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DESCRIPTION OF A REMOTE IONOSPHERIC SCINTILLATION DATA COLLECTION FACILITY

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16. Abstract

An experimental technique is described which measures L-band ionospheric scintillation at a remote, unmanned site. Details of an automatic data collection facility are presented. The remote facility comprises an L-band receiver, and a complete VHF command and control telemetry link which are coupled through an integral computer. The remote facility is controlled from a central data collection facility via the VHF link through either the ATS-1 or ATS-3 spacecrafts. L-band scintillation measurements taken at the remote facility are also relayed through the spacecraft to the central facility

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PREFACE

This report presents an experimental technique to measure L-band ionospheric scintillation at a remote, unmanned site. An automatic data collection facility is described which is a remotely controlled experimental test facility. The automatic data collection facility comprises a complete VHF telemetry command and control system with an L-band receiver coupled through an integral computer.

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LIST OF ABBREVIATIONS

addr	address word
AC	alternating current
ADCF	automatic data collection facility
AEROSAT	aeronautical satellite
AGC	automatic gain control
ALSEP	Apollo Lunar Surface Experiment Package
AM	amplitude modulation
AMP	amplifier
ASCII	American Standard Code for Information Interchange
ATS	Applications Technology Satellite
ATSOCC	ATS Operations Control Center
A/D	analog-to-digital
BPF	bandpass filter
BW	bandwidth
CA	Radio Corporation of America
CDCF	central data collection facility
CF	center frequency
CG	center of gravity
CIRC	circulator
CPU	central processing unit
CW	continuous wave
C-band	The portion of the radio frequency spectrum between 4,000 MHz and 8,000 MHz (Wavelengths between 7.5 and 3.75 cm)
dB	decibel
dBm	power relative to a milliwatt expressed in dB
DC	direct current
DEC	Digital Equipment Corp.
DEI	Defense Electronics Industries
DET	detector
DISC	discriminator
DIV	divider
DOT	U.S. Department of Transportation
D/A	digital-to-analog

E	East
EDP	electronic data processing
EIRP	equivalent isotropic radiated power
EOT	end of transmission
ESSA	Environmental Science Services Administration
f	frequency
f_c	center frequency
f_o	fundamental frequency
FFT	Fast Fourier Transform
FLT	filter
FM	frequency modulation
FT	frequency translation mode
GE	General Electric Co.
GHz	Gigaherta = 10^9 Hz
hr	hour
Hz	Hertz = 1 cycle per second
HP	Hewlett-Packard Co.
HR	hour
in.	inch
IF	intermediate frequency
Intelsat	names of satellites sponsored by INTELSAT
INTELSAT	International Telecommunications Satellite Concortium
IR	infrared
I/O	input-output
kHz	kilohertz = 10^3 Hz
KW	kilowatt = 10^3 W
LES-6	Lincoln Experimental Satellite-6
LHCP	left-hand circular polarization
LIM	limiter
L-band	The portion of the radio frequency spectrum between 1,000 MHz and 2,000 MHz (Wavelengths between 30 and 15 cm)
LO	local oscillator
LPF	low pass filter
LT	local time
min	minute
ms	millisecond = 10^{-3}s

mA	milliamp = 10^{-3} ampere
mW	milliwatt = 10^{-3} W
MA	multiple access mode
MHz	Megahertz = 10^{6} Hz
Min	minute
MIX	mixer
MMW	millimeter wave
MO	master oscillator
MT	magnetic tape
ns	nanosecond = 10^{-9}s
N	north
NASA	National Aeronautics and Space Administration
NB	narrow-band
NBFT	narrow-band frequency translation mode
NBS	National Bureau of Standards
NF	noise figure
NPD	noise power density
OMNI	omnidirectional
OTA	operational transconductance amplifier
PCM	pulse-code modulation
PFM	pulse-frequency modulation
PLACE	Position Location and Aircraft Communications Experiment
PM	phase modulation
PREAMP	preamplifier
PWR	power
rms	root-mean-square
rpm	revolutions per minute
RCVE	receive
RF	radio frequency
RFI	radio frequency interference
RHCP	right-hand circular polarization
RHG	RHG Electronics Laboratory
RPTR	repeater
®	registered trademark
s	second
sync	synchronizing word

S	south
SHF band	Super-high frequencies. The portion of the radio frequency spectrum between 3 GHz and 30 GHz (wavelengths between 10 and 1 cm)
SIG	signal
SSB	single sideband
STADAN	Space Tracking and Data Acquisition Network
SUM	summer
SW	switch
SYNC	synchronization
S/C	spacecraft
S/N	signal-to-noise ratio
TC	time constant
TSC	Transportation Systems Center
TV	television
TWT	travelling wave tube
TWTA	travelling wave tube amplifier
TXCO	temperature componsated crystal oscillator
T/R	transmit/receiver
UT	universal time
VCO	voltage controlled oscillator
VCXO	voltage controlled crystal oscillator
VDC	direct current voltage
VHF	very high frequencies. The portion of the radio frequency spectrum between 30 and 300 MHz (wavelengths between 10 and 1 m)
VSWR	voltage standing-wave ratio
W	watt, west
WBDM	wide-band data mode
WBFT	wide-band frequency translation mode
XMIT	transmit
XTAL	crystal
x2,x3	multiplier (by 2, by 3 etc.)
μs	microsecond = 10^{-6}s

1. INTRODUCTION

The objective of this test plan is to describe an experimental technique for acquiring scintillation data, at L-band frequencies (1550 MHz). The technique utilizes an automatic data collection facility in a remote region and a geostationary satellite as a source of transmitted electromagnetic energy. The scintillation data collected at the remote facility is retransmitted via another geostationary satellite(s) to a central data collection facility where it is analyzed in near real-time.

Ionospheric scintillation is produced by the presence of small-scale irregularities within the ionosphere which introduce random phase changes in the wave front of a traversing electromagnetic wave. The phase of a radio wave emitted by a satellite transmitter will not be constant over the ground but will form an irregular pattern. This pattern appears to move as a consequence of ionospheric winds shifting the irregularities. The result is that the phase and amplitude of the received signal will fluctuate or scintillate.

Experimental observations of amplitude statistics at VHF and L-band frequencies have revealed that there are ionospheric fluctuations or scintillations (Kuegler, 1970; Aarons, Whitney and Allen, 1971; Crampton and Sessions, 1971; Ponnappa and Serghini, 1972 and Whitney et al. 1971 and 1972). Recent measurements at frequencies above 1 GHz have shown unexpected ionospheric scintillation effects as for example Christiansen, 1971; Skinner et al. 1971; and Craft and Westerlund, 1972. Thus scintillation at L-band must be further investigated.

Since ionospheric scintillations are dependent on geomagnetic location it is important to be able to measure scintillation effects in a variety of geomagnetic locations at the same time in order to determine and correlate the severity and dependence of the fluctuations on geomagnetic location. A data collection system, depicted in Figure 1-1, is being developed by DOT/TSC for the purpose of collecting statistical data concerning scintillation at L-band frequencies.

The remote facility is controlled by a VHF radio link from the central facility located at Westford, Massachusetts, through either the NASA Applications Technology Satellites ATS-1 or ATS-3. The results of the measurements taken at the remote facility are then relayed back to the central facility where they can be analyzed concurrent with any scintillation measurements being taken simultaneously at the central facility. A pictoral representation of the scheme is presented in Figure 1-2.

The main objectives in deploying such a remote facility are:

1. Characterize a wide-band coherent channel for navigation and communication at L-band.
2. Obtain sufficient data to determine a channel model for system design use.
3. Collect propagation data throughout the region where the proposed AEROSAT[1] system will be deployed to obtain information on expected system performance as a function of geometry, geomagnetic situations and locations.
4. Obtain sufficient statistical information to evaluate the channel model under different geophysical conditions.

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1. Discussed in IEE (1973).

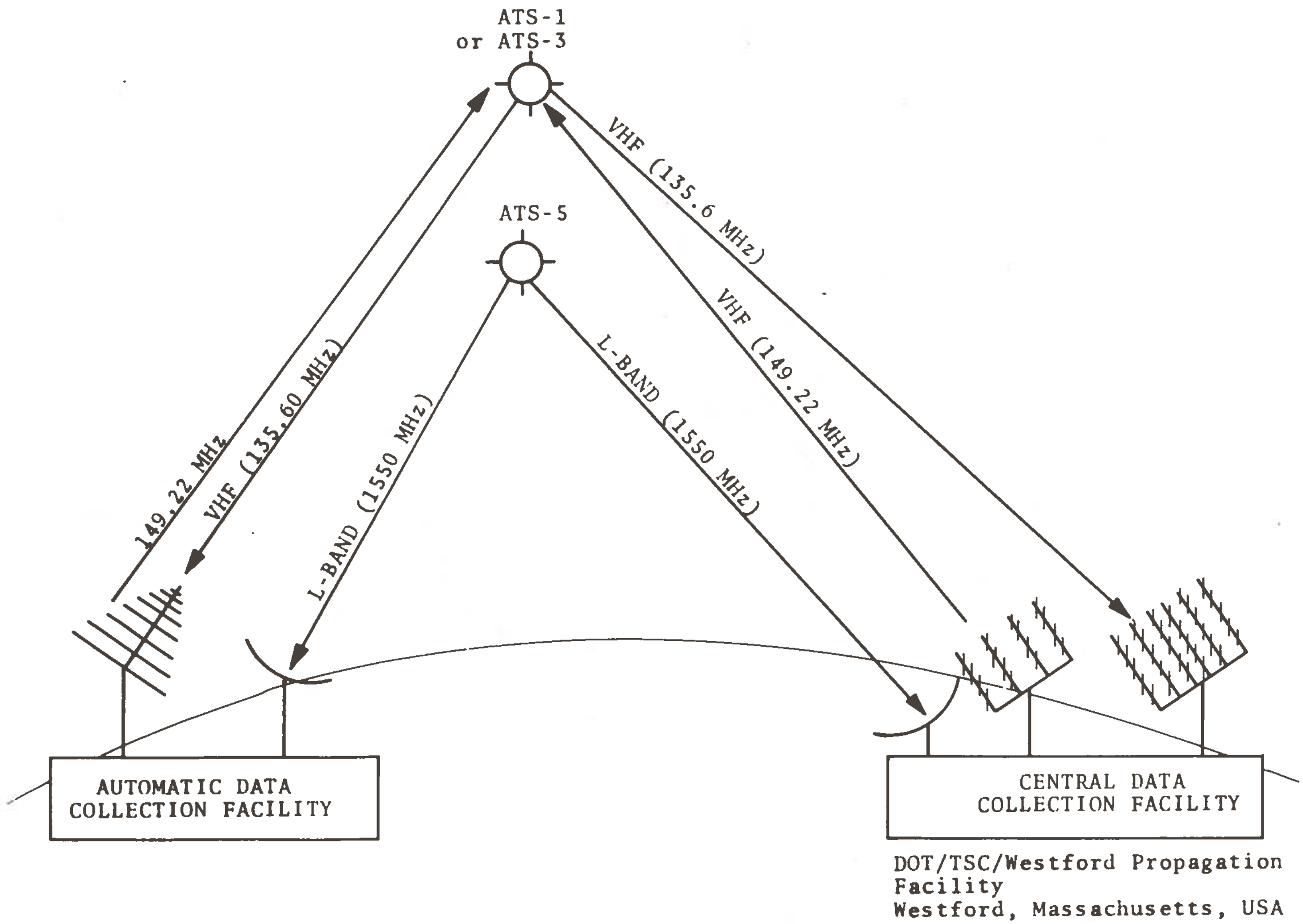

Figure 1-1. Overall System Concept of an Automatic Data Collection Facility Used with a Central Data Collection Facility

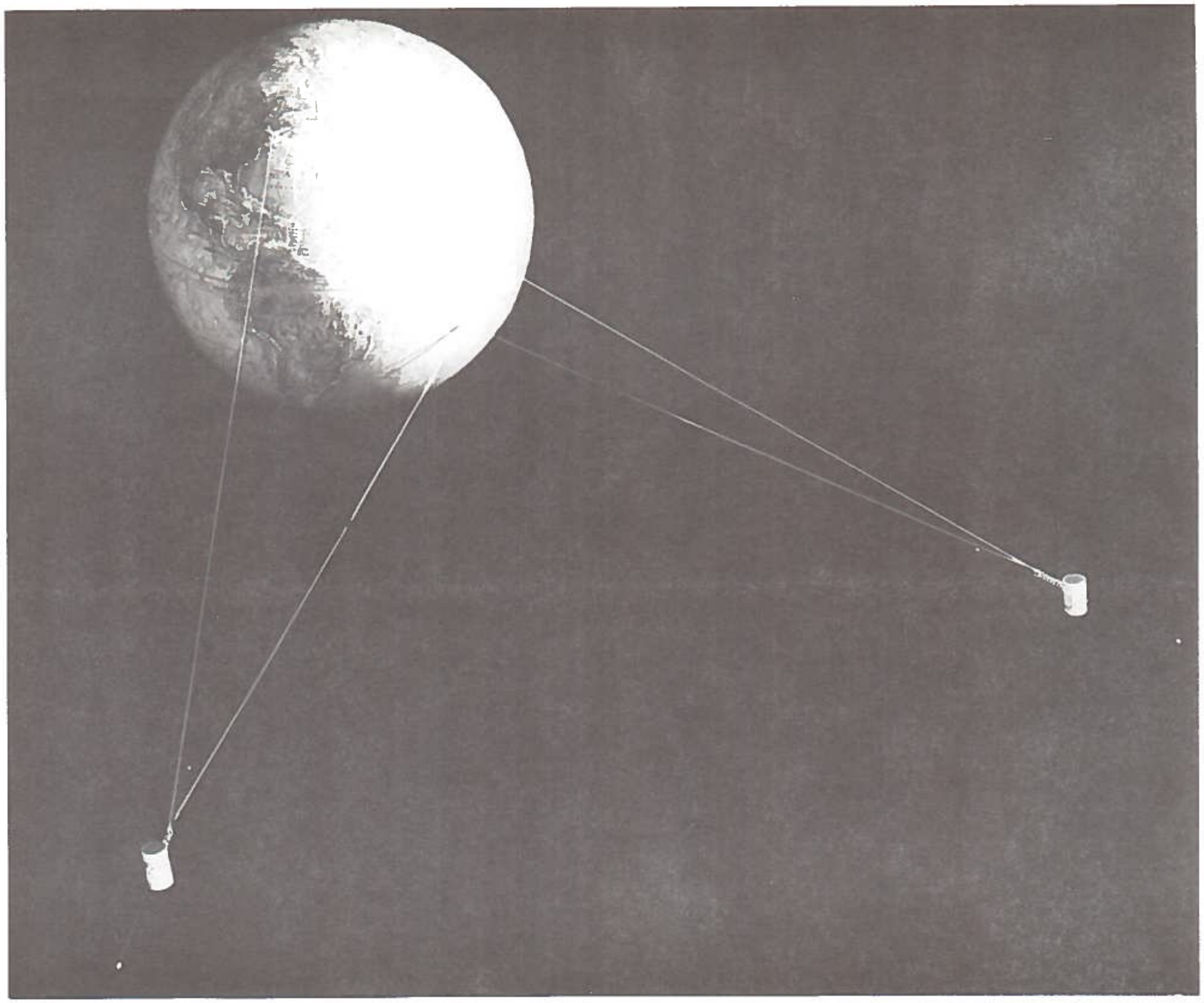

Figure 1-2. Pictorial Representation of the Scintillation Measurement Techniques Using ATS Spacecraft

2. MEASUREMENT SYSTEM HARDWARE

2.1 INTRODUCTION

The schematic diagram of the ionospheric scintillation measurement system hardware is presented in Figure 2-1. In the figure are simplified functional block diagrams of the instrumentation which comprise the automatic data collection facility and the central data collection facility which is located at the DOT/TSC/Westford Propagation Facility in Westford, Massachusetts. Figure 2-1 also presents a function description of the various radio frequency links between the Applications Technology Satellite spacecrafts, the remote facility and the central facility. A possible location for the remote facility is discussed in Chapter 5.

The measurement system works as follows. The remote facility is sent all of its command and control functions via a coded VHF signal sent from the central facility. When given the proper command the remote facility monitors the scheduled L-band transmis sions of the ATS-5 spacecraft.[1] The remote facility then processes, formats and stores the L-band scintillation data until given an additional command. Upon command the remote facility transmits the L-band data by modulating the VHF link back to the central facility. The L-band data is demodulated from the VHF link at the central facility and further processed.

A more detailed description of how the measurement system works is as follows. Coded VHF signals are sent from the VHF transmitting system at the central facility to the ATS-1 or ATS-3 spacecraft at 149.22 MHz and are retransmitted by the satellite at 135.6 MHz to the remote facility. The 135.6 MHz signals are received by the remote facilities' VHF antenna and decoded by the remote facilities' VHF receiver. The decoded instructions are sent to the central processing unit of the remote facilities' computer to initiate the L-band receiver to make the particular measurement

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[1] In the future it may also monitor L-band transmissions from the ATS-F spacecraft.

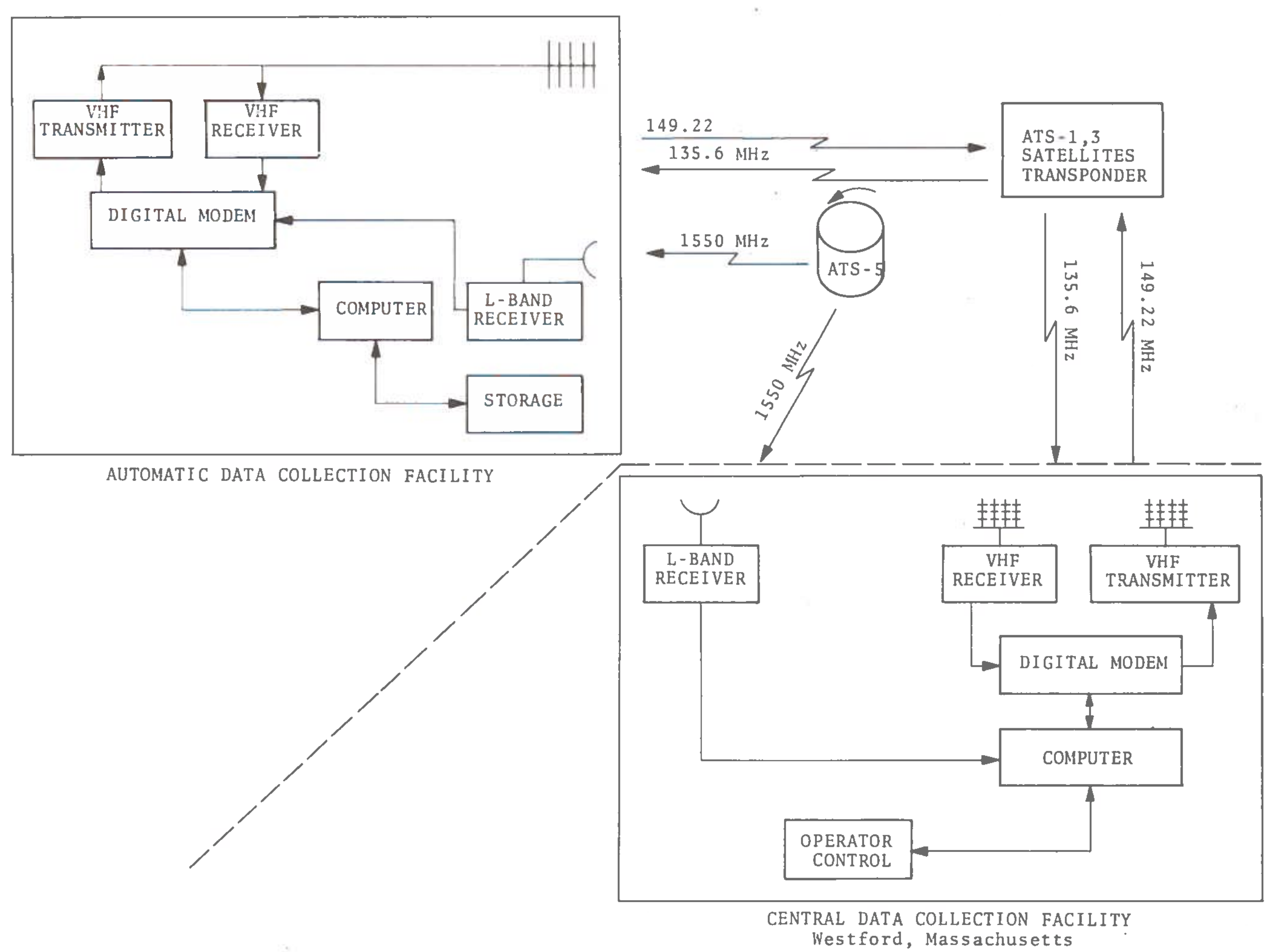


Figure 2-1. Diagram of the Remote Scintillation Data Collection Experiment

desired. The L-band measurements are processed, reformatted and stored on magnetic tape. When the proper command is received the digital data from the magnetic tape is pulse code modulated on the 149.22 MHz VHF uplink to the appropriate geostationary satellite.* The data relayed back at 135.6 MHz will not be received by the VHF receiver at the remote facility because the receiver will be disconnected from the antenna during the transmit cycle. The VHF receiver at the central facility decodes the data and routes it to its computer's central processing unit. The data passes from the central processing unit to disc storage at the central facility for later processing after all the data from the current observing period has been received.

2.2 REMOTE FACILITY

2.2.1 Introduction

The automatic data collection facility consists of the following items as shown on in Figures 2-1 and 2-2:

VHF Portion

- o crossed log periodic VHF antenna for mounting on a vertical pipe with dual linear or left-hand circular polarization or right-hand circular polarization and a linear gain of 10 dB.
- o 300 W power amplifier.
- o VHF transmitter and receiver with a demodulator and tone-code ranging responder within its cabinet.

L-Band Portion

- o 6 foot diameter parabolic L-band antenna.
- o L-band receiver with a bandwidth of 8 kHz and a noise figure of 2.7 dB for scintillation measurements.

*The transmission of the data back via the pulse code modulation over the VHF links avoids scintillation contamination by the VHF links.

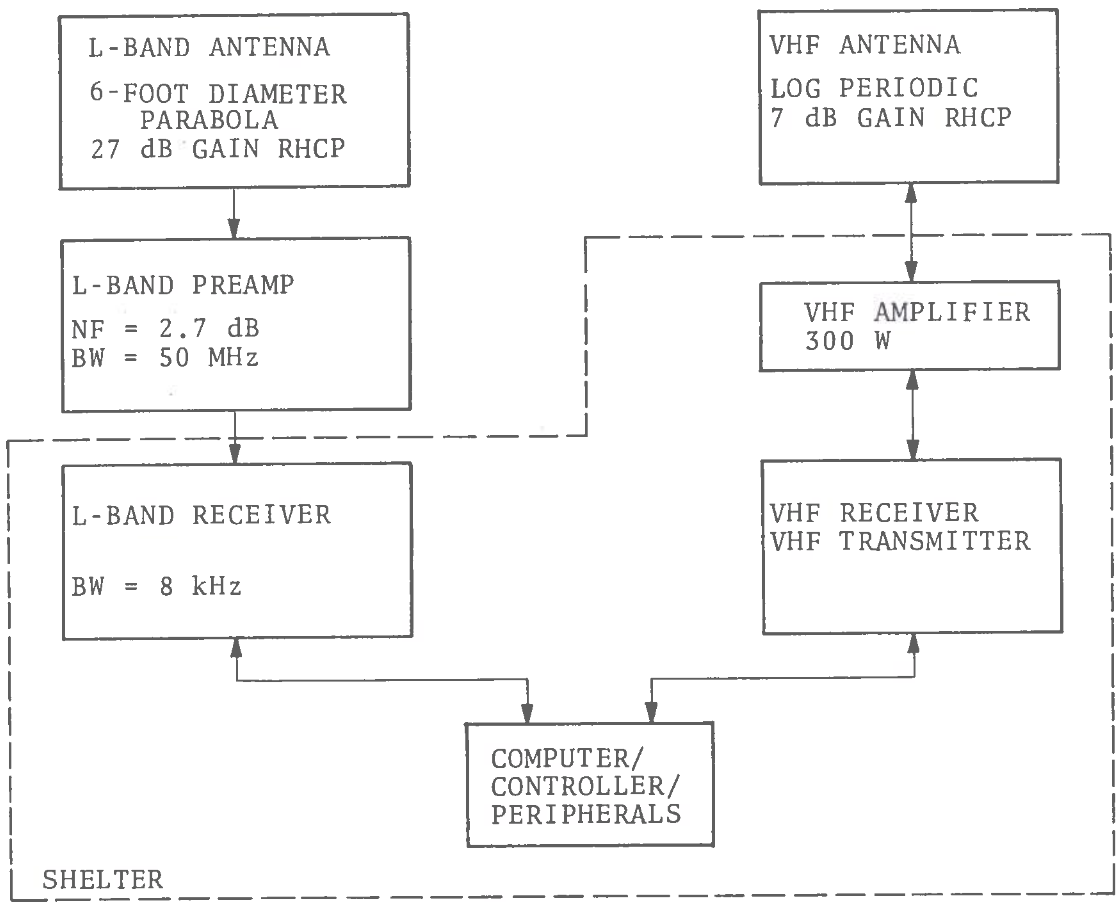


Figure 2-2. Simplified Block Diagram of the Remote Facility

Electronic Data Processing Equipment

- o 6 foot standard relay rack containing a computer, dual DECtape unit, and associated peripherals.
- o A teletype unit.

The remote facility will operate in a fully unmanned mode. It will receive L-band signals from the ATS-5 or ATS-F spacecraft and measure the amplitude of the signals, digitize them with an 8-bit analog-to-digital converter, and record the samples together with timing information on magnetic tape and be capable of preprocessing the recorded data. Using the data scheme described herein it is possible to store 22 hours of data. The L-band signal-to-noise ratio will be about 23 dB, with the overall accuracy of the measurement being about 0.5 dB. This number includes equipment instabilities, receiver noise and processing errors.

The remote facility can be interrogated at any time through a VHF transponder in either the ATS-1 or ATS-3 spacecraft whenever satellite time is made available. The selected data can be relayed back to the central facility through the satellite upon command.

2.2.2 Remote Facility L-Band Equipment

The L-band receiving system of the remote facility is diagrammed in Figure 2-3 and 2-4 and a detailed description of major components is presented in Table 2-1. The L-band receiving system is capable of receiving continuous wave transmissions from a geostationary satellite (ATS-5 or ATS-F) at a fixed frequency of 1550.250 MHz $\pm$ 100 kHz. The ATS-5 is in the wide-band data mode and transmits a continuous wave signal at $\approx$1550.245 MHz. This signal is double heterodyned to 10.7 MHz and contained within a 8 kHz bandwidth for linear amplitude envelope detection. Due to the spin anomaly of the ATS-5 spacecraft (76.2 rpm) the received signal is a replica of the spacecraft antenna pattern which repeats itself every 783 ms. The - 10 dB "window" is approximately 105 ms wide.

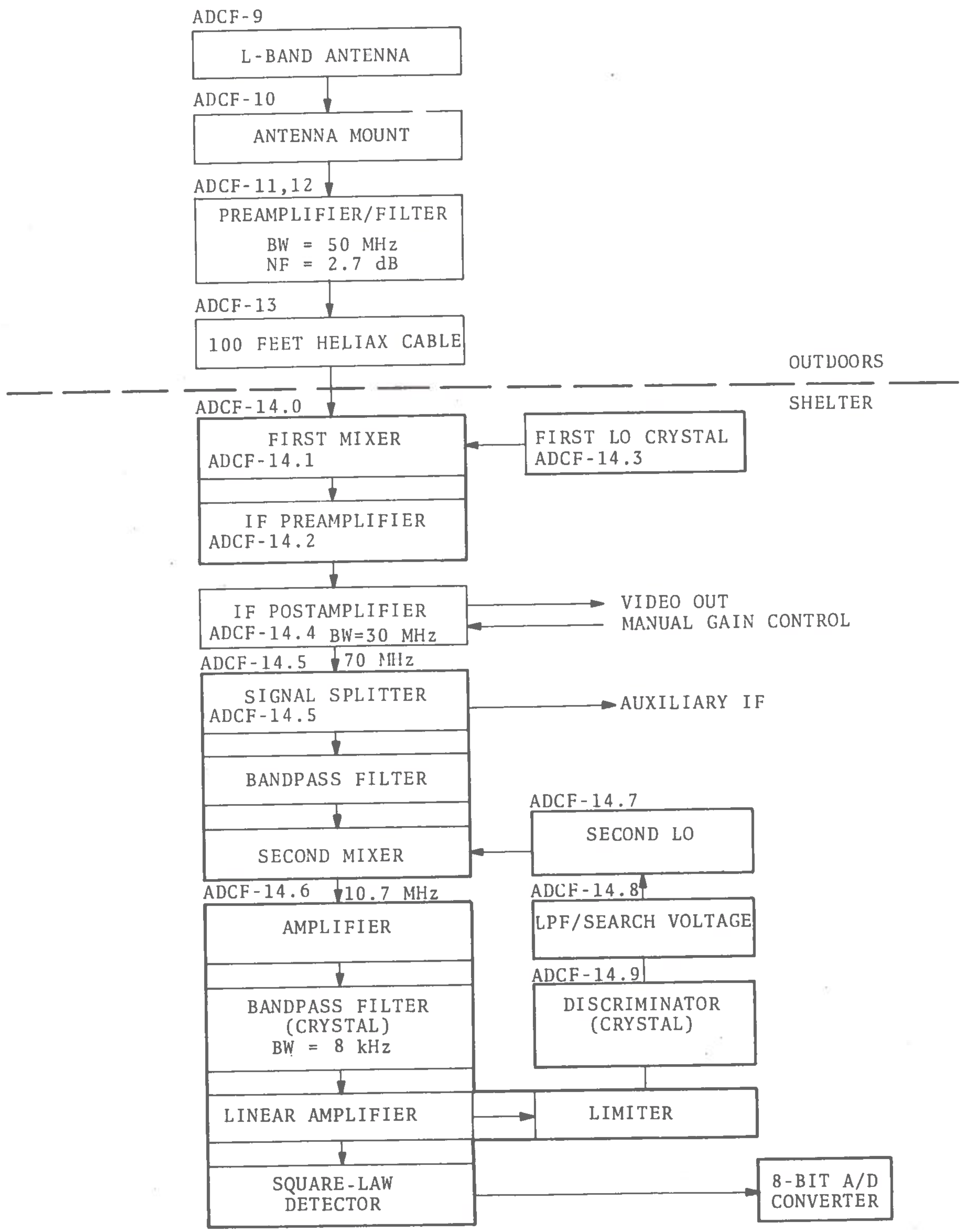


Figure 2-3. Simplified Block Diagram of the L-Band Portion of the Remote Facility

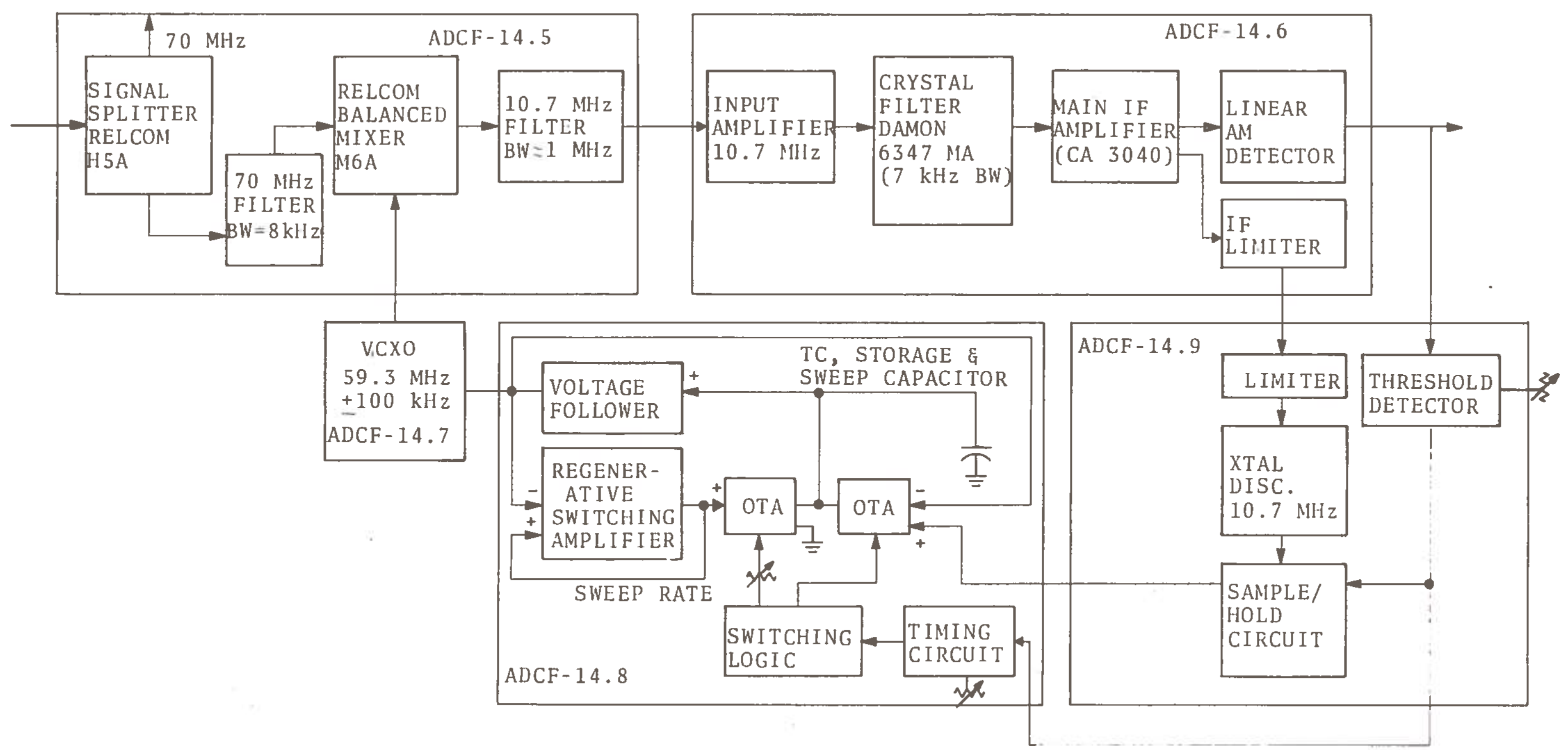


Figure 2-4. Detailed Block Diagram of the L-Band Receiver in the Remote Facility

TABLE 2-1. SPECIFICATIONS OF THE L-BAND PORTION OF THE REMOTE FACILITY

Item Number	Type of Equipment	Comments
ADCF-9	L-band Antenna	Andrew Corp. Model M60006-15; Type P6C Series 6-foot diameter parabolic antenna with a spun aluminum reflector and a cavity backed spiral feed. Axial ratio of cavity backed spiral feed is 2 dB. Capable of receiving/transmitting up to 300 W CW right hand circular polarization. The feed has a type N coaxial fitting. Andrew Corp. (1971)
ADCF-10	Antenna Mount	Adjustable vertical tilt mount adjustable from 0-45° in elevation and 0-360° in azimuth. Andrew Corp. Series VT6, Andrew Corp. (1972) Adjustment manual and clamps to a 4 inch diameter vertical pipe.
ADCF-11	L-band Preamplifier	The L-band preamplifier is an Aertech Model A4563 which is weather-proofed and mounted at the L-band Antenna. It has a center frequency of 1550 MHz, 50 MHz minimum bandwidth and a measured noise figure (NF) of 2.7 dB, solid state, 12 VDC input with 27.9 dB ± 0.2 dB gain.
ADCF-12	Bandpass Filter	Telonic Industries bandpass filter Model TBP1550-50-4FE centered at 1550 MHz with a BW = 50 MHz, and an insertion loss of 2.8 dB
ADCF-13	Cabling	Heliax® FHJ4-50B (Andrew Corp.), 100-feet at 4 dB loss per hundred feet. Type N male connectors on each end. The cable is 1/2 inch diameter with foam dielectric.

TABLE 2-1. SPECIFICATIONS OF THE L-BAND PORTION OF THE REMOTE FACILITY (CONTINUED)

Item Number	Type of Equipment	Comments
ADCF-14.0	L-band Reciever	Envelope detect BW = 8 kHz
ADCF-14.1	First Mixer	Double balanced mixer at 1 - 2 GHz input, 10 - 200 MHz output. RHG Model DM1-2/10HH
ADCF-14.2	Preamplifier	RF to IF gain approximately 25 dB with input of 12 VDC. Housed and part of RHG Model DM1-2/10HH listed as ADCF-14.5
ADCF-14.3	First LO Crystal	For conversion to an IF of 70 MHz an oven controlled crystal oscillator/multiplier. The fundamental frequency is 123 MHz and the multiplying factor is 12. This unit is being supplied with crystal interchangeability over $\pm$ 29 MHz at 1480 MHz. Output power is 10 mW. Stability over 0-50°C is 1×10^{-6} ($\pm$ 1500 Hz at injection frequency). 24 VDC is required at 250 mA maximum. Crystal is TO size and replaceable in the field without soldering. Greenray Industries Model EYHK-118-BD.
ADCF-14.4	IF Post Amplifier	70 MHz with 30 MHz bandwidth and 80 dB power gain. An external 0-5 VDC power supply will allow a manual gain control of 50 dB. RHG Model EVT 7030-RFI.
ADCF-14.5	Signal Splitter/ Bandpass Filter/ Second Mixer	Detailed in Figure 2-4. The power splitter provides an isolated (20 dB) auxiliary output for future wide-band use.
ADCF-14.6	Linear IF Amplifier/ Crystal Filter/ Linear Detector	Detailed in Figure 2-4. The IF is 10.7 MHz and the BW = 8 kHz. Output voltage is 0-10 VDC.

TABLE 2-1. SPECIFICATIONS OF THE L-BAND PORTION OF THE REMOTE FACILITY (CONTINUED)

Item Number	Type of Equipment	Comments
ADCF-14.7	Second LO	A VCXO, center frequency = 59.3 MHz, frequency control range = $\pm$ 100 kHz.
ADCF-14.8	LPF/Search Voltage	Automatic search, acquire and track unit which controls the VCXO.
ADCF-14.9	Limiter-Crystal Discriminator	10.7 MHz limiter and crystal discriminator, plus a threshold detector for determining the presence of signal.

The computer program samples and stores the peak amplitude of each spin cycle, with provision for storing multiple samples within the spin cycle. Details are given in the block diagram of Figure 2-4.

Table 2-2 presents L-band power budgets for the ATS-5 and ATS-F spacecraft to remote facility for a fully saturated signal in the spacecraft. A summary of various L-band modes of operation of the ATS-5 are presented in Table 2-10.

2.2.3 Remote Facility VHF Equipment

The VHF command and control link controls the L-band data equipment via the ATS-1 or ATS-3. It can also provide range measurements from which the ionospheric delay of the VHF link can be derived. The ionospheric delay measurement capability of the experiment facility, although of interest, is not addressed in this report. However, the round trip equipment delays and path delays will be used in the present experiment to indicate that the VHF link is operating properly.

The basic purpose of the VHF command and control link is to control the operation of the remote facility as well as selectively transmit stored data at the remote facility to the central facility by specific commands over this link.

The VHF portion of the remote facility is depicted in a general way in Figure 2-1. A more detailed block diagram of the VHF receiver/transmitter is given in Figure 2-5. Details of some of the individual components are presented in Table 2-3. Figures 2-6 and 2-7 are photographs of some radio frequency hardware to be used in the remote facility. Power budgets for both VHF links between the remote facility and either the ATS-1 or ATS-3 spacecrafts are presented in Tables 2-4 and 2-5.

2.2.4 Remote Facility Electronic Data Processing Equipment

The electronic data processing equipment to be used in the remote facility consists of the items listed in Table 2-6. The electronic data processing equipment acts as the control center of the remote facility. The basic functions of the electronic data

TABLE 2-2. L-BAND DOWNLINK POWER BUDGET TO REMOTE FACILIY FROM THE ATS-5 AND ATS-F

Item		ATS-5	ATS-F	
Spacecraft Transmitter Power	(dBm)	43.4[1]	46.0[2]	46.0
Antenna Gain	(dB)	14.0	32.0[3]	38.0[4]
Circuit Loss	(dB)	-2.0	-0.4	-0.4
EIRP	(dBm)	55.4	77.6	83.6
Space Loss	(dB)	-187.8	-187.8	-187.8
ADCF Antenna Gain (6 ft. RHCP)	(dB)	27.0	27.0	27.0
Pointing Loss[5] (7° beamwidth)	(dB)	-0.5	-0.5	-0.5
Polarization Loss	(dB)	-0.2	-0.2	-0.2
Circuit Loss	(dB)	-0.5	-0.5	-0.5
Off-beam Loss (diurnal)[6] spacecraft motion N-S)	(dB)	-1.0	-1.0	-1.0
Total Received Power	(dBm)	-107.6	-85.4	-79.4
Receiver Noise Power Density for 3 dB NF	(dB/Hz)	-171.0	-171.0	-171.0
Carrier-to-Noise Power Density	(dB/Hz)	63.4	85.6	91.6
IF BW (8 kHz)	(dB)	39.0	39.0	39.0
Carrier-to-Noise in IF BW	(dB)	24.4	46.6	52.6
For Spacecraft Configured in One-Half Power Mode - 3 dB	(dB)	21.4		

1. 20 W Kissel (1970)
2. 40 W, NASA (1971), Sabelhaus (1971)
3. Fan Beam Antenna, NASA (1971), Sabelhaus (1971)
4. Pencil Beam Antenna, NASA (1971), Sabelhaus (1971)
5. Maximum Pointing Loss for orbit inclinations up to 1.5°.
6. Minimum; function of ADCF location relative to satellite antenna beam.

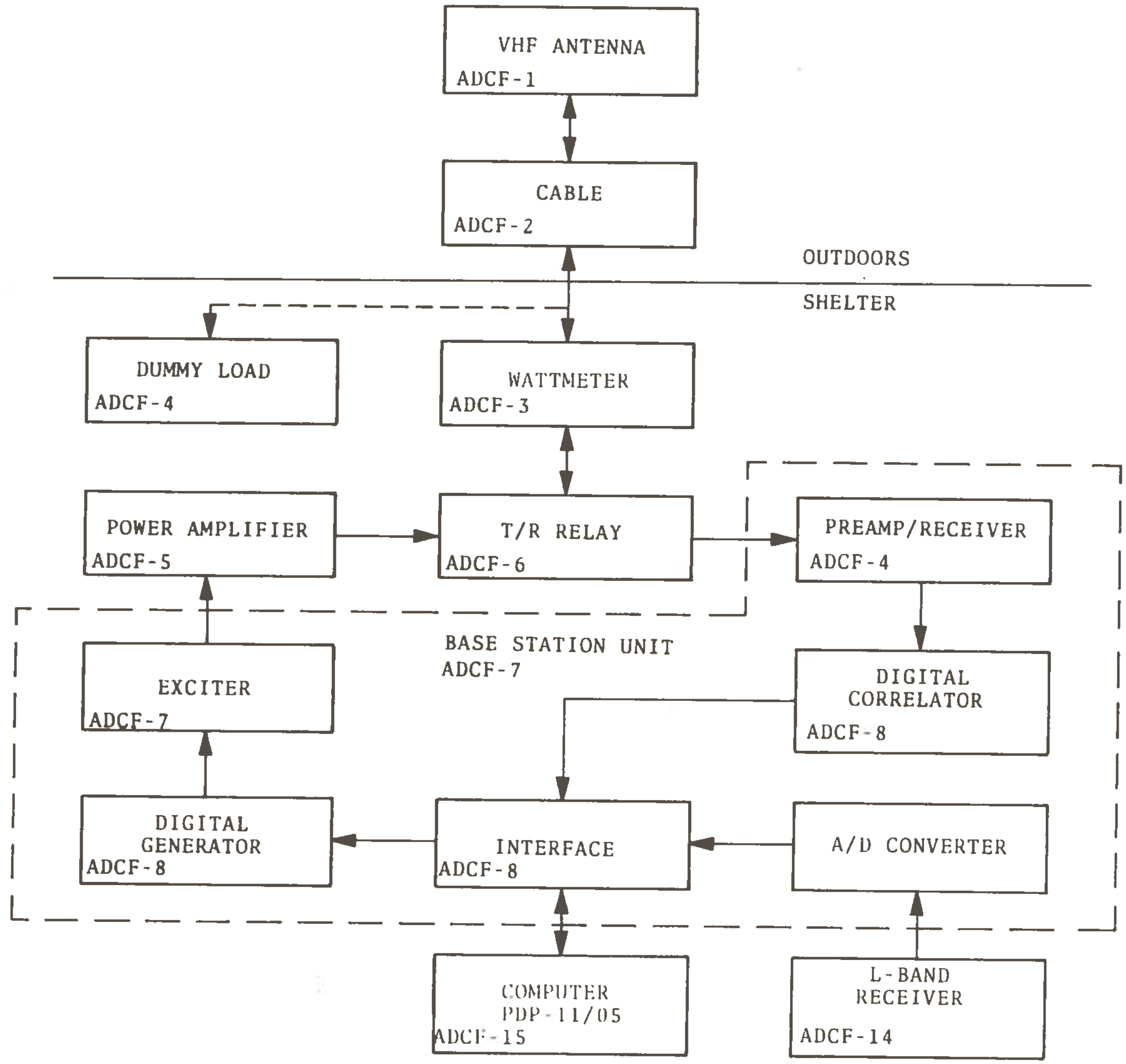


Figure 2-5. Detailed Functional Block Diagram of the VHF Portion of the Remote Facility

TABLE 2-3. SPECIFICATIONS OF THE VHF EQUIPMENT IN THE REMOTE FACILITY

Item Number	Type of Equipment	Comments
ADCF-1	Antenna & Mount	Scientific-Atlanta Model 31C-0135/150 crossed log periodic array with dual polarization. Nominal linear polarization or gain of 10 dB when matched linear to linear or 7 dB if not matched. Maximum axial ratio of 2.0 dB. Minimum front-to-back ratio: 20 dB. Maximum inter-channel isolation: 25 dB. Maximum VSWR: 2.0:1. Maximum Beamwidth: E-plane: 50°; H-plane: 75°. Maximum power input: 500 W. (Scientific-Atlanta, Inc., (1971).
ADCF-2	Cable	Andrew Corp. Type No. FHJ4-50B Heliax® foam dielectric flexible coaxial cable. The diameter is 1/2 inch and attenuation is 1.0 dB per hundred feet at 150 MHz.
ADCF-3	Wattmeter	Bird Electronics Model 43.
ADCF-4	Dummy Load	Bird Electronics Model 8135, 150 W.
ADCF-5	Power Amplifier	Motorola AM-494-GR, 300 W, See Figure 2-6, Motorola, 1953A,B).
ADCF-6	T/R Switch	Integral part of ADCF-5.
ADCF-7	Mobile Radio Base Station	General Electric Mastr Progress Line Desk Mate® station. VHF transmitter/receiver Model No. DT76LFP55. Item ADCF-8 will be housed in ADCF-7. See Figure 2-7. (General Electric 1970, 1971).
ADCF-8	Computer/ Transmitter/ Receiver Interface Unit	Item custom built on Contract No. DOT-TSC-485. Mounted in ADCF-7

Figure 2-6. Photograph of UHF Power Amplifier

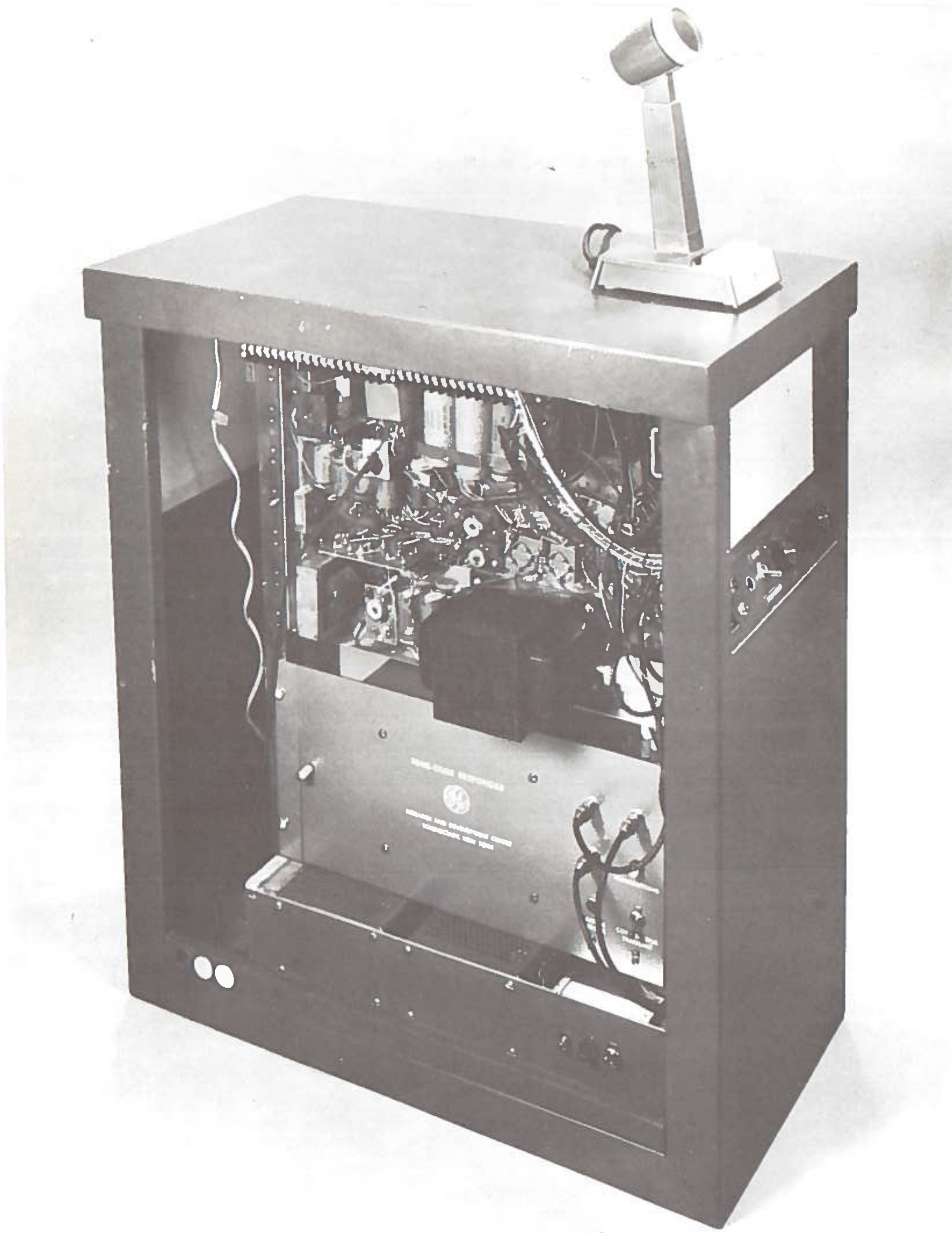


Figure 2-7. Photograph of a Typical Mobile Radio Base Station of the Type Used in the Remote Facility

TABLE 2-4. POWER BUDGETS FOR THE VHF UPLINKS BETWEEN THE REMOTE FACILITY AND THE ATS-1 OR ATS-3 SPACECRAFT AT 149.22 MHz

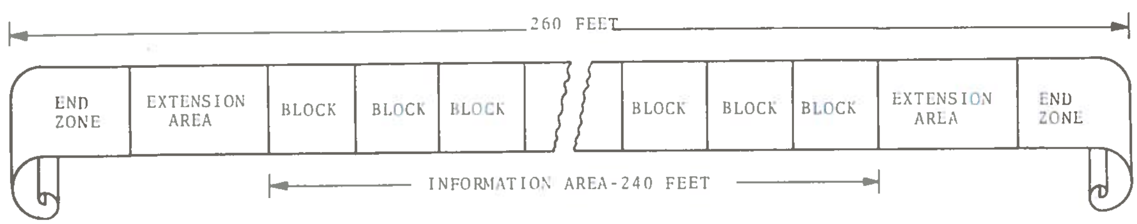
Quantity	Value	Comments
ADCF Transmit Power	55.0 dBm	(300 W)
Antenna Gain	10.0 dB	
Circuit Loss	-1.4 dB	
EIRP	63.6 dBm	
Space Loss	-167.5 dB	(22,500 miles)
Spacecraft Antenna Gain	8.0 dB	
Circuit Loss	-1.5 dB	
Polarization Loss	-3.0 dB	
Total Received Power	-100.4 dBm	
Receiver Noise Power Density (NPD)	-170.5 dBm/Hz	(3.5 dB NF)
Carrier/NPD in Spacecraft Receiver	70.1 dB/Hz	
IF Noise BW	50.0 dB	(100 kHz)
S/N in IF	20.1 dB	

TABLE 2-5. POWER BUDGETS FOR THE VHF DOWNLINKS BETWEEN THE REMOTE FACILITY AND THE ATS-1 OR ATS-3 SPACECRAFT AT 135.60 MHz

Quantity	Value	Comments
Spacecraft Transmit Power	46.0 dBm	(40 W)
Antenna Gain	8.0 dB	
Circuit Loss	-1.8 dB	
EIRP	52.2 dBm	
Space Loss	-166.9 dB	(22,500 miles)
ADCF Antenna Gain	10.0 dB	
Circuit Loss	-1.3 dB	
Polarization Loss	-3.0 dB	
Total Received Power	-109.0 dBm	
Receiver NPD	-171.5 dBm/Hz	(2.5 dB NF)
Carrier/NPD at ADCF	62.5 dB/Hz	
Carrier/NPD at Satellite	70.1 dB/Hz	
Carrier/NPD Resultant	62.0 dB/Hz	
IF Noise BW	42.0 dB	(15 kHz)
S/N in IF	20.0 dB	(Satellite full power)
S/N in IF[1]	≈ 13.0 dB	(Satellite half power)

1. See Sections 2.4.2 and 2.4.3.

TABLE 2-6. ELECTRONIC DATA PROCESSING EQUIPMENT SPECIFICATIONS FOR THE REMOTE FACILITY

<table>
<tr><th>Item No.</th><th>Type of Equipment</th><th>Comment</th></tr>
<tr><td>ADCF-15</td><td>Computer</td><td>Digital Equipment Corp. Model No. PDP-11/05. Storage of 8192 16-bit words with a cycle time of 900 ns. Digital Equipment Corp. (1971; 1972A; 1972B).</td></tr>
<tr><td>ADCF-16</td><td>Teletype Unit</td><td>Teletype Corp. Model No. ASR-33. Teletype Corp. (1971)</td></tr>
<tr><td>ADCF-17</td><td>Dual DECtape Unit</td><td>Digital Equipment Corp. Model TU56. Digital Equipment Corp. (1972C; 1972D).</td></tr>
<tr><td colspan="3">The DECtape block arrangement is shown in the following


1 Block = 256 Words; 578 Blocks/DECtape</td></tr>
<tr><td>ADCF-18</td><td>General Purpose Digital Interface</td><td>Digital Equipment Corp. Model DR11-A</td></tr>
</table>

processing equipment are described in detail in Chapter 3.

2.2.5 Remote Facility Computer/VHF Interface Equipment

The interface unit at the remote facility consists of a code generator/correlator synchronous data set for interfacing the transmitter/receiver with a computer using 16-bit words.

All messages sent or received by the remote facility or the central facility have the same format. The signaling is done at 2441.4 baud. Each message starts out with 1024 "ones". This string of "ones" is used to phase the clock at the receiving station to the bit stream that is to follow. The 1024 "ones" are followed by a 15-bit synchronizing (sync) word and a 15-bit address (addr) word. This preamble is used with every transmission. Figure 2-8 illustrates the preamble as well as a hypothetical message that might follow.

The first word following the preamble is the record length. The record length is the number of data words in this transmission. It does not include the check sum work (the arithmetic total of all data words) and the end of transmission word. The next word is the check sum word. Following the check sum are the number words as specified in the record length. The last word transmitted is the end of transmission symbol.

The digital bits used to construct the preamble are generated or processed by the interface unit only. Once the interface unit has phased its oscillator (usually after about 600 ones) it begins to search for the sync word and addr word combination. As soon as it has found them it has found its place in the received bit stream. All the words that follow the preamble are used by the computer. Each of the bits which form a digital word used by the computer are sent three times making a 48-bit word. The computers at both the remote facility and the central facility use 16-bit words, thus for each 16-bit computer word 48 bits are sent and consequently received.

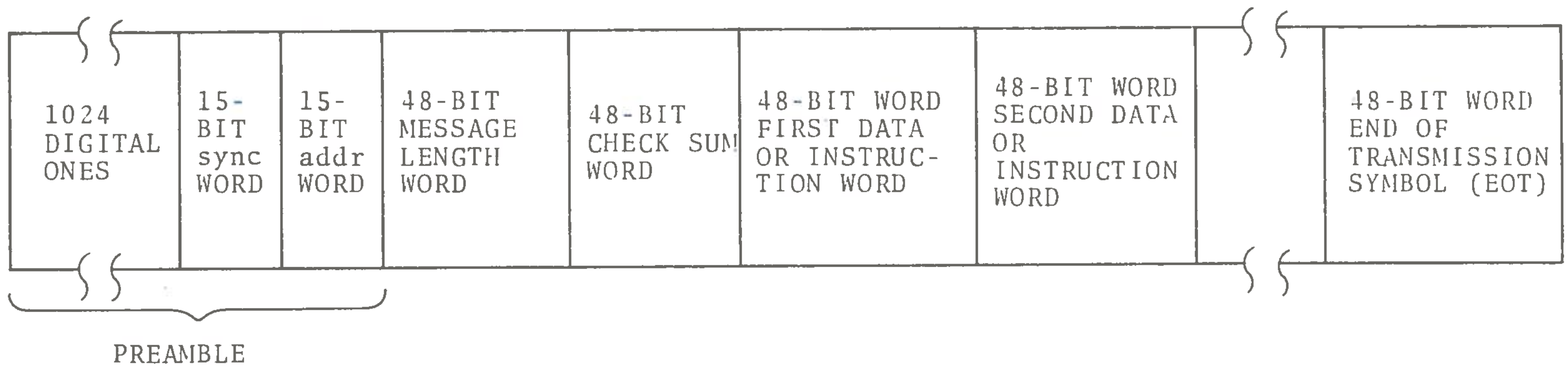


Figure 2-8. Message Format on the VHF Command, Control and Data Link

The interface unit knows that as soon as it has found the sync and addr words all the words that follow are 48-bit words that must be converted to 16-bit words for the computer. The interface unit takes the three bits intended to become one computer bit and determines the two out of three average of the three bits. This average bit is the one supplied to the computer. Consequently, though the transmission is at 2441 baud the actual information is only sent a 813 baud to insure the reliability.

As soon as synchronization is obtained using the sync and addr words the next 48 bits are clocked in. On the 48th clock pulse the 16 individual two out of three averages are found, the 16-bit computer word is constructed and placed in a buffer for transmission to the computer. At this time a flag is sent to the computer. The interface unit proceeds to clock in the next 48 bits.

When the computer senses the interface unit's flag it reads in the 16-bit word and clears the flag. Typically this all happens during the next clock pulse since the computer operation is much faster than the interface unit's clock.

The first word read into the computer is the number of data words to be sent during this transmission. The computer program uses this information to set aside a buffer of the proper size for the data that will be coming during this transmission.

The second word sent is the check sum word. The check sum of the data was computed by the remote facility computer prior to the initiation of the transmission. The central facility computer saves the check sum word for this transmission and will use it after all the data has been received.

The third and successive words sent are the data words. The final word is the end of transmission symbol. When the end of transmission is detected the computer no longer expects data from the interface unit and the controlling program continues in the central facility.

The phase matcher circuit is used to synchronize the oscillator in the receiver interface unit with the 2.4414 kHz tone as it is being received (See Figure 2-9). The 10 MHz oscillator used in the interface is divided down to 5 MHz and then to the 2.4414 kHz reference frequency.

The 10 MHz is divided down to 5 MHz and then to 2.5 MHz. The 2.5 MHz is then passed through an add-inhibit circuit and then divided by 2^{10} in a 10 stage divider to obtain 2.4414 kHz. This 2.4414 kHz signal is then phase compared with the received tone at 2.4414 kHz. The phase error (lag or lead) is a pulse whose width is proportional to the phase error. The lag or lead error is used to gate a burst of 2.5 MHz pulses. The burst of 2.5 MHz pulses is divided down by 64 in a 6 stage divider. Hence, following the gating of the 64 clock pulses at a 2.5 MHz rate, an add or inhibit pulse is generated depending on the sign of the phase error (i.e. lag or lead). The phase relationship of the add or inhibit pulses and their time duration is such that in either case they act to eliminate of blank out one 2.5 MHz pulse that is going into the 10 stage divide down counter. However, each time an add pulse is generated, two 5.0 MHz pulses are gated into the main stream of 2.5 MHz pulses in place of the blanked out pulse. The add and inhibit circuits, therefore, have the effect of advancing or delaying the output of the 10 stage divider in 0.4 μs increments.

Due to the averaging effect of the 6 stage divider in both the add and inhibit lines the digital phase match circuits have an equivalent time constant of 0.026 s (i.e. 64 cycles of 2.4414 kHz). This is an equivalent bandwidth of approximately 6 Hz.

As soon as clock synchronization has occurred the receiving correlator begins to search for the synchronization code and the address code. Figure 2-10 is a block diagram of the receiving correlator and digital data processor.

Upon obtaining correlation it immediately begins to transfer in the data bits. Three bits at a time are ready, the two out of three average is found and transferred into the 16-bit shift register. Three more bits are clocked in before another read and average operation. As soon as the 16-bit register is full it is

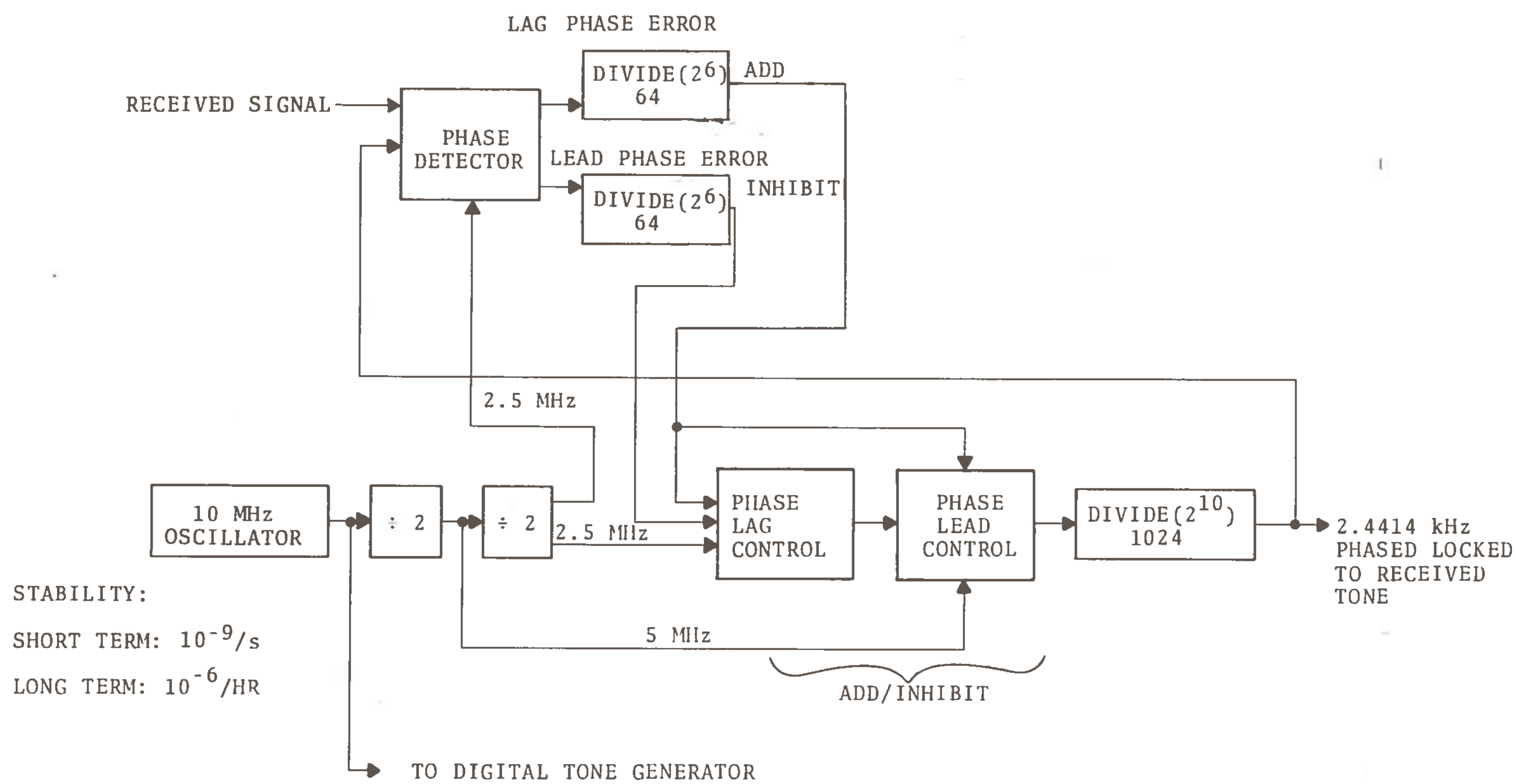


Figure 2-9. Functional Block Diagram of a Receiving Digital Phase Matcher

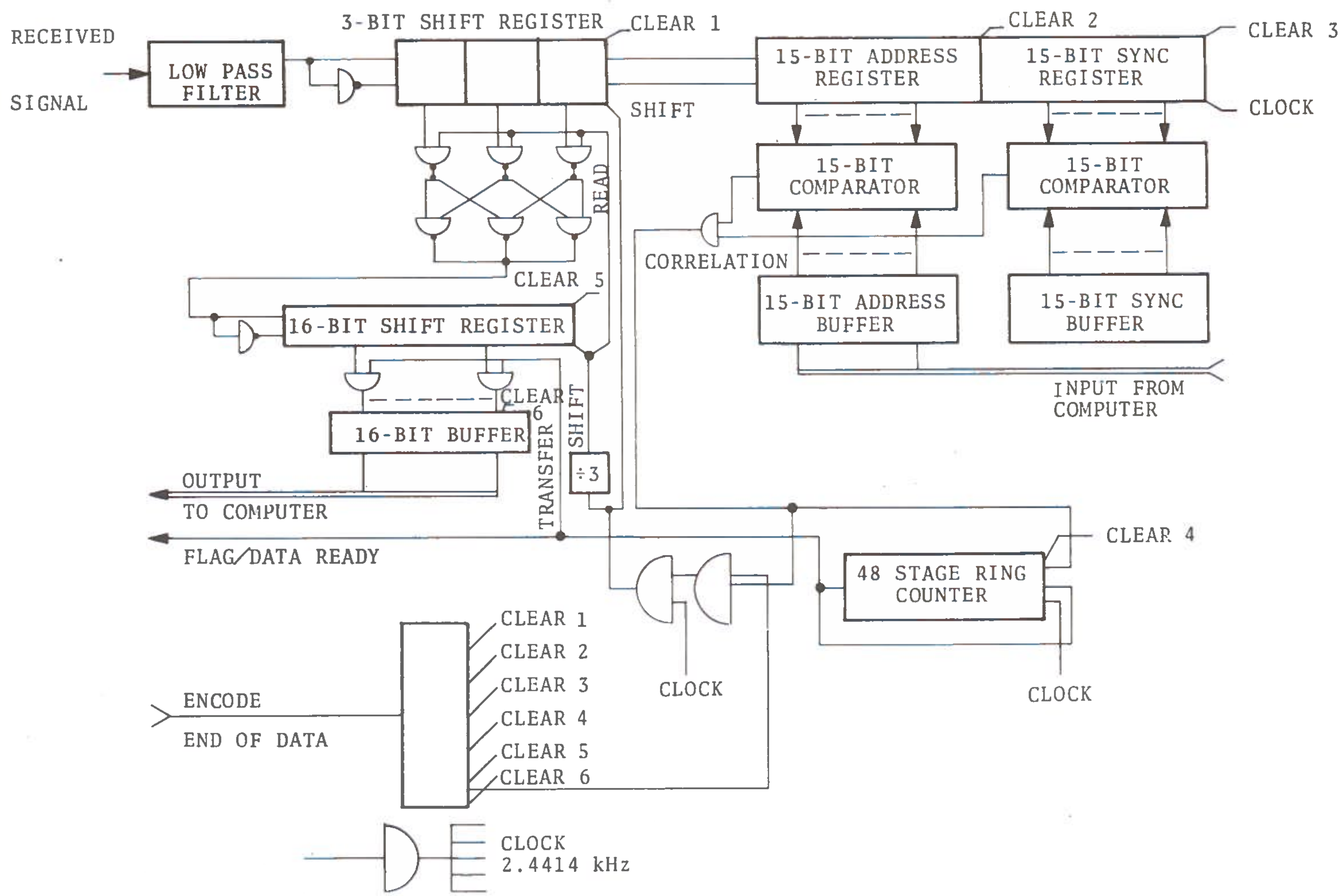


Figure 2-10. Functional Block Diagram of the Receiving Correlator and Digital Data Processor

transferred to a buffer for transmission to the computer. Meanwhile the operation of reading in 3 bits, finding the average, and storing continues. When the word passed to the computer is an "End of Transmission" word, the computer immediately responds by sending an "End of Data" pulse which stops the reading operation and clears the registers and buffers.

The receiving correlator is the same as the one used at the central facility except for one thing. The 15-bit address buffer in the remote facility has its address hardwired into it, the same way the sync word in hardwired into both the remote and central facility units. The address buffer, however, may be loaded by the computer in the central facility. This allows the correlator to receive messages from more than one remote facility.

The transmission control (see Figure 2-11) is provided by the transmit control logic. The logic and registers are initially cleared by loading an address word with bits 15 and 16 set to one (1) and all other bits are set to zero (0). After system clear a data transmission is initiated by sending an address word to the interface unit along with an encode pulse.

As in the case of the receiving control unit the remote facility has its address hardwired into an address buffer, consequently it is not necessary for the computer to send it an address. The unit used in the central facility, however, allows the computer to pass an address to it thus allowing communication with several different remote facilities.

The transmission is started by the presence of bit 16 in the address word. First 1024 cycles of continuous 2.4414 kHz tone are transmitted, then the 15-bit sync word. After the sync word, the 15-bit address word is transmitted. While the address is being transmitted the first data word from the computer is placed into the storage buffer. At the end of the address the first data word is transferred into a shift register and another data word is requested. As the control bits of the data word are read out of the shift register each is used to control three (3) cycles of the modulating 2.4414 kHz tone to the transmitter consequently a 16-bit computer word is transmitted as a 48-bit word.

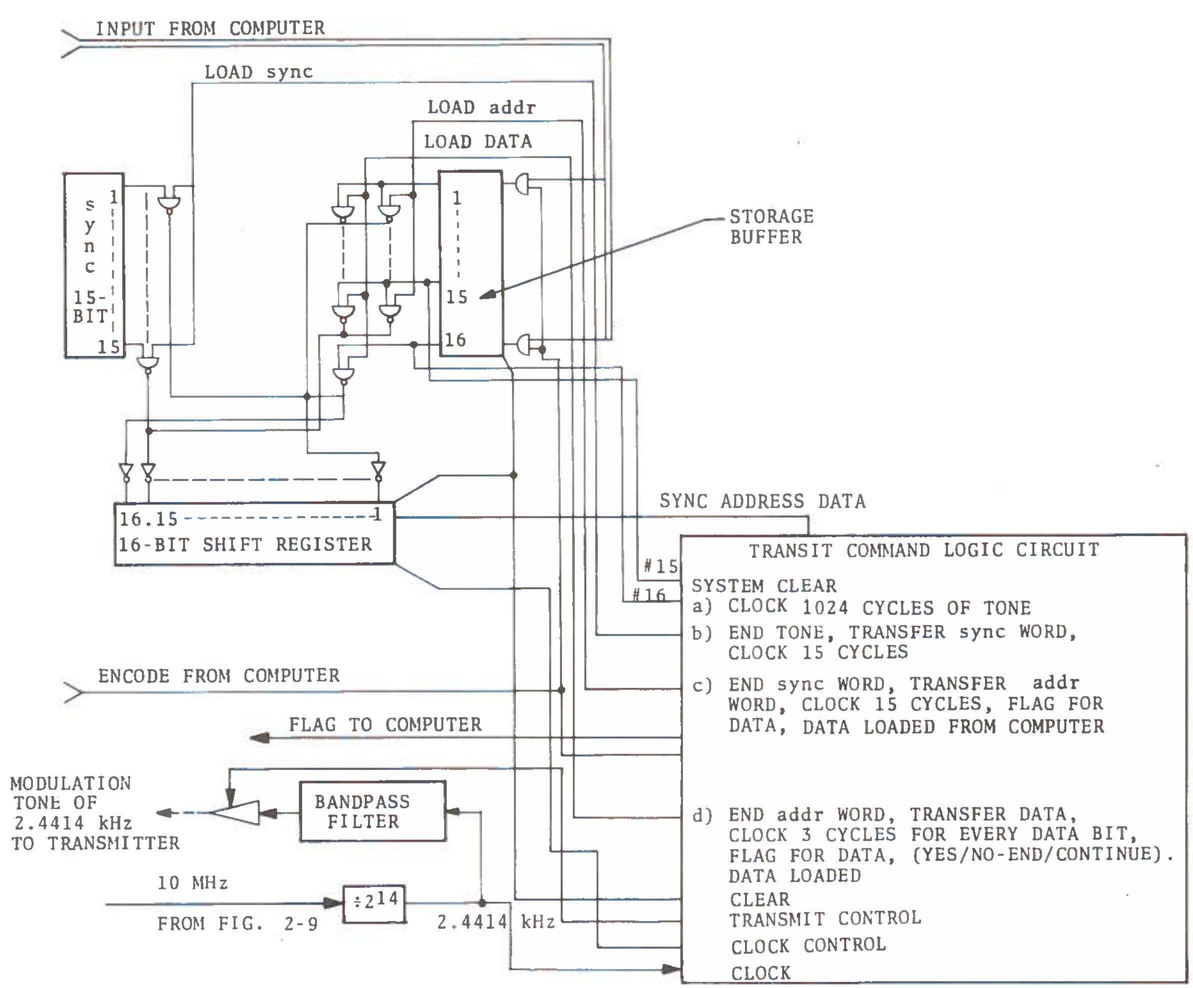


Figure 2-11. Transmit Control and Digital Data Processor

Each time a data word in transferred to the buffer an encode pulse is also sent to the control logic. The encode pulse tells the logic that a word is available to be transmitted when the present one is finished. If no more encode pulses are received the logic realizes that no more words are to be sent. Consequently, the transmitter is shut off and the transmit control and command logic is cleared and reset so as to be ready for the next transmission.

An example of a code scheme is given below.

	sync	ADCF address
(1024 "ones")	000111100110111	010000010101100
	15	15

2.3 CENTRAL FACILITY

2.3.1 Introduction

The central data collection facility described in this report is located at the DOT/TSC Westford Propagation Facility in Westford, Massachusetts at a geographic latitude of 42.60°N and a geographic longitude of 71.50°W. A photograph of the Westford Propagation Facility is shown in Figure 2-12. A detailed description of some of the L-band capabilities of the Westford Propagation Facility will be given elsewhere (Brown, Haroules and Thompson, 1973). The pertinent VHF and electronic data processing equipment is discussed in the following sections.

2.3.2 Central Facility L-Band Equipment

The pertinent L-band equipment at the central facility is diagrammed in Figure 2-13.

2.3.3 Central Facility VHF Equipment

The VHF equipment consists of both a receiving and a transmitting system. The receiving and transmitting systems are shown in Figures 2-1, 2-14 and 2-15.

Figure 2-12. Photograph of the DOT/TSC/Westford Propagation Facility; Westford, Massachusetts; Looking North

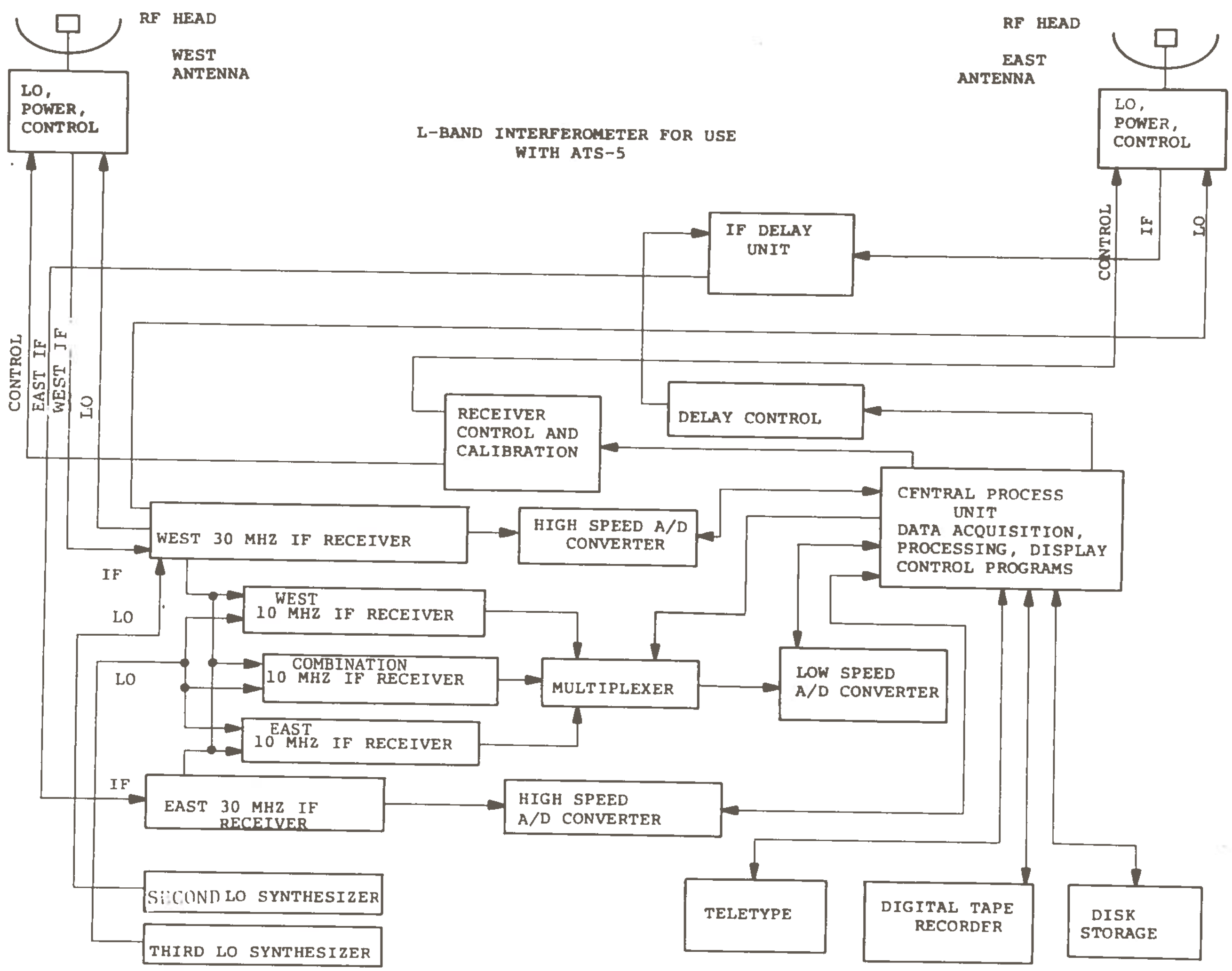


Figure 2-13. Block Diagram of the L-Band Receiving System at the DOT/TSC/Westford Propagation Facility

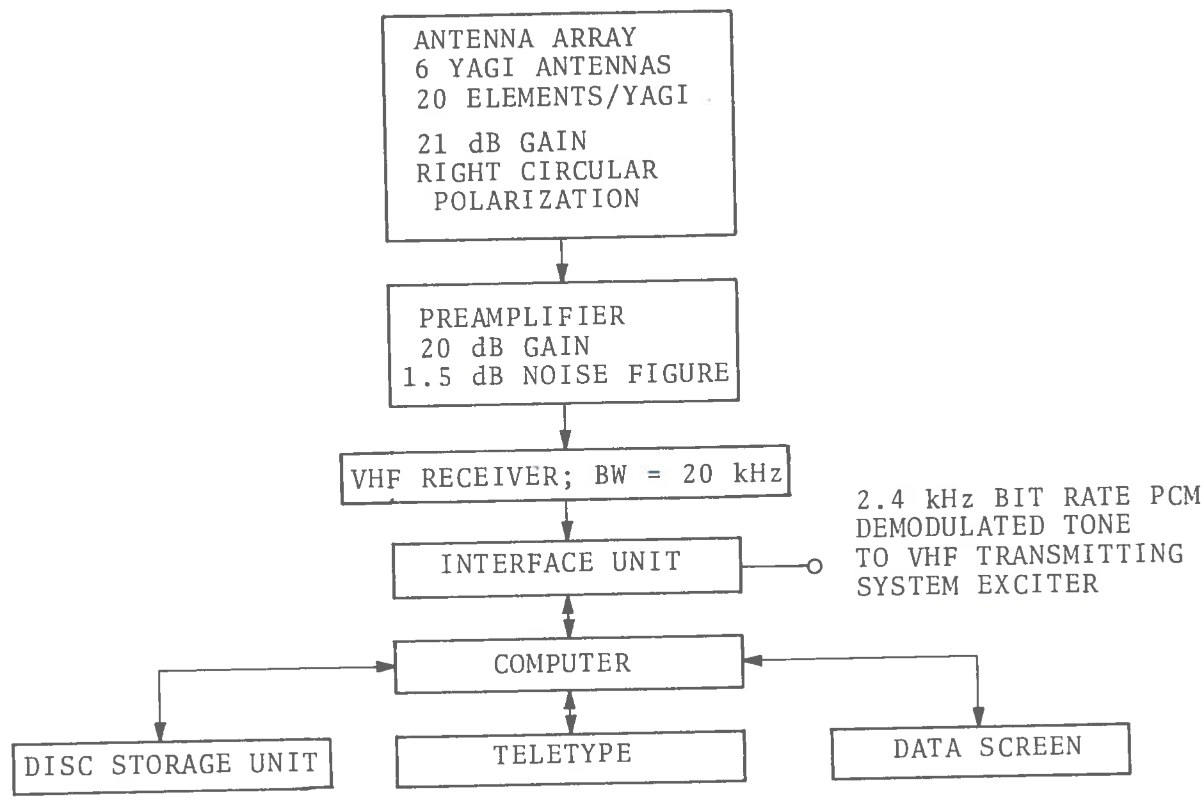


Figure 2-14. Block Diagram of the VHF Receiving System of the DOT/TSC/ Westford Propagation Facility

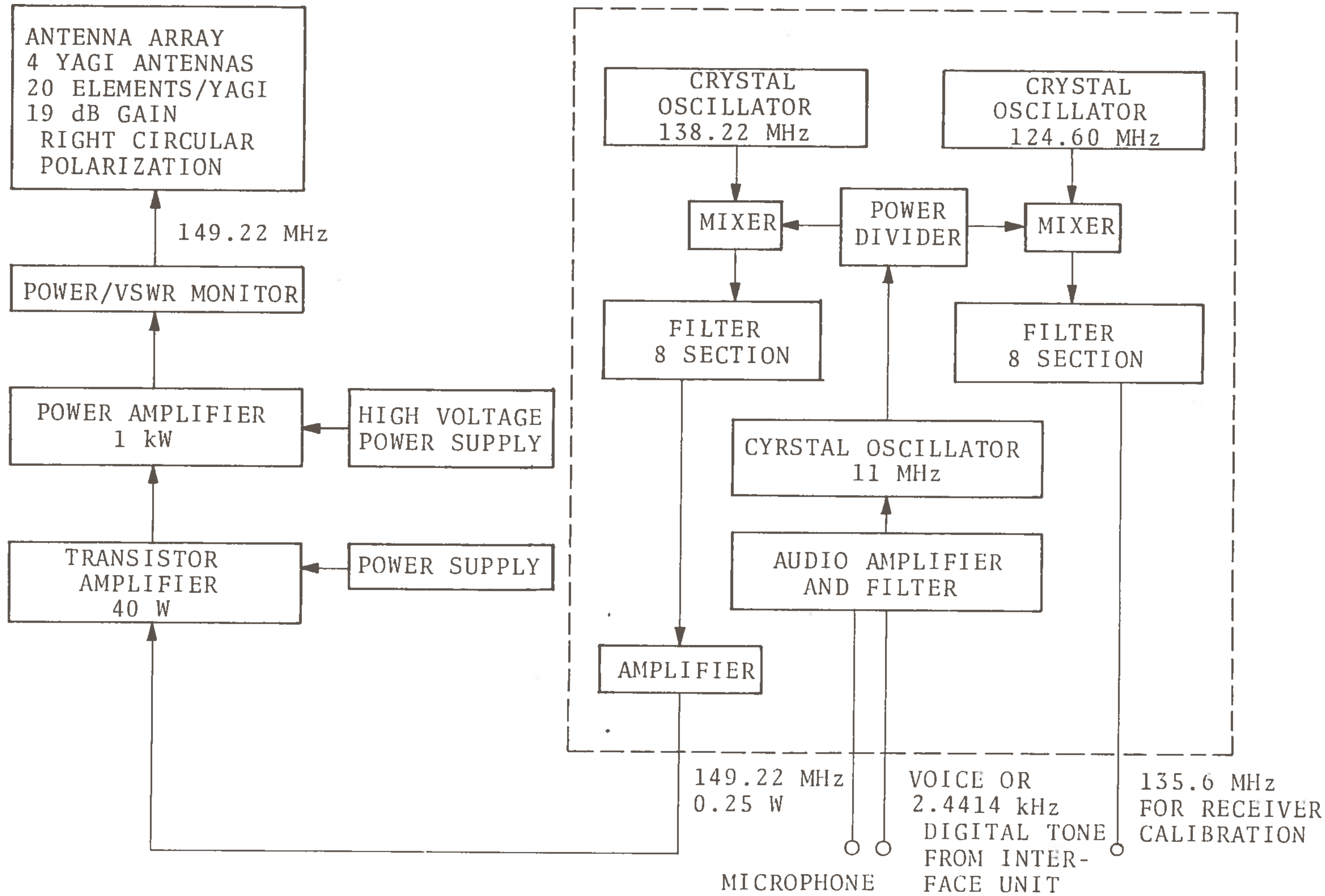


Figure 2-15. Block Diagram of the VHF Transmitting System at the DOT/TSC/Westford Propagation Facility

The VHF receiving system consists of an 120 element, circularly polarized Yagi antenna array and associated receiver (Figure 2-12). The antenna array has six crossed Yagi antenna arrays with 20 elements per array.

The VHF transmitting system consists of four 20 element crossed Yagi antennas in a right-circularly polarized mode and the associated transmitter (Figure 2-15).

2.3.4 Central Facility Electronic Data Processing Equipment

The electronic data processing equipment consists of the items listed in Table 2-7.

2.3.5 Central Facility Computer/VHF Interface Equipment

The computer/VHF interface unit performs essentially as discussed in Section 2.2.5 with the exception that the address buffer may be loaded by the computer in the central facility so that many remote facilities may be addressed.

2.4 THE APPLICATIONS TECHNOLOGY SATELLITES

2.4.1 Introduction

The Applications Technology Satellites (ATS) are a series of seven spacecraft which have been or will be launched by the National Aeronautics and Space Administration. The underlying design philosophy of the ATS program has been the development of a multiple-mission satellite having a large and adaptable volume for mounting various experimental payloads, while still satisfying the requirements for spin, gravity-gradient or three axis stabilization.

Of prime importance among the major experiments conducted on board the ATS-1 through ATS-5 were those concerned with the stabilization of the satellites by gravity-gradient techniques and providing standardized antenna beams from spinning satellites. The ATS-F spacecraft differs in this respect as it is three-axis stabilized by the use of wheels and jets.

TABLE 2-7. ELECTRONIC DATA PROCESSING EQUIPMENT OF THE CENTRAL FACILITY AT THE DOT/TSC/WESTFORD PROPAGATION FACILITY

Type of Equipment	Comments
Computer	HP 2114B with storage for 32 K 16-bit words of core and 2 μs cycle time.
Teletype Unit	Teletype Corp. Model ASR-33
Parallel Transfer Data Terminal with Keyboard and Screen	TEC Model 415
Disc Storage Unit	HP 2870: 2.4 million words; 35 ms access time

Table 2-8 lists several historical features on the ATS series and Table 2-9 lists the radio frequency assignments of the various radio links associated with the ATS series. The various types of emissions etc. are defined in RCA (1969).

2.4.2 ATS-1

The ATS-1 is located and maintained at 149°W longitude. In January 1972 the orbit inclination of ATS-1 was 3.9° and will continue to increase at 0.86° per year. The radio frequencies of the various radio links are given in Table 2-9 and a photograph of the ATS-1 is presented in Figure 2-16. The earth coverage areas are presented in Figure 5-1 for areas of interest in this program.

The VHF communications transponder is an active frequency-translator limiting (Class C) repeater receiving at a frequency of 149.22 MHz and retransmitting the received signal at 135.6 MHz. Reception and transmission is through an eight-element phased array antenna.

Because the intermediate frequency amplifiers include automatic gain control circuitry, and the final power amplifier stages are operated in Class C, the VHF transponder is best suited to relaying one or more frequency (or phase) modulated carriers. Other types of modulated carriers can also be successfully relayed.

TABLE 2-8. SELECTED CHARACTERISTICS OF THE ATS-1 THROUGH ATS-G SPACECRAFT (NASA, 1971)

Satellite	Launch Date	Present Location (Latitude)	Comments
ATS-1	December 7, 1966	149°W	(ATS-B Before Launch) spin-stabilized synchronous satellite;
ATS-2	April 6, 1967	-	(ATS-A Before Launch), Reentered the earth's atmosphere on Sept. 2, 1969 and was destroyed.
ATS-3	November 5, 1967	69°W	(ATS-C Before Launch)
ATS-4	August 10, 1968	-	(ATS-D Before Launch) Reentered the earth's atmosphere and was destroyed on October 17, 1968.
ATS-5	August 12, 1969	105.5°W	(ATS-E Before Launch)
ATS-F	April 12, 1974	94°W*	(ATS-F Before Launch); Experiments performed at 94°W for one year.
		35°E*	One year of experiments performed.
		94°W*	Indefinite time at this longitude
ATS-G			Cancelled as of January 1973

*As of Oct. 1971.

TABLE 2-9. RADIO FREQUENCY ASSIGNMENTS FOR THE ATS SERIES

PROJECT	FREQUENCY (MHz)	EMMISSION/POWER[1]	OPERATIONAL FUNCTION AND CHARACTERISTICS
ATS-1, Applications Technology Satellite	136.47	30F9/.75 W	PCM/PM telemetry of spacecraft systems and experiment status on command
	137.35	30F9/.75 W	PFM/PM telemetry of experimental data on command
	148.26	30A9/3 KW	Earth to spacecraft telecommand
	135.6	90F9/30 W	Spacecraft to earth VHF experiment link
	149.22	90F9/5 KW	Earth to spacecraft VHF experiment link
	149.22	90F9/100 W	Aircraft and ships to spacecraft VHF experiment link
	4119.599 & 4178.591	25000F2,F3,F4, F5, F9/2.5 W	Spacecraft to earth experimental communication data links
	4135.946 & 4195.172	AO/2.5 W	Spacecraft tracking aids
	6212.094 & 6301.050	25000F2,F3,F4, F5, F9/10 KW	Earth to spacecraft experimental communication data links
ATS-3, Applications Technology Satellite	Same frequency complement as ATS-1, plus:		
	412.05	270F9/.1 W	Spacecraft to earth electron density measurement experiment; phase coherent with 137.35 MHz signal
	Note: Power on 4119.599 & 4178.591 MHz is 24 W in lieu of 2.5 W		
AST-5, Applications Technology Satellite	136.47	30F9/.75 W	PCM/PM telemetry of spacecraft systems and experiment status on command
	137.35	30F9/.75 W	PFM/PM telemetry of experimental data on command
	148.26	30A9/3 KW	Earth to spacecraft telecommand
	412.05	270F9/.1 W	Spacecraft to earth electron density measurement experiment; phase coherent with 137.35 MHz signal
	1550.0	15000F2, F3, F9/25 W	Spacecraft to earth PLACE experiment link
	1565.82	A0/.3 W	Spacecraft experiment CW beacon on command
	1650.0	15000F2, F3, F9/1 KW	Earth to spacecraft PLACE experiment link
	4119.599 & 4178.591	25000F2,F3,F4, F5, F9/24 W	Spacecraft to earth experimental communication data links
	4135.946 & 4195.172	A0/2.5 W	Spacecraft tracking aids
	6212.094 & 6301.050	25000F2,F3,F4, F5, F9/10 KW	Earth to spacecraft experimental communication data links
	15,250-15,350	1A9/.2 W	Spacecraft to earth millimeter wave propagation experiment links
	31,500-31,800	A0/1 KW	Earth to spacecraft millimeter wave propagation experiment links
ATS-F & G, Applications Technology Satellites	136.23	30F9/2 W	PCM/PM telemetry on command
	137.11	30F9/2 W	PCM/PM telemetry on command
	148.26	30A9/3 KW	Earth to spacecraft telecommand (Backup)
	154.2	30A9/3 KW	Earth to spacecraft telecommand (Primary)
	20.008	AO/1 W	Spacecraft ESSA (NBS) ionospheric sounder beacons
	39.0156	AO/.125 W	
	39.91596	AO/.125 W	
	40.016	AO/.5 W	
	40.11604	AO/.125 W	
	41.0164	AO/.125 W	
	139.0556	AO/.065 W	
	140.056	AO/.25 W	
	141.0564	AO/.065 W	
	360.04396	AO/.04 W	
	360.144	AO/.16 W	
	360.24404	AO/.04 W	
	450	AO/500F9/500 W	Earth to spacecraft attitude determination and antenna evaluation experiment link
	850	M40F3,F5/80 W	Spacecraft to earth (India only) TV link
	1550	M12F2,F3,F9/40 W	Spacecraft to earth PLACE experiment link
	1650	M12F2,F3,F9/1 KW	Earth to spacecraft PLACE experiment link
	1650	M12F2,F3,F9/500 W	Aircraft to spacecraft PLACE experiment link
	1800	M12F5,F9/20 W	Spacecraft to spacecraft data relay link
	1800	M12F5,F9/20 W	Spacecraft to earth data relay link tests
	2247	M20F5,F9/20 W	Spacecraft to spacecraft data relay link
	2250	M40F5,F9/50 W	Earth to spacecraft data relay link tests
	2253	M20F5,F9/20 W	Spacecraft to spacecraft data relay link
	3950	M500F9/20 W	Spacecraft to earth RFI experiment link
	3750,3950 & 4150	M40F2,F3,F4,F5, F9/24 W	Spacecraft to earth experimental communication data links
	5950,6150 & 6350	M40F2,F3,F4,F5, F9/10 KW	Earth to spacecraft experimental communication data links
	6301.05	M25F9/10 KW	Earth to spacecraft RFI experiment link
	6301.05	M25F9/100 W	Earth (mobile) to spacecraft RFI experiment link
	19,000-21,000 & 29,000-31,000	AO/10 W	Spacecraft to earth millimeter wave propagation experiment links

1. See RCA (1969) for definitions of emission symbols.

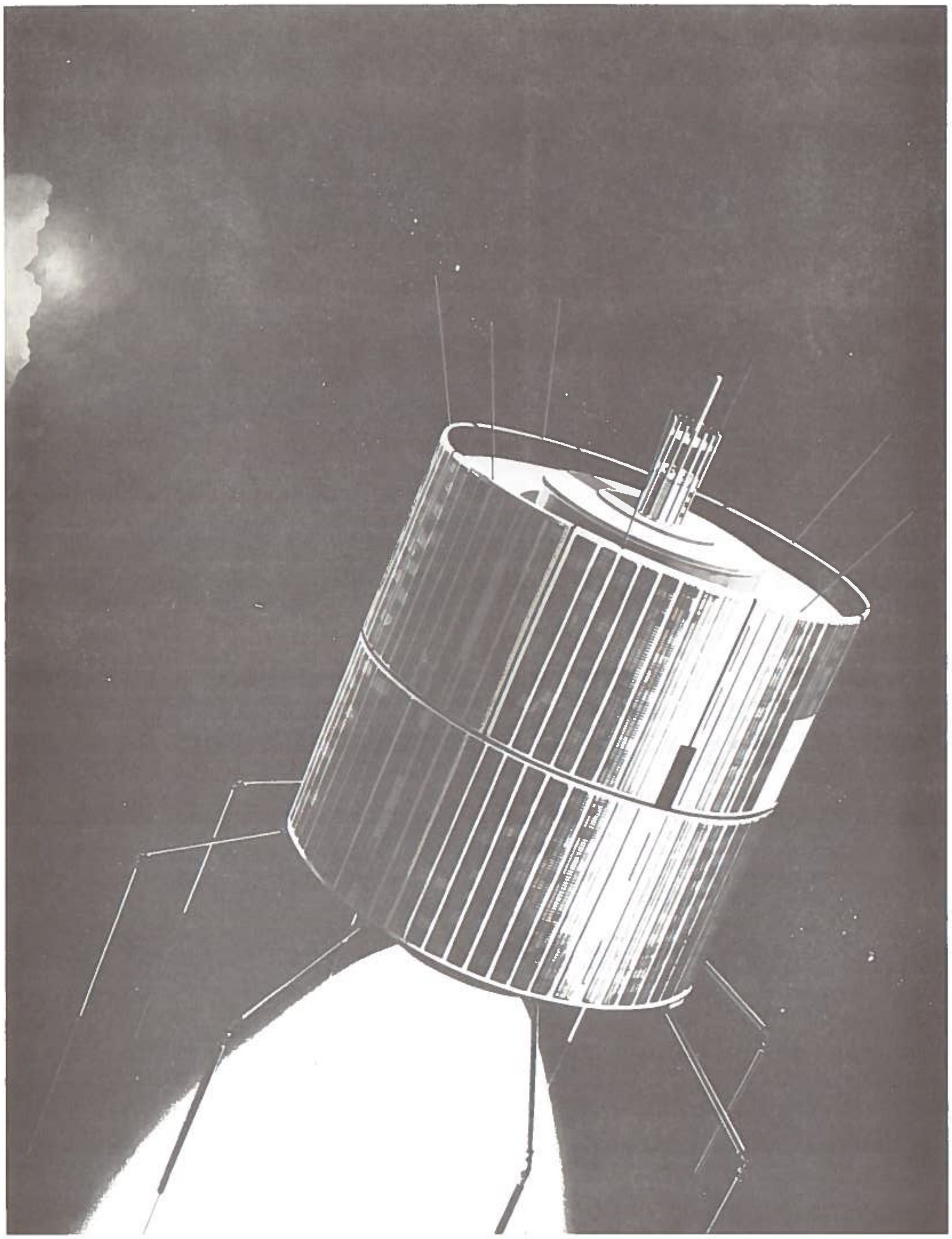


Figure 2-16. Photograph of the ATS-1 Spacecraft

By judicious selection of earth operating parameters, the experimenter can use other signals such as double- and single-sideband amplitude modulation.

Figure 2-17 is a block diagram of the transponder and the antenna control system. The ATS-1 repeater characteristics are:

Measured EIRP (as of Sept. 1970)	48.0 dBm
Receiver NF	4.0 dB
Receiver BW	100.0 kHz
Transmitter Frequency	135.6 $\pm$ 0.05 MHz
Receiver Frequency	149.22 $\pm$ 0.05 MHz
Translation Error	$\pm$ 50.0 Hz

The transponder operates as follows. Each dipole element receives incoming signals at 149.22 $\pm$ 0.05 MHz, routes them through a duplexer, amplifies them by a low-noise receiver, and shifts them in phase to compensate for the relative position of each dipole antenna. The waveform generator drives the phase-shifter in each receiver unit, causing the receiver output to be in phase only for those signals originating from the earth. The eight receiver outputs, summed together, filtered, and down-converted to an intermediate frequency of 29.95 MHz, pass after amplification through a crystal filter to limit the receiver bandwidth to 100 kHz. The intermediate frequency is then up-converted and amplified before being divided into eight equal parts by the power-splitter network feeding the transmitters. Each output of the power splitter is routed to a transmitter for phase-shifting and amplification to the final design output of 5 W. The transmitter phase shift is also controlled by the waveform generator, reinforcing the signals of each antenna in the direction towards the earth.

In the full-power mode, all eight transmitters are energized; in the half-power mode either the odd-numbered transmitters or the even-numbered transmitters are energized, depending on the regulator selected. Selection is made by ground control from the ATS Project Operations Control Center through one of its ATS Ground Stations at either Rosman, North Carolina or the Mojave ATS ground

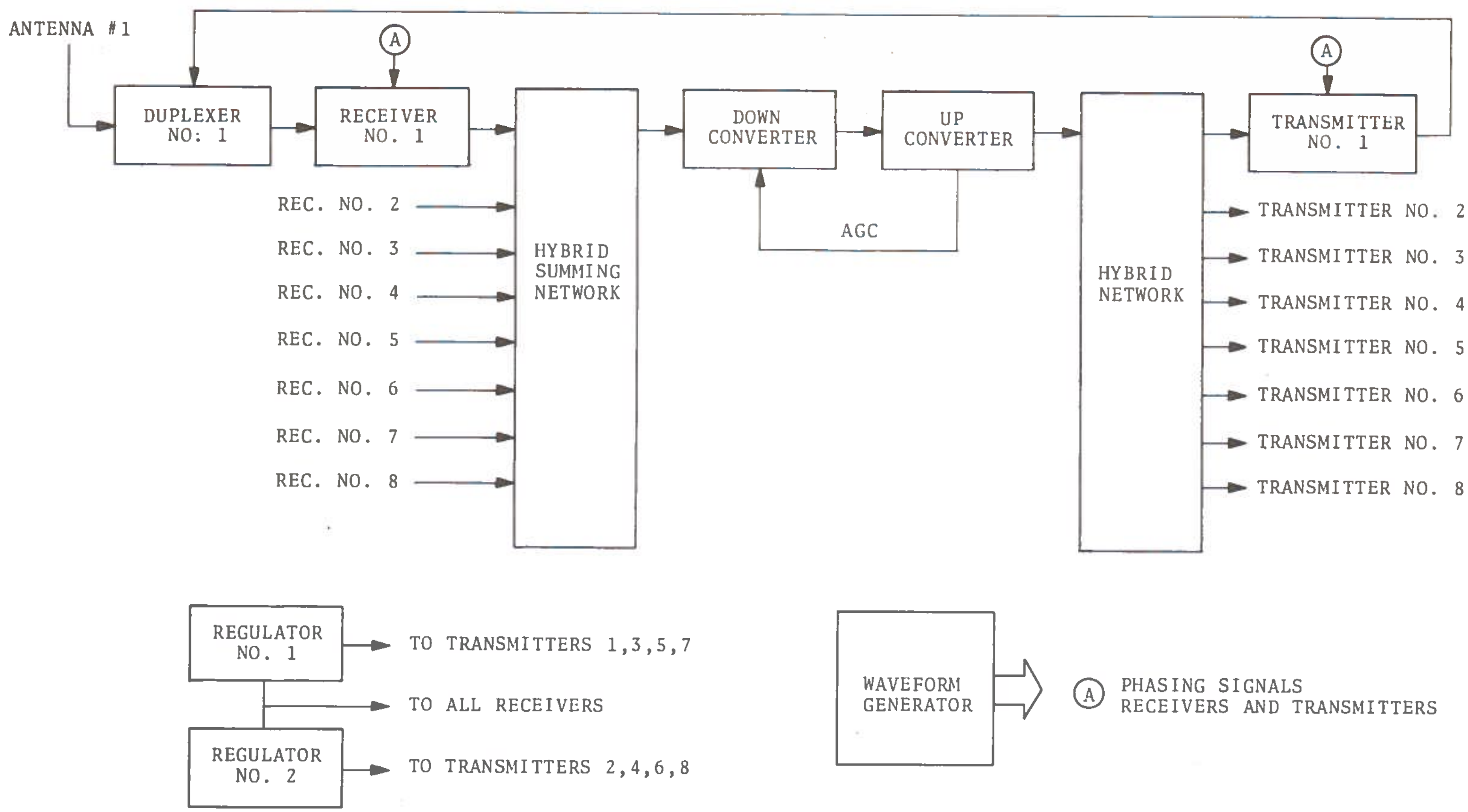


Figure 2-17. Block Diagram of the ATS-1 VHF Transponder and Antenna Control System (After NASA, 1972)

station in California. In either case, all eight receivers and their associated antennas are always employed.

The phased array can operate as an omni antenna by deenergizing the waveform generator thereby not phasing the beam.

Figure 2-18 is a graph of ATS-1 VHF transponder output power as a function of ground station transmitted power. The three curves indicate the effects of the four spacecraft configurations. When operating in the full power mode, the spacecraft output power is 48 dBm. When operating in the half-power mode with four transmitters and four phased antenna whips, the spacecraft output power is 41.4 dBm when regulator 1 is used, and approximately 40 dBm when regulator 2 is used. The omni mode also produces an output power of approximately 40 dBm.

Accuracies of the individual characteristics are ± 1 dB. However, the received level depends on many variables and should not be assumed to be only a function of free space loss. Experience indicates that received signal level is a function of geomagnetic latitude, season of the year, time of day, pointing direction of the spacecraft antenna, elevation angle and ionospheric disturbances.

More elaborate details of the satellite can be found in NASA (1972)

2.4.3 ATS-3

The ATS-3 is located and maintained at 70° (± 1°)W longitude. In January 1973 the orbit inclination of ATS-3 was 3.16° and will continue to increase at 0.86° per year. The radio frequencies of the various radio links are given in Table 2-9 and a photograph of the ATS-3 is presented in Figure 2-19.

Except for the final stages of the transmitting power amplifier, and the addition of a cross strap feature, ATS-3 transponder operation is the same as that of ATS-1. Figure 2-20 is a simplified block diagram. Transponder characteristics are:

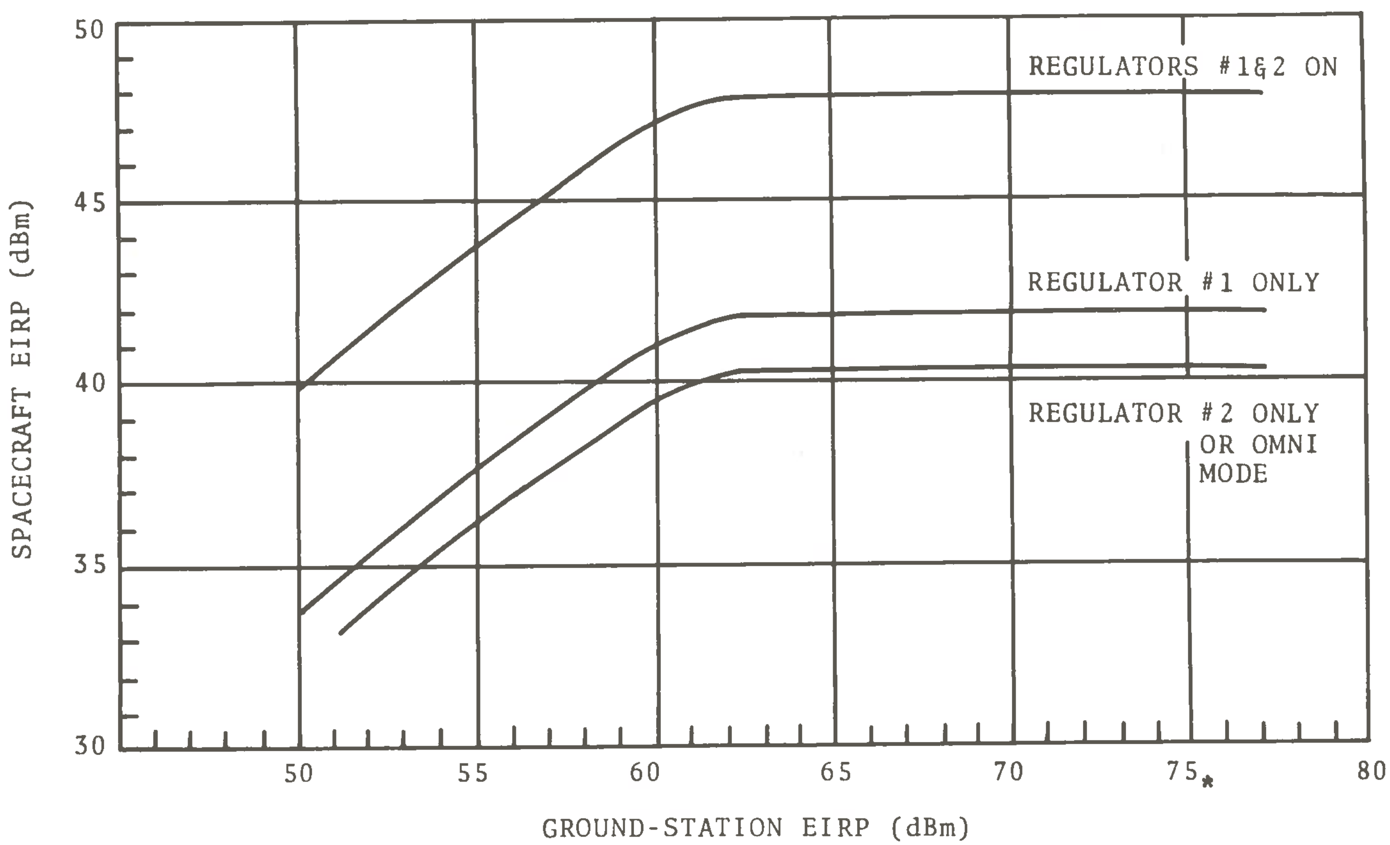


Figure 2-18. Graph of the ATS-1 VHF Transponder Output Power Versus Ground Station Transmitted Power (After NASA, 1972)

*Effective Isotropically Radiated Power of the VHF Transmitter (1 kW Output with Linear Polarization)

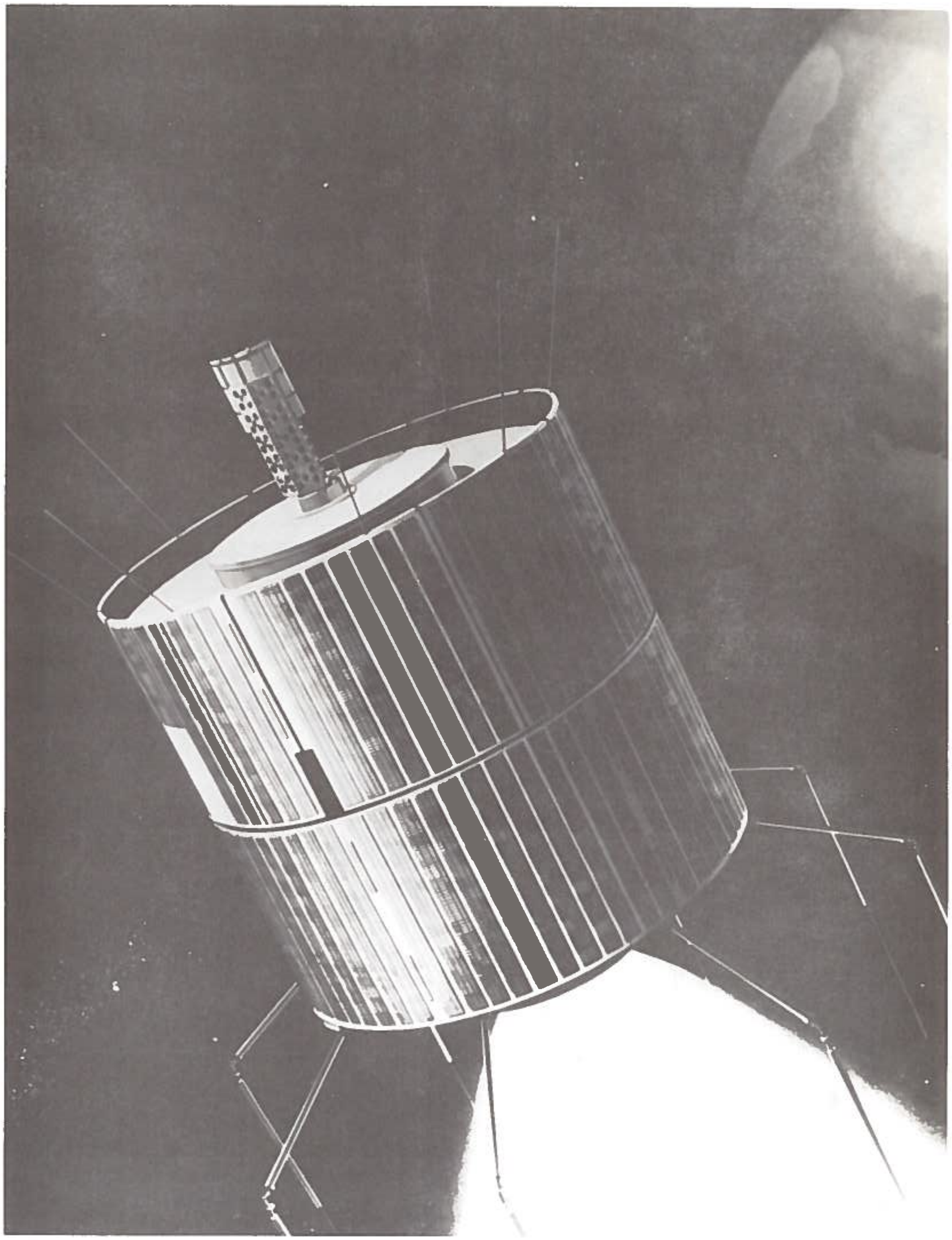


Figure 2-19. Photograph of the ATS-3 Spacecraft

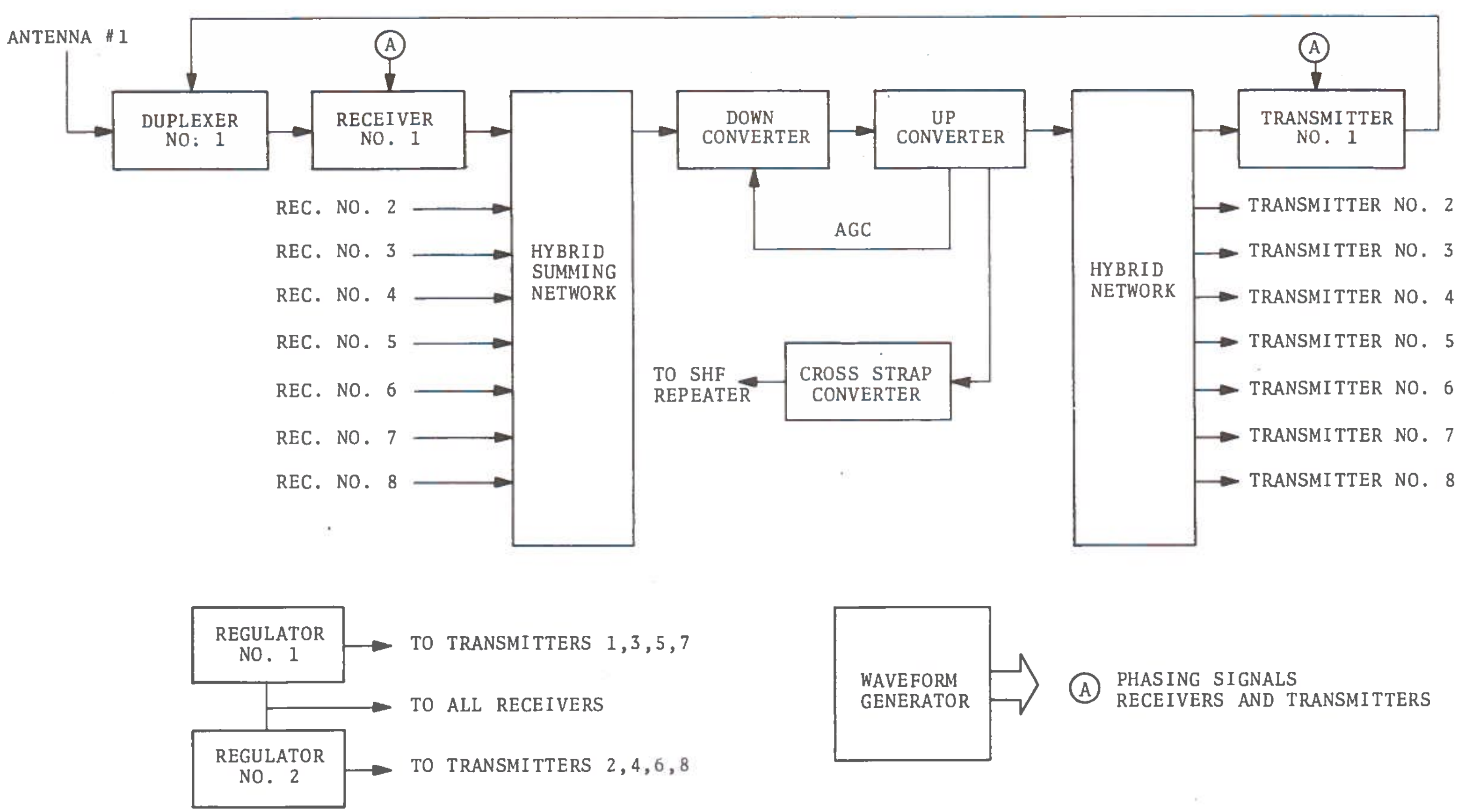


Figure 2-20. Block Diagram of the ATS-3 VHF Transponder (After NASA, 1972)

Measured EIRP (as of September 1970)	47.6 dBm
Receiver NF	4.0 dB
Receiver BW	100.0 kHz
Transmitter Frequency	135.6 ± 0.05 MHz
Receiver Frequency	149.22 ± 0.05 MHz
Translation Error	+800 Hz, ± 100 Hz

The final power amplifier stages of ATS-3 were designed for a maximum power output capability of 10 W each (80 W total). However, the driver stages and the automatic gain control circuits were designed to limit the maximum output level to 5 W for each transmitter element. Thus when subjected to two or more input carriers, ATS-3 does not exhibit the compression characteristics for the weaker input as does ATS-1.

The cross strap feature of ATS-3 converts the received VHF signal spectrum (centered at 149.33 MHz) to a low frequency spectrum between 250 and 350 kHz at a level suitable for modulating the C-band downlink transmitter in its wide-band data modes. The 4.2 GHz downlink signal is phase modulated with an index between 0.6 and 1.2 radians peak.

Figure 2-21 indicates the ATS-3 VHF transponder output power as a function of ground station transmitted power. Maximum power out, 47.6 dBm, reduces to 43.4 dBm when operating with the four transmitters and antennas associated with regulator 2. When operating with regulator 1 and its associated transmitters and antennas, the spacecraft effective isotropic radiated power is 40.7 dBm. It appears that one of the transmitters associated with regulator 1 is malfunctioning and reducing both forward power and antenna gain. When the spacecraft is put into the omnidirectional mode the effective isotropic radiated power becomes 39.8 dBm. As with the ATS-1, the measurement accuracies are ± 1 dB, but the actual level received is a function of many variables.

It has been observed that when the ground station's effective isotropic radiated power is reduced to low values, the spacecraft output power exhibits discrete jumps of 1-2 dB. This

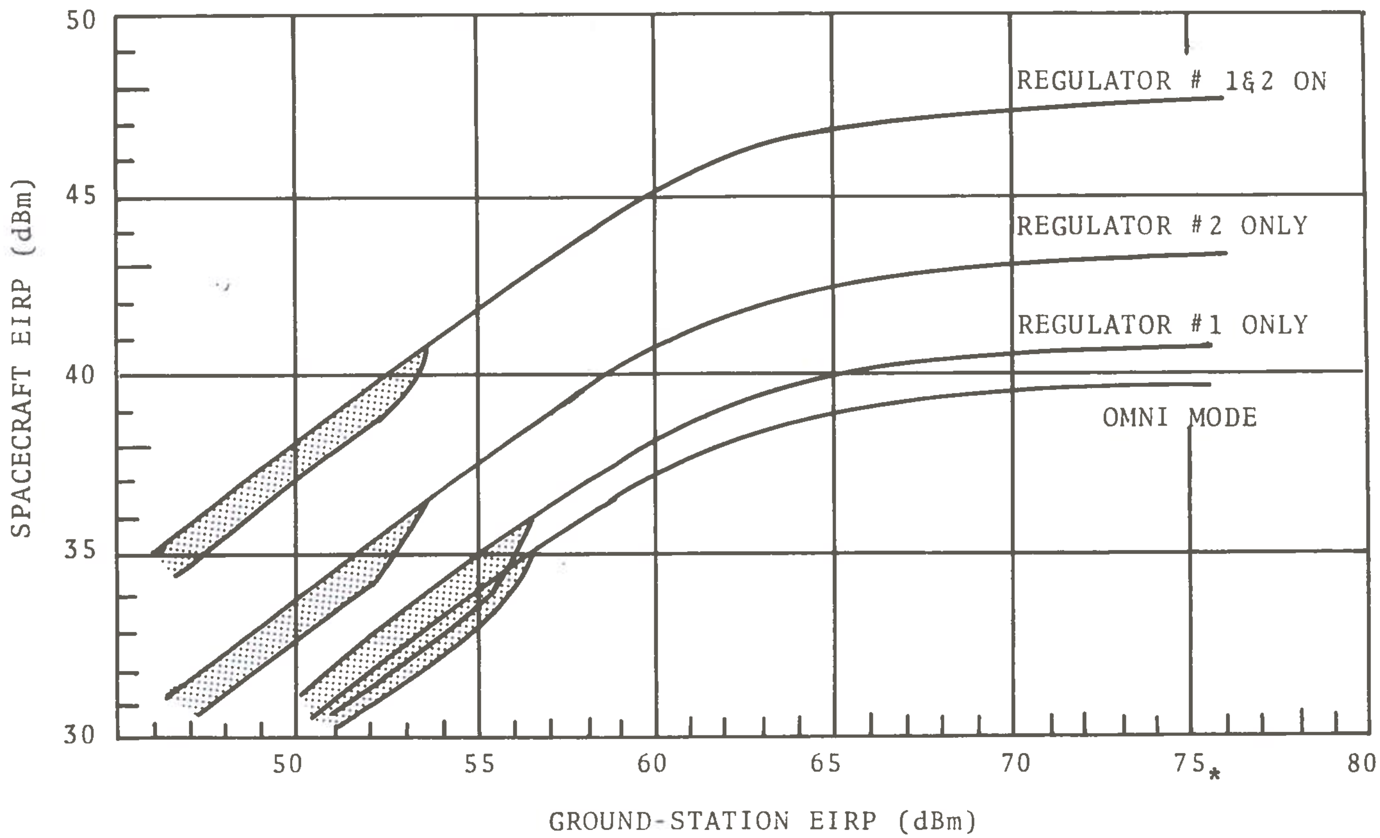


Figure 2-21. Graph of the ATS-3 VHF Transponder Output Power Versus Ground Station Transmitted Power (After NASA, 1972)

*Effective Isotropically Radiated Power of the Central Facility's VHF Transmitter (1 kW Output with Linear Polarization) is indicated in Figure 2-21 by shading at the lower end of the graphs. Additional details are referenced in NASA (1972).

2.4.4 ATS-5

The ATS-5 is located and maintained at 105°W longitude and its orbital inclination is about 1.5°. Originally the ATS-5 spacecraft, shown in Figure 2-22, was designed to operate in an equatorial orbit of synchronous altitude. It was to be gravity gradient stabilized and utilize a high gain phased array antenna for L-band communications (Kissel, 1970). Difficulties were encountered during the orbit injection making it impossible to despin the spacecraft. Therefore, for all practical purposes the ATS-5 is spin stabilized. The current period of rotation is approximately 782.47 ms with the axis of spin approximately parallel with the Earth's spin axis. The spacecraft antenna thus illuminates the Earth for a brief time during each spacecraft revolution. The -3 dB points illuminate the Earth station approximately 52.5 ms each revolution. The orbital geometry is shown in Figure 2-23. Figure 2-24 depicts the variations in intensity that may be expected over the Earth due to the orbit of the ATS-5 spacecraft.

The ATS-5 spacecraft has three major modes of operation. They are the multiple access, the frequency translation and the wide-band data modes. The multiple access and frequency translation modes may be cross-strapped between the C-band and L-band transponder.

The frequency translation mode employs two bandwidths: wide-band at 25 MHz and narrow-band at 2.5 MHz (in the C- to L-band cross-strap mode the wide-band bandwidth is 6 MHz). The narrow-band mode is identical to the wide-band except an improved signal-to-noise ratio is achieved for narrow-band signals by employing a filter prior to the limiter-amplifier and saturated traveling wave tube amplifier. Figure 2-25 is a block diagram of the ATS-5 L-band transponder and will be used to give a brief discription of the transponder operation.

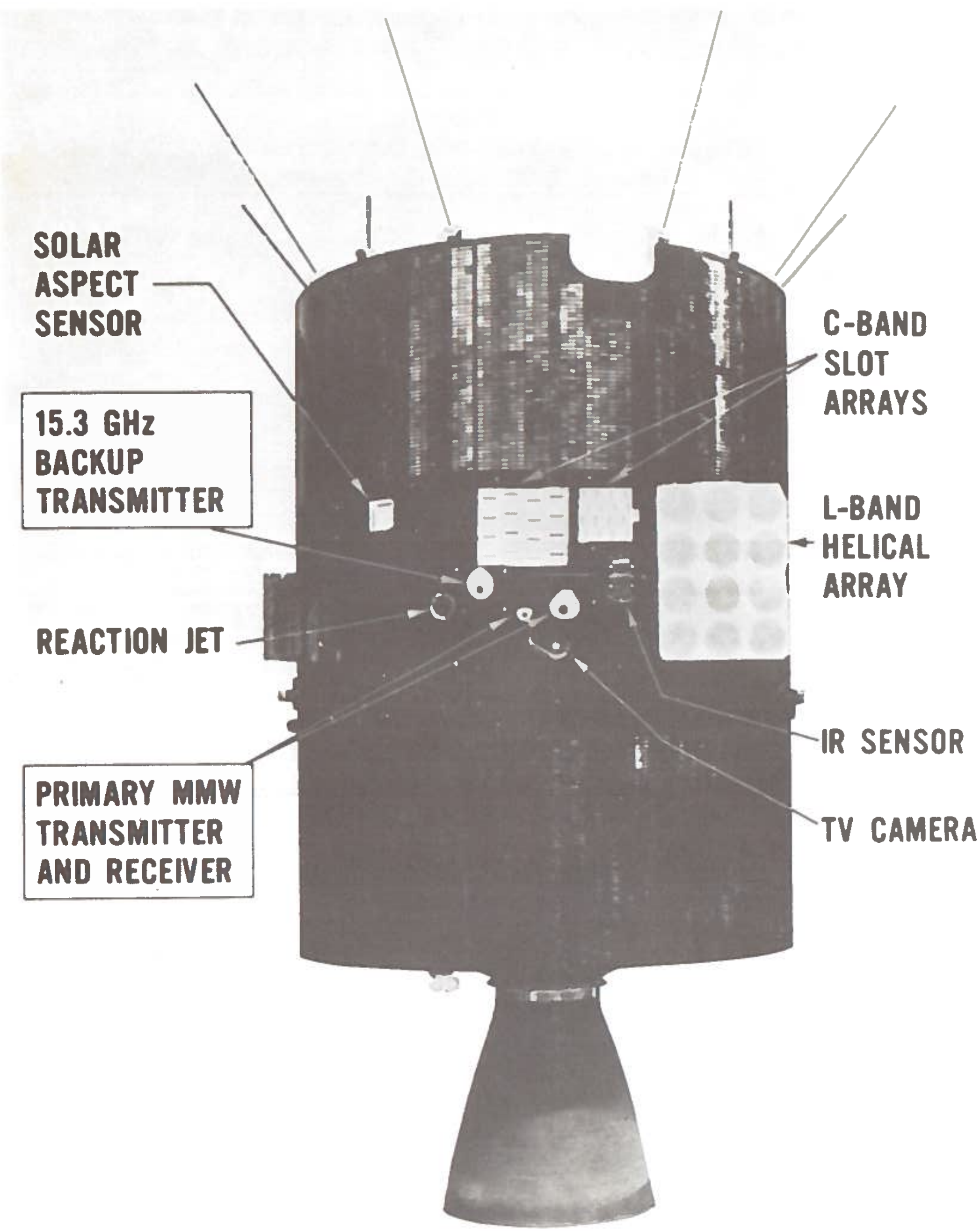


Figure 2-22. Photograph of the ATS-5 Spacecraft

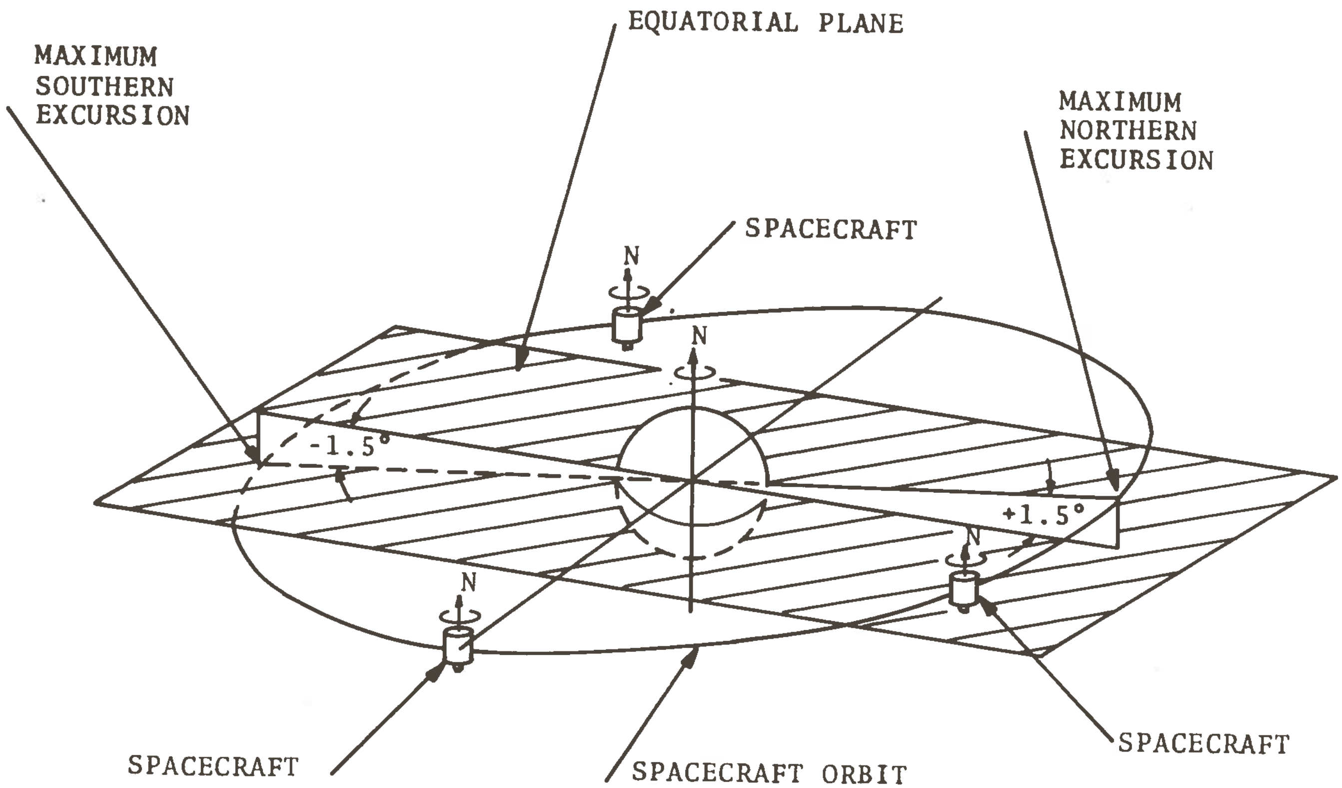


Figure 2-23. ATS-5 Orbit Geometry as of July 1972

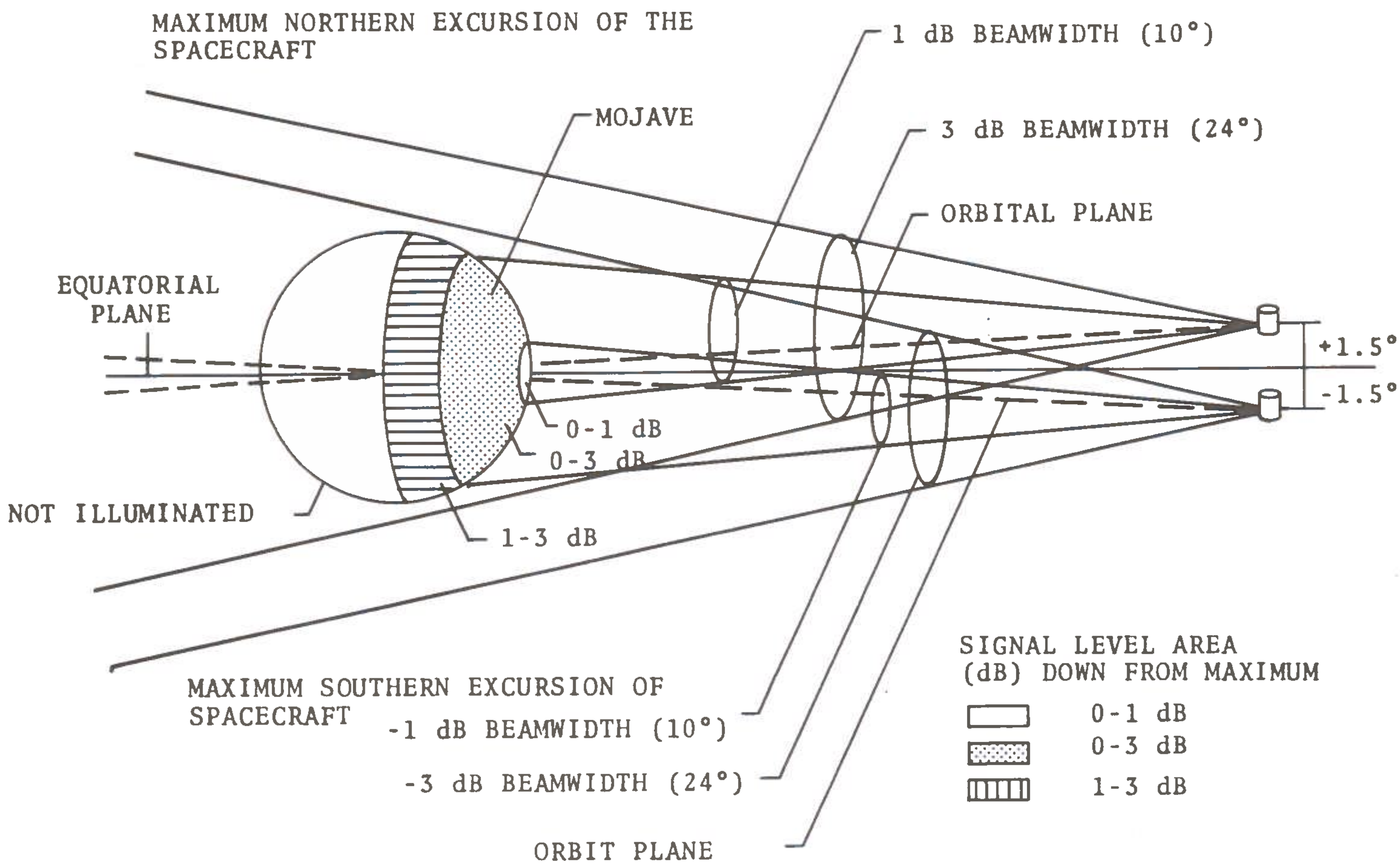


Figure 2-24. Earth Illumination Intensity of the ATS-5 L-Band Transmissions (July, 1970)

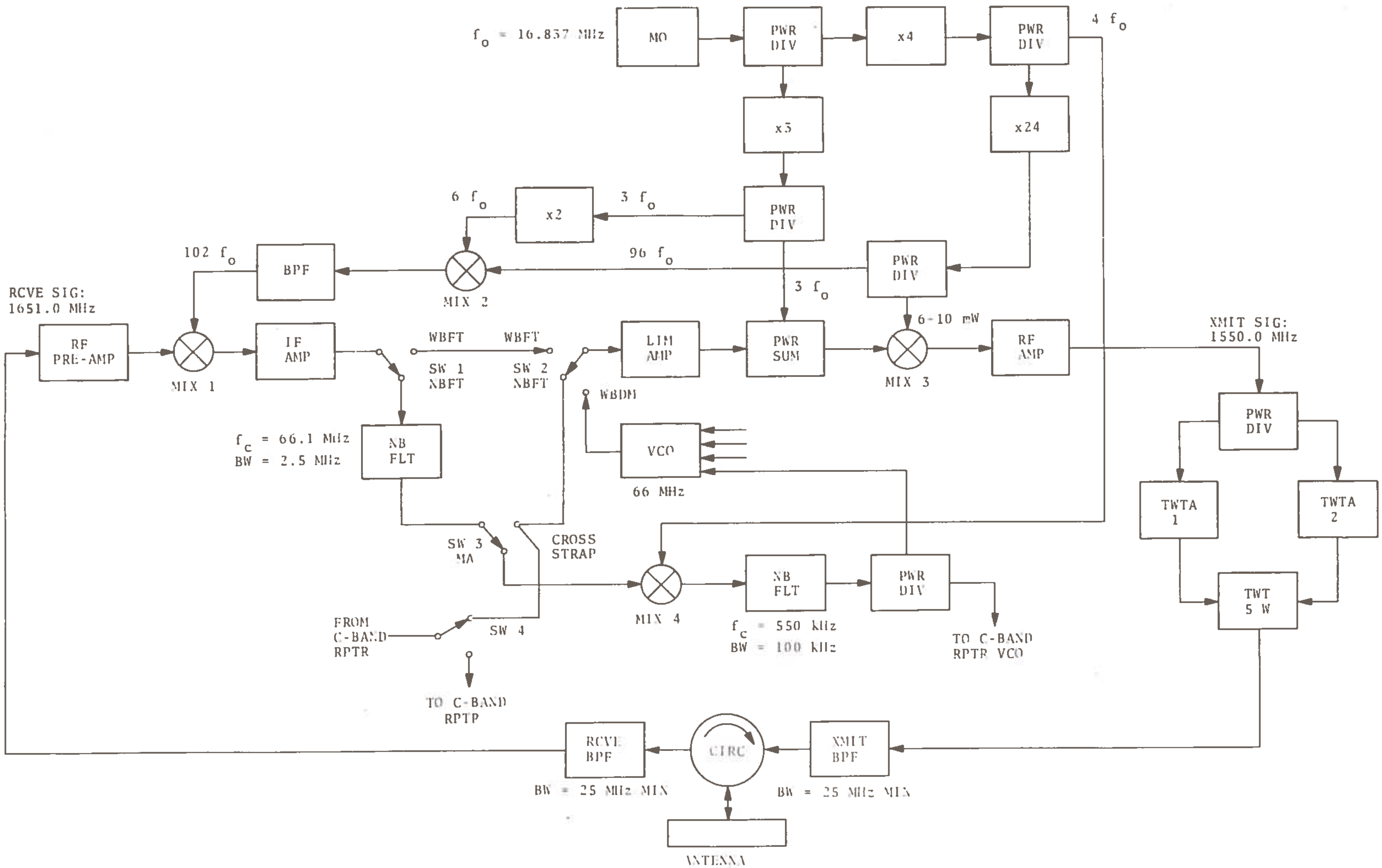


Figure 2-25. Block Diagram of the L-Band Transponder on the ATS-5 Spacecraft (After Kissel, 1970)

In the frequency translation mode the received signal at 1651 MHz is down-converted to the transponder intermediate frequency of 66.1 MHz in mixer 1. The intermediate frequency signal is amplified and filtered, if desired, and limited. A beacon signal at 50.511 MHz derived from the master oscillator is then added to the intermediate frequency signal. The composite signal is then up-converted in mixer 3, amplified and retransmitted. The output power is shared between the transmitted signal and the beacon.

When the transponder is operated in the narrow-band frequency translation mode and the received signal at 1651 MHz is strong enough to saturate the intermediate frequency limiters then the retransmitted signal will be at full strength and the beacon signal will be about 10 dB weaker than the retransmitted signal.*

If the received signal at 1651 is not strong enough to saturate the limiters the full retransmitted power will not be realized and the power at the beacon frequency will consequently be stronger.

If no signal is received and only receiver noise is retransmitted then the beacon will be approximately 7 dB stronger than the case of the beacon when the retransmitted signal saturates the transponders limiters. When the transponder is operated in the wide-band frequency translation mode and no signal is received, the beacon is the full 19 dB stronger or as strong as a carrier saturating the limiters would be.

The transponder is operated in the C- to L-band cross-strap frequency translation mode with a 66.1 MHz intermediate frequency signal from the C-band transponder routed over to the L-band transponder for retransmission.

In the multiple access mode the received L-band signals are converted to video (500 to 600 kHz). The video signal is then used to modulate the transponder's voltage controlled oscillator.

---

*The transponder's receiver now appears to have 6 dB less intermediate frequency gain than at launch, consequently it now takes a 6 dB stronger signal at 1651 MHz to saturate the limiters.

The transponder's voltage controlled oscillator's nominal operating frequency is 65.89 MHz.

The wide-band data mode of operation is intended for transmitting spacecraft video data. In the wide-band data mode no signal is received by the transponder. The 66 MHz voltage controlled oscillator that is used in the multiple access mode is also used to obtain an intermediate frequency signal for transmission at L-band. The voltage controlled oscillator's intermediate frequency signal is strong enough to saturate the limiters. Under this condition there is no input to the voltage controlled oscillator which is left in a free running state. As a consequence the L-band output in the wide-band data mode is an FM signal (the amplified voltage controlled oscillator signal) in which the FM modulation is comprised of the "noise" modulated voltage controlled oscillator signal. The noise is the instability of the voltage controlled oscillator's input. Also the beacon in this mode is 19 dB below the wide-band data signal.

The ATS-5 L-band transmit antenna pattern is shown in Figure 2-26 as measured at the Mojave STADAN ground station. Figure 2-27 illustrates the voltage control oscillator's drift and master oscillator drift.

The final amplifier of the L-band transponder employs two 12 W traveling wave tube amplifiers. The units may be run individually or in parallel. The circuit loss from the amplifier to the antenna is 2 dB and the antenna gain is 14 dB giving an effective isotropic radiated power of 52.8 dBm for one traveling wave tube. Table 2-10 presents sample power budgets for various L-band modes on the ATS-5 spacecraft.

The transmitted signal is right-circular in polarization with an axial ratio less than 2 dB. For ground antennas with similar such ellipticities the polarization loss is of the order of 0.2 dB.

Consulting Table 2-10 we see that the nominal signal strength as would be received on the ground with an isotropic antenna

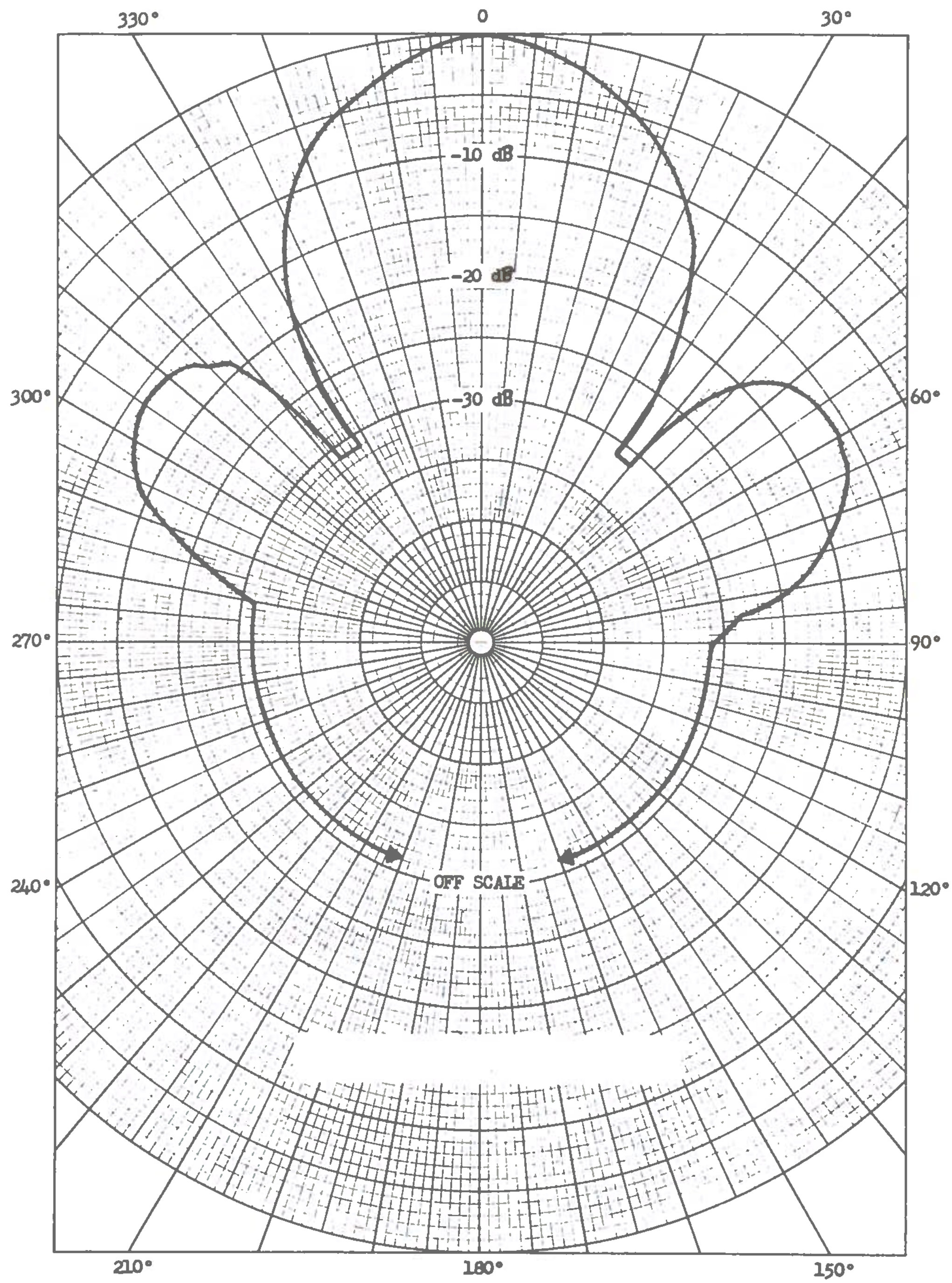


Figure 2-26. Plot of the ATS-5 L-Band Transmit Mode Antenna Pattern (After Kissel, 1970)

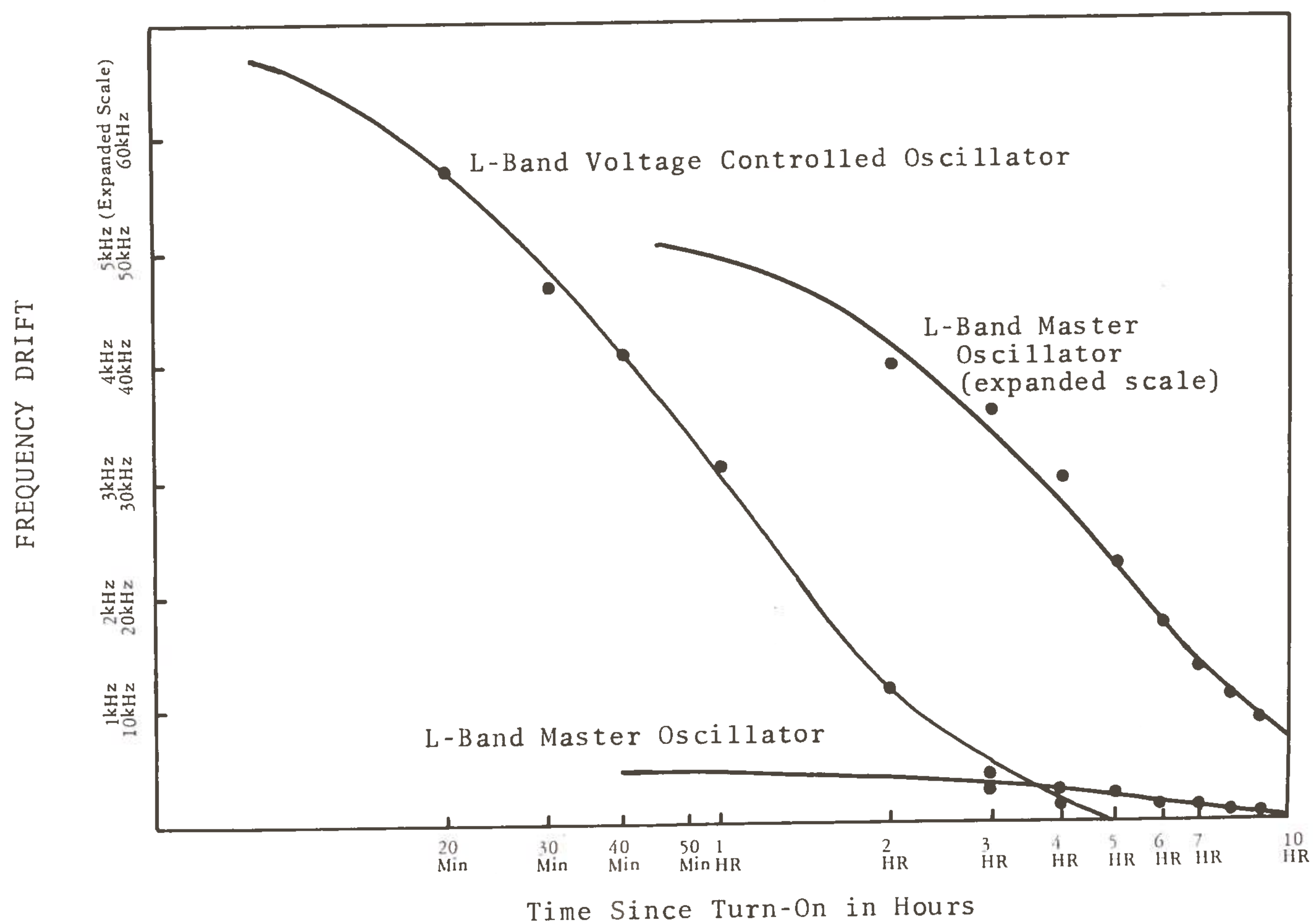


Figure 2-27. Plot of the Voltage Controlled Oscillator Drift and the Master Oscillator Drift on the ATS-5 Spacecraft as a Function of Time Since Turn on (After Kissel, 1970)

TABLE 2-10. SUMMARY OF L-BAND SIGNALS TRANSMITTED FROM THE ATS-5 SATELLITE AND THE NET SIGNAL STRENGTH AS RECEIVED AT THE EARTH

					BEACON SIGNAL				
		WBDM	NBFT[1]	WBFT[1]	WBDM	NBFT[1]	NBFT[2]	WBFT[1]	WBFT[2]
1. Transmitter Power (1 TWT)	dBm	+ 40.8 (12 W)	+ 40.8 (12 W)	+ 40.8 (12 W)	+ 20.8(.12W[3])	+ 20.8(.12W[3])	+ 28.7[3](.75W[3])	+ 20.8(.12W[3])	+ 40.8(12W[3])
2. Transmitter Circuit Losses	dB	- 2.0	- 2.0	- 2.0	- 2.0	- 2.0	- 2.0	- 2.0	- 2.0
3. Transmitter Antenna Gain	dB	+ 14.0	+ 14.0	+ 14.0	+ 14.0	+ 14.0	+ 14.0	+ 14.0	+ 14.0
4. Net EIRP	dBm	+ 52.8	+ 52.8	+ 52.8	+ 32.8	+ 32.8	+ 40.7	+ 32.8	+ 52.8
5. Free Space Loss	dB	-187.8	-187.8	-187.8	-187.8	-187.8	-187.8	-187.8	-187.8
6. Polarization Loss	dB	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2
7. Ground Station Pointing Loss	dB	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2
8. Nominal Atmospheric Loss	dB	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2
9. Spacecraft Pointing Loss (Nominal) Due to Diurnal Spacecraft Motion	dB	- 1.1 $\pm$0.8	- 1.1 $\pm$0.8	- 1.1 $\pm$0.8	- 1.1 $\pm$0.8	- 1.1 $\pm$0.8	- 1.1 $\pm$0.8	- 1.1 $\pm$0.8	1.1 $\pm$0.8
10. Net Propagation Loss	db	-189.5 $\pm$0.8	-189.5 $\pm$0.8	-189.5 $\pm$0.8	-189.5 $\pm$0.8	-189.5 $\pm$0.8	-189.5 $\pm$0.8	-189.5 $\pm$0.8	-189.5 $\pm$0.8
11. Net Signal Strength at the Earth as Would be Received by an Isotropic Antenna	dBm	-136.7 $\pm$0.8	-136.7 $\pm$0.8	-136.7$\pm$0.8	-156.7 $\pm$0.8	-156.7 $\pm$0.8	-148.8 $\pm$0.8	-156.7 $\pm$0.8	-136.7 $\pm$0.8

1. Transponder saturated by uplink signal
2. No uplink signal
3. Inferred from ground based measurements

would be -137 dBm in the wide-band data mode or in the narrow-band frequency translation mode if the uplink signal saturates the transponder's limiters. At the same time the beacon signal (approximately 16 MHz higher in frequency) would have a nominal strength of -156 dBm. The actual signal presented to the ground receiver will be stronger by the amount of the net antenna gain which in the case of a 6-foot diameter reflector is 27 dB minus the associated losses (Table 2-2).

2.4.5 ATS-F

The ATS-F spacecraft is scheduled to be launched in the fall of 1974. A photograph of the planned ATS-F is presented in Figure 2-28. Initially the ATS-F will be in an equatorial geo-stationary orbit at a longitude of 94°W for about one year. Then the spacecraft will be moved to a longitude of 35°E for about one year. Finally the spacecraft will be moved back to a longtitude of 94°W for the rest of its lifetime.

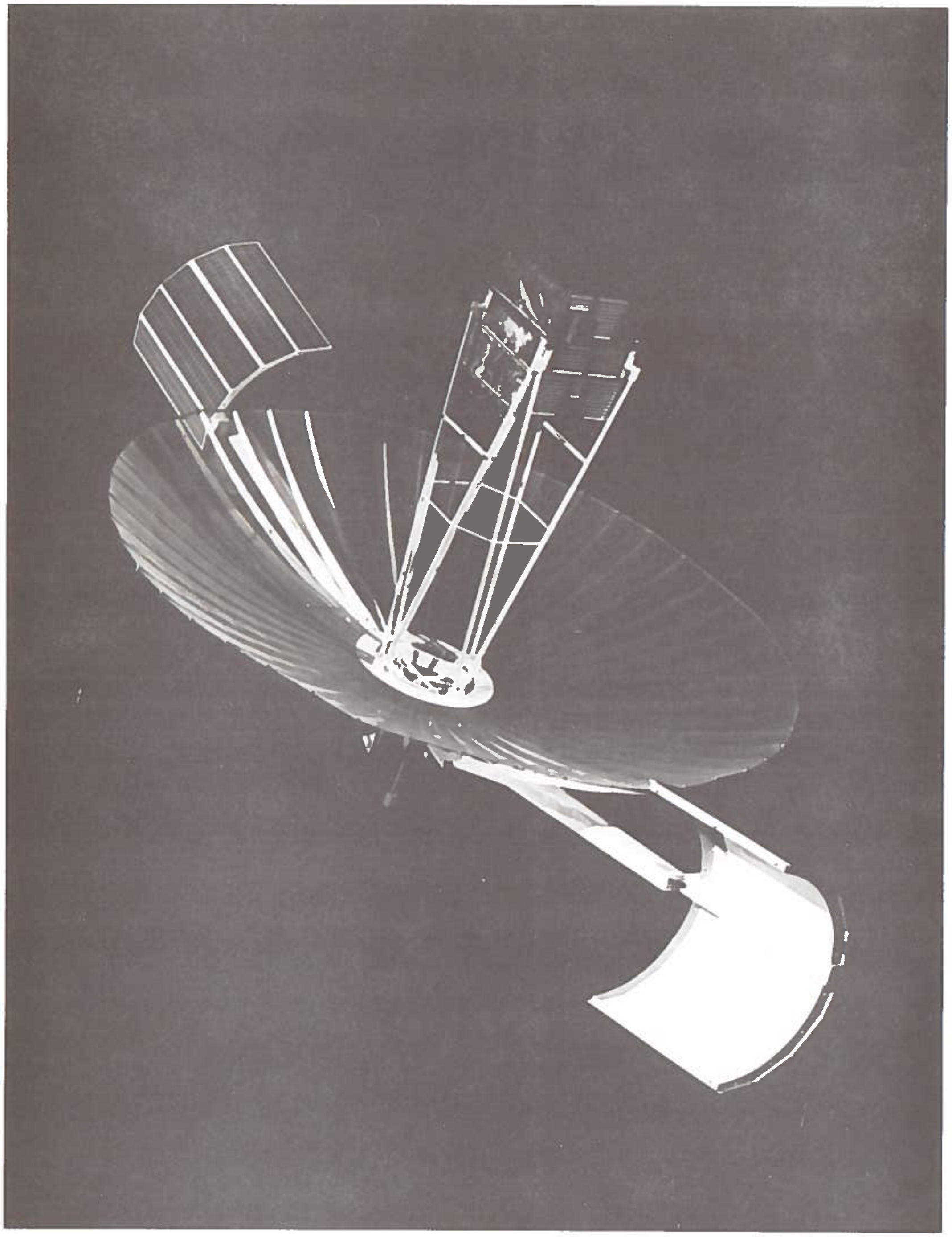


Figure 2-28. Photograph of the ATS-F Spacecraft

3. MEASUREMENT SYSTEM SOFTWARE

3.1 REMOTE FACILITY

The interface unit between the VHF receiver/transmitter and the computer has been described in Section 2.2.5. The interface unit performs some decoding and coding of the received and transmitted signals.

All messages sent or received by the remote or central facility have the same format. The signaling is done at 2441.4 baud. Each message starts out with 1024 "ones". This string of ones is used to phase the clock at the receiving station to the bit stream that is to follow. The 1024 ones are followed by a 15-bit synchronizing word and a 15-bit address word. This preamble is used with every transmission. Figure 2-8 illustrates the preamble as well as a message that might follow.

The first word following the preamble is the record length. The record length is the number of data words in this transmission. It does not include the check sum word (the arithmetic total of all data words) and the end of transmission word. The next word is the check sum word. Following the check sum are the number of data words as specified in the record length. The last word transmitted is the end of transmission symbol.

The digital bits used to construct the preamble are generated or processed by the interface unit only. Once the interface unit has phased its oscillator (usually after about 600 ones) it begins to search for the sync word and addr word combination. As soon as it has found them it has found its place in the received bit stream. All the words that follow the preable are used by the computer. Each of the bits which form a digital word used by the computer are sent three times making a 48-bit word. The computers at both the remote facility and the central facility use 16-bit words, thus for each 16-bit computer word, 48 bits are sent and consequently received.

The interface unit knows that as soon as it has found the sync and addr words all the words that follow are 48-bit words that must be converted to 16-bit words for the computer. The interface unit takes the three bits intended to become one computer bit and determines the two out of three average of the three bits. This average bit is the one supplied to the computer. Consequently, though the transmission is at 2441 baud the actual information is only sent a 813 baud to insure the reliability.

As soon as synchronization is obtained using the sync and addr words the next 48 bits are clocked in. On the 48th clock pulse the 16 individual two out of three averages are found, the 16-bit computer word is constructed and placed in a buffer for transmission to the computer. At this time a flag is sent to the computer. The interface unit proceeds to clock in the next 48 bits.

When the computer senses the interface unit's flag it reads in the 16-bit word and clears the flag. Typically this occurs during the next clock pulse since the computer operation is much faster than the interface unit's clock.

The first word read into the computer is the number of data words to be sent during this transmission. The computer program uses this information to set aside a buffer of the proper size for the data that will be coming during transmission.

The second word sent is the check sum word. The check sum of the data was previously computed by the remote facility's computer prior to the initiation of the transmission. The central facility's computer saves the check sum word for this transmission and will use it after all the data has been received.

The third and successive words sent are the data words. The final word is the end of transmission symbol. When the end of transmission is detected the computer no longer expects data from the interface unit and the controlling program continues in the central facility's computer.

The computer program which operates the remote facility is written so as to only accept certain control and command functions.

A control or command function may consist of one to ten 16-bit instruction words. The instruction words are transmitted and received exactly the same way the data word discussed above are transmitted or received initially. The remote facility's computer program will not be expecting a string of data words, consequently it will treat the initial information sent to it as instructions. The set of command and control functions are listed in Table 3-1. The first instruction is the command or control word. In the case of control functions often additional parameters are sent to the remote platform. In this case the parameters are the second, third, etc. instructions of the transmission.

In all cases, after each command or control function is received by the remote facility an acknowledgement is sent back to the base station. This acknowledgement might simply be to ensure that the message has been received, or it might be a short answer to a control function or it might be blocks of data. Transmissions are limited to about 3 minutes in length. If there is still data to be transmitted then a new preamble is sent followed by about 3 minutes of data. It is necessary to send a new preamble about every 3 minutes in order to rephase the clocks.

The acknowledgement reply which is appropriate for the control or command function just received is determined by the program in the remote facility's computer. When the program is ready to reply it sends a "start of transmission" flag to the interface unit. The interface unit commences to generate the string of 1024 ones. The sync word is then appended to the end of the bit stream. The address code of the remote facility is then appended to the sync word. Meanwhile the first 16-bit computer word has been put into the interface unit's input buffer and then converted and transferred to a 48-bit buffer. As soon as the last bit of the address code has been clocked out the first 48-bit word is appended to the bit stream. After the EOT word has been sent the interface unit is disabled from appending more bits to the bit stream. The transmitter is shut off and the receiver is turned on again.

TABLE 3-1. LISTING OF POSSIBLE COMMAND AND CONTROL FUNCTIONS FOR USE BETWEEN THE REMOTE AND THE CENTRAL FACILITY

Keyboard Operator Command	Control Functions	ASCII Code Binary Data Sent to ADCF	Acknowledgement ASCII Code/Binary Data Sent to CDCF
RO	Request Open	RO	AO
FO	Force Open	FO	AO
RT	Request Current Time and Day Number	TD	AH(our) AM(in) AS(ec) AD(ay)
RS	Request Current Schedule	RS	AD(ay) Start AH(our) Start AM(in) Start AH (Stop) AM (Stop) AC(ontrol) AD AH AM AH AM AC
RM	Request status of current measurements in storage.	MS	AD AH Start AM Start AH Stop AM Start AC AB(locks) AD AH AM AH } 2nd day AM AC AB
RC	Request close	RC	AC
	Control ERROR send function again	AE	AE

TABLE 3-1. LISTING OF POSSIBLE COMMAND AND CONTROL FUNCTIONS FOR USE BETWEEN THE REMOTE AND THE CENTRAL FACILITY (CONTINUED)

Keyboard	Command Function	Instruction Words	Acknowledgement
ST,H,M, S,D	Send current time and day number	ST;SA;SM; SS;SD	AT
SS,D_1,H_{1S} M_{1S};H_{1E}; M_{1E};C_1; D_2;H_{2S}; M_{2S}; H_{2E};M_{2E}; C_2	Send schedule	SS SD_1 SH_{1S} SM_{1S} SH_{1E} SM_{1E} SC_1 SD_2 SH_{2S} SM_{2S} SH_{2E} SM_{2E} SC_2	AS
SB,D	Send summary block for days, D.	SB SD	AB DATA $WORD_1$ - DATA $WORD_{256}$
SD,MMM, NNN,DDD	Send data blocks MMM through NNN for day number DDD.	SD SMMM SNNN SDDD	AD (Data $Word_1$ - Data $Word_{256}$) block MMM (Data $Word_1$-Data $Word_{256}$) block NNN
	Command Error	AE	AE

3.2 CENTRAL FACILITY

The message format and preamble generation by the central facility's interface unit and preamble processing by the central facility's interface unit are exactly the same as was discussed in Section 3-1 for the remote facility.

The operation of the remote and central facility equipment are under control of the operator at the central facility. The operator communicates with the program in the central facility. The operator must use only the commands that the system will recognize (any other command will be rejected and the correct command must be reentered). The central facility's computer will than perform the task requested. These tasks always involve an exchange of information with the remote facility's computer. The central facility's computer program creates the proper instruction word for the command or control function - then signals the interface unit that it is ready to make a transmission. The actual transmission is under the control of the interface unit and not the computer. After the computer has instructed the interface unit to start the transmission the computer program goes on with other processing. It does not wait for the interface unit since the interface unit is much slower than the computer, however, as the interface unit needs instruction words from the computer it requests them. The computer answers the requests almost instantly due to its greater speed. When the computer passes the last instruction word (i.e. the end of transmission symbol) it also flags the interface unit that this is the end and the transmitter can now be shut off and the receiver switched on.

When the returned acknowledgement is received the acknowledgement instruction will be processed by the portion of the computer program that sent the previous transmission. If it is the correct acknowledgement and instruction words were returned with it the instruction words will be processed. The acknowledgement is typed on the teletype to indicate to the operator that is was correct. Also if information was returned with the acknowledgement it will be put in the proper format and typed on the teletype unit. If the incorrect acknowledgement is returned an acknowledge error is typed on the teletype unit for the operator to see. The operator can then reinitiate his command. An acknowledge error will also be typed out if there was a check sum error in the initial transmission to the remote facilities' computer or if a check sum error occurs on the return acknowledgement transmission. No matter what the cause of the error the command must be reentered.

The central facility's computer subprograms that effect the control functions which return the current time and day number, current schedule or status of current measurements in storage also formats the returned data and prints it on the teletype unit in appropriate tables for the operator to use.

The central facility's computer subprogram that effect the command functions to return the summary table also formats the returned data and prints on the teletype unit the summary table. The summary table has an entry for every 15 minutes block of data during the total observing period. Each entry in the table contains the mean, the maximum and minimum signal strength, and the standard deviation of the signal during that period and the storage block numbers where this segment of data resides on the DECtape unit of the remote facility. Figure 3-1 illustrates a typical format for the summary table.

```
RUN-1  HM,  HM,  MEAN, STANDARD DEVIATION, MAX., MIN., BLOCK #(s)
RUN-2  HM,  HM,  MEAN, STANDARD DEVIATION, MAX., MIN., BLOCK #(s)
...
RUN-n  HM,  HM,  MEAN, STANDARD DEVIATION, MAX., MIN., BLOCK #(s)
```

Figure 3-1. Format for a Summary Table of the Remote Facility's Measurements Currently in Storage on the Remote Facility's DECtapes

The contral facility's computer subprogram that effect the command function to return blocks of data simply stores the data in core as it is being returned. It is then copied onto a disc at the central facility. A return data transmission has a maximum length of 24 blocks before another preamble is sent. With the data collected from the ATS-5 at a rate of one measurement per pulse then 1.5 minutes of data will fill one block or 15 minutes will fill 10 blocks on the DECtape. Following the 15 minutes of one measurement per pulse will be approximately 7.5 seconds of high speed measurements. These measurements will be at a rate of one measurement per millisecond, and the measurements will be centered on the central 50 ms of a pulse. Consequently the measurement of 10 pulses at the high speed rate will fill two blocks. The high speed measurements are not summarized in the summary table.

The observing period is thus divided into runs of approximately 15 minutes in length with 2560 measurements of a single pulse amplitude (10 blocks of DECtape) and 10 pulses of 50 measurements each (1 measurement per ms) which are stored on 2 blocks of DECtape. Thus 2 runs of data of 12 blocks each may be relayed back at one time. The relay transmission time is about 3 minutes.

4. MEASUREMENT OPERATIONS

4.1 REMOTE FACILITY MEASUREMENT TECHNIQUE

The receiving equipment for the L-band measurements has been described previously in Section 2.2.2. The signal-to-noise ratio of the ATS-5 signal is given in Table 2-2. The initial measurements performed by the remote facility will be the measurement of the signal strength of the ATS-5 L-band signal. The receiver is capable of receiving the wide-band data mode signal or a continuous wave signal when the ATS-5 transponder is operated in the frequency translation mode. The crystal of the first local oscillator may be changed so that the receiver could be used to receive the L-band beacon signal. In such a case care must be taken to insure that the satellite beacon is of sufficient strength to give an acceptable signal-to-noise ratio.

The measurement technique to be employed at the remote facility will be to measure the signal-to-noise ratio of the signal. This will be accomplished by measuring the noise power for a short period of time between the pulses. The noise level or baseline will be measured for 64 ms at a rate of one measurement per ms. The 64 measurements will be averaged to establish the baseline level. Also the root-mean-square of the baseline measurements is calculated and compared with a preset level (about 3 times what the baseline standard deviation should be). If the measured rms value exceeds this preset level then the preceeding data measurement during the pulse is disregarded. This is done to insure that intermittent interference is not present in the data.

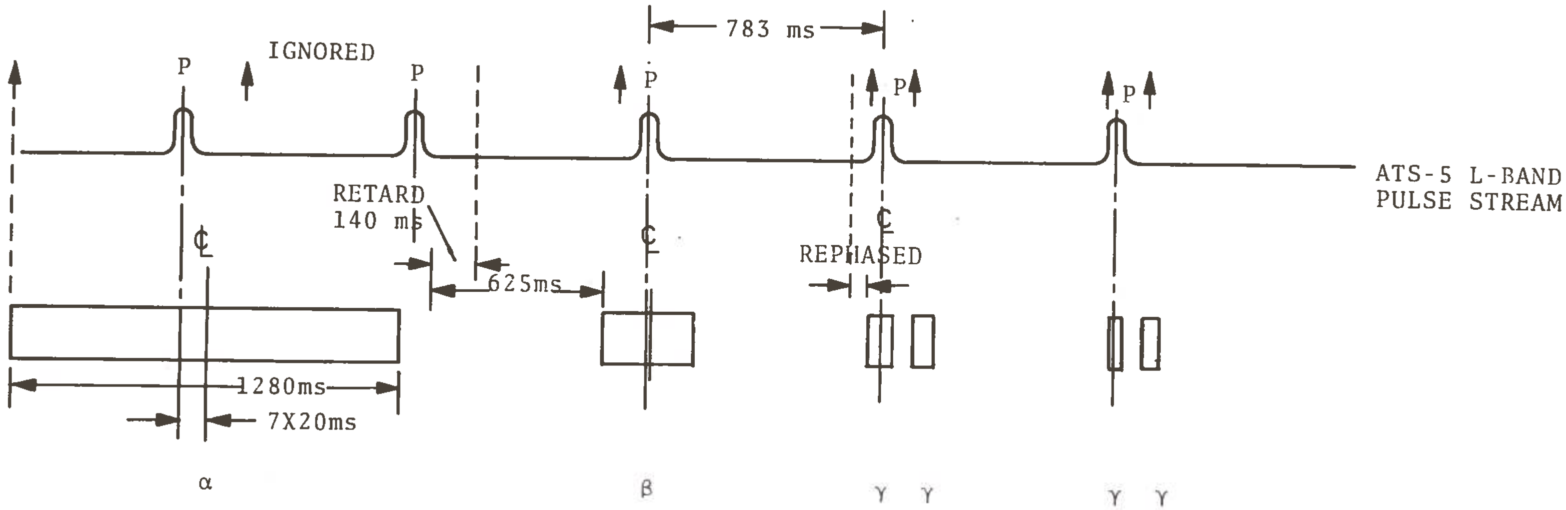
During the peak of the pulse as the ATS-5 spacecraft rotates around toward the Earth 64 measurements are taken. The measurements are taken every millisecond with 32 before the peak and 32 after the peak of the signal. The eight measurements on the peak of the pulse are used as the measure of the signal strength. The eight measurements are averaged and the average is then compared with some preset limits to insure that the data are reasonable. The number representing the baseline level is then subtracted from the amplitude number, the resultant being the numerical value of the signal-to-noise ratio.

The eight measurements of signal strength are averaged to insure that an individual value selected as the peak does not contain a noise spike in addition to the signal. The limit comparison is done to insure that the signal is of sufficient strength to be useful and also to insure that the absolute gain of the receiver has not drastically changed. A large increase in gain could cause the detector operation to be non-linear.

The computer program in the remote facility will control the data acquisition such that the data will be taken during the time period when the ATS-5 spacecraft is pointed toward the Earth. Of course, the program could be modified to accomodate a non-spinning spacecraft. The procedure for locking the data acquisition to the spinning is as follows.

Measurements are taken in blocks of 64 as discussed above for the baseline and the peak of the pulse. The data acquisition sequence is initiated once every 783 ms, the spin rate of the ATS-5 spacecraft. The 783 ms timing is done in the software of the computer. The 783 ms timing must be phased with the rotation of the spacecraft. The procedure is to measure the phase difference and constantly adjust the phasing of the 783 ms timing to keep the data acquisition correctly timed.

Initially, measurements will be taken at the rate of one every 20 ms, thus the 64 measurements will include 1280 ms (the command to measure again at 783 ms is ignored). This period will insure that at least one pulse has been measured. The 64 measurements are then examined starting with the first measurement. The first measurement of the pulse is determined. This is followed by 64 measurements and the location of this pulse with respect to the center of the 64 measurements is recorded, if the pulse occurred 7 measurement blocks before the center (measurement number 32). Then the programmed logic determines that this block of measurements was started 7 times 20 ms too late to have the pulse occur in the center of the 64 measurements. Figure 4-1 illustrates the data acquisition technique



KEY

α : 20 ms DATA ACQUISTION RATE (64 MEASUREMENTS TAKE 1280 ms)

β : 5 ms DATA ACQUISTION RATE (64 MEASUREMENTS TAKE 320 ms)

γ : 1 ms DATA ACQUISTION RATE (64 MEASUREMENTS TAKE 64 ms)

P : MAXIMUM SIGNAL INSIDE PULSE

℄ : CENTER OF MEASUREMENT INTERVAL (i.e., MEASUREMENT NO. 32)

↑ : COMPUTER GENERATED START DATA ACQUISTION COMMAND PULSE

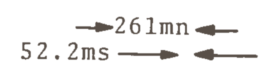


Figure 4-1. Schematic Diagram of the Data Acquisition Technique Used at the Remote Facility

The course synchronization, using measurements once every 20 ms, may now be refined to measurements at a rate of once every 5 ms. This will give a total measurement period of 5 ms times 64 or 320 ms. The data acquisition command must now be properly re-shaped in order to center the 320 ms period of the signal pulse. In order to rephase the data acquisition command, the pulse is first retarded by 140 ms as required for the above example and then advanced 626 ms.

The new set of 64 measurements, taken at a rate of once every 5 ms, is then examined to find where the center of the pulse is with respect to measurement number 32. Suppose, for example, that it is in number 35, three after the center pulse. Thus the data acquisition command pulse would have to be advanced 3 times 5 ms or 15 ms in order to center the measurement period on the pulse when measurements are made at this rate of once per 5 ms.

During the next data acquisition period and subsequent periods during the data taking period, measurements are made at the rate of one measurement every millisecond. The rephasing procedure utilized is as described above. In order to rephase, the data acquisition command must first be advanced 15 ms and then advanced 125 ms.

This next set of 64 measurements, now at a rate of one per millisecond, is processed as described previously when the eight maximum readings are averaged. If the center of this block of 8 readings is not number 32 then the 783 ms timing is rephased again. Note that now the number of readings between the center of the block of 8 and reading number 32 is the number of milliseconds of correction needed to rephase the 783 ms timing command. The data reading of this pulse is saved so that the baseline reading may be subtracted.

One hundred milliseconds following the 64 data measurements 64 baseline measurements are taken. The data measurement and the baseline measurements are processed as previously explained and if acceptable are recorded. At a time 683 ms later or 783 ms plus or minus any phase correction the 64 data measurements are again taken. This procedure continues until 2560 pulses have been measured (approximately 15 minutes). At that time the "High Speed" data acquisition is started. In this case the centered 50 measurements of pulse are stored. Following the baseline measurement the baseline reading is subtracted from each of the 50 data measurements and the results stored. This is done for 10 pulses.

Prior to the storing of the measurements of these 2570 pulses on magnetic tape for retransmission to the central facility the necessary summary calculations are made on the first 2560 pulses for storage in the summary table discussed in Figure 3-1. The average of the 2560 pulses is found, the rms is found, the maximum and minimum signal strengths are noted as well as the starting time for this data run and the completion time is noted in addition to the block numbers where the data will be stored on the DECtape unit.

The 15 min data taking and storage process just described is known as a "run". The starting and stopping of data acquisition runs is automatic. The schedule sent to the remote facility (see Table 3-1) determines the time interval during the day when it will perform the data runs. When the start time of the schedule is the same as on the internal clock at the remote facility then data acquisition will commence. Data acquisition will end when the scheduled end time agrees with its internal clock. All data acquisition is done in 15 min runs. During the 15 minutes 12 blocks of DECtape are filled. Since there are 1056 blocks on the two DECtapes 22 hours of data may be stored. If there is not time for the last 15 min run then the program will adjust the measurement scheme such that the last 10 pulses at 50 measurements per pulse are made before the end time.

Upon completion of the L-band scheduled measurements the remote facility will return to the VHF receive mode. If however, there are other scheduled L-band observations which have not been completed the remote facility will continue to check its clock and day count to determine when to start another L-band data acquisition period.

4.2 CENTRAL FACILITY

The raw data returned from the remote facility is stored in a 2570 word buffer by the computer program at the central facility as it is being received. If the transmission is made with no errors then the 2570 word buffer is stored on a track in the disc for later processing. If a transmission error occurs the 2570 words are sent again, the 2570 words in the buffer are not stored on the disc, but are purged. The summary table is also stored on the disc so that it may be recalled at a later time.

Two types of preliminary analyses are performed on the raw data. A probability analysis is performed on each 15 min run of data where the measurements are made at a rate of one every pulse. A temporal and spectral analysis is performed on each of the ten pulses with fifty measurements per pulse.

The probability density for each of the 15 min runs is calculated and stored. At the end of the observing period all of the probability density plots for the individual runs are plotted for visual inspection. The mean and standard deviation of the signal along with the half-width of the probability density plot are also calculated for each run.

Also the autocorrelation of the first 2048 of the single pulse measurements of the 2560 single pulse measurements of each run is calculated.* The autocorrelation calculations, probability density and general statistics for each run are then tape recorded for further analysis and plotting at a later time.

The power spectrum of the "High Speed" data acquisition data will be determined. Spectral components with a period between 2 ms and 20 ms may accurately be determined in this way (Bracewell, 1965). Consequently, components with a period less than 2 ms, though of great interest, will require faster data acquisition speeds.

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*The reason for 2048 measurements is because the largest number of points the Fast Fourier Transform unit can handle is 2048. This unit is part of the central facility's computer.

The software computer programs used in the central facility's computer and the remote facility's computer are very closely interrelated with respect to command and control of the remote facility. Each program has its own section for data acquisition and processing. The processing performed by the remote facility's computer (called preprocessing in the present arrangement) is intended to format and prepare the measurements for transmission back to the central facility.

The remote facility's computer may be thought of as interfaced and interconnected to the central facility's computer by means of a radio link instead of a cable. The data interchange is performed exactly as if it was through a short cable.

Since the VHF link is not available for extended periods of time on a daily basis it is necessary to send instructions to the remote facility' computer and then have them executed at the appropriate time. At present the program is arranged so that two observing periods may be scheduled ahead of time. The data is relayed back during the next period the VHF link is available. The data relayed back is compressed in time about 18:1. Thus, 18 minutes of observing may be relayed back in approximately 1 minute.

It is anticipated at this time that the data will be relayed back on a daily basis, however, should unforseen equipment problems or satellite schedule changes occur, allowances have been incorporated into the control programs to handle these situations.

It is possible with the equipment described here that the remote facility's measurements could be relayed back to the central facility in real time. This would of course require scheduling the VHF transponder in the ATS-1 or ATS-3 and the L-band transponder in the ATS-5 at the same time. For this type of operation an L-band signal would be transmitted from the central facility, the L-band signal would be repeated by the L-band transponder on the ATS-5 and received at the central facility and the remote facility. The signal from the remote facility would be relayed back to the central facility for processing and comparison with the signal received at the central facility. The capabilities are built into the central facility's computer to handle this type of experiment, though initially signal strength measurements will only be made and remote facility's measurements returned by delayed relay.

The measurements made at the central facility are similar to those made at the remote facility except that absolute calibration is employed and the high speed measurements are about 10 times faster. At the central facility each pulse from the ATS-5 is measured at the rate of once every 100 μs. There are 512 measurements at the particular rate during the central portion of the pulse. The high speed data storage at the central facility allows this type of measurement to be made. At the remote facility only 7.5 s of measurements at the rate of 1 measurement per ms is possible due to the limited high speed data taking arrangement presently available.

The data from the remote facility is reduced as soon as it all has been received at the central facility via the VHF link. The data reduction for the measurements from both the central facility and the remote facility is accomplished in essentially the same manner. Allowing for the fact that different amounts of data are present and the acquisition rates are different the reduction procedures are essentially the same. There are at present three types of analysis performed: spectral, temporal and probability.

The spectral measurements will allow measurement of the scintillation spectrum during the course of one pulse. The temporal analysis will determine the time behavior (period of fade) both during a pulse and through many pulses (i.e. minutes to hours). The probabilistic analysis will determine the signal level reliability during one pulse or a set of pulses or during several sets of pulses. A very important consideration in the probabilistic calculation is the number of data points or individual measurements used in determining the signal strength. In other words, the accuracy of the probabilistic calculation depends on the number of points averaged.

Consequently, using the high speed data acquisition of the central facility as an example, a measurement once every 100 μs will give 512 measurements per pulse. Thus in the probabilistic analysis of individual pulses the central 300 measurements are used first, then two consecutive measurements are averaged and used, then 3 consecutive measurements, then 4 consecutive measurements, etc. Likewise in the analysis of sets of pulses, first the total number of peak measurements will be used, that is 1 pulse per data point, then sets of consecutive pulses will be averaged before calculating the probabilities.

This analysis procedure will try to simulate digital bits of longer and longer duration and words of varying lengths and redundancies. The different reliabilities for the different bits and word sizes will give an indication of the reliabilities that may be expected if a signal of similar coding were tried and analyzed.

5. FIELD SITE SELECTION AND INSTALLATION

The geometry of the experimental situation is described by the relative positions of the DOT/TSC/Westford Propagation Facility (42.60°N; 71.5°W), the ATS-1 (0.00°N; 149°W), the ATS-3 (0.00°N; 69°W), the ATS-5 (0.00°N; 105.5°W), and possibly the ATS-F (0.00°N; 94°W initially; 0.00°N; 35°E after one year). The probable positions of the AEROSAT(s) is another consideration. Figure 5-1 presents the proposed coverage areas of the proposed AEROSAT spacecrafts. These maps were taken from the December 1972 AEROSAT Technical Performance Specification. In addition the density of the air routes should be taken into account as well as locating in a geomagnetic regime other than mid-latitude where the central facility is located. The choice of the site is now considerably narrowed to southern Greenland. Details of the exact location will be worked out in the immediate future.

It is estimated that the equipment for the remote facility will weigh approximately 1200 lbs not including an instrument shelter. The component specifications for the remote facility may be seen in Table 5-1. The power requirement should be well under 120 VAC at 30 amp. The typical set-up and check out time is 8 hrs. Disassembly and crating is also 8 hrs. It should be emphasized that the remote facility is unmanned when operational.

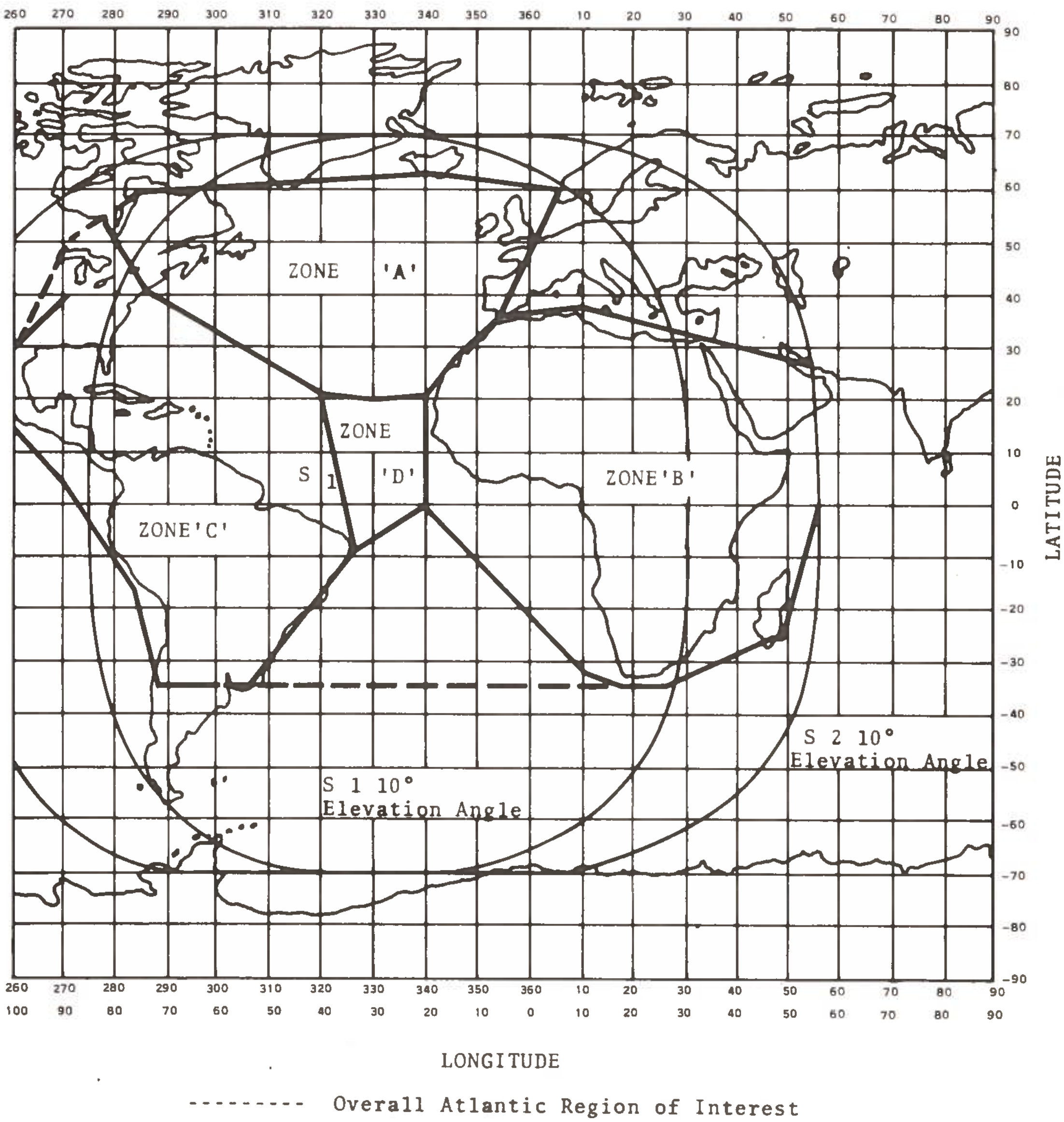

Figure 5-1. Preposed Location of the First Two AEROSATs as of December, 1972

TABLE 5-1. SPACE AND WEIGHT REQUIREMENTS FOR THE REMOTE FACILITY

Instrument	Size	Weight
<u>Inside Shelter</u>		
1. one 6 foot standard relay rack containing the PDP-11-05 computer and TC11 DECtape controller	72 in. high 24 in. wide	Weight: 150 lbs. Shipping: 200 lbs.
2. one ASR-33 Teletype Unit	24 in. wide 18.5 in deep 44 in. high	Weight: 60 lbs. Shipping: 80 lbs.
3. one General Electric Desk Mate VHF transmitter and Receiver with Demodulator and tone-code ranging re-sponder built into its cabinet	30.5 in. high 14.0 in. wide 25.5 in. deep	Weight: 189 lbs. Shipping: 250 lbs.
4. one Motorola Modem AM-494/GR 300 Watt power amplifier	26.8 in. high 16.5 in. deep 20.2 in. side	Weight: 185 lbs Shipping: 250 lbs
5. L-band Receiver	5.5 in. high 19 in. side 21 in. deep	Weight: 20 lbs Shipping: 60 lbs.
6. one Kennedy Model 3110 Tape Recorder	14.0 in. high 24.5 in. wide 19.0 in. deep	150 lbs. shipping
<u>Outside Shelter</u>		
7. L-band Antenna (Adjustable mount) Andrews Corp.	6 foot diam. parabola	90 lbs. 170 lbs. shipping
8. VHF Antenna crossed log periodic 10 dB gain		20 lbs. 30 shipping
9. Necessary cabling	200 feet	Weight: 19 lbs. Shipping: 40 lbs
10. Bird Thru-line Wattmeter	7" x 4" x 3"	4 lbs

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