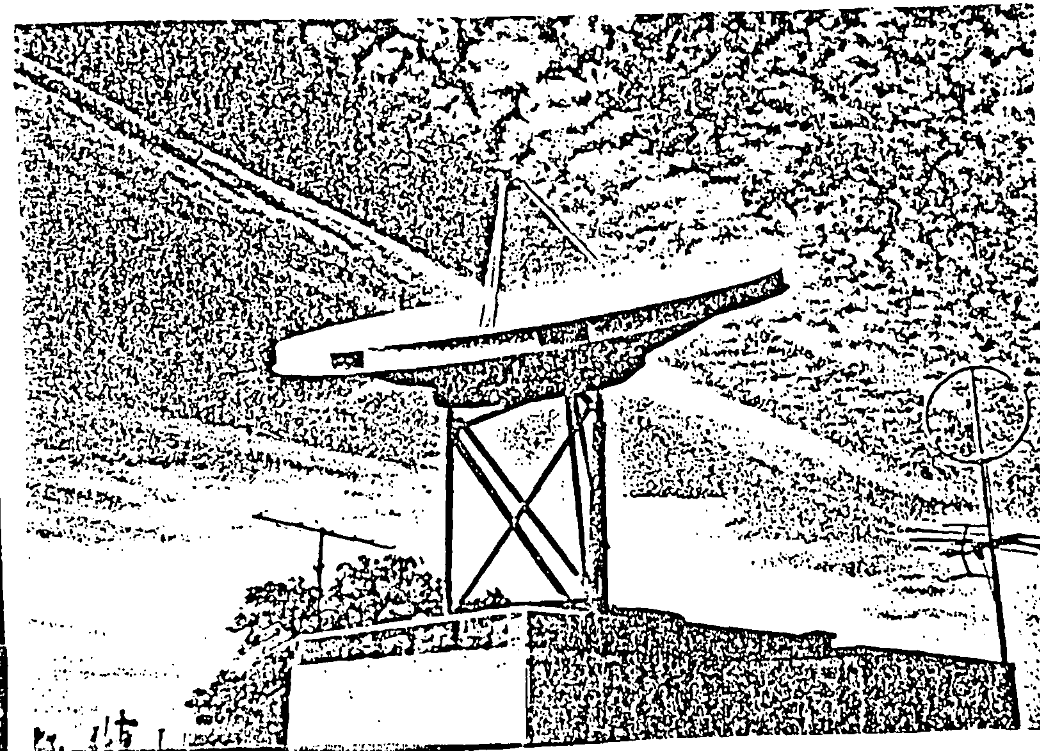

Figure 2. High-Data-Rate Receiver Station at Stanford.

The most critical part of the link is the down-link from the satellite to the 5 meter receiving antenna. This link must have a C/N of 10.85 db. The link calculations are presented in Table IV.

Table IV: Down Link Signal-to-Noise Calculation

Data Bit Rate	56 kb/sec	1,544 kb/sec
Satellite EIRP	3.4 dBw	17.8dBW
Free Space Loss: (f=3738 MHz D=24,7000 Mc)	-195.9 dB	-195.9 dB
Absorption (Water Vapor, Oxygen)	-0.2 dB	-0.2 dB
(Rainfall)	-0.8 dB	-0.8 dB
Receive Antenna Gain (5 Meter Diam)	44.9 dB	44.9 dB
Pointing Error ($\approx$ 0.4 BW)	-2 dB	-2 dB
Polarization Error	-0.25 dB	-0.25 dB
Received Signal Power	-150.85 dBW	-136.45 dBW
Receiver Noise Temperature ($110^{o}K$) (LNA=$85^{o}K$, Antenna Noise =$25^{o}K$)	20.4 $dB^{o}K$	20.4 $dB^{o}K$
Boltzman's constant ($dBW/^{o}K \cdot Hz$)	-228.6	-228.6
Receiver Bandwidth	46.5 dBHz	60.9 dBHz
Received Noise Power	-161.7 dBW	-147.3 dBW
C/N Downlink	10.85 dB	10.85 dB

The up-link power required is calculated knowing the desired down-link EIRP from the satellite, given in Table IV and the characteristics of the satellite. The Galaxy Satellite characteristics are given in Table II. This calculation is given in Table V. Note that the required EIRP is in absence of rain absorption. The EIRP provided by the ground station must in addition account for up-link atmospheric absorption and antenna pointing error. The satellite transponder gain is greater for a transponder operated backed off from saturation. This is assumed to be the case for the NASA application.

Table V: Uplink Power Calculation

Data Bit Rate	56 kb/sec	1,544 kb/sec
Satellite EIRP Down	3.4 dBW	17.8 dBW
-EIRP Saturation	-34.5 dBW	-34.5 dBW
+ Flux Density For Saturation	-86 dBW/M^2	-86 dBW/M^2
-5 dB for Back-Off Gain Increase	-5 dB	-5 dB
4 II R^2 For Flux Density Conversion	+163 dBM^2	+163 dBM^2
Uplink EIRP Required (Note absorption and pointing not included)	40.9 dBW	55.3 dBW

With the indicated up-link EIRP, the up-link carrier-to-noise calculations can be made. These are presented in Table VI. Note that up-link absorption and pointing loss are not included. These factors are included in calculating the ground station power budget, assuming the ground station output power will be adjusted to get the required satellite output EIRP, thus overcoming any up-link losses.

Table VI: Up-Link Signal-to-Noise Calculation

Data Bit Rate	56 kb/sec	1,544 kb/sec
Up-Link EIRP	40.9 dBW	55.3 dBW
Free Space Loss (F=6000 MHz, D=24,700 mi)	-199.8 dB	-199.8 dB
Satellite Receive Gain, Gr	25 dB	25 dB
Received Signal Power	-133.9 dBW	-119.5 dBW
Receive Noise Temp., TR	30 dB°K	30 dB°K
Boltzman's constant (dBW/°K·Hz)	-228.6	-228.6
Receiver Band Width	46.5 dBHz	60.9 dBHz
Received Noise Power	-152.1 dBW	-137.7 dBW
C/N Up-Link	18.2 dB	18.2 dB

The power required for the up-link is calculated in Table VII. Note that the power calculation is done for two different antenna sizes, a 6 meter and a 7.3 meter. The two options are evaluated because of the significant price difference between the two antennas.

Table VII: Up-Link Power Amplifier Required

Data Bit Rate	56 kb/sec	1,544 kb/sec
Nominal Up-Link EIRP	40.9 dBW	55.3 dBW
Pointing Error Margin	2 dB	2 dB
Atmospheric absorption Margin	1 dB	1 dB
Available Up-Link EIRP	43.9 dBW	58.3 dBW
(With 7.3M Antenna) Transmit Gain	50.7 dB	50.7 dBW
Up-link Power	-6.8 dBW	+7.6 dBW
Up-link Power	0.21 Watts	5.7 Watts
(With 6M Antenna) Transmit Gain	48.6 dB	48.6 dB
Up-link Power	-4.7 dBW	9.7 dBW
Up-link Power	0.34 Watts	9.3 Watts

The margins included in the calculations are 3.05 dB on the down-link and 3dB on the up-link, including pointing errors absorption and polarization mismatch. When everything is properly tuned and pointed, we could have as much as 6 dB excess C/N on the links. In addition to these margins, the average site will have some extra margin due to the beam shape of the satellite antenna; the worse case satellite performance was assumed.

The parameter that is fairly critical from cost considerations is the power amplifier requirement. The nominal power is 9.3 watts for worse case 1,544 kb/sec and the 6 meter antenna. With the margins available, a 10 watt amplifier should be acceptable; this rating is available at reasonable cost. The antenna and power amplifier options will be discussed further in the cost section.

III. High-Data-Rate Ground station Design:

The ground station components have been selected from commercial hardware available from standard suppliers. The particular equipment and pricing below represent the best overall price and performance. However, it was found that several companies produce similar equipment at similar prices. This report therefore is not intended to endorse the particular equipment selected. However, the architecture of the network is felt to be optimum; it allows use of the very efficient, moderate-cost stations for up to 2 Mb/sec of data transmission.

The transmit station is shown in block diagram form in Figure 3. It consists of a 6 meter antenna equipped with a transmit-receive feed, a ten-watt solid state power amplifier, an up converter and two modulator encoders. The modulator encoders are controlled by signals from the small ground station, which is also used to transmit low-rate-data directly to the local computer system.

The equipment shown in Figure 3 will be implemented during the current phase. It will allow the station to originate either 56db/sec or 1.544 Mb/sec data from Goddard. The price of the stations equipped with one data rate is $51,993; with both data rates, it is $56,993.

At Goddard the equipment will be located in a four-story building. The large antenna and an instrument box containing the power amplifier and up converter will be located on the roof. Coaxial cable will connect the roof unit to the modulators inside the computer facilities. The small-data-rate outdoor unit will be located on the roof also with coaxial cable bringing the signals to the indoor unit electronics.

Figure 4 shows the receive only ground site. It is equipped with a 5 meter antenna, 85^{o} low noise amplifier, down converter and two receive modems capable of receiving 56 kb/sec or 1.544 Mb/sec. At the receive site, the small station is also used for control of the high-data-rate station and for direct low-rate-data transfer to the local computer network. The approximate cost is $31,990.

Figure 5 shows the configuration of the Phase II central ground-station. It is an expansion of the first station shown in Figure 3. In this full version, three additional receive channels have been added to allow the center to receive data from other centers. The costs shown in Figure 5 are approximate. The full stations are expected to be implemented in about one year. During this period the major modem manufacturers will have newer equipment on the market that is expected to be more flexible (it can change data

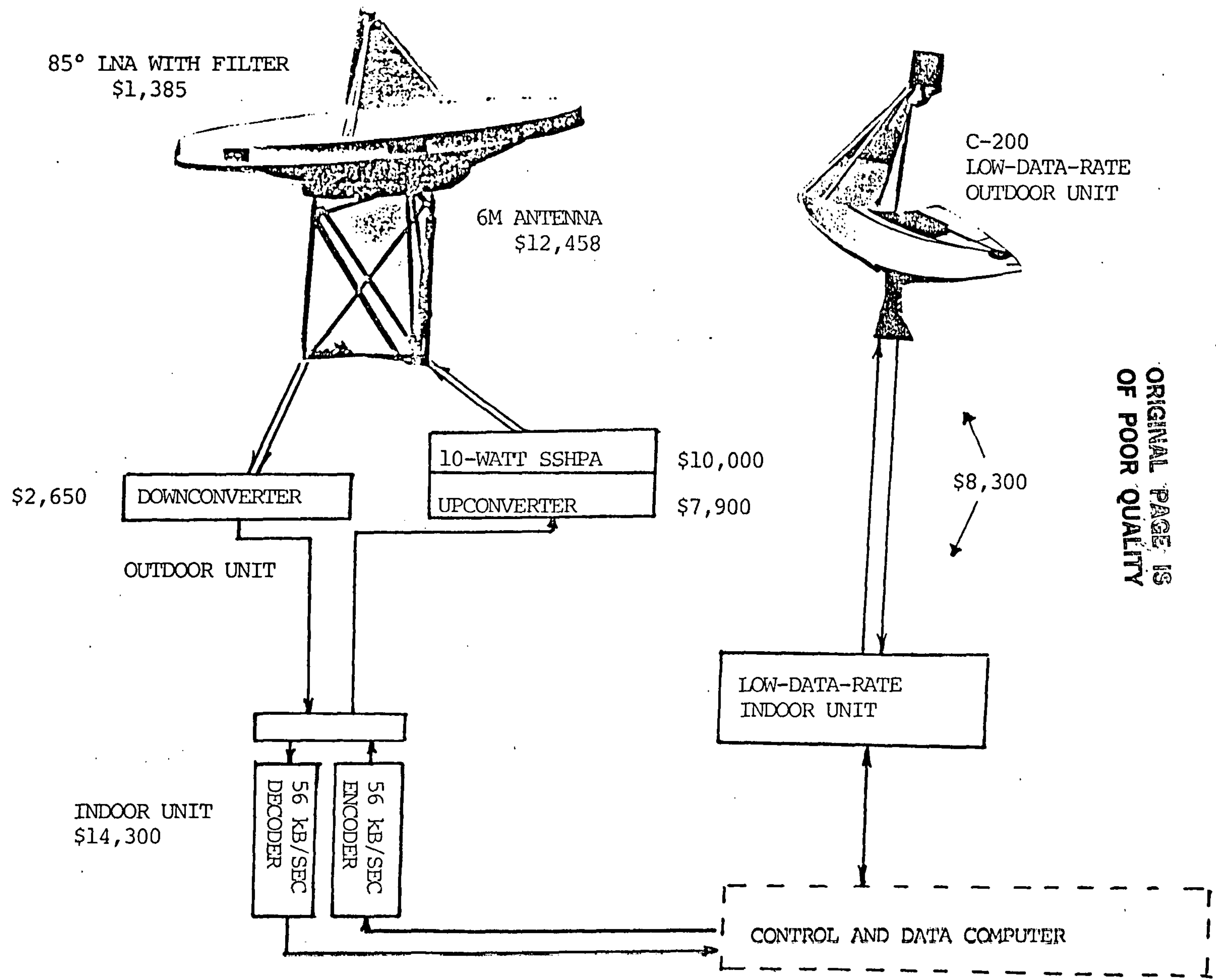

Figure 3. Central Ground Station Facility, First Configuration, $56,993.

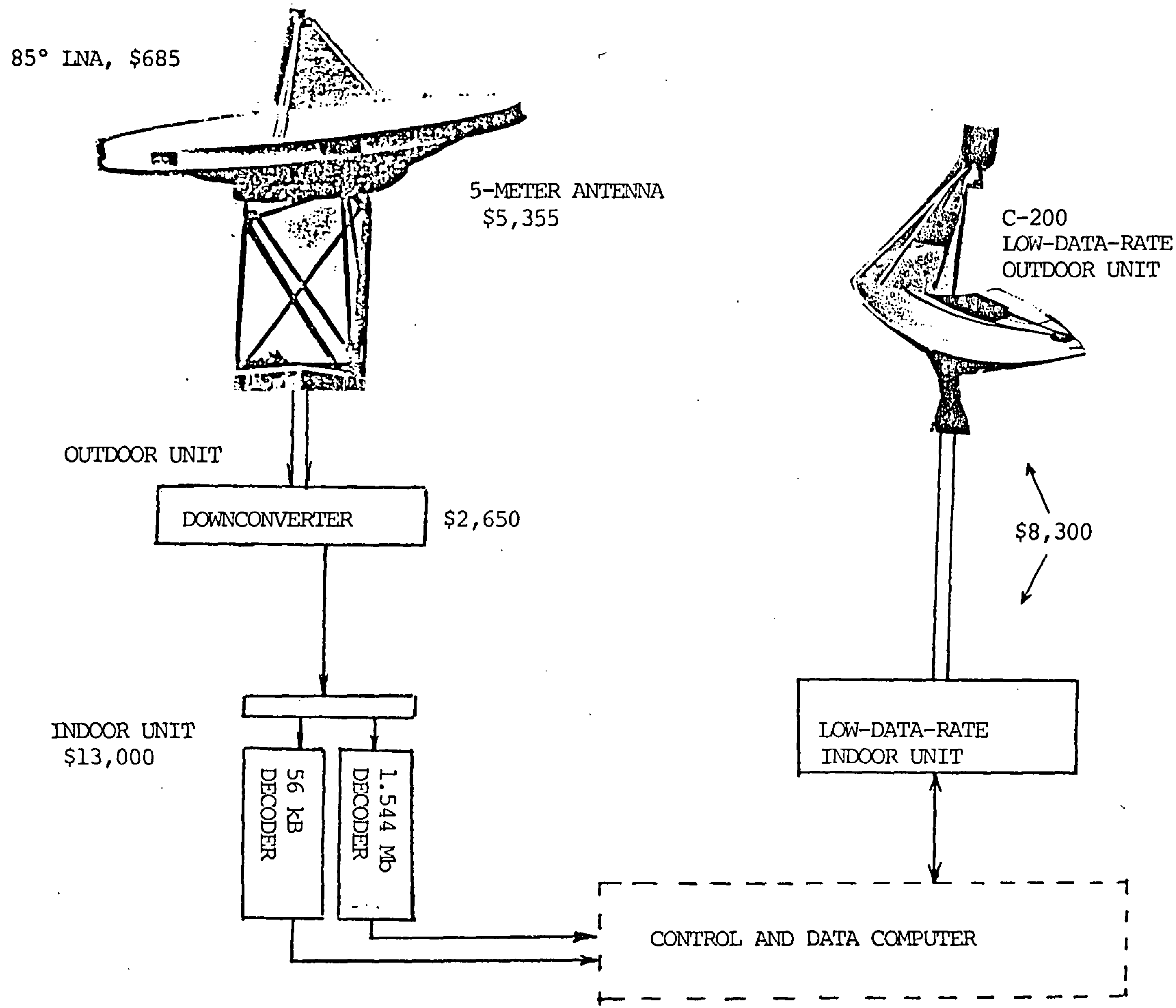

Figure 4. High-Data-Rate Receive Facility, $31,990.

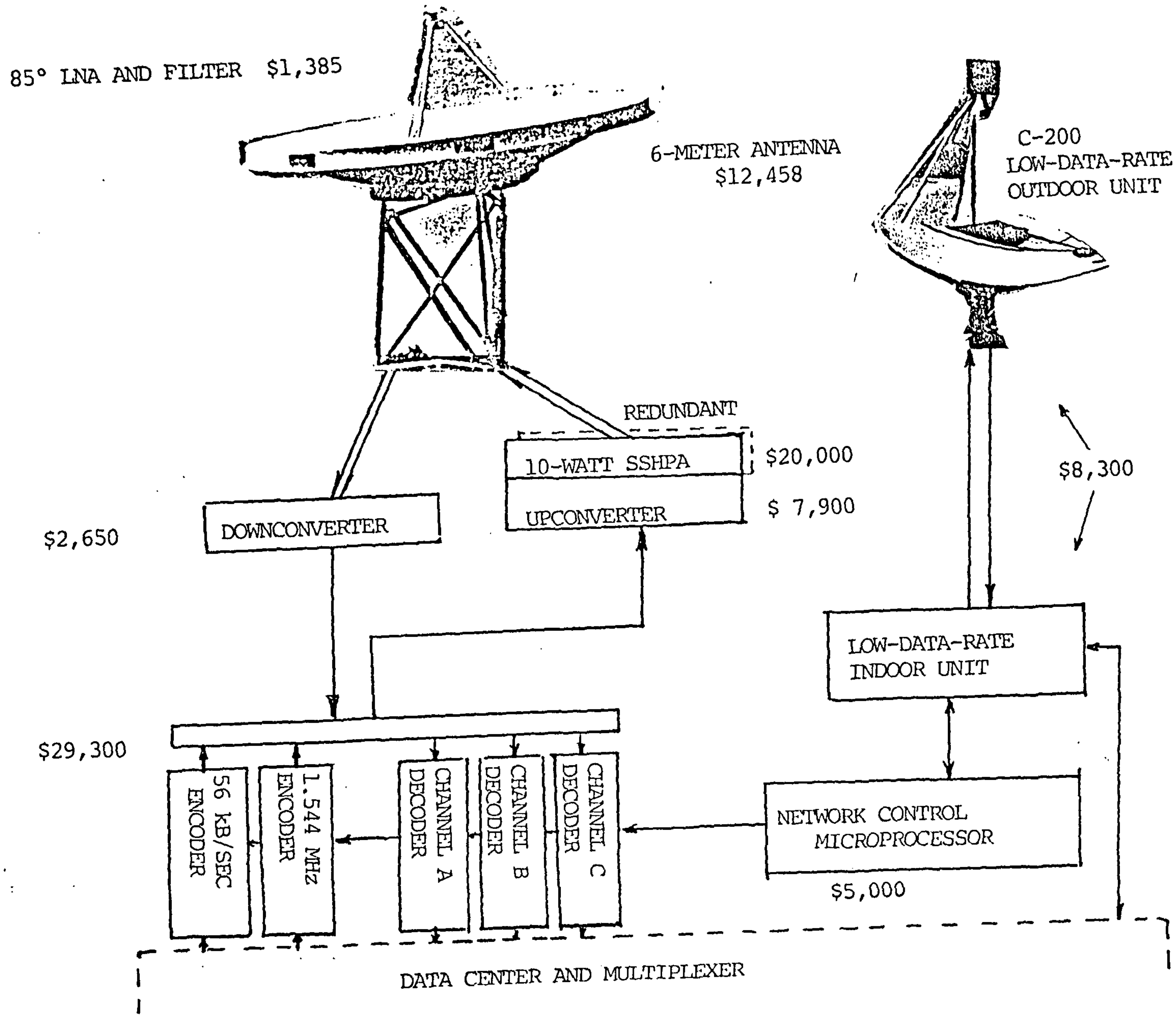

Figure 5. Central Ground Station Facility. Final Configuration, $86,993.

rate by command) and less expensive. The use of continuous rate modems is becoming more standard, which means higher production volume and better costs to users.

The components of these ground stations are shown in Appendix A. The price quotes for this equipment and for the other equipment manufacturers which bid are given in Appendix B.

Note that the size of the transmitting station antenna has been chosen to be 6 meters. This has been selected as most cost efficient with the use of the Galaxy III satellite. The savings in direct cost of the antenna is about $18,000; there is another $2,000 to $3,000 savings in assembly cost. The smaller antenna will result in higher satellite costs for signals transmitted directly between major centers but not for signals transmitted to the 5 meter receive only sites. The main cost disadvantage would have been the need of a higher-power transmitter at the transmit station. However, the sensitivity of the Galaxy III satellite is high. The saturation flux density (Ψ) is -86 dBW/M^2, to achieve 34.5 dBW output Effective Isotropic Radiated Power (EIRP); the Westar satellite requires -84 dBW/M^2 flux density to achieve 32 dBW EIRP. Westar would require about 2.8 times as much power to be trasmitted for the same satellite output.

For the 1.544 Mb/sec data rate, the six meter ground station antenna requires a ten watt power amplifier.

Ten watts is available with a Solid State Power Amplifier (SSPA) at a cost of $10,000 (less in large quanities.) Using the 7.3 meter antenna would allow use of a six watt power amplifier. However, there is little cost difference between six and ten watt SSPA's. (In fact, a six watt SSPA is not available; the five watt unit is priced at $8,000.) Thus, with the Galaxy satellite, the purchase of the larger antenna at an added cost of $18,000 will not be offset by a similar reduction in the cost of the power amplifier.
If the Westar Satellite is used, the ground station power required for the same satellite output power is 2.8 times greater. With a six meter antenna, 1.544 Megabits/sec data rate requires 26.2 watts. With the 7.3 meter antenna, the requirement is sixteen watts. The cost of a Traveling Wave Tube Amplifier (TWTA) able to supply over 26.2 watts is about $18,000. The cost of a SSPA capable of sixteen watts (the current upper limit) is about $13,000. Even if the lower reliability of the TWTA required redundancy where the SSPA did not, the cost of the six meter antenna and redundant TWTA's would be about $45,000. The cost of the 7.3 meter antenna with the single SSPA would be about $40,000. The six meter antenna with redundant SSPA's would be $53,000.

It should be noted, that if the margin for pointing errors on up-link and/or down-link are not included (the antenna pointing can be adjusted periodically), then the sixteen watt SSPA could be used with the six meter antenna with the 1.544 Mb/sec data rate. The six meter antenna with the sixteen watt SSPA and all margins included, would support a data rate of 1 Mb/sec. With a ten watt SSPA it would support 0.6 Mb/sec. The applications for a full 1.544 Mb/sec has not yet been defined for the NASA network; 0.6 Mb/s or 1 Mb/sec may be adequate for many applications.

The decision at this time is to implement the six meter transmit antenna. Used with the Galaxy III Satellite, this antenna can support a 1.544 Mb/sec data rate with a ten watt SSPA. Used with the Westar Satellite, it can support from 0.6 Mb/sec to 1.5 Mb/sec depending on the margins used for pointing error.

IV. Operational Costs Of A NASA Data Network

The see where the current development is headed, it is useful to determine the price of a full network based on the hardware and satellite prices. The following cost estimate is based on fixed-price quotes from equipment manufacturers and satellite common carriers contained in Appendix B.

The parameters of the network are summarized below.

Master Sites

There are four master sites located through the United States. Each site is equipped with two satellite stations, a large high-data-rate station and a small network management station. The high-data-rate stations have two channels of data transmission equipment, to be able to originate different data rates. Each also has three receive channels to receive from the other stations. The high-data-rate stations have a six meter antenna and a ten watt Solid State Power Amplifier (SSPA). Pricing estimate includes a spare SSPA. (Reliability estimates indicate however that this might not be necessary.) The station receiver uses an 85°K Low Noise Amplifier (LNA). The Network Management Station is an Equatorial C-200 ground station providing direct control for the selection of bit-rate, power level, and center frequencies for the high-data-rate station. In addition, the Network Management Station provides a direct link for low-data-rate information transmission between all sites in the network.

The capital cost for this site including radio licensing and installation is approximately $57,000.

Remote Receive Sites

There are eight remote receive sites throughout the United States. Each site is equipped with a high-data-rate receive station and a Network management Station.

The high-data-rate stations are each equipped with two receive channels that can receive two simultaneous channels from any of the four master sites. They use a five meter antenna and an 85°K LNA.

The remote receive sites have a Equatorial C-200 ground station for network management. It sets the receiver units to match the required network configuration. In addition, it provides an alternative network link for low-rate data transfer.

The capital cost is approximately $32,000.

Auxiliary Sites

There are assumed to be another ten locations in the United States equipped with low-data rate facilities only. Low-rate data transmitted from any of these ten sites, the four master sites, or the eight remote sites can be received at any other. Each site can originate data at a 1,200 b/s rate and can receive an aggregate data rate up to 19.6 db/sec if necessary. The auxiliary sites normally would not be linked with the control network for the high-data-rate sites. They would be used for more standard direct information transfer among the NASA scientific community. They cost $83,000. 8,300

Network Control

The low-data-rate C-200 stations are configured in a fully interconnected single network for management information flow. Any message input at one station will come out at all the other stations. Standard software procedures are used to "address" the messages for the desired destination. The computers connecting to each station review the address field of the data packet, ignore it if it is not theirs, and route it accordingly if it is desired.

Because input from one station appears at all stations outputs, the packet addressing can be used either to send data just one site to another, from one site to many (a broadcast mode), or from many sites to many sites (a community bulletin board mode).

The C-200 stations at the high-data-rate sites are equipped with a second port entirely separate from the more general network described above. This port is used to control transmissions through the satellite and thus must be rigidly controlled to avoid unauthorized power levels or frequency changes that will cause interference to other users of the satellite or that might result in loss of data to the NASA users. The control signals are originated from one site that can be any one of the high-data-rate locations. Responses return to that site only. The network is not complicated and the computer programs needed to control it are not difficult. However, they do require cross checks and access coding to avoid miscues.

A $5,000 control computer is assumed to be used at the central control site to display network status and manage changes. $2,000 control computers are included at the high-data-rate sites to monitor status and check change orders.

Satellite System

The network interconnection is based on use of channels in the Galaxy III Satellite. The Pricing is quoted in Appendix B. The costs will be a function of the actual data rates used and these can be adjusted on a month-by-month basis to suite the needs for data interconnect.

The monthly charges for the high-data-rate services are summarized in Table VIII. It is felt that the "Background Level", 56 kb/sec from all four master sites, might be used under most conditions when a photographic type of scientific mission is not in progress. The "Typical Mission" is assumed to require 1.544 Mb/sec from two sites and 56 kb/sec from the other two. Note that any combination of transmissions adding to the same total data rate would have the same cost. Note also that any number of remote receive-only sites can be added to observe the data without increasing satellite costs.

The "Maximum Capacity" calculation assumes that each of the four master sites originate 1.544 Mb/sec. These data streams can be received in any desired combinations at all high-data-rate sites. Note that the "Maximum Capacity" represents what is felt to be a reasonable upper limit for NASA's needs. At the current stage of development, it is not as yet defined how this rate would be usefully employed. The equipment purchased is actually able to transmit 2 Mb/sec from each site with no major modification.

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Table VIII. Satellite Segment Costs

I.	Background Level:	
	Low-data-rate station; assumes access charges for 12 sites and 4.8 kb/sec data max	$ 6,300/mo
	High-data rate - 56 kb/sec for 4 channels @ $500/mo each.	2,000/mo
	Total Background Level	$ 8,300/mo
II.	Typical Mission Level:	
	Low-data-rate station; assumes access charges for 12 sites and 4.8 kb/sec data max	$ 6,300/mo
	High-data-rate - 56 kb/sec for two channels @ $500/mo each	1,000/mo
	High-data-rate 1,544 Mb/sec for two channels @ $7,500/mo each	$15,000/mo
	Total Typical Mission	$22,300/mo
III.	Maximum Capacity	
	Low-data-rate station; assumes access charges for 12 sites and 4.8 kb/sec data max	$ 6,300/mo
	High-data-rate - 1,544 Mb/sec for four channels @ $7,500/mo each	$30,000/mo
	Total Maximum Capacity	$36,300/mo

Appendix A

Ground Station Hardware

Transmit Station:

Antenna - Starview 6 Meter, Model 6M
Power Amplifier - Comtech 10 Watt, HPA 280-X02
Up Converter - Comtech - Model 250 AU
Modem - General Description - SM 200A
- Convolutional Encoder
- Modulator
- Modem Switch
- Frequency Synthesizer

Receive Station:

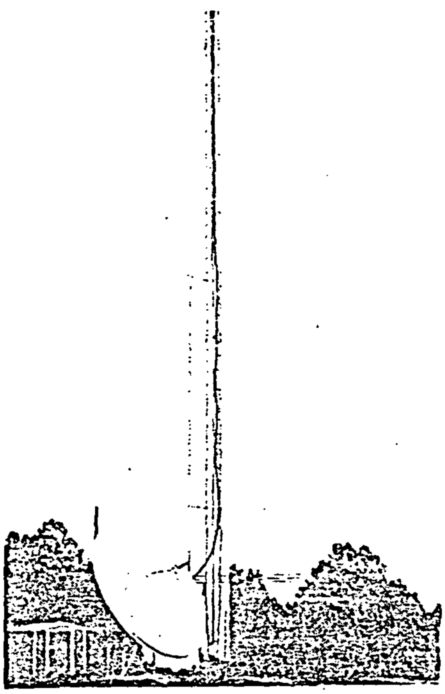
Antenna - Comtech 5 Meter
Low Noise Amplifier - Comtech 85°K
Down Converter - Comtech Model 250 AD *
Modem - General Description - SM 200A
- Demodulator *
- Modem Switch
- Frequency Synthesizer *
- Convolutional Decoder *

* Same Brochure As Transmit Station

CRAIG®

Star View Systems™

6 METER SATELLITE TVRO ANTENNA SYSTEM



MODEL 6M

FEATURES

- ECONOMICAL
- LIGHTWEIGHT
- LOW SHIPPING VOLUME
- HIGH-EFFICIENCY PERFORMANCE
- ADJUSTABLE ELEVATION/AZIMUTH MOUNT
- PRIME FOCUS BUTTON-HOOK FEED SYSTEM
- 32-25 LOG θ PATTERN
- RAPID INSTALLATION AND PERFORMANCE VERIFICATION
- MEASURED SIDE LOBES ARE IN COMPLIANCE WITH FCC REQUIREMENTS FROM THE FIRST LOBE TO 48° OFF BORESIGHT, AND ARE BELOW – 10 dBi FROM 48°.

DESCRIPTION

Designed specifically to meet the growing demand for large antenna systems for television receive-only and special application satellite communication earth terminals, the Model 6M Antenna System offers a unique combination of high efficiency and compact packaging. Extremely light weight and low shipping volume make the system ideal for transport to, and handling at, remote locations, congested areas, or points of difficult access such as rooftop installations.

The system consists of the 6-meter parabolic reflector, prime focus feed, and an elevation/azimuth mount which provides adjustments in latitudes from 0° to 360° and elevations from 5° to 70°.

The reflector is a solid surface heavy duty structure 6 meters (20 feet) in diameter with a focal length of 76 inches. Construction is of high strength, corrosion resistant fiber glass, assuring minimum shipping weight. Mounting holes are drilled with precision machining fixtures to facilitate accurate and trouble-free assembly at the site.

The dual-polarized high efficiency feed is located at the prime focus of the reflector with the low noise amplifier mounting to the ortho modecoupler. The input to the feed is through a polarization rotation plate which permits a 360° rotation of the feed to change polarity. When the optional low noise amplifier is supplied, the input connector is type "N" female.

The entire system is designed to facilitate rapid on-site installation, whether installed by the user or installed by H&R on a turnkey basis.

H&R COMMUNICATIONS

Subsidiary of Craig Corporation

800-643-0102 or 501-647-2291 Pocahontas, Arkansas 72455

Star View Systems™ CRAIG®

6 METER SATELLITE TVRO ANTENNA SYSTEM SPECIFICATIONS

ELECTRICAL

Frequency	3.7 - 4.2 GHz (C-Band) and 11.7 to 12.2 GHz
Polarization	Linear (Fixed, Rotatable 360°) or Duel
Noise Temperature	
Elevation Angle (Deg.)	Noise Temperature (Deg. Kelvin)
5	39.54
10	31.40
20	22.94
30	19.61
40	17.51
50	16.43
Gain @ 4.0 GHz ± 0.2 dBi =	46 dB
First Side Lobes	-10 dBi
VSWR	1.25 max.
Half Power Beamwidth	0.97°
-15 dB Beamwidth	2.05°
Input to feed	CPR - 229F Waveguide Flange
Input to Low Noise Amplifier (optional)	Type "N" female
Gain, ± 0.2 dBi	
12 GHz at Input Flange	55
Beamwidth, Degrees (mid-band)	
12 GHz	
−3 dB	0.3
−15 dB	0.6
VSWR (Maximum)	1.30/1
Input Flange 12 GHz	WR-75
Side Lobe Characteristics	Side lobes are below an envelope formed by 32-25 log θ from the first side lobe to 48° off boresight. From 48° on, the side lobes are below — 10 dBi.

MECHANICAL

Reflector Diameter	6 meters (20 feet)
Mount Type	Elevation/Azimuth
Reflector Surface Tolerance	040 RMS static
F/D Ratio	.31
RMS Pointing Error	0.06° to 30 MPH winds gusting to 45 MPH and ¼ inch radial ice 0.08° with 45 MPH winds gusting to 60 MPH and ¼ inch radial ice
Operating Temperature	-51° C to + 55C
Survival Wind Loads	85 MPH winds with ½" radial ice 120 MPH winds - no ice
Survival Shock	1X on Mercalli scale with 30 MPH winds
Survival Temperature	-51°C to + 70°C
Elevation Adjustment Coverage	5° to 70°
Azimuth Adjustment	0° to 360°
Antenna Weight	850 pounds
Shipping Cube	700 cu. ft.

H&R COMMUNICATIONS
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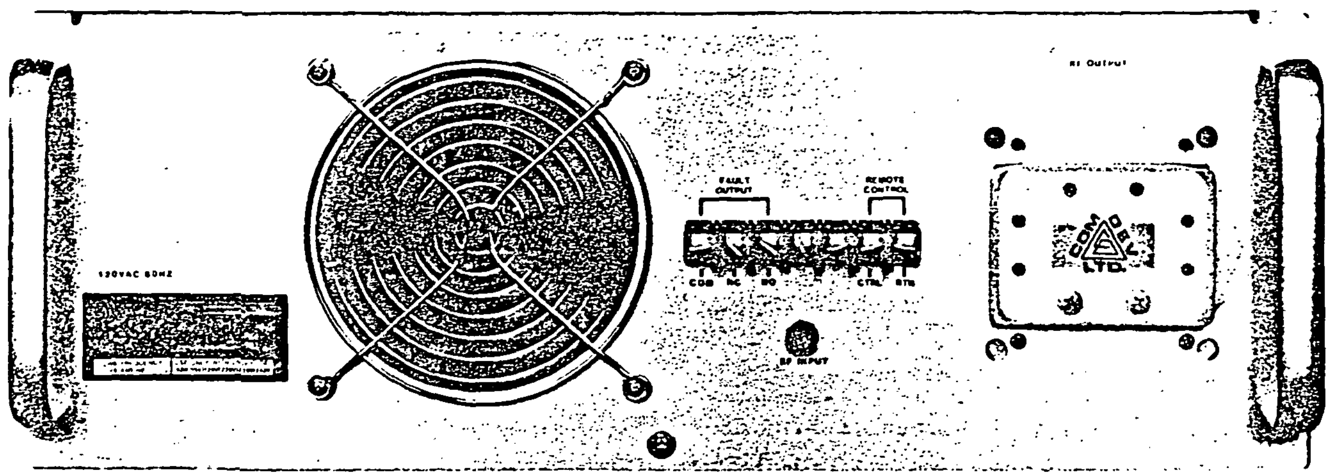

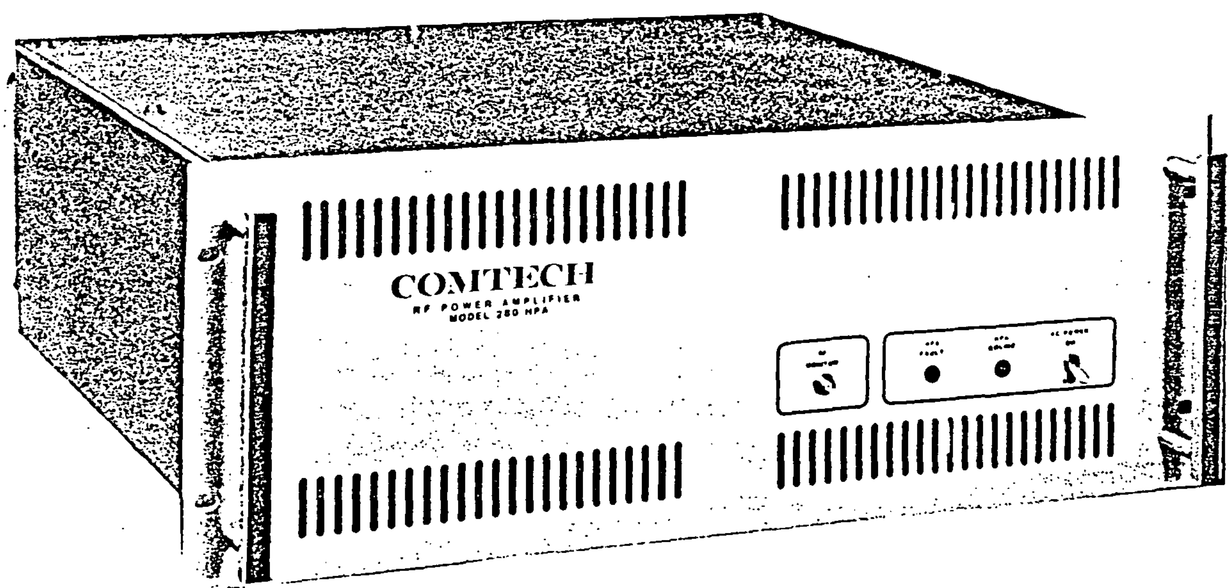

FEATURES

- 5, 10 or 16 Watt Power Output
- Fault Summary
- Thermal Cutout
- Front Panel RF Monitor

INTRODUCTION

Comtech Data Corporation's power amplifier was designed specifically for use with low power satellite uplinks. Packaged in a standard 19" rack mount housing, they are ideal for use in small aperture low power uplinks transmitting SCPC, analog and digital signals. Operating in the 5925 to 6425 MHz frequency range, the amplifier is compatible with Comtech's 250 series of up/down converters and complements Comtech's CDM 1120 SCPC Modulator.

The amplifier features a thermal cutoff and is equipped with a fault summary indicator.

OPTIONAL FEATURES:

- Fault senses loss of output RF signal
- ON/OFF Remote Control
- 5 Watt X01
- 10 Watt X02
- 16 Watt X03*

$8,000

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$10,000

SPECIFICATIONS

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

5 WATT POWER AMPLIFIER - SPECIFICATIONS

INPUT FREQUENCY:	5925 MHz - 6425 MHz
NOISE FIGURE:	10 dB maximum
INPUT IMPEDANCE:	50 ohms, VSWR = 2:1
INPUT LEVEL:	−19 dBm to −13 dBm
GAIN FLATNESS:	+/−0.5 dB over any 20 MHz segment for a constant input level of −16 dBm, +/−0.5 dB over any 24 hour period.
GAIN (at −10 dBm input)	47 dB minimum
POWER DEVICE:	GaAs FET Amplifier
OUTPUT SPURIOUS:	−25 dBm maximum with an input level of −10 dBm
HARMONIC OUTPUT	−35 dBc
OUTPUT IMPEDANCE:	50 ohms, VSWR + 1.3:1 maximum
OUTPUT POWER CAPABILITY:	+37 dBm for an input level of −10 dBm
AM/PM @ 1dBc COMPRESSION:	1.5°/dB typical
TYPICAL OPERATING LEVEL:	+30 dBm
CONNECTORS:	SMA-F
XMIT BANDPASS FILTER:	
Passband:	5925 MHz - 6425 MHz
Loss:	0.15 dB maximum
VSWR:	1.15:1 maximum
Connectors:	Type CPR-137G Waveguide flange
PACKAGE:	19″ wide, 5½″ high, and 21″ deep rack mount
WEIGHT:	30 lbs
POWER CONSUMPTION:	110 VAC, 60 Hz, 168 Watts
MTBF	37, 464 HRS

10 WATT POWER AMPLIFIER - SPECIFICATIONS

INPUT FREQUENCY:	5925 MHz - 6425 MHz
NOISE FIGURE:	10 dB maximum
INPUT IMPEDANCE:	50 ohms, VSWR = 2:1
INPUT LEVEL:	−19 dBm to −13 dBm
GAIN FLATNESS:	±0.5 dB over any 20 MHz segment at 25 dBm output; 0.2 dB over any 20 MHz segment at −10 dBm input
GAIN (at −12 dBm input)	52 dB minimum
POWER DEVICE:	GaAs FET Amplifier
OUTPUT SPURIOUS:	−60 dBc minimum
HARMONIC OUTPUT:	−30 dBc minimum
OUTPUT IMPEDANCE:	50 ohms, VSWR + 1.3:1 maximum
OUTPUT POWER CAPABILITY:	+40 dBm for an input level of −12 dBm
AM/PM @ 1 dBc COMPRESSION:	2°/dB maximum
MAXIMUM INPUT LEVEL:	−5 dBm for 10 minutes maximum
CONNECTORS:	SMA-F
XMIT BANDPASS FILTER:	
Passband:	5925 MHz - 6425 MHz
Loss:	0.15 dB maximum
VSWR:	1.15:1 maximum
Connectors:	Type CPR-137G Waveguide flange
PACKAGE:	19″ wide, 5½″ high, and 21″ deep rack mount
WEIGHT:	30 lbs
POWER CONSUMPTION:	110 VAC, 60 Hz, 248 Watts

*Contact Comtech for 16 Watt specifications

COMTECH

Comtech Data Corporation   Comtech Antenna Corporation

Subsidiaries of Comtech Inc.

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COMTECH ANTENNA CORPORATION • 3100 COMMUNICATIONS RD • PO BOX 428 • ST. CLOUD, FLORIDA 32769 • (305) 892-6111 • TWX 810-870-0220

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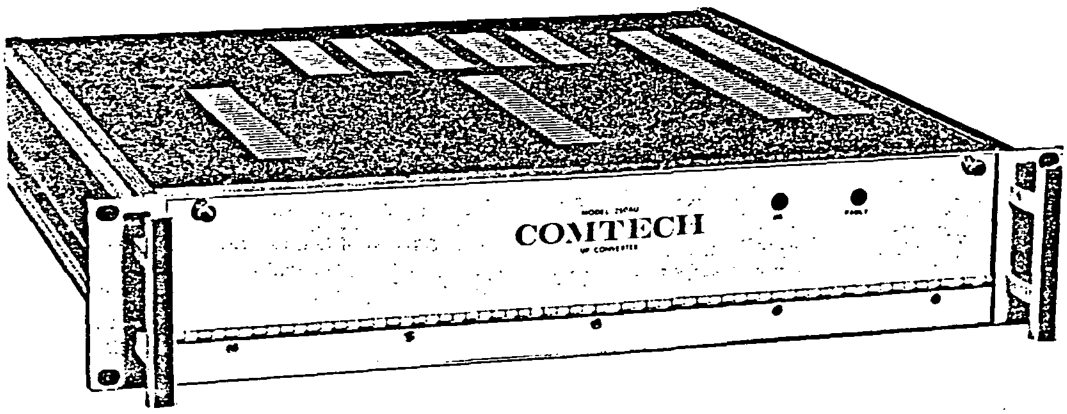
MODEL 250AU
5.925 TO 6.425 GHz UP CONVERTER



FEATURES

- Designed for data and analog transmission
- Dual conversion
- High performance — Low cost
- 15dB (1dB step) gain control
- Automatic shutdown in event of failure

OPTIONS

- Remote control
- Second local oscillator
- 1:1 or 1:8 backup switching available
- Equalizing for INTELSAT series satellites
- IF and RF input connectors located on front panel
- Continuously variable gain adjustment from front panel
- High frequency stability

DESCRIPTION

The Comtech 250AU Up-Converter is designed for both analog and data transmission applications. Typical applications include Video, SCPC, TDMA, and FM/FDM data transmission. The model 250AU is a complete self-contained dual conversion C-band up-converter housed in a rugged 3½" housing containing the power supply, all up-converter circuitry and local oscillators. A protective drop-down front panel allows access to all monitor connectors, as well as, frequency adjustment points for the IF and RF local oscillators. The IF input and RF output connectors are located on the rear panel or, optionally, can be located on the front panel. A "D" type interface connector located on the rear panel provides for complete control and monitoring capability.

The Model 250AU utilizes dual conversion to up convert the 70 MHz IF input to the 5925 to 6425 MHz RF output range. An IF frequency of greater than 1 GHz is used to provide superior rejection of the LO and spurious signals at the RF output. Gain adjustment of up to 15 dB in 1 dB steps is provided or, optionally, front panel continuous gain adjustment of up to 40 dB is available. The RF output is isolated with a ferrite isolator to provide an excellent output match as well as isolation from external equipment.

Complete fault monitoring of the power supply and the IF and RF local oscillators is provided. In the event of a failure, an appropriate fault LED is illuminated along with a summary fault LED which is visible with the front panel closed. Any fault condition will automatically inhibit the up-converter to prevent the possible transmission of spurious signals.

A back-up RF LO option is available which provides a secondary LO that can be manually or remotely switched on line as a back-up LO or as a means of switching to a second transponder frequency.

The Model 250AU can be used in conjunction with the Model 251 1:1 redundancy switch to switch a back-up up-converter on line in the event of an equipment failure.

PERFORMANCE SPECIFICATIONS

Converter Type	Dual Conversion, noninverting
OUTPUT	
Frequency	5.925 to 6.425 GHz
Impedance	50 Ohms
Return Loss	20 dB minimum
Signal Level	To −10 dBm for 1 dB gain compression (−5 dBm optional)
INPUT	
IF Input Frequency	52 to 88 MHz
Impedance	75 Ohms
Return Loss	20 dBm minimum
OVERALL	
First IF Frequency	Above 1 GHz
Bandwidth	36 MHz minimum
IF to RF Gain	15 dB minimum
Gain Adjustment	15 dB in 1 dB steps

GENERAL SPECIFICATIONS

Dimensions	19" wide, 3.5" high
Operating Temp Range	+10 to +50 degrees C
Humidity	10% to 90% non condensing
Power Input	117 VAC ± 10% 60 Hz 230 VAC ± 10% 50 Hz (special order) 100 Watts
CONTROLS BEHIND FRONT PANEL	
AC ON/OFF	Applies power to the unit
RF LO Select	Manual selection of primary or auxillary RF LO
RF LO REF Select	Selects internal or external reference for primary RF LO
AC Line Fuse	
FRONT PANEL INDICATORS	
IF LO Alarm	Indicates IF LO fault
RF LO Alarm	Indicates RF LO fault
Supply Alarm	Indicates power supply fault
Summary Alarm	Indicates summary of above faults
RF LO REF Select	Indicates selected RF LO
FRONT PANEL CONNECTORS	
IF LO Monitor	Type BNC, female
RF LO Monitor	Type BNC, female
RF Output Monitor	Type BNC, female
IF Input Monitor	Type BNC, female
REAR PANEL CONNECTORS	
Up Converter IF In	Type BNC, female
Up Converter RF Out	Type SMA, female
AC Power	Standard AC power cord
Interface	37 pin connector — Form C closure of all alarms — Relay closure or TTL input for PRI/AUX RF LO Select, Up Converter ON/OFF

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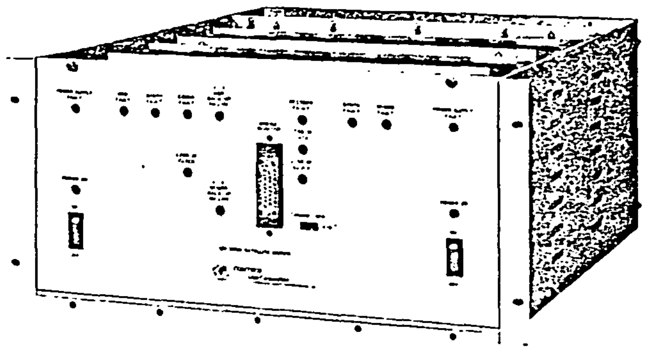
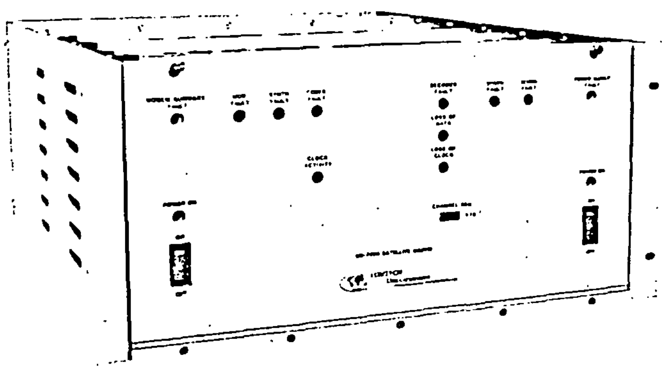
SM200A SATELLITE MODEM





FEATURES

- Bandwidth Efficient
- Data Rates up to 6.0 Mbps.
- Sequential or Threshold Decoding
- Baseband and IF Loopback.
- Optional 52 to 88 MHz Agility.
- M&C Interface Allows Remote Programming via Computer.

APPLICATIONS

- Satellite Communications
- Point-to-Point and Multidrop
- Single Channel per Carrier (SCPC)
- Process Automation, Robotics, Telemetry, Remote Data Processing
- Computer-to-Computer and PBX Traffic

INTRODUCTION

The SM200A Satellite Modem has been designed for use with 70 MHz IF satellite communications equipment to allow the transmission and reception of digital data via satellite. It may be used in full-duplex or simplex data links operating at data rates ranging from 50 Kbps to 6.0 Mbps. An optional 1:1 switch module also allows use in situations requiring automatic on-line backup. Installations having more extensive backup requirements may use the companion SE-381 1:8 Modem Switch.

Error correcting convolutional encoding plus either soft-decision sequential decoding (up to 2.048 Mbps) or hard-decision threshold decoding are used to provide exceptional bit error rate performance. Actual modem performance using sequential decoding is guaranteed not to deviate from theoretical performance by more than 1.2 dB.

One other outstanding feature of the SM200A is a high-slope modulator output spectral density. This characteristic defines the rectangularity of the output frequency spectrum and determines the minimum channel spacing. This in turn dictates the number of channels that may be used on a satellite transponder and also the transponder cost for each. The SM200A filter performance reduces this channel spacing to .7 times the symbol rate for versions using QPSK and 1.4 times the symbol rate for versions using BPSK. This can mean lower operating costs in many situations.

Up to 255 SM200A modems may be remotely programmed via the M&C (Monitor & Control) interface. This capability allows operating parameters such as synthesizer frequencies, modulator output, and codec rates to be examined and changed by a computer or similar device. The EIA RS-485 serial interface requires only a 6-wire cable.

Several SM200A configurations are available to allow a modem to be tailored for a specific application. Full duplex or simplex operation, frequency agility, power supply redundancy, AC or DC power operation, and 1:1 switching capabilities may be supplied. Fault monitoring, V.35 scrambling/descrambling, baseband/IF loopback, and the M&C interface are standard on all configurations.

FUNCTIONAL DESCRIPTION

General

The standard modem configuration is referred to as a -X101 shelf and is shown in the block diagram of Figure 1. The 1:1 switch configuration, referred to as a -X102 shelf, is used to provide redundancy for an on-line -X101 shelf and is shown in Figure 2. Fault monitoring is not shown but is provided on all modules.

-X101 Shelf

This shelf is the mainframe for the standard modem. The 8 3/4" high chassis is designed for mounting in a standard 19" rack. It will accept a CODER module, MODULATOR module, DEMODULATOR module, DECODER module, up to two optional SYNTHESIZER modules, and up to two POWER SUPPLY modules (the second is optional). Included is a 52 to 88 MHz bandpass filter for the modulator RF output and connectors for data, power, faults, modulator and demodulator external L.O. inputs, IF input and output, and M&C interface.

-X102 Shelf

This shelf is the mainframe for a modem incorporating the 1:1 switch. It is dimensionally similar to the -X101 shelf and accepts the same number and types of modules. An additional module, a 1:1 SWITCH, is used for data and modulator IF output switching. It also provides additional connectors for attachment to an on-line modem and a front panel bridge monitoring connector (not shown).

Coder Module

The CODER module accepts data and clock lines from the data interface connector and provides a convolutionally and differentially encoded output for use by the MODULATOR module. The data interface type may be V.35, MIL-STD-188, RS-449, Bell T1 (DS-1), or TTL. Other interface types may also be supplied. Coding rates may be selected as either 1/2, 3/4, or 7/8 when sequential decoding is used and 7/8 when threshold decoding is used. A V.35 scrambler may also be switched into the data stream.

Modulator Module

The MODULATOR module uses the encoder output of the CODER module to produce a QPSK or BPSK modulated IF carrier within the range of 52 to 88 MHz. The carrier frequency is determined by either an on-board crystal controlled local oscillator (L.O.) or an external oscillator such as the optional SYNTHESIZER module. Nyquist filtering limits the modulated bandwidth to .7 times the symbol rate (QPSK) and a rear-panel bandpass filter removes out-of-band RF components.

Switch selectable L.O. routing is provided to ease IF loopback testing. This routing supplies the modulator L.O. signal to the demodulator so that it will operate on the same frequency as the modulator. An external cable is then used at the rear panel to supply the modulator output to the demodulator input.

Demodulator Module

The DEMODULATOR module accepts a 52 to 88 MHz IF input and performs QPSK or BPSK demodulation at a carrier frequency determined by either an on-board crystal controlled L.O. or an external oscillator such as the optional SYNTHESIZER module. The encoded output is provided to the DECODER module where the data is recovered using either sequential or threshold decoding.

The use of dual conversion reduces image response and increased filtering in the second IF stage increases the available dynamic range. The performance results for a 56 Kbps data rate are shown in Figure 3.

Either soft decision or hard decision outputs are provided for use by the DECODER module. Soft decision is standard and is used for sequential decoding. Hard decision logic is provided when threshold decoding is required.

Decoder Module

The DECODER module accepts either soft or hard decision outputs from the DEMODULATOR module and provides data and clock outputs conforming to any of the interface types mentioned in the CODER module discussion. Sequential decoding is performed on soft decision inputs and threshold decoding is performed on hard decision inputs. Grey code differential decoding and V.35 compatible descrambling (switch enabled) are also provided.

The use of sequential decoding provides significant coding gain. Typical bit error rate performance is shown in Figure 4 for several data rates using encoding rates of 1/2 and 7/8.

Synthesizer Module

Up to two SYNTHESIZER modules may be used in either the -X101 or -X102 shelf. These provide detent tuning in 25 KHz steps using BCD rotary switches at the front of the modules. Full operation is provided over the 52 to 88 MHz IF range.

1:1 Switch Module

The 1:1 SWITCH module is used only in the -X102 shelf. It provides relay switching of the data interfaces and IF output lines in hot-standby configurations (see Figure 2). The failure of a -X101 on-line modem activates the relays, switching either the -X102 modulator, demodulator, or both on-line depending on the failure.

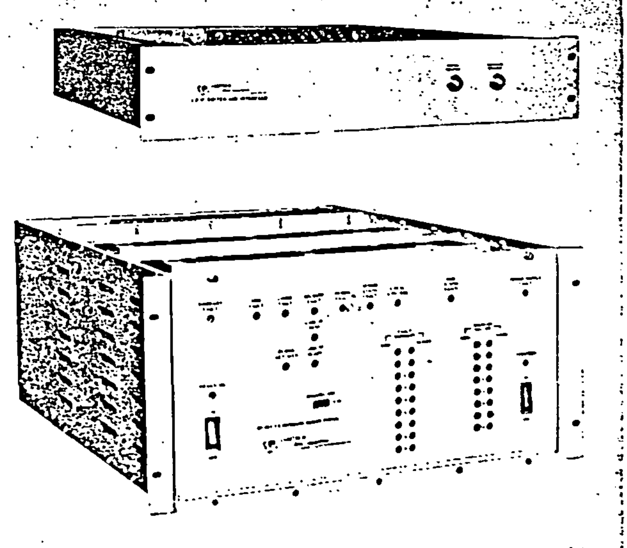
M&C Interface

Operation of the SM200A may be remotely controlled via the M&C 6-wire interface. It is provided as a standard feature on all configurations and provides full remote control. An overview is provided on the opposite page. Full programming and interfacing details are provided in the comprehensive installation and operation manual.

Power Supply Modules

Four types of POWER SUPPLY modules are available to allow operation from 115 VAC, 230 VAC, -48 VDC, or -24 VDC. One module will power a full -X101 or -X102 shelf and an optional second module may be used for redundancy. Each module provides a shelf fault summary Form C relay closure at the rear panel.

COMPANION SE-381 SWITCH



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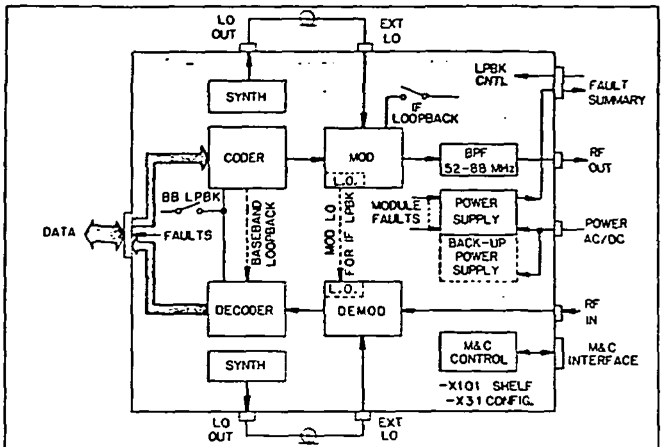


FIGURE 1. STANDARD MODEM BLOCK DIAGRAM.

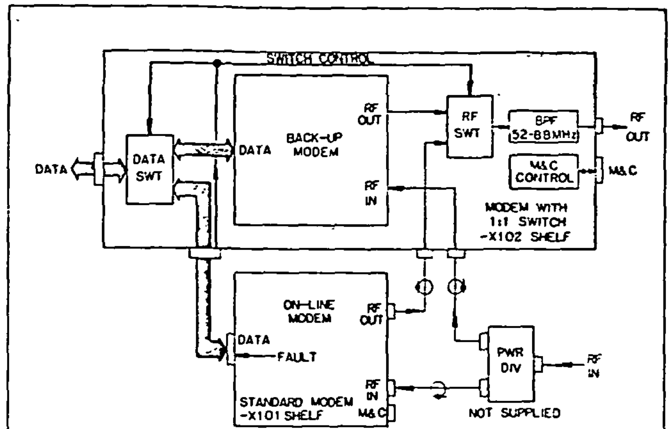


FIGURE 2. REDUNDANT MODEM CONFIGURATION USING STANDARD -X101 MODEM ON-LINE AND -X102 MODEM WITH 1:1 SWITCH FOR BACK-UP UNIT.

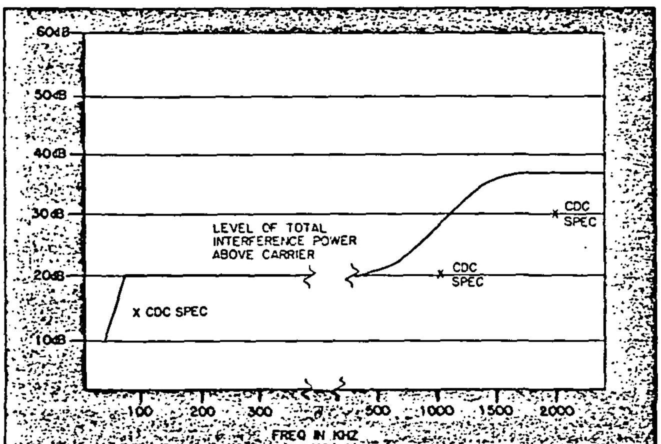


FIGURE 3. TYPICAL INTERFERENCE PERFORMANCE FOR .5dB DEGRADATION AT 56 KBPS.

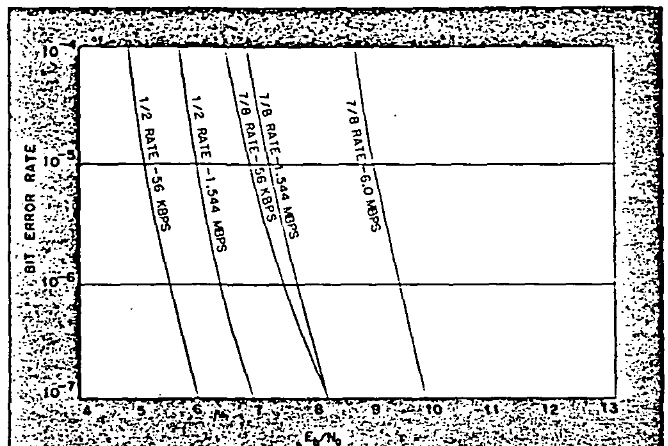


FIGURE 4. BER APPROXIMATION CURVES FOR 56 KBPS AND 1.544 MBPS OPERATION.

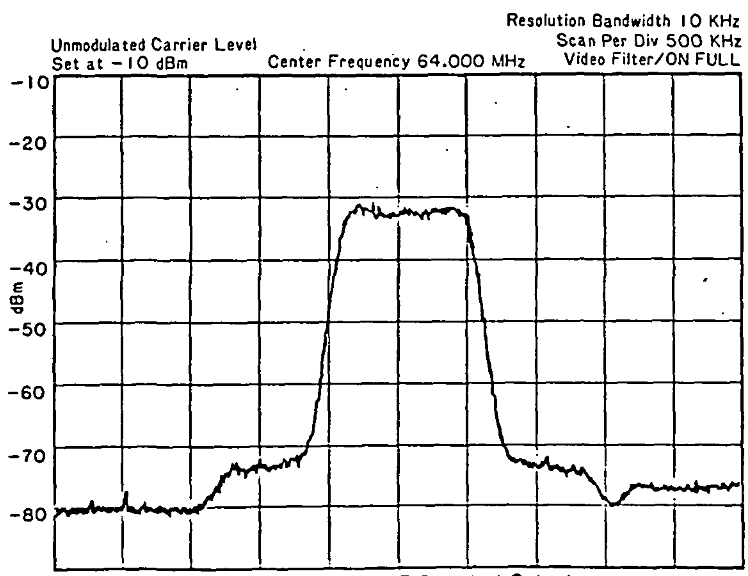
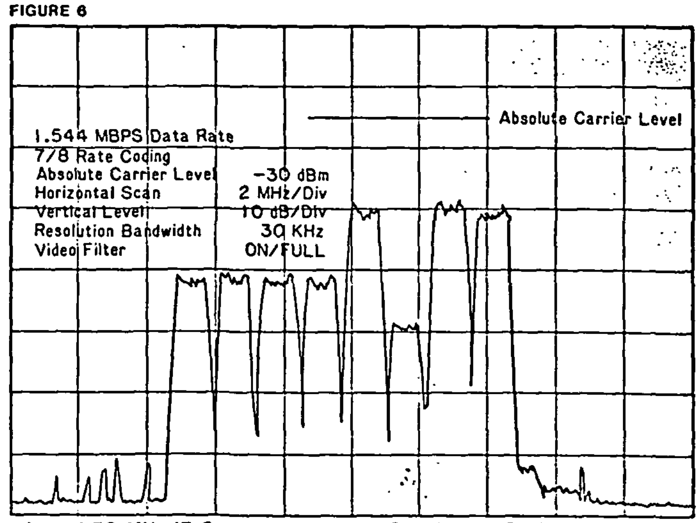


FIGURE 5 Typical SM200A RF Spectral Output

FIGURE 6



Actual 70 MHz IF Spectrum showing 8 adjacent SM200A carriers, each operating at a T1 rate without errors. Note that the third carrier from the right has a level 20 dB below adjacent carriers.

ORDERING INFORMATION

EXAMPLE **M200-X31-BB4ASEBNS**

Power Supplies	Configuration	Freq. Control	Chassis # w/o 1:1 SWT	Chassis # with 1:1 SWT
1	Mod/coder/ Demod/Decoder	2 Synth.	-X31	-X43
		2 L.O.	-X32	-X44
	Mod/Coder Only	1 Synth.	-X33	-X45
		1 L.O.	-X34	-X46
	Demod/Decoder Only	1 Synth.	-X35	-X47
		1 L.O.	-X36	-X48
2	Mod/Coder/ Demod/Decoder	2 Synth.	-X37	-X49
		2 L.O.	-X38	-X50
	Mod/Coder Only	1 Synth.	-X39	-X51
		1 L.O.	-X40	-X52
	Demod/Decoder Only	1 Synth.	-X41	-X53
		1 L.O.	-X42	-X54

Contact factory for data rates and interfaces not shown.

Use the letters "X" or "XX" for parameters not listed. Include a description of requirements.

Configuration codes for non-standard configurations (excludes data rate variations) must have an "S" suffix attached.

BIT RATE
- BB = 50KB
- CC = 56KB
- DD = 192KB
- EE = 208KB
- FF = 224KB
- HH = 550.5024KB
- JJ = 772KB
- KK = 1544KB
- LL = 16KB
- MM = 100KB
- NN = 1344KB
- PP = 193KB
- RR = 450.33KB
- SS = 153.6KB
- TT = 37.7KB
- UU = 112KB
- VV = 256KB
- WW = 448KB
- YY = 3072KB
- ZZ = 1536KB
- AB = 384KB
- AC = 500KB
- AD = 768KB
- AE = 86.4KB
- AF = 128KB

CODE RATE
- 2 = 1/2
- 4 = 3/4
- 8 = 7/8

INTERFACE
- A = V.35
- B = MIL-188C
- C = MIL-188-114
- D = EIA-449
- E = T1
- H = TTL
- J = RS-422
- L = CEPT

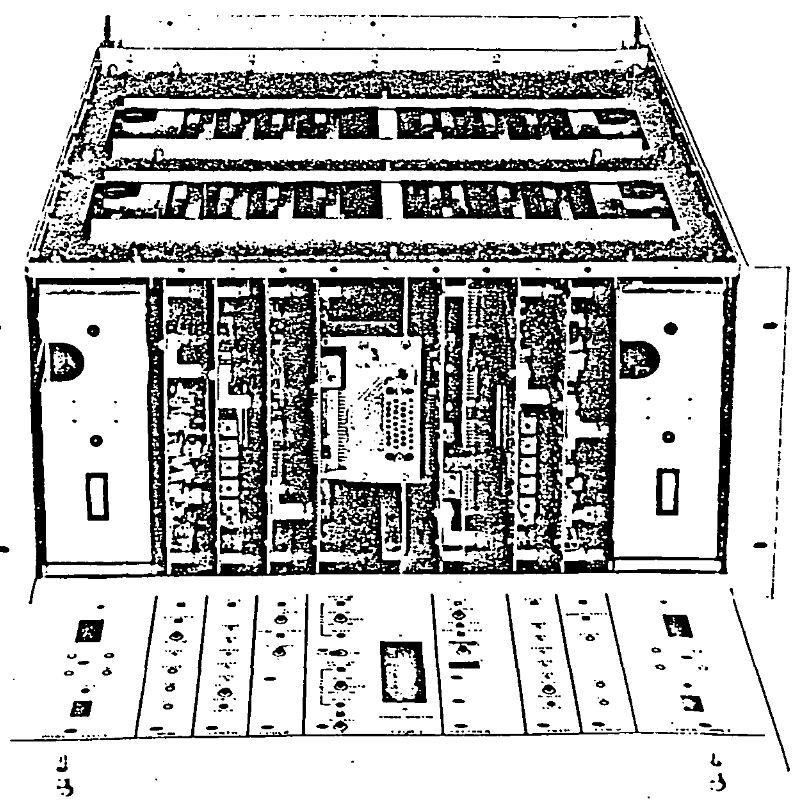
CODE TYPE
- T = Threshold
- S = Sequential

LO
- I = Internal
- E = External

MODULATION
- B = BPSK
- Q = QPSK

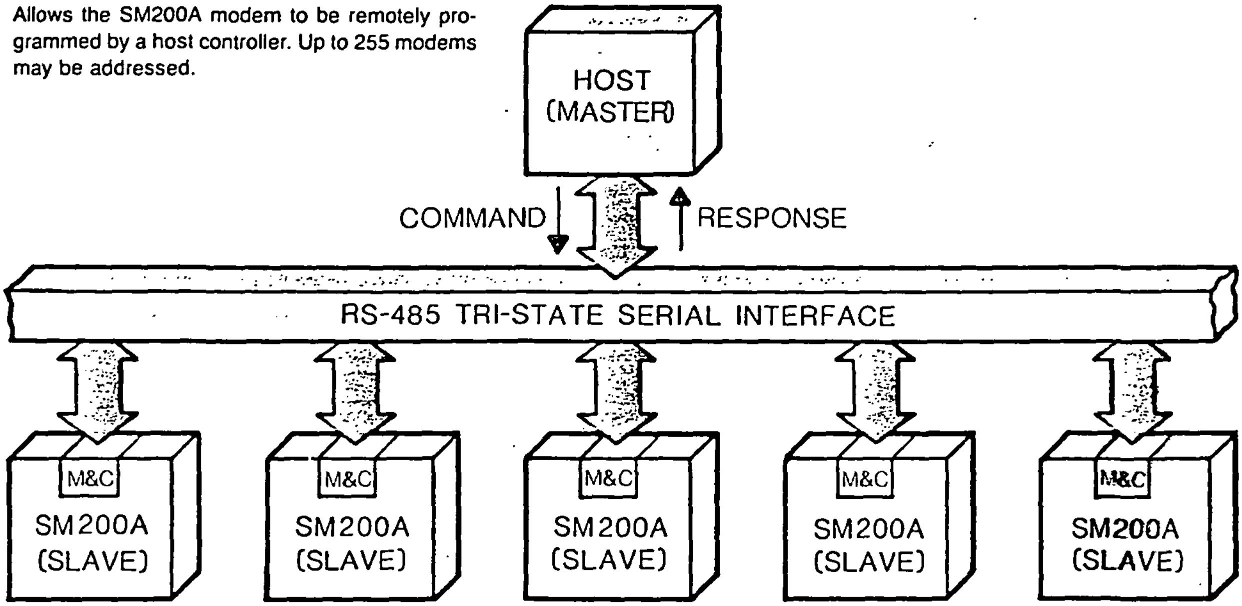
MODEL
- N = SM200A

Add for special configurations



MONITOR AND CONTROL INTERFACE

Allows the SM200A modem to be remotely programmed by a host controller. Up to 255 modems may be addressed.



OPERATION

The host sends commands globally or on an individual basis using device addresses. Each M&C interface either sends a response or changes the modem operating parameters when it detects a message addressed to it.

MESSAGE FORMAT

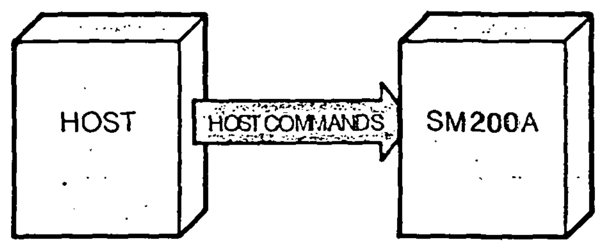
All messages conform to one of the two formats shown. The "Message I.D." format is used for most host commands. The "Body" format is used for returning modem status, configuration data, and bit error rate values.

MESSAGE I.D. FORMAT

STX 02	BYTE COUNT	DEVICE ADDRESS	MESSAGE I.D.	CHECK SUM	ETX 03

BODY FORMAT

STX 02	BYTE COUNT	DEVICE ADDRESS	MESSAGE I.D.	BODY	CHECK SUM	ETX 03



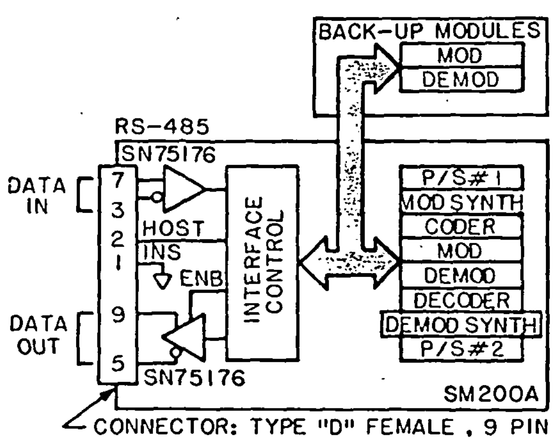
The host controller may:

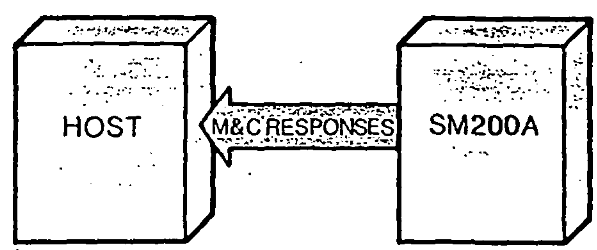
- Reset the SM200A.
- Request the SM200A configuration.
- Request the status of all SM200A modules.
- Request the uncorrected and corrected bit error rates.
- Send new parameters for:

Modulator synth freq	Demodulator synth freq
Modulator output power	Decoder rate
Transmitter ON/OFF	Baseband loopback mode
Coder rate	

SERIAL INTERFACE

The SM200A communicates to a host controller via an EIA RS-485 serial interface. This interface type is the latest EIA standard for multi-unit communications over a common bus. It is also RS-422 compatible when only one modem must be controlled. The pin-out and electrical description are shown below.





The SM200A modem may:

- Acknowledge a message.
- Return the SM200A configuration.
- Return the uncorrected and corrected bit error rates.
- Return status of all modules including:

Modulator	Demodulator	M&C interface
Modulator synth	Demodulator synth	Power supply #1
Coder	Decoder	Power supply #2
Modulator AGC value	Demodulator AGC value	
Backup modulator	Backup demodulator	

SPECIFICATIONS

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

GENERAL

Communication Modes	Full Duplex, simplex.
Operating Modes	Normal, baseband loopback, IF loopback.
Modulation	QPSK standard, BPSK optional.
Coding	Grey code differential plus either sequential or threshold coding/decoding. V.35 scrambling and descrambling are switch selectable.
Data Interfaces	See configuration code.
Data Rates	50 Kbps to 2.048 Mbps using sequential decoding. 50 Kbps to 6.0 Mbps using threshold decoding.
Coding Rates	1/2, 3/4, 7/8.
Carrier Spacing	QPSK: 0.7{(Data Rate)/(Coding Rate)}. BPSK: 1.4{(Data Rate)/(Coding Rate)}.
Physical	19" wide by 8¾" high by 22" deep, 25 pounds nominal.

MODULATOR

Output Connector	BNC, 75 ohms.
Output Level	Standard: Adj −15 to −5 dBm. 1:1 Switch: Adj −15 to −5 dBm. 1:8 Switch: Adj −29 to −19 dBm/CXR.
Frequency Range	52 to 88 MHz.
Carrier Stability	1 x 10^{-5}, or ± 700 Hz maximum offset.
Output Spectrum	The modulated spectral density is −25 dBc maximum at f_o ± {.75(Symbol Rate)} Hz, and −30 dBc at f_o ± {1.0(Symbol Rate)} Hz, where f_o is the carrier frequency.
Spurious Outputs	
In Band	−50 dBc, 52 to 88 MHz.
Out of Band	−60 dBc, 1 to 500 MHz excluding 52 to 88 MHz.
Harmonics	−60 dBc, 1 to 500 MHz excluding 52 to 88 MHz.
Return Loss	20 dB minimum.
Scrambling	V.35 compatible, may be disabled.
Ext LO Input	98 to 134 MHz, +7 to +11 dBm, 50 ohms, BNC.

SYNTHESIZER

Output Connector	BNC, 50 ohms.
Output Level	+7 to +11 dBm.
Frequency Range	98 to 134 MHz, tuneable in 25 KHz steps ± 12 Hz using front mounted miniature BDC rotary switches.
Stability	1 x 10^{-6}.
Spurious Levels	−55 dBc both in and out-of-band.

M&C INTERFACE

Type	EIA RS-485 multi-unit communications bus, tri-state serial 6-wire, 8-bit format.
Bus Hierarchy	Host is master, modems are slaves. Up to 255 slaves may be used per bus.
Transmission Options	Baud rate selectable 50 to 9600 baud, 1 or 2 stop bits, odd or even parity.
Mating Connector	Type "D" male, 9-pin.

FAULT SUMMARY

Output	Form C relay contact closure plus indicator.
Faults Monitored	CODER Module, MODULATOR Module, DEMODULATOR Module, DECODER Module, SYNTHESIZER Module(s), POWER SUPPLY Module(s).

SWITCHING PERFORMANCE

Data Contact Resist.	50 milliohms maximum.
IF Insertion Loss	.25 dB maximum.
Switchover Time	
1:1 Switch	Modulator — 2 sec. maximum. Demodulator — 2 sec. maximum.
1:8 Switch	Modulator — 100 millisec. maximum. Demodulator — .5 to 32 sec., selectable.

DEMODULATOR

Input Connector	BNC, 75 ohms.
Input Level	Standard: −55 to −35 dBm. 1:1 Switch: −52 to −32 dBm. 1:8 Switch: −42 to −22 dBm/CXR.
Frequency Range	52 to 88 MHz.
Return Loss	20 dB minimum.
Acquisition Range	±25 KHz.
L.O. Input	98 to 134 KHz, +7 to +11 dBm, 50 ohms, BNC.
Descrambling	V.35 compatible, may be disabled.
Bit Error Rate	Typical E_b/N_o requirements for a BER of 10^{-7} using sequential soft decision error correction:

Code Rate	E_b/N_o 1.544 Mbps	56 Kbps	6.0 Mbps
1/2	6.9 dB	6.0 dB	—
3/4	7.5 dB	6.9 dB	—
7/8	8.2 dB	8.2 dB	9.8 dB

The above performance shall be provided in the presence of two adjacent like-modulated carriers at a spacing equal to .7 times the data rate using QPSK or 1.4 times the data rate using BPSK. The levels may be 14 dB higher.

POWER REQUIREMENTS

Input Voltage	103 to 130 VDC, 47 to 450 Hz, 206 to 260 VAC, 47 to 450 Hz, −48 VDC, or −24 VDC.
Power Consumption	100 Watts nominal.

ENVIRONMENTAL

Temperature	+10° to +40° operating, −25° to +85°C storage.
Humidity	5 to 95% noncondensing.
Altitude	Up to 10,000 feet operating, up to 50,000 feet shipping.

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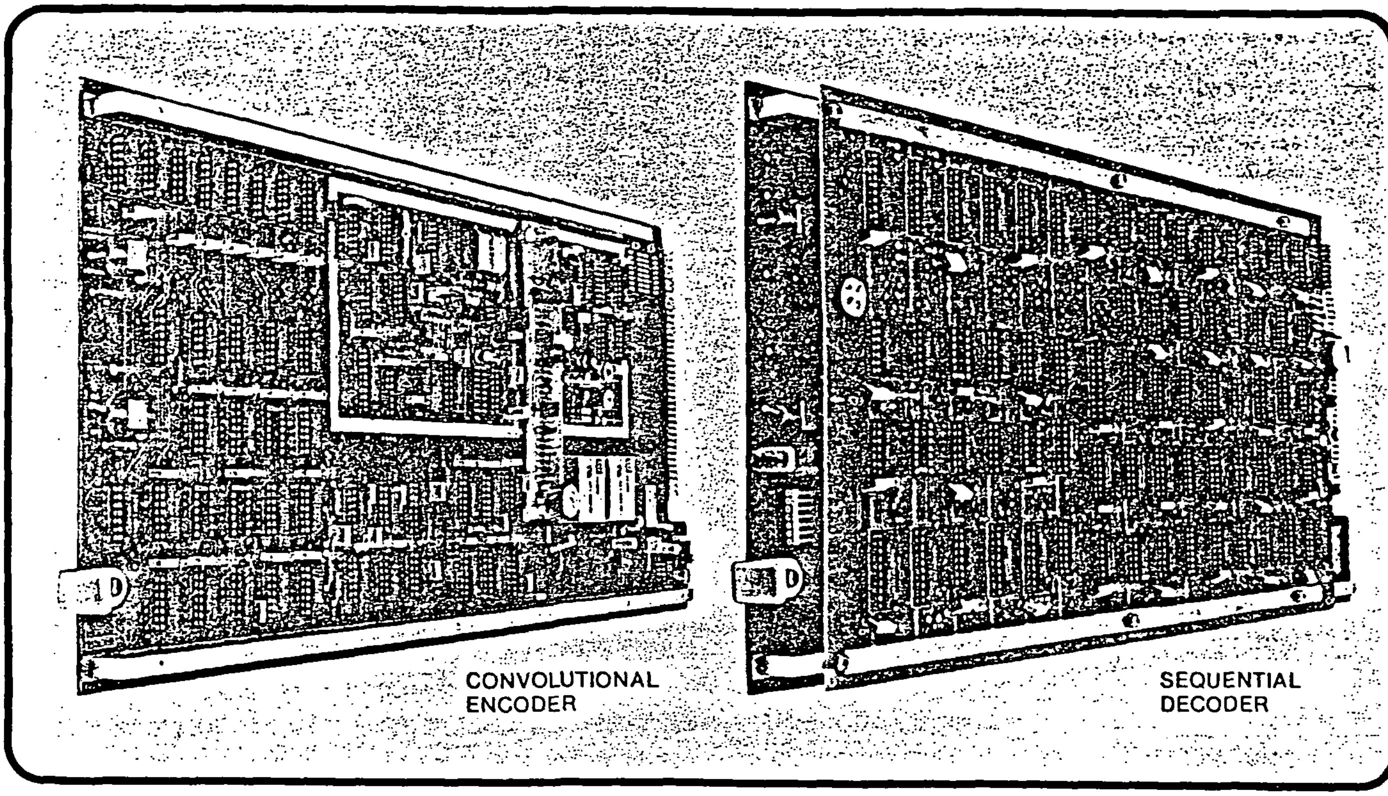
SM200A CONVOLUTIONAL ENCODER AND SEQUENTIAL DECODER WITH CCITT SCRAMBLING-DESCRAMBLING



FEATURES

- Code rates of 1/2, 3/4, or 7/8
- Data rates up to 2 MBPS (3/4 and 7/8 rate), up to 1.6 MBPS at 1/2 rate
- Physically separate encoder and decoder allows full duplex or simplex operation
- Mounts in standard SM200A Series X101 or X102 chassis and SE-381 1:8 switches
- Several customer interface options including CCITT V.35, RS-232, RS-449, DS1, and MIL STD-188
- Standard RS-422 interface for modem
- Three digit LED display provides continuous measured channel BER
- Includes switch selectable CCITT scrambling and descrambling capability
- Soft decision logic for use with a QPSK system
- Remote BER monitoring capability

INTRODUCTION

The SM200A Convolutional Encoder-Sequential Decoder is a full duplex rack-mounted unit that provides a significant reduction in the received energy per bit-to-noise ratio, Eb/No, that is needed to achieve a given bit error rate (BER) when coupled to a QPSK modem. The unit provides a coding gain of greater than 5 dB at rate 1/2 when using QPSK soft decision. The accompanying charts provide an approximation of the coding gain achievable at 56 KBPS and 1.544 MBPS over an ideal uncoded modem.

This coding gain can be directly translated into reduced satellite power (EIRP) or lower G/T values in receiver terminals or perhaps a combination of both. Lower EIRP usually translates into lower satellite tariff rates, while a lower G/T translates into initial system cost savings (ie. smaller antenna and less expensive low noise amplifiers).

GENERAL

One of the most important factors in the design of an efficient and reliable communications system is to maintain a low bit error rate with a given data rate using the most economical method. Careful selection of modulation techniques is certainly an important consideration, but system performance can be greatly improved through the use of error correcting codes.

Several error correcting techniques have been employed that substantially reduce the Eb/No to attain a desirable BER. For many applications, the most practical and best-performing technique for the space channel known is the convolutional encoder and sequential decoder combination. Coupled with soft decision logic, sequential decoders achieve a significant improvement in the Eb/No versus BER over uncoded modulation techniques.

Convolutional Encoding

Convolutional coding has perhaps become an industry standard due to its superior coding scheme over other techniques, such as block coding. In convolutional coding, long sequences of digital data are encoded continuously in a serial form. The digital data is sequentially shifted through an N-bit shift register. After each shift, parity bits are obtained. The number of parity bits obtained after the shift depend on the code rate (1/2, 3/4, 7/8). The length N of the shift register is called the constraint length of the code. For certain convolutional codes, as the constraint length increases the error probability decreases exponentially. Convolutional codes, when used with a good decoder outperform block codes of the same degree of complexity.

Sequential Decoding

Sequential decoding involves a trial-and-error search of variable duration. It basically operates by generating a hypotheses about what information sequence was actually sent, until it finds some that are reasonably consistent with what was received. It does this by a forward and backward search through the received data.

It starts by going forward, generating a sequence of hypotheses about what was sent. It then compares what was received with what would have been transmitted, given the hypotheses. As long as the received data and the transmitted data (by hypotheses) are correct, it goes forward. If incorrect, it searches in a reverse direction, changing the hypotheses one by one until the two data streams again are correct; at which time it returns to a forward search.

When reception is perfect, the decoders first guess is always correct, and therefore only one hypotheses is generated per bit. The more noise, the more hypotheses must be generated. In fact, a rather large buffer storage of the received data must be provided to permit long searches, for it may take up to literally thousands, or perhaps millions, of hypotheses to decode a short segment.

Soft Decision QPSK

Use of soft (quantized) decision logic from QPSK demodulator adds approximately ½ to 1 dB of coding gain to the decoded output by allowing the decoder to determine the ambiguity range of the demodulated output. Most QPSK outputs in current use utilize two bits to determine the sign (one or zero) and magnitude of the level actually sent.

The magnitude is a quantized measure of the strength of the decision. A null zone is established midway between a zero and one whereby the decision is treated as a no or "soft" decision. When the signal to noise ratio (Eb/No) is high, the magnitude of the received data is nearly always a logic one; and when the Eb/No is near threshold, the magnitude will become nearly always zero. The magnitude of the decision is used by the decoder in computing the hypotheses of the transmitted signal.

FUNCTIONAL DESCRIPTION

Convolutional Encoder

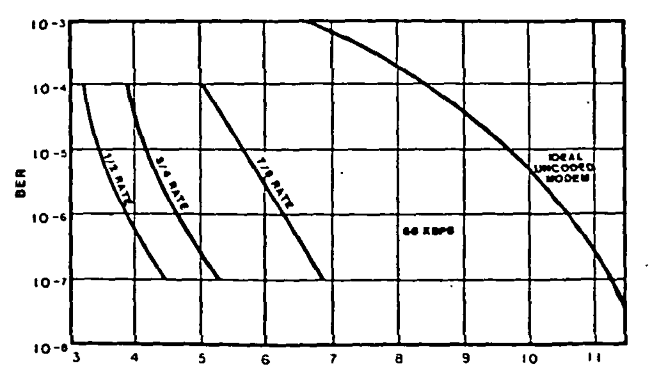
The Convolutional Encoder (Figure 2) includes a customer selected Interface Adapter Unit (IAU) that converts many interface standards (ie. V.35, RS-422, DS-1, etc.) to TTL levels. Baseband loopback is also provided (not shown) that is switch selectable from the front edge of the module. The encoder includes an optional V.35 Serial Clock Transmit (SCT) oscillator.

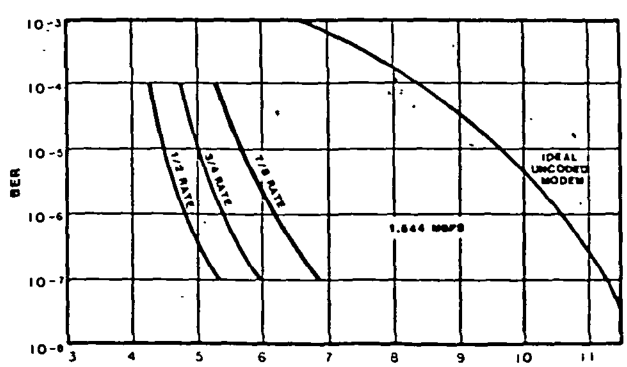
A clock recovery circuit generates its own clock from either the incoming data or clock stream. It is basically a VCXO with a PLL that locks onto the incoming data or clock.

The scrambler follows the CCITT V.35 recommendations for energy dispersal. Switch selection on the encoder module allows the scrambler to be turned ON or OFF, independent of the descrambler.

The differential encoder is used to resolve phase ambiguity in the decoder. Its output is the data input to the convolutional encoder.

The convolutional encoder utilizes an N bit shift register and a series of odd parity generators and exclusive OR circuits to generate the parity. Two outputs from the encoder, data and parity, are routed to the output circuits.





The output circuits combine the data and parity into an I and Q stream suitable for a QPSK modulator (RS-422 format). Parity is always placed on the Q channel, and is all that appears on that channel for the 1/2 rate. For 3/4 and 7/8 rate, the parity and data are interspersed on the Q channel. (The I channel always carries data, regardless of coding rate.)

An activity detector monitors several lines to ensure that they are changing state. Should a failure occur, a fault is generated and summed.

Sequential Decoder

The Sequential Decoder receives the demodulated I and Q sign and magnitude data and, in the input circuits, converts RS-422 format to TTL level. Activity detectors monitor the data and clock, which, in the absence of transitions of either signal, generates a fault that is summed.

The clock regenerator, a PLL oscillator operating at around 12.5 MHZ, is an integer multiple of the input and output data rates. The baud clock is at the input data (symbol) rate, while the bit clock is at the output data (bit) rate.

The sequential decoder operates at a clock rate substantially higher than the input symbol rate, allowing the decoder to search at a rate faster than the input symbols are arriving. Incoming symbols and output data from the sequential decoder are stored in 4K Random Access Memories (RAM). These RAMs are necessary because, as the decoder backs up to search through possible paths, the old data and the incoming new data must be readily available.

During the computation of the decoder output, an ambiguity of the I and Q channels exists. This ambiguity is resolved by the differential encoder and differential decoder circuits.

The input sign bit from the one channel to the decoder and the decoded symbol from the same channel are compared in an error detector to detect possible errors. These errors are counted and routed to a BER display. The Baud clock, down counted by a 10,000 is used to update the display. The BER display thus indicates the amount of errors in 10,000 symbols, or BER $\times 10^{-4}$. It is updated every ½ second.

The differential decoder output is then CCITT descrambled and both outputs are made available to the IAU, the outputs of which are selectable by a switch mounted on the decoder module. The IAU converts the TTL level output to the customer-selected option.

A fault summary circuit sums various faults (ie. Encoder, Fault, Loss of Data, etc.) and provides a relay closure output (Form A) and a LED indication to the front panel. Individually displayed faults provide a useful tool for troubleshooting path problems.

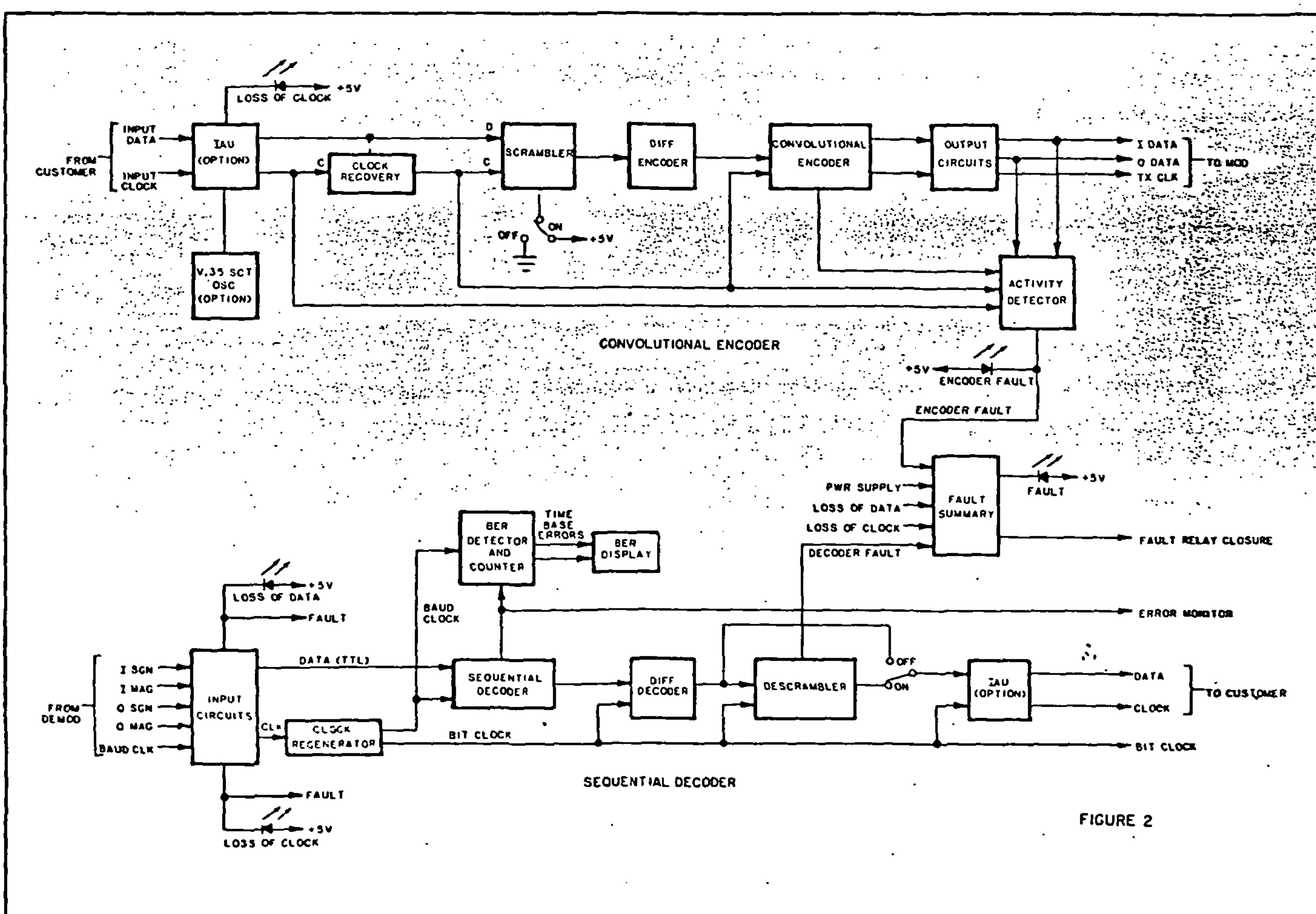


FIGURE 2

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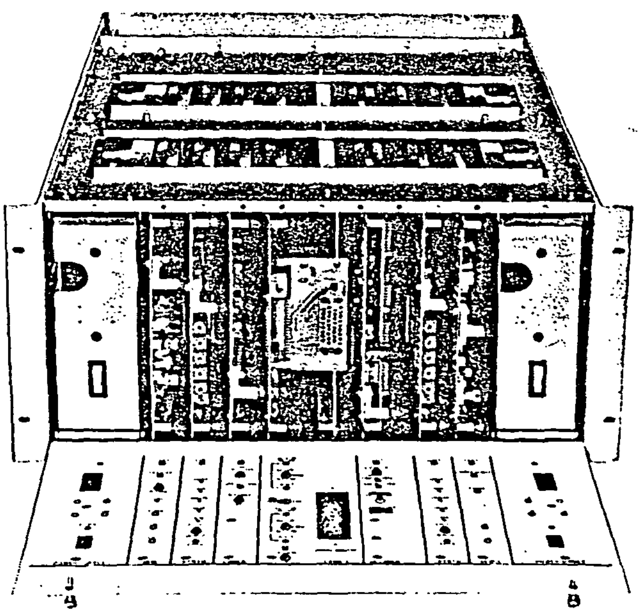
SPECIFICATIONS

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

Data Rate	Up to 2 MBPS, 3/4 and 7/8 rate Up to 1.6 MBPS, 1/2 rate	
Transmit/Receive Clock Ratio	Code Rate 1/2 3/4 7/8	Clock Ratio 1:1 3:2 7:4
Coding Gain	(See accompanying chart)	
Total System Delay (Encoder In to Decoder Out)	Code Rate 1/2 3/4 7/8	Delay (in data bit times) 4000 (Approx) 6000 (Approx) 7000 (Approx)
Interface	DS-1, V.35, RS-422, MIL-188	
Connectors	In SM-200A modem tray, the interface to modem is internal; standard interface connectors are on rear of tray.	
Displays/Indicators	Encoder: Decoder:	Loss of Clock and Fault (several activity detectors) Loss of Clock, Loss of Data, Fault Summary, and Channel BER ($\times$ 10^{-4})
Controls (Internal)	Encoder: Decoder:	Baseband Loopback ON/OFF Scrambler ON/OFF Clock EXT/INT Select Descrambler ON/OFF
Thermal	Operating: Non-Operating:	0°C to 40°C −30° C to 75°C
Physical	Mounting: 19 inch × 8 ¾ inch tray	

OPTIONAL EQUIPMENT

MODULATORS
DEMODULATORS
THRESHOLD TRIPLE ERROR CORRECTION
SYNTHESIZERS
BIT ERROR MONITORS
1:8 PROTECTION SWITCH
1:1 PROTECTION SWITCH



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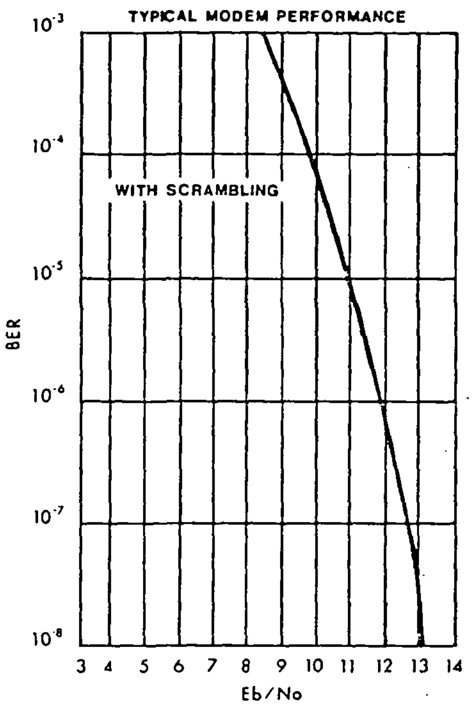
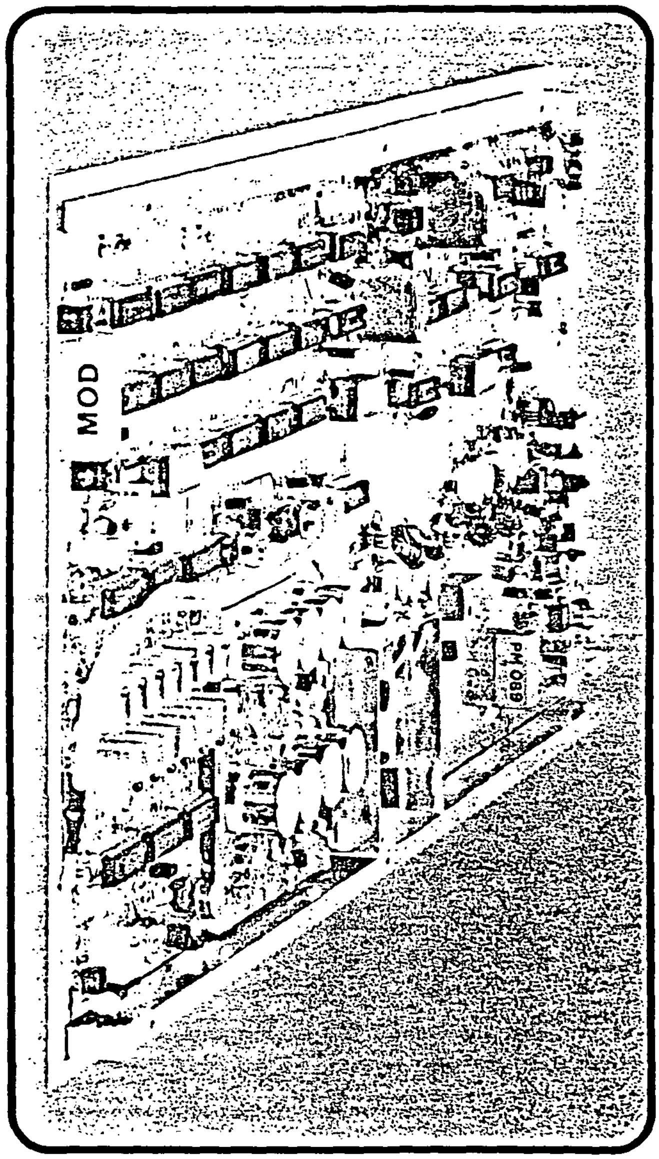
SM200A SATELLITE MODULATOR
52-88 MHz





The SM200A series of digital satellite communications equipment is a family of interchangeable modules vertically integrated into a standard 19 inch tray. The SM200A series was conceived to give maximum configuration flexibility to systems designers and provide the high level of maintainability and operational efficiency required for cost effective operations.

The QPSK/BPSK modulator consists of an equalizer, Nyquist filters, QPSK/BPSK modulator and IF processors. It also can optionally include an interface adapter unit (IAU), symbol sync, V.35 scrambler, and an SCT oscillator for interface to codec units not having this capability.

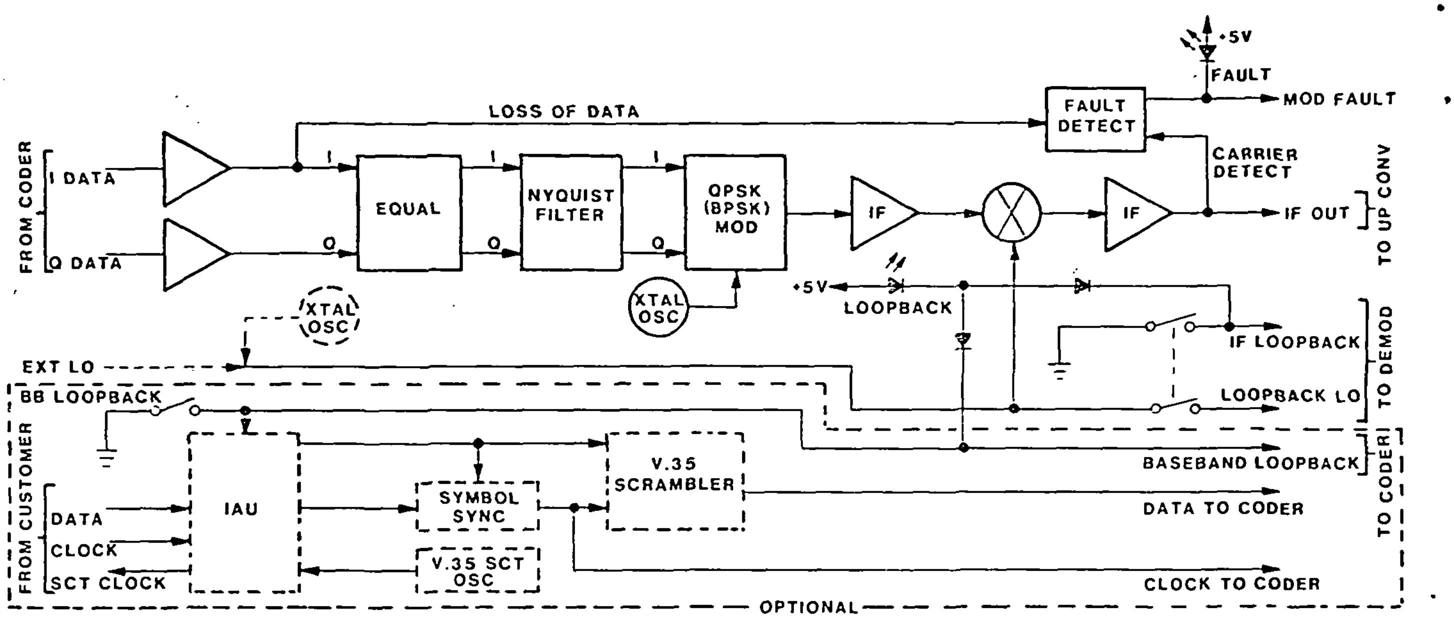
The QPSK modulator accepts I and Q data from an external codec unit. Delay equalizers and Nyquist filters process the I and Q data and are subsequently phase modulated onto an IF carrier in the 52 to 88 MHZ frequency range. The final IF carrier frequency may be set by an internal crystal oscillator, or externally, the latter of which may utilize Comtech's synthesized LO to provide frequency agility in the 52 to 88 MHZ band. In IF loopback, the LO frequency (internal or external) is routed to the companion demodulator module for IF loop testing.

The optional IAU adapts V.35, RS-232, and RS 449/422 clock and data and T-1 data to TTL level. The symbol sync regenerates an internal bit clock for retiming the data. A V.35 SCT oscillator provides an external clock for customer interface. Once data is retimed and squared, it is scrambled for energy dispersal according to CCITT recommendations. Baseband loopback switches connect the customer input data to output data for loop testing.

Loss of carrier and data are summarized in a fault summary circuit which is made available to edge connector and a front panel LED indicator. The front panel also carries the looping switch and buffered monitor points for eye pattern and clock. IF output level is set on the front panel.

FEATURES

- QPSK/BPSK
- No Tuning
- 50Kb/s to 1.544 Mb/s
- Low Power Consumption
- External/Internal LO
- Bandwidth Efficient
- IF Loopback
- Data Loopback (Optional)



SPECIFICATIONS

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

GENERAL

Modulation: QPSK/BPSK
Coding: Absolute or Differential
Scrambler: Per CCITT V.35
Spacing: .7 of Data Rate: QPSK
1.4 of Data Rate: BPSK

DIGITAL

Data Rate: 50Kb/s to 3.088Mb/s
Interface: V.35, R-232, RS-449/422, T-1
Clock: Internal or External
Filter: Nyquist Type

IF

Range: 52 Mhz to 88 Mhz
Connector: Female BNC/75 ohms
Level: −10 ± 5dBm
Spurious: −50 dBc In Band
Local Oscillator: Internal/External

ENVIRONMENTAL

Temperature: 10°C to 40°C
Humidity: 90% Non-condensing
Storage: −40°C to 120°C at 95% Non-condensing

PHYSICAL

Mounting: 19 inch by 8¾ inch tray
Weight: 1.9 Lbs.
Power Dissipation: 6.3 Watts

OPTIONAL EQUIPMENT

DEMODULATORS
SEQUENTIAL ERROR CORRECTION
THRESHOLD DOUBLE ERROR CORRECTION
SYNTHESIZERS
BIT ERROR MONITORS
I:N PROTECTION SWITCH

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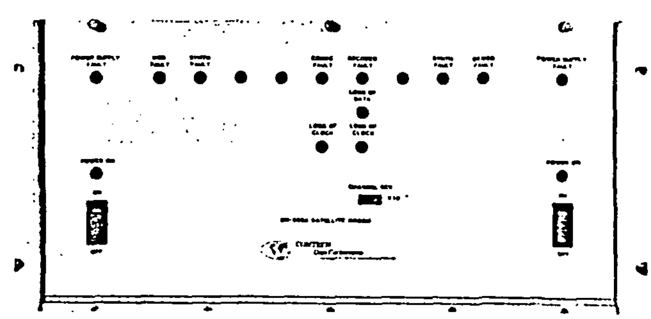

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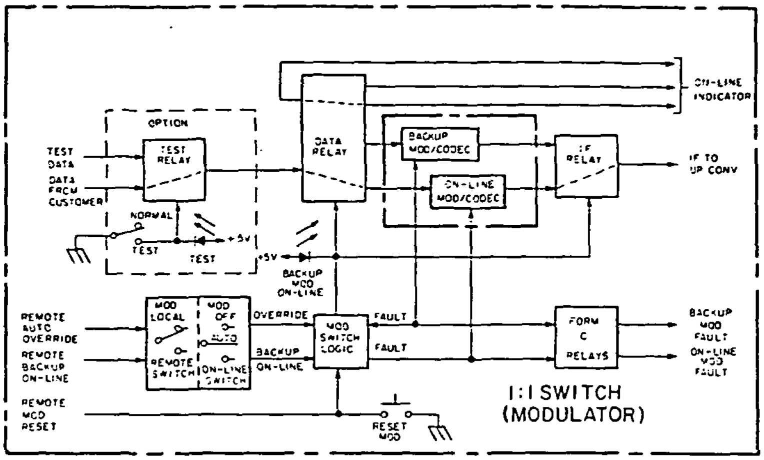

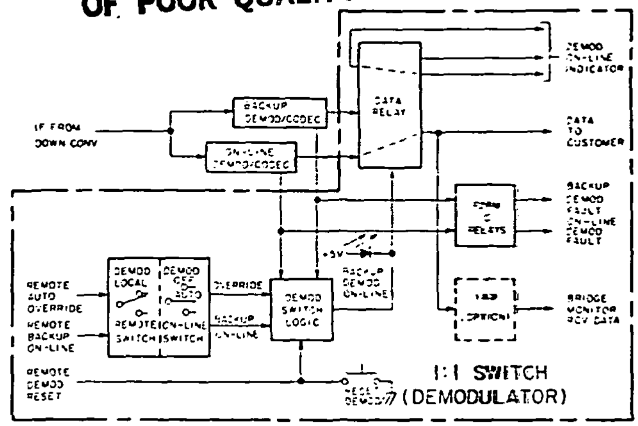

SPECIFICATIONS

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Data Relay Contact Resistance:	Less than 50 Milliohms
IF Relay Insertion Loss:	Less than 0.25 dB
Remote Input:	Form C or TTL: Backup On-Line, Auto Override, and Reset for Mod/Demod
Outputs:	Form C Relay Closure: Mod/Demod Fault Summary, Backup On-Line Indicators
Bridge Monitor Interface (Option):	V.35, T1, RS-449/422, MIL-188
Switchover Time:	Approximately 2 seconds for both Modulator and Demodulator

OPTIONAL EQUIPMENT

MODULATORS
DEMODULATORS
SEQUENTIAL ERROR CORRECTION
THRESHOLD DOUBLE ERROR CORRECTION
SYNTHESIZERS
BIT ERROR MONITORS
1:N PROTECTION SWITCH

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SM200A 1:1 MODEM SWITCH

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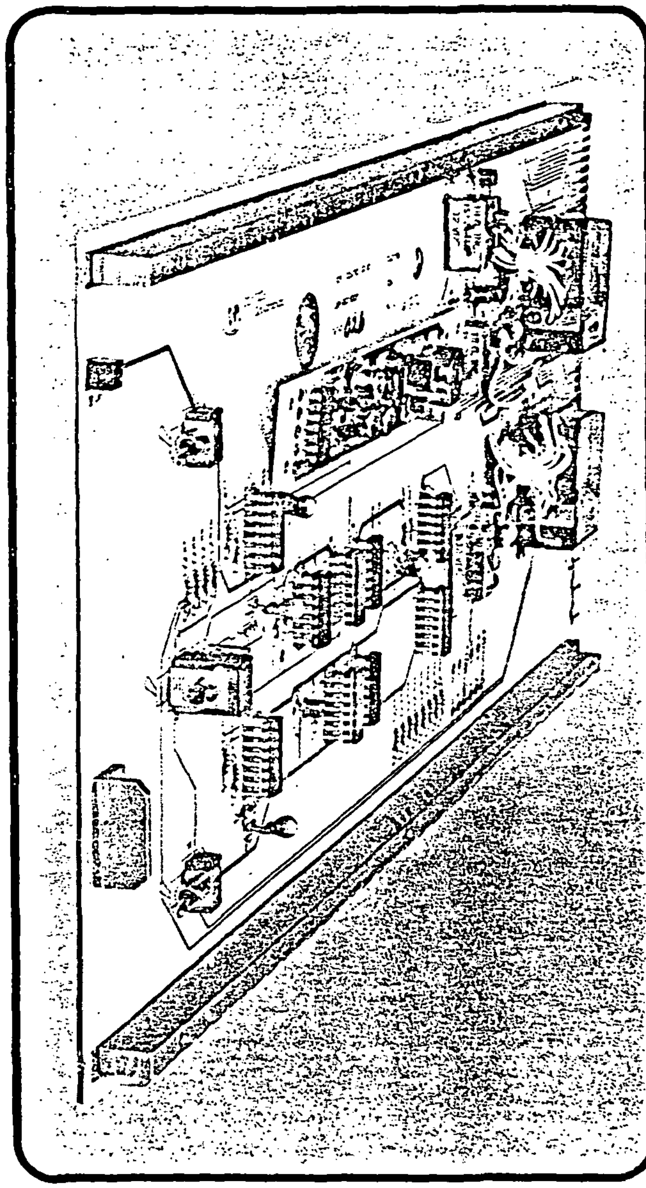

The SM200A series of digital satellite communications equipment is a family of interchangeable modules vertically integrated into standard 19 inch trays. The SM200A series was conceived to give maximum configuration flexibility to systems designers and provide the high level of maintainability and operational efficiency required for cost effective operations.

The 1:1 modem switch provides automatic switching of primary (on-line) to backup channels for the modulator and demodulator modules and includes fault signal distribution. There are three different combinations of the 1:1 switch; two versions are for modulator and demodulator only, and the third version is for modulator and demodulator combined.

It may be ordered with optional circuits to switch the modulator to a test data input that includes a TEST/NORMAL switch. Included in this option is an interface adapter unit (IAU) that allows bridge monitoring of customer receive data. The accessibility for the test data input and the bridged received data output are made available at a front panel connector.

The unit can be operated in one of three different operating modes; AUTOMATIC, LOCAL, or REMOTE, the latter of which can be operated using FORM C contact closures. Form C contact closures are also provided for modem on-line indications and modulator and demodulator fault summary. All data and IF switching is performed by relays.

FEATURES

- Single Circuit Protection
- Relay Switching for Data and IF
- Form C Modem On-Line and Fault Summary Output
- Optional Test Input/Output Data Connector
- Automatic, Local and Remote Operation

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Data Corporation

FREQUENCY SYNTHESIZER 52-88 MHZ

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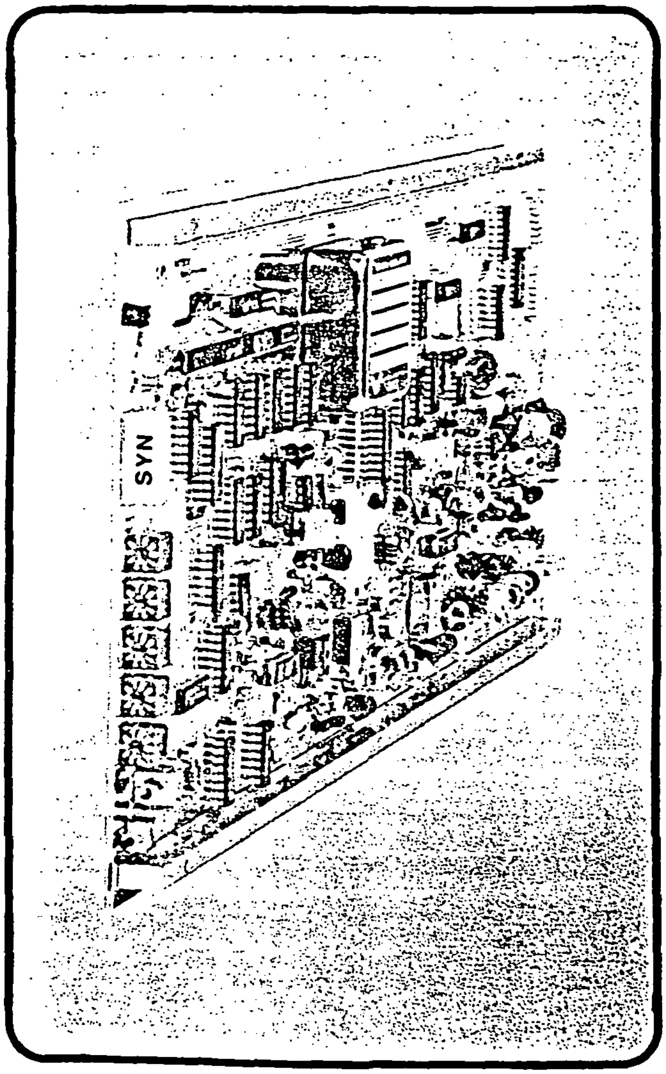
The SM200A series of digital satellite communications equipment is a family of interchangeable modules vertically integrated into standard 19 inch trays. The SM200A series was conceived to give maximum configuration flexibility to systems designers and provide the high level of maintainability and operational efficiency required for cost effective operations.

The SM200A synthesizers were designed to provide frequency agility for the SM200A series modems. Frequency selection can be either local by using rotary switches that are edge-mounted on the front of the module, or remote controlled via BCD input from a microprocessor or other control device. The synthesizer may be set on 25 KHz centers or multiples thereof.

The synthesizer module consists of six basic functional sections; local and remote frequency selection circuits, a temperature controlled crystal oscillator (TCXO) and reference frequency divider, two phase-locked loops, an output amplifier, and fault detection circuits.

A 50 MHz TCXO provides the basic frequency reference source for the frequency synthesizer. The output of the TCXO is divided down to supply a reference input to high frequency (1 MHz) and low frequency (200 KHz) phased-locked loops. The selected frequency, from either local or remote sources, presets programmable dividers in the two PLL loops. The appropriate output of the TCXO and the output of the programmable dividers are compared in separate phase detectors which controls two voltage controlled oscillators (VCO). The outputs of both VCOs are mixed together and amplified to produce the output signal. The output amplifier is controlled by fault monitoring circuits.

The module includes fault monitoring circuits that sense both the high and low PLLs for an in-lock condition, that the power output of the module is above a preset level, and that any of these conditions is not caused by transients.



FEATURES

- Remote Control
- 52-88 MHZ
- Low Power Consumption
- High Reliability

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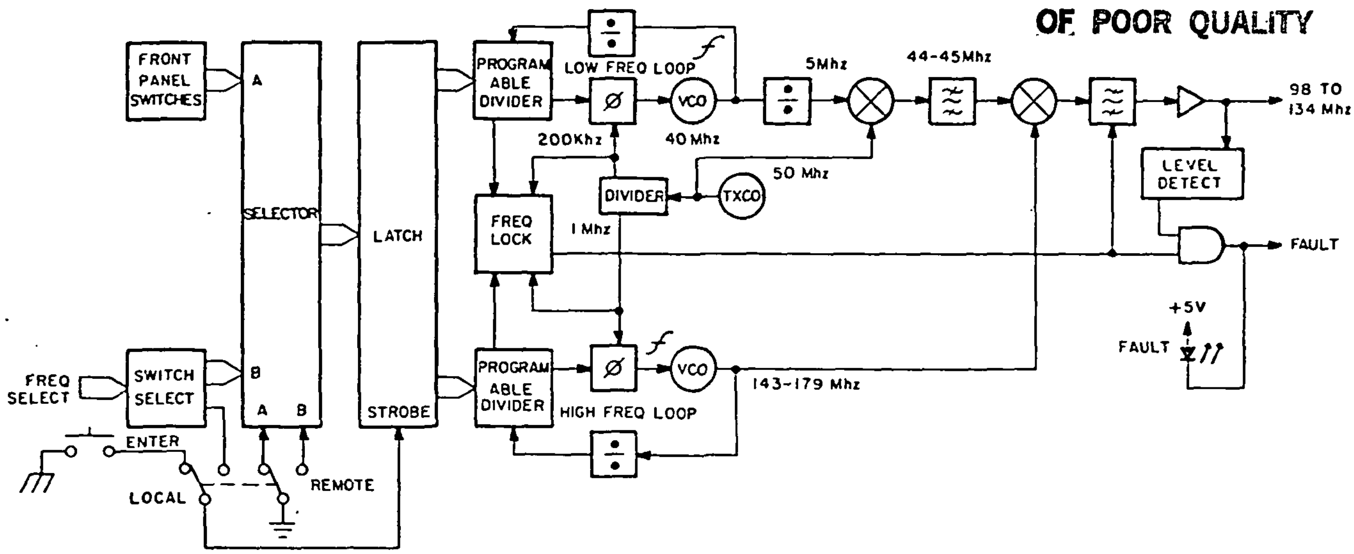


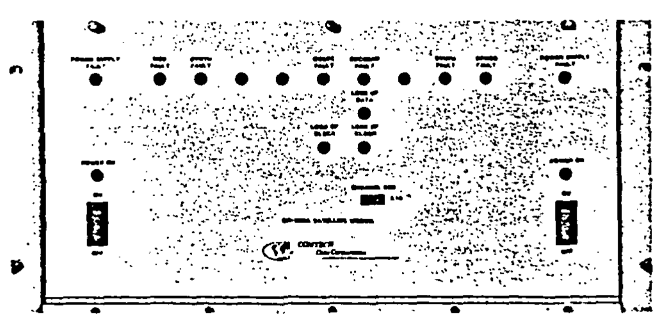
SPECIFICATIONS

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

Output Frequency:	98.000 MHz to 134.000 MHz in 25 KHz steps (±12 Hz)
Output Power:	+7 to 11dB over entire range
Input Signals:	Frequency select in BCD (TTL levels)
Input Command:	52 to 88 MHz in BCD (25 KHz minimum step)
Stability:	1×10^{-6}
Spurious:	-55 dBc

OPTIONAL EQUIPMENT

MODULATORS
DEMODULATORS
SEQUENTIAL SOFT DECISION ERROR CORRECTION
THRESHOLD DOUBLE ERROR CORRECTION
BIT ERROR MONITORS
T:N PROTECTION SWITCH



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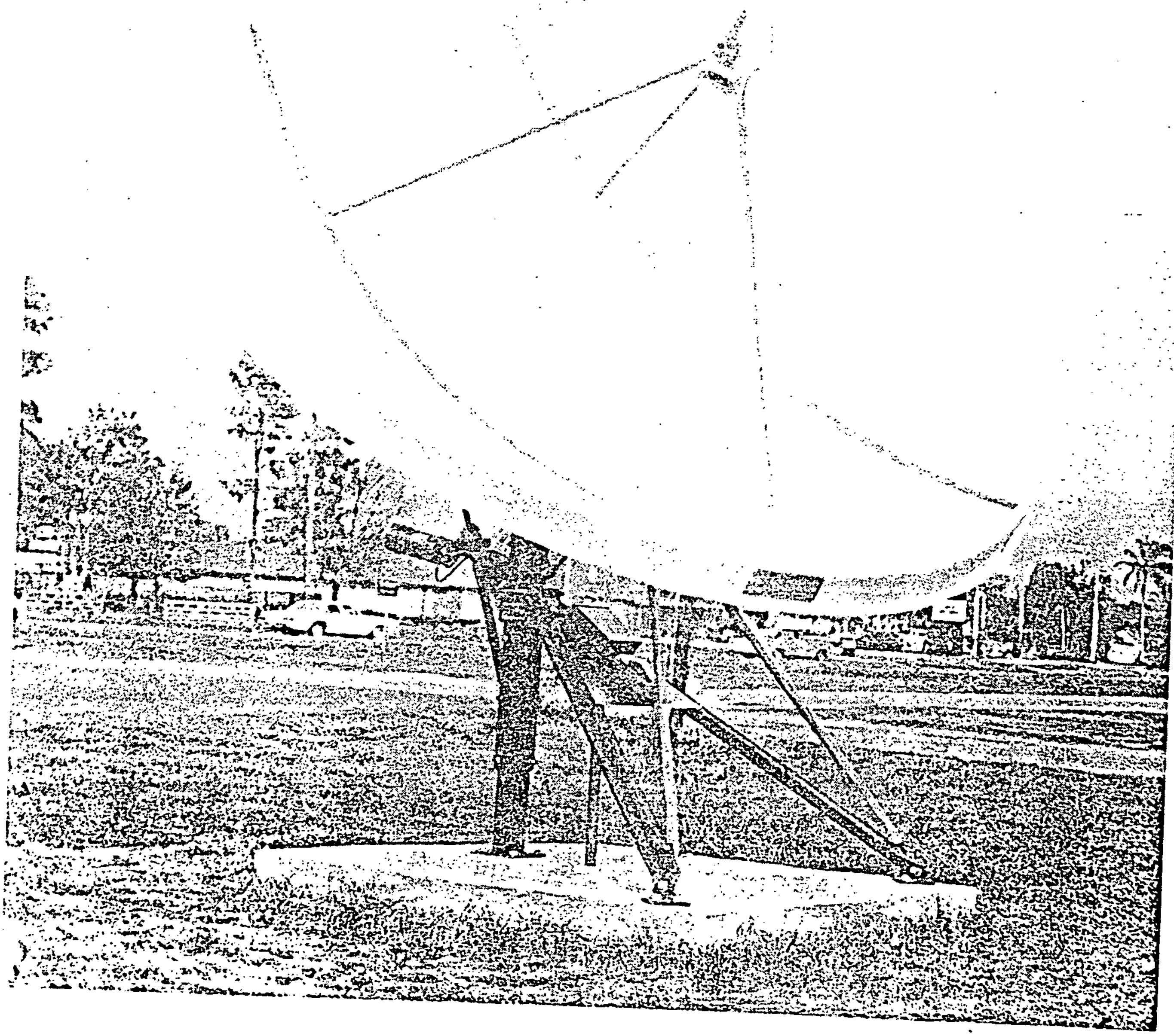
Antenna Corporation

5 METER POLAR MOUNTED ANTENNA

Range Tested



FEATURES

- Fully Automated
- FCC Conforming Patterns
- Parabolic Accuracy
- Full Arc Coverage From Most U.S. Locations
- Mount Stability

5 METER POLAR MOUNTED ANTENNA SPECIFICATIONS

GENERAL DESCRIPTION

Reflector Type	16½ foot, Parabolic 3 piece fiberglass .060 RMS surface
Mount Configuration	Electrically operated polar (equatorial)
Mount Controls	EC5 programmable remote, console or rack mounted
Feed Type	Special conical scalar, fully machined, prime focus, single or dual polarization

ELECTRICAL

Operating Frequency	Receive 3.7/4.2 GHz
Polarization	Single or dual linear
Gain @ 4GHz	44.9 dB
Beamwidth (Half Power)	1.1°
VSWR	1.3 max.
Isolation Between Ports (Dual Pol)	35 dB min.
Input Flanges	CPR-229 F

DRIVE:

Motor	1 HP totally enclosed; 230V, 3-phase with elec. brake
Controls	Linear closed loop, position controller and reversing contactor
Power Requirements	At Antenna-230V, 3-phase, 4-Wire, 5 amp service At Remote Control - 110V AC

ENVIRONMENTAL

Operating Wind	75 MPH
Drive to Stow	85 MPH
Survival Wind	120 MPH

SHIPPING INFORMATION

Gross Weight	2250#
Volume	715 cu. ft.
Size (Packed)	17' L x 5¼' W x 8' H

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

COMTECH

Comtech Antenna Corporation Comtech Data Corporation

Subsidiaries of Comtech Telecommunications Corp.

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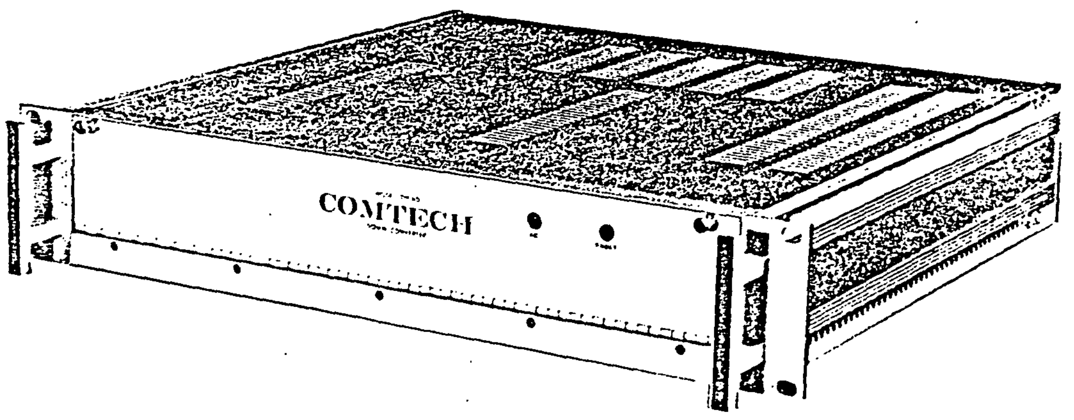
COMTECH
Data Corporation

MODEL 250AD
3.7 TO 4.2 GHz DOWN CONVERTER



FEATURES

- Designed for data and analog transmission
- Dual conversion — 70dB (minimum) image rejection
- High performance — Low cost
- 15dB (1dB step) gain control

OPTIONS

- Remote control
- Second local oscillator
- 1:1 or 1:8 backup switching available
- Equalizing for INTELSAT series satellites
- RF input and IF output connectors located on front panel
- Continuously variable gain adjustment from front panel
- High frequency stability

DESCRIPTION

The Comtech 250AD Down Converter is designed for both analog and data transmission applications. Typical applications include Video, SCPC, TDMA, and FM/FDM data transmission. The model 250AD is a complete self-contained dual conversion C-band down converter housed in a rugged 3½" housing containing the power supply, all down converter circuitry and local oscillators. A protective drop-down front panel allows access to all monitor connectors as well as frequency adjustment points for the IF and RF Local oscillators. The RF input and IF output connectors are located on the rear panel or, optionally, can be located on the front panel. A "D" type interface connector located on the rear panel provides for complete control and monitoring capability.

The Model 250AD utilizes dual conversion to down convert the 3.7 to 4.2 GHz RF input to the 70 MHz IF output. An IF frequency of greater than 1 GHz is used to provide superior image rejection and minimum LO leakage. Gain adjustment of up to 15 dB in 1 dB steps is provided or, optionally, front panel continuous gain adjustment of up to 40 dB is available. The RF input is isolated with a ferrite isolator to provide an excellent input match as well as isolation from external equipment.

Complete fault monitoring of the power supply and the IF and RF local oscillator is provided. In the event of a failure, an appropriate fault LED is illuminated along with a summary fault LED which is visible with the front panel closed.

A back-up RF LO option is available which provides a secondary LO that can be manually or remotely switched on line as a back-up LO or as a means of switching to a second transponder frequency.

The Model 250AD can be used in conjunction with the Model 251 1:1 redundancy switch to switch a back-up down converter on line in the event of an equipment failure.

PERFORMANCE SPECIFICATIONS

Converter Type	Dual Conversion, noninverting
INPUT	
Frequency Range	3.7 to 4.2 GHz
Impedance	50 Ohms
Return Loss	20 dB minimum
Signal Level Range	−75 to −35 dBm
OUTPUT	
IF Output Frequency	52 to 88 MHz
Impedance	75 Ohms
Return Loss	20 dB minimum
Signal Level	To +10 dBm (1 dB gain compression)
OVERALL	
Noise Figure	15 dB maximum
First IF Frequency	Above 1 GHz
Bandwidth	36 MHz minimum
Image Rejection	70 dB minimum
RF to IF Gain	45 dB minimum
Gain Adjustment	15 dB in 1 dB steps

GENERAL SPECIFICATIONS

Dimensions	19″ wide, 3.5″ high
Operating Temp Range	+10 to +50 degrees C
Humidity	10% to 90% non condensing
Power Input	117 VAC ± 10% 60 Hz 230 VAC ± 10% 50 Hz (special order) 100 Watts
CONTROLS BEHIND FRONT PANEL	
AC ON/OFF	Applies power to the unit
RF LO Select	Manual selection of primary or auxillary RF LO
RF LO REF Select	Selects internal or external reference for primary RF LO
AC Line Fuse	
FRONT PANEL INDICATORS	
IF LO Alarm	Indicates IF LO fault
RF LO Alarm	Indicates RF LO fault
Supply Alarm	Indicates power supply fault
Summary Alarm	Indicates summary of above faults
RF LO REF Select	Indicates selected RF LO
FRONT PANEL CONNECTORS	
IF LO Monitor	Type BNC, female
RF LO Monitor	Type BNC, female
RF Input Monitor	Type BNC, female
IF Output Monitor	Type BNC, female
REAR PANEL CONNECTORS	
Down Converter IF Out	Type BNC, female
Down Converter RF Out	Type SMA, female
AC Power	Standard AC power cord
Interface	37 pin connector — Form C closure of all alarms — Relay closure or TTL input for PRI/AUX RF LO Select, Up Converter ON/OFF

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

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Subsidiaries of Comtech Telecommunications Corp.

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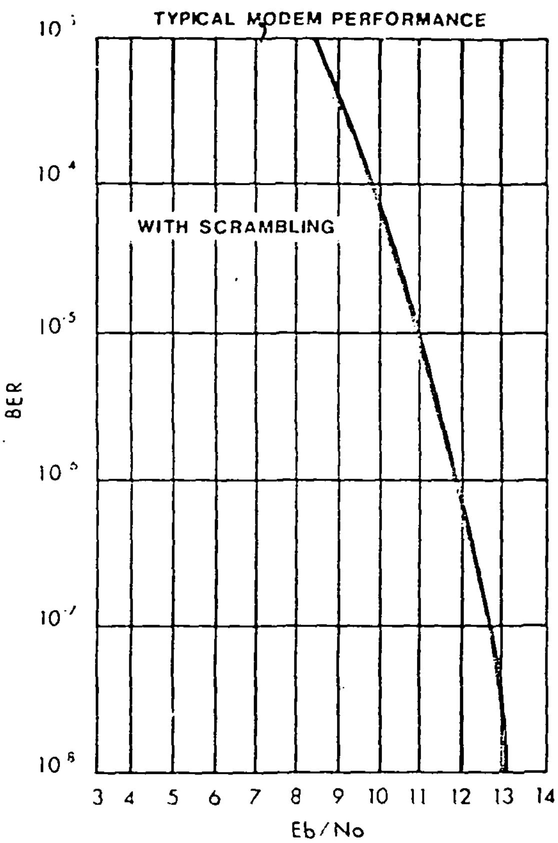
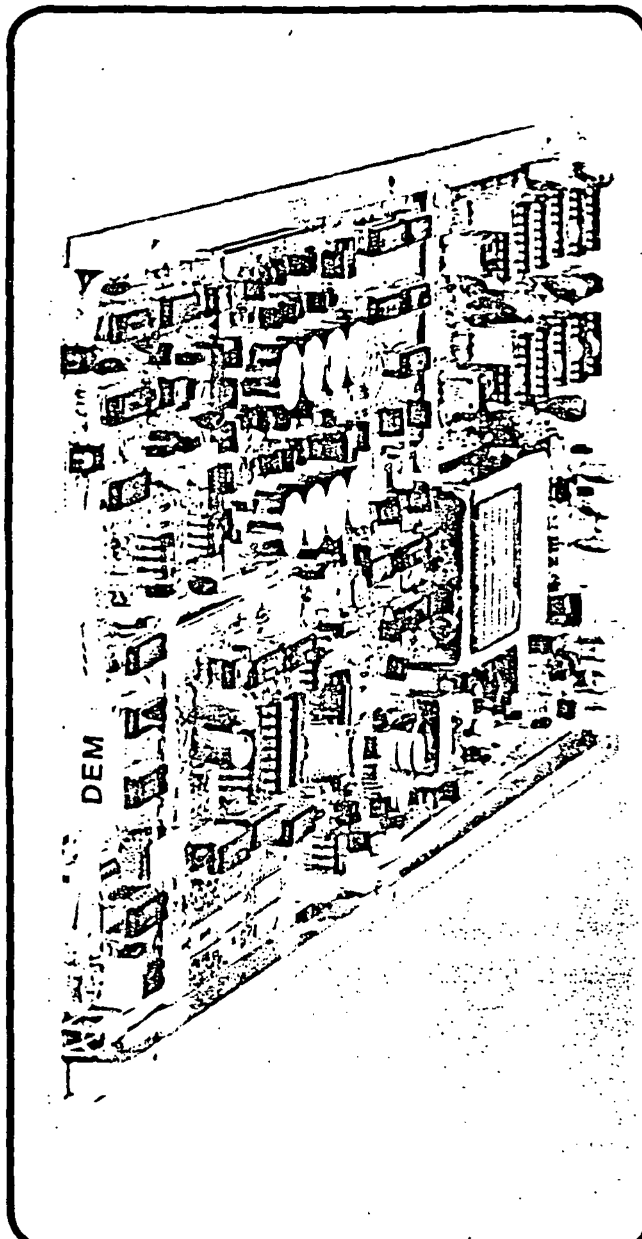
COMTECH
Data Corporation

SM200A SATELLITE DEMODULATOR 52-88 MHZ





The SM200A series of digital satellite communications equipment is a family of interchangeable modules vertically integrated into standard 19 inch trays. The SM200A series was conceived to give maximum configuration flexibility to systems designers and provide the high level of maintainability and operational efficiency required for cost effective operations.

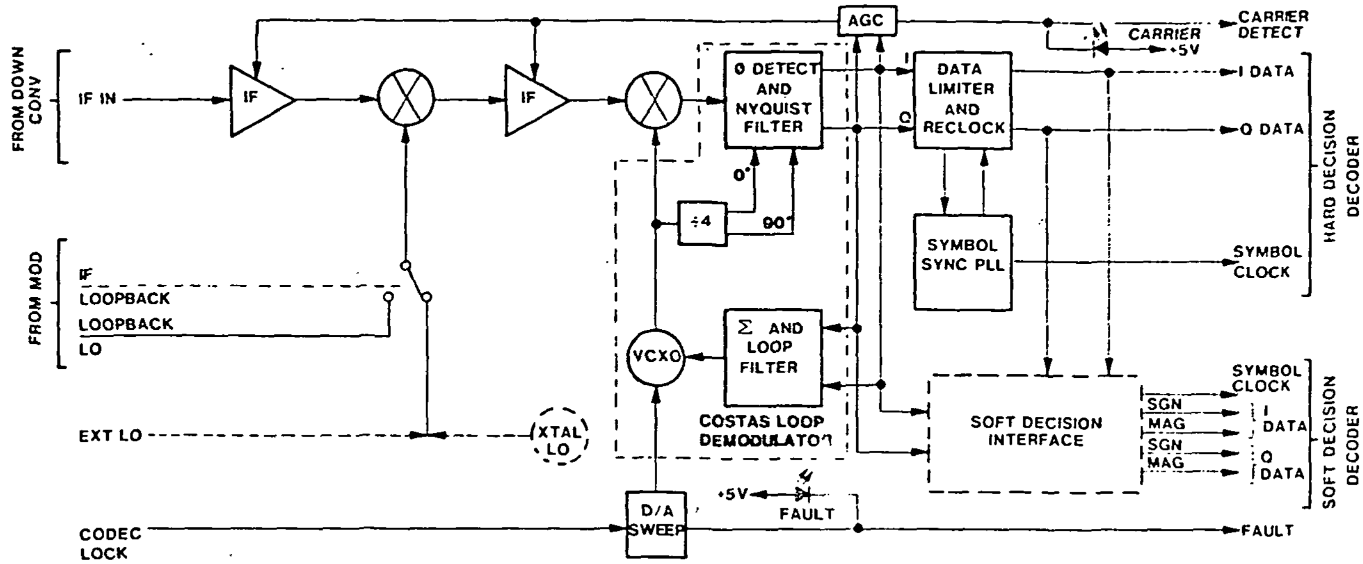
The QPSK demodulator consists of a Costas loop, symbol synchronizer, an IF processor, and an optional soft-decision interface circuit. The IF section amplifies and filters the desired carrier. The Costas loop then locks and passes the data to the Nyquist filters. The symbol synchronizer locks to the data transitions and generates a local clock for strobing data from the demodulator. An optional soft-decision circuit provides sign and magnitude I and Q data for use with sequential soft decision codec units.

Frequency agility over the 52 to 88 MHZ band is accomplished by an external synthesized LO. If the demod is to operate on a single frequency, an optional internal LO is available. In IF loopback mode, the LO frequency from the companion modulator module supplies the LO frequency for the demodulator.

Two faults, CARRIER DETECT and FAULT SUMMARY, are provided. The CARRIER DETECT is derived from the AGC circuit, and the FAULT SUMMARY is derived from the Costas loop, symbol synchronizer, and the decoder lock. The front panel includes a fault summary and carrier detect LED and an IF monitor point.

FEATURES

- QPSK/BPSK
- No Tuning
- 50 Kb/s to 3.088 Mb/s
- Low Power Consumption
- Internal/External LO
- High Reliability
- IF Loopback



SPECIFICATIONS

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

GENERAL

Demodulation: Costas type
Coding: Absolute or Differential
Descrambler: Per CCITT V.35 (optional)
Spacing: .7 of Data Rate-QPSK
1.4 of Data Rate-BPSK

DIGITAL

Data Rate: 50Kb/s to 3.088Mb/s
Interface: V.35, RS-449/422, T-1
Lock: Data Rate Dependent (T1 less than 1 sec)
Filter: Nyquist Type

IF

Range: 52 Mhz to 88 Mhz
Connector: Female BNC/75 ohms
Level: −35 to −55 dBm
Acquisition: ±25 Khz
Local Oscillator: Internal/External

ENVIRONMENTAL

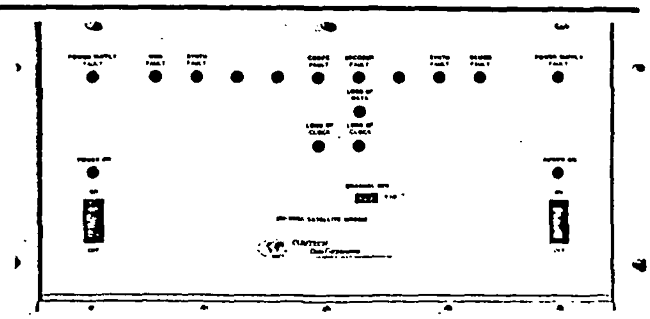
Temperature: 10°C to 40°C
Humidity: 90% Non-condensing
Storage: −40°C to 120°C at 95% Non-condensing

PHYSICAL

Mounting: 19 inch by 8¾ inch tray
Weight: 3.1 Lbs.
Power Dissipation: 8.2 Watts

OPTIONAL EQUIPMENT

MODULATORS
SEQUENTIAL SOFT DECISION ERROR CORRECTION
THRESHOLD DOUBLE ERROR CORRECTION
SYNTHESIZERS
BIT ERROR MONITORS
1:N PROTECTION SWITCH



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Appendix B

Vendor Price Quotes

Equatorial: Satellite rental

Equatorial: C-200 low-data-rate earth stations

Comtech: One-way and two-way high-data-rate stations components

Starview: 6-meter, two-way, high-data-rate antenna

Comtech: 7.3-meter, two-way, high-data-rate antenna

Scientific Atlanta: 7-meter, two-way, high-data-rate antenna

LNR: Modems for high-data-rate stations

RF Associates: High-power TWT amplifiers for two-way station

Comtech: High-power, solid-state amplifiers for two-way station

Equatorial

October 3, 1985

Dr. Bruce Lusignan
Space, Telecommunications &
Radioscience Laboratory
Department of Engineering
Stanford University
Stanford, California 94305

Dear Bruce:

This letter is in response to your request for space segment price quotation for your NASA SPOCC project. Rolf Dyce feels that your EIRP calculations of 3.4 dBW and the 17.8 dBW for the 56 kbps and 1.544 mbps data rates, respectively, are correct.

Equatorial will be pleased to offer you the appropriate transponder capacity at the following lease rates per data channel:

Data Rate	EIRP	Lease Rate Weekly	Lease Rate Monthly
56 kBps	3.4 dBW	$ 200	$ 500
1.544 mBps	17.8 dBW	$3000	$1500~~0~~ see attached

The transponder(s) for the above capacity would be assigned on one of Equatorial's Galaxy III transponders.

If you have any further questions, please don't hesitate to call me at (415) 969-9500.

Best regards,

Eddy

Eddy W. Hartenstein
Vice President
Network Operations & Field Services

EWH/par

Equatorial Communications Company
189 North Bernardo Avenue • Mountain View, California 94043 • (415) 969-9500

Equatorial

November 20, 1985

Dr. Bruce Lusignan
Space, Telecommunications &
Radioscience Laboratory
Department of Engineering
Stanford University
Stanford, California 94305

Dear Bruce:

You are correct. There is a typo on the monthly rate for the 1.544 mBps service in my letter of October 3, 1985. The monthly lease rate for that 1.544 mBps (17.8 dBW) channel should be $7,500.00.

If you have any further questions, please do not hesitate to call me.

Best regards,

Eddy

Eddy W. Hartenstein
Vice President,
Network Operations & Field Service

EWH/brw

Equatorial Communications Company

189 North Bernardo Avenue • Mountain View, California 94043 • (415) 969-9500

Equatorial

July 13, 1984

Dr. Bruce B. Lusignan
Director, Communications Satellite
Planning Center
Durand Bldg., Room 333
Stanford University
Stanford, CA 94305

Dear Bruce:

Further to our discussions on the Stanford University proposal to Goddard Space Flight Center which will involve use of EQUATORIAL technology and products.

The following are costs involved in supplying this technology and products.

1. Micro Earth Stations Series C-200

Volume	Price per System
1-99	$6,950.00
100-499	6,200.00

2. Dual Antenna Assembler
   Mounting Pad Kits

Model	
2410	$285.00

3. Space Segment Example - (monthly charge) Prices apply to space segment ordered at one time on a single channel.

Capacity in KB/S	Inbound	Outbound
4.8	$1,000.00	$5,000.00
9.6	2,000.00	10,000.00

4. Monthly Micro Earth Station Connection Fee — $25.00 per month per Micro Earth Station

Equatorial Communications Company
300 Ferguson Dr., Mountain View, CA 94043 (415) 969-9500

5. Installation

a. Standard Installation — $800.00 per unit
b. Non Standard Installation — T&M

Installation can be provided by Stanford University or EQUATORIAL.

6. FCC License

a. Standard site clearance — $500.00 per unit
b. Non-Standard site clearance — T&M
c. Longitude, Latitude and Elevation determination, if done by EQUATORIAL — 50.00 per site

7. Training

a. Installation (2-day class) — $2,000.00
b. Maintenance (3-day class) with training to module level only) — 3,000.00

Classes are conducted at Mountain View with up to four students. Includes installation or maintenance documentation for each student.

8. Maintenance

There are several third party maintenance companies that EQUATORIAL can recommend to Stanford University unless the maintenance will be handled internally by Stanford.

9. Protocols

Standard offered include:

-IBM SNA/SDLC - 3270 Series
-ASCII ASYNC

Other: If customer requires a protocol which is not listed as one of the EQUATORIAL Standards, prices can be quoted.

The area needing specific definition is the protocol required by Stanford as well as what the overall system is to look like. Because of the various terminals and computers, etc. available to your group selecting an EQUATORIAL standard protocol should not be a problem. The reason I am stressing this is that any new protocol or one where there is a lot of modifications required will delay the delivery timeframe from last quarter of this year until sometime in 1985.

I am meeting with manufacturing next week to find out when there will be 4 systems available in the last quarter of this year for this project.

When you return we must set up a meeting to review and discuss what all the systems requirements are as well as when they can be accomplished.

I will call you to set up this meeting next week.

Sincerely,

H. J. Walker
International Marketing Manager

cc: E. Parker

COMTECH
Data Corporation

A SUBSIDIARY OF COMTECH TELECOMMUNICATIONS CORP.

Quotation

DATE: 3 July 1984

P- 2928

COMPANY: Stanford University
Electrical Engineering Dept.
Stanford, CA 94304

ATTN: Dr. Bruce Lusignan

REF #: Verbal

PHONE: 415-497-3471

PERSON QUOTING:
Wayne A. Berry
602-949-1155

TERMS: Net 30 Days

F.O.B.: Scottsdale, AZ
St. Cloud, FL

VALID UNTIL : 3 September 8

DELIVERY: 120 Days ARO

ITEM NO.	QTY.	DESCRIPTION	UNIT PRICE	TOTAL PRICE
		7.3 METER EQUIPMENT		
1	1	7.3 Meter Antenna, TX/RX feed, including OMT and packing	23,000	$ 23,000.00
2	1	TX Filter	700	$ 700.00
3	1	85° LNA	685	$ 685.00
4	1	RCV 360 Down Converter 10^{-6} Oscillator Stability	2,650	$ 2,650.00
5	1	M250-005 Up Converter 10^{-7} Oscillator Stability	7,900	$ 7,900.00
6	1	M200-X31 Modem, 2 MBPS, Frequency Agile, 1 Power Supply	14,300	$ 14,300.00
7	1	Installation Manual	6,000	$ 6,000.00
		Total for 1 System		$ 55,235.00
		Total for 4 System		$ 200,540.00

80CDA0142 REV. 1

QUOTATION PAGE TWO
P-2928

DATE: 3 July 1984

COMPANY: Stanford Uni

ATTN: Dr. Bruce Lusig

PERSON QUOTING:
Wayne A. Berry

ORIGINAL PAGE IS
OF POOR QUALITY

ITEM NO.	QTY.	DESCRIPTION	UNIT PRICE	TOTAL PRICE
		5.0 METER EQUIPMENT		
8	1	5.0 Meter Antenna E/Az Receive only	4,355	$ 4,355.(
9	1	85° LNA	685	$ 685.(
10	1	RCV 360 Down Converter 10^{-6} Osciallator Stability	2,650	$ 2,650.(
11	1	M200-X35 Demod / Decoder only, Frequency Agile, 1 Power Supply	9,300	$ 9,300.(
12	ALL	Packing		$ 225.(
		Total for 1 System		$ 17,215.(
		Total for 20 Systems		$ 324,337.(
		Total for 4 TX/RX Systems and 20 RX only Systems, if purchased together		$ 512,861.(
		High Gain Option for Up Converter		
13	1	High Gain (0dBm) output for M250-005 Up Converter	1,800	$ 1,800.(
		Total for 4 Systems		$ 7,200.0

FEDERAL EXPRESS

COMTECH
Data Corporation

A SUBSIDIARY OF COMTECH TELECOMMUNICATIONS CORP.

July 3, 1984

Stanford University
Electrical Engineering Department
Communication Satellite Planning Center
Durand Building
Room 333
Stanford, California 94305

Attention: Dr. Bruce Lusignan

Reference: Our P-2928

Dear Dr. Lusignan,

Comtech Data Corporation is pleased to submit the following quote for non-redundant satellite equipment to provide data communications from up to four (4) sites with Comtech Data's 7.3 meter antenna to up to 20 sites with our 5.0 meter antenna. The quote includes equipment for transmit and receive for the 7.3 meter stations (minus the HPA), and receive only equipment for the 5.0 meter earth stations.

Attached are data sheets on the equipment offered in this quote, along with a link analysis for the 7.3 to 5.0 meter path. The latter includes an estimate of the monthly satellite charges based on a two (2) year lease over a Westar satellite using 10^{-7} BER, 7/8 code rate, 2 MBPS data rate and a 3dB fade margin as the baseline.

The quote includes an installation manual for the 7.3 meter and 5.0 meter antennas which describe the necessary cabling, etc., (the latter of which is not provided in the quote). Packing of the antennas and equipment are included in the price, and the F.O.B. points are St. Cloud, Florida for the antennas and Scottsdale, Arizona for the remaining equipment.

350 NORTH HAYDEN RD. • SCOTTSDALE, ARIZONA 85257-4692 • (602) 949-1155 • TWX NO. 910-950-0085
EASTERN OFFICE: 45 OSER AVENUE • HAUPPAUGE, NY 11787 • (516) 231-5454 • TWX NO. 510-227-6148

Highlights to the equipment specifications include:

* 7.3 meter meets FCC 29 minus 25 log theta (2° spacing)
* Bandwidth efficient modems (BW and channel spacing equals 0.7 times the symbol data rate)
* High coding gain (better than 10^{-7} BER with 8.2 Eb/No using 7/8 rate coding)
* Remote monitoring and control capability (fault and remote status reporting, raw and corrected BER, power output control, and TX/RX frequency control)

As indicated in the link analysis, roughly 42 watts is required for a 2 MBPS data rate. I contacted MCL (Mr. Bob Morgan, Sr.) and received a price of $14,200 for a 50dB gain 75 watt HPA (model 10656) and $16,900 for a 70dB gain 75 watt HPA (model 10529). As an option, the Up-Converter can be purchased with a high gain output (0 dBm) for an additional $1,800 per unit. As we discussed a 75 watt HPA allows a little over 2dB of backoff, which will cause a little spreading of the signal. Our engineers have previously tested the modems at 1 dB below compression with the third-order harmonics increasing to -30 dBc.

I am planning on being in the area sometime next week and would like to have the opportunity of meeting with you. Hopefully, we can set a time period that fits our schedules.

Meanwhile, should you have further questions regarding this quote, please feel free to call me at (602) 949-1155.

Best Regards,

Wayne A. Berry
Satellite Products Manager

WAB/msf

Enclosure

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Best Regards,

Wayne A. Berry
Satellite Products Manager

WAB/msf

Enclosure

STARVIEW
BY CRAIG

RECEIVED NOV 15 1985

ROUTE 3 BOX 103 G
POCAHONTAS
ARKANSAS 72455
501-647-2291
1-800-643-0102

QUOTATION

QUOTE NUMBER 118851

DATE OF QUOTE 11-8-85

R.F.Q.

REVISION LEVEL

REVISION DATE

SOLD TO: Communication Satellite Planning Center
Stanford University
Department of Electrical Engineering
Stanford, California 94305
ATTN: Bruce Lusignan, Director

ITEM	QTY	PART NUMBER	DESCRIPTION	UNIT PRICE	TOTAL PRICE
1.	1	32005	6 Meter Antenna	$ 4000.00	$ 4000.00
2.	1	10002	AZ/EL Mount	1058.00	1058.00
3.	1	32080	Single linear polarization for transmit and an othogonal linear polarization for receive.	2800.00	2800.00
4.	---	-----	Crating	500.00	500.00
5.	---	-----	Installation-Customer to furnish crane and antenna pad on roof to Starview specification.	2400.00	2400.00
6.		30004-20	Motorized mount with programable controller-optional.	12783.00	12783.00

The terms and conditions of this order are printed on the reverse side and upon acceptance of this order by Seller at its home office in Pocahontas, AR shall be binding upon Seller and Purchaser.

Estimated Shipment From Factory: 45 days after receipt of purchase order with downpayment and frequencies.

Payment Terms: 50 % with order; ____% prior to release to factory with frequencies; ____% prior to shipment; ____% (balance) net 30 days after shipment. The price and shipment estimate quoted are valid for 90 days from date of this quotation. The price does not include any applicable taxes unless so stated by line item.

NOTE: Any Purchase Order issued as a result of this Quotation should include the statement: "This Purchase Order is in accordance with Seller's Quotation No. 118851."

QUOTATION SUBMITTED BY: John Hastings

TITLE: President

ADDRESS: ~~Rt. 3 Box 103-G~~
Pocahontas, AR 72455

PURCHASER'S ACCEPTANCE

The above Quotation is accepted:

Company ____________

Address ____________

City ____________ State/Zip ____________

SIGNATURE ____________ Date ____________

Title ____________

Customer Order No. ____________

Ship to: Same as above As follows:

Ship VIA: Motor Frt. Rail Frt. Rail Exp. Air Frt. Air Exp. Parcel Post Air Parcel Post

COMTECH Antenna Corporation

A SUBSIDIARY OF COMTECH INC.

July 26, 1985

Stanford University
Electronic Engineering Dept.
Stanford, CA 94305

Attention: Bruce Lusignan, ERL-203

Gentlemen:

Thank you for your inquiry on COMTECH's 7.3 meter antenna. We are pleased to confirm the following prices to you.

Qty.	Description	Unit Price
1-10	7.3 meter xmt/rcv "C" band satellite antenna system with manually position-able polar mount	$27,000.00

Prices:
1. Exclude taxes, duties, permits or similar charges.
2. Are F.O.B. St. Cloud, FL, packed.
3. Are valid for 60 days.

I have enclosed spec sheets on this product for your review.

If I can be of further help, please advise.

Very truly yours,

COMTECH ANTENNA CORP.

Glenn F. Higgins
Vice President/General Manager

GFH/cfs
Enclosure

Scientific
Atlanta

P.O. Box 2668, 10039 Pioneer Boulevard, Santa Fe Springs, CA 90670 Telephone 213 949-9302

August 21, 1985 PVP102

Stanford University
Electrical Engineering Dept.
ERL Room 203
Stanford, California 94305

Attn.: Bruce Lusignan

Dear Bruce:

I enjoyed talking to your about your upcoming project to interconnect research centers via satellite communications. As per your request, I have attached a quotation for a 7-meter C-band transmit/receive antenna. I listed the options of a motorized 7-meter C-band transmit/receive also as per your request. As you indicated, that you may be installing four within a year, I will extend a 4% discount to you providing you buy all four antennas from Scientific-Atlanta within a year's timeframe. I feel confident we can also meet your tight delivery schedule, although you will need to place the order fairly soon.

Since you will be mounting this antenna on a roof, we need structual information on size and construction of the building and where the antenna will be placed.

I look forward to meeting you soon. In the meantime, if you have any questions at all, please feel free to call.

Very sincerely yours,

Pam Pietravalle
Pam V. Pietravalle
Western Regional Account Manager
Satellite Communications Division

PVP/sw

enclosure:

Scientific Atlanta

Quotation and Order Form

Date: 8/21/85
Quote No. 42-86-013
Page 1 of 3

To: Stanford University
Electrical Engineering Dept.
ERL Room 203
Stanford, California 94305
Attn.: Bruce Lusignan
(415) 497-3471

From Pam Pietravalle
10039 South Pioneer Blvd.
Santa Fe Springs, CA 90670
(213) 949-9302

Authorized Signature Pam Pietravalle/bm

This quote is subject to all terms and conditions stated below and on the other side of this form. If Customer's order form is used instead of this one, the following words should be typed on the face of Customer's form: "This order incorporates Quote No. 42-86-013 dated 8/21/85 Scientific-Atlanta Satcom Division."
Quotation valid for 60 days.

Item No.	Quantity		Description	Unit Price	Total Price
1.	1	a)	Model 8010C 7-Meter antenna. Meets the latest FCC specifications for 2° spacing (part 25.209 as amended September 6, 1983). Includes main reflector with stretch-formed panels, elevation-over-azimuth mount, manual drives, anchor bolts and foundation template. The antenna travels continuously 110° in azimuth to cover the entire U.S. satellite arc from most CONUS locations; and is capable of a total swing of 180° by changing one member.		
2.	1	b)	High-efficiency feed and subreflector for transmit and receive with the 7-meter antenna. The corrugated feed has two ports on opposite polarizations for operation on cross-polarized (SATCOM/WESTAR) satellites.		
			Total System		$27,000.00

Special Terms, Conditions and Warranty:
*Payment Terms:
Net 30 days after shipment

Estimated Delivery: 60-90 days ARO

FOB: Atlanta

Payment Terms: Net * days, subject to credit approval

Customer Order

Customer
Name
Title
Customer Order No.

Authorized Signature

Date:

Acceptance of Order

Scientific-Atlanta, Inc.

DIVISION

Name
Title
Scientific-Atlanta Production Order No.
Authorized Signature

Date:

Scientific Atlanta

QUOTATION CONTINUATION SHEET

Date: 8/21/85
Quote No: 42-85-013

This quotation is subject to all terms and conditions stated below and on the other side of this form.

Item No.	Quantity		Description	Unit Price	Total Price
			OPTIONS:		
3.	1	a)	Model 8010C-M High speed 7-meter antenna. Includes main reflector, elevation-over-azimuth mount, dual-speed motor drives, anchor bolts, and foundation template. Features: - Meets the latest FCC specification for 2^{o} spacing (part 25.209, amended September 6, 1983). - High gain associated with a 7-meter antenna - High-speed motors (120^{o}/min azimuth) to cover entire arc in less than 1 minute - Slow-speed motors (1:10 ratio) to accurately point antenna - Continuous 110^{o} azimuth coverage; total 180^{o} coverage by changing one member		
4.	1	b)	Model 8840A Antenna Control package for the motorized 7-meter antenna. Includes remote control, local contactor, 100-foot remote cable, installation hardware, and polarization drive. Features: - Microprocessor controller - 20 Satellite memory; field-programmable for future changes - Pressing four keys sends antenna to different satellites - Automatically starts and stops antenna in slow speed; switches to high speed in between - Non-volatile memory - Calibration on-site by front panel - SAbus interface for remote control		

Scientific Atlanta

QUOTATION CONTINUATION SHEET

Date: 8/21/85
Quote No: 42-86-013

This quotation is subject to all terms and conditions stated below and on the other side of this form.

Item No.	Quantity	Description	Unit Price	Total Price
5.	1	c) High-efficiency feed and subreflector for transmit and receive with the 7-meter antenna. The corrugated feed has two ports on opposite polarizations for operation on cross-polarized (SATCOM/ WESTAR) satellites.		
			Total Options	$46,000.00

LNR

180 MARCUS BLVD., • HAUPPAUGE, N.Y. 11788 • TEL: (516)-273-7111 • TWX: 510-227-9871

July 25, 1985

Mr. B. Lusignan
Electrical Engineering Dept ERL-203
Stanford University
Stanford CA 94035

Dear Bruce:

I enjoyed speaking with you regarding our QPSK Satellite Modem.

As we discussed, the MQ5615 operates at field changeable data rates from 50bps to 1.544Mbps, with a data and coding rate change being accomplished by a technician in about 20 minutes. All front panel controls, indicators and most test points are brought to the rear for remote control and monitoring. These features are coupled with a high calculated MTBF of about 10,000 hrs; an important consideration in applications such as yours.

Budgetary prices for the MQ5615 and other products discussed are in the attached price schedule. Should you wish to purchase any of these products, please contact our Contracts Department. The MQ5615, is in production and depending upon rate and interface requirements, delivery could commence as soon as 30 days ARO.

I'm sure you will find the flexibility, extensive diagnostics, compact size and high MTBF of the MQ5615 ideal for your network. Should you have any questions, please call.

I look forward to hearing from you.

Regards,

Tom Hartin

Tom Hartin
Marketing Specialist

TH:lme
Encl.

Budgetary List Price Schedule

Item	Description	Unit Price
1	MQ5615 QPSK Satellite Modem	15,900*
2	MQ5615 QPSK Satellite Model equipped for Modulator only operation	14,300
3	MQ5615 QPSK Satellite Modem equipped for demodulator only operation	14,300
4	DVU-960 Voice Digitizer	$1,265
5	UC6L-D4 Slimline Synthesized Upconverter. Frequency range 5.925 to 6.425GHz	14,980
6	DC4L-D4 Slimline Synthesized Downconverter. Frequency range 3.7 to 4.2GHz.	14,980

* Note: Since purchase of this equipment in quantities up to 10 pcs is 6 to 12 months away, we will be happy to provide discounts at that time. Previous purchase of items 2&3 will be considered in determining the discount.

R F associates, inc.

microwave specialists

☐ 2127 Sawtelle Bl. L.A., CA 90025-6231 · telephone: (213) 478-1586 · twx: 910-342-6884
☒ 800 san antonio road · palo alto, california 94303 · telephone: (415) 494-3331 twx: 910-373-1223

QUOTATION

TO: Stanford University
Durand Hall
P.O.Box 4409
Stanford, CA 94301

In reply
Refer to RFQ# 1296

Date January 23, 1985

Your reference Interlon Digital Network

Attention: Bruce Lusignan

Gentlemen:

In response to your inquiry we are pleased to quote on the following items manufactured

by MCL Inc. **Prices quoted below supercede verbal 11/16/84 quotation.

Item	Quantity	Type	Description	Unit Price	Extension	Delivery
1	1	10689	Redundant 75W C-Band Hi-gain Standard logic TWT Amplifier System (w/Harmonic filters) consisting of:			* 90 DARO
	2	10529	Amplifiers	$ 17,950.	$ 35,900.	
	1	10674	Redundant Switch-over Assembly	$8,950.	$ 8,950	

* RF Associates will gladly work with Stanford to obtain expedited service if requested.

FOB: LaGrange, IL

TERMS: Net 30 Days

REMARKS:

MCL and RF Associates respectfully request the opportunity to discuss the MCL system, especially the superiority of the MCL Switch-over Assembly.

Very truly yours,

R F Associates, Inc.

By [signature]

David B. Erickson
Applications Engineer

DBE/mp