RADC-TR-72-21
Technical Report
15 December 1971

AD 738305

POLAR FOX II - EXPERIMENTAL PHASE

Raytheon Company

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 1765

Approved for public release;
distribution unlimited.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Projects Agency or the US Government.

Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Raytheon Company Sudbury, Mass. 01776	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP
3 REPORT TITLE Polar Fox II - Experimental Phase Semi-Annual Technical Report No. 1	
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) Interim Report - Semi-Annual Report of Polar Fox II System	
5 AUTHOR(S) (First name, middle initial, last name) Lois W. Campbell Alan H. Katz Delbert E. Patton	
6 REPORT DATE 15 December 1971	7a. TOTAL NO. OF PAGES: 66 7b. NO OF REFS: 1
8a. CONTRACT OR GRANT NO. F30602-71-C-0214 b PROJECT NO 1765 c. Program Code 1E90 d.	9a. ORIGINATOR'S REPORT NUMBER(S) ER71-4457 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) RADC-TR-72-21
10 DISTRIBUTION STATEMENT Approved for public release; distribution unlimited	
11 SUPPLEMENTARY NOTES Monitored By: Adrian Briggs RADC/OCSE Griffiss AFB N.Y. 13440	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency 1400 Wilson Blvd. Arlington, Va. 22209

13 ABSTRACT

This report describes the Polar Fox II HF backscatter system built by Raytheon Company. This system will be used to collect data relating to the effects of auroral clutter on a HF radar system. The Polar Fox II System consists of a transmitter-receiver site co-located north of Caribou, Maine, and three remote beacon sites; one in Thule and in Narssarssuaq, Greenland, and the other in Keflavik, Iceland. The receiver-processors are described along with measurements of system performance. These showed that the system meets or exceeds the design specification as stated in the Statement of Work. Also discussed is the co-located transmitter site and the transmitter and receiver antenna arrays. The processing and displays to be used in the analysis of the data are also presented.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
HF PROPAGATION						
BACKSCATTER						
FORWARDSCATTER						
AURORA						

ER72-4107

POLAR FOX II - EXPERIMENTAL PHASE

Lois W. Campbell
Alan H. Katz
Delbert E. Patton

Contractor: Raytheon Company
Contract Number: F30602-71-C0214
Effective Date of Contract: 1 March 1971
Contract Expiration Data: 31 December 1972
Amount of Contract: $1,900,000.00
Program Code Number: 1E90

Principal Investigator: Dr. George D. Thome
Phone: (617) 443-9521 Ext. 2103

Project Engineer: Vincent J. Coyne
Phone: (315) 330-307

Contract Engineer: Adrian S. Briggs
Phone: (315) 330-3231

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by Adrian S. Briggs, RADC (OCSE), GAFB, NY 13440 under Contract F30602-71-C-0214

PUBLICATION REVIEW

This technical report has been reviewed and is approved.

RADC Project Engineer

RADC Contract Engineer

ABSTRACT

This report describes the Polar Fox II HF backscatter system built by Raytheon Company. This system will be used to collect data relating to the effects of auroral clutter on a HF radar system. The Polar Fox II System consists of a transmitter-receiver site co-located north of Caribou, Maine, and three remote beacon sites; one in Thule and in Narssarssuaq, Greenland, and the other in Keflavik, Iceland. The receiver-processors are described along with measurements of system performance. These showed that the system meets or exceeds the design specification as stated in the Statement of Work. Also discussed is the co-located transmitter site and the transmitter and receiver antenna arrays. The processing and displays to be used in the analysis of the data are also presented.

GLOSSARY OF TERMS

A/D	-	Analog/Digital
ASR	-	Automatic Send/Receive (Teletype)
ATP	-	Array Transform Processor
ATTN	-	Attenuator
az.	-	azimuth
BPF	-	Bandpass Filter
BS.	-	Beam Steering
CHU	-	Call Letters for Standard High Frequency
Comm.	-	Communication
Comp.	-	Computer
CNTR	-	Controller
CRT	-	Cathode Ray Tube
CW	-	Continuous Wave
db	-	decibels
dbi	-	decibels above an isotropic radiator
dbm	-	decibels above milliwatt
dbw	-	db above 1 watt
deg	-	degrees
D.L.	-	Delay Line
DR	-	Driver
DTR	-	Digital Tape Recorder
DSK	-	Magnetic Disk Memory
ENABLE	-	Transmitter Trigger
ESSA	-	Environmental Science Services Administration
Ex	-	Exciter

GLOSSARY OF TERMS (Con't)

fax	-	facsimile
FFT	-	Fast Fourier Transform
FM	-	Frequency Modulated
FSK	-	Frequency Shift Keying
G/A	-	Granger Associates
HF	-	High Frequency
HFDRV	-	High Frequency Data Receiver
HFO	-	High Frequency Oscillator
HFS	-	High Frequency Signal
HP	-	Hewlett Packard
HPA	-	High Power Amplifier
HS	-	High Speed
Hz	-	Hertz
IFI	-	Instruments for Industry
IPA	-	Intermediate Power Amplifier
ITSA	-	Institute for Telecommunications Sciences
kHz	-	Kilohertz
km	-	Kilometer
kw	-	Kilowatt
L.O.	-	Local Oscillator
LPA	-	Low Power Amplifier
MPH	-	Miles Per Hour
MHz	-	Megahertz
MUF	-	Maximum Useable Frequency
PEP	-	Peak Envelope Power
PPP	-	Peak Pulse Power
PTR	-	Printer

GLOSSARY OF TERMS (Con't)

QPR	-	Quadrature Phase Rotator
RBDD	-	Range Bin Doppler Data
RDR	-	Reader
RF	-	Radio Frequency
Rx	-	Receiver
S/H	-	Sample & Hold
SPD	-	Speed
SS	-	Subsystem
SWP	-	Sweep
SYNCH	-	Synchronizer
SYNTH	-	Synthesizer
T	-	True
TCI	-	Technology for Communications International
TN	-	True North
TTY	-	Teletype
Tx	-	Transmitter
usec	-	microseconds
uv	-	microvolts
v	-	volts
vrms	-	root-mean-square voltage
VSWR	-	voltage standing wave ratio
WWV	-	Call Letters for Standard High Frequency Transmissions - United States

TABLE OF CONTENTS

TABLE OF CONTENTS (Con't)

LIST OF ILLUSTRATIONS

LIST OF TABLES

The beacon sites provide either a 1 kw transmitted signal for one-way path loss and spectral width measurements, or a 2-watt transponding beacon for two-way measurements. The beacon sites at Keflavik, Iceland and Narssarssuaq, Greenland provide propagation paths located along the auroral zone and the propagation path to Thule, Greenland crosses the auroral zone.

This report describes the HF radar system at Caribou, Maine and the three beacon sites. Included is a description of the antennas, their computed values of beamwidth and maximum gain, as well as system performance measurements. Also presented is a description of the synoptic mode and an example of a typical hour of data. Finally, a brief discussion of the data processing and display techniques is given.

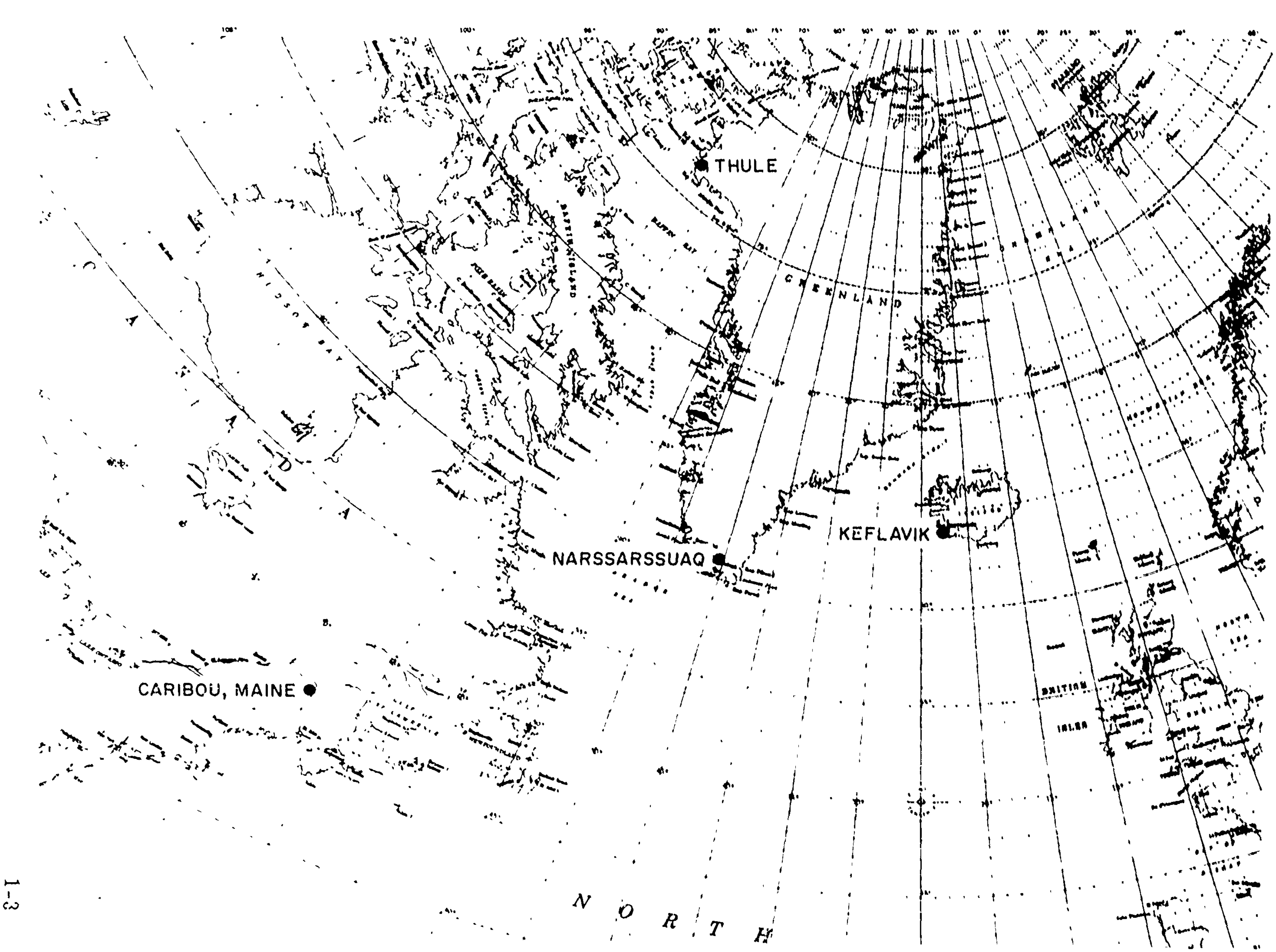


Figure 1-1. Map Showing Polar Fox II System Configuration

SECTION II

POLAR FOX SYSTEM

The Polar Fox System is comprised of a high power radar site in Caribou, Maine and three beacon sites located in Thule and Narssarssuaq, Greenland and Keflavik, Iceland. The location of these sites and the range and azimuth of the beacon sites from Maine are given in table 2-1.

Table 2-1. Polar Fox Site Locations

Site	Latitude	Longitude	Range (Km)	Azimuth (TN)
Maine Rx	46°55.92' N	67°59.89' W	----------	----------
Maine Tx	46°55.90' N	67°59.77' W	----------	----------
Thule	76°33' N	68°34.1' W	3298.35	359.73°
Narssarssuaq	61°10' N	45°26' W	2144.59	34.07°
Keflavik	63°57.5' N	22°43.5' W	3322.32	38.74°

The region to be surveyed by the system is depicted in figure 2-1. It extends from 1000 to 4000 kilometers in range and lies between -30° and +60° azimuth measured from true north. The "Auroral Zone"[1] is shown for reference as a stippled region. The coverage sector includes magnetic north (where the most severe effects might be expected) and extends far enough east to avoid looking through the auroral zone.

The relationship of the beacon sites within the viewing sector is shown. These sites were chosen to provide data from different representative points within the geographical area of interest.

[1] Davies, K., Ionospheric Radio Waves, p. 72.

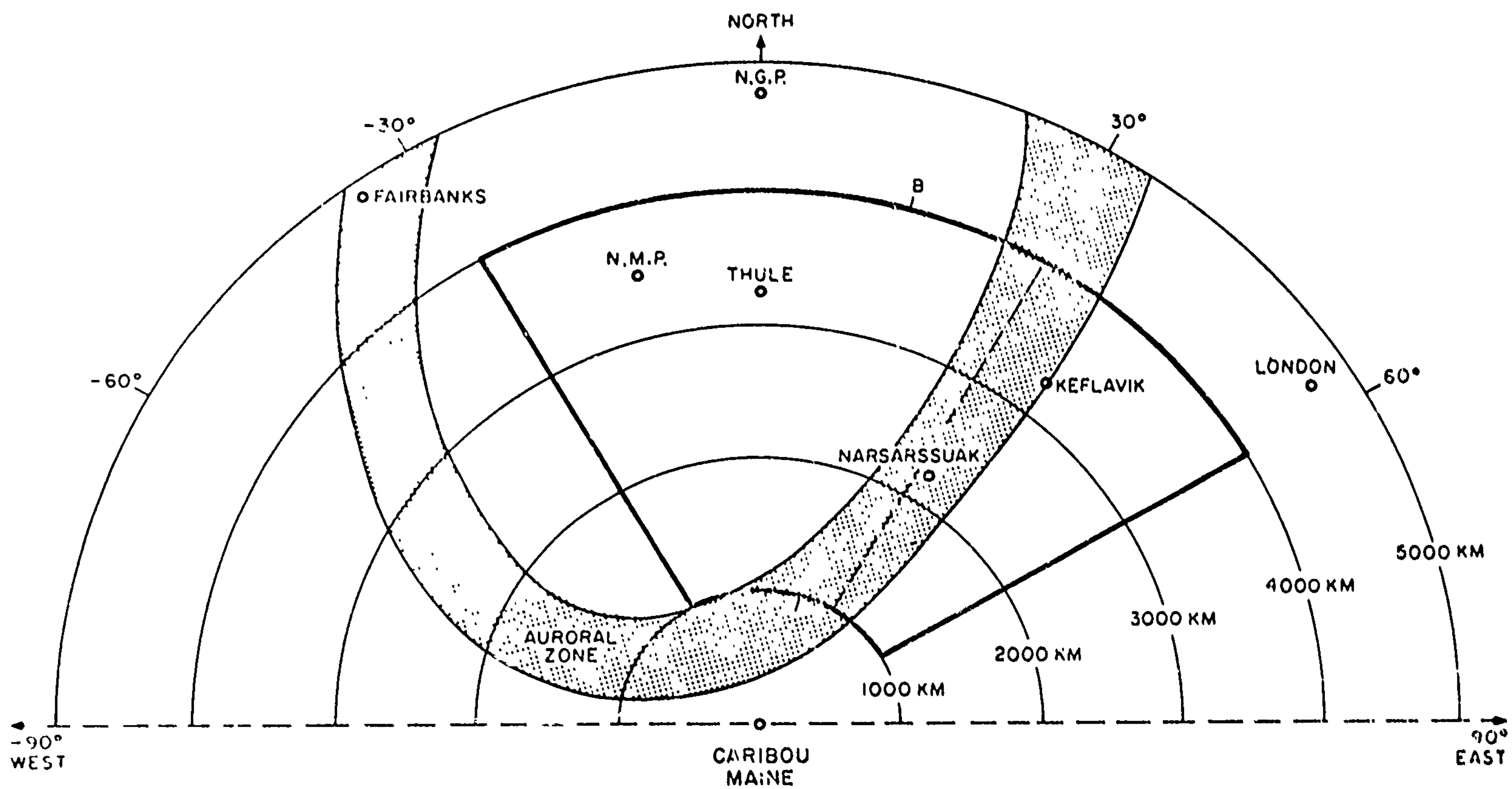


Figure 2-1. Polar Fox II Coverage Map

1. MAINE SITE

A survey was made in Maine early in 1971 to select a suitable location for the Polar Fox radar site. Many factors had to be considered such as the degree of flatness of the land over the required site area and a clear direction of look (i.e., no horizon screening) over the required 90° azimuthal sector.

From several possibilities in Maine, a site was selected near Caribou, five miles north of the town. An aerial photograph of the site taken on 30 April 1971 before the start of construction is shown in figure 2-2. A similar view of the site after almost complete installation is shown in figure 2-3, an aerial photograph taken on 31 August 1971.

A simplified block diagram of the equipment and antenna configuration at the Maine site is shown in figure 2-4. The basic components consist of a transmitting array, a receiving array, beam steering equipment, transmitters, receiver/exciter, synchronizer, computer, realtime displays and a digital incremental tape recorder. Under the operator's instructions, the computer controls the complete system.

An artist's conception of the site is shown in figure 2-5. The receiving complex consists of a 28-element antenna array, a trailer which houses the computer, receiver/exciter, synchronizer, recording and processing equipment, and an office building. The van and office building are physically connected. The transmitting complex includes a 4-element antenna array and 3 vans containing the transmitting equipment. The groundscreen for the antenna is approximately 500 feet long and extends over the full 90° direction-of-look sector.

A. MAINE SITE ANTENNAS

The transmitting array is a 4-element, vertically polarized, log periodic array, TCI Model 510-3-18. Its specifications are given in table 2-2.

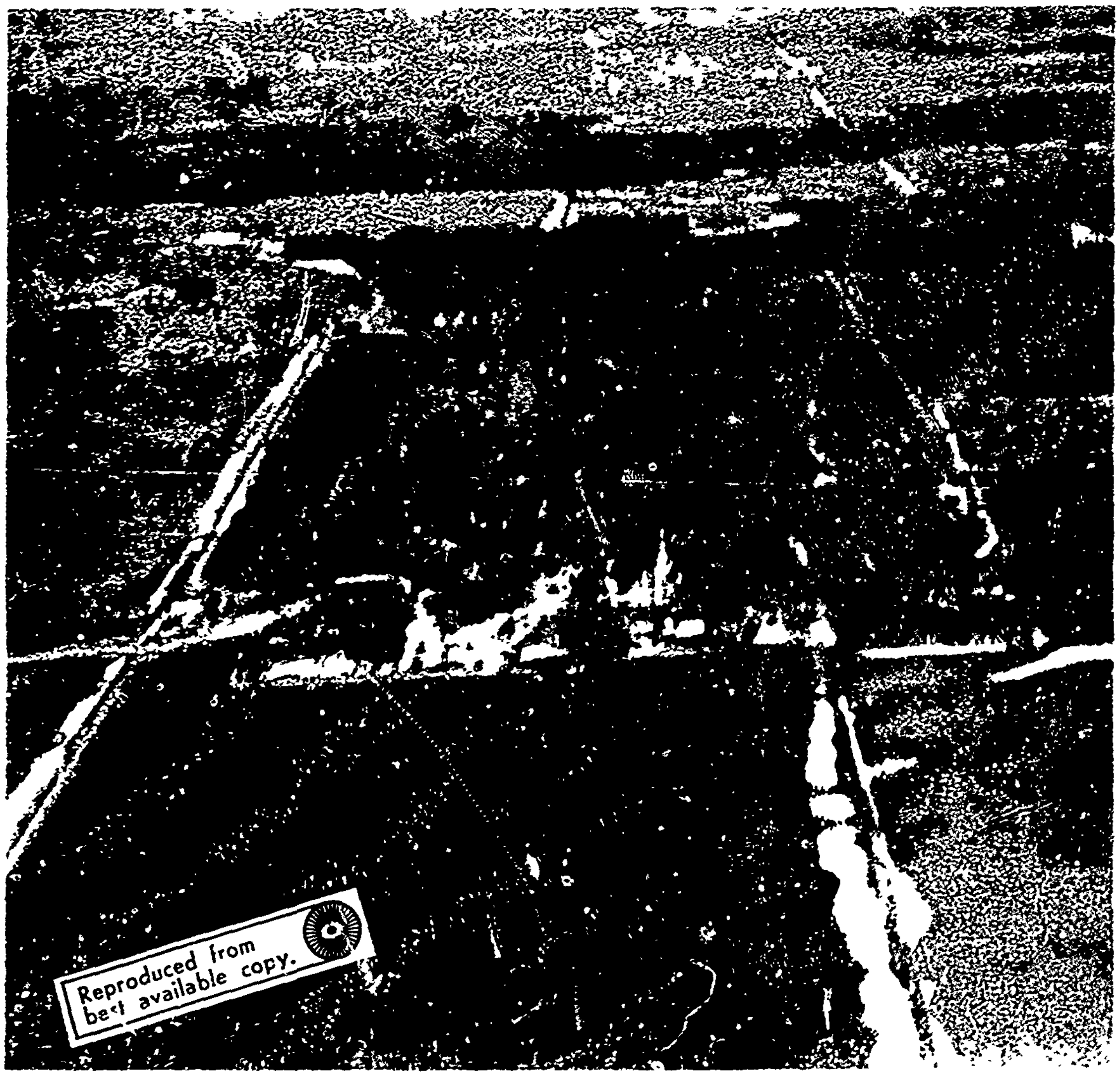


Figure 2-2. Aerial Photograph of Maine Site
Before Installation (30 April 1971)

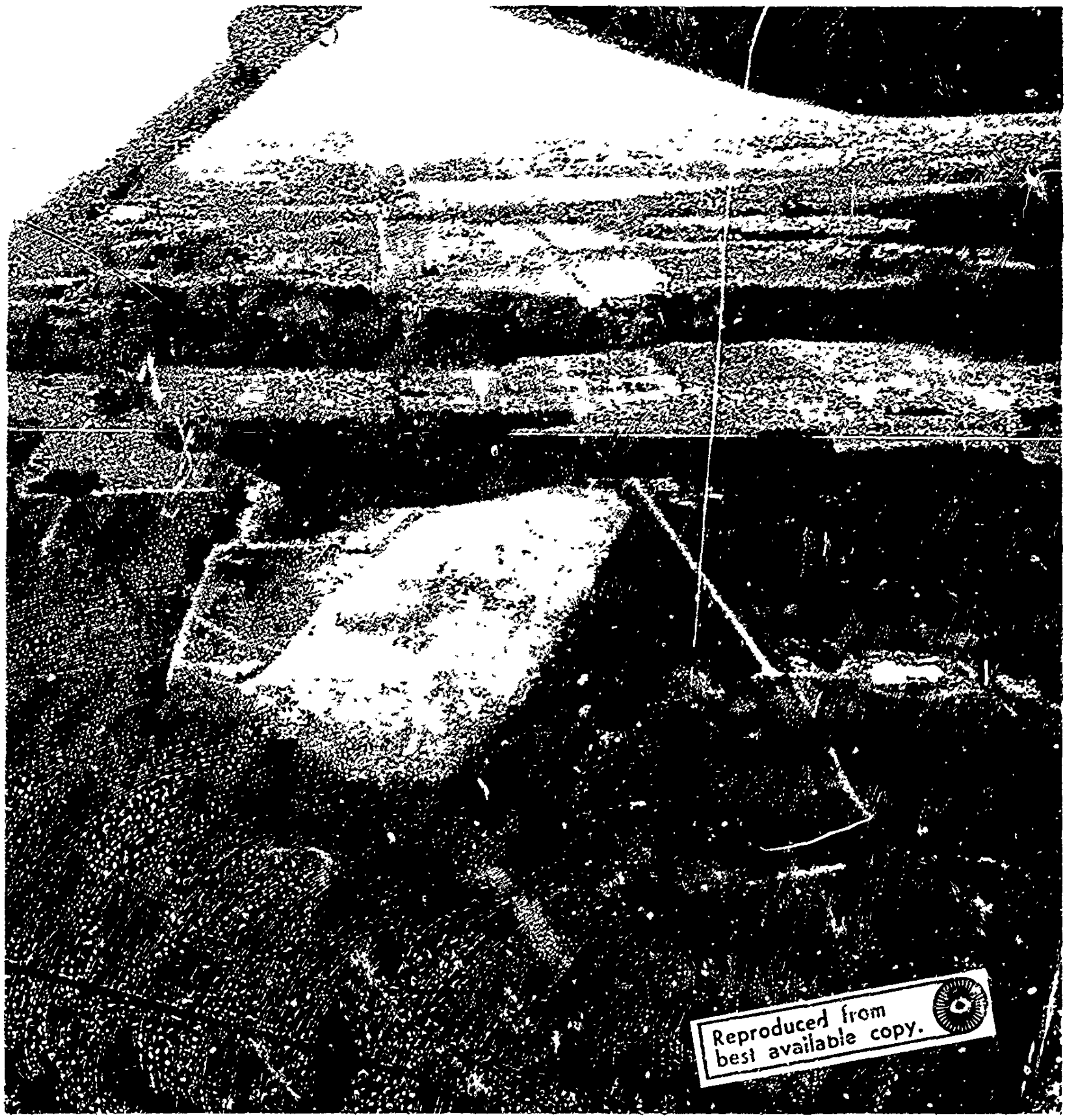


Figure 2-3. Aerial Photograph of Maine Site
Taken After Installation (31 August 1971)

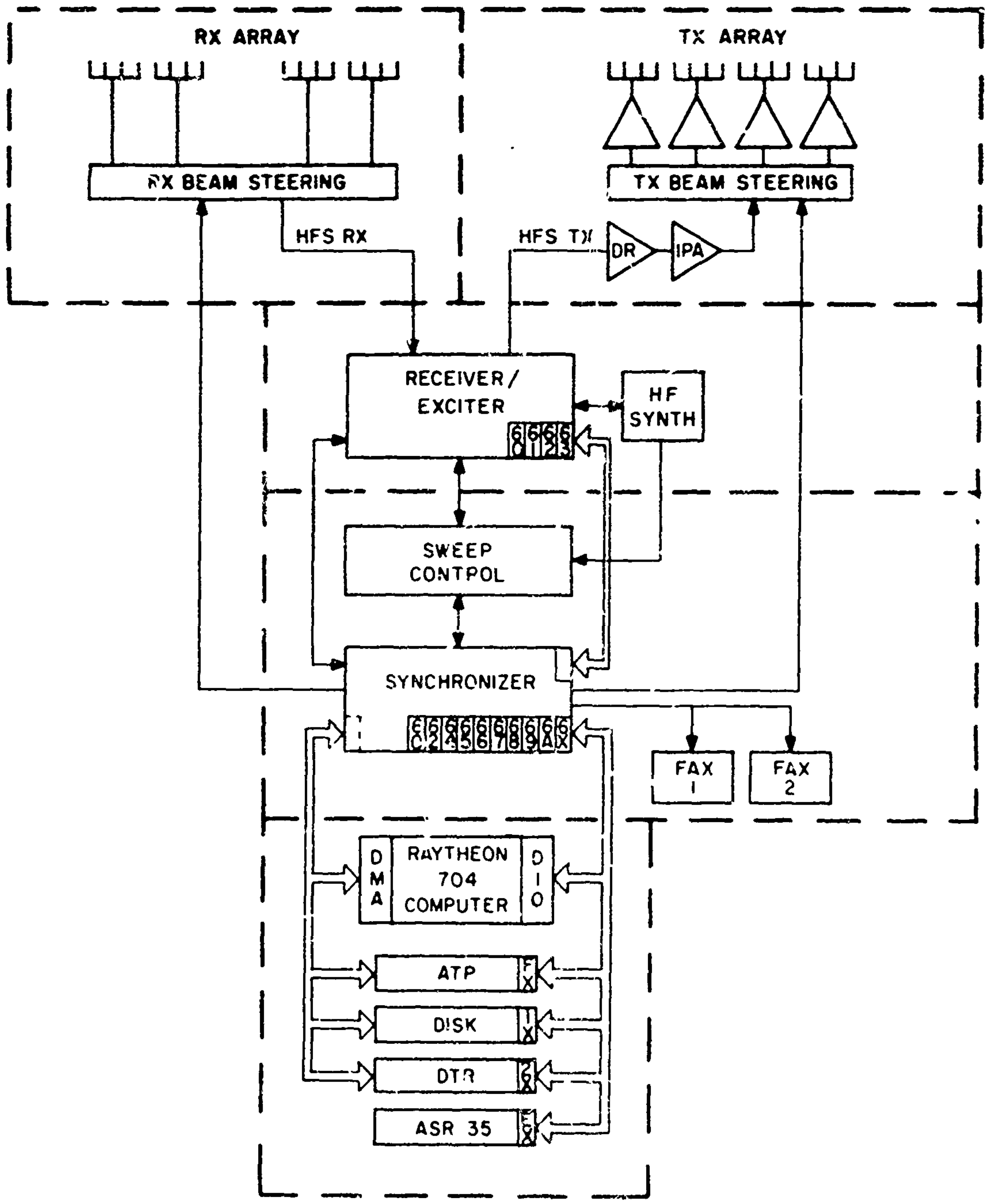


Figure 2-4. Polar Fox II Instrumentation

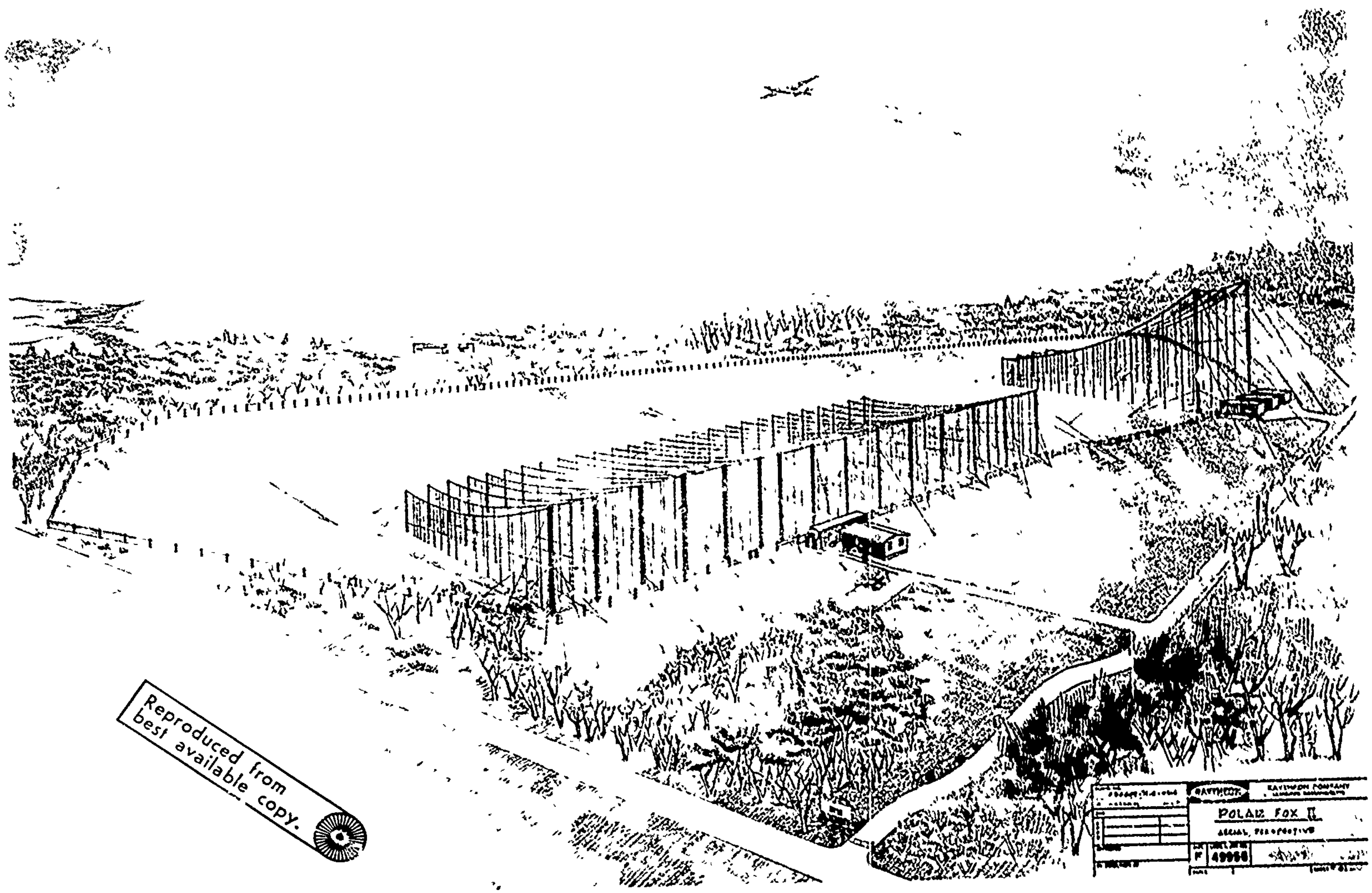


Figure 2-5. Artist's Conception of Polar Fox II Site

Some theoretical calculations have been made of the expected performance of this antenna array. Its half-power beamwidth, peak take-off angle and peak gain are given in table 2-3 and elevation profiles are given in table 2-4.

Table 2-2. Polar Fox Transmit Array Parameters

Number of elements	4
Spacing between elements	23 feet
Maximum tower height	200 feet
Type of element	TCI Model 510-3-18 Vertically polarized log periodic
Frequency range	6-30 MHz
VSWR (each element)	2:1
Power handling capability (per element)	20 kw average, 200 kw peak
Ground screen	500 feet diamond mesh
Grating lobes	Below sidelobes, 6-20 MHz, $\pm 45^{o}$ scan
Sidelobes	-13 db
Front-to-back ratio	15 db near 17.7 MHz, 20 db elsewhere
Number of beams	7
Beam positions	0, $\pm 15^{o}$, $\pm 30^{o}$, $\pm 45^{o}$
Beam Switch time	30 Milliseconds
Environmental performance	140 MPH - no ice 90 MPH - 1/2" radial ice

Table 2-3. Polar Fox Transmit Array Performance

Freq. (MHz)	Azimuth (deg) 3 db Beamwidth	Take-off angle (deg) Peak-of-beam	Peak Gain dbi
6	65	15	12.8
10	50*	14	15.0
20	35*	12	18.1
26	26	11	17.5

Table 2-4. Polar Fox Transmit Array Elevation Profile (Gain dbi)

Elevation Angle (deg)	6 MHz	10 MHz	20 MHz	26 MHz
2	1.0	4.3	8.6	8.5*
6	7.9	11.6	16.3	16.0*
12	11.7	14.6	18.1	17.3*
18	12.8	15.0	12.1	11.5*
* Extrapolations				

A TCI Model 547-6-02 28-element vertically polarized array is being used for receiving. Specifications for this array are given in table 2-5. Its expected performance and elevation profiles are given in tables 2-6 and 2-7, respectively.

Table 2-5. Polar Fox Receive Array Parameters

Number of elements	28
Spacing between elements	28 feet
Maximum tower height	100 feet
Type of element	TCI Model 547-6-02 Vertically polarized log periodic
Frequency range	6-30 MHz
VSWR (each element)	2:1
Ground screen	500 feet - diamond mesh
Grating lobes	None 6-20 MHz, $\pm 45^\circ$ scan
Sidelobes	Nominal 30 db Dolph-Tschebyschev taper. Worst case -22 db (20 MHz, 45° scan)
Front-to-back ratio	15 db near 17.7 MHz, 20 db elsewhere
Number of beams	31
Beam steps	3°
Beam switch time	2 milliseconds (computer controlled)
Environmental performance	140 MPH - no ice 90 MPH - 1/2" radial ice

Table 2-6. Polar Fox Receive Array Performance

Freq. (MHz)	Azimuth (deg) 3 db Beamwidth	Take-off Angle (deg) Peak-of-Beam	Peak Gain dbi
6	13	20	18.5
10	8	18	21.4
20	4	12	26.5
26	3	11	27.5

Table 2-7. Polar Fox Receive Array Elevation Profile (Gain dbi)

Elevation Angle (deg)	6 MHz	10 MHz	20 MHz	26 MHz
2	6.6	9.5	17.0	18
6	13.3	17.0	24.7	25.7
12	17.3	20.6	26.5	27.5
18	18.3	21.4	20.5	21.5

The absolute gain of the Polar Fox antennas, as a function of elevation and azimuthal angle, is required for the analysis of the data. Two approaches are presently planned to obtain this information. The first of these involves making calculations using actual measured impedances of the antenna elements. These measurements are planned for the near future at the Maine site and TCI will make the calculations.

During December it is planned to make aircraft measurements of the Maine site antenna patterns. Tentative arrangements have been made for a helicopter rental and transmitting test equipment developed and constructed at Lincoln Laboratories will be used. For these measurements both of the Maine antennas will be used in a receiving mode. Procedures for these measurements have been developed and will be published at a later date along with the measured and calculated patterns.

B. RECEIVING/PROCESSING SUBSYSTEMS

(1) Receiving Subsystem. - A block diagram of the basic components of the receiving subsystem is given in figure 2-6. The receiver/exciter works intimately with the HF synthesizer and under the command of the sweep control and the synchronizer, which in turn, operates under the command of the computer. When the receiver/exciter operates in the receive mode, HF signals are received through the beam steering unit. These signals are appropriately attenuated, amplified, filtered, and mixed before being fed into sample and hold circuits. They are then converted into digital data which is transmitted serially to the computer via the synchronizer.

When the receiver/exciter operates in the transmit mode, its quadrature phase rotator (QPR), which receives signals from the sweep control and fixed frequency synthesizer, generates a phase modulated signal. This phase modulated signal is mixed with a 3 MHz signal and passed through the 10 KHz or 30 KHz bandpass filter and mixed with the HFO/SYN signal. The HF signal is passed through the HF bandpass filters, amplified, and sent to the Tx driver through the beam steering control.

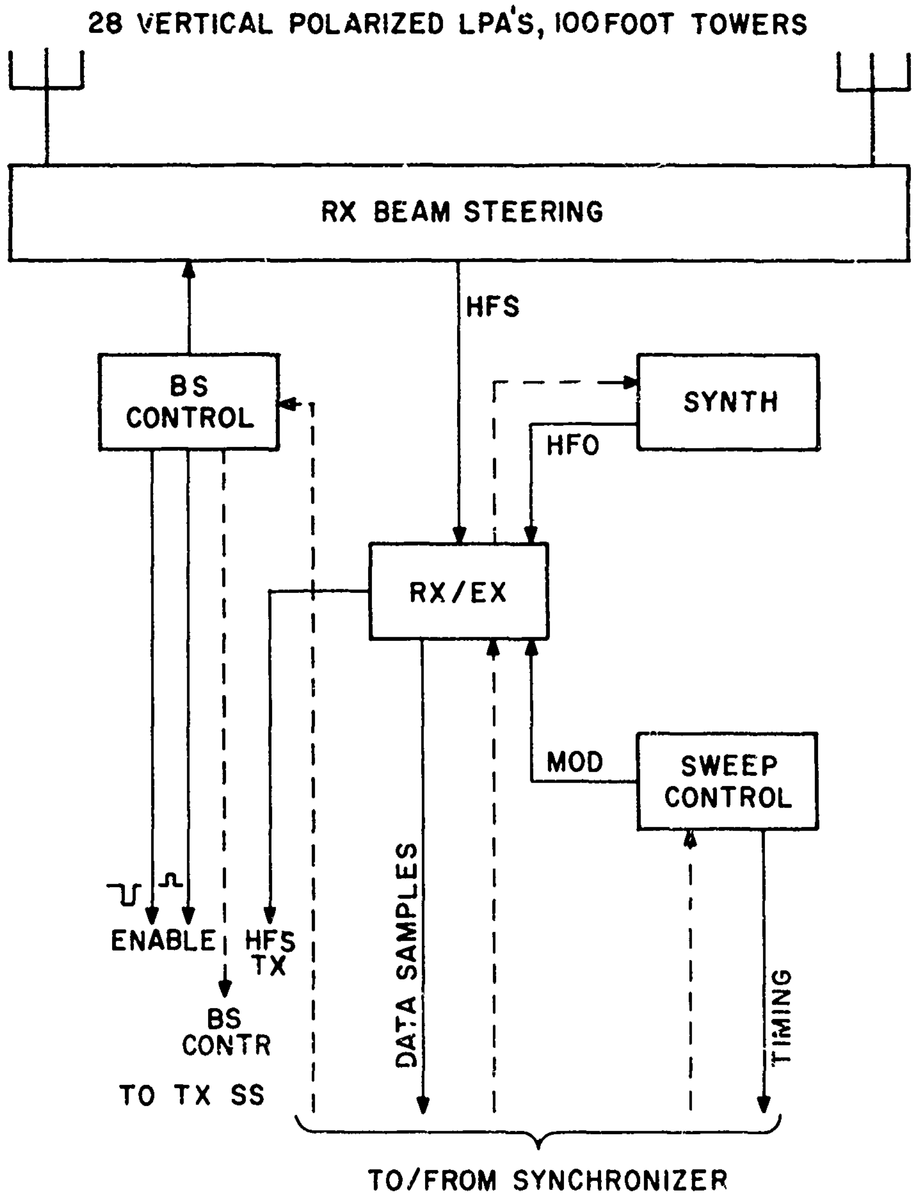


Figure 2-6. Receiving Subsystem

Floor and elevation plans of this and peripheral equipment located in the receiving van are shown in figure 2-7a and b.

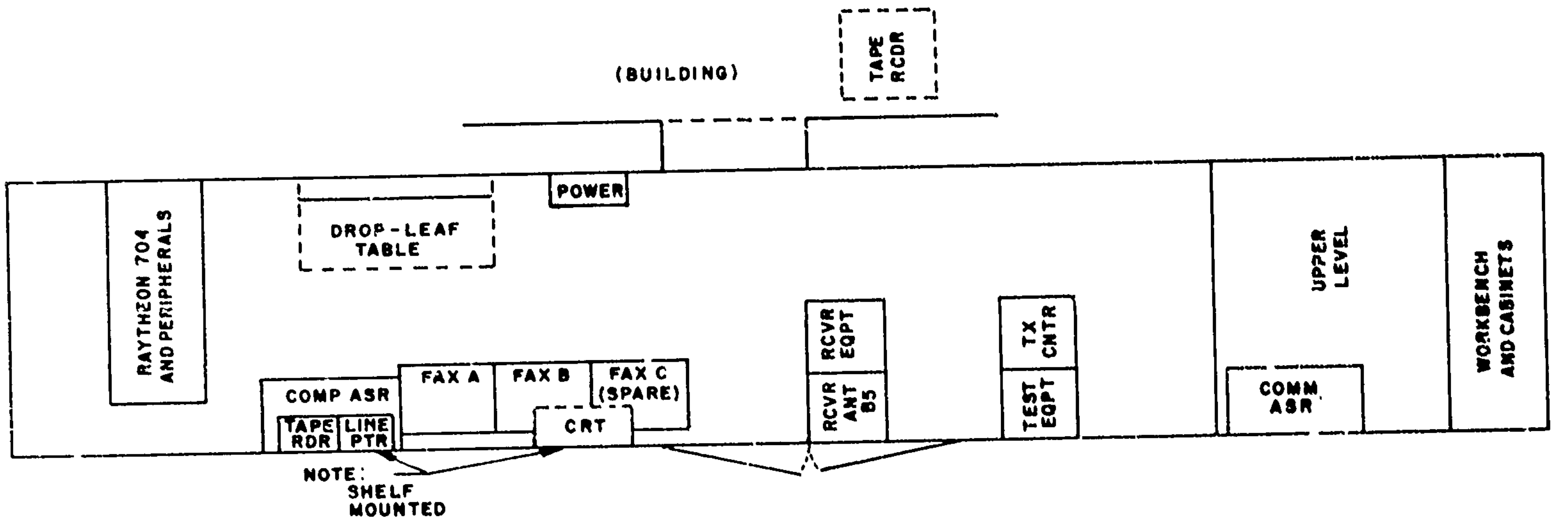
A diagram of the control, processing and display subsystem is given in figure 2-8. This gives a concise description of the control provided by the type of data being collected by and the function of the various units of the system.

For more detailed information, it is recommended that the reader refer to the previously published "System Performance Manual."

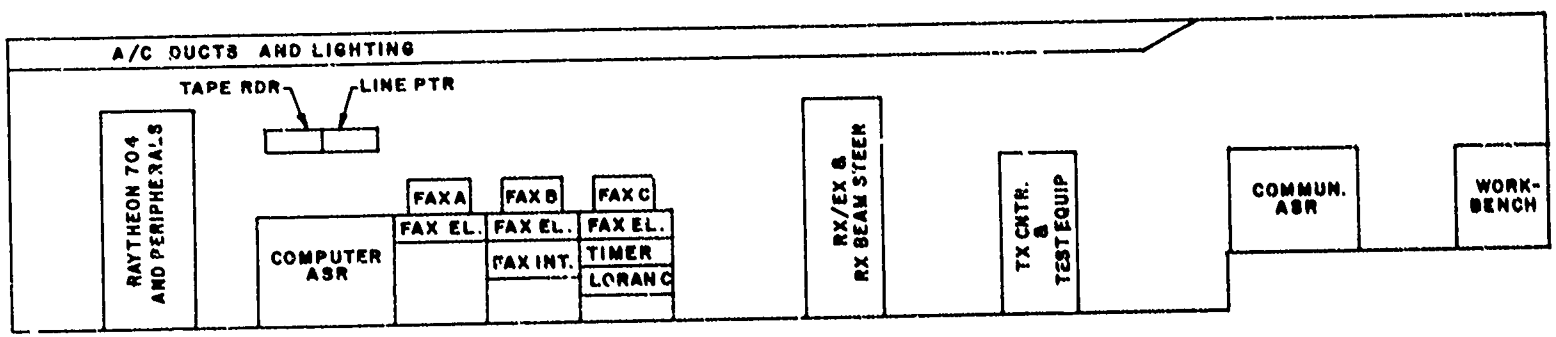
(2) Control System. - Considerable flexibility exists in the operation of the Polar Fox System and the processing of the data. A Raytheon 704 Computer with 32k memory, is used for all commands and the operator communicates with the computer through a teletype machine (ASR-35). Each command word consists of a letter and four decimal digits. The letter identifies the command word and where in the computer memory its four digits have to be stored. The computer prints out all commands and records the time at which they have been entered. A complete set of commands is given in table 2-8. These include operation, processing, display and recording information.

The synchronizer links the computer subsystem with all the other equipment and fulfills the following functions:

1. Accepts commands from computer.
2. Passes on commands to receiver/exciter.
3. Controls the operation of the sweep control which, in turn, controls the operation of the quadrature phase rotator in the receiver/exciter that generates the transmitted radar pulses (chirps).
4. Controls the operation of the transmitter.
5. Passes on commands to the transmitter and receiver beam steering.



a. Floor Plan



b. Elevation Plan

Figure 2-7. Receiver Van Layout

UNIT	CONTROL DESCRIPTION
RX HF DATA RECEIVER	MODE: NORM, CAL, 0, 1, 2; A D START STEP FREQ: 6-26 MHZ; ATTN 0-29 DB; BW: 10, 30 KHZ
EX EXCITER (P O RX)	GAIN: 0-15 DB; TX ENABLE
SWC SWEEP CONTROL UNIT	BW: 10, 30 KHZ PRR: 15-120 PPS; PW: 5.12-.64 MS
TX HF PULSE TRANSMITTERS	BAND: HI, LO; ENABLE
RXA 28 EL. BEAM STEER	BEAM NO: 0-15; DIR: RT, LFT
TXA 4 EL. BEAM STEER	BEAM NO: 0-3; DIR: RT, LFT

UNIT	DATA DESCRIPTION
RX HF DATA RECEIVER (input)	RANGE-TIME SAMPLES: 100, 33.3 µS
A SC A SCOPE DISPLAY (output)	RANGE-TIME (X), AMPL (Y)
FAX FACSIMULE RCDRS (output)	RANGE-TIME (X), TIME (Y), AMPL (Z) DOPPLER (X), AMPL (Y)

UNIT	FUNCTION DESCRIPTION
SYNCH	SYSTEM TIMING DATA BUFFER CONTROL INTERFACE
704 COMP	SYSTEM CONTROL SIGNAL PROCESSING DATA FORMATTING
ATP ARRAY TRANSF. PROC	SIGNAL PROC. COMPUTATIONS FFT
DTR DIGITAL MAG. TAPE RCDR	PROGRAM INPUT DATA STORAGE
DSK MAG DISK MEMORY	PROGRAM STORAGE TEMPORARY DATA STORAGE
ASR AUTO SEND RCV. TTY	PARAMETER ENTRY, SYSTEM CONTROL COMPUTER MOUTHPIECE
HSPTR HI SPD PAPER TAPE RDR	PROGRAM INPUT
HSLP HI SPD LINE PRINTER	PROGRAM LISTING

Figure 2-8. Control Processing and Display Subsystem

6. Controls the collection of data samples which is performed by two S/H circuits and two A/D converters in the receiver/exciter, transforms the serial data received from the A/D converters into parallel data, and enters the parallel data words into the computer memory.
7. Accepts data to be displayed on the facsimile recorders, translates the data into pulse-width modulated fax video signals, and controls the operation of the fax recorder.
8. Controls the collection of transmitter peak power measurements and passes the data on to the computer.
9. Controls system tests.

The signals are subjected to both range and doppler processing in the 704 Computer using FFT and averaging techniques before being recorded on a fax display or stored permanently on magnetic tape. A block diagram of this processing is shown in figure 2-9.

Several types of output will be available from this system for recording on the digital tape recorder. The following is a listing and description of the output types.

1. SAMP records contain samples (I and Q), i.e., data which is produced by the A/D converters in the receiver and which is received by the computer.
2. RANG records contain data (complex numbers) produced in the computer after range processing but before computing their powers.
3. DORW (Doppler raw data) records contain data (powers expressed in log 2 numbers) produced in the computer after Doppler processing, including the computation of their powers.
4. DOAV (Doppler averages) records contain data (powers expressed in log 2 numbers) produced in the computer after computing averages (one minute averages, typically) from the data mentioned under DORW records.
5. FACS records contain data produced in the computer and provided in its fax buffer.

Table 2-8. Description of Computer Commands and Modes

ID	1st Digit	2nd Digit	3rd Digit	4th Digit	
@	YEAR				Time
A	Month		Day		
B	Hour		Minute		
C	10 MHz	MHz	100 KHz	0	Carrier Frequency
D	10 KHz	KHz	100 Hz		
E	First (Left) Beam (1)		Last (Right) Beam (1)		Beam Switching
F	Center Beam or Step Interval (1)		0 or Time Interval (1)		
G	Basic Mode (2)	Major Mode (3)	Minor Mode (4)	Fax Mode (5)	Modes
H	Process. Rate (6)	Range Delay (7)		Range Coverage (8)	Processing
I	Data Recording (9)	Beacon (10)	0	Doppler Averag. (11)	Range Bins Selected for Display of Doppler Data
J	0	1st			
K	0	2nd			
L	0	3rd			
M	0	4th			
N	0	5th			
O	0	6th			
P	0	7th			
Q	0	8th			
R	0	9th			
S	0	10th			
T	0	0	Tx Test 12	Rx Test 13	System Test

Table 2-8. Description of Computer Commands and Modes (con't)

(1) Digit	Beam
1	-15 (North)
2	-14
3	-13
.	.
.	.
.	.
16	0 (Bore Sight)
17	+ 1
.	.
.	.
31	+15 (East)

Beam is stepped from "First Beam" to "Last Beam" at "Step Interval, " and "Time Interval" given in seconds. If "Step Interval" is zero, beam remains at "First Beam" Max. "Step Interval" is 30. Max. "Time Interval" is 90 seconds. All numbers are decimal.

(2) Digit	Basic Mode
0	Off
1	Ionosonde, one beam
2	Ionosonde, beams -15, 0, +15
3	Ionosonde, three beacon beams
4	Backscatter (beacons transponding or off)
5	Beacons or Noise (Maine Tx off, beacons transmitting only, or off)
6	Not used
7	System Test
8	Synopsis
9	Not used

(3) Digit	Major Mode
0	Synchronizer off
1	A (15 pps)
2	B (20 pps)
3	C (30 pps)
4	D (40 pps)
5	E (60 pps)
6	F (80 pps)
7	G (120 pps)

Table 2-8. Description of Computer Commands and Modes (con't)

(4)

Digit	Minor Mode
1	1 (10 kHz BW)
3	3 (30 kHz BW)

(5)

Digit	Fax Mode
1	Print each display point once
2	Print each display point twice
3	Print each display point thrice
4	Print TC, FC, and BC points thrice, RD and DD points once
5	Print TC, FC, and BC points thrice, RD and DD points twice
6	Print TC, FC, and BC points thrice, RD points twice, DD points thrice
7	Print TC, FC, and BC points thrice, RD points of three ionograms once
0	Off

(6)

Digit	Range Coverage	
0	Regular Range (RR)	
1	2/3 RR	each second
2	1/2 RR	each second
3	1/3 RR	each second
4	RR	
5	2/3 RR	each second
6	1/2 RR	each second
7	1/3 RR	each second

(7)

Digits	Range Delay
00	No delay
01	16 samples
02	32 samples
03	48 samples
⋮	⋮
7 7/8	1008_{10} samples

Table 2-8. Description of Computer Commands and Modes (con't)

(8)

Digit	Doppler Averaging and Display
0	no
1	once every minute
2	radar and noise data every minute

(9)

Digit	Data Stored on Tape
0	no
1	samples
2	Range Processing Results
3	Dopper Processing Results
4	Synopsis

(10)

Digit	Beacon
0	attended
1	unattended

(11)

Digit	Tx Test
0	Tx 1
1	Tx 2
2	Tx 3
3	Tx 4

(12)

Digit	Rx Test
0	no test
1	without test signal
2	with low test signal
3	with high test signal

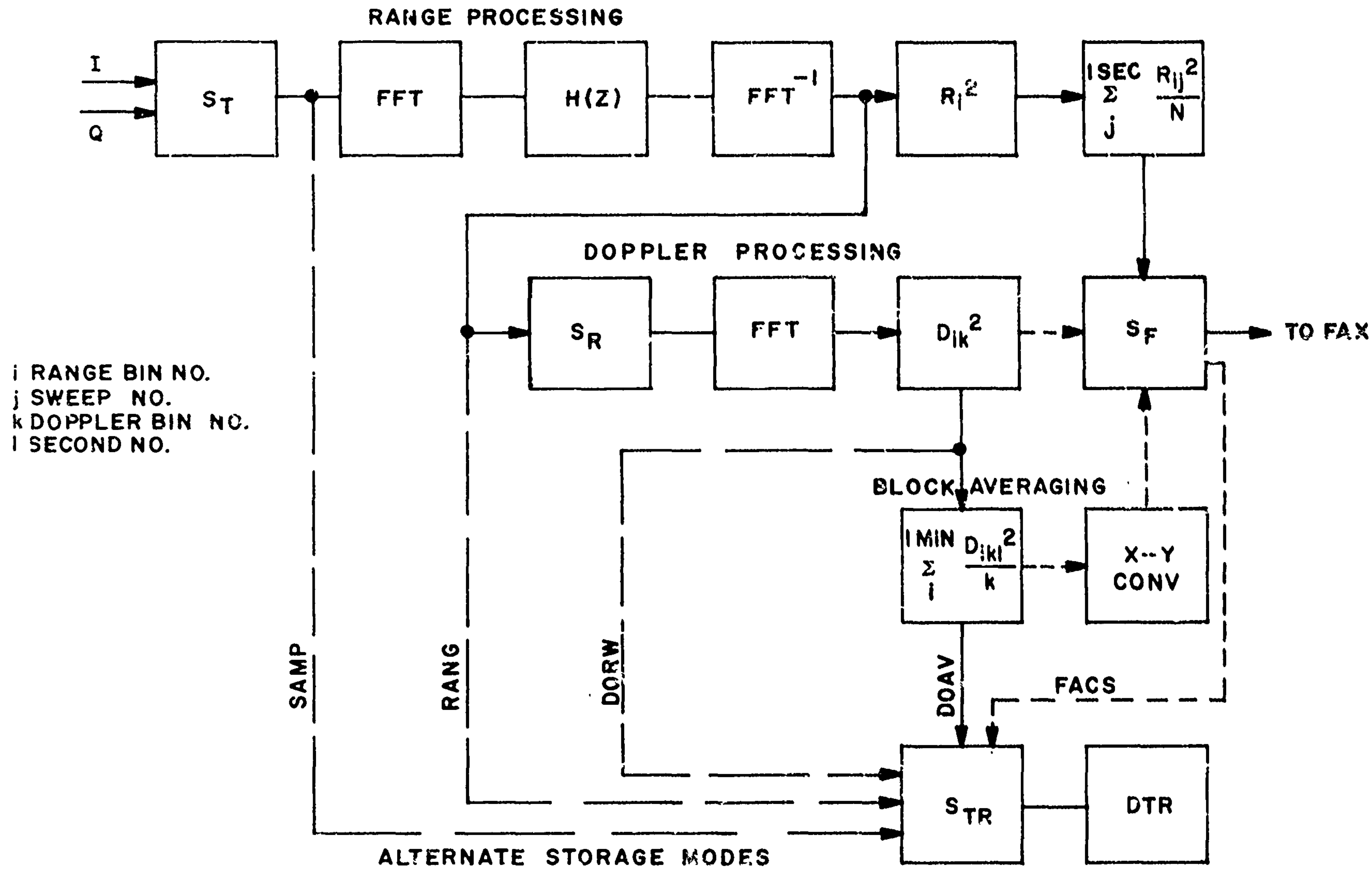


Figure 2-9. Signal Processing Block Diagram

C. TRANSMITTING SUBSYSTEM

The transmitting subsystem is shown in block diagram form in figure 2-10. The 100-mw HF signals from the exciter are fed into an IFI transmitter (LPA) through a Big Boy transmitter (IPA) to a 4:1 power divider. Four signals (16 kw PPP each) are then fed through the beam steering unit and into four Big

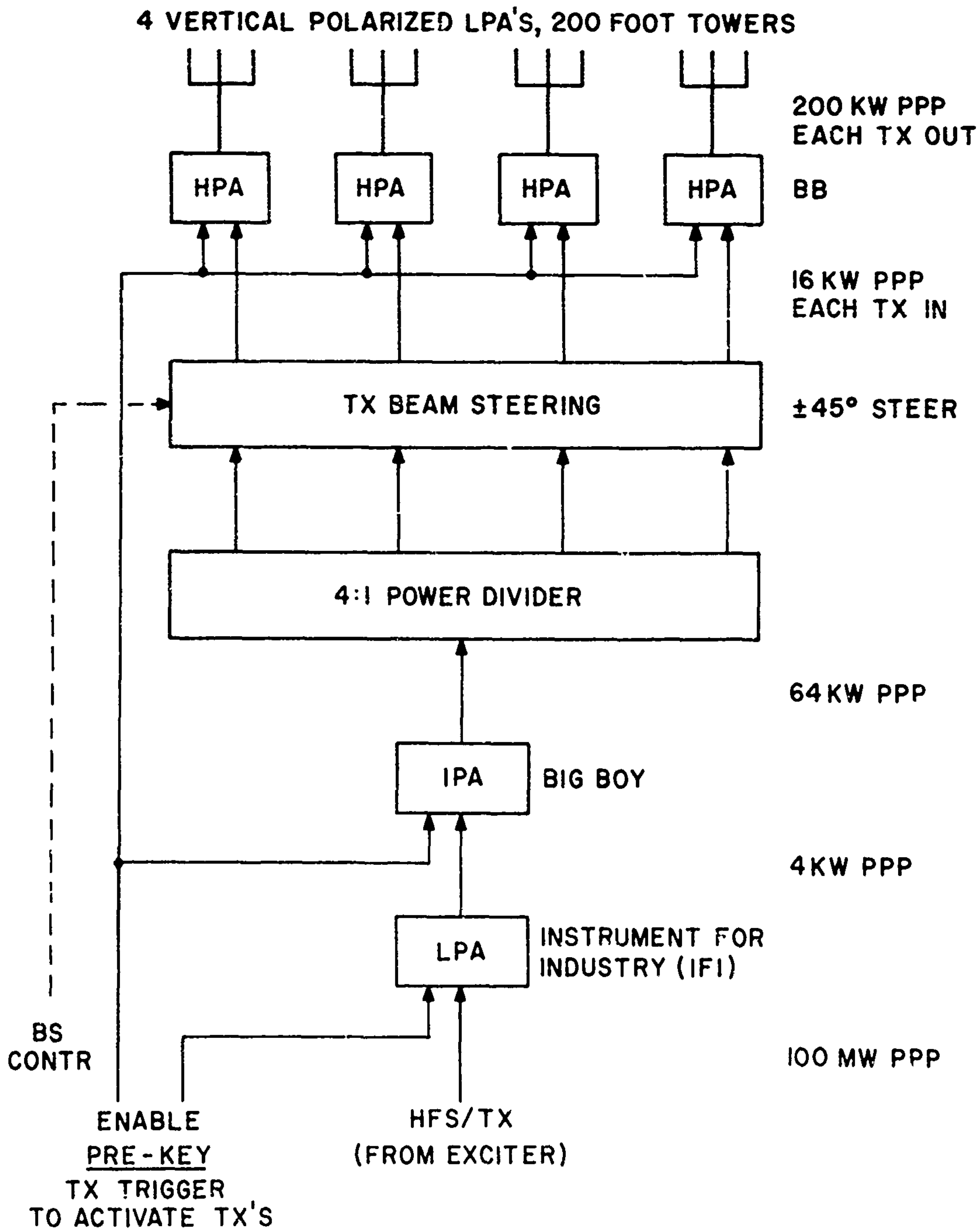


Figure 2-10. Transmitting Subsystem Block Diagram

Boy transmitters (HPA's) to the transmitting array. The transmitters are triggered (ENABLE) and the beam steering is controlled by commands received from the BS control unit of the receiver subsystem.

The system has a transmitting capability of 800 kw peak pulse power and the array is steerable over $\pm 45^{0}$ from boresight.

2. BEACON SITES

The beacon sites at Thule, Narssarssuaq and Keflavik will operate in two modes, transponding and transmitting.

A. TRANSPONDING MODE (See Figure 2-11)

The transponder uses the beacon antenna for both reception and retransmission of enhanced signals from the Maine transmitter. The transponder input/output is connected to the site log periodic antenna via an antenna transfer relay located within the 1-kw transmitter used for FM-CW (Chirp) operation. The transponder is a free-running device which alternates between receive and transmit operation. During the receive mode, the received signal is coupled through an isolation-T to a 0-42 db step attenuator, which is used to set the enhancement level, and then to a bandpass filter which limits operation to the HF band. The received signal is then translated to 56-76 MHz in mixer-1, which receives an L.O. injection of 82.015 MHz for 10 usec. The translated signal is amplified 60 db by two 30 db amplifiers and fed to a broadband 10 usec delay line. After charging the delay line for 10 usec, the L.O. injection of 82.15 MHz is removed from mixer-1 and supplied to mixer-2 for 10 usec. This translates the received signal back to 6-26 MHz. The mixer-2 output drives a 35 db amplifier whose output is coupled via a coaxial relay to an RF switch and modulator. The RF switch allows signal to pass for 10 usec coincident with the mixer-2 injection. The modulator can generate double sidebands, if so desired. A 3 usec delay has been added between end-of-

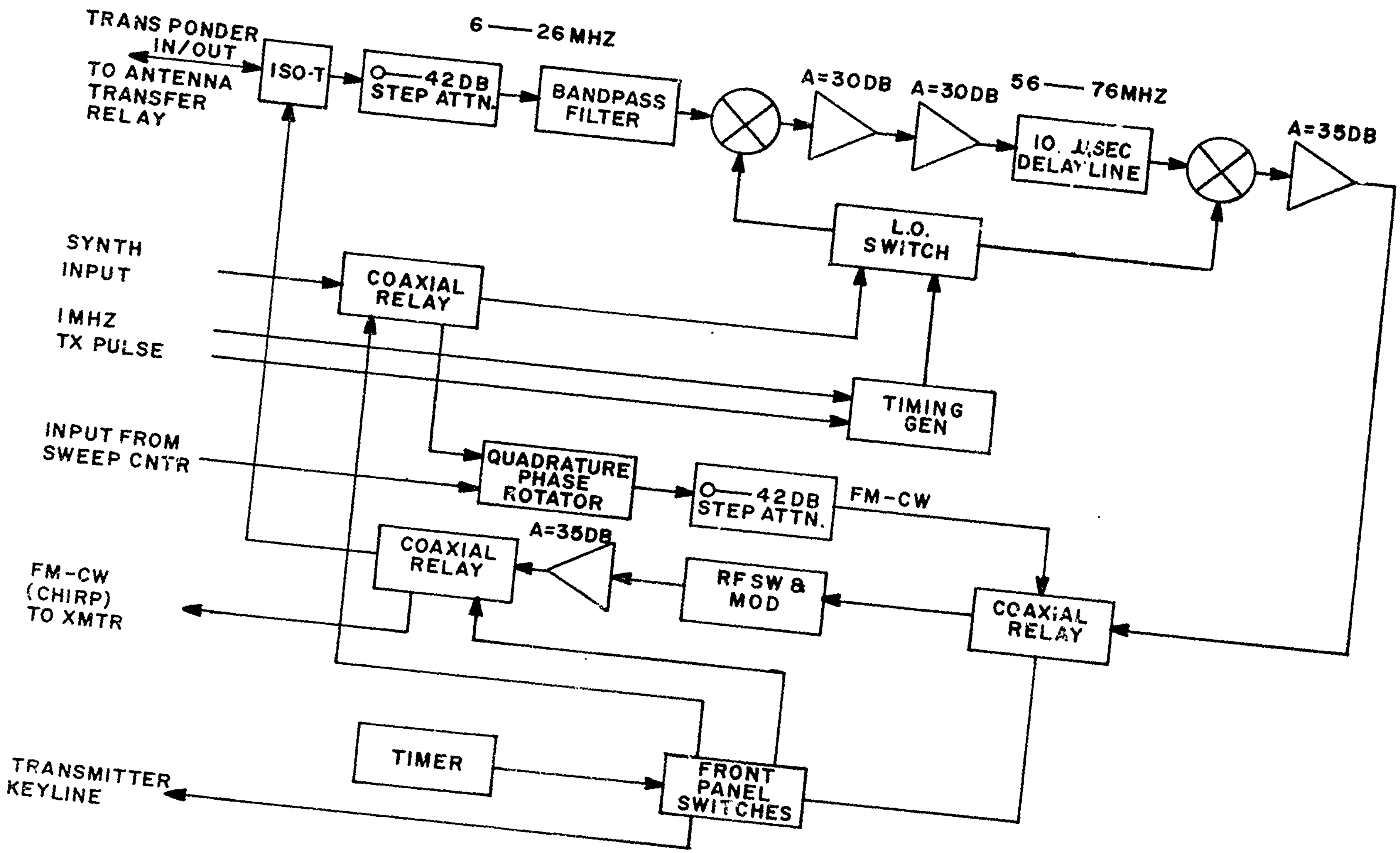


Figure 2-11. Transponder Block Diagram

transmit and beginning-of-receive operations to allow for feedline discharge. The output of the RF switch and modulator is amplified 35 db and then coupled back to the isolation-T via a coaxial relay for re-transmission out the site antenna. The input attenuator is set so as to prevent saturation of the final amplifier in the transponder loop. The transponder is capable of amplifying received signals by 63 db. Attenuation inserted to prevent saturation would be subtracted from 63 db. Input saturation levels are about 3 mv RMS.

B. TRANSMITTING MODE (See Figure 2-12)

The transmitting beacon consists of an HP Synthesizer used as an HF signal source, a quadrature phase rotator, a sweep control unit which supplies control signals to the quadrature phase rotator so as to generate an FM-CW (Chirp) signal using the HF signal source as the carrier, a step attenuator, an RF switch, a 35 db gain amplifier, a 1 kw transmitter, and the site antenna. The quadrature phase rotator (also called phase modulator) and attenuator are located in the transponder chassis and are used exclusively in the transmit (or Chirp) mode of operation. The step attenuator sets the level into the antenna feedline of 1 kw peak power. The 1 kw transmitter is coupled to the antenna feedline via its antenna transfer relay. The RF switch and 35 db gain amplifier are shared with the transponder. The RF switch is used to remove CW between chirps.

The 1 kw transmitter is an RF Communications Model RF110. Its power supply requires 218-242 volts, 1Ø at 20 amperes, 50-60 Hz. All other equipments require 115 volts, 50-60 Hz.

C. SYNCHRONIZATION

During Basic Mode 5 operation (Maine transmitter off) the main problem will be one of synchronization of the operation of the Sweep Control at a beacon site to the Sweep Control at the Maine site. Synchronization between

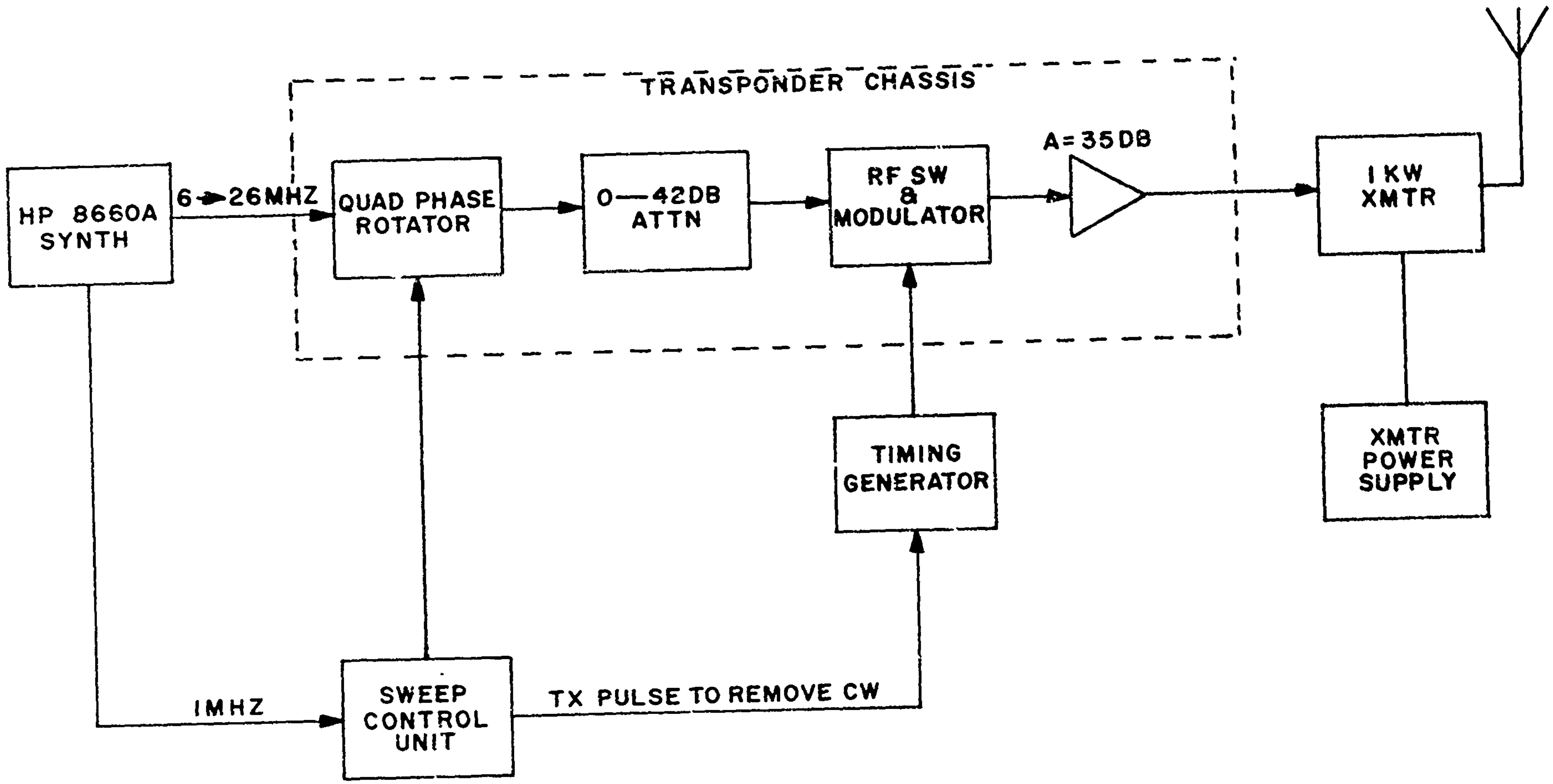


Figure 2-12. Transmitting Mode Configuration

Maine and remote sites will be effected by utilization of Loran C receivers minitoring the East Coast and/or the North Atlantic Lora. C chains. The one beacon site where possible difficulties may arise is ' .e, Greenland. It may be necessary to rely upon skywave Loran C reception for time synchronization.

D. ANTENNA SYSTEM

The beacon sites in Greenland each have an antenna system, 'Iodel 503-6-03, supplied by TCI, Mountain View, California. The antenna is a vertically polarized log periodic dipole antenna with a narrow, low-angle elevation plane pattern. Ground screens have been constructed to improve low angle take off. Directive gain is greater than 12 dbi at an azimuthal half-power beam width of 120^{0}. Side lobe power is 14 db below main lobe. The antenna has a front-to-back ratio of 19 db. The antennas have a 500 foot ground screen along the direction of transmission. The maximum antenna height is around 90 feet.

An existing Granger Model 726-5 vertically polarized log periodic is utilized at Keflavik. Specifications for this antenna are given in table 2-9.

3. <u>COMMUNICATIONS</u>

To adjust the data collection plan to unexpected changes in geophysical conditions, realtime communications is needed between the Maine site and the remote sites. To meet this requirement the government has provided a primary and backup realtime communications system with Thule and Keflavik. These are dedicated TTY and voice telephone circuits. (Thule and Keflavik can communicate with each other over the same lines.) These lines have been checked out and are in operation.

Communications to Narssarssuaq have been more difficult as this site is not colocated with the U.S. Military. Existing communication into and out of Narssarssuaq consists of telegraph and mail. Neither of these are adequate to meet the project operational requirements. Therefore, a technique is under study to modulate the Maine radar with PFSK and receive and demodulate at Narssarssuaq. Narssarssuaq will have a similar PFSK modulator to communicate with Maine using their 1 kw transmitter.

Table 2-9. Specifications for Granger Model 726-5 Antenna

Parameter	Specification
Frequency range	4 to 64 MHz
Application	Receive and transmit
Power capacity	1 kw average, 30 kw PEP
Input impedance	50 ohms coaxial
VSWR	Compatible with G/A sounder transmitter
Level of largest side or backlobe relative to main lobe	-14 db 4.4 to 64 MHz -10 db below 4.4 MHz
Connector	LC type, female
Approximate shipping weight	4390 pounds
Polarization	Vertical
Directive gain, relative to isotropic, above perfect ground	Greater than 10 db
Azimuth beamwidth between half-power points	110^{0} nominal
Permissible	120 mph wind, no ice 100 mph wind, one-half radial ice

SECTION III

OPERATIONS

1. SYSTEM CHECKOUT

The checkout of the Polar Fox System has been two-fold; simulated operation and on-the-air tests. The simulated operation was accomplished during August at the Raytheon Sudbury facility; the on-the-air tests were made at the Polar Fox site in Maine after completion of the installation of all equipment.

The parts of the receiver-processor subsystem which are involved in the generation of the radar chirps, the reception of radar signals, and the processing of the received radar signals were tested in the receiver van to evaluate performance and compliance with design goals. These subsystems comprised:

1. Computer Subsystem
2. Synchronizer
3. Sweep Control
4. Receiver/Exciter
5. HF Synthesizer
6. Fax Display Subsystem

The following characteristics of the receiver-processor subsystem were measured.

1. Range Resolution
2. Doppler Resolution
3. Single Tone Dynamic Range
4. System Noise

The equipment setup for these measurement is shown in figure 3-1. The sweep control and QPR used in the test were from one of the beacon transmitters and were used as a signal source. The results of these measurements are discussed in the following paragraphs.

A. RANGE RESOLUTION

To measure the range resolution and hence the pulse compression and range sidelobe level, the test signal was fed into the receiver and the output of the range processing displayed on the ASR. The results of the measurements are shown in figure 3-2. This shows a signal-to-noise ratio in excess of 65 db. The range sidelobe level is 23 db or more within 1/2 the pulse width (1.28 msec.) of the peak. The width of the peak of the compressed pulse is 100 microseconds. Hence for returns of comparable levels (within 20 db) the range resolution is 100 microseconds.

B. DOPPLER RESOLUTION

To measure the doppler resolution and doppler sidelobes, a test signal was fed in and the output of the doppler processing was plotted as shown in figure 3-3. This demonstrates that the dynamic range obtained with the doppler processing is at least 70 db and the doppler resolution is 15/16 Hz. There are also no sidelobes within 70 db of the peak.

C. SIGNAL TONE DYNAMIC RANGE

Figures 3-2 and 3-3 show that the dynamic range of the range and doppler processor is in excess of 65 db. The programable attenuator in the receiver has a range of 99 db, hence the receiver-processor system can cope with signals over at least a 164-db range.

D. SYSTEM NOISE

The noise figure of the receiver-processor was measured in two ways, with a wideband noise generator, and by determining the smallest discrete signal observable.

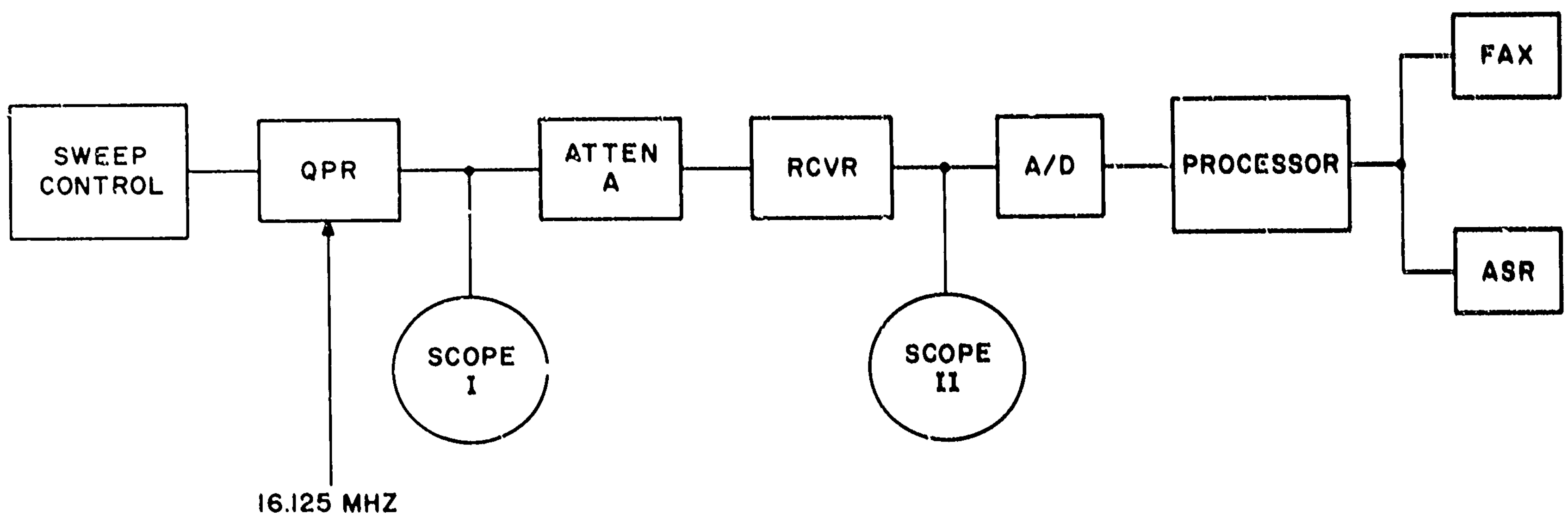


Figure 3-1. Equipment Setup for System Test

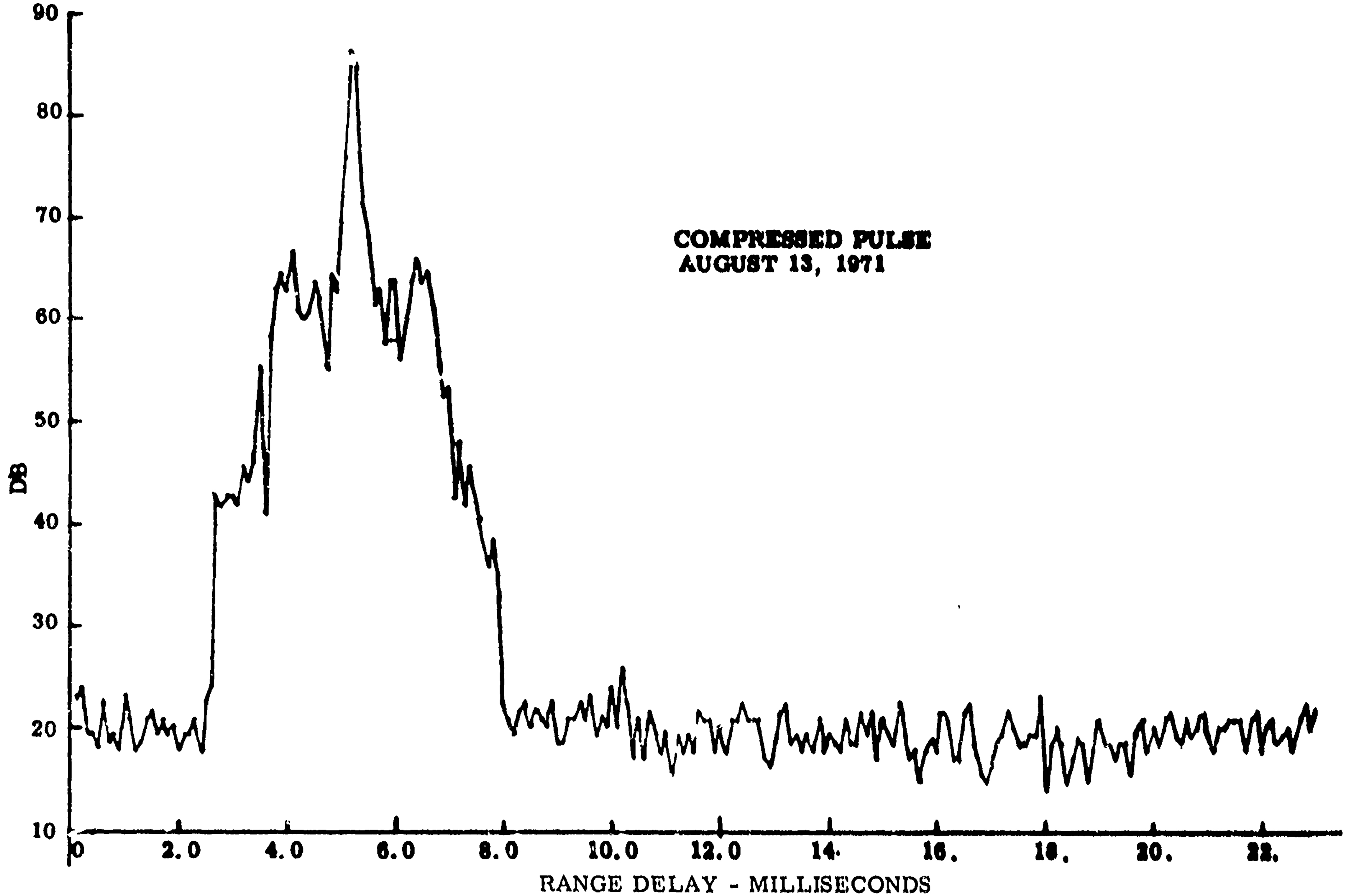


Figure 3-2. Example of Data from Simulated Operation

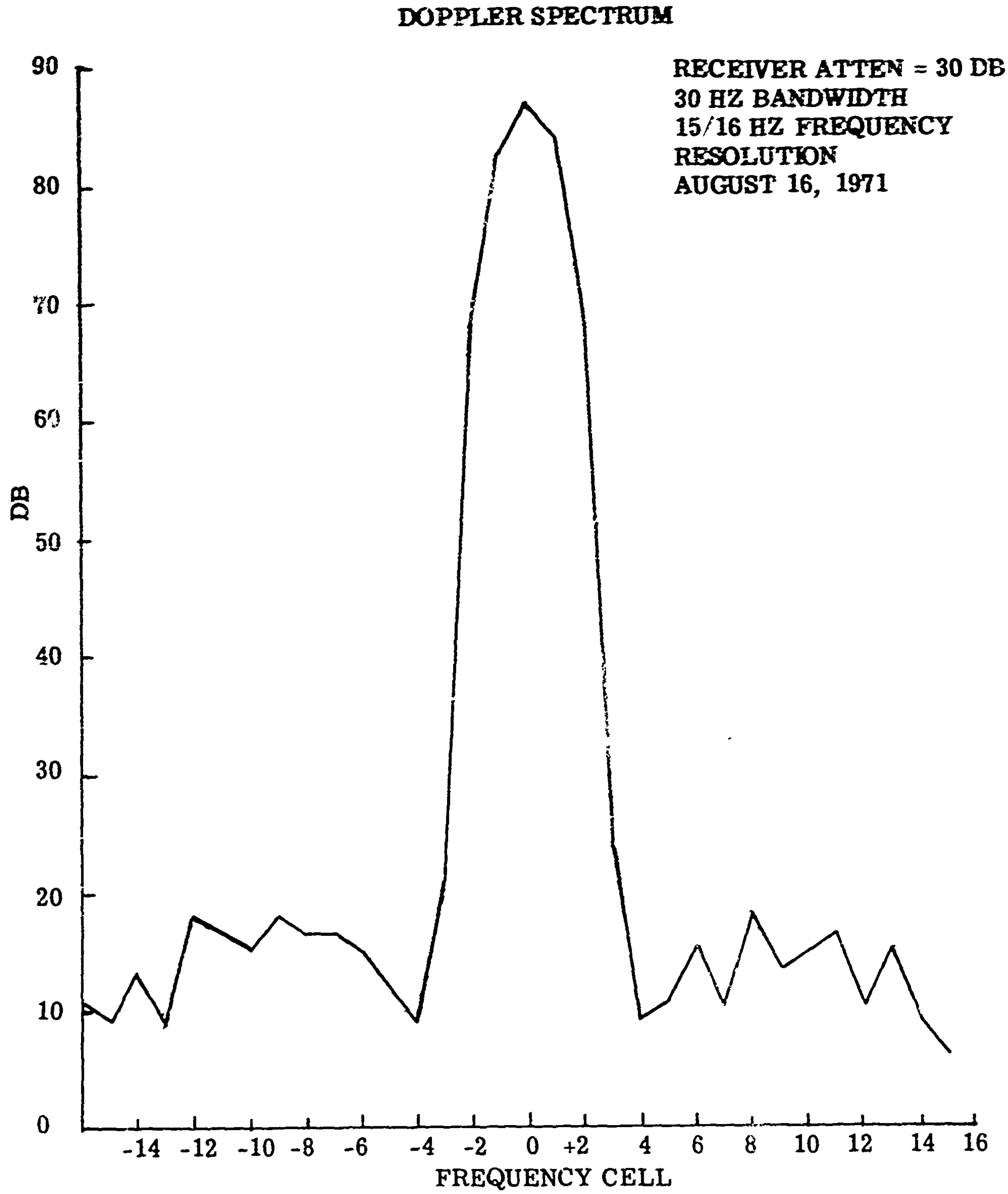


Figure 3-3. Example of Data from On-the-Air Tests

A wideband noise generator was used to measure the noise figure of the receiver by determining the amount of noise power required to raise the receiver noise output by 3 db. This measurement with the receiver running wide open (0 db attenuation) gave a noise figure of 16 db.

As a second method, the test setup shown in figure 3-1 was used to measure the smallest discrete signal that could be observed at the output of the receiver. This measurement gave a noise figure of 15 db which is consistent with the results obtained with the wideband noise source.

2. PLANNED OPERATION

A. SITE MANNING, TASKS, AND SCHEDULES

Operation of the radar site in Maine will be two-fold; to conduct a synoptic data collection experiment and to perform special high resolution tests. The design of the special tests will be formulated as the synoptic data collection experiment progresses.

For the synoptic data collection program the Maine site will operate on a 24-hour schedule every third day, beginning at local noontime (Maine) as shown in figure 3-4. The station will be manned by 4 operators working in pairs for 12-hour shifts. In addition there will be a data analyst working an 8-hour, 5-day shift at Maine. His prime purpose will be to perform a quick-look of the data, recognize changes that should be made in the operation and write monthly quick-look reports on the results. His responsibilities will include the selection, in advance of each synoptic run, of the sequence of radar frequencies to be used and the forwarding of the data tapes to Sudbury for detailed processing and analysis. He will also make recommendations for the scheduling of high resolution runs.

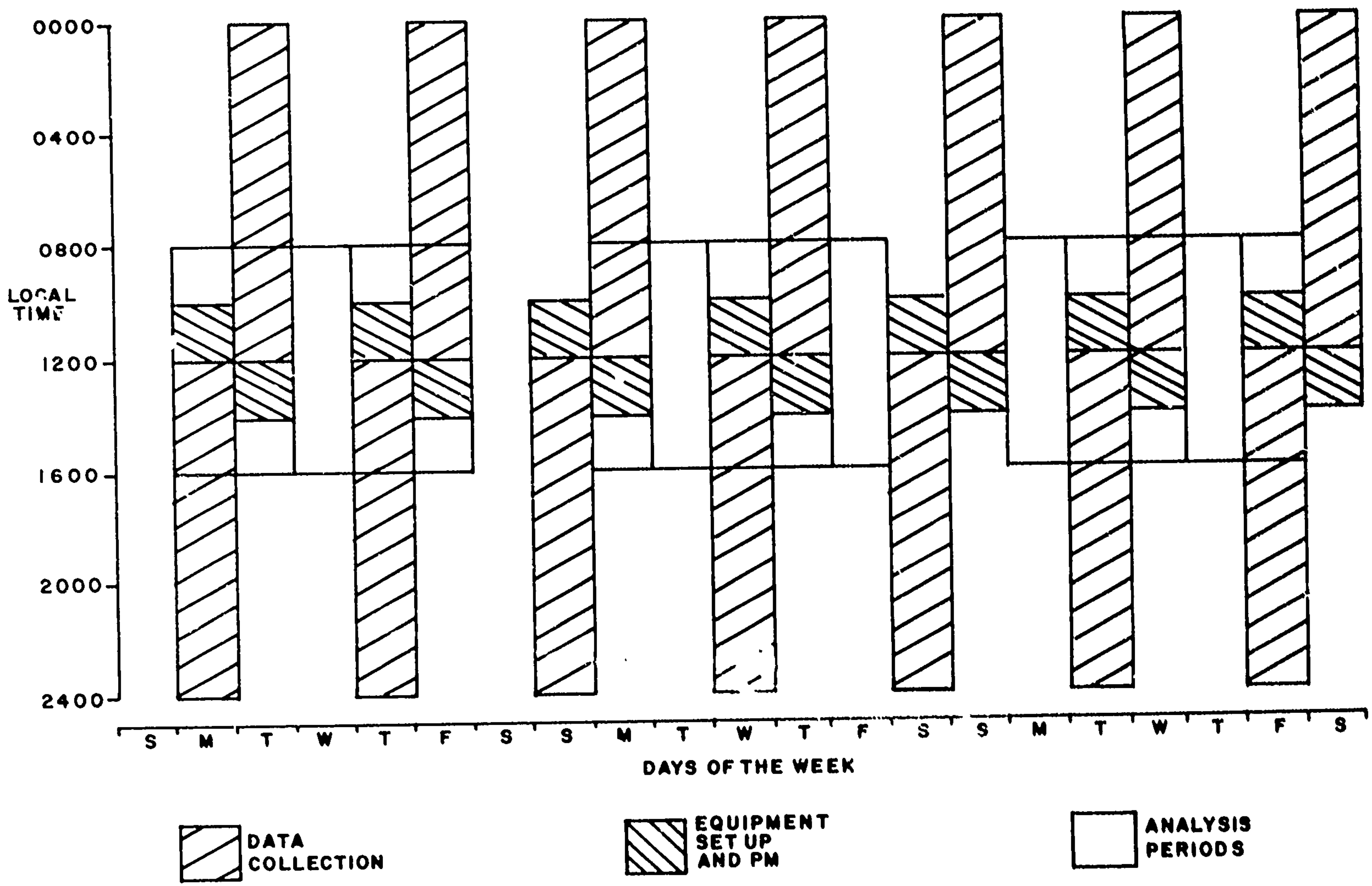


Figure 3-4. Schedule of Operations

A single operator will man each of the three remote beacon sites. He will be responsible for maintenance of the station and will be on-site to change frequencies during times of rapid ionospheric changes. This will vary from site-to-site and with time of year.

B. MODES OF OPERATION

There are 8 basic modes of operation available to the system as listed below.

Basic Mode 0	:	System idle
Basic Mode 1	:	Ionosonde, on one selected beam only
Basic Mode 2	:	Ionosonde, on beams -30^{o}, 15^{o}, and 60^{o} simultaneously
Basic Mode 3	:	Ionosonde, on three beacon beams simultaneously
Basic Mode 4	:	Backscatter (beacons transponding or off)
Basic Mode 5	:	Beacons or noise (Maine transmitter off, beacons transmitting only or off)
Basic Mode 7	:	System test
Basic Mode 8	:	Synopsis (a sequence of modes 2 through 7)

A detailed description of each of these modes is given in Raytheon Technical Memorandum No. RLV-238, 6 April 1971 (see "System Performance" manual).

The Maine transmitter is capable of operating in 7 different major modes, A through G, with 7 different pulse repetition rates (PRR's): 15, 20, 30, 40, 60, 80, and 120 pulses per second (PPS) respectively. It also can operate in 2 minor modes (1 and 3), i.e. with a bandwidth of 10 kHz. The system parameters resulting from the 14 combinations of major and minor modes are given in table 3-1.

Table 3-1. Major and Minor Mode Combinations and Resultant Parameters

a		b	c	d	e	f	g	h	j	k	l	m	n	p	q	r	s	t	u	v
MODE		RADAR PULSES						FREQUENCY STEPPING					RANGE PROCESSING					DOPPLER PROCESSING		
Major	Minor	Pulse Repetition Rate pulses s 1 c	Interpulse Period us 1 b	Pulse Width us	Pulse Bandwidth KHz	Range Bins per Pulse Width (TW Product), d·e	Range Resolution us 1 e	Step Width us	Hz per Step	Steps per Pulse	Pulse Width us h·k	Pulse Bandwidth KHz j·k	Sampling Period us	Complex Samples per Processed Range Interval	Processed Range Interval us	Good Range Bins per Processed Range Interval	Range Covert by Good Range Bins, us	Frame Period s	Pulse Periods per Frame t 6	Total Number of Compl. Samples per Frame, p·u
A	3	15	66,566 2 3	5,120	30	154	33 1 3	320	1875	16	5,120	30	33 1/3	512	17,067	358	11,953	1,000	15	7680
	1				10	51	100		625			10	100	512	51,200	461	46,100		15	
B	3	20	50,000	3,840	30	115	33 1 3	240	1875		3,840	30	33 1/3	384	12,800	269	8,967		20	
	1				10	38	100		625			10	100	384	38,400	346	34,000		20	
C	3	30	33,333 1 3	2,560	30	77	33 1/3	160	1875		2,560	30	33 1/3	256	8,533	179	5,967		30	
	1				10	26	100		625			10	100	256	25,600	230	23,000		30	
D	3	40	25,000	1,920	30	58	33 1 3	120	1875		1,920	30	33 1/3	192	6,400	134	4,467		40	
	1				10	19	100		625			10	100	192	19,200	173	17,300		40	
E	3	60	16,666 2 3	1,280	30	38	33 1/3	80	1875		1,280	30	33 1/3	128	4,267	90	3,000		50	
	1				10	13	100		625			10	100	128	12,800	115	11,500		50	
F	3	80	12,500	960	30	29	33 1 3	60	1875		960	30	33 1/3	96	3,200	67	2,233		80	
	1				10	10	100		625			10	100	96	9,600	36	6,800		80	
G	3	120	8,333 1 3	640	30	19	33 1 3	40	1875		640	30	33 1 3	64	2,133	45	1,500		160	
	1				10	6	100		625	16		10	100	64	6,400	58	5,300	1,000	160	7680

C. SYNOPTIC DATA TAKING SEQUENCE

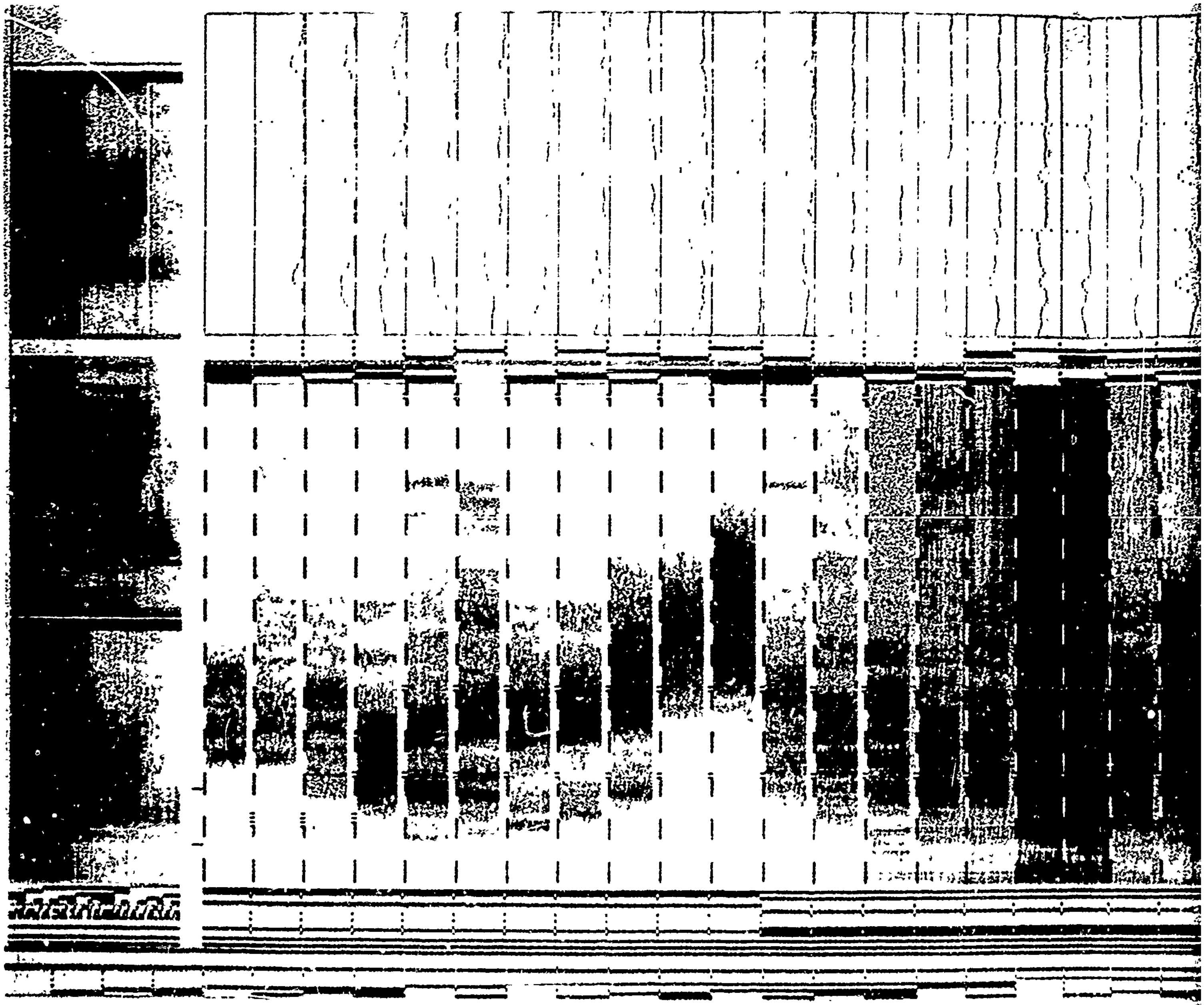
Basic mode 8 is used for the synoptic data taking experiment. When operating this mode the system executes the following sequence:

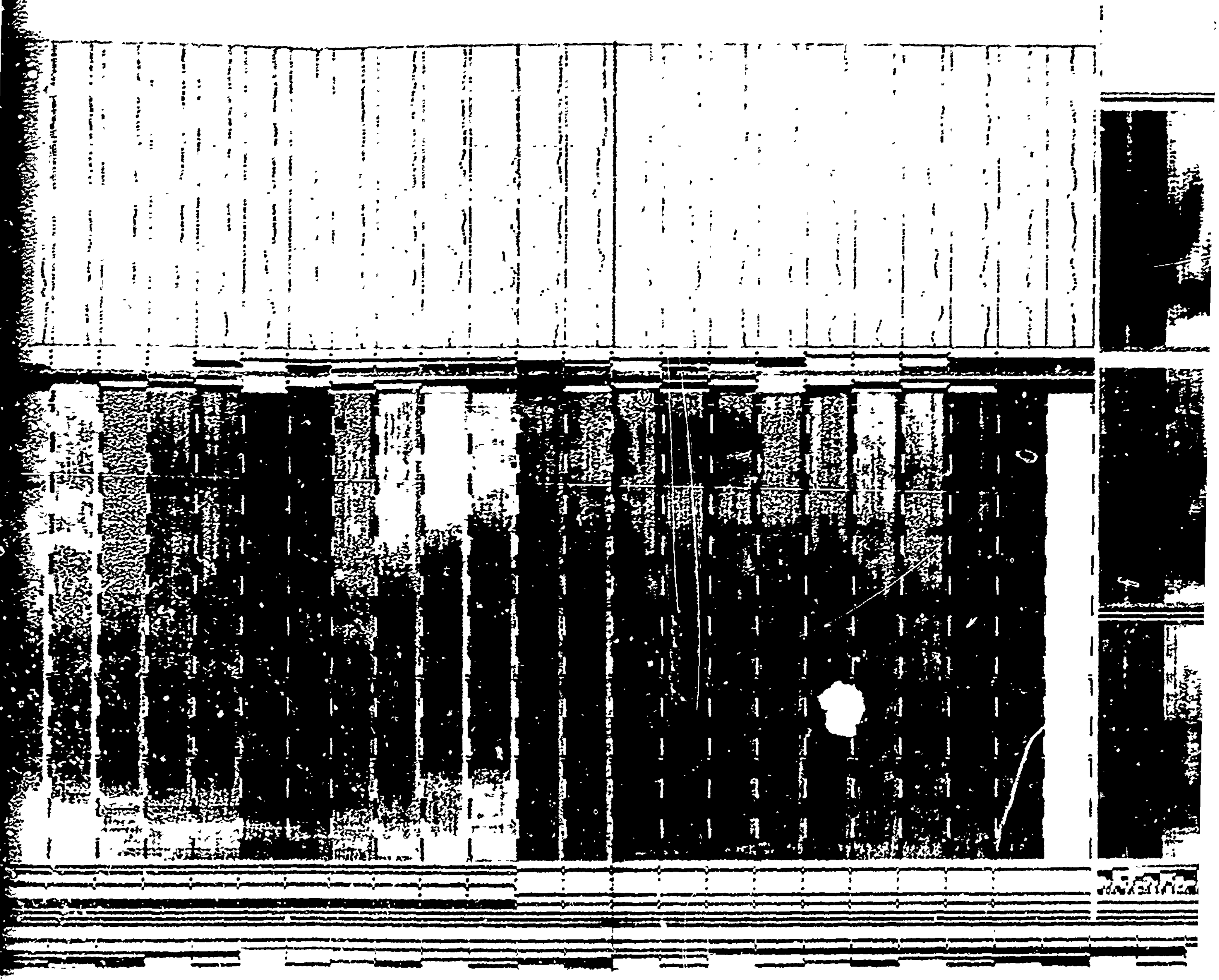
Basic mode 2 for 4 minutes
Basic mode 4 for 34 minutes
Basic mode 3 for 4 minutes
Basic mode 5 for 16 minutes
Basic mode 7 for 2 minutes

The data taking sequence during a synoptic run repeats every hour. Only the radar frequencies used change from hour to hour as ionospheric conditions change. Table 3-2 summarizes the sequence of events within each hour and figure 3-5 illustrates the resulting fax display. The data codes for the fax displays are shown in figure 3-6. The hour begins with a sequence of three backscatter ionograms, one on boresight and one to the east and west of boresight. These soundings set the stage for the backscatter sounding on fixed frequencies which follow, showing how the skip distance varies with range and how conditions vary with azimuth. The ionograms cover 6 to 26 MHz, the full operating range of the radar system. The range coverage is 23 milliseconds which is enough to cover the full 1000 - 4000 kilometer ground range of interest to the program. The radar system operates at 30 pulses per second (major mode C) with a 10-kHz chirp bandwidth (minor mode 1), corresponding to a 15-km range resolution. The beacons operate as transponders during this time and may or may not be seen depending on propagation conditions and the azimuth of the radar beam. The ionograms are displayed in realtime on the facsimile recorder and are simultaneously recorded on magnetic tape (signal intensity at each range gate, on each frequency, and at each azimuth). The three ionograms require somewhat less than 4 minutes to complete.

Table 3-2. Hourly Operating Sequence During Synoptic Data Taking Runs.

I.	Backscatter Ionograms: Fixed Azimuths (-30^{o}, $+15^{o}$, $+60^{o}$T), Variable Frequency (6 to 26 MHz), 4 minutes.
II.	Backscatter Soundings: Fixed Frequencies, Variable Azimuths (-30^{o} to + 60^{o}T in 11 steps of 9^{o} each). A. Low Frequency, 1000-2000 km (11 minutes, 1 min./az. step) B. Mid Frequency, 2000-3000 km (11 minutes, 1 min./az. step) C. High Frequency, 3000-4000 km (11 minutes, 1 min./az. step)
III.	Backscatter Ionograms: Fixed Azimuths (0^{o}, 33^{o}, 39^{o}T), Variable Frequency (6 to 26 MHz), 4 minutes.
IV.	Passive Reception of Beacons: Fixed Frequencies, Variable Azimuths (beacon boresight $\pm 6^{o}$ in 3^{o} step) A. Thule Beacon (5 minutes, 1 min./az. step) B. Narssarssuaq Beacon (5 minutes, 1 min./az. step) C. Keflavik Beacon (5 minutes, 1 min./az. step)
V.	Calibrations: (2 minutes)





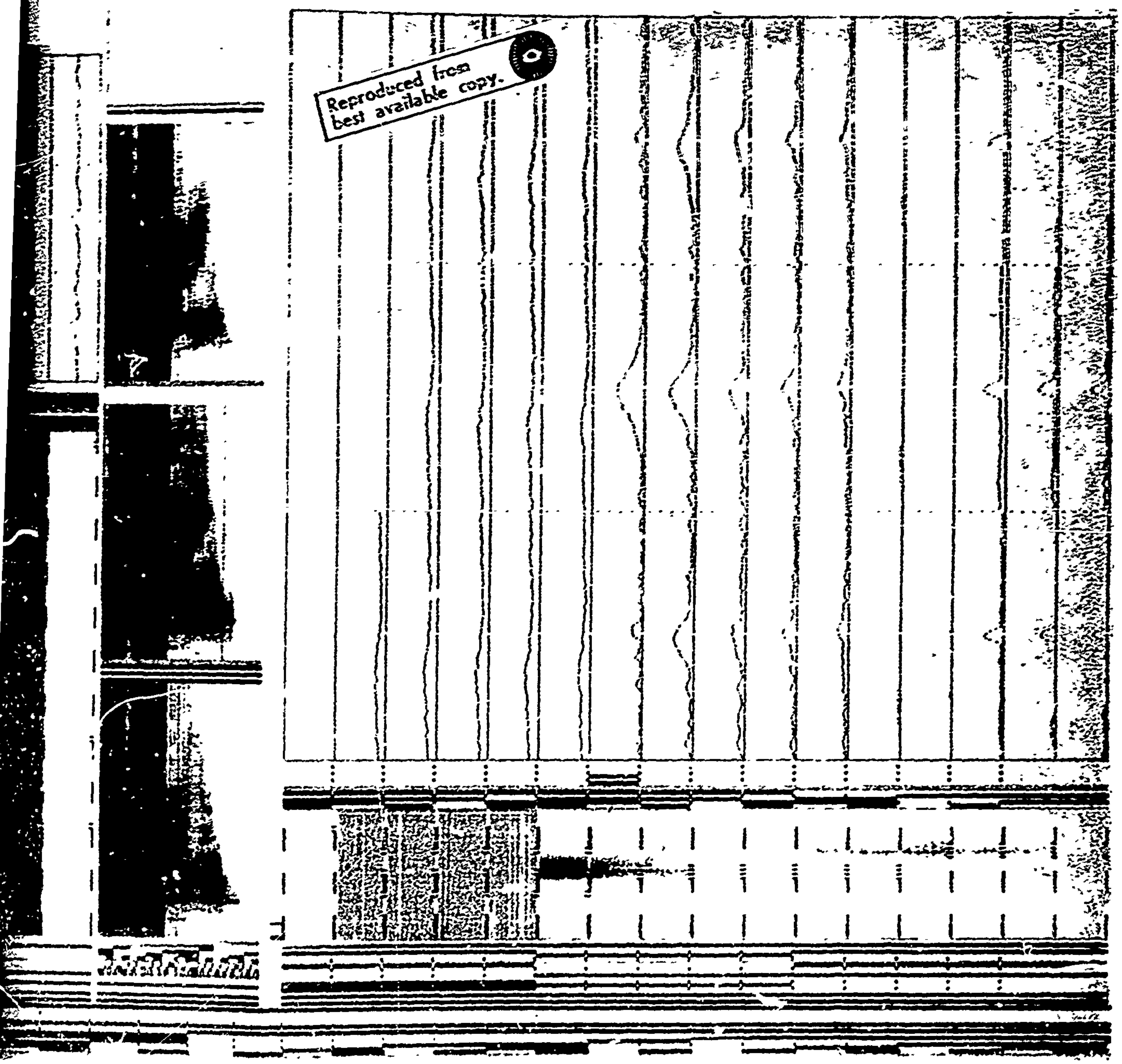


Figure 3-5. Example of One Hour of Synoptic Data. (Data Codes are Currently Being Converted to Numerics)

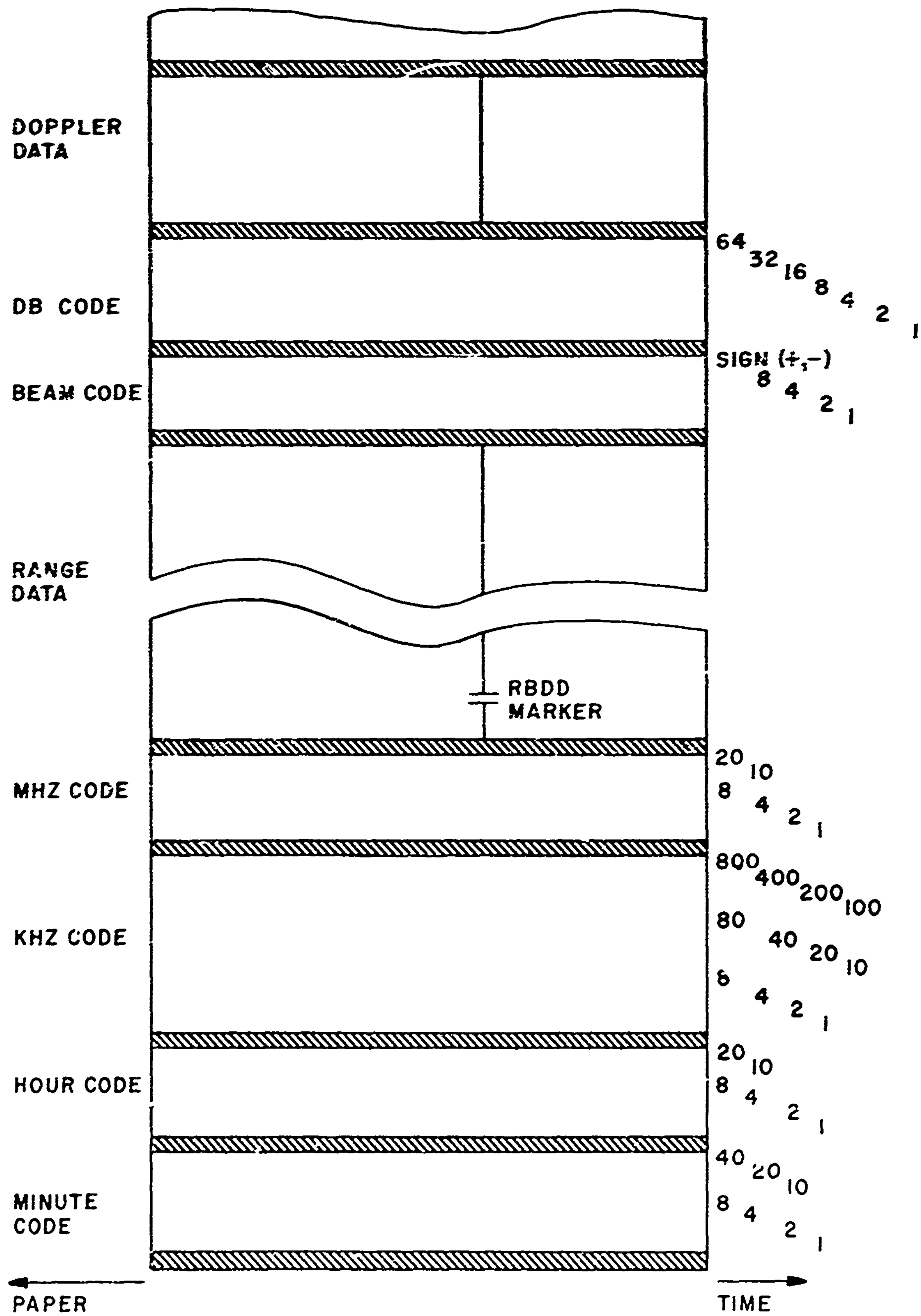


Figure 3-6. Data Codes

Following the ionograms, a series of backscatter soundings are taken. The purpose of these soundings is to examine the strength and doppler spectrum of backscatter as a function of range and azimuth. In an operational system, the radar frequency would be varied to optimize the detection probability at the range being surveyed. One can expect to optimally cover roughly 1000 km of range effectively with a given radar frequency. For this reason three frequencies are used in the Polar Fox II Program to survey backscatter characteristics over the 1000 km to 4000 km range interval. An attempt will be made to predict an appropriate radar frequency for each range interval for each hour well in advance of the run, using ESSA prediction techniques. Alternately, the frequencies can be chosen by the operator in realtime using the backscatter ionograms as guides. Operation begins at the highest of the three frequencies, primarily corresponding to the 3000 - 4000 km range interval. Data are collected at a given azimuth for 1 minute and average doppler spectra computed at each range gate (15 km spacing) in the 1000 - 4000 km interval. At the end of each minute, the average doppler spectrum at each of these range gates is written on magnetic tape. The spectra consist of 32 points spaced by 15/16 Hz. The radar beam is then stepped by 9 degrees in azimuth (about a beamwidth at 10 MHz) and the process completed until the full 90° scan sector has been covered. This takes 11 minutes. The radar frequency is then changed to maximize coverage in the 2000 - 3000 km range interval and the azimuth scan sequence repeated. Finally, observations of the same type are made at the frequency appropriate to maximize the 1000 - 2000 km range interval. During the 33 minutes of backscatter sounding, the beacons are operated in the transponding mode and will appear, along with the backscatter, when the radar beam points in the proper direction if propagation conditions permit. Realtime facsimile output during the backscatter consists of all range information in the range interval being surveyed and plots of the average doppler spectra at 3 selected ranges in that interval. This output is used primarily to monitor the system operation and as a starting point for the quick-look data analysis done on-site. In contrast to the data recorded on magnetic tape which are 1 minute averages, the range data displayed on the realtime facsimile recorder is only averaged over 1 second. The realtime facsimile records thus provide a means of determining whether or not significant variations took place over a 1-minute period.

The backscatter soundings are followed by a set of 3 backscatter ionograms. These cover the same frequency and range interval as those taken at the beginning of the hour but differ in that the azimuths of the 3 beacons are used instead. The objective is to make oblique ionograms from Maine to each of the transponding beacons. This will help in mode identification for the beacon observations which follow. As before, the ionograms are recorded on magnetic tape and require less than 4 minutes to complete.

At this point the Maine transmitters are turned off and the beacons are switched from the transponding to the transmitting mode. The beacon signals are received passively at Maine. These 1-way (forwardscatter) paths make the following 4 important contributions to the program:

1. Since 1-way paths are involved, the signal-to-noise ratio of the signals received at Maine is much higher than for backscatter and consequently the doppler spectrum can be examined further from the carrier.

2. The 1-way signals are contained within a smaller range-delay interval than the backscatter signals and consequently a higher pulse repetition rate can be used before range ambiguities appear. For this reason the beacon transmitters will be run at 120 pulses per second compared to the 30 pulses per second used for the Maine transmitters. The importance of this is that over the 1-way paths the doppler spectrum can be examined over 120 Hz compared to the 30 Hz available in backscatter operation.

3. The beacon transmitters will be calibrated so that the received signal strength will be a measure of attenuation and/or path loss due to spreading.

4. In contrast to the backscatter returns, the signals originate from point scarces of known position and hence their angle of arrival at Maine can be used to study the bearing deviations imposed by the auroral environment.

The beacon data-taking sequence begins with the Maine receiving beam steered 6^{o} west of the great circle azimuth to Thule. The radar frequency used is just below the computed MUF for the 3300 km path. Data are collected for 1 minute and, at the end of this time, average doppler spectra written for each range gate on magnetic tape. The range interval examined is only one-fourth of that for the backscatter observations but the doppler window for each gate is 4 times as wide. After recording, the receiving beam is stepped 3^{o} closer to the Thule great circle path and the data-taking process repeated. The sequence is continued through Thule boresight and 2 3^{o} beam-steps to the east. This azimuth scan (5 steps) across the Thule beacon required 5 minutes. The process is repeated for the Narssarssuaq and Keflavik beacons (at suitable frequencies).

The last 2 minutes of each hour are devoied to calibrations. These are done under computer control and the results written on the same digital tape containing the experimental data.

D. FREQUENCY SCHEDULES

(1) Maine Site. - For the synoptic mode of operation three frequencies (low, medium and high) must be selected at the beginning of each hour of operation at the Maine site. These frequencies are intended to maximize

covering the 1000 - 2000, 2000 - 3000 and 3000 - 4000 km ranges, respectively. Hourly predictions for each month of data collection will be made in Raytheon's Laboratory at Sudbury and frequency schedules will be forwarded to the site periodically. An example of such a schedule is shown in figure 3-7. These schedules are intended as guides for the site supervisor and actual selection will be made at his discretion (although still keeping within the ground rules) after viewing the backscatter ionograms taken at the beginning of the hour or possibly at the same hour on the previous data collection day.

Investigation of MUF's for the three ranges shows a considerable variation over the 90° azimuthal sector of interest. Examples of this are shown in figure 3-8. For instance, a frequency selected for a ground backscatter range of 3000 - 4000 km in one direction (say $+30^{\circ}$T) may not be appropriate at all for another direction (say 0° or -15°T). It therefore will be necessary to select a compromise frequency and during the course of a month different frequencies will be used in order to obtain a large enough statistical sample for each range and period of time.

(2) Beacon Sites. - For the first 42 minutes of each hour during the synoptic data collection periods the beacons will operate in the transponder mode. Immediately following this the Thule beacon will transmit on a scheduled frequency for a period of 5 minutes and then shut down completely until the beginning of the next hour when it will return to the transponder mode. At the end of the Thule transmissions the Narssarssuaq transmitter will start a 5-minute transmission period on its own scheduled frequency. Similarly, Keflavik will transmit for a 5-minute period immediately following the Narssarrsuaq transmissions. This operation is summarized in table 3-3.

Maximum usable frequencies (MUF'S) for each of the paths from the 3 beacons to the Maine site will be predicted and separate operating schedules will be forwarded to each beacon site. These schedules should be strictly adhered to until updated schedules are received.

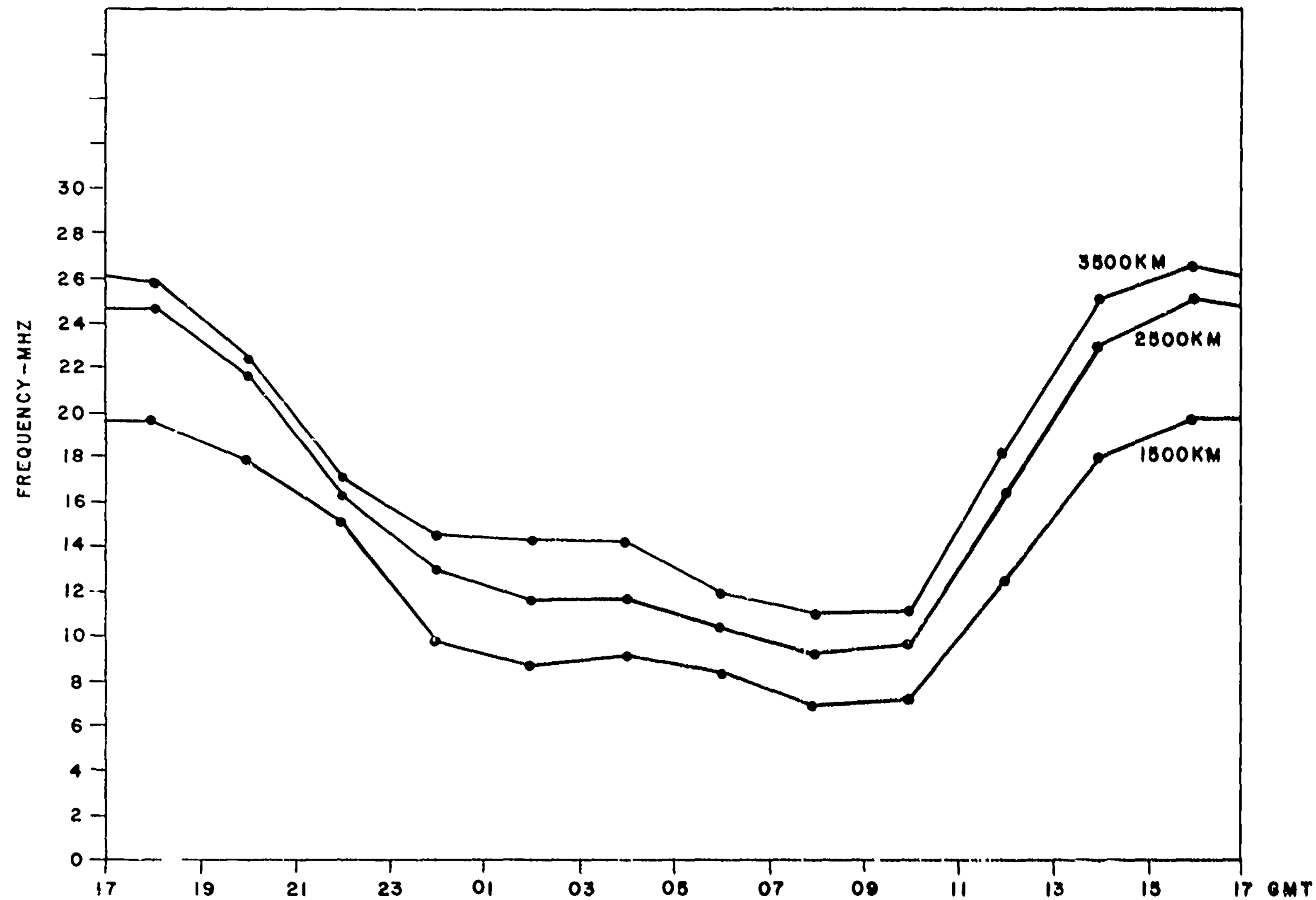


Figure 3-7. Example of Backscatter MUF Predictions

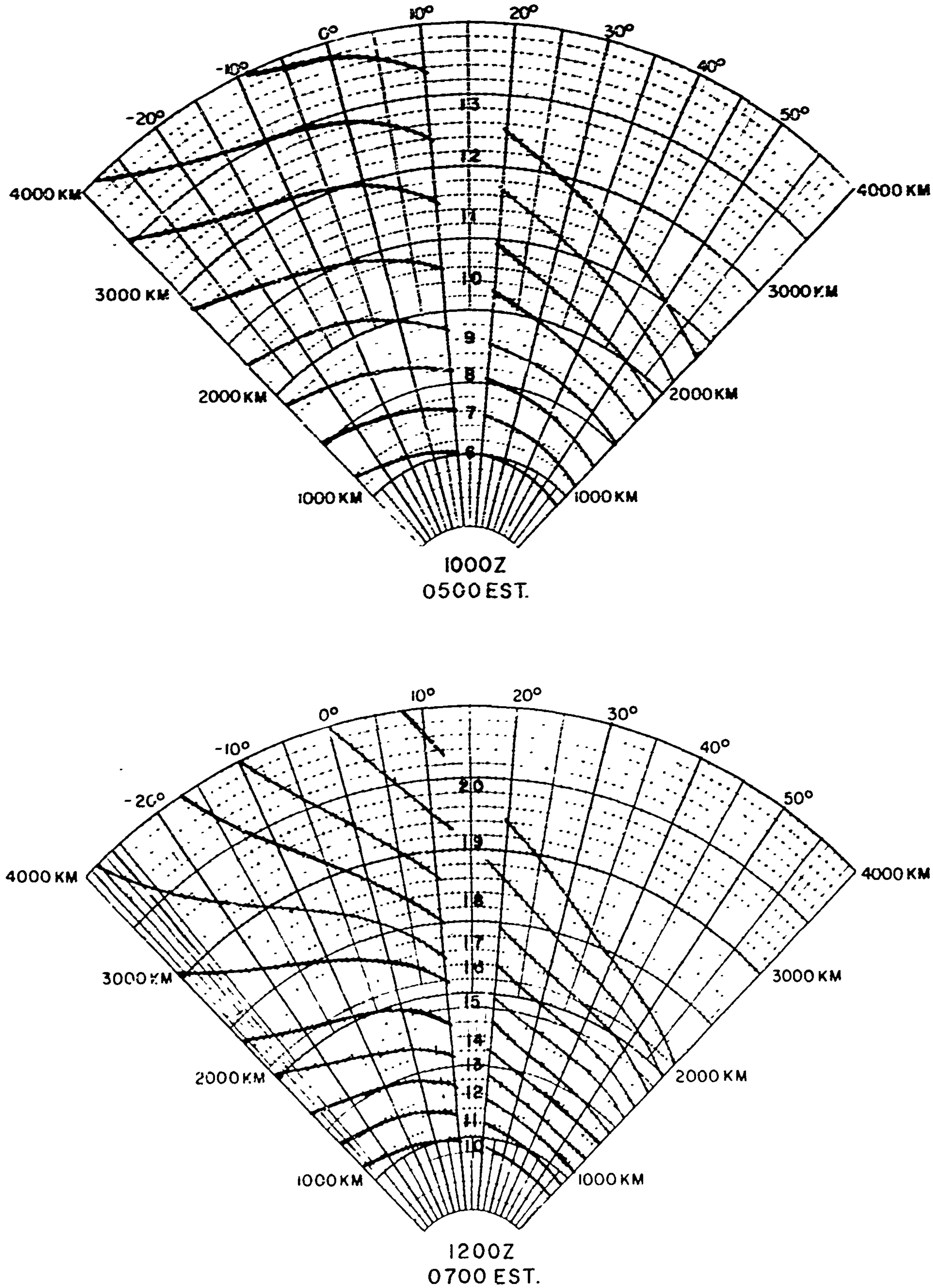


Figure 3-8. Example of Skip Distances Over 90° Azimuthal Scan

Table 3-3. Beacon Operation Schedule

Time (Each Hour)	Thule	Narsarssuak	Keflavik
XX00 - XX42	Transpond	Transpond	Transpond
XX42 - XX47	Transmit	Off	Off
XX47 - XX52	Off	Transmit	Off
XX52 - XX57	Off	Off	Transmit
XX57 - XX00	Off	Off	Off

3. LABORATORY LEVEL ANALYSIS

This section describes the data flow for the analysis portion of the Polar Fox II Program for synoptic mode data. Figure 3-9 shows an overall flow diagram for the analysis of this data. For convenience, the data flow will be divided into three general divisions. The first is the validating, editing and sorting of the original tapes from Maine to produce clean library tapes; these programs will be referred to as editing programs. The second division will be the processing programs. These will be used to display the data before any analysis processing takes place. The last division contains the Analysis Programs. These will remove the system parameters from the data, determine various statistical relations and reduce the quantity of data by various averaging techniques.

A. EDITING PROGRAM

The Editing Program will perform a variety of miscellaneous tasks, as required to generate clean (no missing data, all erroneous data flagged etc.) library tape. The tasks required will certainly include the following. Validation of the data from the original tapes. This will identify any missing data or data fields, any improperly formatted data etc. Editing of the tapes to, for example, correct incorrectly entered date-time information, to add missing data, to flag bad data etc. The editing programs will evolve as dif-

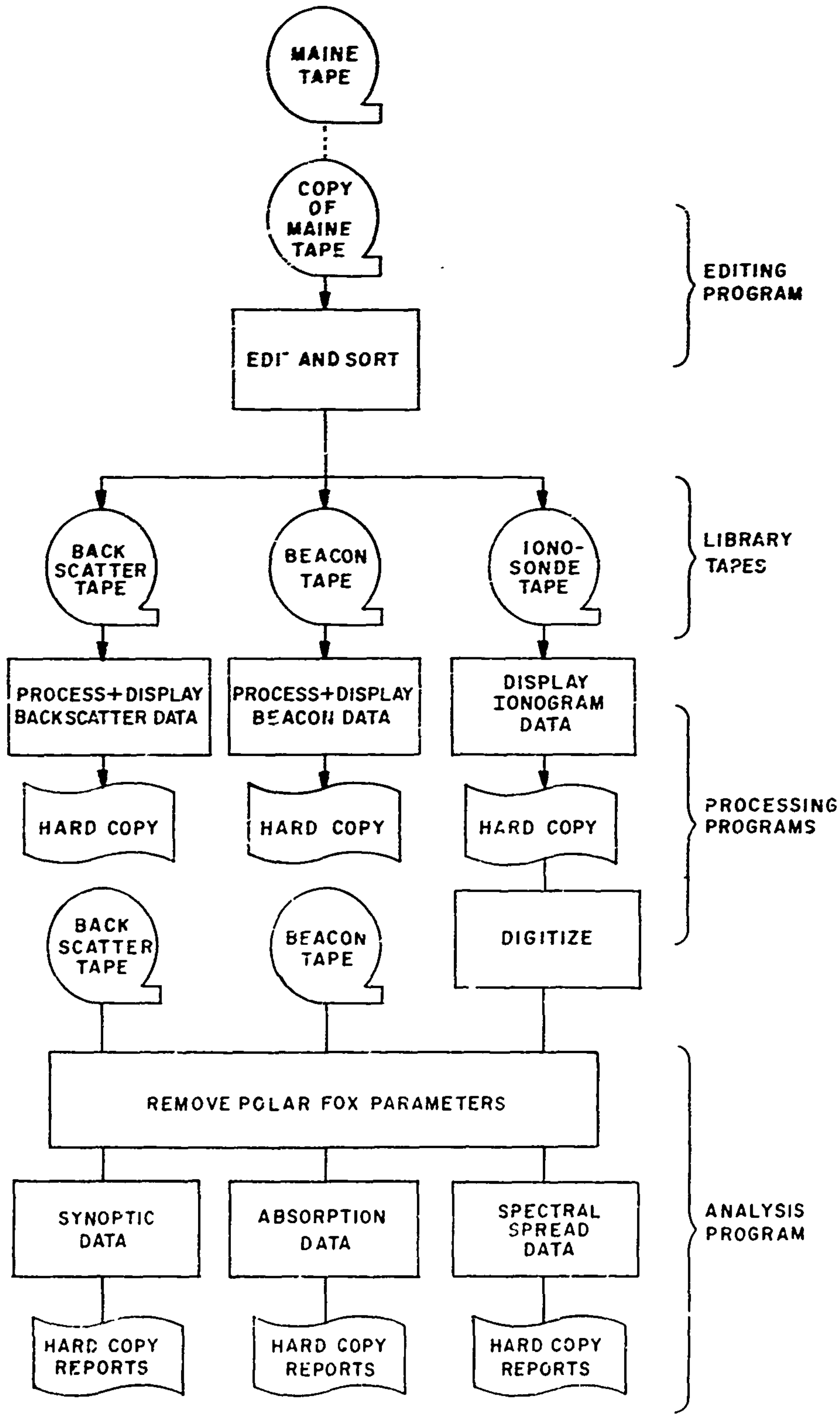


Figure 3-9. Polar Fox II Data Flow Diagram

ferent problems or situations are encountered with original field tapes. The input to the editing program will be a copy of the field tape. The output will be three library tapes, one containing ionogram data, one backscatter data and one beacon data.

B. PROCESSING PROGRAMS

The processing programs consist of three types, according to the kind of data processed. They are the Ionogram, Beacon and Backscatter Programs. The inputs to all the programs are the library tapes generated by the Editing Program. These processing programs display the data on the fax display and the CRT plotter with a minimum of manipulation.

(1) Ionogram Display Program. - The objective of the ionogram program is two-fold. First, to provide data for mode identification and take-off angle determination for use by the analysis programs and second, to provide a catalogue of backscatter ionograms to illustrate diurnal and seasonal variation. The inputs to the program are the library tapes containing ionogram data. The output is in the form of ionograms, intensity modulated delay time versus frequency on a linear scale. These ionograms will be used to scale parameters, using the HP digitizer, for use in calculating take-off angles. The latter will be required in the analysis programs. This program is operational. See figure 3-10 for sample display.

(2) Beacon Programs.

(a) Beacon Signal Strength Program. - The objective of this program is to obtain the signal strength and spectral spread data from the beacon data. The input to the programs are the library tapes containing beacon data. The program will have two types of output. One will be a table of received signal and noise levels in dbw. They will be for all range, azimuth and doppler cells (i.e., area under the curve).

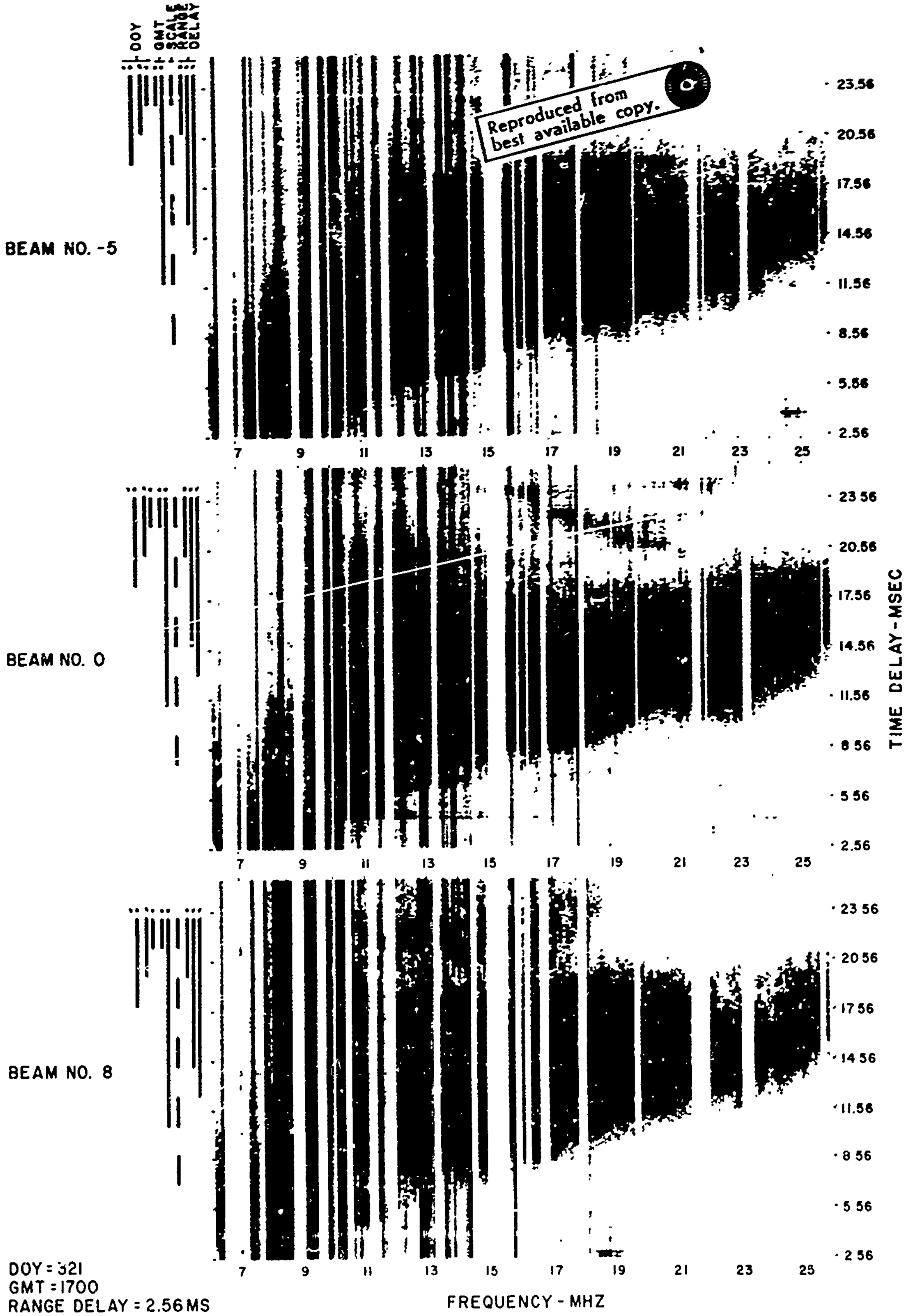


Figure 3-10. Example of Processed Ionogram Data

(b) Beacon Spectral Spread Program. - The objective of this program is to display the azimuthal and range character of the spectral spread from the beacon. The input to the program is the library tape containing beacon data. The program has two types of output, one displays, on a Fax display, the amplitude (intensity modulated) as a function of range and azimuth, for all doppler frequencies or for selected doppler frequencies. The second type of output plots contours of amplitude on a CRT display. Again these are as a function of range and azimuth, for selected or all doppler frequencies.

(3) Backscatter Programs. - The objective of these programs is to display the azimuthal and range character of the noise and spectral spread taken during the backscatter mode. The programs use the library tape containing backscatter data as input. There are two types of output, either intensity modulated or contour plotted. The programs display the signal strength (or noise) data, in a range versus azimuth pie-shaped presentation. This is the received power for all doppler frequencies or selected frequencies. The CRT display presents a contour plot of total power for levels of interest. The intensity modulated presentations are outputted on Fax displays, three at a time (Low, Medium, and High frequency) for each hour. These programs are operational. A sample output is included in figure 3-11.

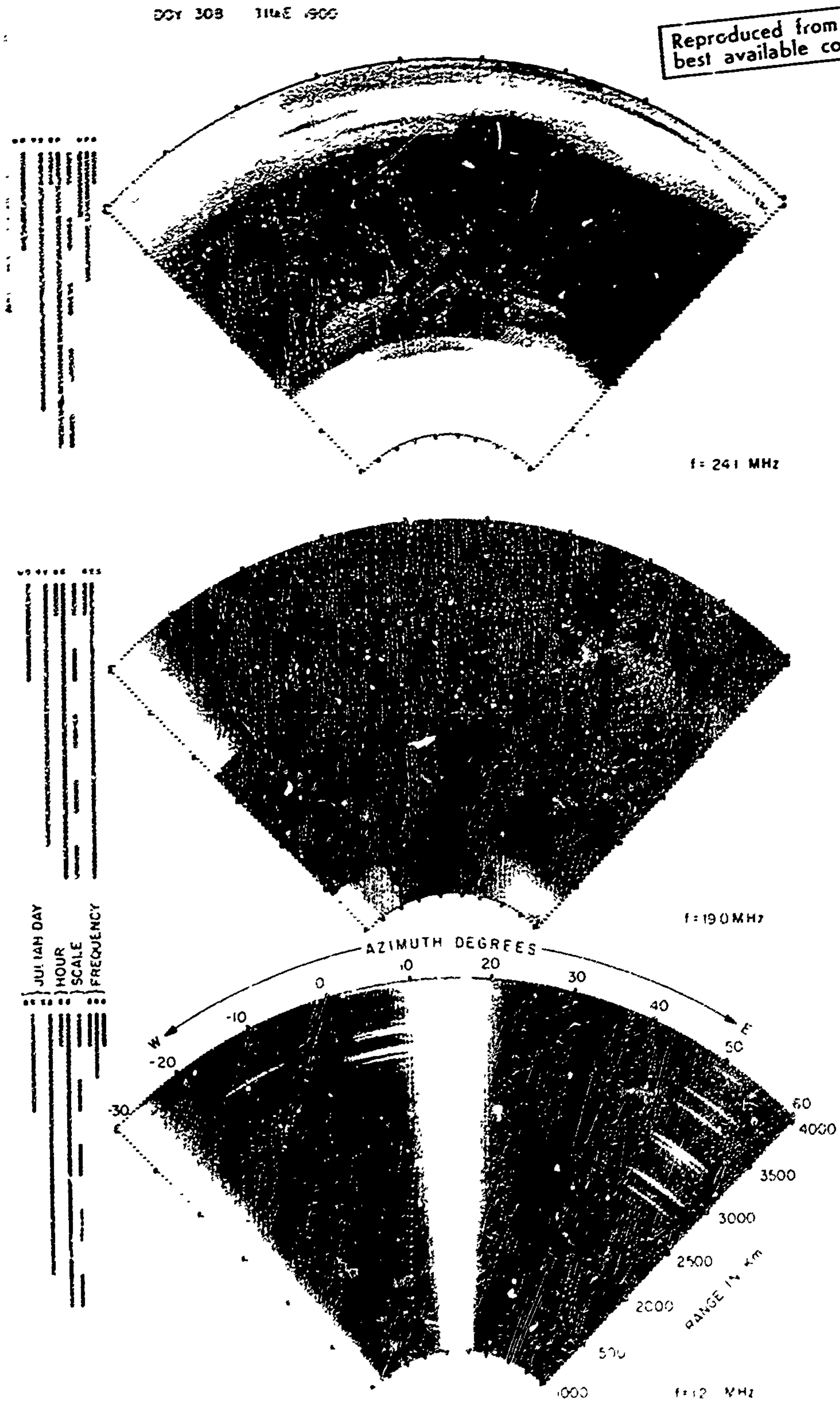


Figure 3-11. Example of Intensity Modulated Backscatter Program Display

SECTION IV

CONCLUSION

The Polar Fox II System has been assembled by Raytheon and is in operation at the field site north of Caribou, Maine. The system, as tested to date (antenna characteristics have not yet been measured) meets or exceeds characteristics stated in the Statement of Work. These are listed in table 4-1.

Table 4-1. System Characteristics

	Specified	Measured
Range Resolution	100 usec and 33 usec	100 usec and 33 usec
Frequency Resolution	1 Hz	15/16 Hz
Dynamic Range	>60 db	>60 range >70 doppler

The site started routine operation on 4 November 1971 and the data is being processed and analyzed as it is received at Raytheon's Engineering Facility at Sudbury, Massachusetts.

SECTION V

SUMMARY

This report describes the HF radar system at Caribou, Maine and the three remote beacon sites which comprise the Polar Fox II System. Included is a description of the antenna system as well as system performance measurements. These latter values showed the Polar Fox II System to have a dynamic range in excess of 60 db, a frequency resolution of 15/16 Hz, a range resolution of 15 km (in the synoptic mode) and a receiver noise figure of 15 db. This report contains a description of the synoptic mode and an example of a typical hour. Finally the data processing and display techniques are briefly described.