INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

H4.SMR/645-12

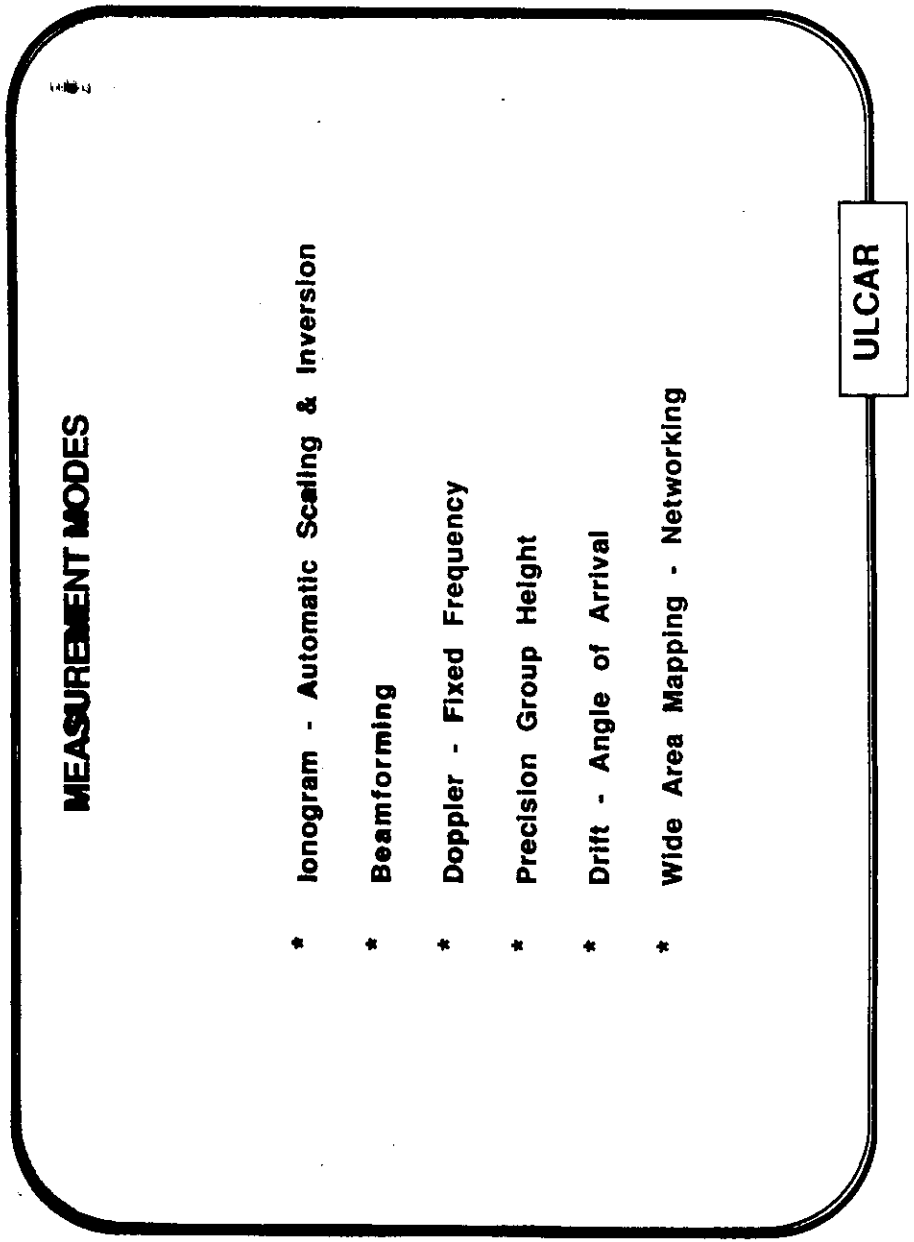
SCHOOL ON PHYSICAL METHODS FOR THE STUDY OF THE UPPER AND LOWER ATMOSPHERE SYSTEM

26 October - 6 November 1992
Miramare - Trieste, Italy

Measurement Modes

Bodo W. Reinisch
College of Engineering
University of Massachusetts Lowell
Lowell, MA
USA

MAIN BUILDING STRADA COSTIERA, 11 TEL. 22401 TELEFAX 224163 TELEX 460392 ADRIATICO GUEST HOUSE VIA GRIGNANO, 9 TEL. 224241 TELEFAX 224531 TELEX 460449
MICROPROCESSOR LAB. VIA BEIRUT, 31 TEL. 224471 TELEFAX 224600 TELEX 460392 GALILEO GUEST HOUSE VIA BEIRUT, 7 TEL. 22401 TELEFAX 224559 TELEX 460392

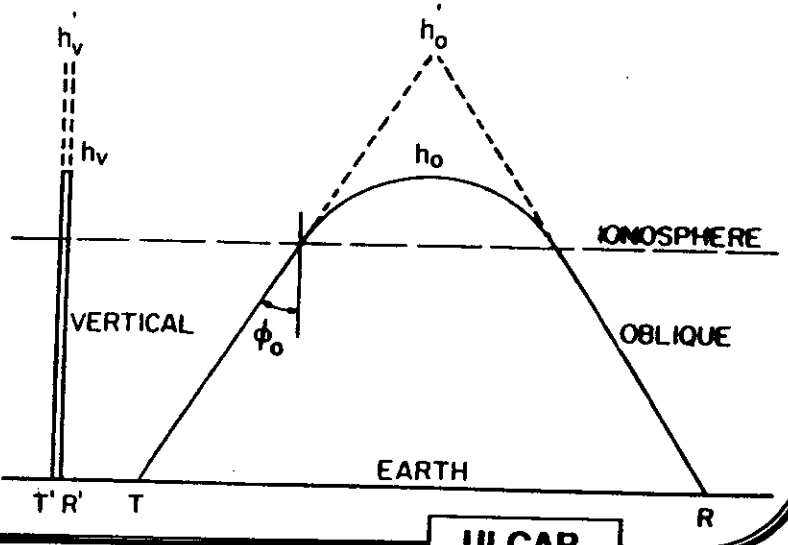


IONOSPHERIC REFLECTION & REFRACTION

$$f_p = \frac{1}{2\pi}\sqrt{\frac{N_e e^2}{\varepsilon_0 m}} \sim 9\sqrt{N_e} \text{ Hz} \quad (N_e \text{ in } m^{-3})$$

$$f_{critical} \sim 9\sqrt{N_{max}}$$

$$MOF \sim f_{critical} \sec \phi_o$$



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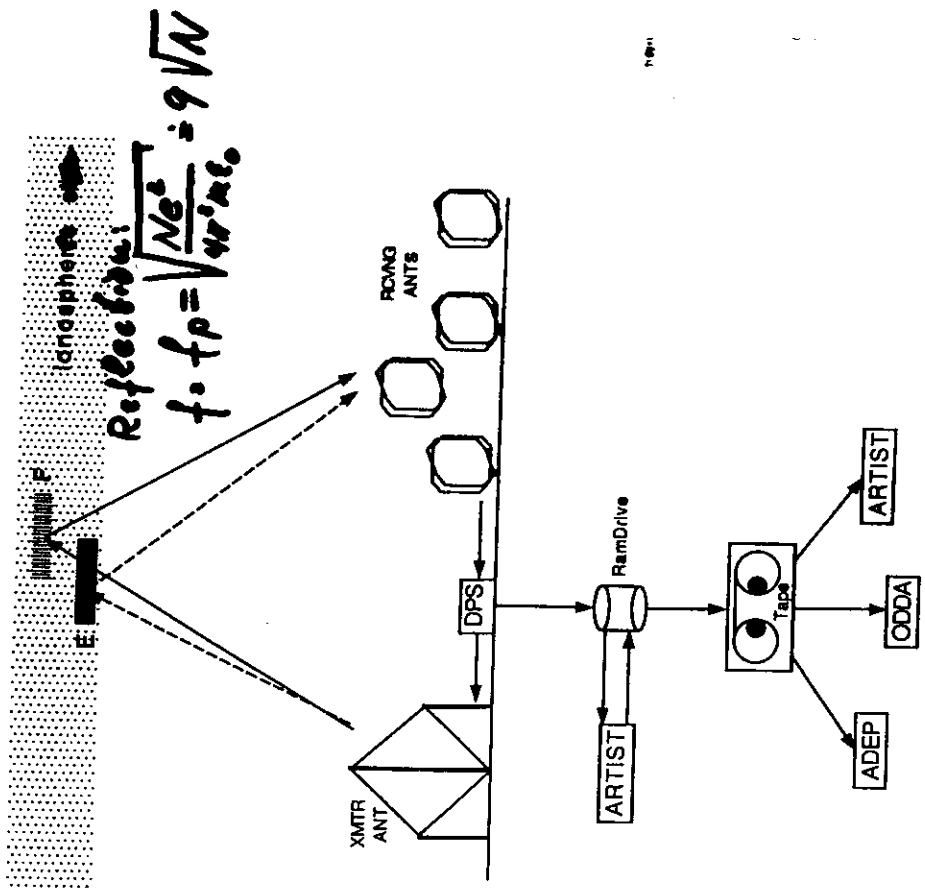
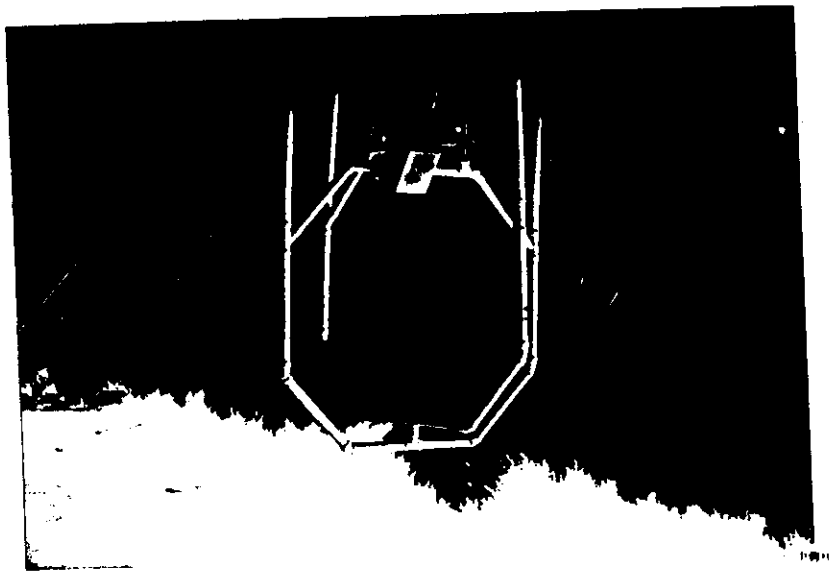
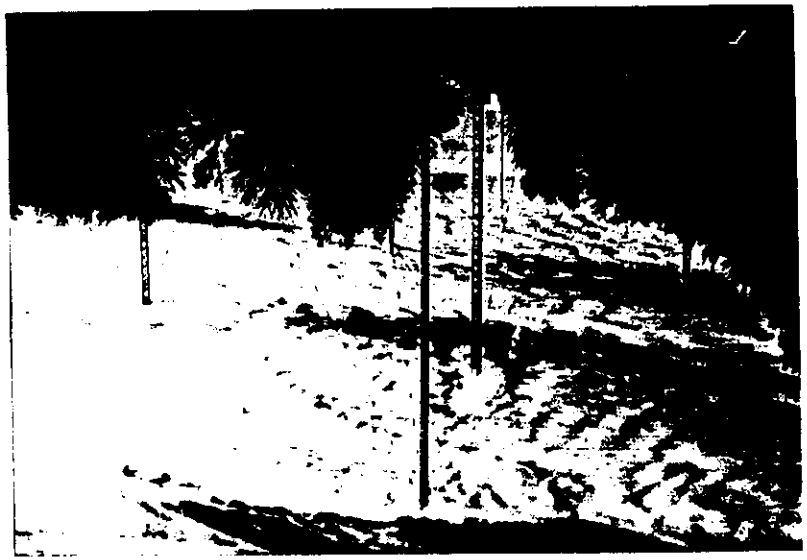
DS2

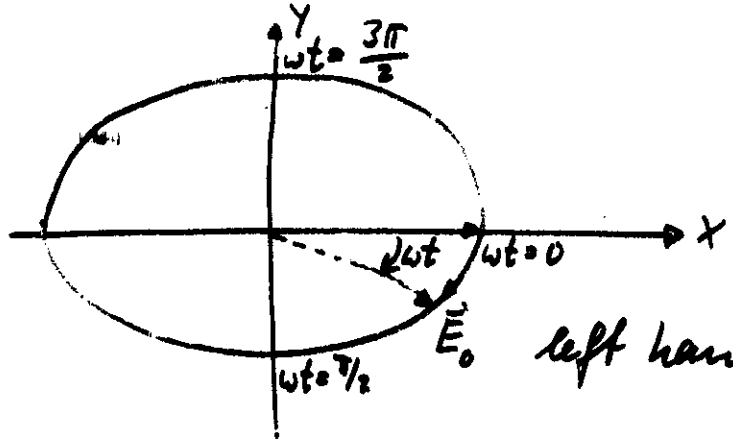
The Big Picture -- Data-Wise







Polarization



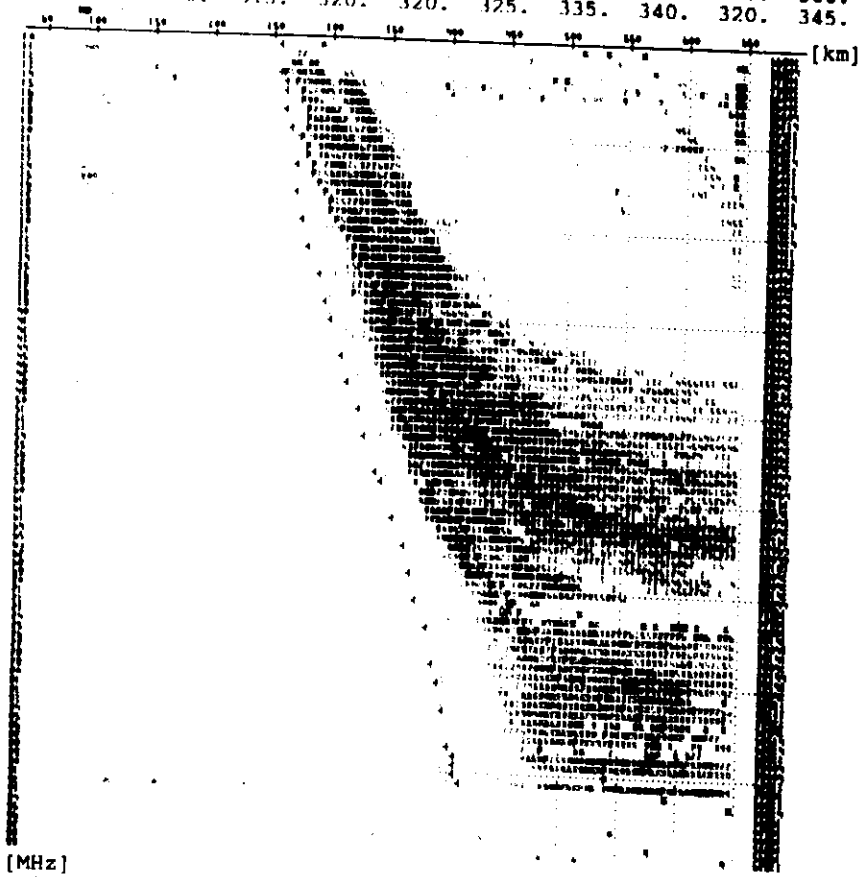
left hand elliptic

$$\vec{E}_0 = \mathrm{Re}\left(A_{0x}\hat{x} + iA_{0y}\hat{y}\right) e^{i(\omega t - kz)}$$

$$E_{0x} = A_{0x}\cos(\omega t - kz)$$

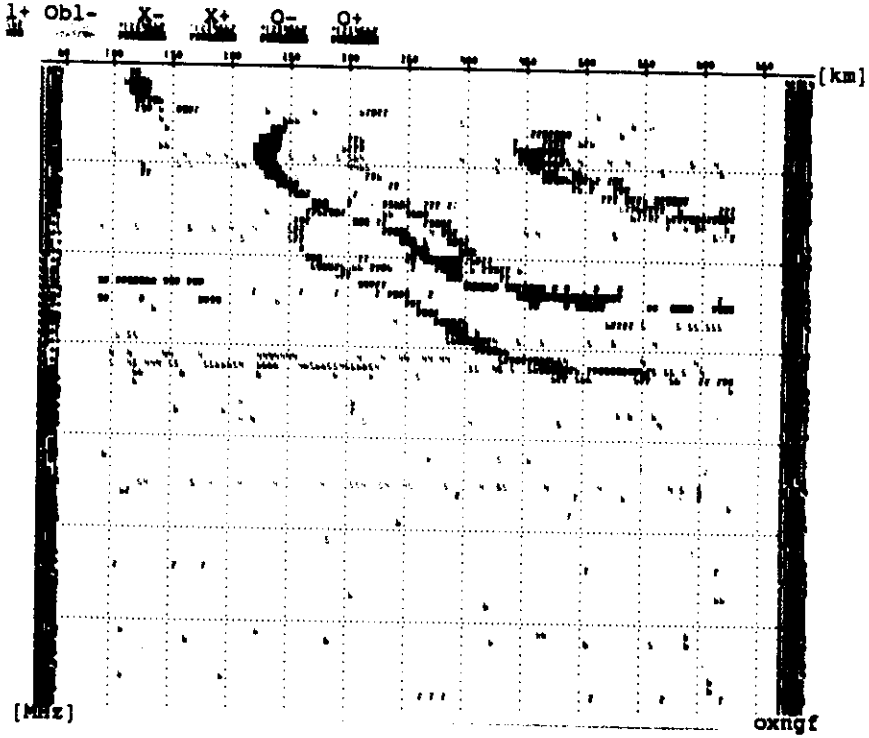
$$E_{0y} = -A_{0y}\sin(\omega t - kz)$$

```
+  Station: Ny Alesund, Svalbard, Norway   LAT 79.8N   LONG 12.    +
+                                          DIP 82.0    fH 1.5 M    +
+ Lowell Digisonde Portable Sounder - V8.08.91        88# 160      +
30 January 1992  20:59:59 UT                                      029
PPPPPPP SS Q UU XLZT NRW HEIG PR MUF    50   100   200   400   600   800 1000 1200  KM
12B0100 01 1 10 10D1 532 1218 B3       9.9   9.9  10.0  10.3  10.8  11.5  12.6  13.8 MHZ
 foF2  foF1     foE        foEs  MUF M3000 h'F h'F2 h'E h'ES fmin   fxI  fF   fE
9.10 ****/***p ****/ .6P **** 23.5  2.59 282  ***  90  *** 1.30 10.0  *** ***
     AUTOSCALED TRACES [KM]:
     ----------------
      1. ***** ***** *****  260.  268.  275.  275.  280.  280.  280.
      2.  275.  280.  280.  285.  285.  290.  295.  300.  280.  280.
      3.  310.  315.  320.  320.  325.  335.  340.  320.  345.  370.
```



Lowell Digisonde Portable Sounder
1992 ~~30~~ 20:59 Station: Ny Alesund, Svalbard, Norway

Digisonde Portable Sounder -- Univ of Massachusetts, Lowell USA
PS DP LL C UU SXARN HEM IG 1992 DAY 266 11:58 UT
B0 00 02 1 09 01035 591 18 09/22/92 11:58:03 UT



Beamforming Ionogram.
Oblique is in yellow.

7 OBSERVABLE IONOSPHERIC PARAMETERS

1. Amplitude
2. Frequency
3. Height (Range or Time Delay)
4. Phase
5. Doppler Spread
6. Wave Polarization
7. Angle of Arrival

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SUMMARY of DPS FEATURES

* 1-45MHz Frequency Range
* 42dB Coherent Signal Processing Gain
* Precision Time Synchronization
* Polarized Transmit & Receive
* Automatic Fixed Gain Control
* Frequency Search
* Battery Powered Operation
* High Level Language Control & Data Handling

ULCAR

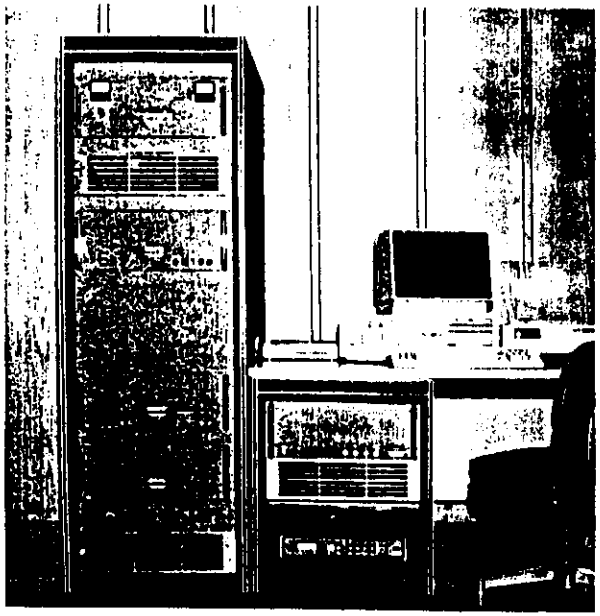
DPS collects data for an ionogram:

* 128 heights
* 32 coherent looks
* 1 MHz to 12 MHz, 100 kHz steps
* 2 polarities
* 4 receiving antennas

The amount of information stored in memory, after pulse-compression, after FFT, and assuming the raw-data was squeezed into byte-size = 3.6 MBytes

If data is collected every 15 minutes, then, at this pace, the 150 MByte tape will be filled in 10 hours.

rsf1



DIGISONDE 256 SOUNDING SYSTEM WITH ARTIST

The transmitter on the left produces 10 kw peak power, an advantage for ionospheric research and oblique propagation studies.

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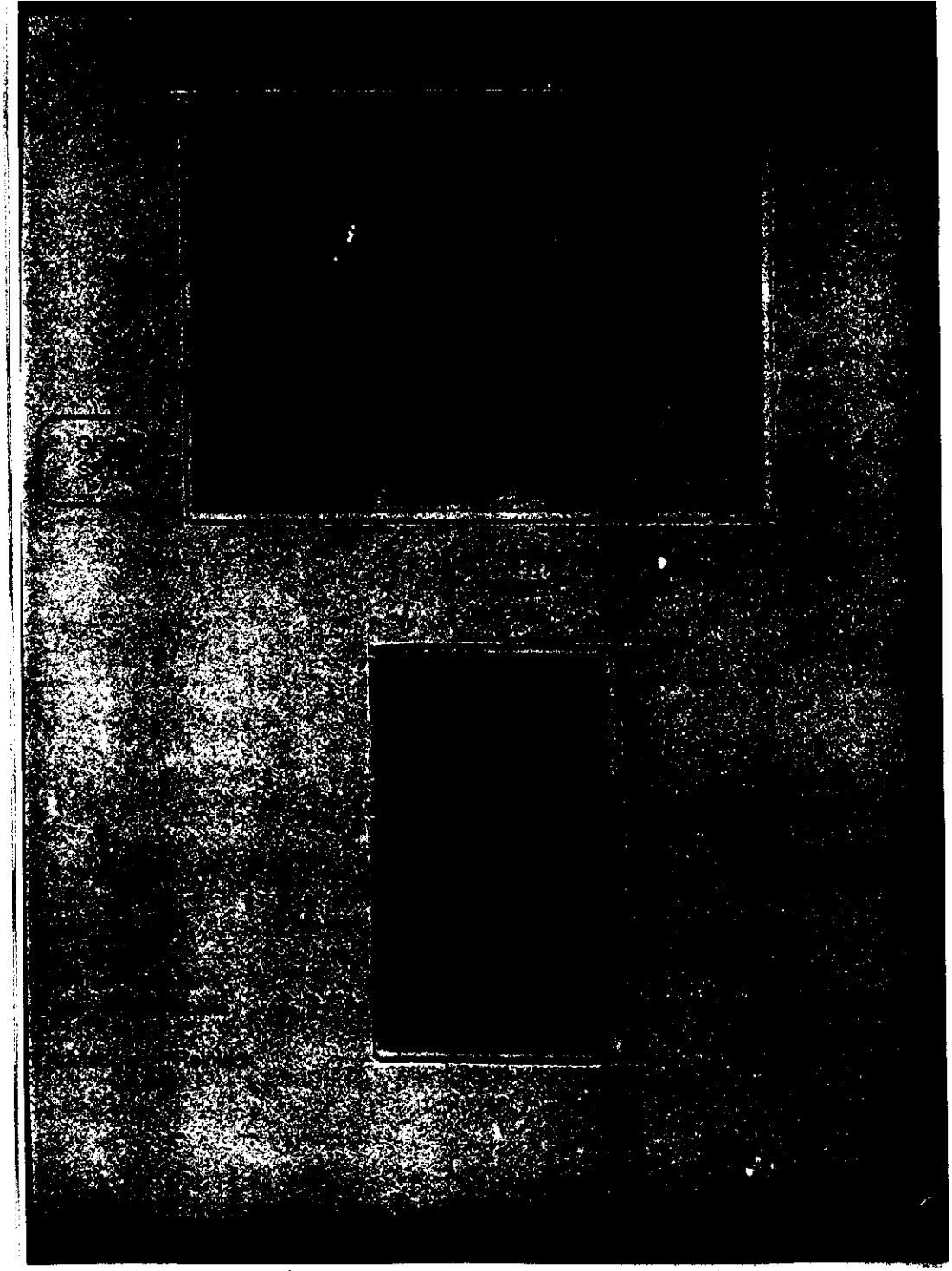
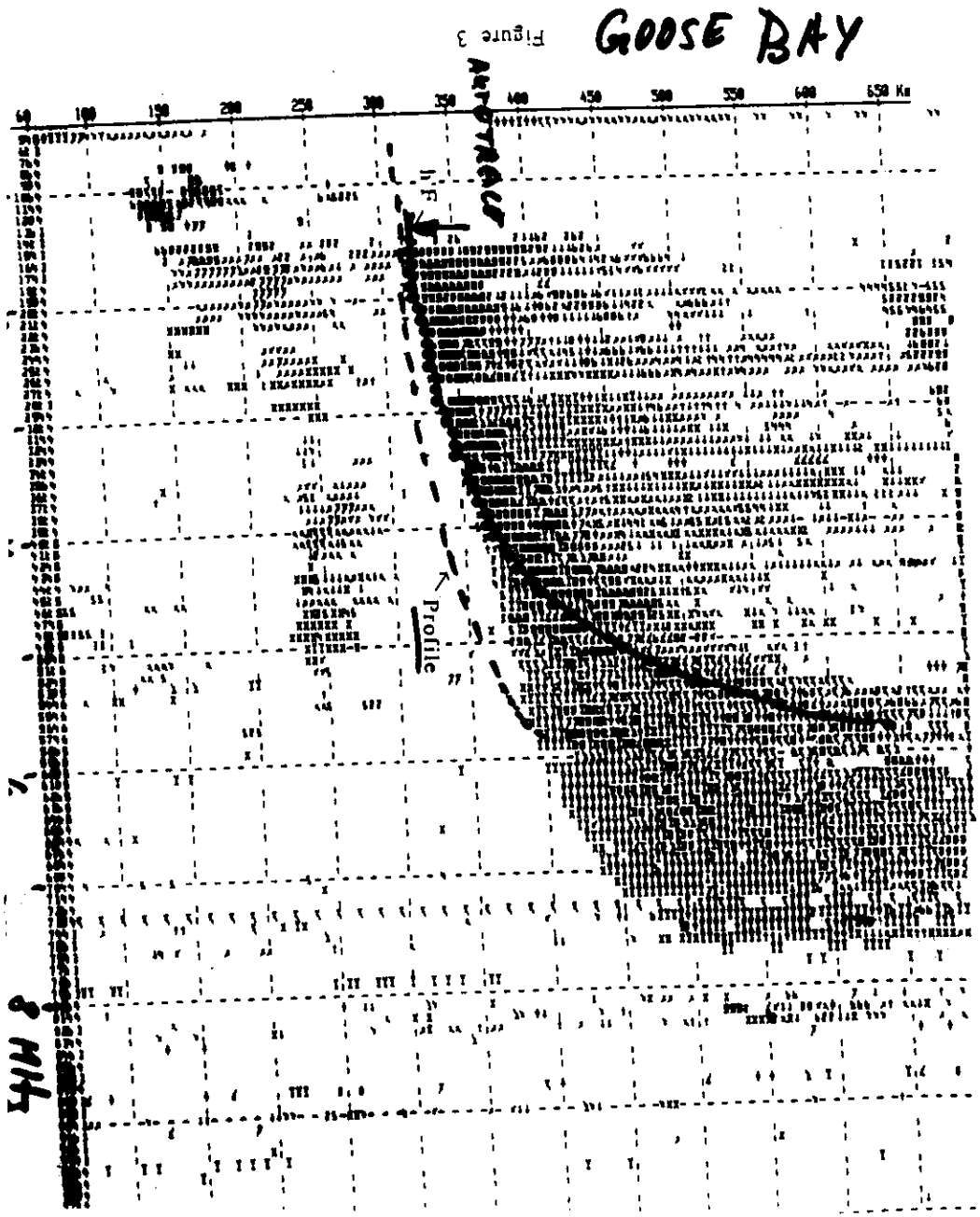



GOOSE BAY
Figure 3
ARIOTRACE
Profile
8 MHz

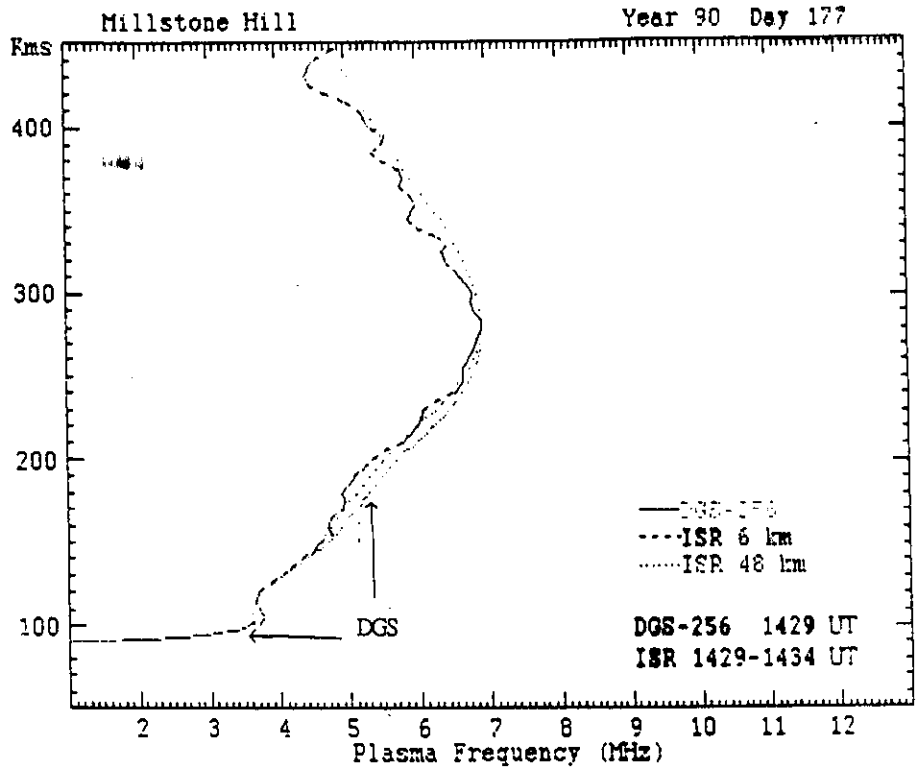

Millstone Hill
Year 90 Day 177
Kms
400
300
200
100
ISR 6 km
ISR 48 km
DGS
DGS-256 1429 UT
ISR 1429-1434 UT
2 3 4 5 6 7 8 9 10 11 12
Plasma Frequency (MHz)

Figure 5C

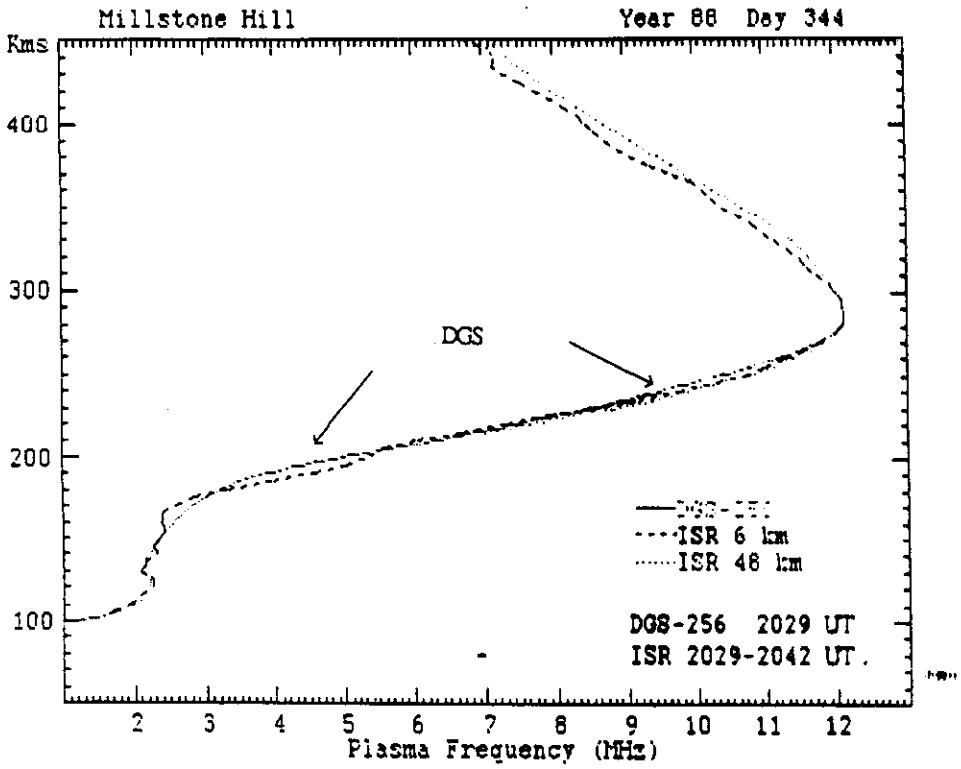


Figure 5A

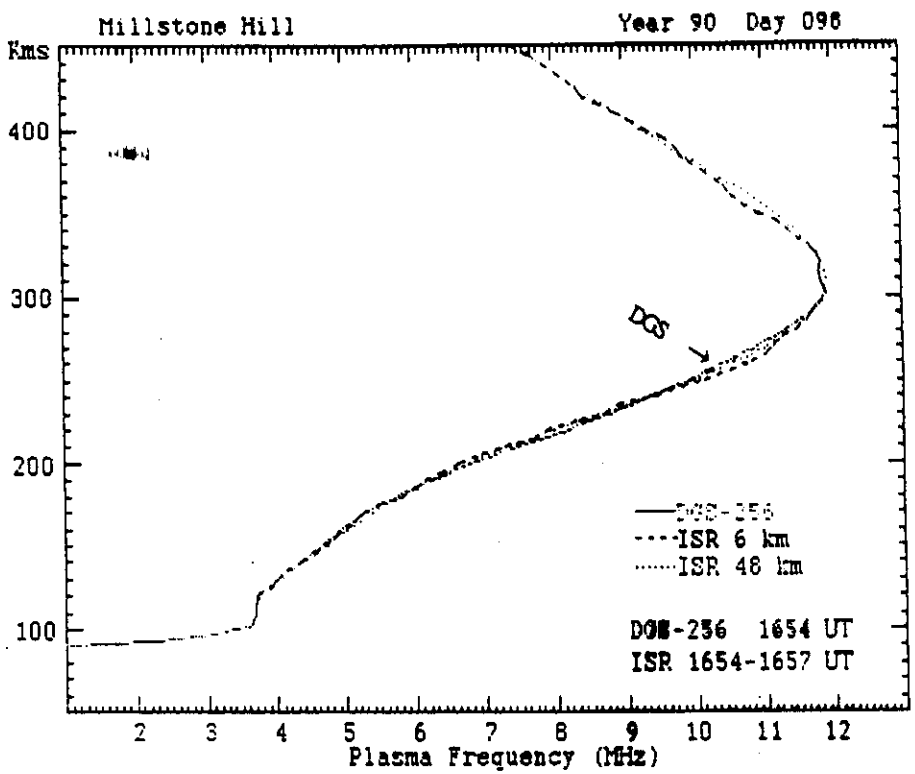
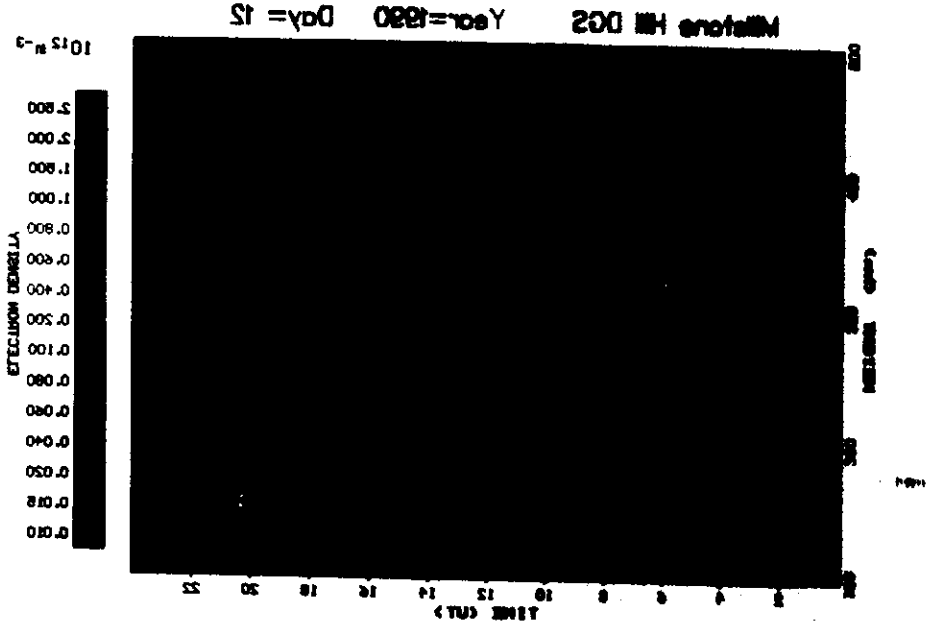
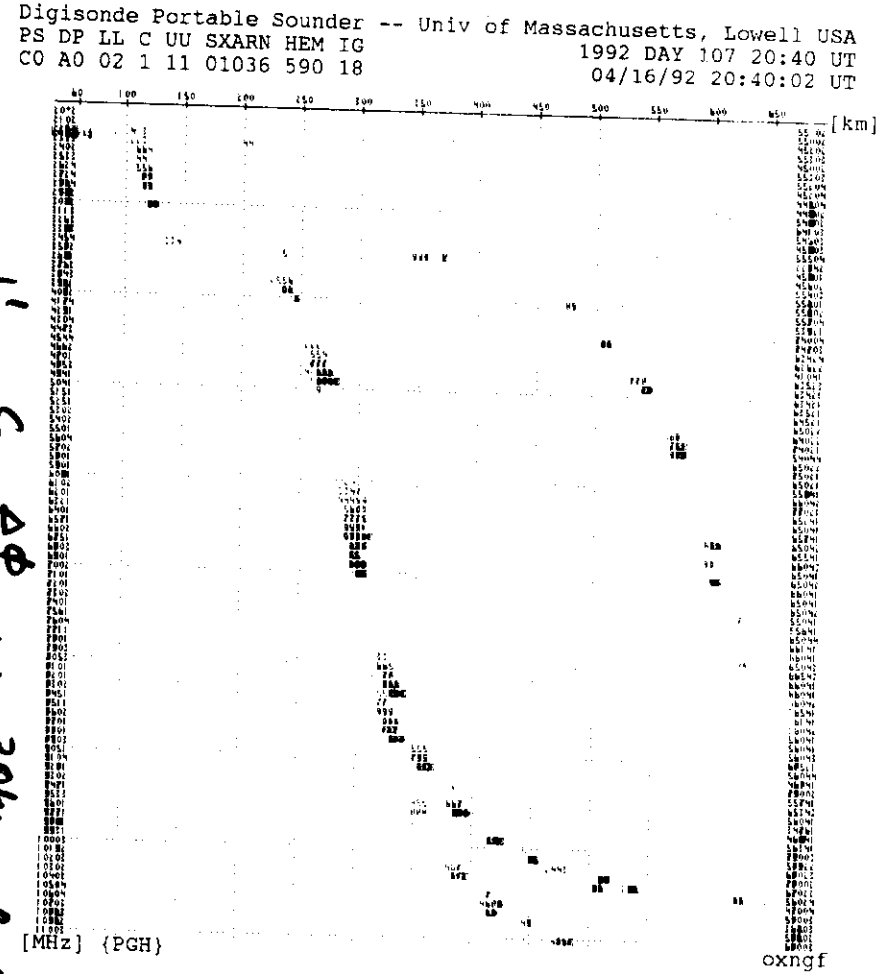
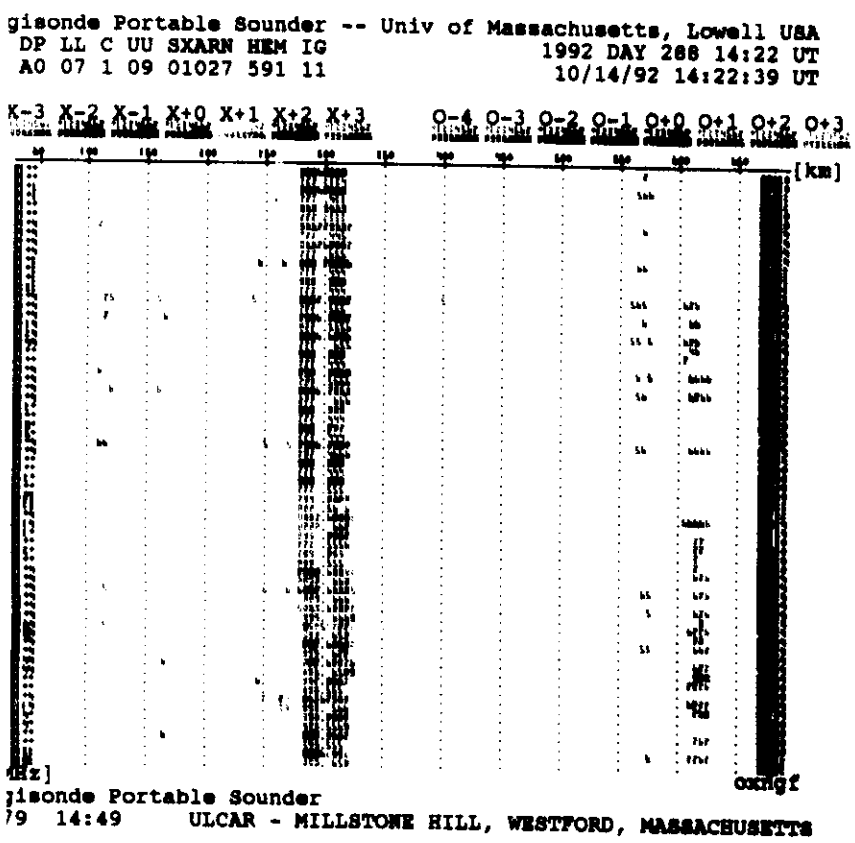


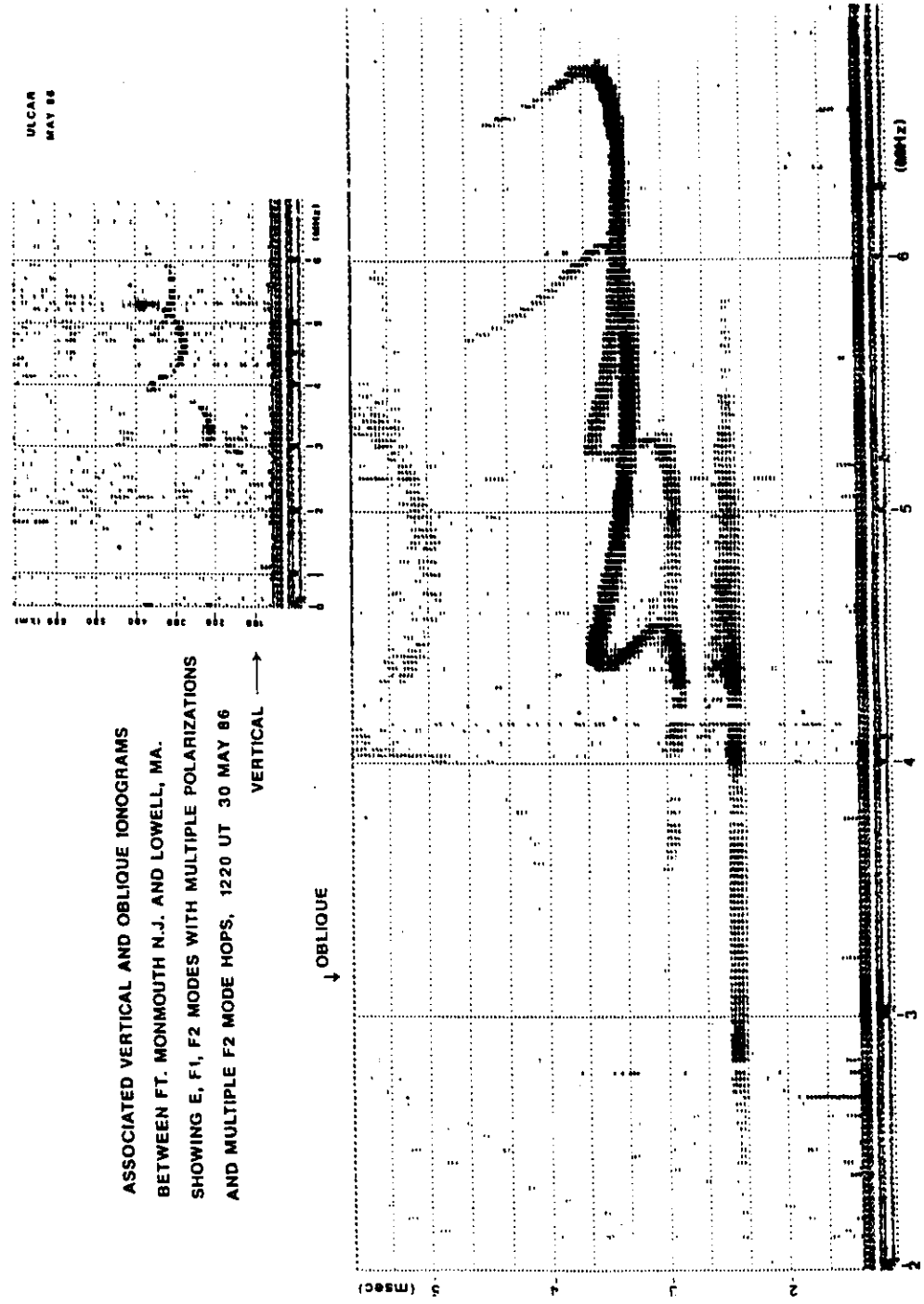
Figure 5B





$$h' = \frac{c}{4\pi}\frac{\Delta\phi}{\Delta f} + n \cdot 30\,km \quad \text{for } \Delta f = 5\,kHz$$





ASSOCIATED VERTICAL AND OBLIQUE IONOGRAMS
BETWEEN FT. MONMOUTH N.J. AND LOWELL, MA.
SHOWING E, F1, F2 MODES WITH MULTIPLE POLARIZATIONS
AND MULTIPLE F2 MODE HOPS, 1220 UT 30 MAY 86

Figure 4

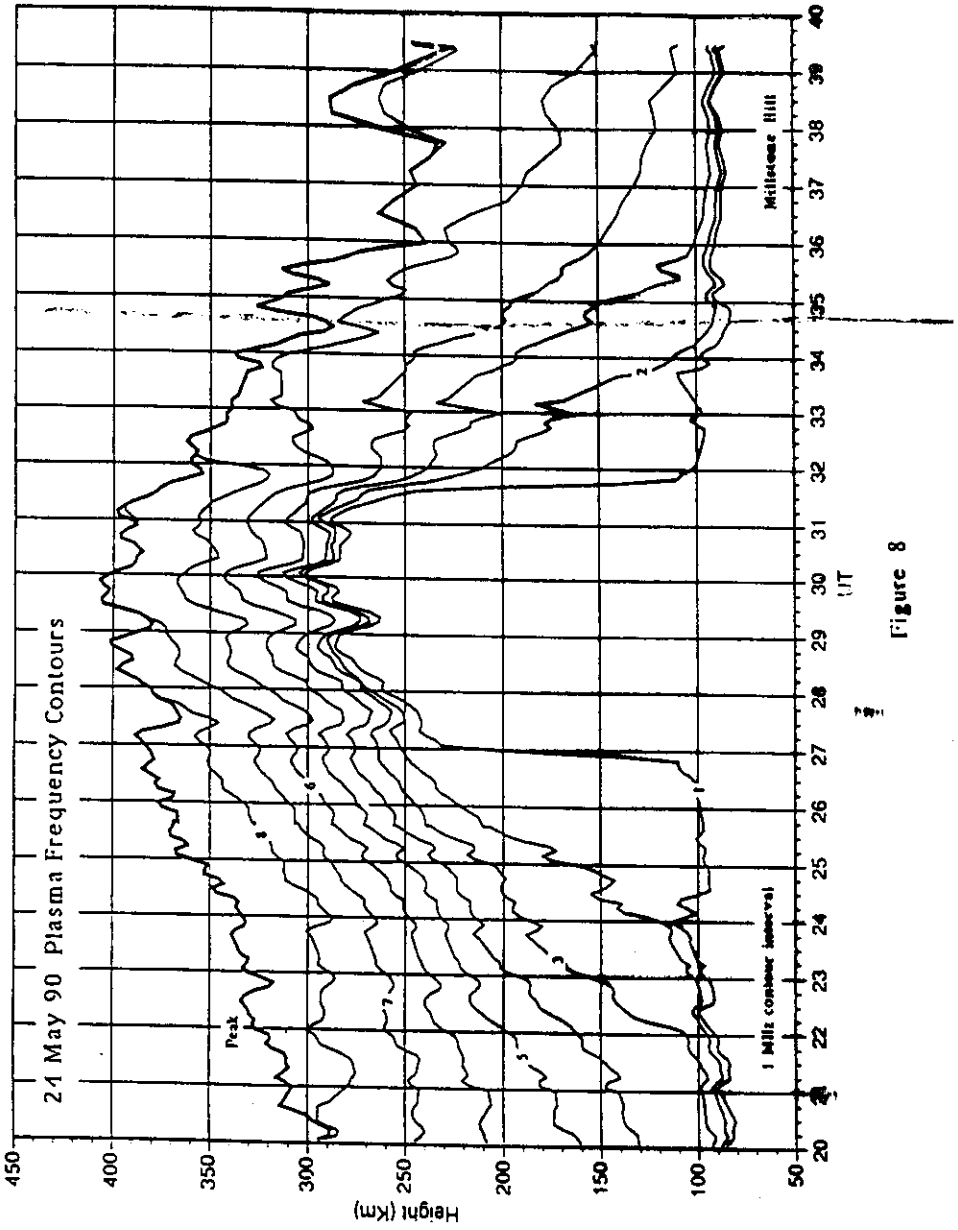


Figure 8

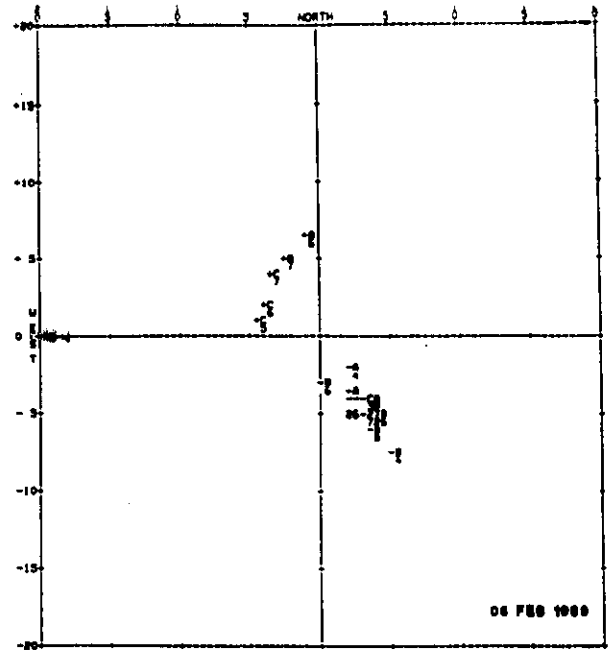


Figure 6A

11:48 LT

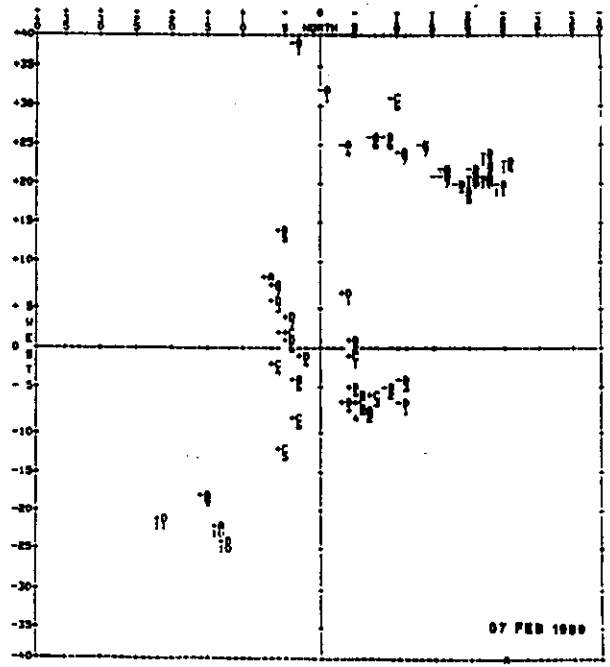
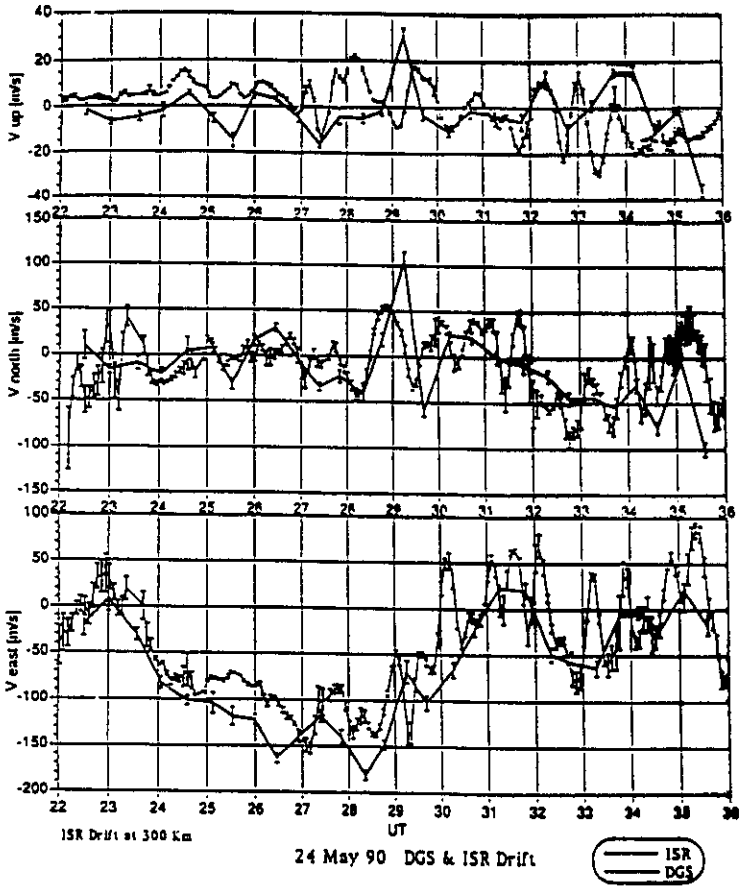


Figure 6B

05:17 LT

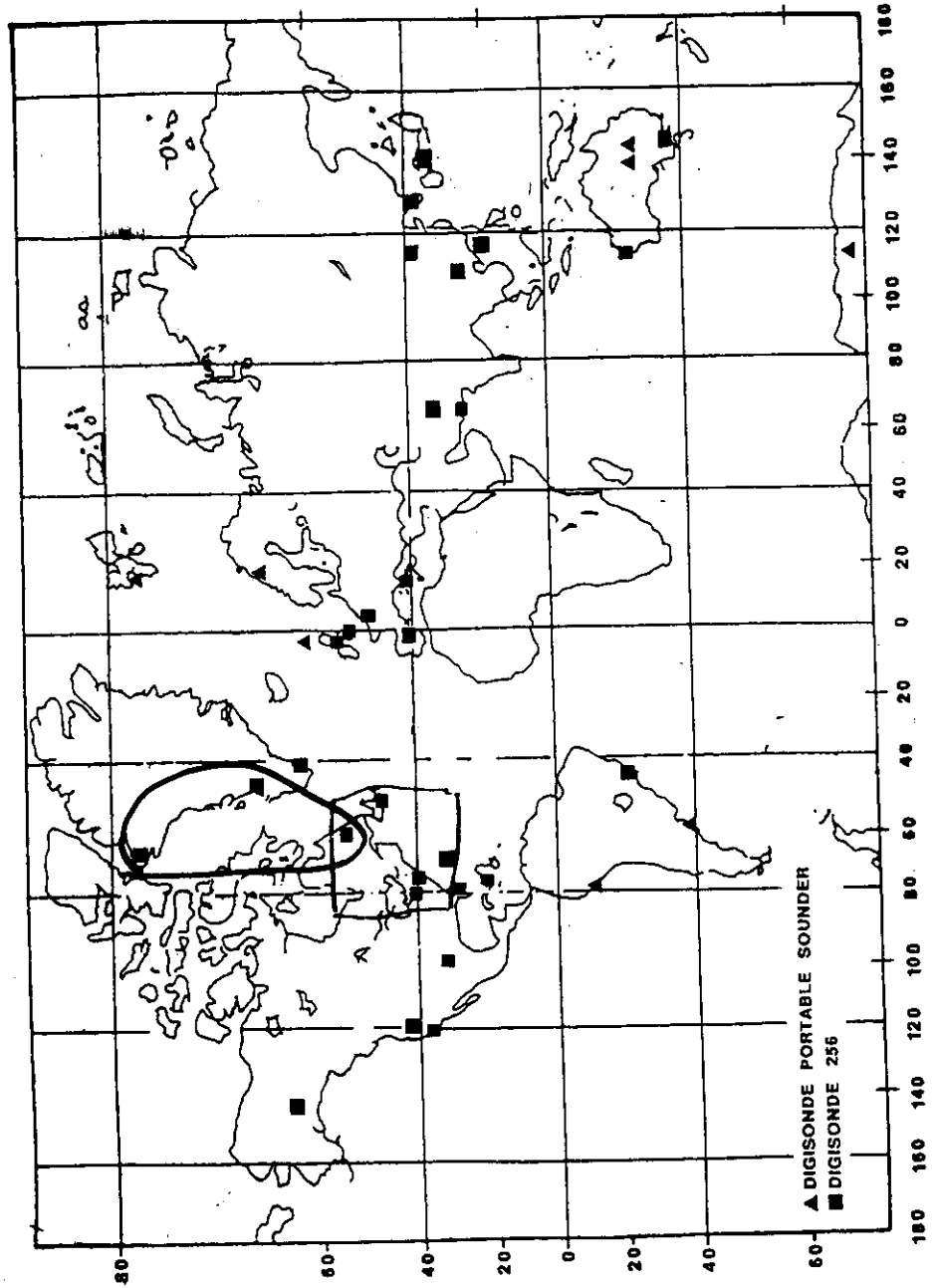
Millstone Hill Digisonde 256

Figure 6

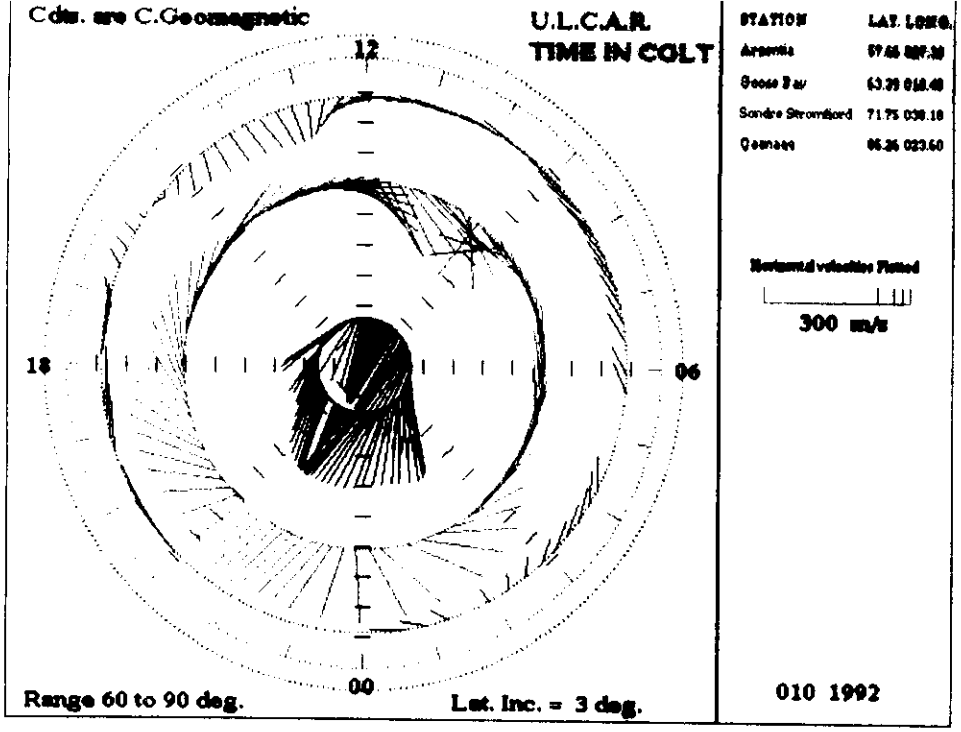


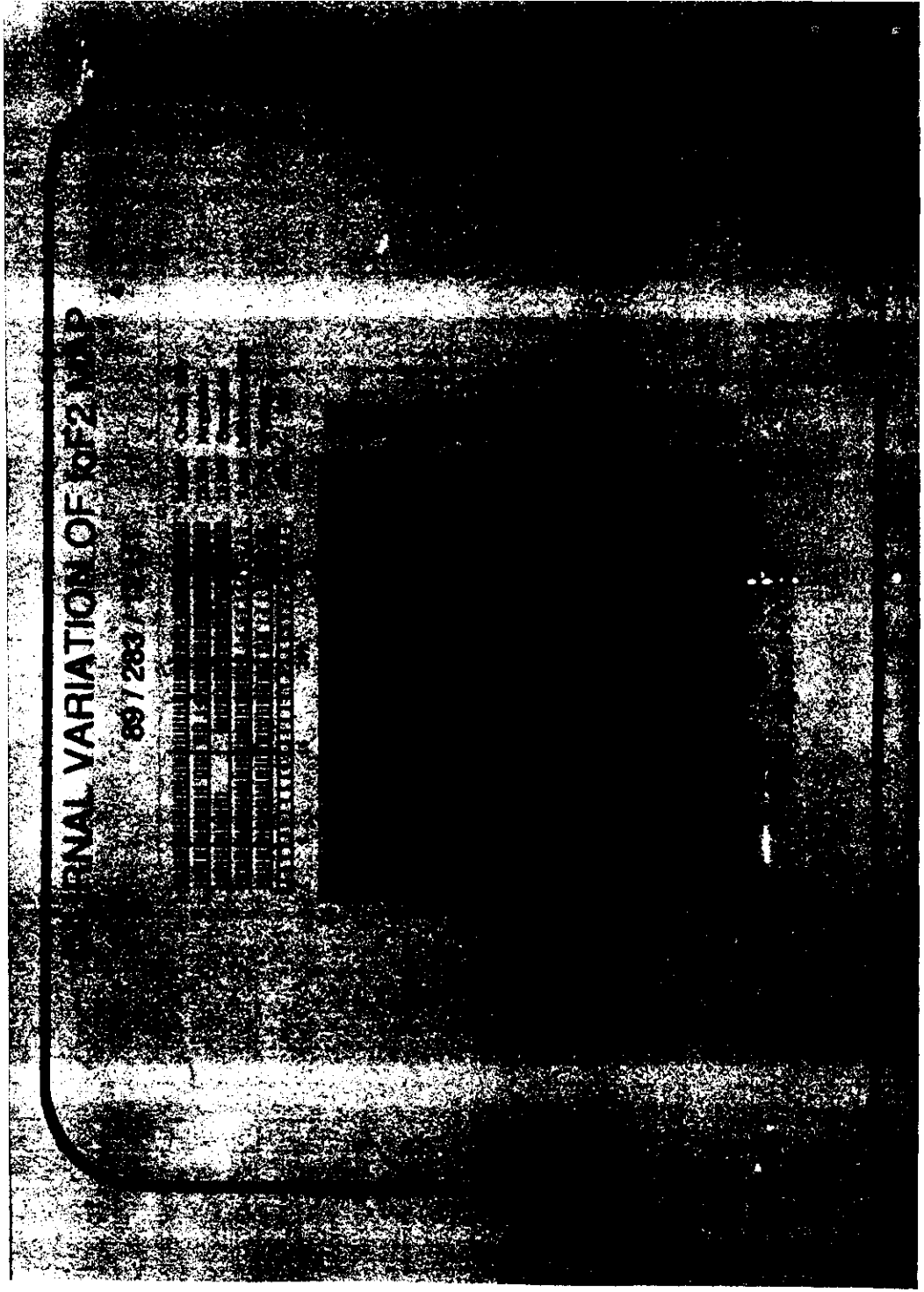
ISR & DGS DRIFT VELOCITIES

ULCAR



GLOBAL DIGISONDE NETWORK


Cdns. are C.Geomagnetic
U.L.C.A.R.
TIME IN COLT
12
18
06
00
Range 60 to 90 deg.
Lat. Inc. = 3 deg.
STATION
300 m/s
010 1992


NAL VARIATION OF hF2
89/283

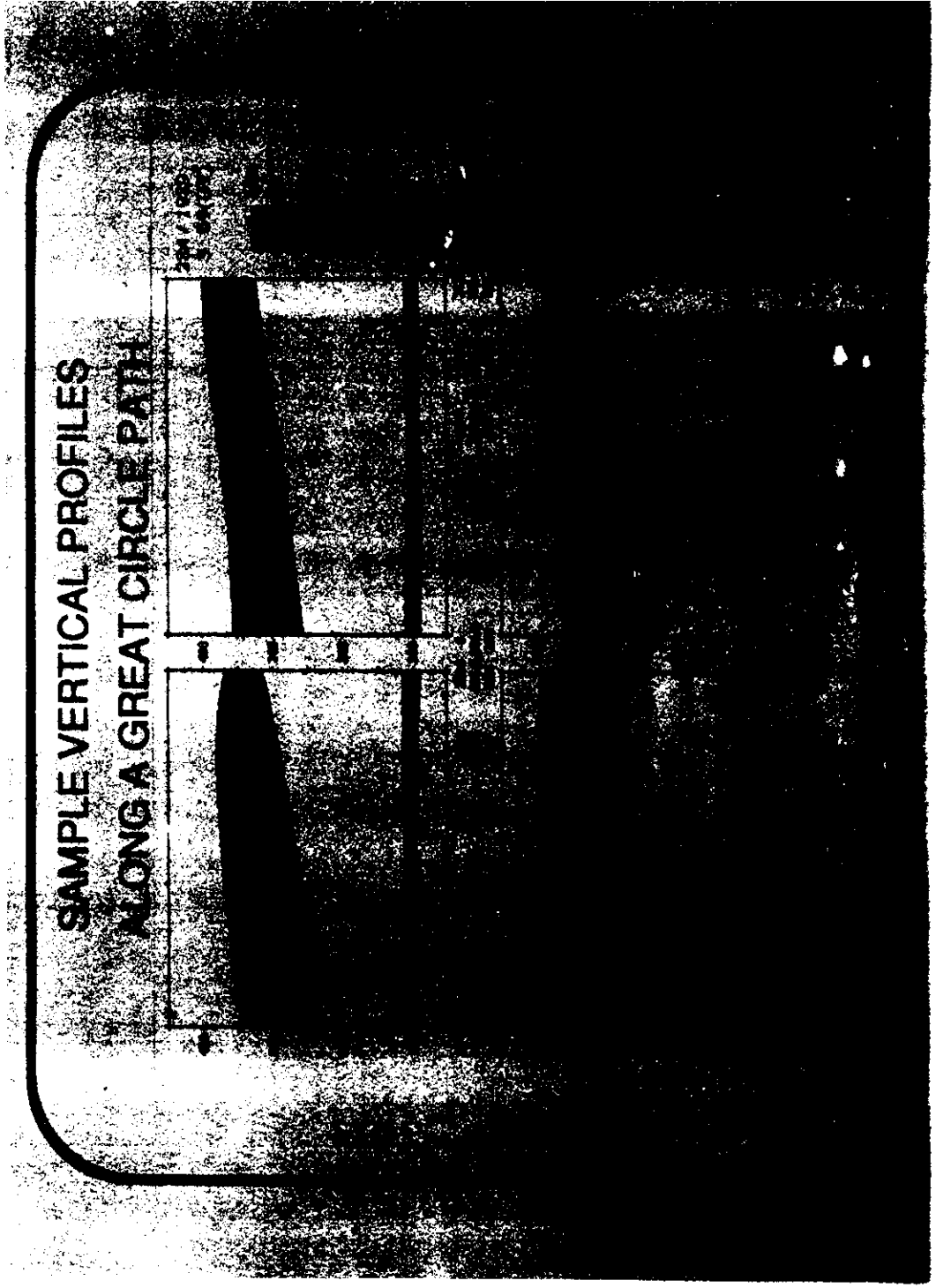
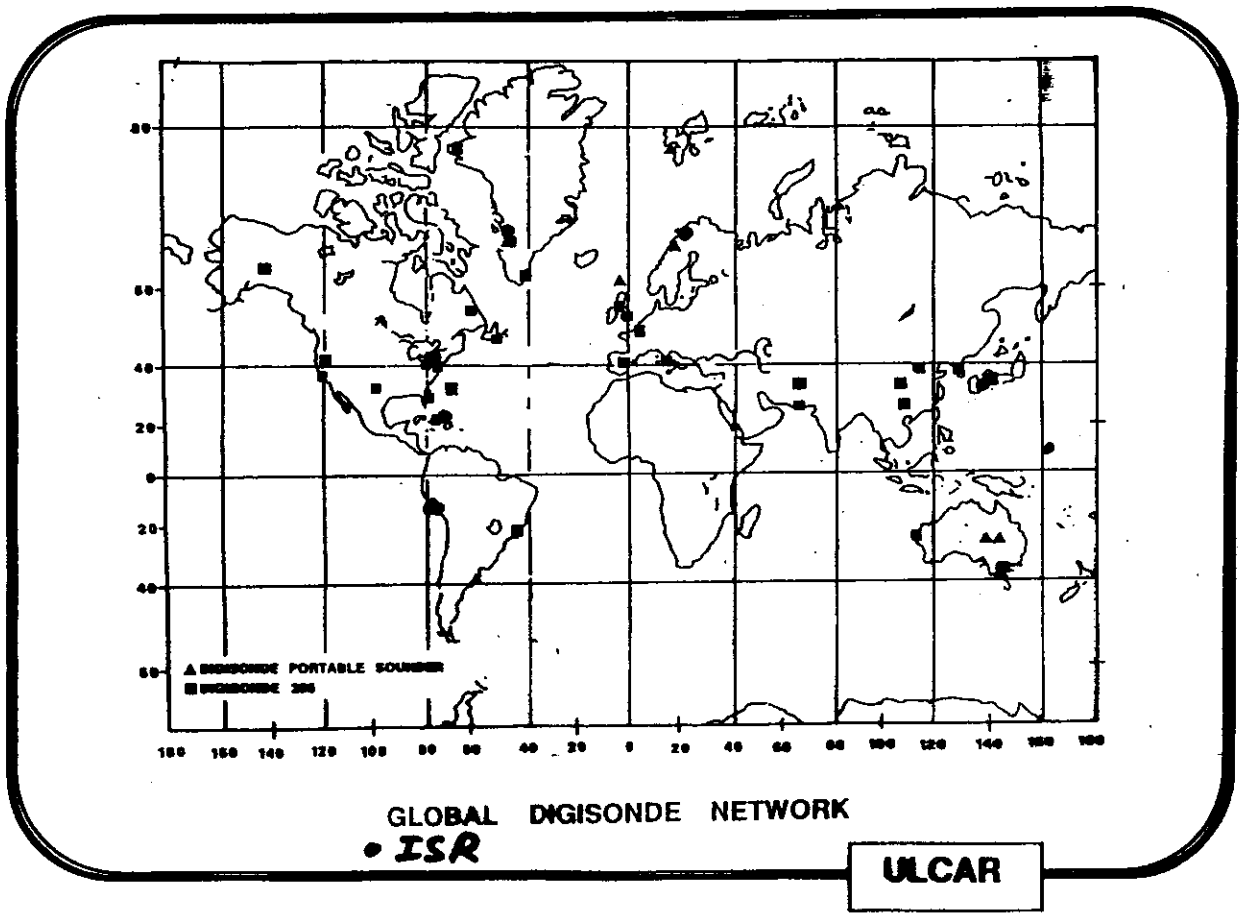


Table 1. Specifications for Digital Ionosonde

Operational Parameters		Typical Setting for VI Ionograms
Frequency Range:	0.5-30 MHz	1-16 MHz
Frequency Scale:	linear or logarithmic	linear
Frequency Steps:	5, 10, 25, 50, 100, 200 kHz	100 kHz
Range Resolution:	2.5, 5.0, 10.0 km	5.0 km
Number of Range Pixels:	128, 256	128
Range Start:	Selectable	60 km
Pulse Repetition Rate:	50, 100, 200 s^{-1}	200 s^{-1}
Pulse Width:	66, 133 μs	66 μs
Transmitter RF Power:	≤10 kW	5 kW
Duration of Ionogram:	≥1 min	2 min
Phase Code:	Interpulse Pseudo-Random Biphase Coding	
Digitization:	12 bit linear	
Amplitude Resolution:	0.25 dB	
Phase Resolution:	1.4°	
Doppler Resolution:	4 Hz to 12 mHz	1 Hz
Wave Polarization:	O/X	
Incidence Angles:	Selectable	
Data Display:	Video and Paper Print	
Data Storage:	9 track tape, floppy disk	Tape

Facility	Geographic Latitudes	Geographic Longitudes	References and Remarks
Jicamarca, Peru 1963 -	11°S	16°W	Bowles (1963)
Arecibo, Puerto Rico	18°N	66°W	Gordon (1964)
Altair radar, Kwaljalein	9°N	167°E	Tsundoa et al. (1979) f = 415 MHz
MU radar Shigaraki, Shiga, Japan 1985 -	35°N	136°E	Kato et al. (1984)
Millstone Hill, MA, USA 1960 -	42°N	71°W	Evans and Lowenthal (1964) Baron (1984)
EISCAT, Tromso, 1981 -	69°N	19°E	Kelley (1983)
Sondrestrom,. Greenland 1983 -	67°N	51°W	



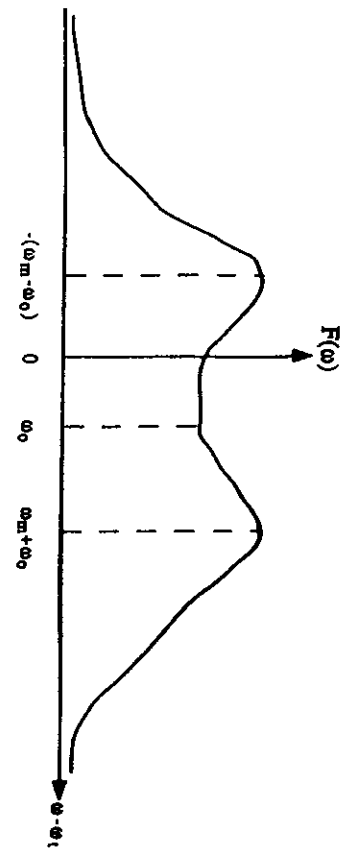


Figure 9.

Radar	Location	Type	Frequency, MHz	Power (kW)	Antenna Arrays	Beam Width	Special Features
BARS	Canada	VHF (Auroral)	48.5	60	Two 16 x 4 8-element yagi	3.6°	Two stations, phase array at Nipawin, Saskatchewan, and at Red Lake, Ontario
CUPRI	USA	VHF (Auroral)	49.92	25	Two 26-el.	3.5°	Interferometer
DAR	USSR	VHF (Auroral)	88	75	Four 10-el. Six 5-el.	17°, 9°	Two interferometers (lake)
SABRE	UK/Sweden	VHF (Auroral)	150	-	-	-	-
STARE	Scandinavia	VHF (Auroral)	140, 143.8	60	Four 16x4 8-el. yagi	3.6°	Two stations, phased array
SLOPE-POINT	New Zealand	VHF (Auroral)	53.5	15	26-el. coax	5.6°	Interferometer (sea)
Syowa	Antarctica	VHF (Auroral)	51, 112	15	Three 14-el. coax	3-4°	Meteor radar, double beam
Goose Bay	Canada	HF	8-20	16	Two 16-el. arrays of 10-el. log. periodics	3.3°	Interferometer, phased array
SOUSY	Scandinavia	VHF (MST)	53.5	200	576 4-el. yagi	3.0°	Steerable in four directions
SHERPA	Canada	HF	8-20	1	Eight 10-el. log. periodics	10°	Phased array
PACE	Antarctica	HF	8-20	16	One-16el. of 10-el. log arrays periodics	3.3°	Interferometer, phased array

Satellite/ Type	Frequency Range MHz	Sweep Rate MHz/s	PRF Hz	Pulse Width (μs)	Transmitter Power (W)	Remarks
Alouette I sweep	0.5-12	~1	63	100	100	1962, 1000 km polar orbit
Alouette II	0.12 - 14.5	0.13 – 1.0	30	100	300	L1965, 500-3000 km polar orbit
Explorer XX step	1.50 - 7.22	0.57 – 1.1			100	L1964, 800 km polar orbit
ISIS I step and sweep	Fixed frequency from 0.25 - 9.3	0.376 – 1.5	45	87	400	L1971, 1400 km circular polar orbit
ISS-b step and sweep						L1978, 972-1220 km orbit at 70° inclination

L = "Launched".