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First Results from HF Oblique Backscatter Soundings to the Northwest of College, Alaska Using a Modified ULCAR Digisonde D-256

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This report describes, in detail, the modified Air Weather Service Digital Ionospheric Sounding System (DISS, AN/FMQ-12) located at College, Alaska. The HF sounding system at College, Alaska is used to investigate the behavior of groundscatter, plus E&F-region direct backscatter caused by high latitude ionospheric irregularities. These echoes may manifest themselves as "clutter" in the proposed Alaskan OTH radar system. Soundings to the northwest of College have been identified as groundscatter plus several types of auroral "clutter" echoes.

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I. Introduction

When a high-frequency (HF) sounder utilizes an antenna whose main lobe is directed obliquely to the ionosphere, one receives information about the characteristics of: a) the ionosphere near the reflecting point; b) the surface of the earth; and c) other targets between the earth and the ionosphere. Peterson (1951) and Dieminger (1951) independently developed the theoretical explanation for the *ground scatter* echo in terms of a *least-time-focusing* effect, and Bates and Albee (1970) described direct backscatter from large field-aligned irregularities in the auroral F-region.

During the 1960's several groups in the U.S. developed narrow-beam oblique HF backscatter sounder systems for various purposes (Tveten and Hunsucker, 1969; Althouse et al., 1971; and Basler and Scott, 1971), and these systems produced new information on *target* characteristics such as land-sea boundaries (Blair et al., 1969); mid-latitude ionospheric irregularity *fine-structure* (Hunsucker, 1971 and *sea-state* Barrick and Peake, 1968) — also see the review by Croft (1972). Results of many of the foregoing studies were published in the classified literature. A review of high-latitude ionospheric irregularities of varying scale size has been published recently by Tsunoda (1988). He points out that the basic cause of the large scale irregularities is probably due to convective plasma processed by the EXB interchange instability.

In the early 1980's a more sophisticated HF oblique ionospheric sounder for research was developed by adding digital signal processing of the phase coherent returned pulses and utilizing a phased array antenna (Greenwald et al., 1985). When one operates an oblique HF backscatter sounder whose primary ionospheric reflection points lie in or near the auroral oval, many anomalous echoes from the E & F region are usually observed in addition to the groundscatter echo (Bates, 1970; and Hunsucker and Bates, 1969; Möller, 1963; Lund et al., 1967). Direct backscatter from geomagnetic-field-aligned irregularities requires that the line-of-sight (LOS) from the radar intercept the irregularity at nearly perpendicular incidence. Ionospheric refraction usually *bends* the HF radar LOS to nearly normal incidence, but VHF/UHF auroral radars must be sited carefully to fulfill this requirement (Haldoupis, 1989). A review of polar ionospheric F-region irregularities has been recently published by Tsunoda (1989). To an OTH Radar system operating at high latitudes these anomalous backscatter echoes can be regarded as *clutter* which may hamper the primary use of the radar.

In order to gain some information on auroral clutter for the USAF Alaskan OTH Radar we (with the assistance of ULCAR engineers) have modified our digital ionosonde system (DISS/D256) to add the oblique HF sounding capability. This sounder system is a monostatic radar using 2 log-periodic antennas to produce a main antenna lobe of ~50° azimuthal width directed toward an azimuth of 290°. It operates over ~4-20 MHz and records both amplitude and Doppler information of the echoes. Several vertical ionograms and HF oblique backscatter ionograms per hour are recorded on magnetic tape continuously.

The purpose of this report is to describe research carried out by the Geophysical Institute of the University of Alaska Fairbanks in support of the Alaska Over-the-Horizon (OTH) radar system, which is scheduled to start the first phase of construction in 1989. This research effort is under a Geophysics Laboratory (AFSC) contract funded by the OTH Radar Program Office. Task 2 of our research effort entailed measuring and characterizing the Radio Frequency Interference (RFI) and electrical noise at the OTH receiving site at Tok, Alaska, and a report describing these results was submitted to AFGL in 1988. A rather complete description of the theory and practice of OTH systems is given by Kolosov et al. (1987), which contains many references to unclassified literature published in the USSR and elsewhere up to ~1980 and another monograph by Gurevich and Tsedilina (1985), covers the propagation of HF waves over long distances.

Research Task 1 includes modification of the Air Weather Service College Digital Ionospheric Sounding System (DISS, AN/FMQ12), a militarized version of Digisonde D-256 ionosonde, to permit obtaining oblique backscatter echoes in addition to vertical ionograms. Analysis of the oblique HF backscatter records should provide information on the importance of *auroral clutter* on the Alaskan OTH system. The HF backscatter modification was accomplished in September 1988. We will discuss analysis of selected HF backscatter records obtained in Fall - Winter 1988-89 in this report.

II. Instrumentation

The primary instrumentation for Task 1 of this project (Auroral Clutter research) is located at the Sheep Creek Field Site (SCFS), 11 km (6.6 miles) northwest of the Geophysical Institute. Figure 1 is a map showing the various instrumentation sites in the Fairbanks area utilized by the Geophysical Institute, and Figure 2 is a plan view of the newly refurbished Sheep Creek Field Site building.

A. Description of the D-256: The D-256 vertical sounder has been described in considerable detail by Bibl et al. (1981), but for the sake of completeness, the essential parameters are listed in Table 1, and Figure 3 shows the essential block diagram of the transmitter and receiver.

B. The Modified System, D-256 Modified for Backscatter Operations: We have modified the standard D-256 configuration to incorporate two log-periodic antennas, co-aligned to an azimuth of 290°. The two antennas, spaced two wavelengths apart at 3.6 MHz, are shown in plan view in Figure 4. Andrew Model 747F-CD wire log periodic antennas (LPA) were chosen for the application and predicted azimuth and elevation patterns are shown in Figure 5. Specifications for the LPA's are listed in Table 2. The two log-periodic antennas are fed from individual 10 Kw Final Power

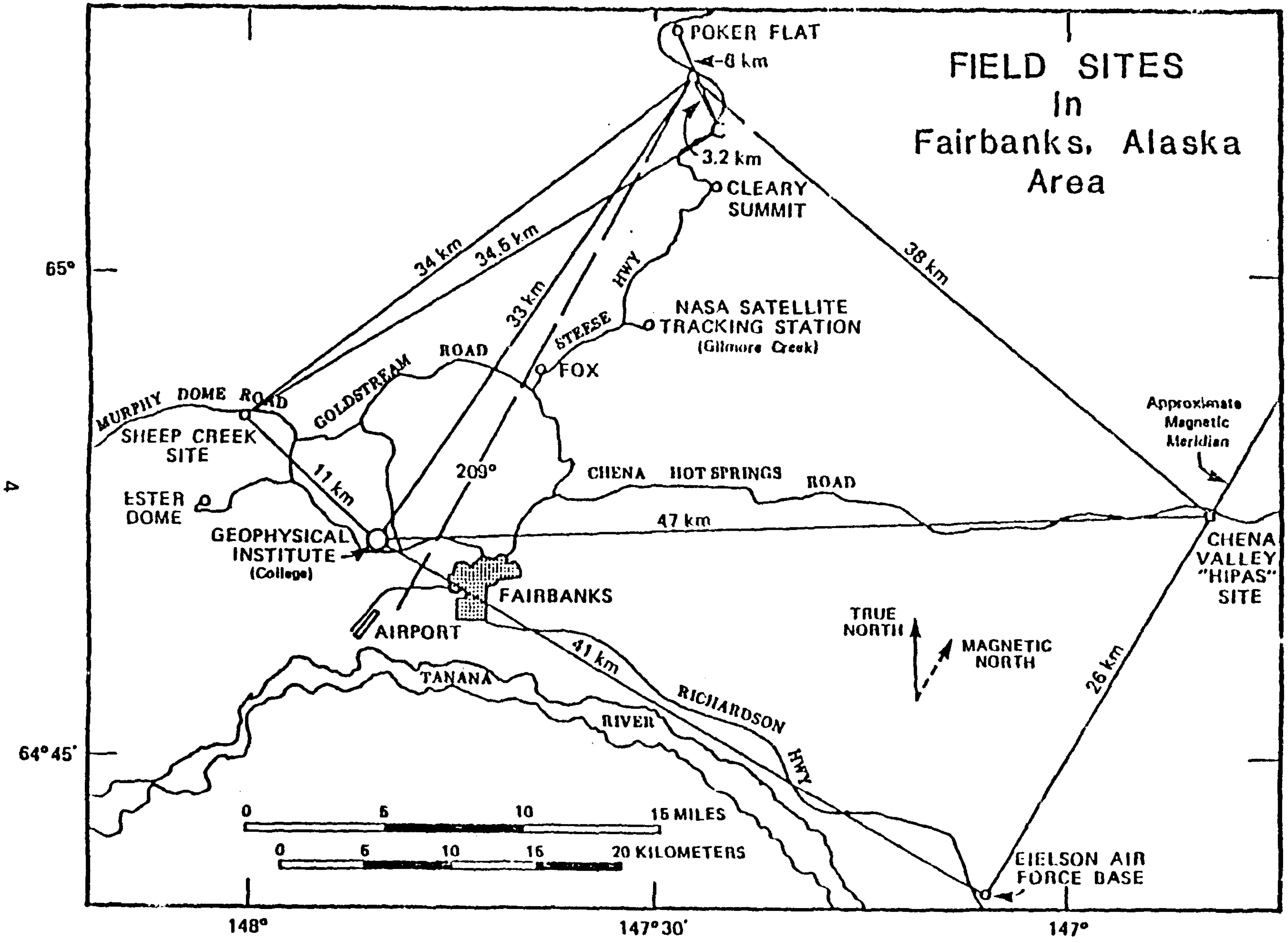
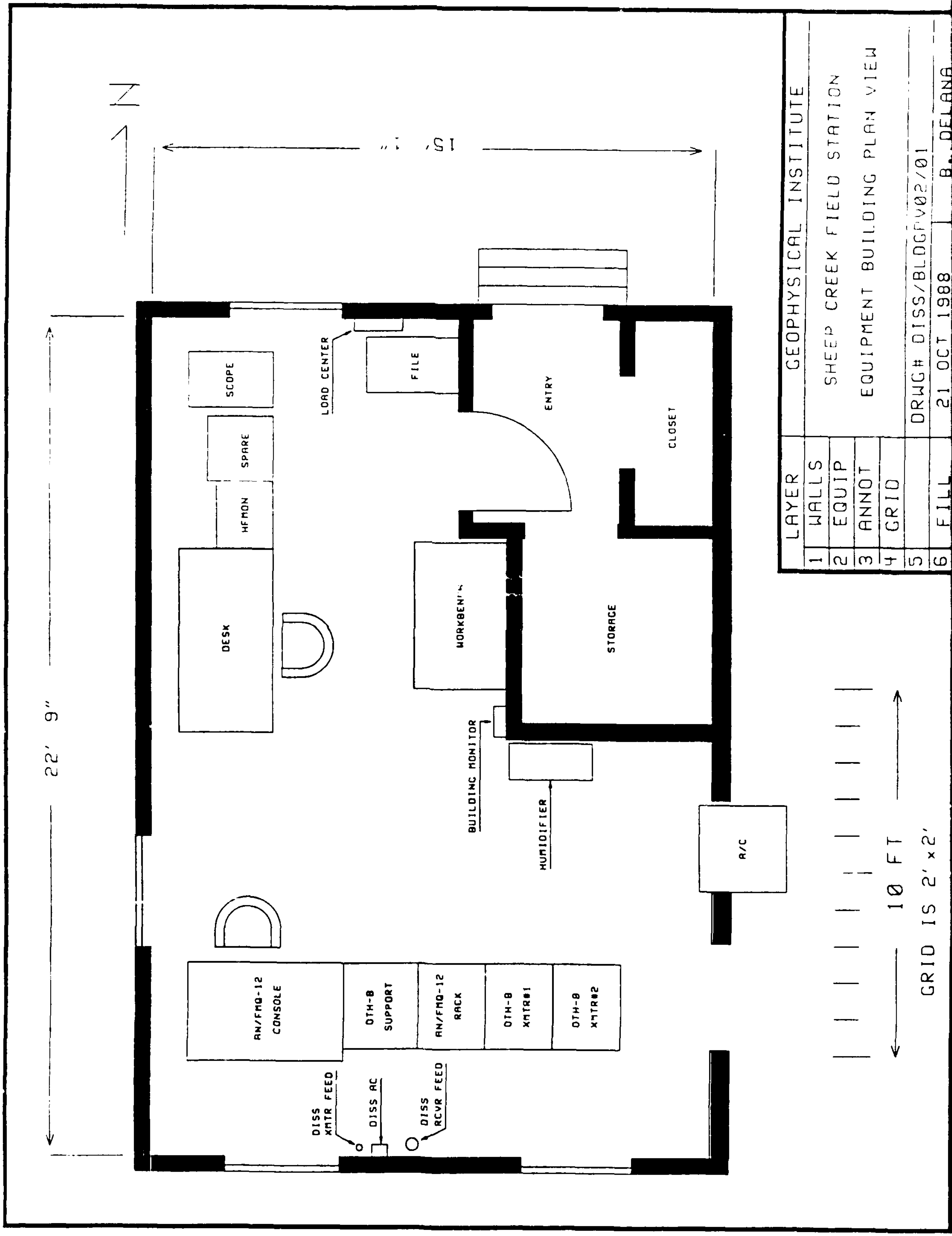


Fig. 1 Map showing Fairbanks area instrumentation



N
15' 1"
22' 9"
SCOPE
SPARE
HFMON
LOAD CENTER
FILE
ENTRY
CLOSET
DESK
WORKBENCH
STORAGE
BUILDING MONITOR
HUMIDIFIER
A/C
AN/FMQ-12 CONSOLE
OTH-B SUPPORT
AN/FMQ-12 RACK
OTH-B XMTR#1
OTH-B XMTR#2
DISS XMTR FEED
DISS AC
DISS RCVR FEED
10 FT
GRID IS 2' x 2'
GEOPHYSICAL INSTITUTE
SHEEP CREEK FIELD STATION
EQUIPMENT BUILDING PLAN VIEW
DRWG# DISS/BLDGPV02/01
21 OCT 1988
B. DELANA
LAYER
1 WALLS
2 EQUIP
3 ANNOT
4 GRID
5
6 FILL

Table 1
SPECIFICATIONS

GENERAL:

Frequency Range: 0.5 - 30 MHz

Sweep Duration: Programmable, 20 sec to several minutes

Frequency Step Size: 5, 10, 25, 50, 100, 200 kHz linear. 20, 40, 80 steps per octave logarithmic. 50, 100, 200 kHz pseudo-random linear.

Frequency Search: Prior to transmission, the Digisonde listens at the nominal frequency, + 10 kHz and + 20 kHz and uses the one with the lowest interference level.

Restricted Frequencies: The user can restrict transmission on any frequency or band of frequencies.

Pulse Repetition Rate: 50, 100, or 200 Hz.

Pulse Width: 66 or 133 μsec.

Phase Coding: Interpulse and intrapulse pseudo-random phase coding to minimize effects of coherent interference.

Dynamic Range: 64 dB, plus digital AGC in 6 dB steps.

Frequency Source: Rapid switching frequency synthesizer derived from crystal with 10^{-9} stability.

Automatic Operation: User-friendly interface allows operator to design schedules which repeat every hour. During the hour, starting times of up to 12 each of three different ionograms can be specified.

At specific times during the day diurnal changes in both schedule and sounding programs may be made automatically. The same facility allows similar changes to be made for a more intense World Day Schedule.

Modes of Operation:

Multiparameter ionograms (A, B and C modes). Operational parameters for nine different type ionograms can be stored in EEPROMs for automatic access. The system can run vertical incidence and oblique incidence (bistatic) ionograms.

Fixed-frequency sounding (F mode). Fixed-frequency soundings (either one or four frequencies simultaneously) can be run in between ionograms.

Doppler-Drift observations (G mode). For detailed studies of ionospheric structures (tilts) and motions, the system operates in the drift mode.

Input Power: 100 - 130 VAC or 200 - 260 VAC, 50 or 60 Hz. Uninterruptable Power Supply (UPS) bridges operation over short power outages and allows automatic orderly shutdown during longer power outages.

U.S. Government Nomenclature: AN/FMQ-12, Digital Ionospheric Sounding System (6660-01-148-4205).

TRANSMITTER:

Output Impedance: 50 Ohms.

Output Power: 10 kW during pulse, nominal.

Max. VSWR: Any mismatch permitted.

SIGNAL PROCESSING:

Digitization: 12 bit linear, quadrature sampling of IF signal (225 kHz).

Amplitude Resolution: ¼ dB.

Phase Resolution: 1.4°

Height Resolution: 2.5, 5.0 and 10.0 km

Range Bins: 128 and 256. Selectable range start.

Doppler Resolution: Discrete Fourier Transform has resolution of 1/T, where T is the observation time. T is selectable from 0.25 to 82 seconds.

Doppler Bins: Variable, 2 to 256.

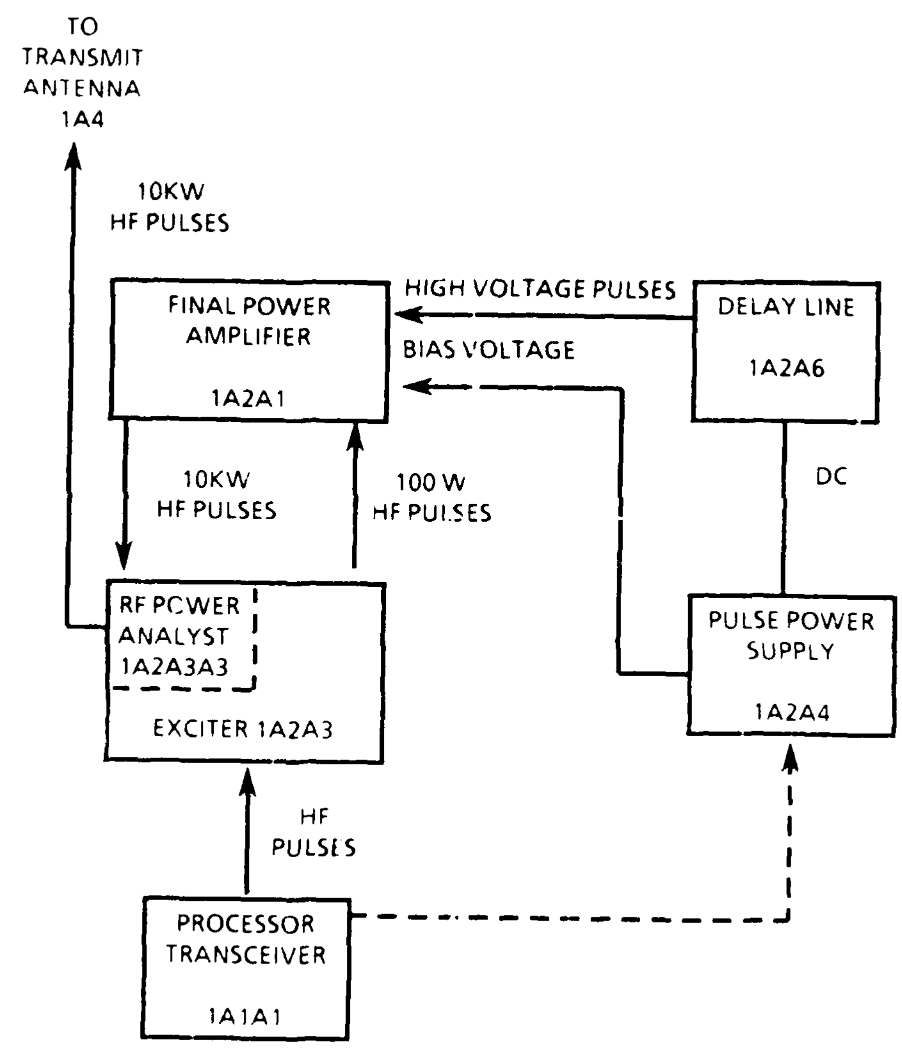


Figure 3 1 DISS Transmitter Simplified Functional Block Diagram

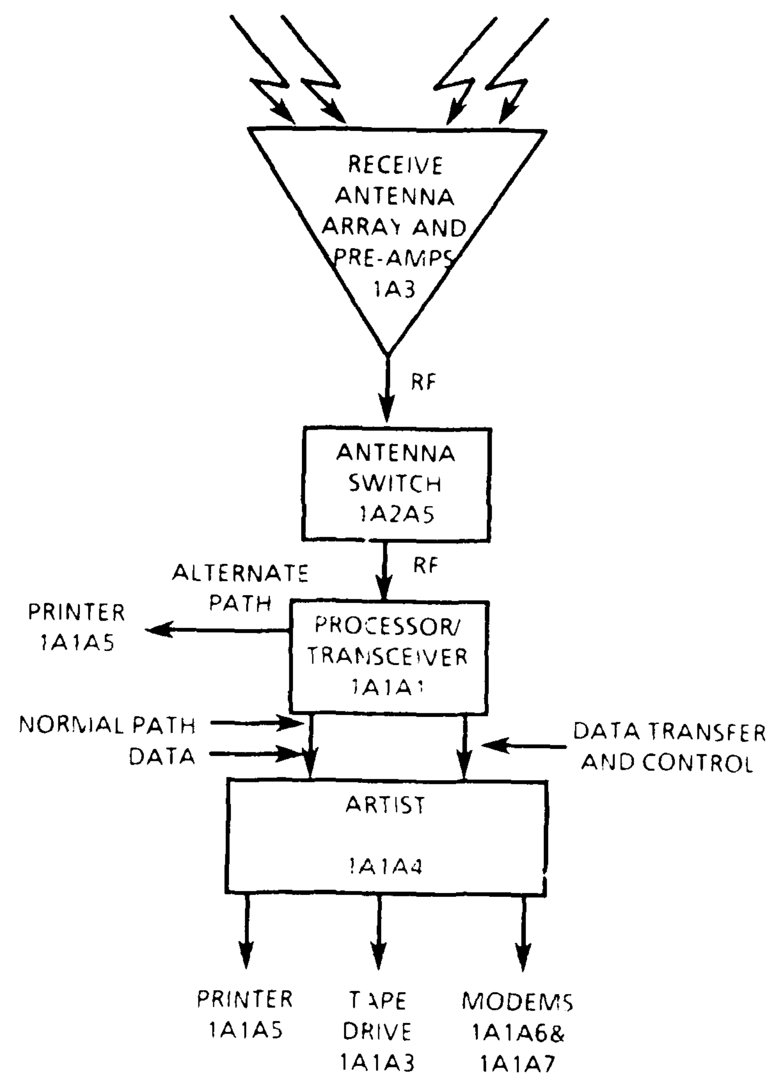


Figure 3 2 DISS Receiving/Processing Functional Block Diagram

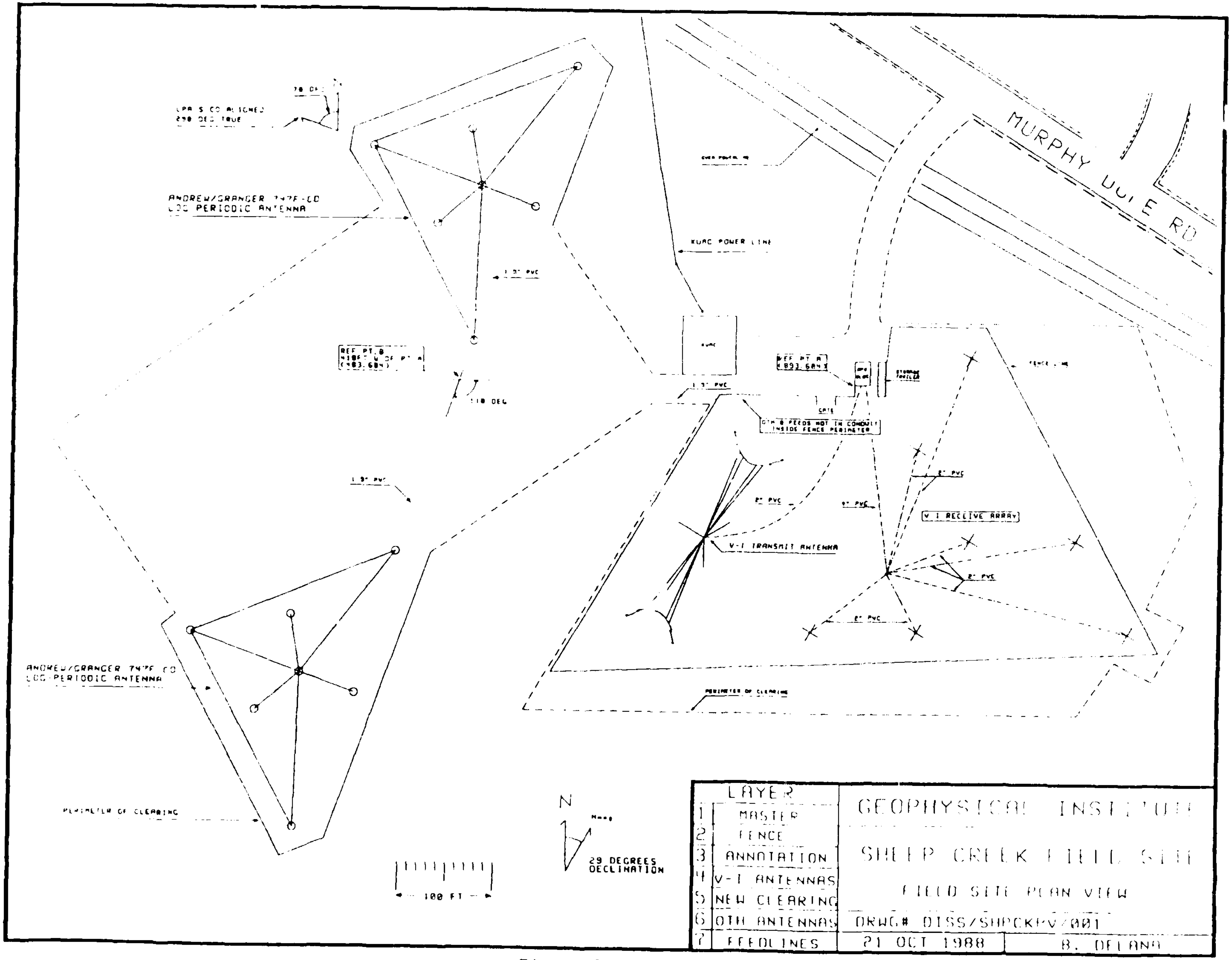

MURPHY DOME RD
KURC POWER LINE
ANDREW/GRANGER 747F-CO
LOG PERIODIC ANTENNA
ANDREW/GRANGER 747F-CO
LOG-PERIODIC ANTENNA
PERIMETER OF CLEARING
V-I TRANSMIT ANTENNA
V-I RECEIVE ARRAY
OTH-B FEEDS NOT IN CONDUIT
INSIDE FENCE PERIMETER
REF PT A
REF PT B
110 DEG
70 DEG
2" PVC
1.5" PVC
N
29 DEGREES
DECLINATION
100 FT
LAYER
1 MASTER
2 FENCE
3 ANNOTATION
4 V-I ANTENNAS
5 NEW CLEARING
6 OTH ANTENNAS
7 FEEDLINES
GEOPHYSICAL INSTITUTE
SHEEP CREEK FIELD SITE
FIELD SITE PLAN VIEW
DRWG# DISS/SHPCKPV/001
21 OCT 1988
B. DELANA

Figure A

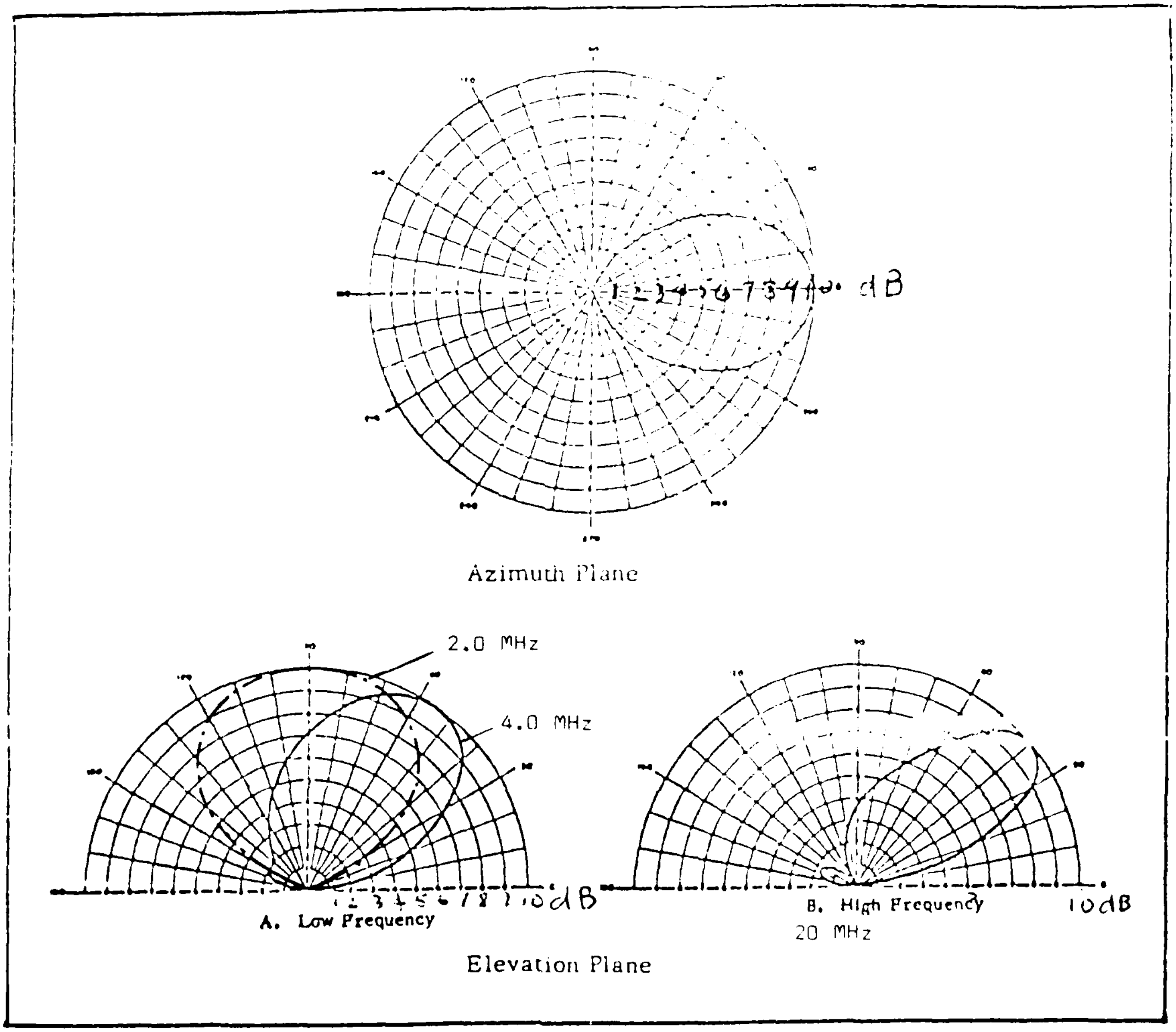


Figure 5 Radiation Patterns in Relative Field Strength.

TABLE 2 SPECIFICATIONS

Frequency Range:		2-30 MHz.(4-30 MHz optional.)
Polarization:		Horizontal
Directive Gain:		8 db above isotropic at 2 MHz 13 db above isotropic at 30 MHz
Azimuth Plane Beamwidth:		60° nominal (omnidirectional at 2 MHz)
Elevation Plane Beamwidth:		95° at 2 MHz 32° at 30 MHz
Take-Off angle (above horizon):		90° at 2 MHz 27° at 30 MHz
VSWR:		2.5:1 at 2 MHz, 2.1: Nominal (4-30 MHz)
Front to Back Ratio:	4-30 MHz	14 db nominal
Side Lobe Level:	4-30 MHz	-14 db nominal

Model No	Frequency (MHz)	Power Handling Cabability (KW)	Impedence (Ohms)
747F CD-2	2 - 30	Receive only	50 (75 optional)
747F CD-3	2 - 30	1/2	50
747F CD-7	2 - 30	10/30	50
747F CD-9	2 - 30	2.5/30	50
747F CD-42	4 - [illegible]	Receive only	50 (75 optional)
747F CD-43	4 30	1/2	50
747F CD-44	4 - 30	20/30	50
747F CD-47	4 - 30	10/30	50
747F CD-49	4 - 30	20/30	50

Environment:		120 mph wind with no ice 90 mph wind with ½" radial ice
Tower Height:		75 feet (22.8m)
Site Area Requirement:	2-30 MHz	326' (99.4 M) in radiating direction 318' (97.0 M) wide
	4-30 MHz	192' (58.6 M) in radiating direction 315' (95.1 M) wide

Amplifiers (FPA), identical to the standard D-256 FPA. Each FPA receiver tap couples the return signals from its associated LPA to a low-noise RF preamp. The preamp output is routed to the D-256 Antenna Switch chassis, which has been modified to incorporate support for the two additional receiver signals. The two-antenna/FPA system should provide nominally 13 dB of effective gain over the range of frequencies of interest. A block diagram of the backscatter system is shown in Figure 6. The *radio horizon* for the Sheep Creek Site is shown in Figure 7, and a photo of one of the oblique backscatter antennas is presented in Figure 8. The D-256 Processor/Transceiver has been augmented with a dedicated 9-track tape drive and printer. The peripherals record all backscatter and vertical-incidence (V-I) ionograms for subsequent analysis.

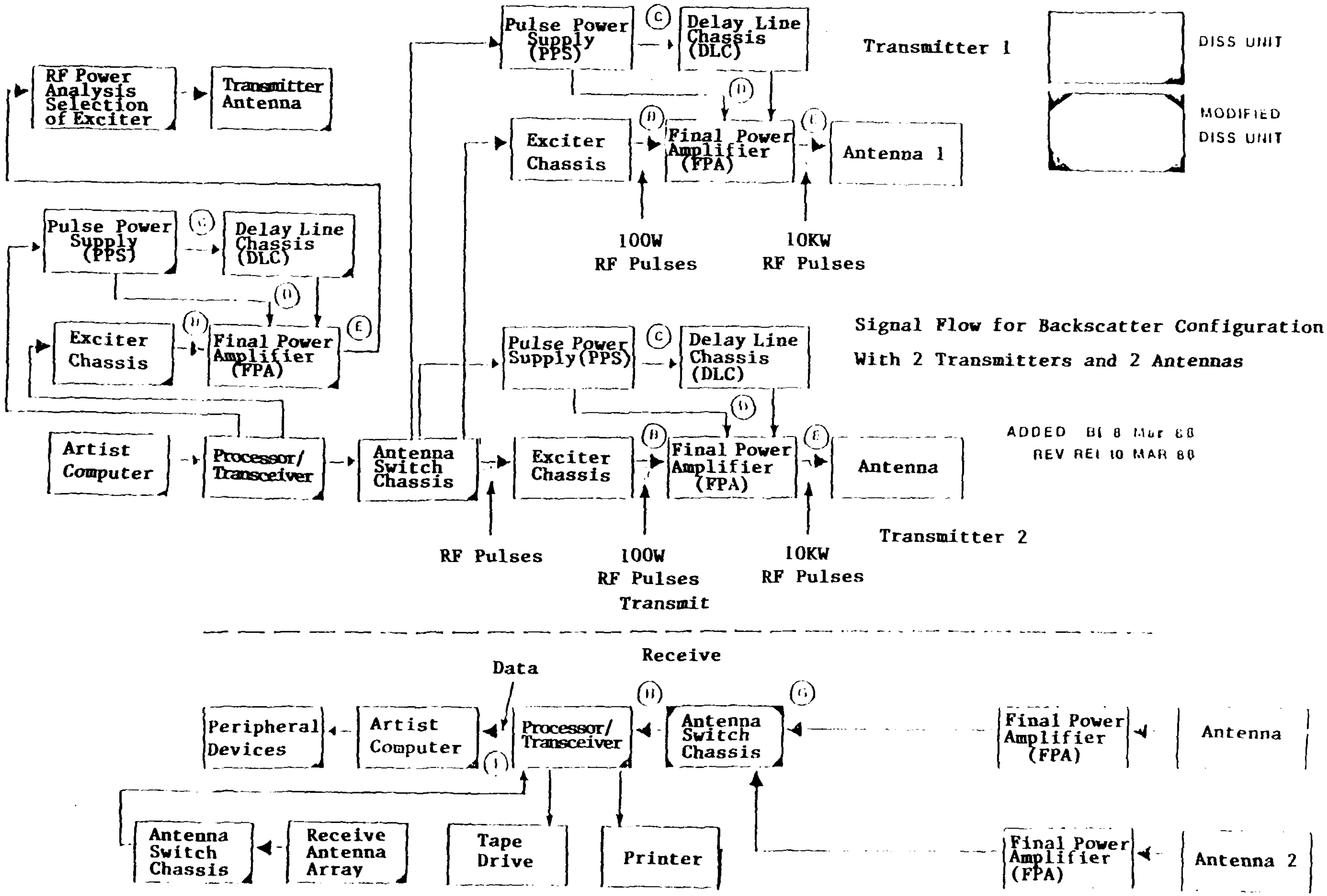
C. <u>Chronology</u>:

1.	Notice to Proceed	-	July 16, 1987
2.	Initial Site Preparation	-	Sept./Oct. 1987
3.	Antenna Installation	-	Aug./Sept. 1988
4.	D-256 Modification	-	Sept. 1988
5.	Start of Data Acquisition	-	September 24, 1988

D. <u>Backscatter Operations</u>: The D-256 backscatter system was accepted fo service on September 24, 1988. A routine schedule of V-I and backscatter ionograms was instituted, consisting of V-I ionograms at each quarter hour interspersed with backscatter ionograms. Two distinct backscatter modes are implemented, one which accentuates ground scatter and the other which is more sensitive to aurorally-induced scatter.

The backscatter system has operated without significant interruption since start-up.

Figure 6



Signal Flow for Backscatter Configuration With 2 Transmitters and 2 Antennas

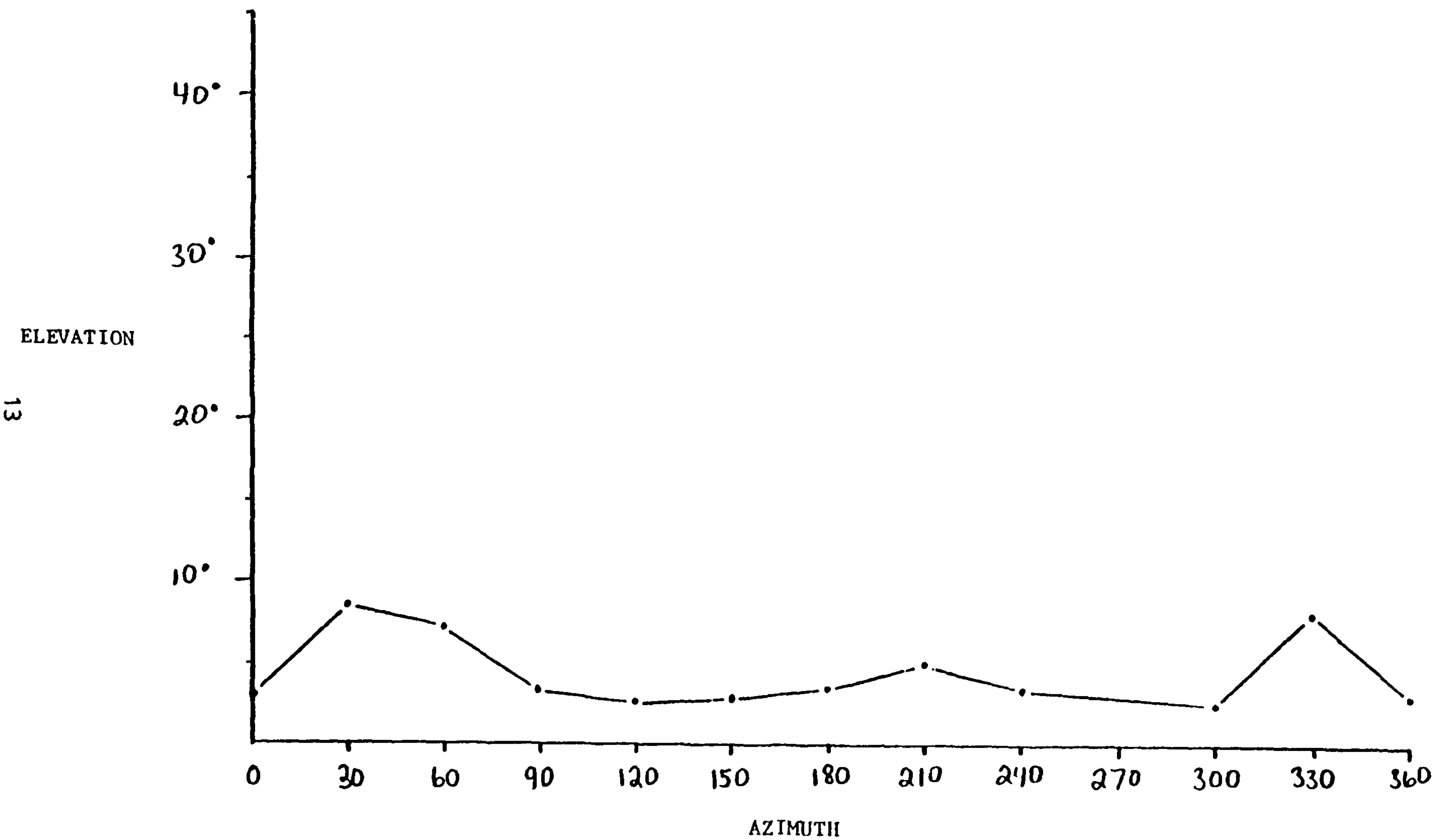


Figure 7. Sheep Creek Station, horizon mask

Figure 8

III. Examples of Vertical Incidence and Backscatter Data

General Characterization of Geophysical Conditions During the Observing Period (Fall - Winter 1988-1989): From all reports (NOAA/SGD, 1989) sunspot Cycle 22 is increasing toward its maximum at a rate greater than even Cycle 19 — which was the largest maximum previously reported. Thus, rapid changes in the character of the vertical ionograms and in the oblique backscatter traces obtained from the College, Alaska, sounder might be expected. Figure 9 is a recent plot (NOAA/SGD, 1989) showing the previous sunspot cycle and the progression of Cycle 22.

A. Fall 1988 --- Figures 10, 11, and 12 are examples of ionograms obtained in our 3 basic sounding modes at College. Figure 10 is a vertical ionogram, with the frequency sweep range from ~500 kHz to 10 MHz on the abscissa, and the ordinate showing two scales of 0 to 700 km each. The bottom plot is related to the amplitude of the ionospheric echo, and the top plot displays the "STATUS" (which contains information on the polarization and the "2D" location of the individual echoes). "OPTIFONT" characters are used in these plots to quantify each point. The optifont values can be combined with the numerical values along the top and bottom of the abscissa to yield the echo *signal strength*. Optifont provides digital information in a font where the number of dots composing each character is proportional to its numerical value. Therefore, the darker the point in the lower plot appears, the larger is the amplitude. Displayed are 16 amplitude levels (4 bits) in number 0 to 15 with ~4 dB per level for the >60 dB dynamic range of the receiver. Some of the *standard ionogram parameters* obtained from Figure 10 (October 13, 1988 at 2244 UT) are : f min $\simeq$ 2.8 MHz, and foF2 $\simeq$ 9.8 MHz. (150° Western Meridian Time = UT - 10 hours).

OBSERVED AND ONE-YEAR-AHEAD PREDICTED SUNSPOT NUMBERS

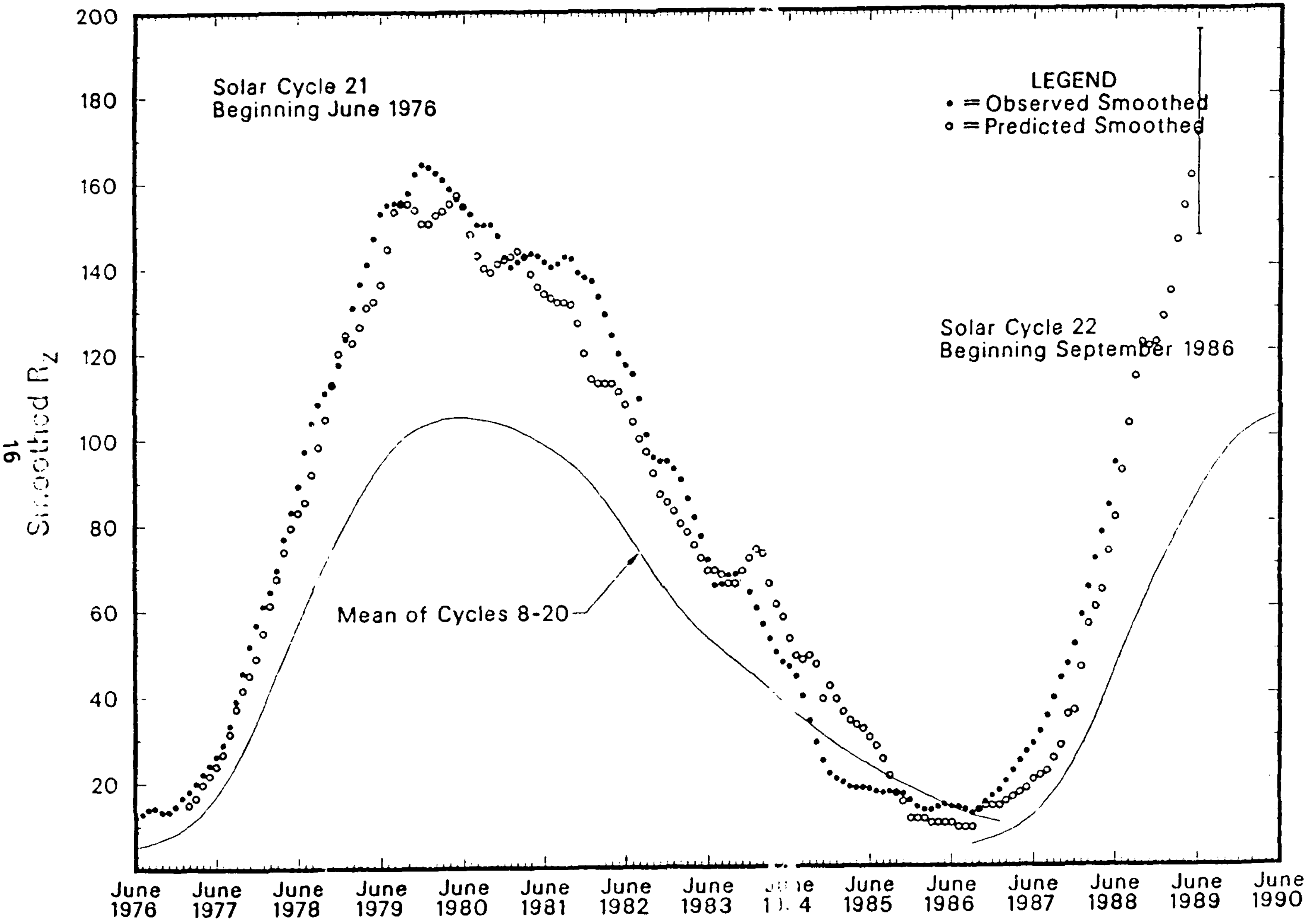


Figure 9

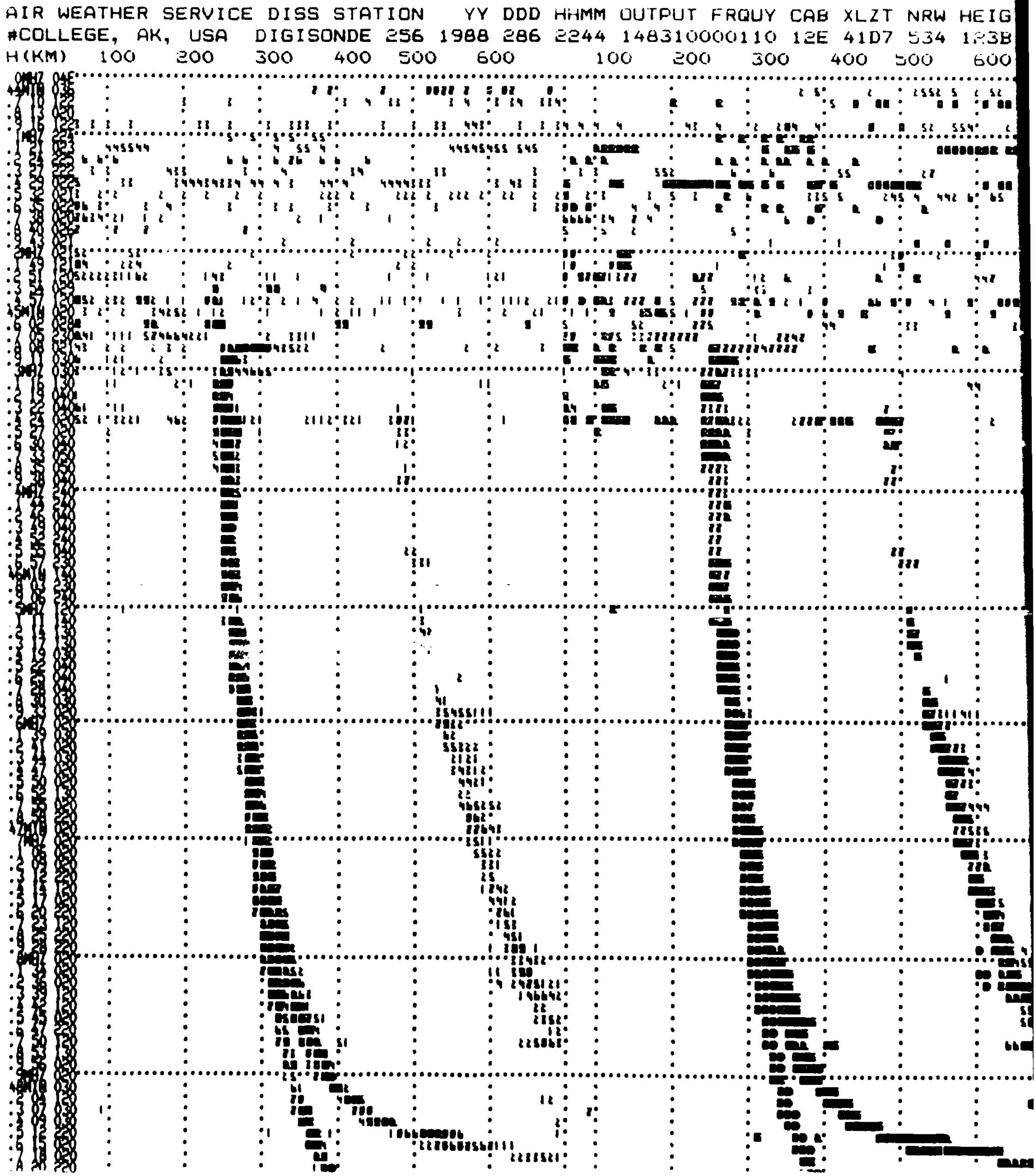
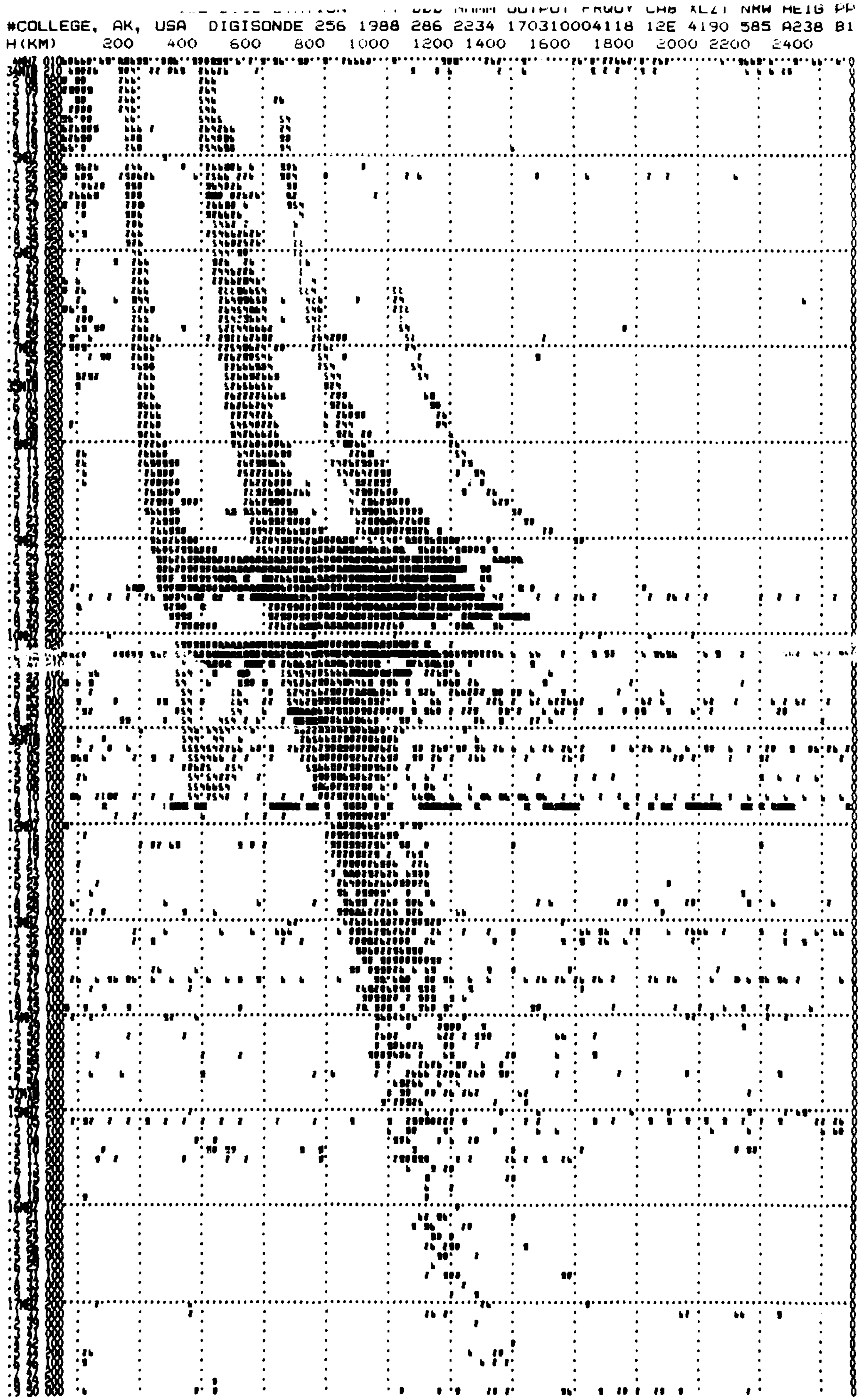

AIR WEATHER SERVICE DISS STATION YY DDD HHMM OUTPUT FRQUY CAB XLZT NRW HEIG
#COLLEGE, AK, USA DIGISONDE 256 1988 286 2244 148310000110 12E 41D7 534 123B
H(KM) 100 200 300 400 500 600 100 200 300 400 500 600

Figure 10

Figure 11

13 Oct. 1988



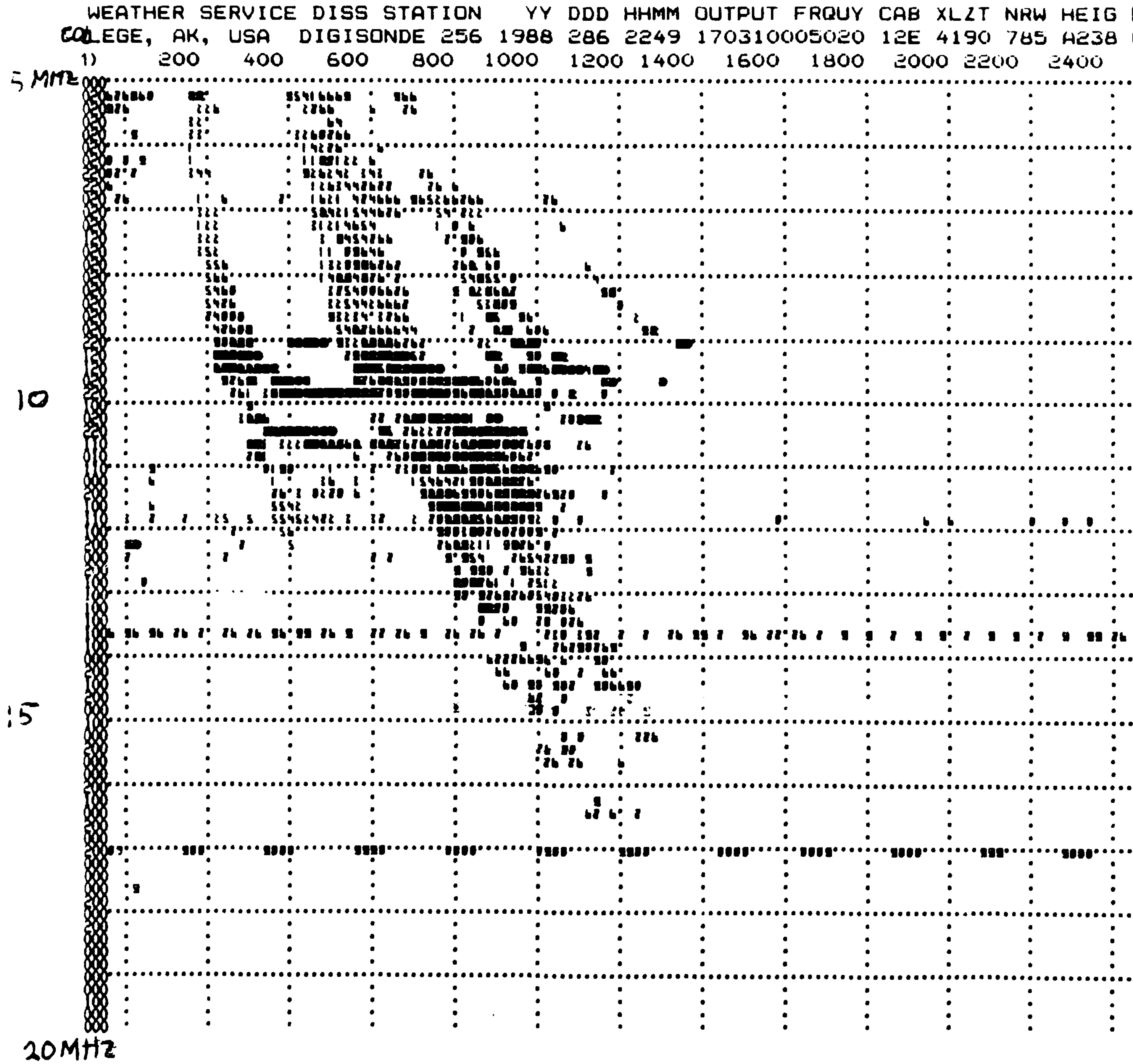

WEATHER SERVICE DISS STATION YY DDD HHMM OUTPUT FRQUY CAB XLZT NRW HEIG
COLLEGE, AK, USA DIGISONDE 256 1988 286 2249 170310005020 12E 4190 785 A238
1) 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
5 MHz
10
15
20MHz

Figure 12

Figure 11 illustrates our "B1" mode which sweeps in frequency from 4 MHz to 18 MHz in 100 KHz steps with a path length (Group Path) range from ˜50 - 2400 km. Each individual character is coded in OPTIFONT and represents the ULCAR "STATUS" value -- which includes amplitude and Doppler information based on 64 samples at each frequency (see Table 3). The B1 mode utilizes our Log-Periodic oblique antennas for both transmit and receive, in contrast to the A1 mode which uses a TCI 613F Broadband Dipole antenna for transmitting, and seven turnstile antennas in the receiving array.

The B1 operating mode shown in Figure 11 displays some E-layer returns at ˜100 km range, and the first, second, third and fourth multiples of the F-region vertical incidence traces. As discussed by Peterson (1951), Dieminger (1951), and Bates (1960), the *groundscatter* trace is tangential to the 2nd order VI trace, and is quite identifiable on this record from ˜10 - 14 MHz. The echoes extending from the 1st order VI trace at ˜10.3 to 11.7 MHz and from the 2nd order VI trace at ˜14 - 16.8 MHz are *auroral or ionospheric clutter* echoes. These represent specular reflection from large-scale irregularities, showing both low and high path modes via the oblique path to the irregularity.

The other backscatter mode utilized in this investigation is the C1 mode shown in Figure 12, which sweeps in frequency from 5 - 20 MHz in 200 KHz steps covering ˜100 -2400 km in range. This mode uses a longer integration time (256 samples per frequency) than in mode B1, and hopefully, will increase the signal-to-noise ratio of clutter echoes which are semi-stationary such as the ground. As in the example of Figure 11, the 1st, 2nd, 3rd and 4th order VI traces plus the groundscatter trace are recognizable. There are clutter echoes extending from the 1st and 2nd order VI traces in Figure 12.

Table 3

Status Table for Current Sounder Modes at Sheep Creek

1. VI Z T H X
D 7 1 4 (for actual Doppler values, see Table 5.7 in Bibl et al, 1981)

Azimuth Sequence

Code Table 5.9 (Bibl)	N	P	X	S	U	F	L	V
°E of N	0°	300°	240°	180°	120°	60°	X	0
Status #s								
+ Doppler	8	9	10	11	12	13	14	15
- Doppler	0	1	2	3	4	5	6	7

all oblique echoes have O-polarization and X&0 are vertical

Actual Dopplers are ± 1/2T for T = 3
± 1/T for T = 7

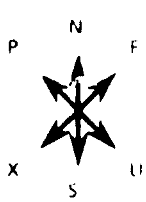
2. Backscatter/BI/CI Mode
One Antenna only 128 height ranges → ± 8 Doppler
Presently used 256 height ranges → ± 4 Doppler (see Bibl Table 5.7)

Z T H X
9 0 A 4 for actual Doppler values (see Bibl Table 5.7)

Doppler #s

Status from upper of two bins	-- 0 / 1	← 2 / 3	← 4 / 5	- 6 / 7	+ 8 / 9	→ 10 / 11	→ 12 / 13	+ + 14 / 15	
Status from lower of two bins	$-\frac{7}{2T}$	$-\frac{5}{2T}$	$-\frac{3}{2T}$	$-\frac{7}{2T}$	$+\frac{1}{2T}$	$+\frac{3}{2T}$	$+\frac{5}{2T}$	$+\frac{7}{2T}$	←T = 0
Actual Doppler values (Hz)	$-\frac{7}{T}$	$-\frac{5}{T}$	$-\frac{3}{T}$	$-\frac{1}{T}$	$+\frac{1}{T}$	$+\frac{3}{T}$	$+\frac{5}{T}$	$+\frac{7}{T}$	←T = 4

The 256 Range Bin mode is displayed by selecting the bigger amplitude of two adjacent height bins, thereby compressing the ionogram to 128 height bins. ODD status indicates (1 bit activated) that lower of the two bins shown.



L = X
V = 0

(See Bibl Table 5.9)

	N	P	X	S	U	F	L	V	
+	8	9	10	11	12	13	14	14	Status
-	0	1	2	3	4	5	6	7	

B. Spring 1989 --- Figures 13 through 20 illustrate the behavior of the ionosphere during a moderate geomagnetic storm on February 8-9, 1989, and Table 3 summarizes the main features of the vertical and oblique ionograms, plus the College 30 MHz Riometer and earth-current data. Figures 13 and 14 are moderately disturbed days and show rather *spread* echoes, the predominantly low status numbers (0,1,2,3,4 and 5) indicate substantial velocities away from the radar of the whole ionosphere/irregularity structure in the antenna field of coverage. This is likely the signature of the sunward convection westward in the premidnight (CGMCT) sector. Figures 15 and 16 show increased spread in the VI and oblique traces. Figure 17 shows no echoes on the VI trace at 1759 UT — which is indicative of total absorption, and the oblique backscatter sounding at 1806 UT only displayed weak echoes — which is not surprising, since the College 30 MHz Riometer indicated ~6 dB of absorption during those soundings.

Figures 19 and 20 are representative of ionograms observed after the geomagnetic storm subsided. Of particular interest is the backscatter ionogram taken at 0351 UT on 9 February (Figure 20) showing a *clutter* echo at 11.2 -13.4 MHz and range ~940 - 1300 km. There is an indication that this scatter region existed already at 0336 UT (Figure 19) at a range of 1040 km.

From Table 4, we see that the VI traces disappear for values of College Riometer Absorption 3dB<A<6dB. This suggests that the D-256 system sensitivity is at least 2-4 dB greater than the C4 ionosonde previously used at College. Since the Telluric current data represent the strength of the auroral electrojet and hence, electron density overhead, these data probably cannot be related to oblique backscatter.

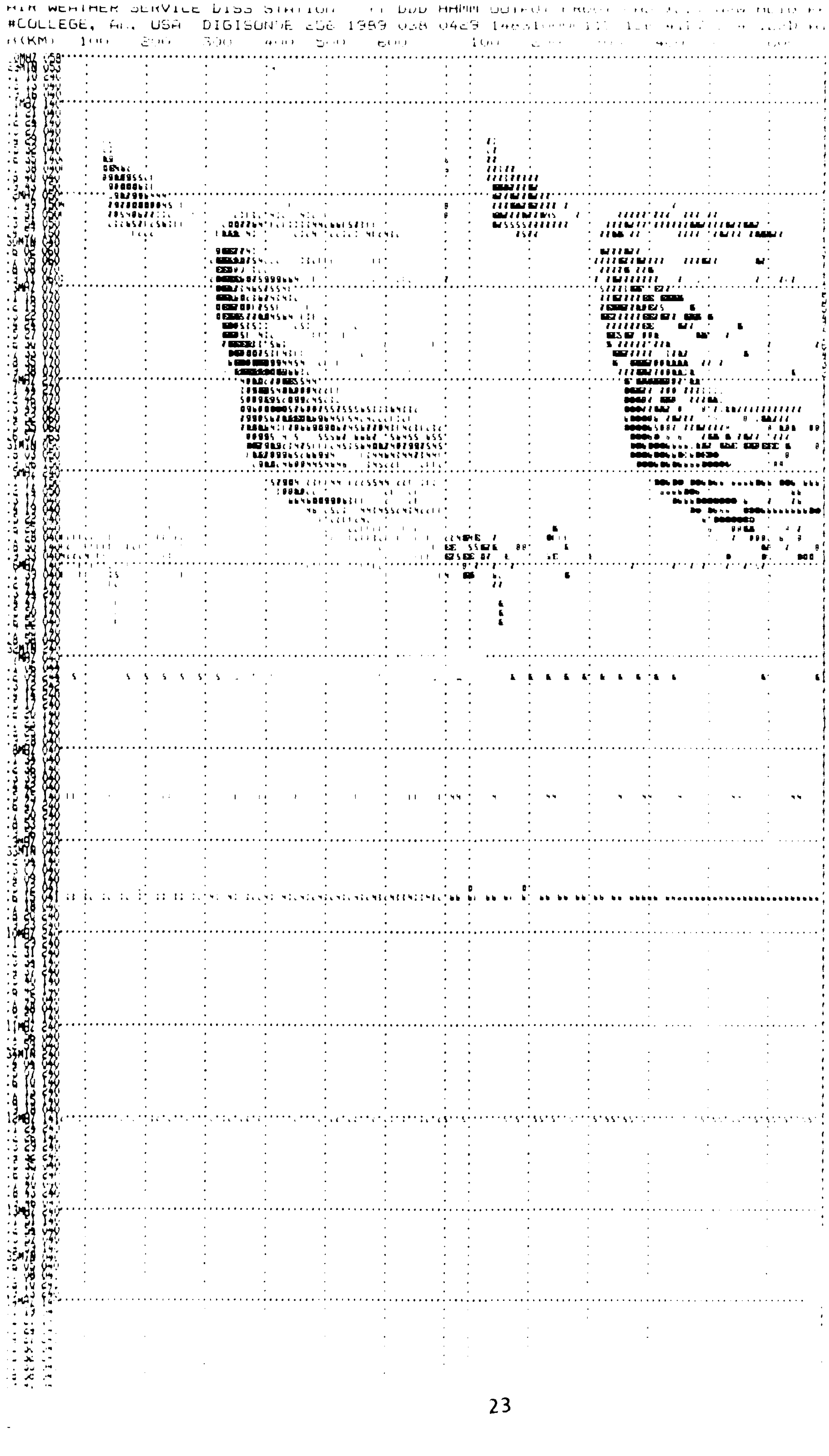


Figure [illegible]

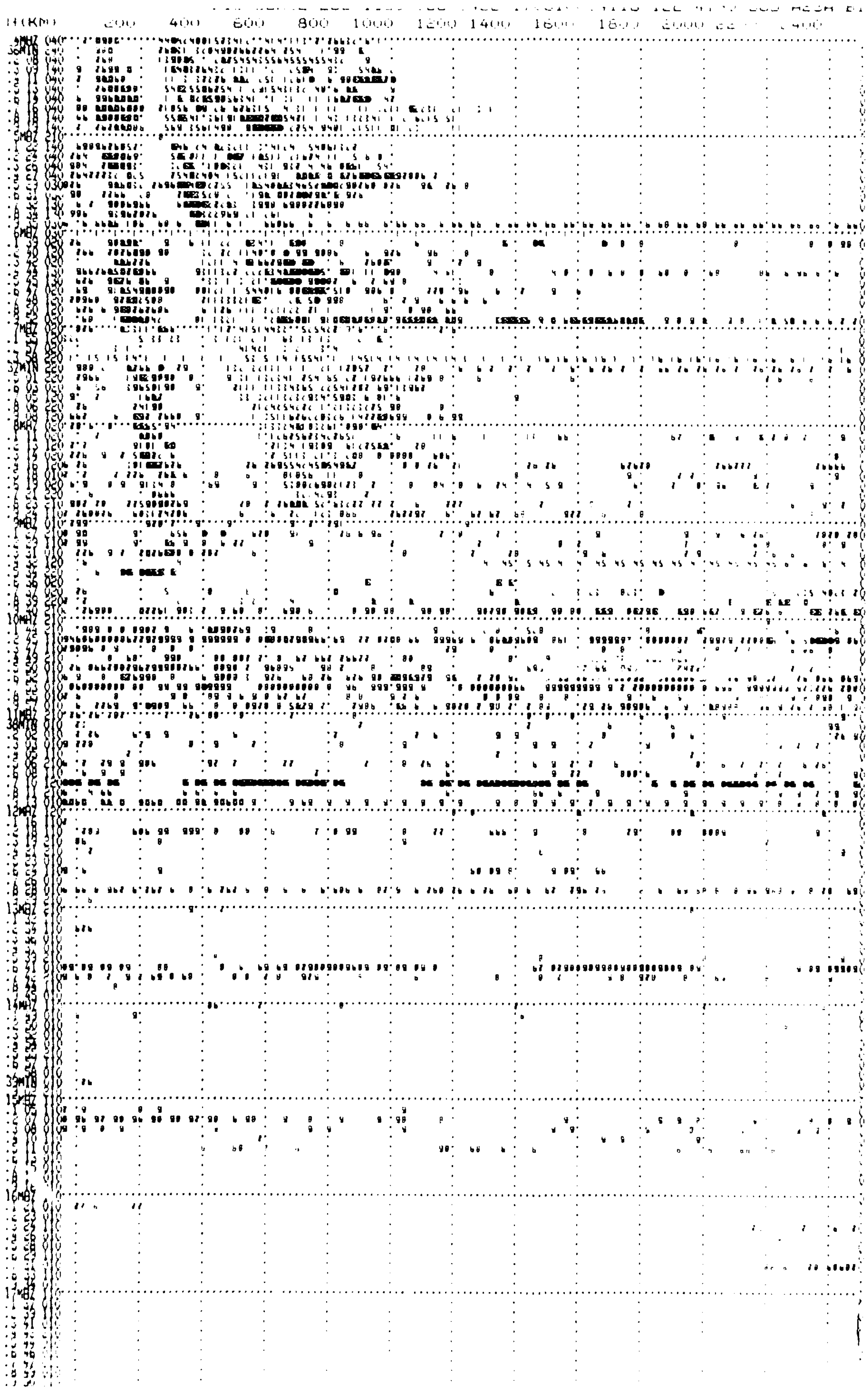


Figure 14

AIR WEATHER SERVICE DISS STATION
#COLLEGE. AK. USA DIGISONDE 256 1989 038 1729 148310000115 12E 41D7 5-4 123D A1

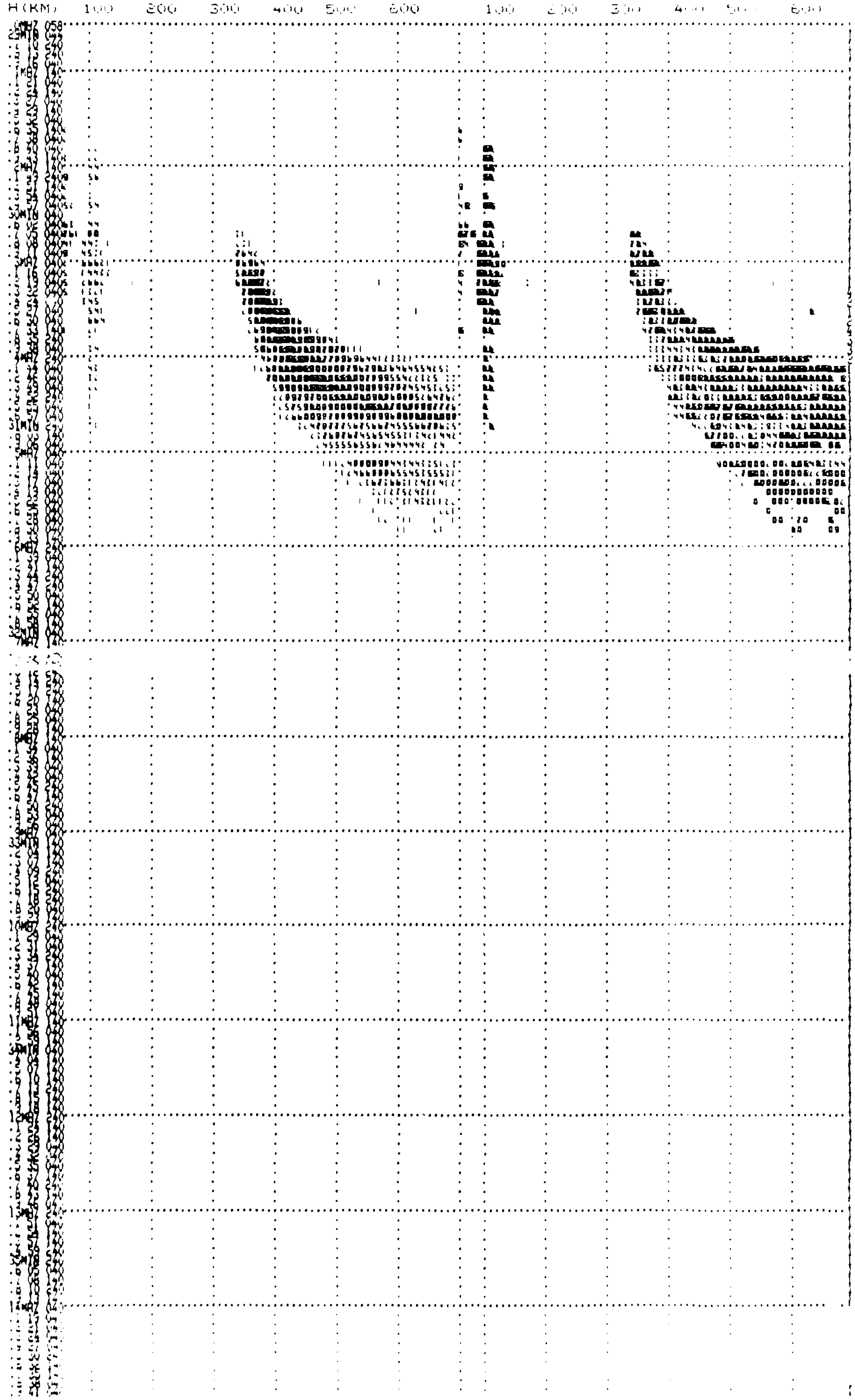


Figure 15

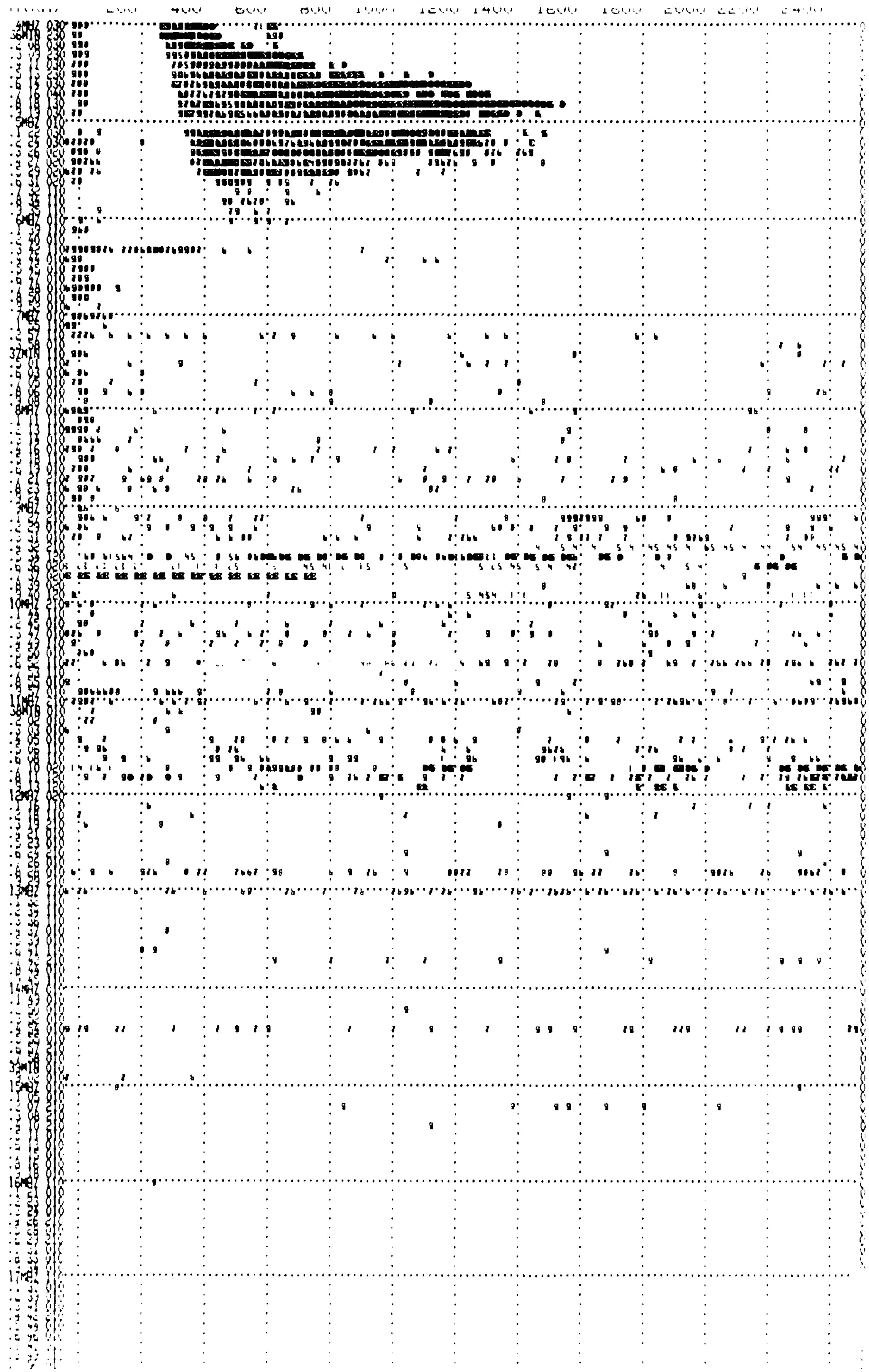


Figure 16

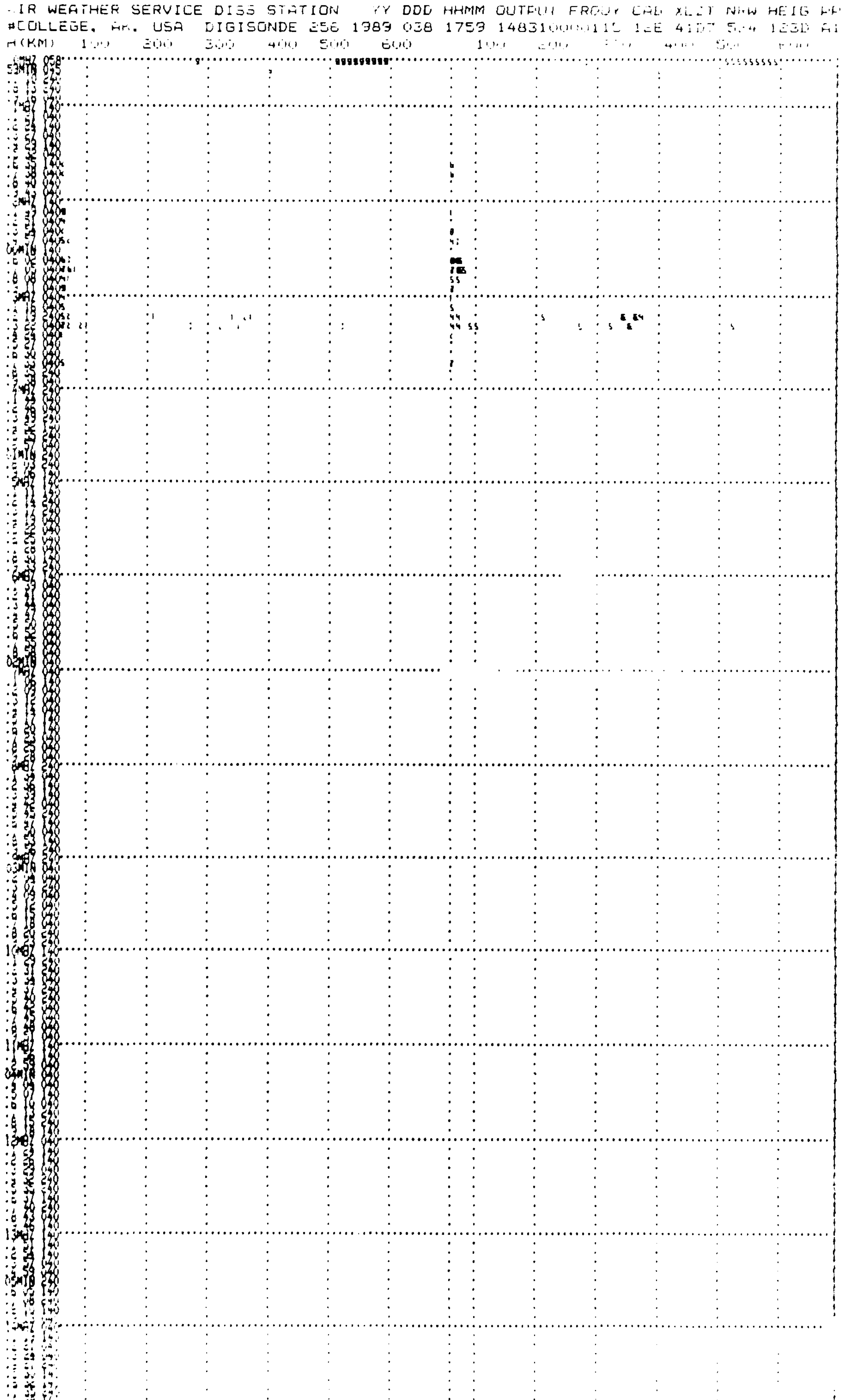

AIR WEATHER SERVICE DISS STATION YY DDD HHMM OUTPUT
#COLLEGE, AK. USA DIGISONDE 256 1989 038 1759
H(KM) 100 200 300 400 500 600

Figure 17

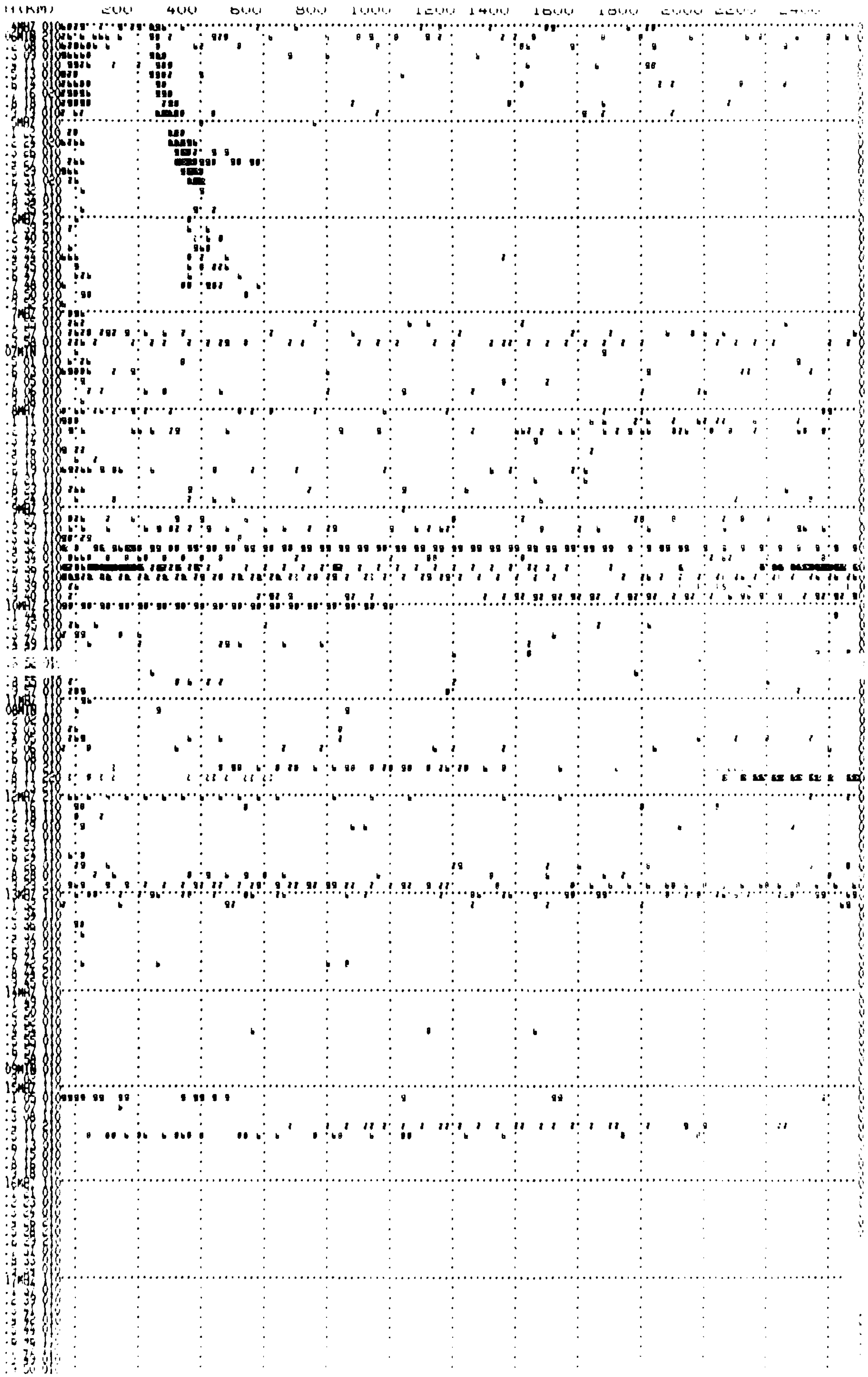
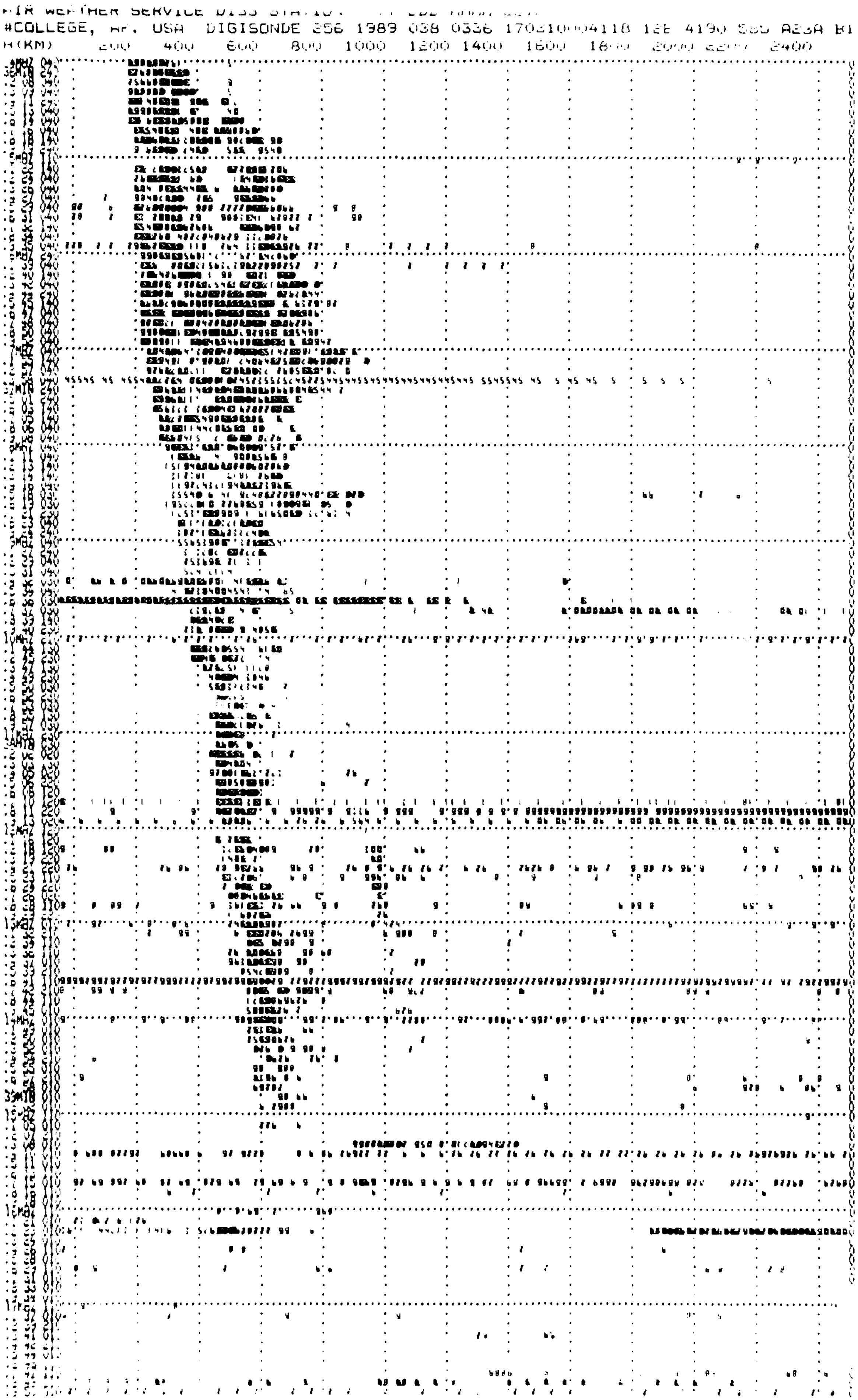


Figure 18



#COLLEGE, AK, USA DIGISONDE 256 1989 038 0336 170310004118 1EE 4190 S85 A23A B1
H(KM) 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400

Figure 19

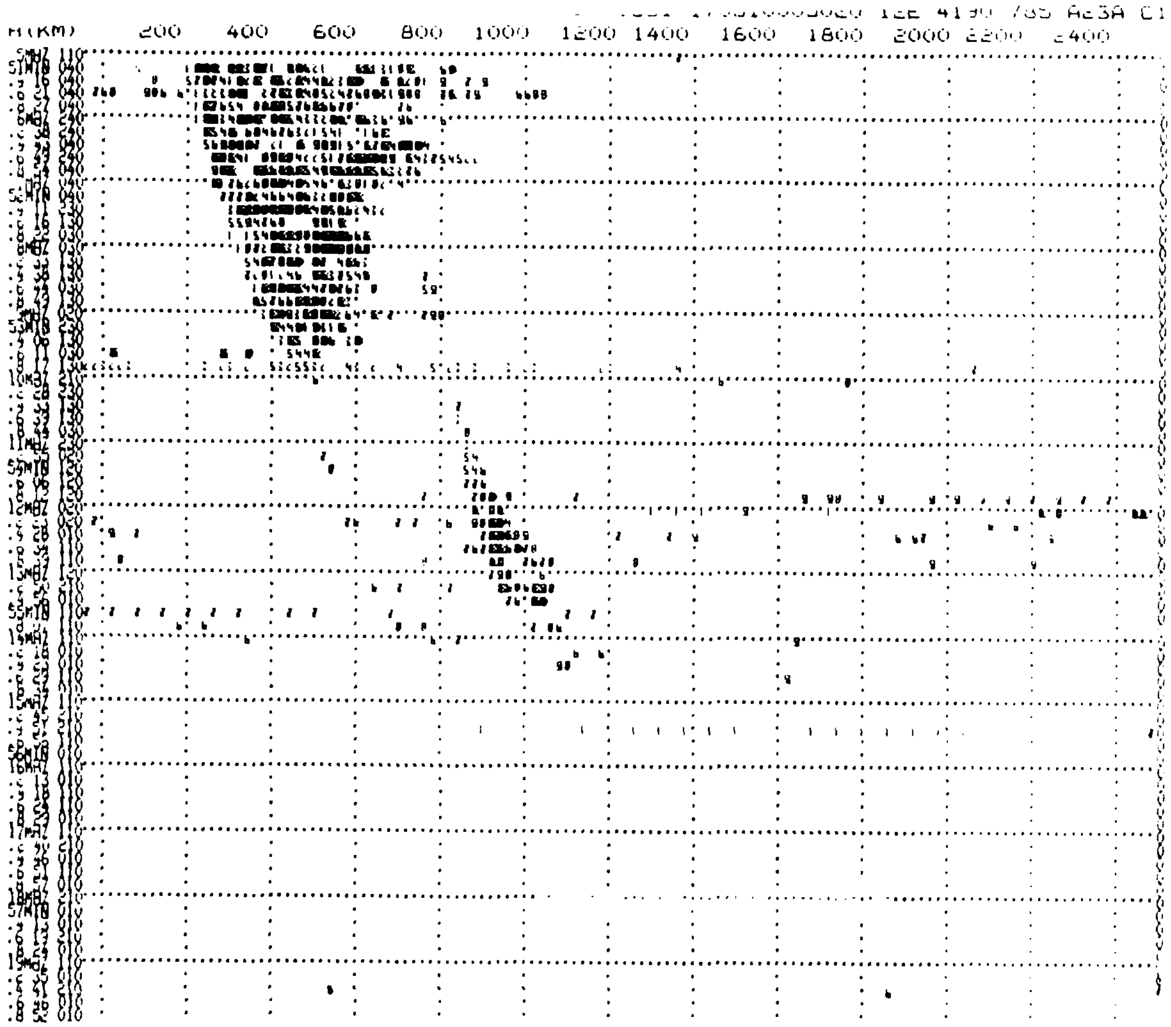


Figure 20

Table 4
VERTICAL AND OBLIQUE IONOGRAMS FROM DAYS 038/039 (FEBRUARY 7-8, 1989) COLLEGE, ALASKA (SHEEP CREEK FIELD SITE)

FIGURE NUMBER	UT	RECORD	REMARKS	30 MHz ABS	EARTH CURRENT AMPLITUDE AT COLLEGE, AK
13	0429	VI	$f_{mp} \simeq 1.4$ MHz $f_oF1 \simeq 2.3$ MHz $f_o F2 \simeq 5.0$ MHz	~0 dB	~0/4
14	0436	OB	slant-F from ~4-9 MHz ΔR ~180-1200 km	~0	~0/4
15	1729	VI	$f_{mp} \simeq 2.6$ MHz $f_oF2 \simeq 4.4$ MHz spread - F	~3dB	~ + 1.0/6
16	1736	OB	F-scatter from ~4-5.8 MHz and ΔR ≃ 250 - 1550 km	~4dB	~ + 2.0/6
17	1759	VI	Essentially no echoes	~6dB	-1.0/6
18	1806	OB	Weak F-scatter Δf ~4-5.7 MHz ΔR ~275-400 km	~6 dB	+ 3.0/4
19	0336	OB	Slant -F out to ~15 MHz	~0.8 dB	~0/4
20	0357	OB	GS(+ Clutter?)	0.5 dB	~0/4

IV. Discussion of Results

A. Selected Examples of Data

HF Backscatter and vertical ionograms have been obtained with the sounder system described in Section II since September 24, 1988. Table 5A is a listing of all the D-256 data recorded on magnetic tape, while Table 4B lists the *hardcopy* data available from our on-site printer. The number of vertical and backscatter soundings per hour has varied since this program started, but there have always been at least 2 vertical incidence and 2 backscatter soundings per hour. Table 5 shows our sounding

Table 5A
D-256 BACKSCATTER DATA LOG

Date: 23 March 1989

Printer Printout

From	To	Notes
1988/263/2229	264/1859	+
264/1944	265/1633	+
265/1644	266/0503	+
268/0138	269/0218	Start-up testing
269/0222	269/0837	+
269/0859	269/1759	+
271/0129	271/1619	
271/1629	274/2029	
275/2344	277/0534	
277/0544	277/1534	Data bad due to end-of-tape
277/1544	277/1604	
277/1604	278/0059	Data lost due to printer jam
278/0059	278/1434	
278/1434	278/1546	Data lost due to power failure
278/1546	279/1949	
279/1949	280/0144	Data lost due to power failure
280/0149	282/1919	
282/1929	282/2019	Data lost due to power failure
282/2019	284/1134	
284/1134	284/1551	Data lost due to end-of-paper
284/1559	285/2359	
285/2359	286/0159	Data lost due to power failure
286/0159	286/2219	
286/2219	290/1144	
290/1144	291/1600	Data lost due to printer jam
291/1600		B/S Printer shut down
1989/024/0151	024/0844	B/S System Restart
034/2044	035/0159	
062/0252	065/1637	System hung at 17.6 MHz from 062/1922-063/0224
067/0237	068/0327	System hung at 4.9 MHz from 067/2037-068/0327
069/0159	069/1644	A grams no good - FPA underperforming
072/1707	075/0300	A FPA back online at 074/1815
080/1649	086/1552	

Table 5B

D-256 BACKSCATTER DATA LOG

Date: 04 April 1989

Tape Drive Data

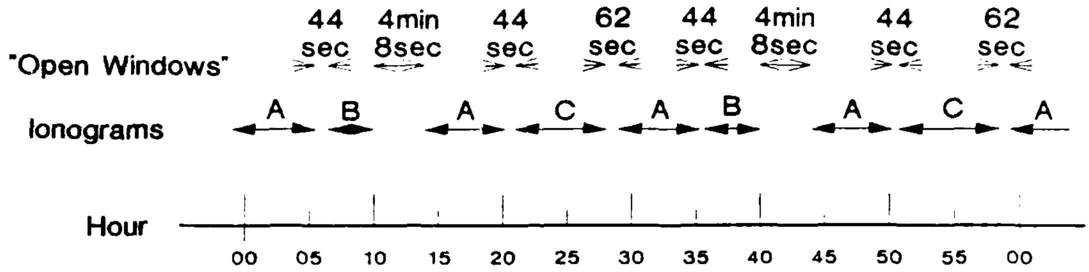
Tape On	EOData	Tape #	Notes
88/268/0330	277/0544	88/01	TRO @ 277/0544, 277/0544-1540 no data
88/277/1540	278/1540	88/02	PF @ 278/1436, 278/1436-1540 no data
88/278/1542	279/1949	88/02	PF @ 279/1950, 279/1949-280/0137 no data
88/280/0137	282/1919	88/03	PF @ 282/1919, 282/1919-282/2019 no data
88/282/2018	285/2359	88/04	PF @ 286/0000, 285/2359-286/0159 no data
88/286/0159	293/1556	88/05	
88/293/1555	298/1734	88/06	
***** 298/1734 to 304/2350 no data logged during AF Training Session *****			
88/304/2350	312/1658	88/07	TRO unsure of last gram on tape
88/312/1700	319/1650	88/08	See Note 1. No A grams since 319/1200
88/319/1650	319/2325	88/09	See Note 2. No A grams on this tape.
88/319/2335	333/1645	88/10	TRO No A grams on this tape.
88/333/1656	338/1850	88/11	PF 338/0717. 338/0717-1850 no data
88/338/1850	343/1645	88/12	PF 343/0625. 343/0625-1659 no data
88/343/1650	350/1653	88/13	
88/350/1655	358/0255	88/14	TRO
88/358/0300	365/0140	88/15	
88/365/0145	89/002/0312	88/16	System shut down @ 002/0312
	System shut down from 002/0312 through 024/0151 pending renewal		
89/024/0151	030/1714	89/001	System restarted on Day 024
030/1750	034/????	89/002	PF about 1800UT
034/2026	043/0336	89/003	TRO
043/0340	046/0226	89/004	DISS Rack AC Trip sometime after 045/1830
046/0235	052/2320	89/005	
052/2321	056/08??	89/006	PF between 0800 and 0900 on 056
058/1710	065/1652	89/007	
065/1655	072/1712	89/008	TRO
072/1715	079/1654	89/009	
079/1654	086/1650	89/010	
086/1650	093/2148	89/011	TRO

TRO - Tape Run Out
PF - Power Failure

Notes:

1. V-I transmitter failed between 1100 ands 1200 UT on Day 319. No A grams from this time through end of tape (about 6 hours).
2. While attempting to repair V-I system failure we inadvertently glitched the B/S system causing the B/S tape drive to go offline. The tape was replaced.
3. V-I system returned to service 336/2244UT.

Table 6
D-256 SOUNDING SCHEDULE AS OF 14 FEBRUARY 1989



schedule as of February 14, 1989.

Figure 21 is an ionogram obtained from magnetic tape using Geophysical Institute developed software showing some sporadic-E and 3 multiples of the F-layer for 2304 UT (1300 150 WMT). Although we now have the capability of obtaining vertical and oblique ionograms from the magnetic tape data, our program is slow and not very *user friendly*. We plan to streamline this program to improve its efficiency during the follow-on effort.

B. Ray-Tracing Results

In order to better understand some of the physical mechanisms responsible for the backscatter echoes which we observe, we have utilized a sophisticated 3D ray tracing program developed by Jones and Stephenson (1975). This program has been modified by Kile Baker at JHU/APL and further modified by us to produce plots using various ionospheric models as input to the program. Figures 22, 23 and 24 are plots obtained by using the D-256 vertical ionogram to obtain the E- and F-layer parameters as input to the ray tracing program. The backscatter sounding frequency is 11.3 MHz and the input parameters are foE = 2.6 MHz and foF2 = 9.5 MHz. Figure 22 is for an azimuth of 1.0° True bearing, Figure 23 for an azimuth of 16°, and Figure 24 for an azimuth of 31° (magnetic north). This input model fits parabolic layers to the observed VI data and includes a transverse ionosphere density variation.

The next 5 figures illustrate the behavior of groundscatter range at a given takeoff angle (10°) using the same foE and foF2 values as the preceding figures, ray tracing on the center azimuth of the College sounder, but employing two Chapman layers. The behavior is as expected, with the ground range increasing from ~1400 km at 7.0 MHz to ~1575 km at 15.0 MHz in Figures 25 - 27. Although the range scale on Figure 28 is too short, the E-layer refraction is of interest. The last of this sequence (Figure 29) shows the frequency where groundscatter is no longer obtained at this

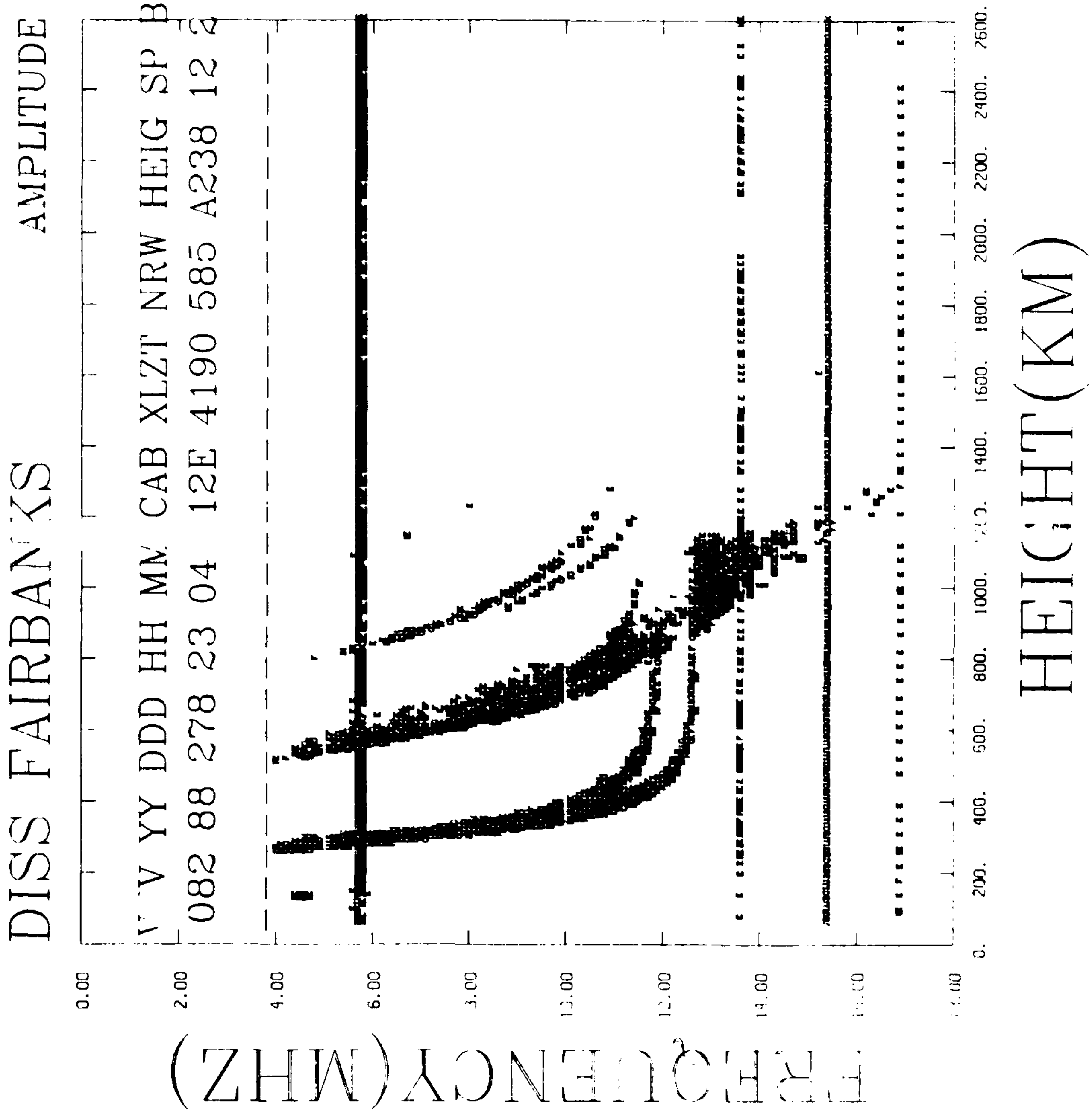


Figure 21

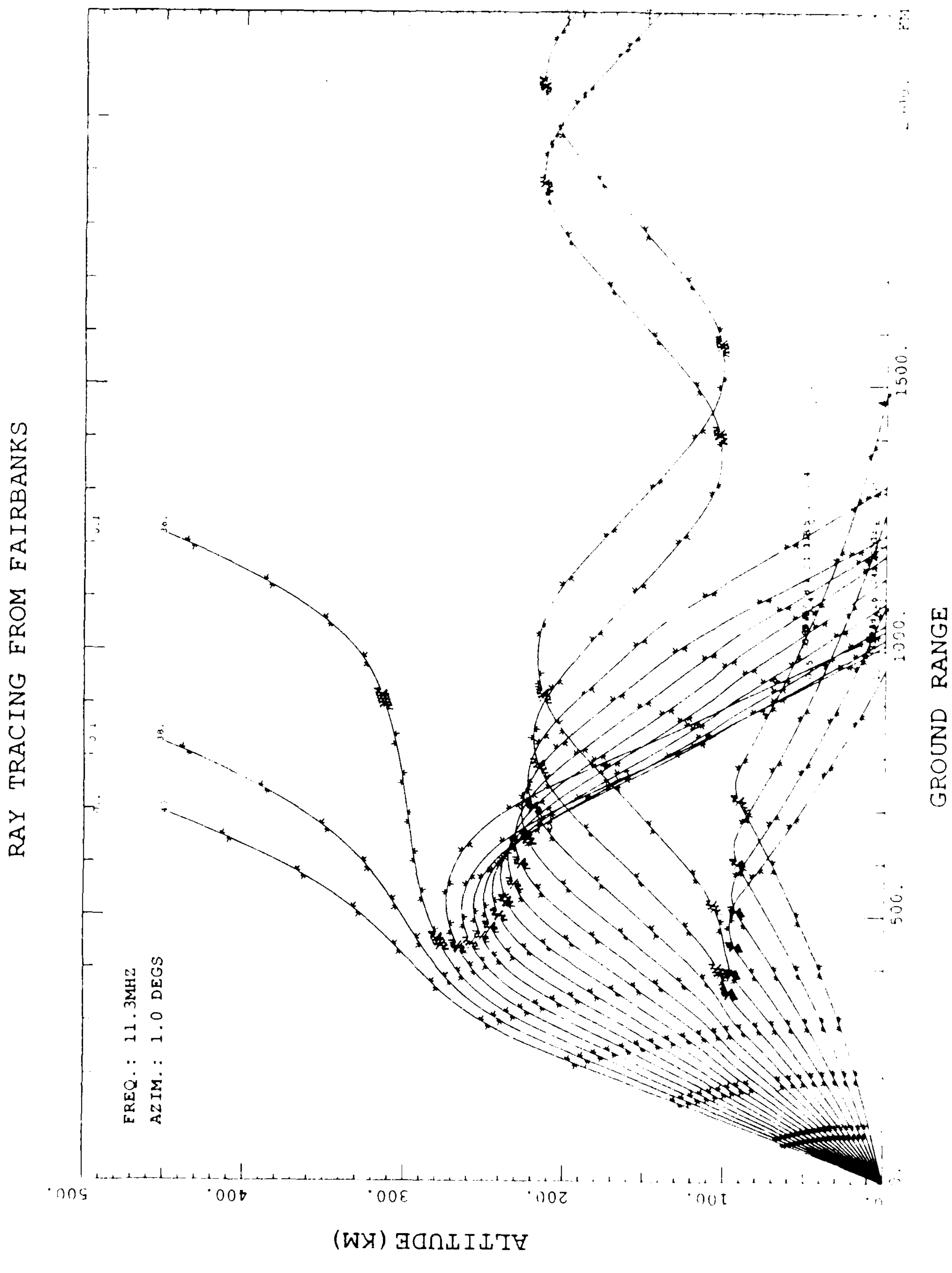
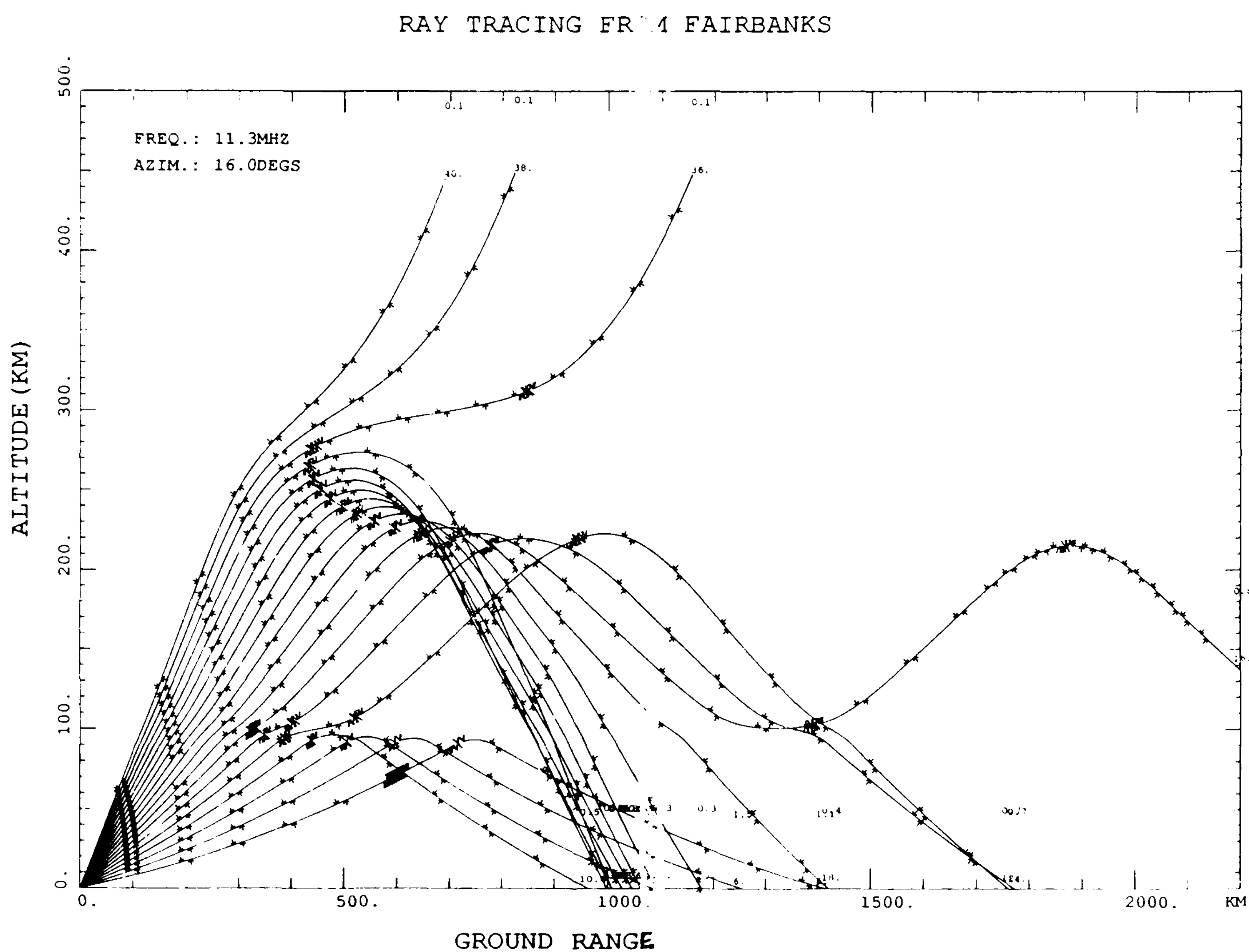

RAY TRACING FROM FAIRBANKS
FREQ.: 11.3MHZ
AZIM.: 1.0 DEGS
ALTITUDE (KM)
GROUND RANGE
500.
1000.
1500.
100.
200.
300.
400.
500.

Figure 2[illegible]



RAY TRACING FR M FAIRBANKS
FREQ.: 11.3MHZ
AZIM.: 16.0DEGS
ALTITUDE (KM)
GROUND RANGE
0.
500.
1000.
1500.
2000.
KM
100.
200.
300.
400.
500.

Figure 23

RAY TRACING FROM FAIRBANKS

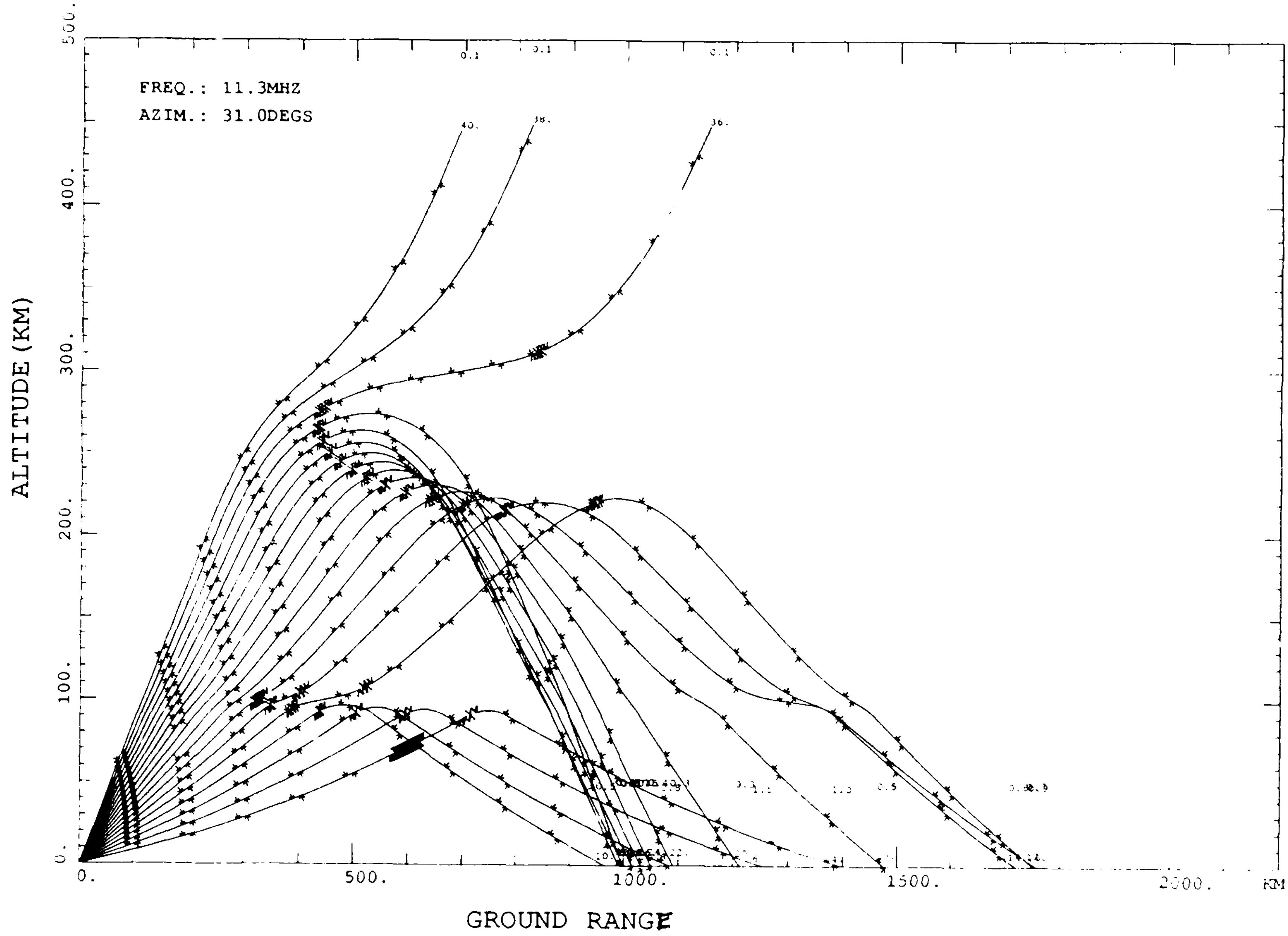


Figure 24

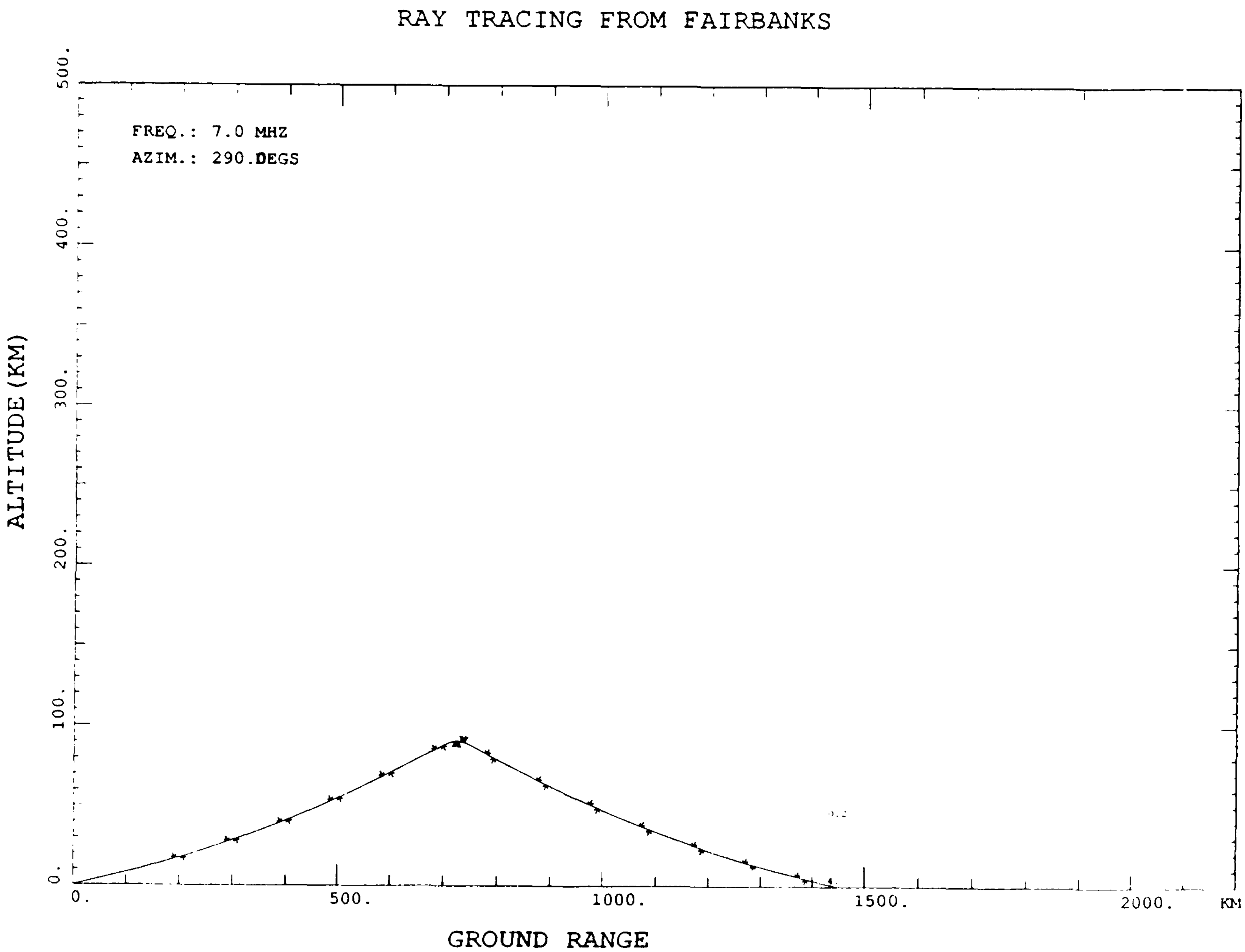

RAY TRACING FROM FAIRBANKS
FREQ.: 7.0 MHZ
AZIM.: 290.DEGS
ALTITUDE (KM)
0.
100.
200.
300.
400.
500.
0.
500.
1000.
1500.
2000.
KM
GROUND RANGE

Figure 25

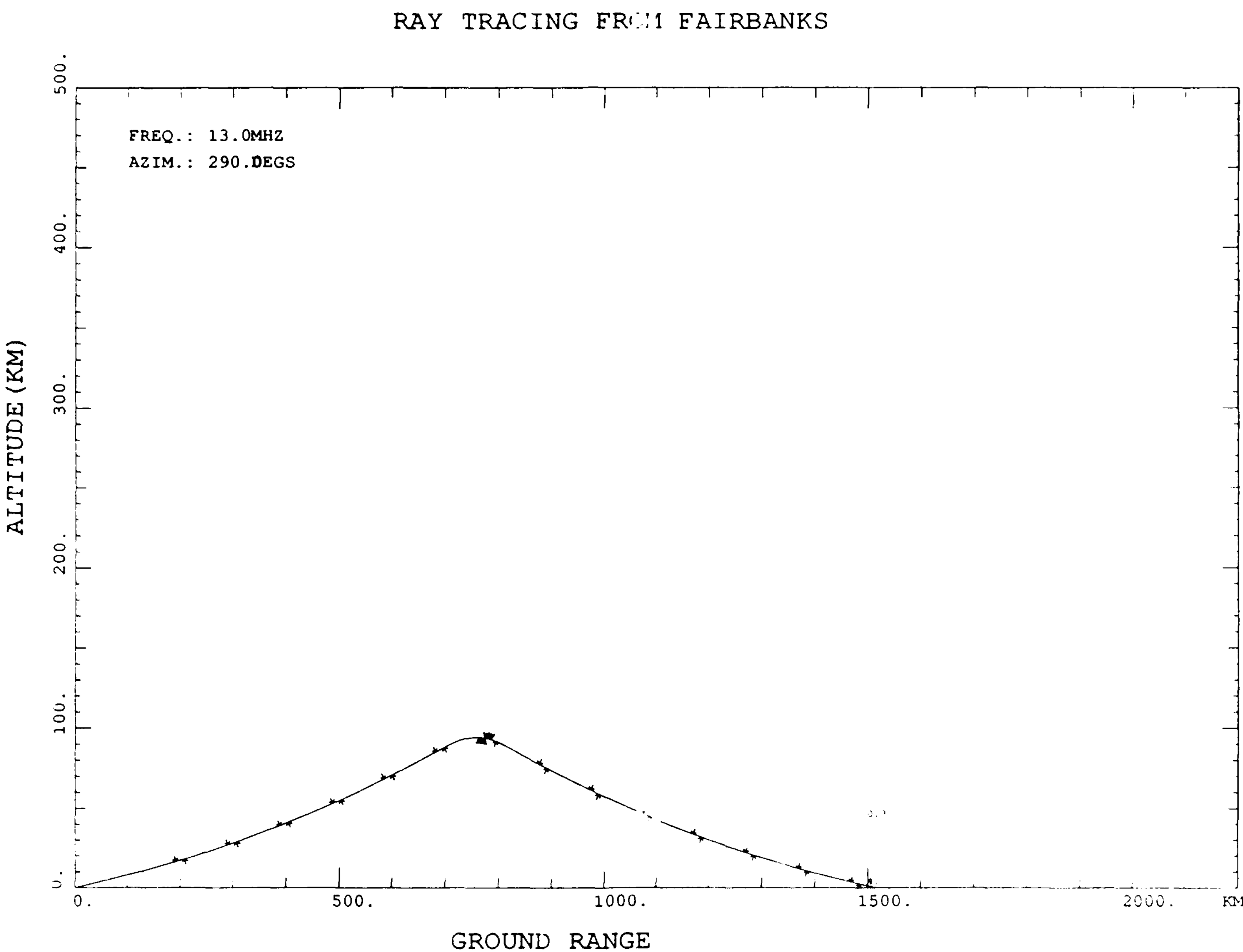

RAY TRACING FR·M FAIRBANKS
FREQ.: 13.0MHZ
AZIM.: 290.DEGS
ALTITUDE (KM)
500.
400.
300.
200.
100.
0.
0.
500.
1000.
1500.
2000.
KM
GROUND RANGE

Figure 26

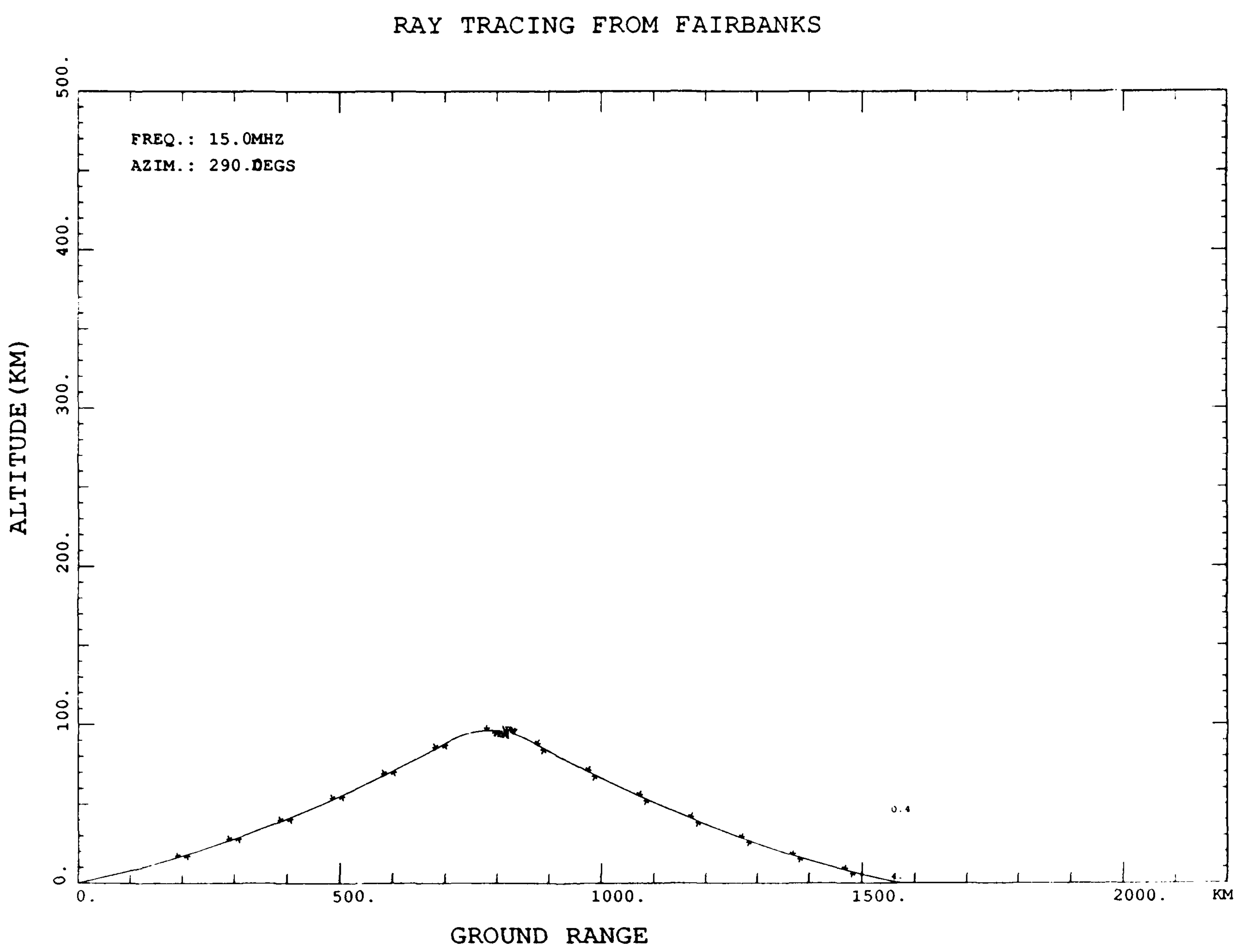

RAY TRACING FROM FAIRBANKS
FREQ.: 15.0MHZ
AZIM.: 290.DEGS
ALTITUDE (KM)
0.
100.
200.
300.
400.
500.
0.
500.
1000.
1500.
2000.
KM
GROUND RANGE

Figure 27

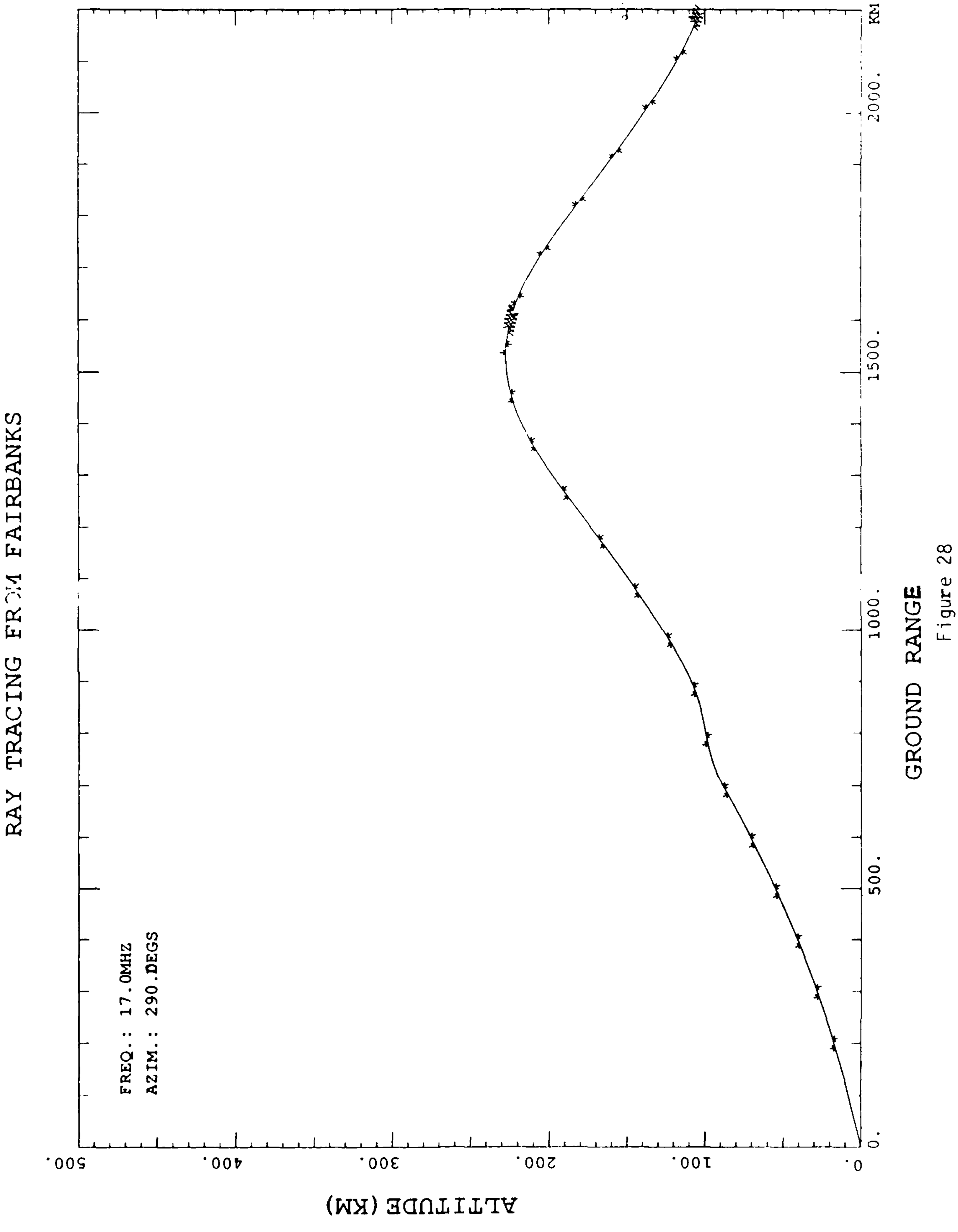

RAY TRACING FROM FAIRBANKS
FREQ.: 17.0MHZ
AZIM.: 290.DEGS
ALTITUDE (KM)
0.
100.
200.
300.
400.
500.
GROUND RANGE
0.
500.
1000.
1500.
2000.
KM

Figure 28

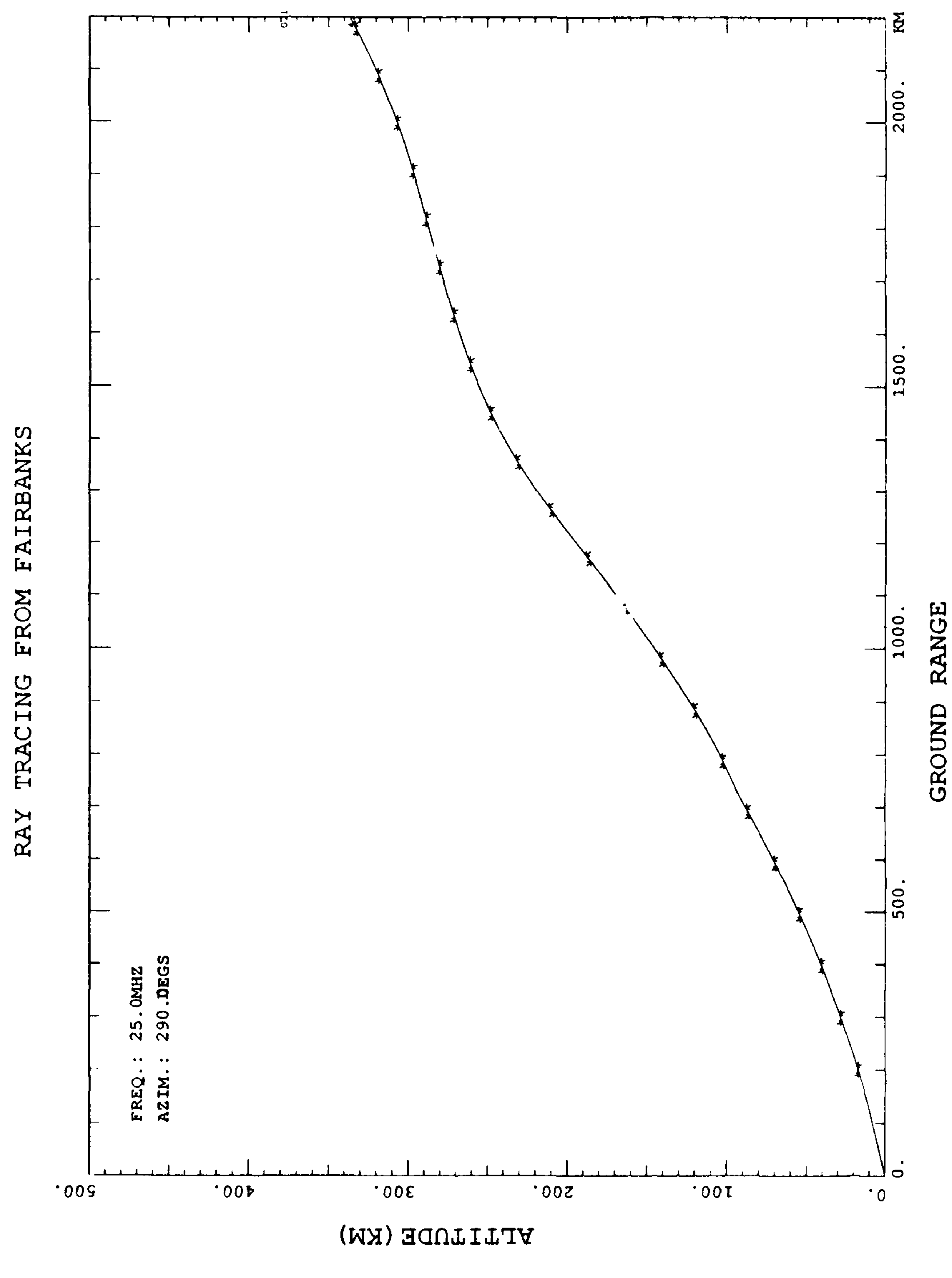

RAY TRACING FROM FAIRBANKS
FREQ.: 25.0MHZ
AZIM.: 290.DEGS
ALTITUDE (KM)
0.
100.
200.
300.
400.
500.
GROUND RANGE
0.
500.
1000.
1500.
2000.
KM

Figure 29

elevation angle.

During the follow-on effort we plan to utilize the 3D ray tracing program with some typical isoionic contours obtained with the Chatanika Incoherent Scatter Radar (ISR) meridian scan mode as input to study the effect of field-aligned F-region irregularities *blobs* on our HF backscatter ionograms (Hanuise et al., 1985). We plan to include an ionosphere with electron density irregularities imbedded in it and ray trace through this model on selected azimuths and frequencies pertinent to the Alaska OTH radar.

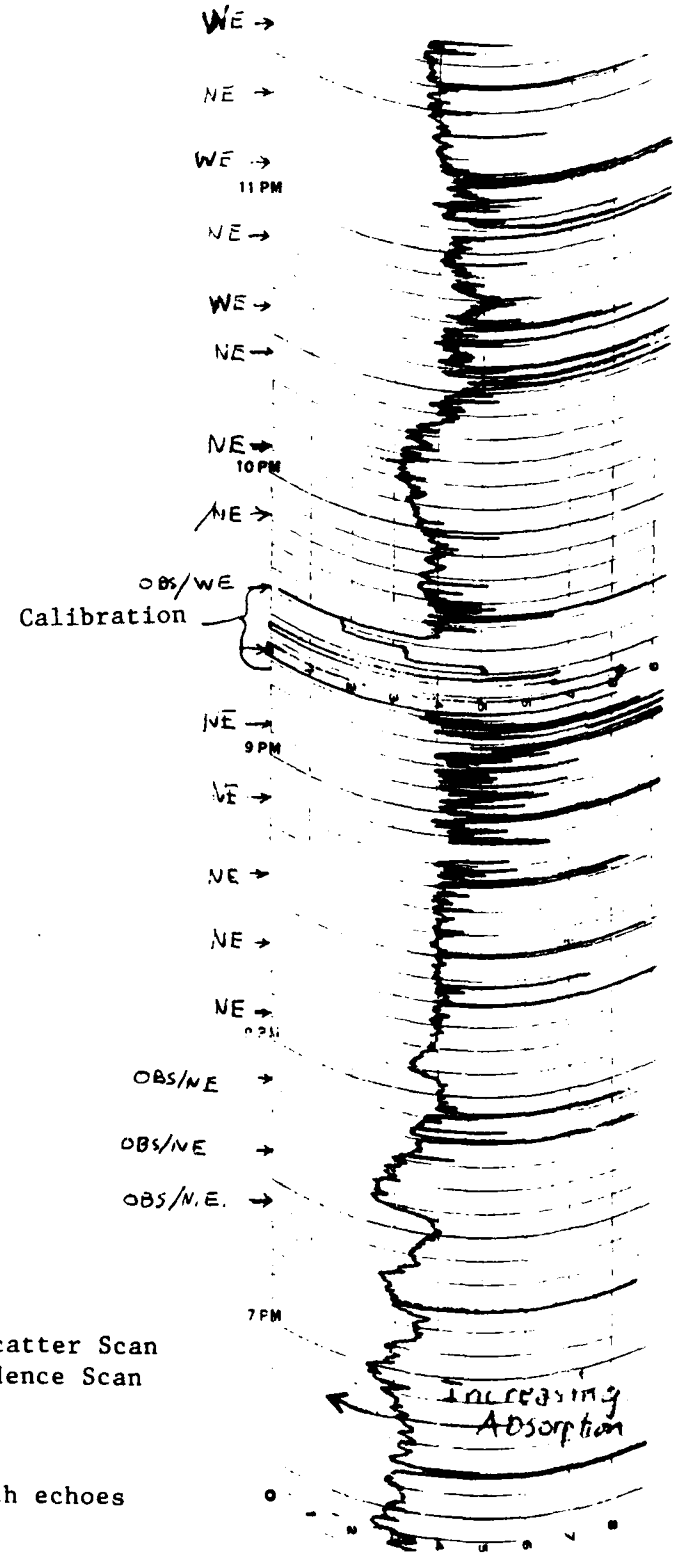
C. Correlation with Other Data

Correlation between College 30 MHz Riometer data and D-256 Ionograms. March 13, 1989 was a very active day geomagnetically with a sudden commencement reported at 0127 UT and a 5 dB polar cap absorption event shown on the Thule 30 MHz Riometer. This was the most active geomagnetic day of the month at College, with a College K = 9 from 12 - 15 UT. The College Ak = 211 for March 13. Ak = 00 - 30 is considered *magnetically quiet*. March 14 was considerably less disturbed, with an Ak of 88 for the day and a maximum Kp of 7 at various times through the day.

During that period no VI soundings using the 7-element receiving antenna array were made because of problems with that system. We do however, have backscatter soundings from that period and since our oblique antennas have a significant vertical lobe, we have both oblique and vertical ionograms. Since the College Riometer responds to absorption essentially overhead, we would not expect much of a correlation between College absorption and echo strength on the oblique backscatter ionograms, but there should be a positive correlation between absorption and the vertical ionogram.

Figures 30 through 35 are copies of the College 30 MHz riometer records from

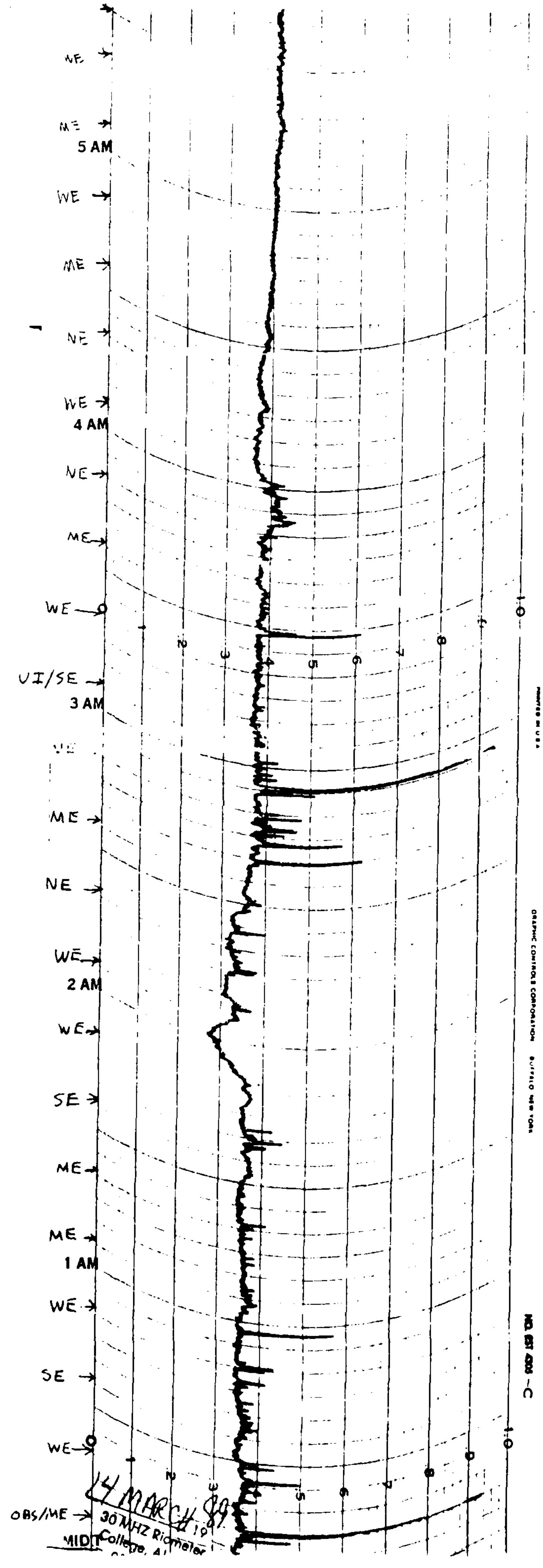
Figure 30



Day 072 1989
College, Alaska
30MHz Riometer

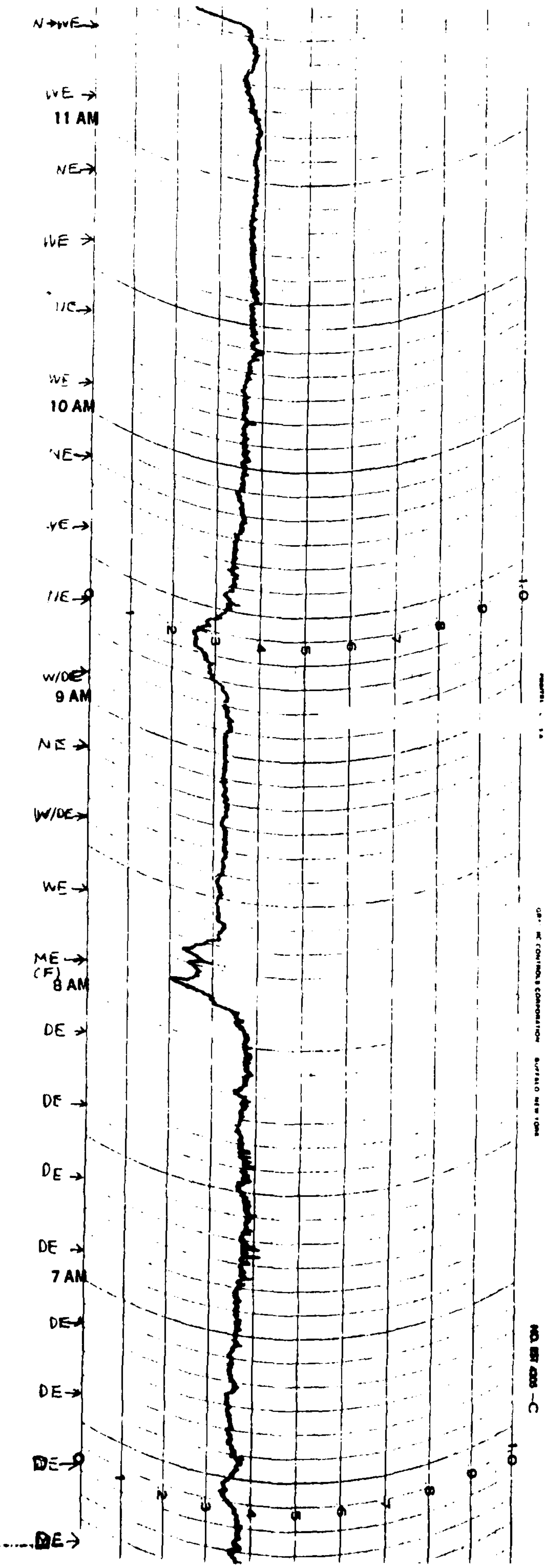
OBS = Oblique Backscatter Scan
VI = Vertical Incidence Scan
N.E. = No echoes
W.E. = Weak echoes
S.E. = Strong echoes
M.E. = Medium strength echoes

Figure 31



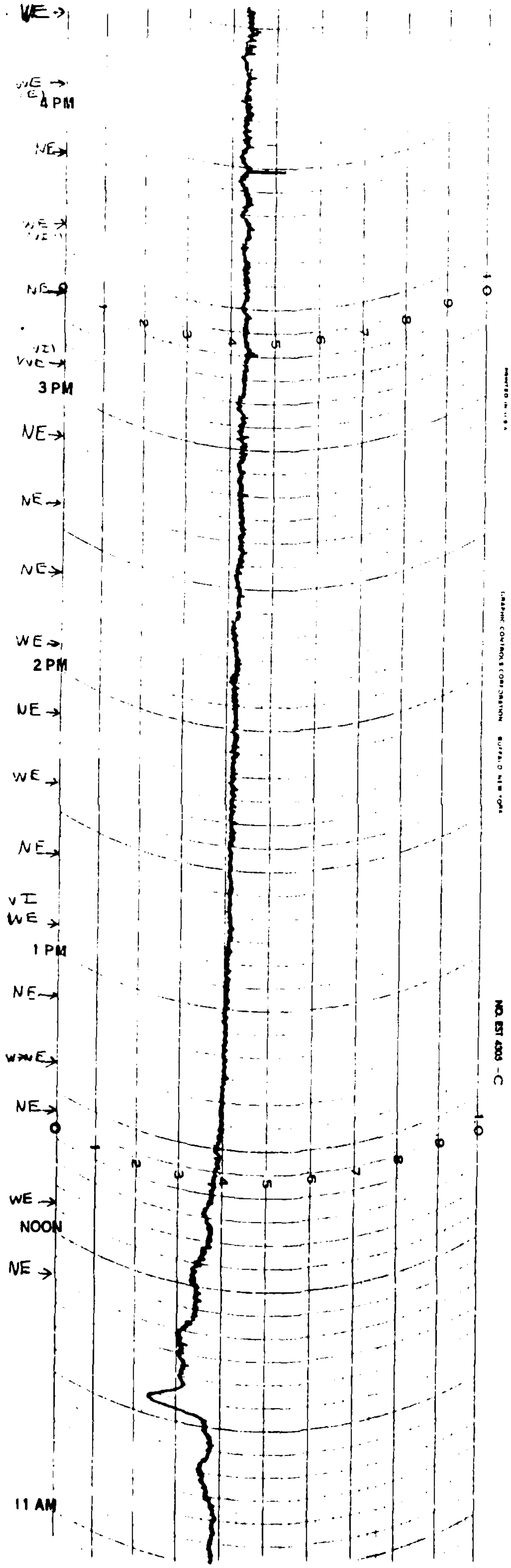
WE
ME
5 AM
WE
ME
NE
WE
4 AM
NE
ME
WE
UI/SE
3 AM
ME
NE
WE
2 AM
WE
SE
ME
ME
1 AM
WE
SE
WE
OBS/ME
MIDT
14 MARCH 89
30 MHZ Riometer
College, A
GRAPHIC CONTROLS CORPORATION BUFFALO NEW YORK
PRINTED IN U.S.A.

Figure 32



Day 073 = 14 March 1987

Figure 33



Day 073 1989

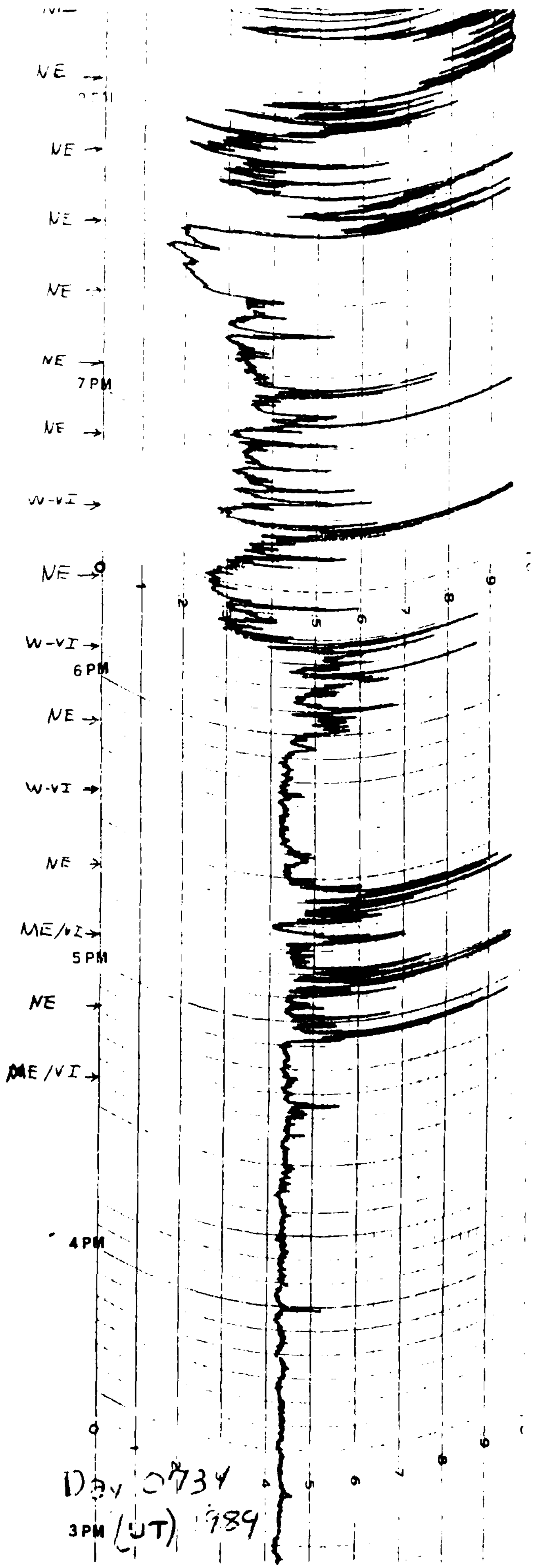
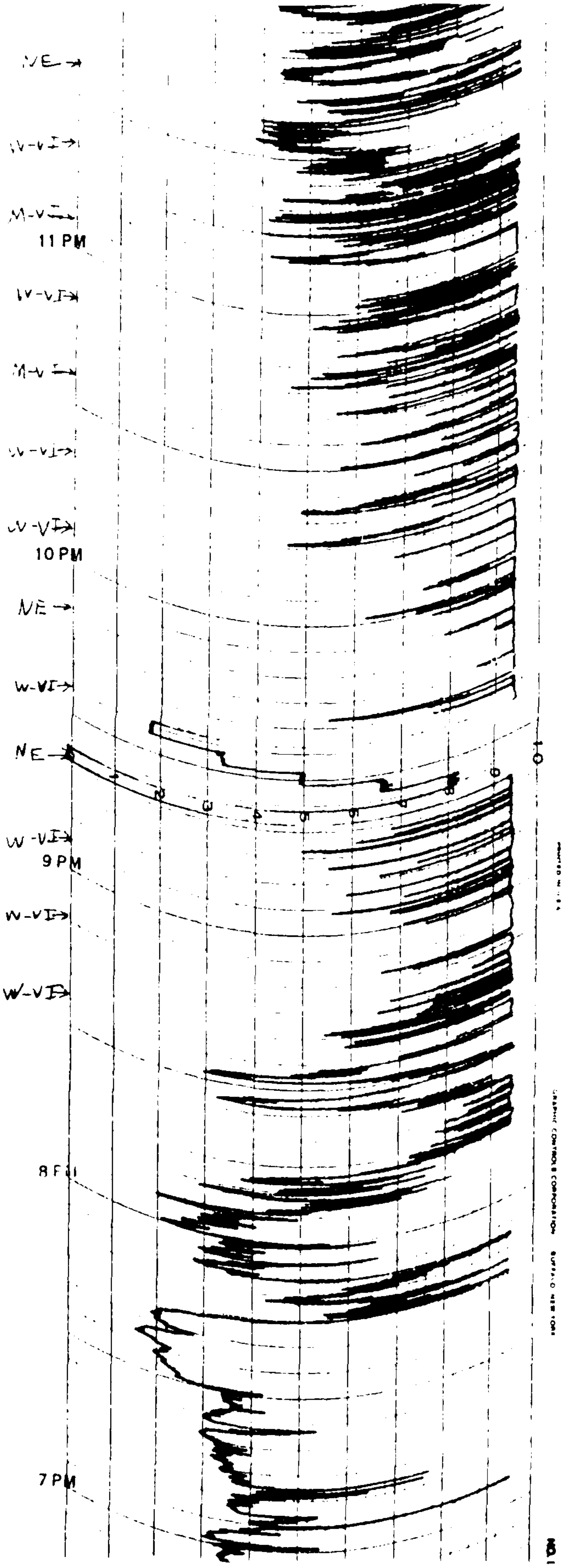

NE
NE
NE
NE
NE
7 PM
NE
W-VI
NE
W-VI
6 PM
NE
W-VI
NE
NE/VI
5 PM
NE
NE/VI
4 PM
3 PM
(UT)

Figure 34

Figure 35



Day 073

1930 UT March 13 until 2335 UT 2335 UT March 14, 1989. The time on the charts is UT, and the 2 or 3 letter groups marked on the left side of the chart describe the types of echoes observed on the backscatter records as defined by the legend at the lower left in Figure 30.

As can be seen in this sequence of ionograms, vertical echoes were not observed consistently until the recovery from the storm (~2030 UT March 14) and oblique echoes were absent during most intense part of the storm during which data were available. As the storm abated, the backscatter echoes became stronger, but they did not show a peak-to-peak correlation with absorption. Also, direct- E (DE) signatures (clutter) were only present after the main phase of the geomagnetic storm. Thus at least qualitatively, these results are in line with what we expected.

Figures 36 and 37 are included in this report to illustrate *typical signatures* observed on vertical and oblique ionograms from an auroral oval station. Figure 36 for 0303 UT on February 28, 1989 shows a high foF2 (~11.5 MHz) on the vertical ionogram. We have increased the VI frequency sweep from the original value of 10 MHz to 14 MHz in order to record these high foF2 values. Figure 37 is an oblique ionogram taken at 0507 UT on the same day, showing the extreme *spread* echoes seen during disturbed conditions. The echo from ~13-14.5 MHz is probably a *clutter* echo.

The map in Figure 38 shows the center azimuth of the backscatter antenna from College and the location of the auroral oval for 0800 UT for Kp = 5. This program will be revised to include the *terminator* and the azimuth beam half-power points during the next project period. Figure 39 from Bates (1966) backscatter soundings investigations illustrates some of the properties of groundscatter and direct backscatter from the College step-frequency 30 kw sounder. Of particular interest is the bottom backscatter ionogram using the northern directed antenna. Note the similarity of the clutter echo at ~1500 km range with similar clutter echoes

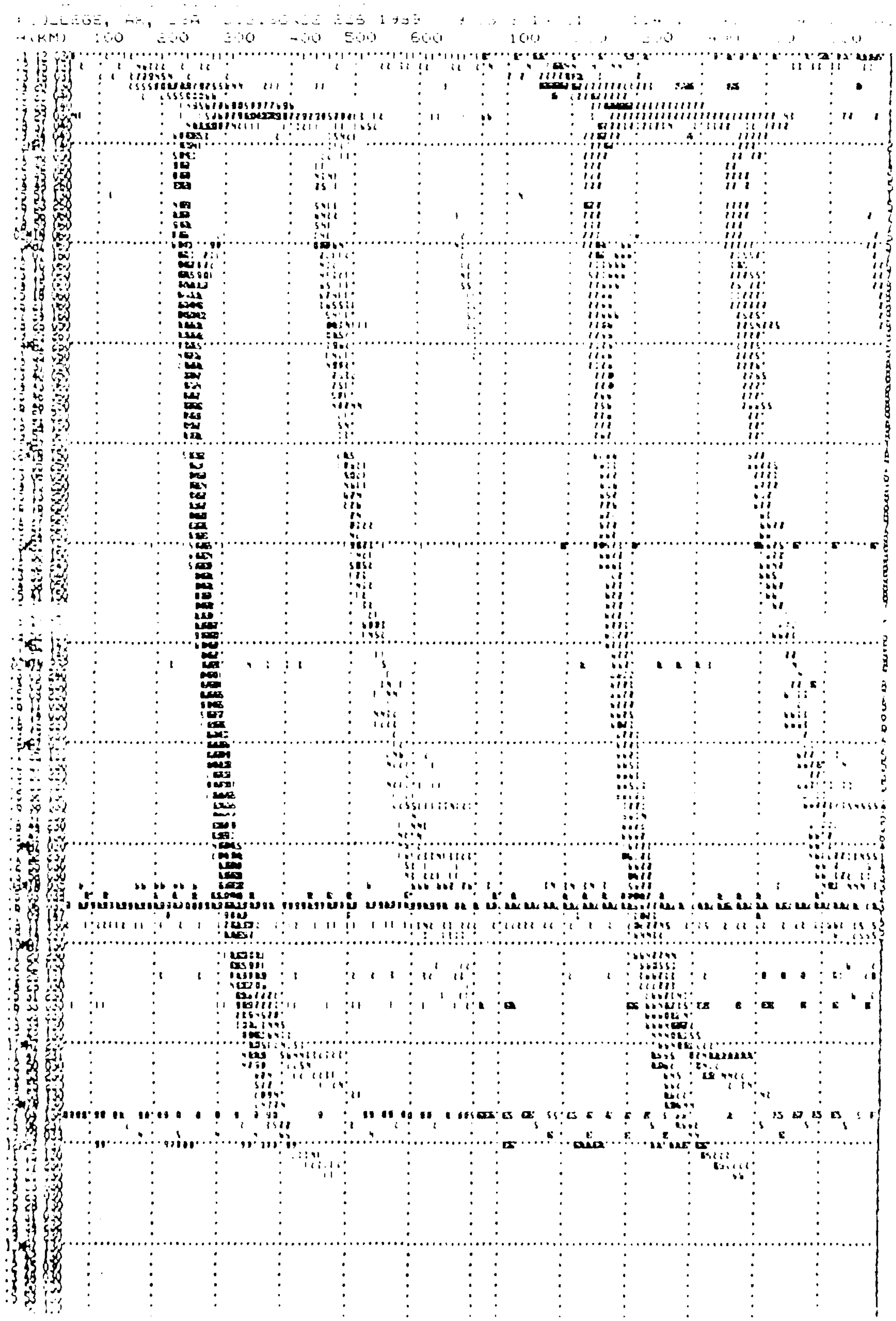
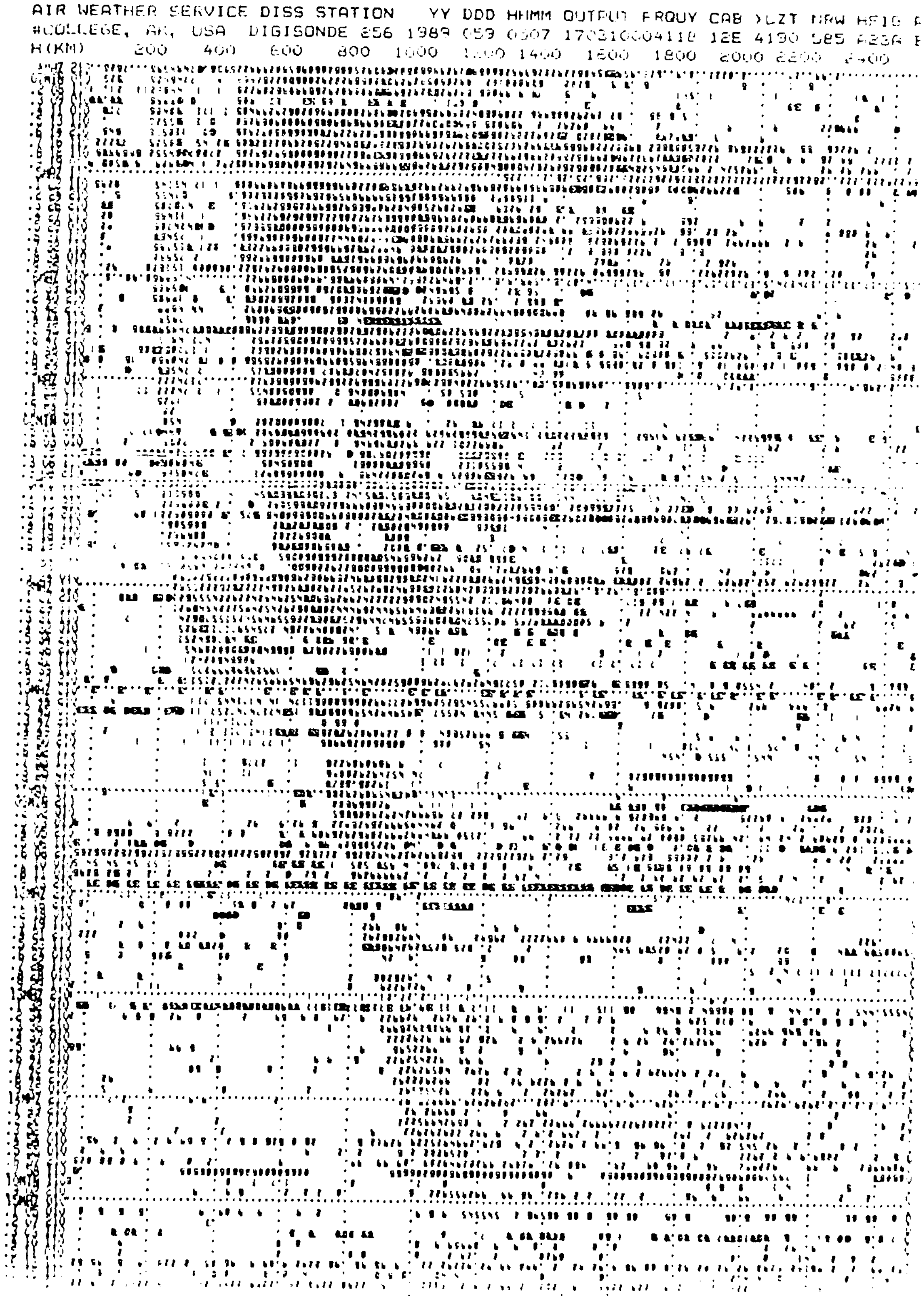


Figure 36



AIR WEATHER SERVICE DISS STATION YY DDD HHMM
COLLEGE, AK, USA DIGISONDE 256 1989 059 0307
H(KM) 200 400 600 800 1000 1400 1600 1800 2000

Figure 37

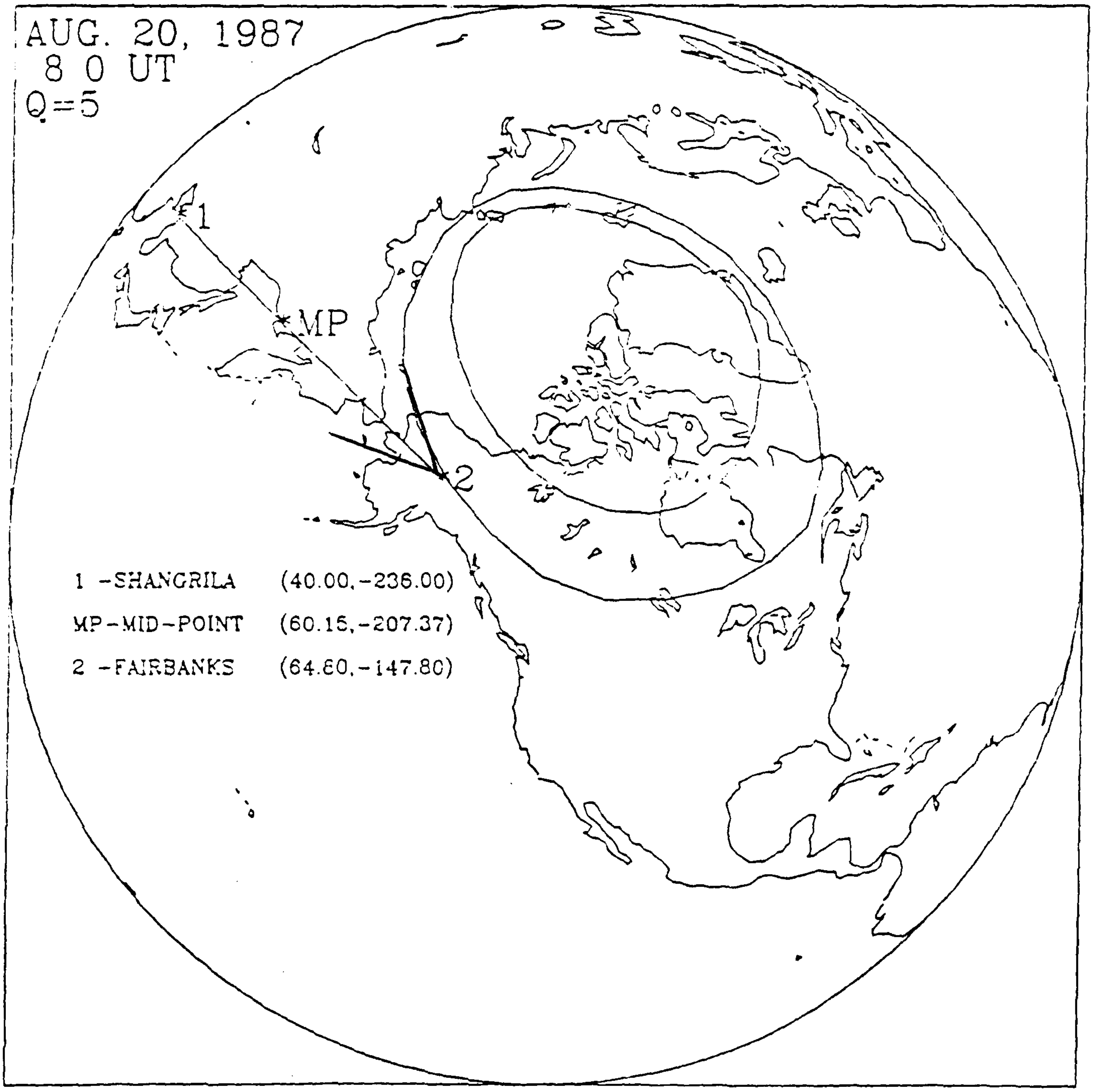


Figure 38. Boresight azimuth for the Sheep Creek HF oblique sounder system in relation to a "typical auroral oval" (K_p=4, 0800 UT, 20 Aug 1987). Estimated 50° azimuth half-power beamwidth is also shown.

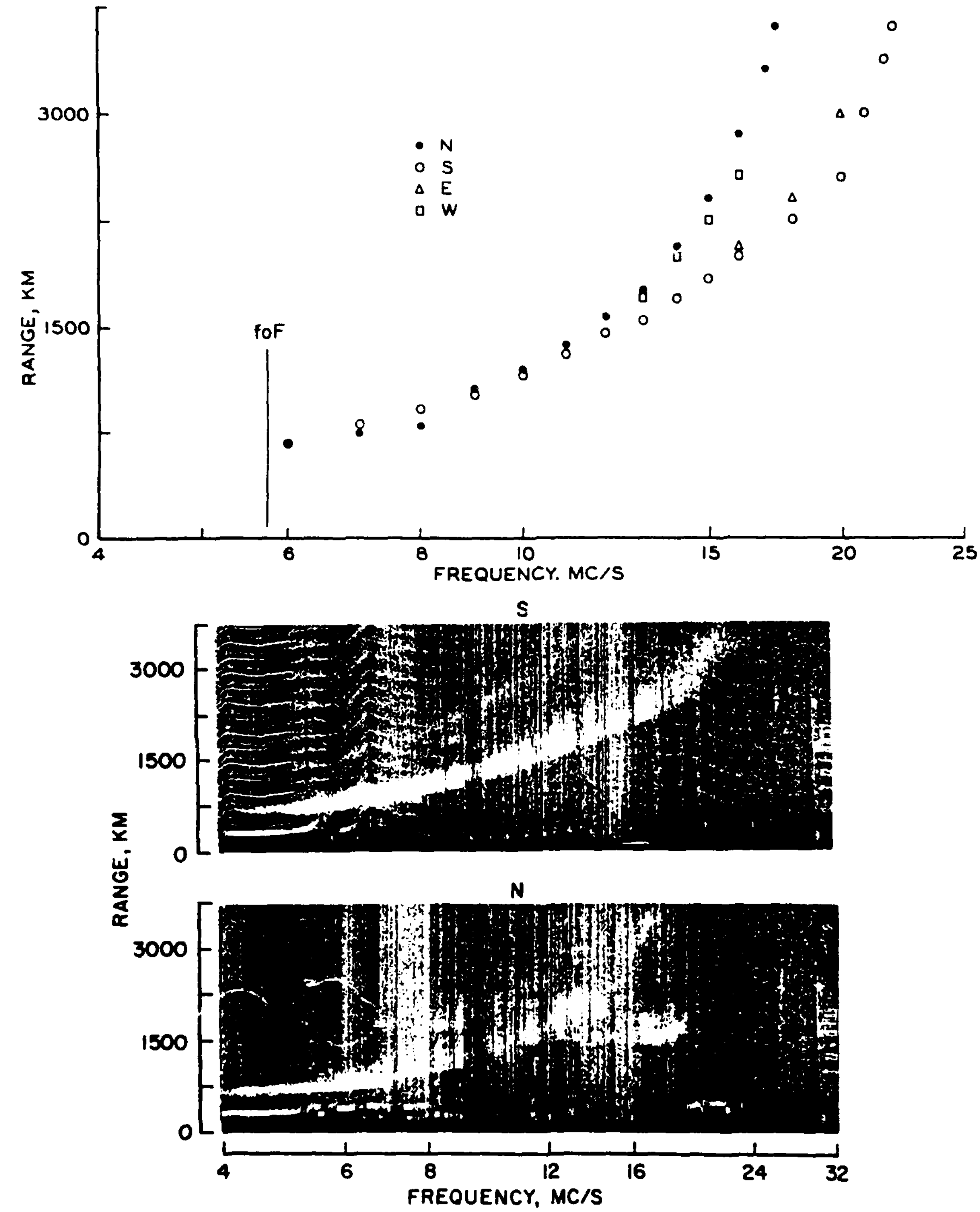


Fig. 39. The leading edge versus frequency of the groundscatter traces recorded from the four magnetic directions near noon, October 3, 1965. Where the traces overlapped at their low-frequency end, some of the points are omitted for clarity. The south (S) record, containing a second-order groundscatter trace in addition to the fundamental trace; and the north (N) record, containing auroral backscatter traces at 1500 km range are included.

in Figures 11, 12, and 20 of this report. We will make use of some of Bates backscatter ionograms as models in our next year's effort.

V. Conclusions and Future Plans

The modification of the D-256 into a backscatter sounder has been quite successful. The estimated system gain of the 2 final amplifier/two antenna sounder over a single final amplifier/antenna is ~14 - 19 dB as a function of frequency. The oblique sounder system has been *on the air* since ~September 25, 1988, continuously except for some power failures and maintenance problems as noted in Tables 4A and 4B.

Good quality groundscatter echoes are consistently obtained, and the clutter *signature* has been well identified. At the present time we are making four VI and four oblique soundings per hour as shown in Table 5. We have also found that the *B-ionogram* is not of much use because of its short integration time (a factor of four less than our *C-ionograms*). Having the vertical ionograms interlaced with the backscatter soundings has proven to be valuable, since the VI ionogram helps in identification of certain backscatter trace signatures. We are considering changing one of the modes to optimize detection of groundscatter and clutter.

We have modified and used the "3D" ray tracing program developed by Jones and Stephenson (1975) and found it to be valuable in interpreting backscatter ionograms. In the future we will use the ray tracing program to model different electron density distributions and irregularity models.

Ionograms of some of the clutter echoes obtained during this program have been compared with some clutter signatures obtained by Bates (1966) using a step-frequency sounder at College in the late 1960's, and the resemblance has been remarkably close. We will use some of Bates models and ionograms as this study continues to help in identification of clutter morphology.

Since the maximum activity of solar sunspot cycle will occur in the period 1988 - 1991 this affords an excellent opportunity to obtain *worst-case* groundscatter and auroral clutter echo morphology. We plan to obtain statistics on the behavior of these two echoes as a function of time-of-day and season (Fall 1988, Winter 1988-89, Spring 1989 and Summer 1989); as well as geomagnetic disturbance variation. If the system were still operational through calendar 1990, we could also obtain some sunspot cycle effects on clutter and groundscatter.

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