1995109269

N95- 14683

Radiometer Calibration Procedure

and

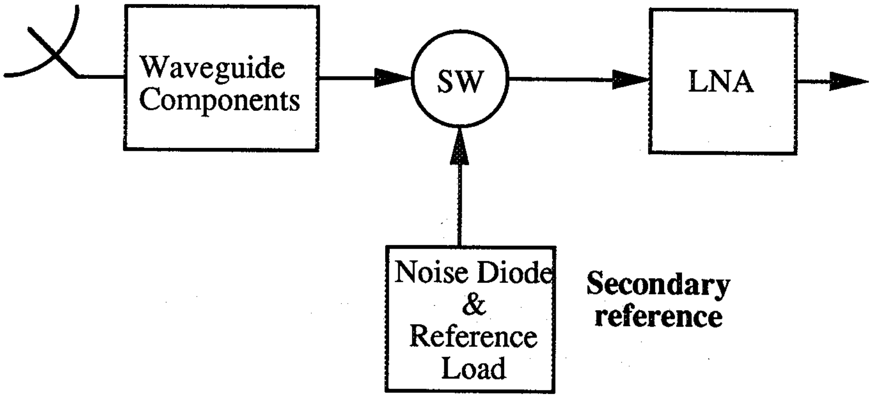
Beacon Attenuation Estimation Reference Level

by

Robert K. Crane

University of Oklahoma

RADIOMETER SYSTEM



- VSWR through switch is high (~ 2:1)
- Match secondary reference to LNA not the same as match antenna to LNA
- Hot/Cold load measurements not necessary match probably different from other loads
- No absolute calibration possible using loads and secondary reference

RADIOMETER CALIBRATION

PRIMARY:

- Compare Radiometer Attenuation with Beacon Attenuation
- Compare Sky Temperature Estimates with Calculations Using Simultaneous Meteorological Data

SECONDARY:

- Noise Diode and Reference Load Measurements
- Adjust for Outside Temperature and Component Temperature Changes

RADIOMETER CALIBRATION MODEL

$Tr = A + B\ V$

$Ts = C\ Tr + D\ To + E$

$Ar = -4.343 \ln ((Tm - Ts)/(Tm - Tb))$

A, B from noise diode, reference load measurements

C from beacon attenuation vs radiometer attenuation measurements

D, E from radiometer estimates of sky temperature vs calculated sky temperature

Tm from calculations

Tb from theory

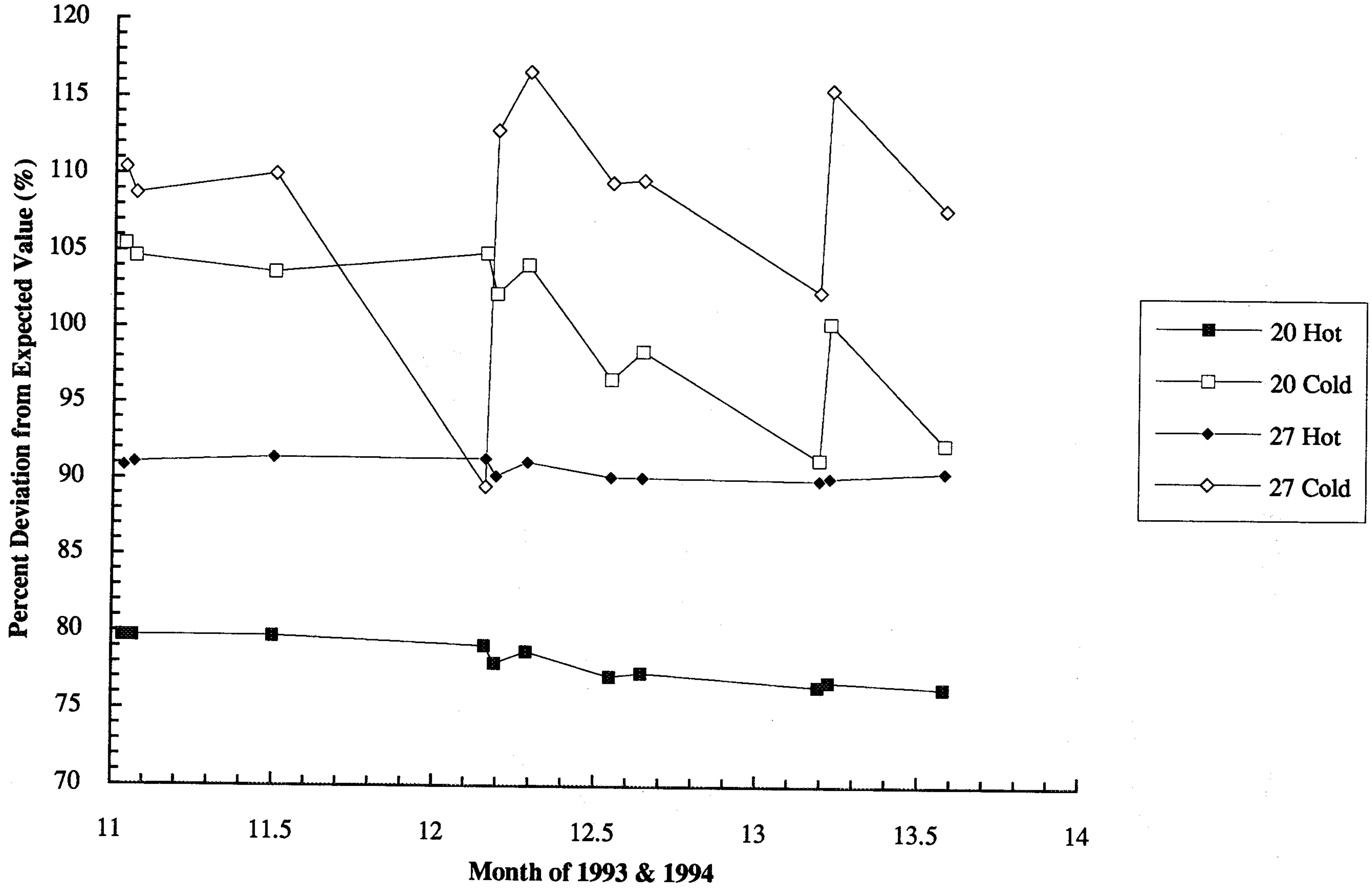
SYSTEM CALIBRATION IS ITERATIVE

- **Need beacon attenuation to compare to radiometer**
- **Need radiometer attenuation to set beacon reference level**

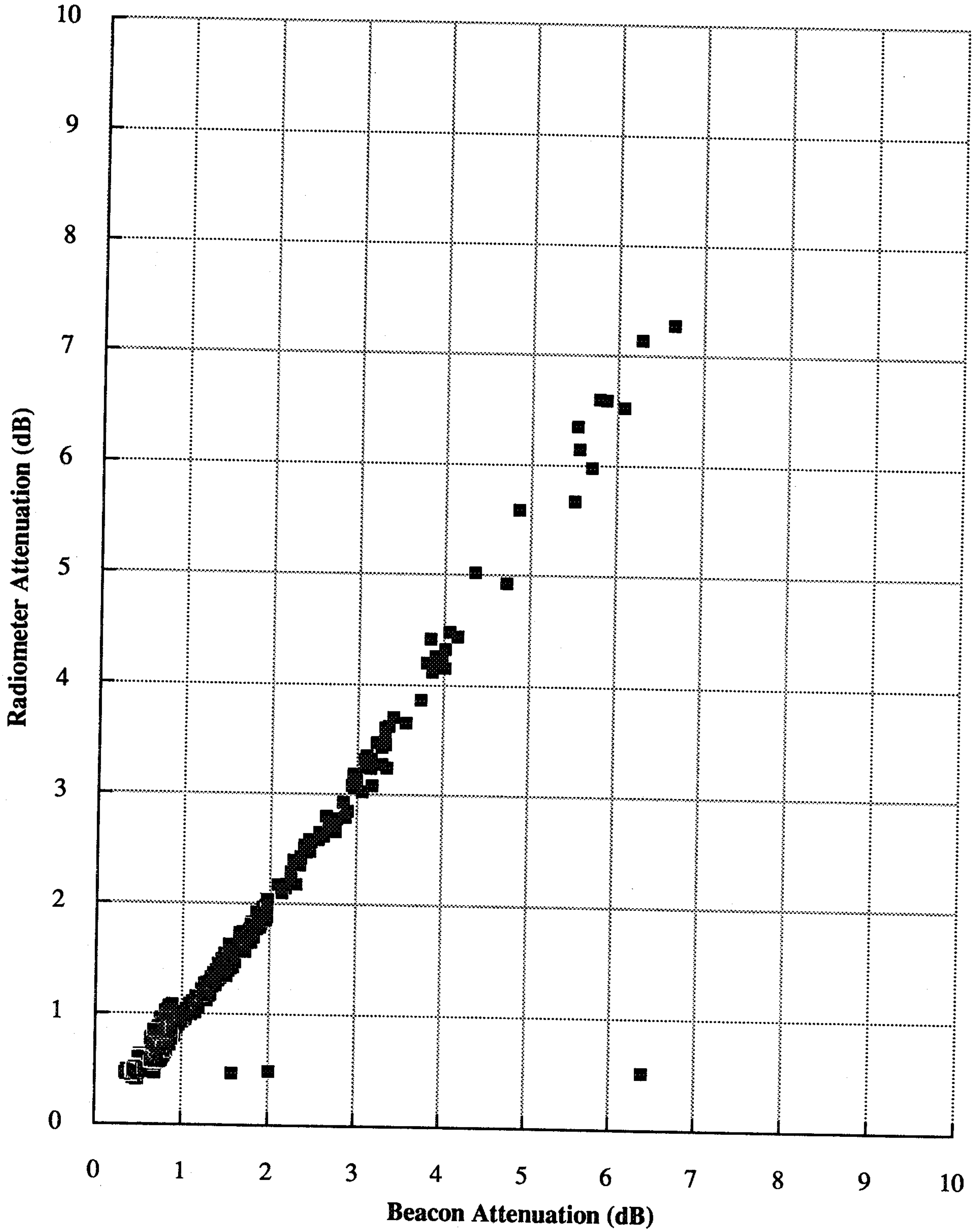
Assumptions

- **Beacon receiver is linear, need only find reference level to estimate beacon attenuation**
- **Radiometer receiver temperature is a linear function of radiometer output voltage, need only estimate gain and offset**
- **Sky temperature is a linear function of radiometer receiver temperature, need only estimate efficiency and background temperature**
- **Radiometer attenuation may be estimated from sky temperature if the medium temperature is known**

Hot/Cold.plt



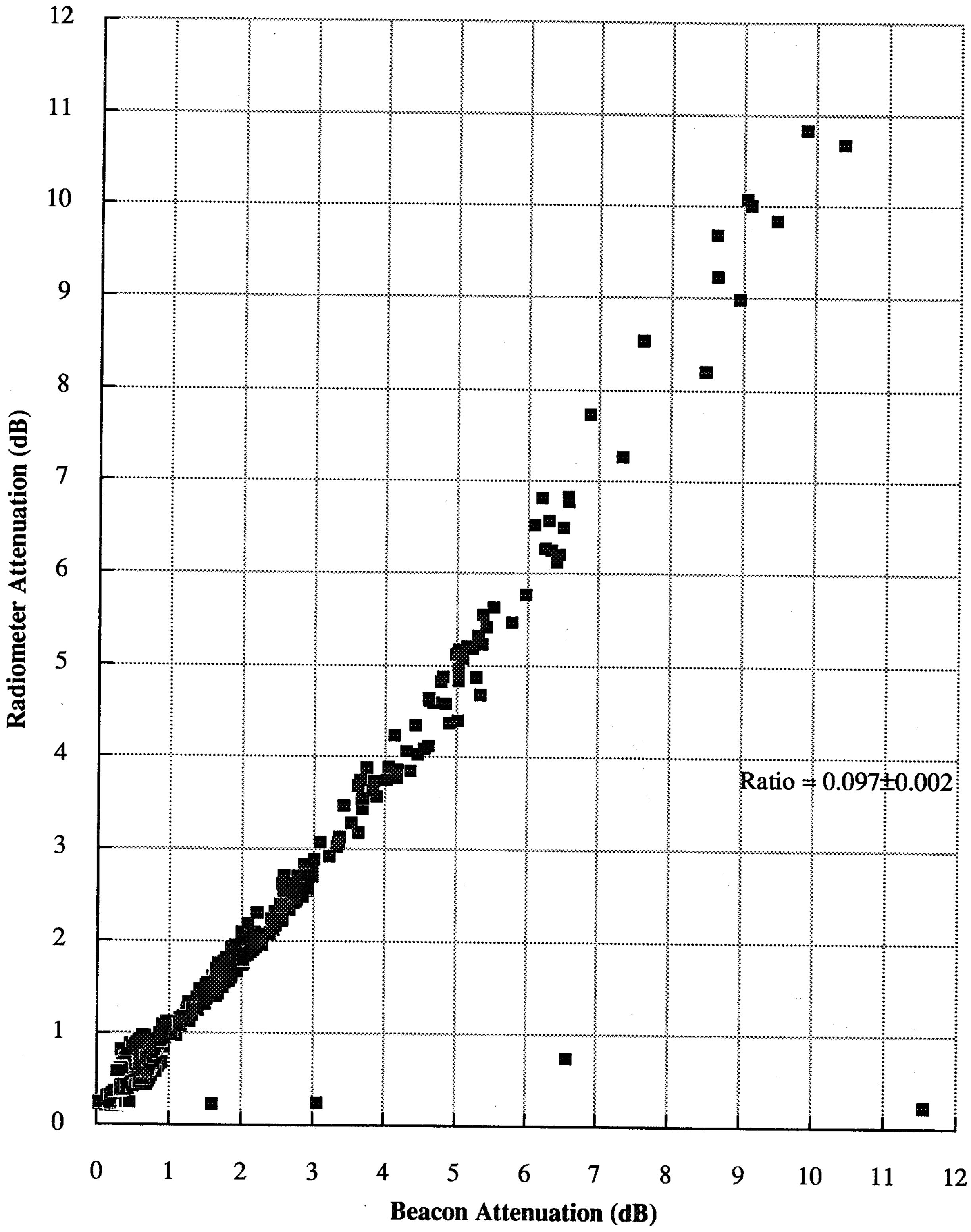
Percent Deviation from Expected Value (%)
120
115
110
105
100
95
90
85
80
75
70
11
11.5
12
12.5
13
13.5
14
Month of 1993 & 1994
20 Hot
20 Cold
27 Hot
27 Cold

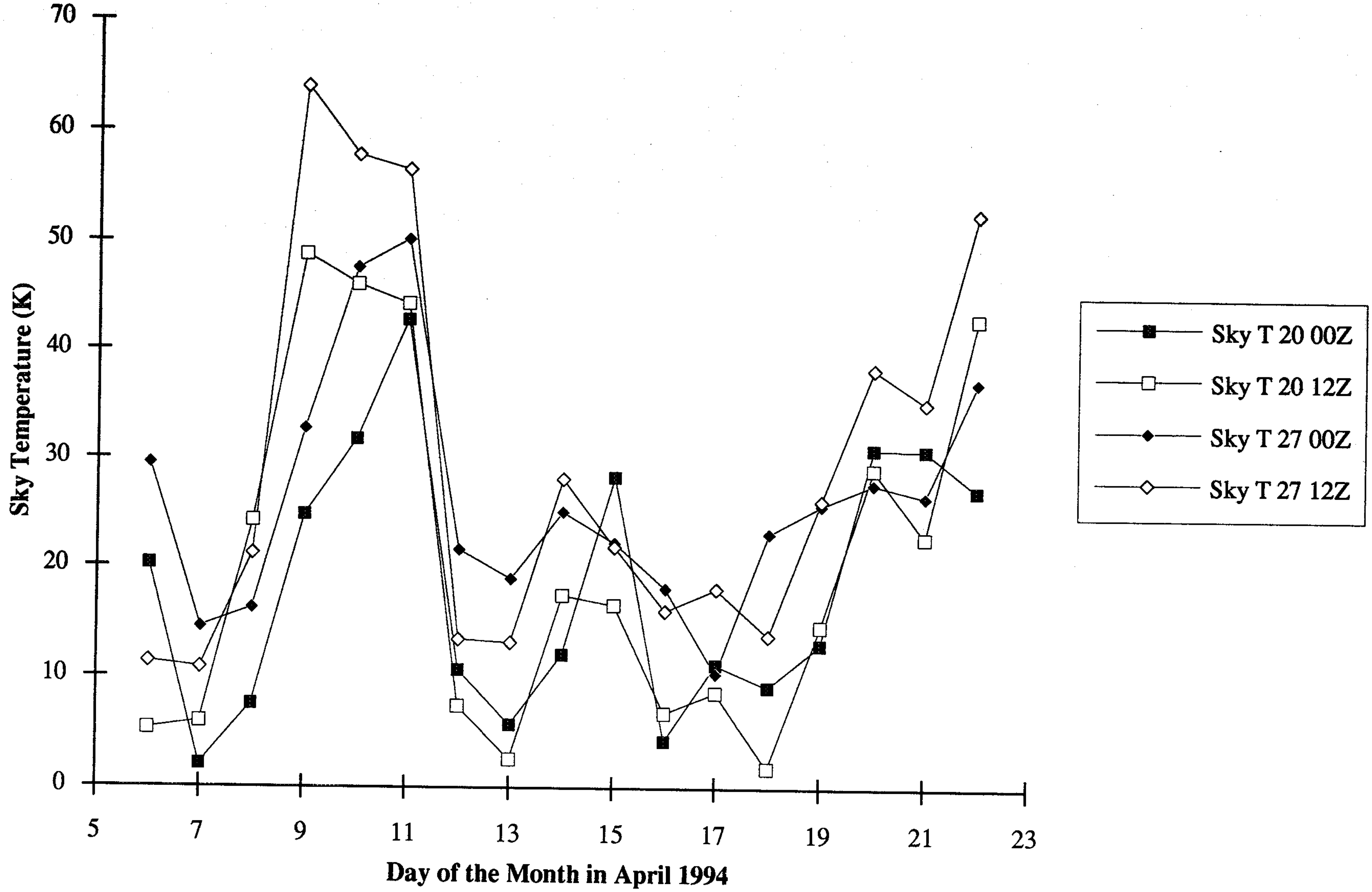


10
9
8
7
6
5
4
3
2
1
0
Radiometer Attenuation (dB)
0
1
2
3
4
5
6
7
8
9
10
Beacon Attenuation (dB)

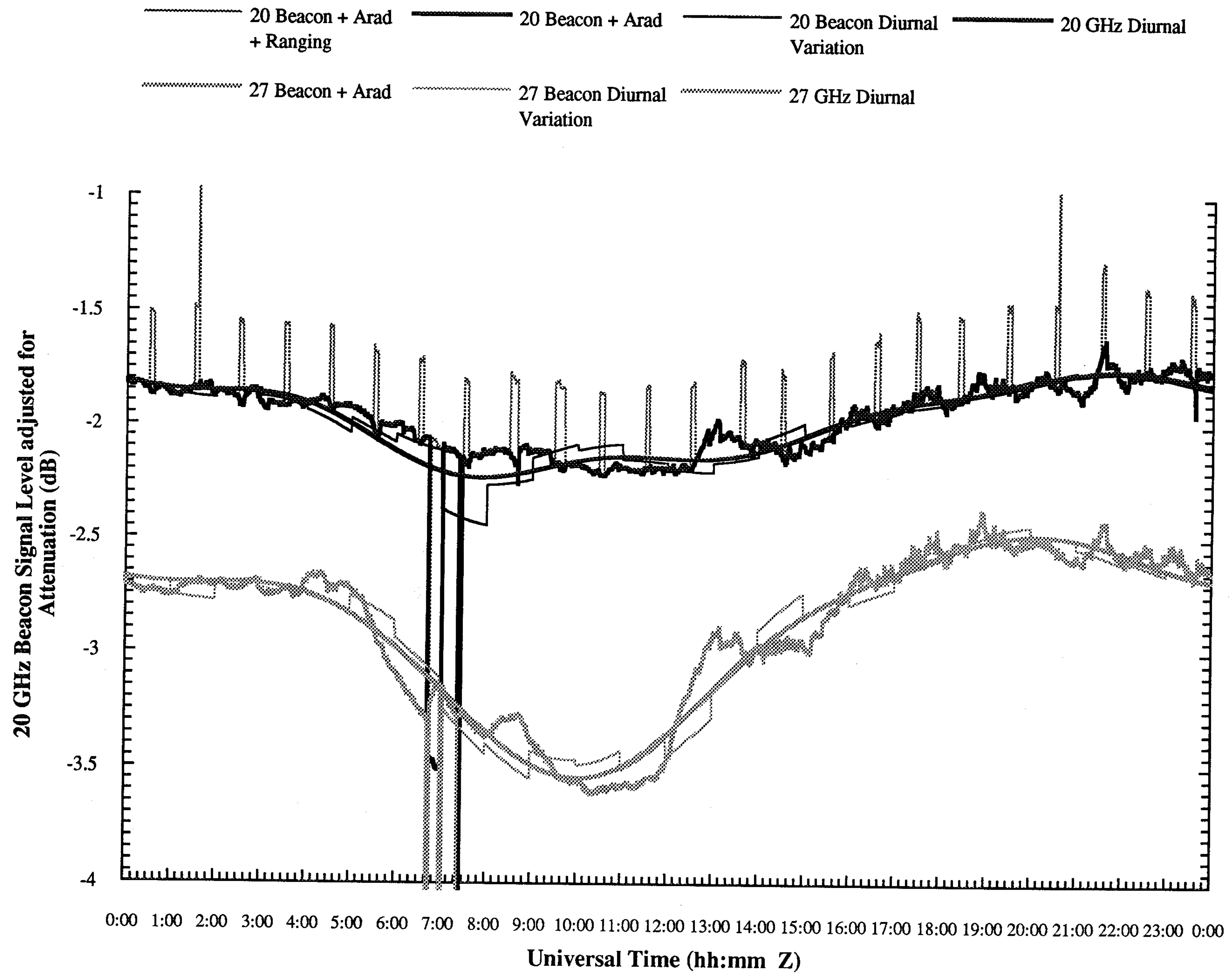
C-4.

940228OK.a2

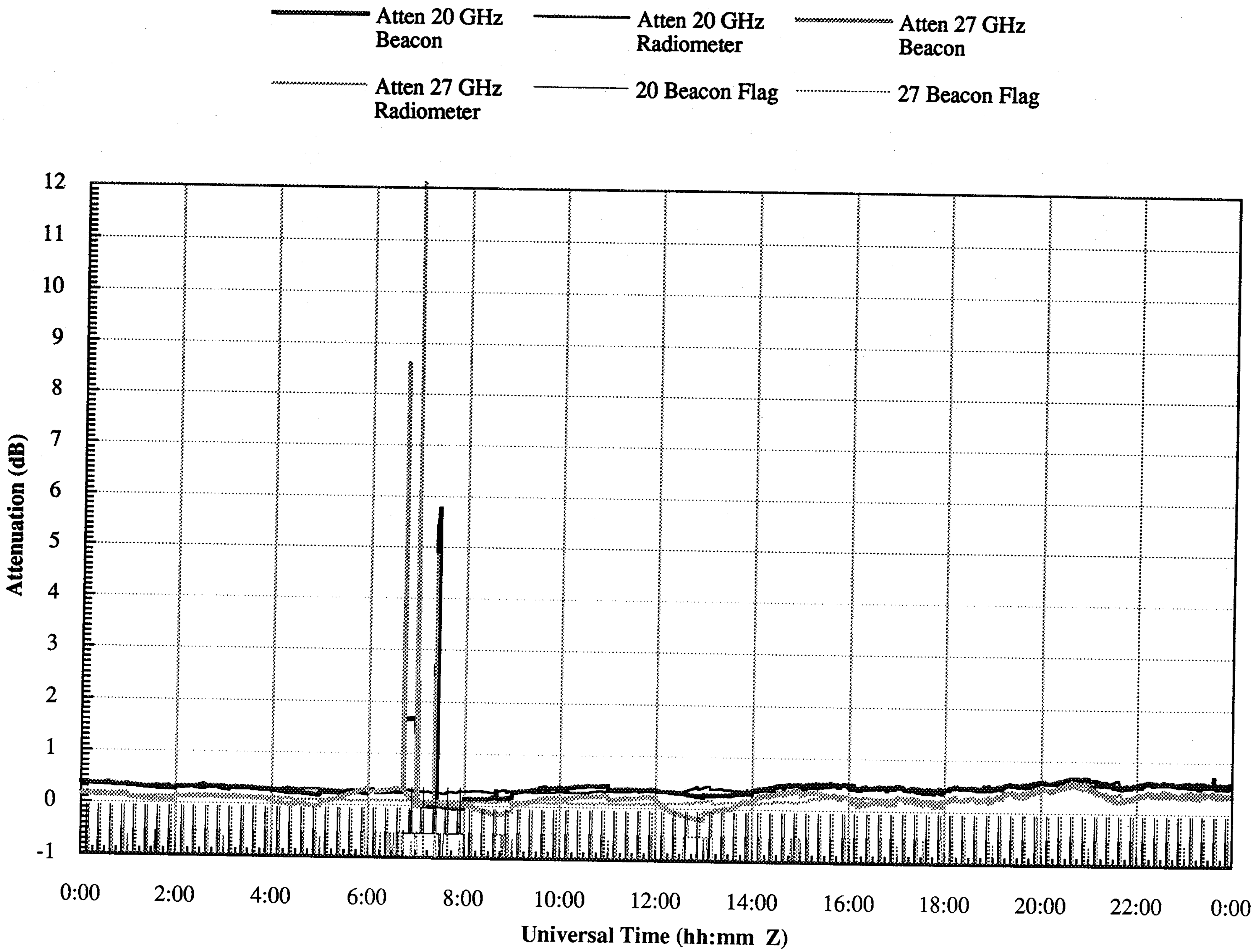

Radiometer Attenuation (dB)
Beacon Attenuation (dB)
Ratio = 0.097±0.002
0
1
2
3
4
5
6
7
8
9
10
11
12


Sky Temperature (K)
70
60
50
40
30
20
10
0
5
7
9
11
13
15
17
19
21
23
Day of the Month in April 1994
Sky T 20 00Z
Sky T 20 12Z
Sky T 27 00Z
Sky T 27 12Z

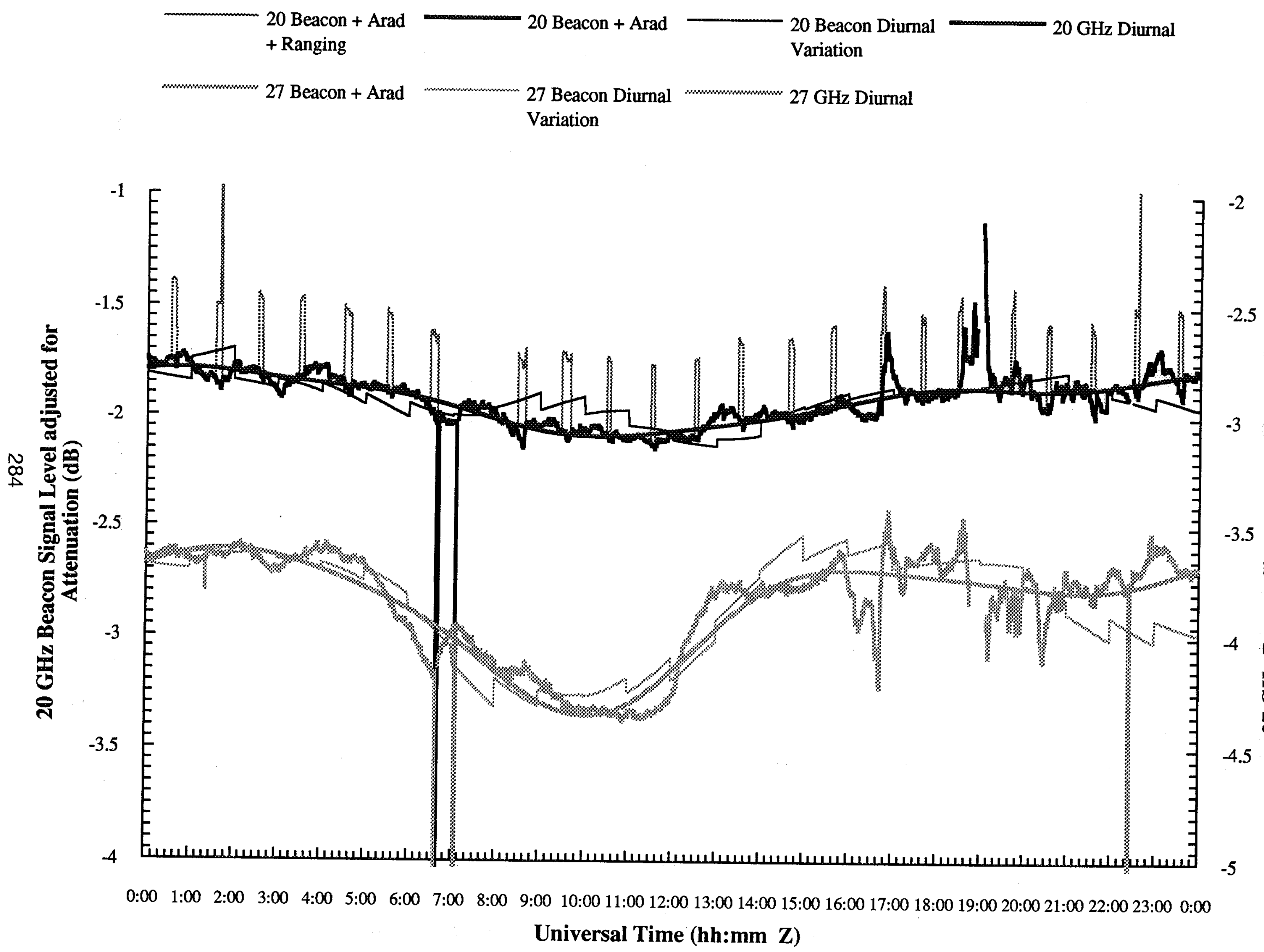
940227OK.np


20 Beacon + Arad + Ranging
20 Beacon + Arad
20 Beacon Diurnal Variation
20 GHz Diurnal
27 Beacon + Arad
27 Beacon Diurnal Variation
27 GHz Diurnal
20 GHz Beacon Signal Level adjusted for Attenuation (dB)
27 GHz Beacon Signal Level Adjusted for Attenuation (dB)
-1
-1.5
-2
-2.5
-3
-3.5
-4
-2
-2.5
-3
-3.5
-4
-4.5
-5
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Universal Time (hh:mm Z)

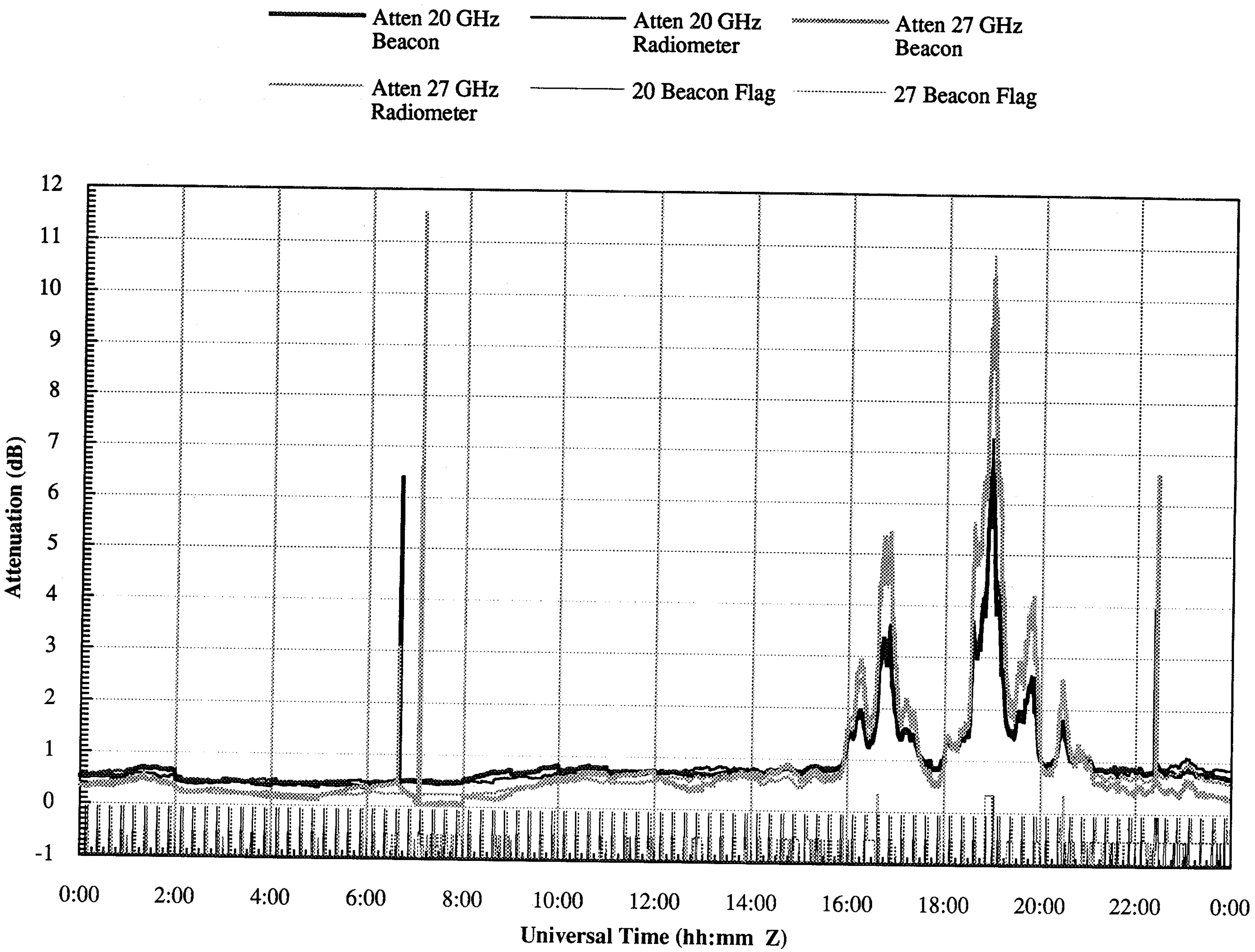
940227OK.na


Atten 20 GHz Beacon
Atten 20 GHz Radiometer
Atten 27 GHz Beacon
Atten 27 GHz Radiometer
20 Beacon Flag
27 Beacon Flag
Attenuation (dB)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Universal Time (hh:mm Z)

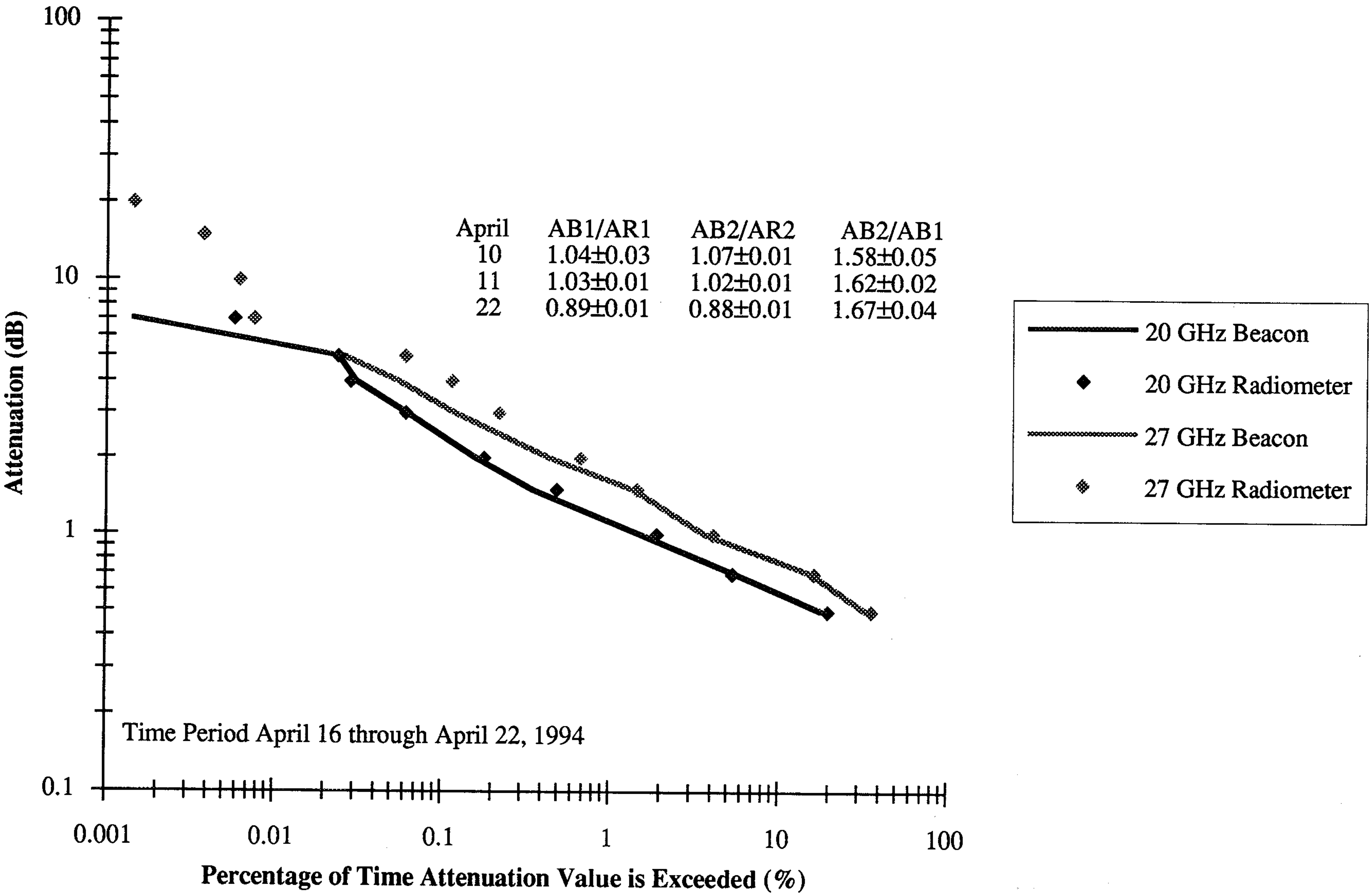
940228OK.np


20 Beacon + Arad + Ranging
20 Beacon + Arad
20 Beacon Diurnal Variation
20 GHz Diurnal
27 Beacon + Arad
27 Beacon Diurnal Variation
27 GHz Diurnal
20 GHz Beacon Signal Level adjusted for Attenuation (dB)
27 GHz Beacon Signal Level Adjusted for Attenuation (dB)
-1
-1.5
-2
-2.5
-3
-3.5
-4
-2
-2.5
-3
-3.5
-4
-4.5
-5
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00
Universal Time (hh:mm Z)

940228OK.na



Atten 20 GHz Beacon
Atten 20 GHz Radiometer
Atten 27 GHz Beacon
Atten 27 GHz Radiometer
20 Beacon Flag
27 Beacon Flag
Attenuation (dB)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Universal Time (hh:mm Z)


100
10
1
0.1
Attenuation (dB)
April AB1/AR1 AB2/AR2 AB2/AB1
10 1.04±0.03 1.07±0.01 1.58±0.05
11 1.03±0.01 1.02±0.01 1.62±0.02
22 0.89±0.01 0.88±0.01 1.67±0.04
20 GHz Beacon
20 GHz Radiometer
27 GHz Beacon
27 GHz Radiometer
Time Period April 16 through April 22, 1994
0.001
0.01
0.1
1
10
100
Percentage of Time Attenuation Value is Exceeded (%)

EERL / Univ. of Texas

DATA CENTER STATUS REPORT

BY

WOLFHARD J VOGEL

&

ALI SYED

EERL/UTAU

10100 BURNET RD

AUSTIN, TX 78758-4497

PRESENTED AT APSW-VI

VANCOUVER, BC

JUNE 16, 1994

EERL / Univ. of Texas

ACTS DC Services

- ☑ Archive Raw and Pre-processed Data from Stations
- ☑ Archive Event & Fault Logs from Stations
- ☑ Audit Pre-processed Data
- ☑ Distribute Monthly Audit Reports to Stations
- ⌛ Distribute Archived Data to Propagation Community

EERL / Univ. of Texas

Raw Data Status

Desktop Editor - [C:\ACTS-D\ACTSRAW.TXT]

File Edit Search Options Window Help

New Open Save Close Print Undo Cut Paste Del Prev Find Next Help Exit

```
S   9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
T   3  4  4  4  4  4  4  4  4  4  4  4  4  5  5  5  5  5  5  5  5  5  5  5  5
A   1  0  0  0  0  0  0  0  0  0  1  1  1  0  0  0  0  0  0  0  0  0  1  1  1
T   2  1  2  3  4  5  6  7  8  9  0  1  2  1  2  3  4  5  6  7  8  9  0  1  2

AK 31 31 28 31 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

BC 31 31 28 31 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

CO 30 31 28 31 XX .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

FL 29 31 28 29 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

MD XX XX XX 17 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

NM 29 31 25 18 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

OK 31 31 28 31 XX .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..
```

Line 18 Col 78

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Pre-processed Data Status

Desktop Editor - [C:\ACTS-D\C\ACTSPPD.TXT]

File Edit Search Options Window Help

New Open Save Close Print Undo Cut Paste Del Prev Find Next Help Exit

```
S   9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
T   3  4  4  4  4  4  4  4  4  4  4  4  4  5  5  5  5  5  5  5  5  5  5  5  5
A   1  0  0  0  0  0  0  0  0  0  1  1  1  0  0  0  0  0  0  0  0  0  1  1  1
T   2  1  2  3  4  5  6  7  8  9  0  1  2  1  2  3  4  5  6  7  8  9  0  1  2

AK 31 31 28 31 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

BC 25 31 28 31 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

CO 29 31 28 30 XX .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

FL 28 18 28 27 30 .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

MD XX XX XX XX XX .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

NM XX 30 23 XX XX .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..

OK XX XX XX XX XX .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. .. ..
```

Line 18 Col 78

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Data Archival Status

FIRST RAW DATA CD-ROM WRITTEN ON 5/27/94

1105 MB IN
838 RAW DATA
FILES

543 MB
ON CD-ROM

COMPRESSION RATIO OF ~2.0

751 MB IN
570 PP DATA
FILES

213 MB
ON HARD DISK

COMPRESSION RATIO OF ~3.5

Audit & Analysis Status

☹ **INCORRECT DATA STRUCTURE CAUSED ERROR IN AUDIT & ANALYSIS. BUG FIXED.**

☒	Time Stamp	Beacon at 20 GHz	Radiometer at 20 GHz	Beacon at 27 GHz	Radiometer at 27 GHz	Status 1	Status 2
☑	Time Stamp	Beacon at 20 GHz	Beacon at 27 GHz	Radiometer at 20 GHz	Radiometer at 27 GHz	Status 1	Status 2

☹ **INCORRECT SCALING FOR STATUS QUANTITIES CAUSED ERROR IN AUDIT REPORT. BUG FIXED.**

QUANTITY	***CORRECT SCALE***	***RANGE***
RainGauge [Volts]	1000	0 to 500 mm/Hr
AirTemp. [C]	100	-50 to 70 C
Rel.Humd [%]	100	0 to 100 %

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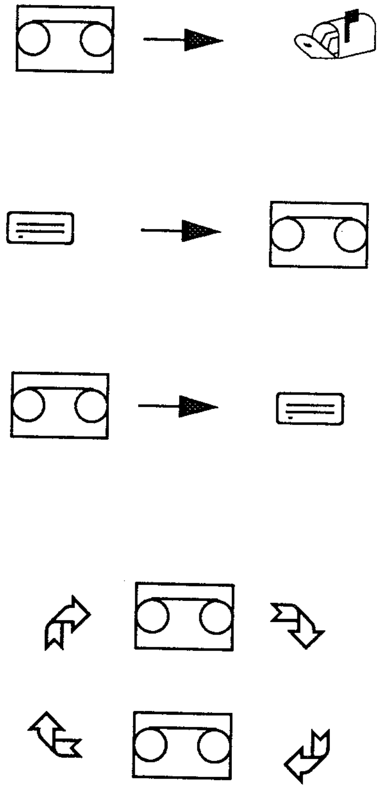
DC System Status

- CD WRITER OK
- 120 MB TAPE DRIVE OK
- HARD DRIVE SCSI CARD FAILURE IN 3/94 RESULTED IN ~2 WEEKS DOWNTIME
  - SYSTEM & DATA RESTORED FROM TAPES
  - DAILY BACKUP SCHEDULE ADOPTED

Data Tapes Status



44 DATA TAPES RECEIVED FROM STATIONS

DIFFERENT BACKUP PATHS NOT A PROBLEM

COLORADO BACKUP LITE VER 1.20 USED BY DATA CENTER

DATA TAPES WILL BE RECYCLED

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Feedback Schedule

DATA

LOGS

RECEIVED STATUS

E-MAIL TO DOERS EVERY FRIDAY

PP DATA

AUDIT REPORT FOR ALL STATIONS IN MONTH

E-MAIL TO DOERS FIRST WEEK OF EVERY MONTH

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CONCLUSION

- DATA COMPRESSION AND ARCHIVAL HAS WORKED WITH REAL DATA
- BUGS FOUND IN AUDIT & ANALYSIS ROUTINES HAVE BEEN FIXED
- WEEKLY DATA RECEIVED STATUS REPORT WILL BE DISTRIBUTED VIA E-MAIL
- MONTHLY AUDIT REPORT FOR STATIONS WILL BE DISTRIBUTED VIA E-MAIL
- SOME FINE TUNING IS EXPECTED IN THE FOLLOWING MONTHS

ALASKA ACTS PROPAGATION TERMINAL: DATA ANALYSIS PROCEDURE, SYSTEM STATUS AND RESULTS

ACTS PROPAGATION MINIWORKSHOP
AND NAPEX-XVIII
VANCOUVER, BC
JUNE 16, 1994

BRAD JAEGER
CHARLIE MAYER
UNIVERSITY OF ALASKA FAIRBANKS

Alaska ACTS Propagation

OUTLINE

I. DATA ANALYSIS PROCEDURE AND RESULTS
   - JAEGER

II. SYSTEM STATUS AND RESULTS
   - MAYER

III. FUTURE PLANS
   - MAYER

Alaska ACTS Propagation

I. DATA ANALYSIS PROCEDURE

A. COUNT EVENTS

B. ANALYZE INDIVIDUAL EVENTS

C. ANALYZE CUMULATIVE STATISTICS

D. FORMULATE MODELS OF VARIOUS PARAMETERS

Alaska ACTS Propagation

A. COUNT EVENTS

- RAIN EVENTS
- SNOW EVENTS
- SCINTILLATION EVENTS

CATEGORIZE THESE EVENTS IN TERMS OF MAXIMUM FADE, FADE SLOPE, FADE DURATION, ETC.

Alaska ACTS Propagation

B. ANALYZE INDIVIDUAL EVENTS

- TIME SERIES ANALYSIS
- POWER SPECTRAL DENSITY ANALYSIS
- SCINTILLATION INTENSITY
- FADE SLOPE

Alaska ACTS Propagation

C. ANALYZE CUMULATIVE STATISTICS

- BIN THE VARIABLES
- RUNNING AVERAGE TO REMOVE SCINTILLATIONS
- CUMULATIVE BINS
  - DAY
  - MONTH
  - YEAR
  - EXPERIMENT LENGTH

Alaska ACTS Propagation

C. ANALYZE CUMULATIVE STATISTICS

- STATISTICAL ANALYSIS
  - CDFs
  - TIME PERCENTAGES VALUES EXCEEDED
  - WORST MONTH
    - » WORST MONTH TO ANNUAL AVERAGE
    - » WORST MONTH TO OTHER MONTHS
  - FREQUENCY SCALING
    - » ATTENUATION RATIOS
    - » SCINTILLATION RATIOS
  - SCINTILLATION DIURNAL AND ANNUAL VARIABILITY PLOTS
  - RAIN RATE ANALYSES
    - » DIURNAL VARIABILITY
    - » ANNUAL VARIABILITY

Alaska ACTS Propagation

D. FORMULATE MODELS OF VARIOUS PARAMETERS

- ATTENUATION RATIO VS. FREQUENCY
- SCINTILLATION RATIO VS. FREQUENCY
- SCINTILLATION INTENSITY VS. ELEVATION ANGLE
- ULTIMATE FADE DEPTH
- FADE DURATION
- TIME BETWEEN FADES

Alaska ACTS Propagation

BINNING PROCEDURE

Variable	Small Bin	Large Bin	Increment
Rain Rate	0 mm/hr	>200 mm/hr	2 mm/hr, R<30 mm/hr
			5 mm/hr, R>30 mm/hr
Beacon Attenuation	-8 dB	30 dB	1 dB or 0.2 dB
Attenuation Ratio	0	15	0.05
Radiometric Attn.	0 dB	15 dB	1 dB or 0.2 dB
Fade Slope	-1.25 dB/s	1.25 dB/s	0.05 dB/s
Ultimate Fade Depth	1 dB	30 dB	1 dB or 0.2 dB
Fade Duration	0-1 s; 1-2, 2-3, 3-5, 5-10,		for fade levels of -8 to
	10-20, 20-30, 30-60 s &		30 dB in 1 dB
	min., >60 min.		increments
Time Between Fades	as above		as above
Sky Temperature	0 K	>300 K	2 K
Scintillation Intensity	0	4	0.05

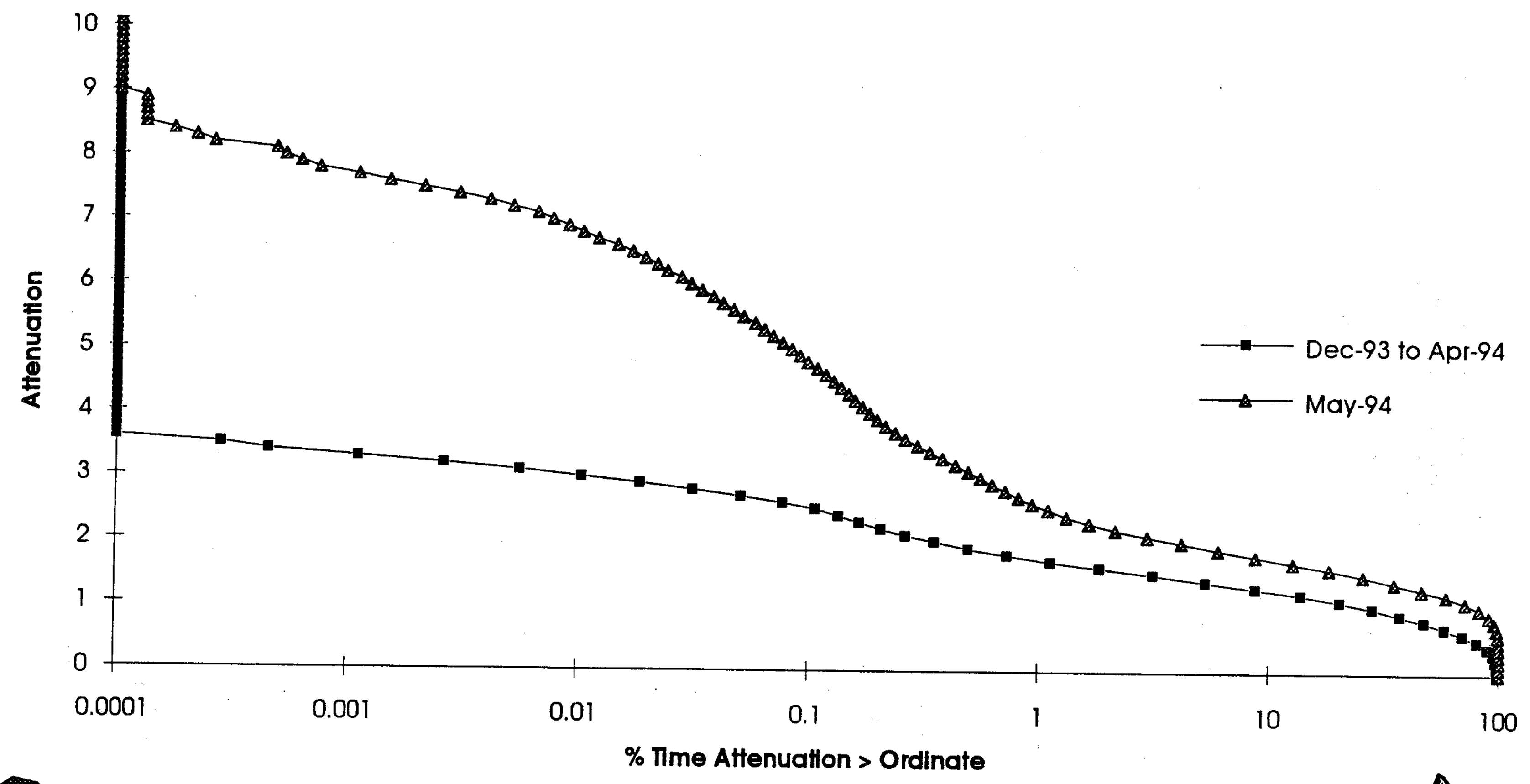
Alaska ACTS Propagation

II. SYSTEM STATUS

- **APT MODIFICATIONS**
  - ANGLED MOUNT POLE
  - RF BOX BRACING
  - SNOW FAN
  - ADDITIONAL INSULATION WITH REFLECTIVE COATING
- **PROBLEMS**
  - EMI
  - DYNAMIC RANGE LIMITATIONS
  - SATELLITE POINTING VARIATIONS
- **OPERATION**
  - POWER OUTAGES

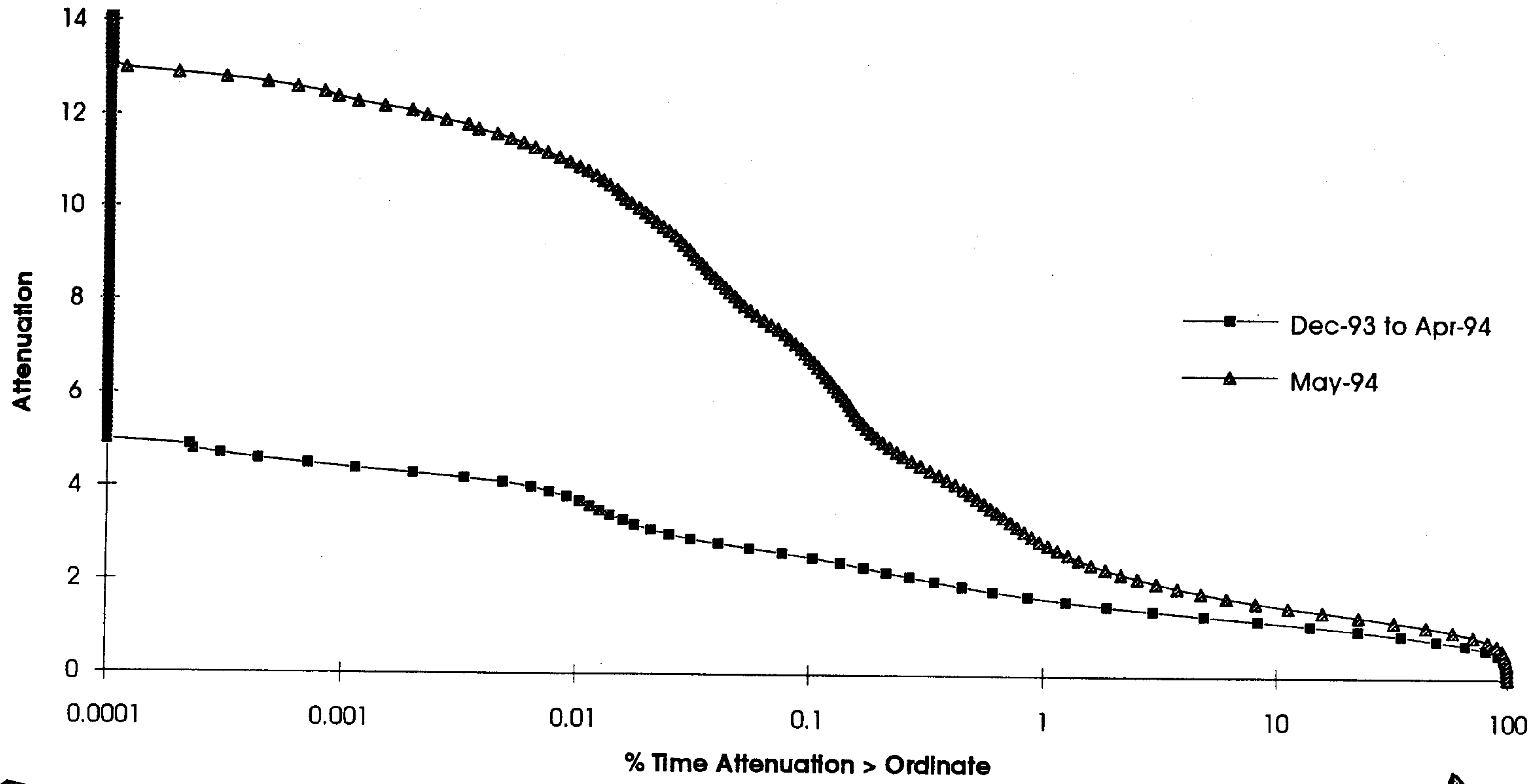
Alaska ACTS Propagation

20.185 GHz Beacon CDFs

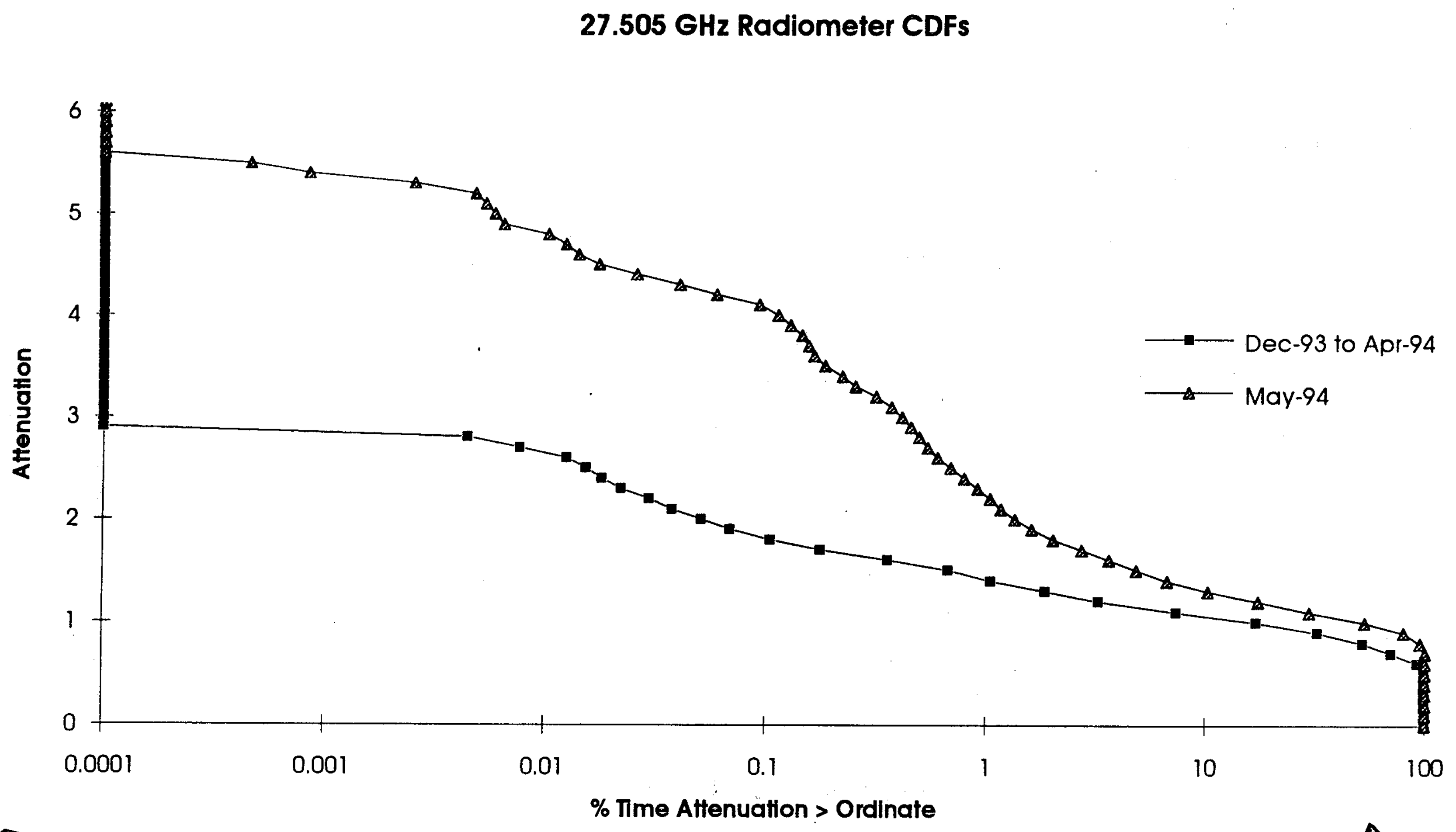


Alaska ACTS Propagation

27.505 GHz Beacon CDFs

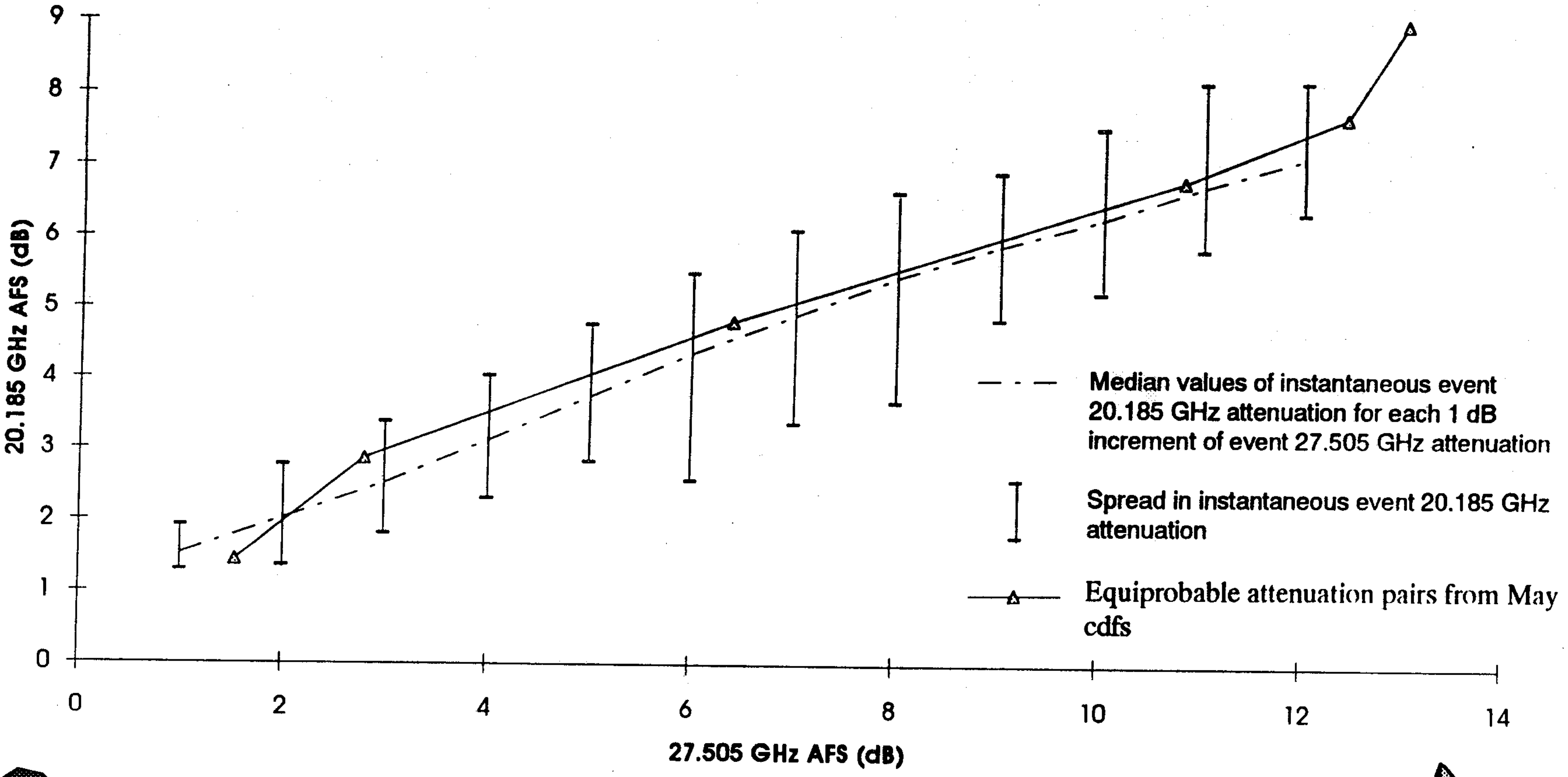


Alaska ACTS Propagation



Alaska ACTS Propagation

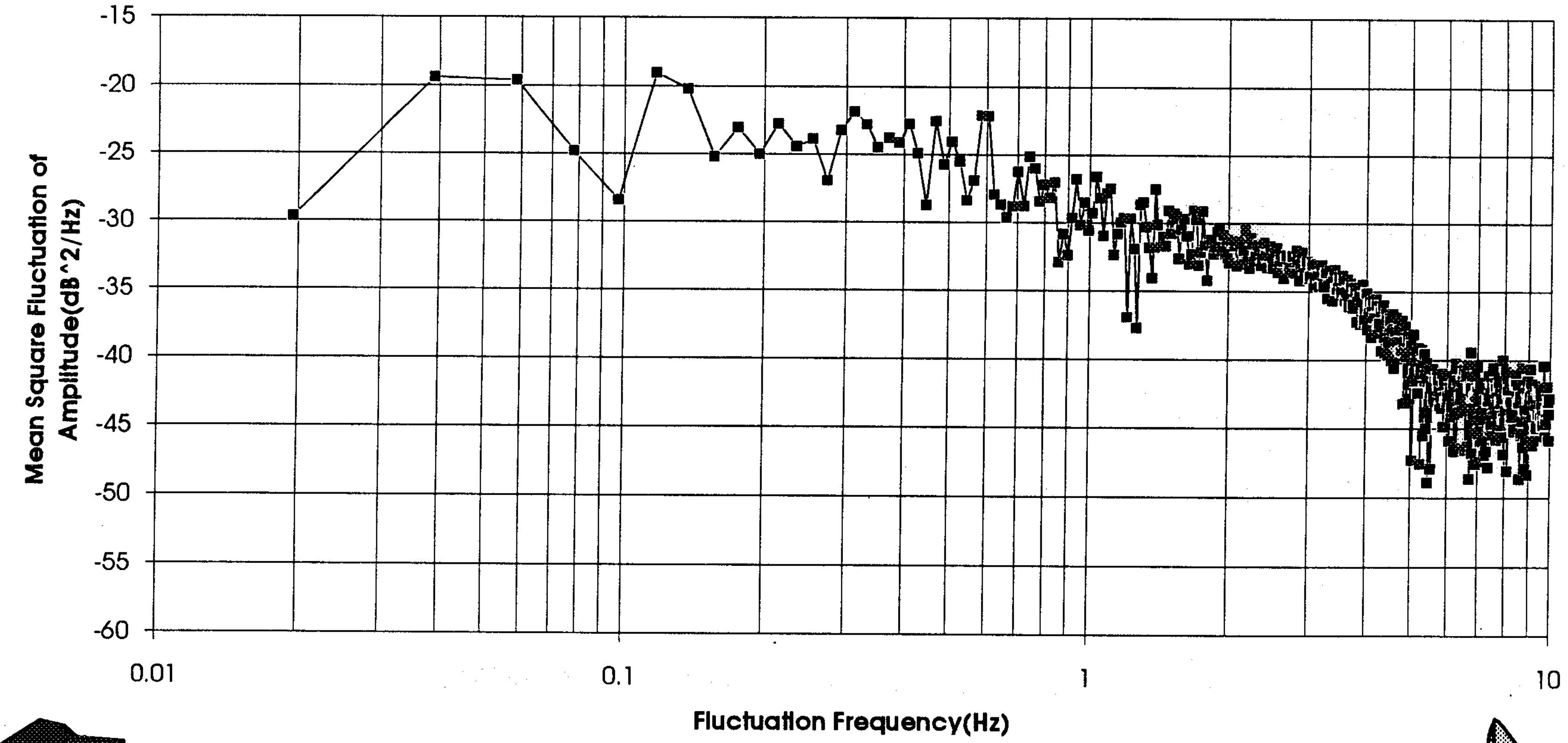
20.185GHz AFS vs 27.505 GHz AFS 5/24/94 11-12 H GMT



Alaska ACTS Propagation

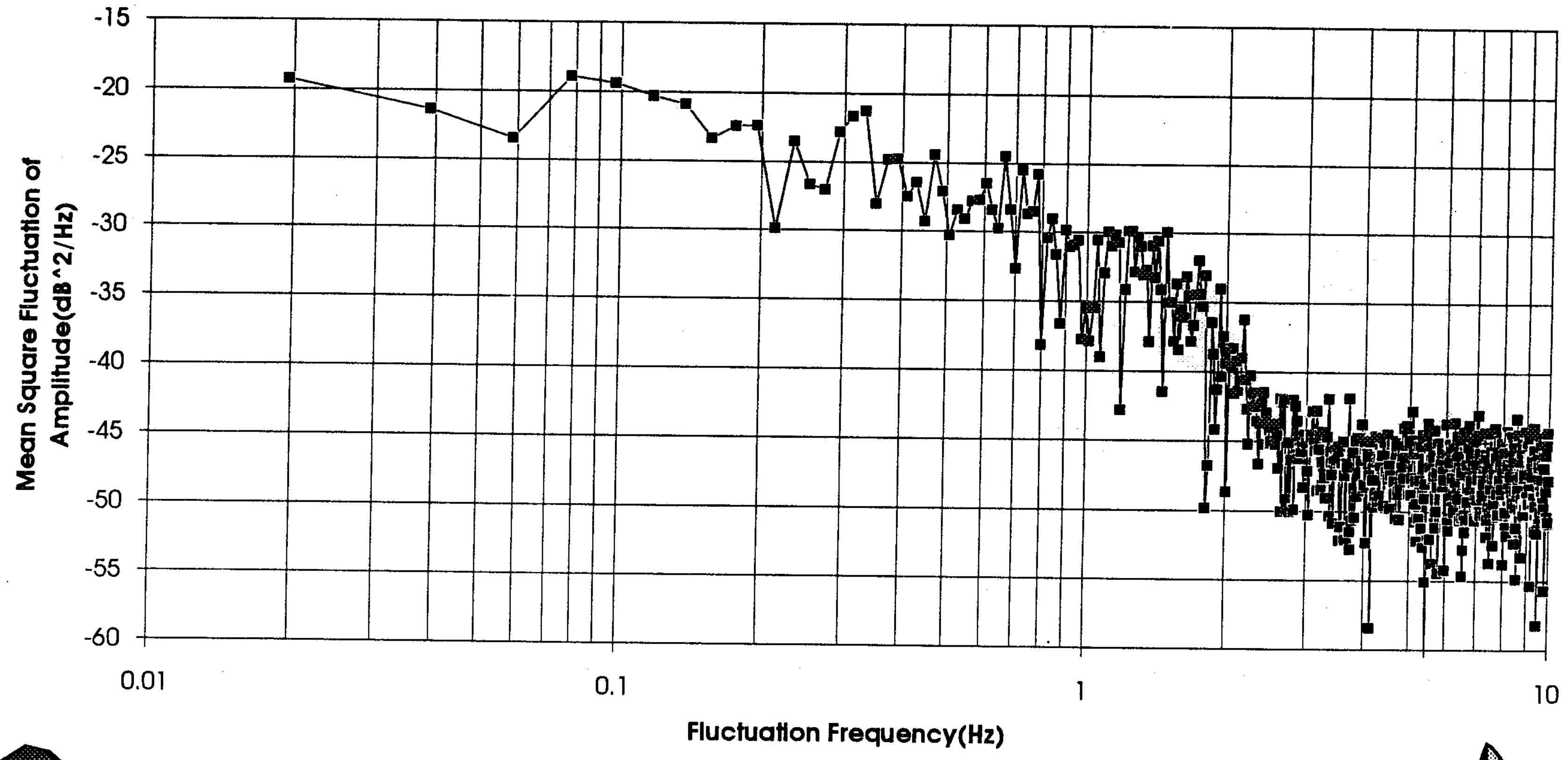
27.505 GHz Scintillation Spectrum

Scintillation Intensity of 0.19 on 5/25/94   07:41:51-07:42:42.2 GMT



Alaska ACTS Propagation

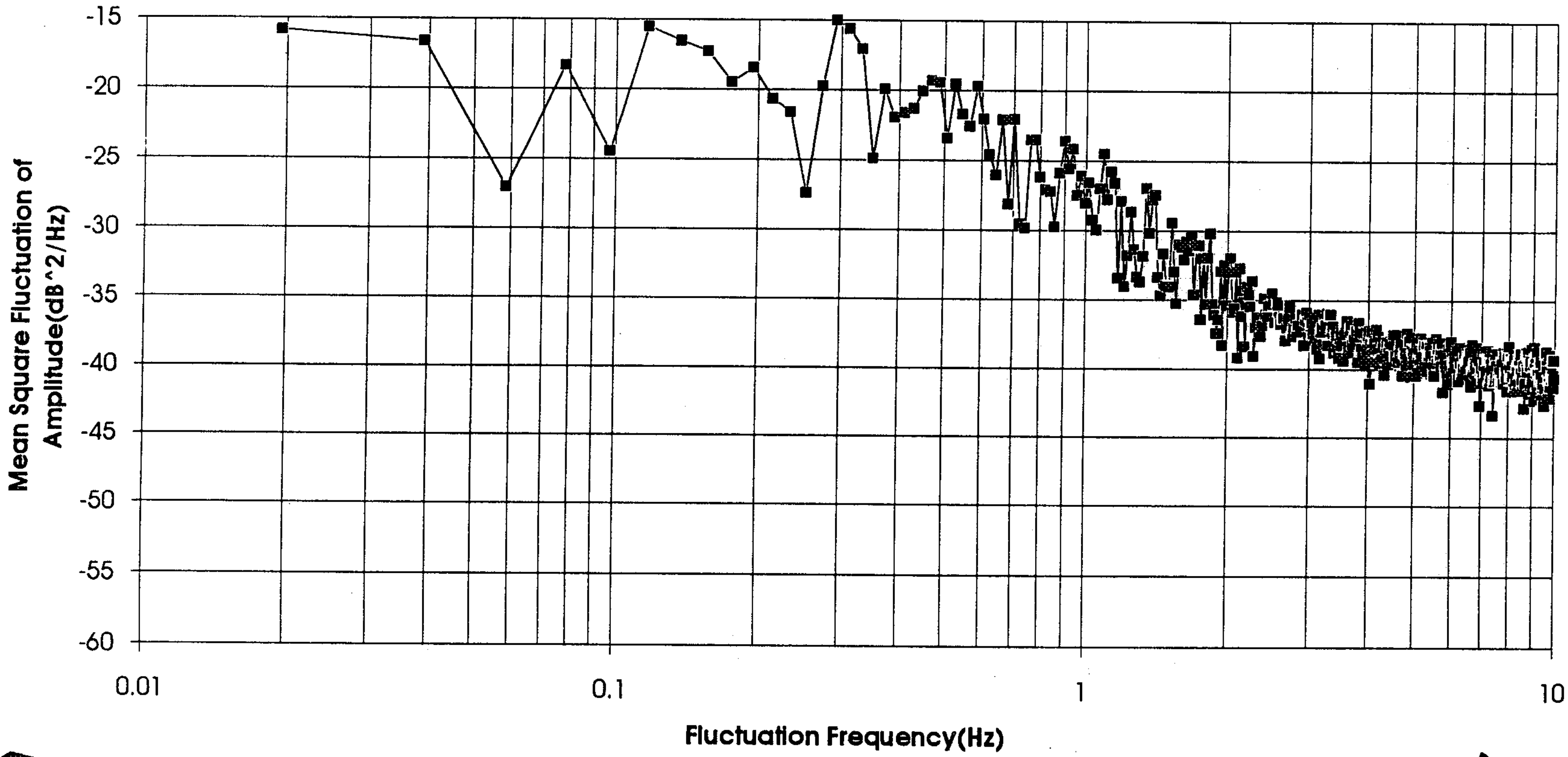
27.505 GHz Scintillation Spectrum
Scintillation Intensity of 0.50 on 5/25/94 22:57:04-22:57:55.2 GMT

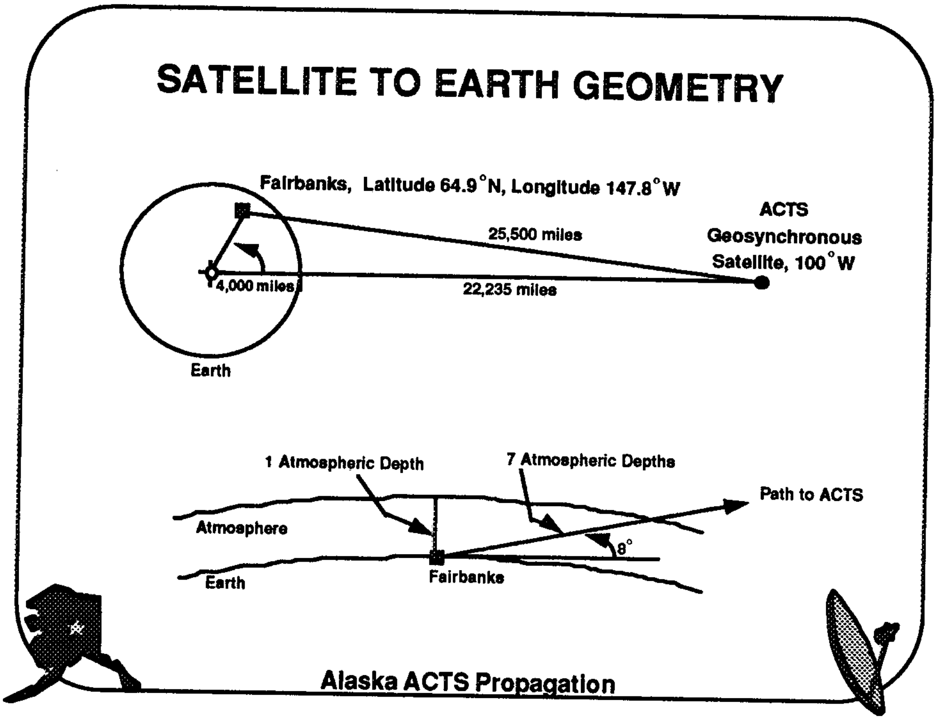


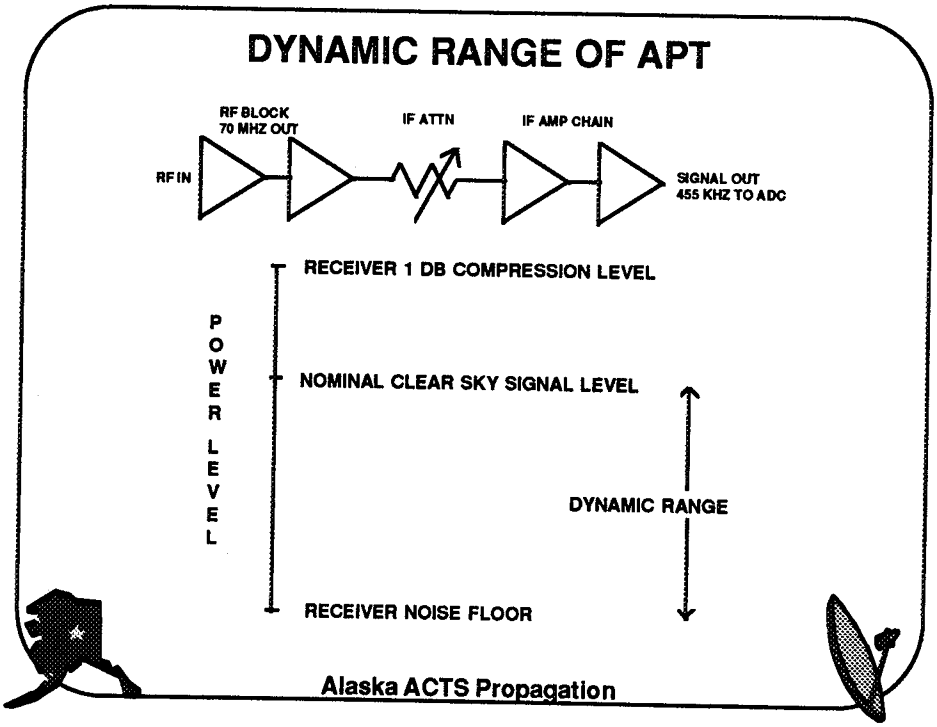
Alaska ACTS Propagation

27.505 GHz Scintillation Spectrum

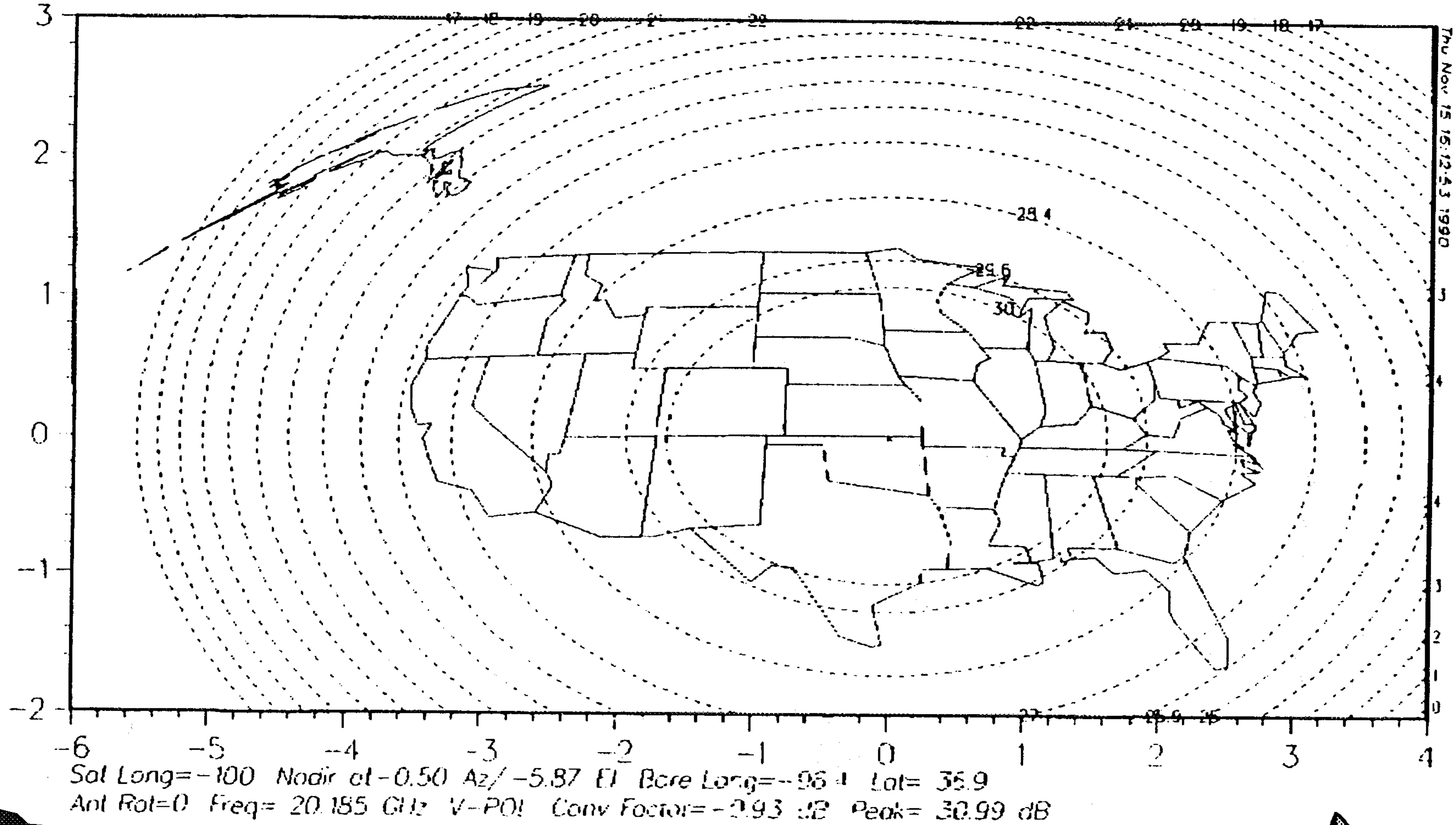
Scintillation Intensity of 0.51 with 3.4 dB AFS on 5/27/94 23:14:42-23:15:33.2 GMT



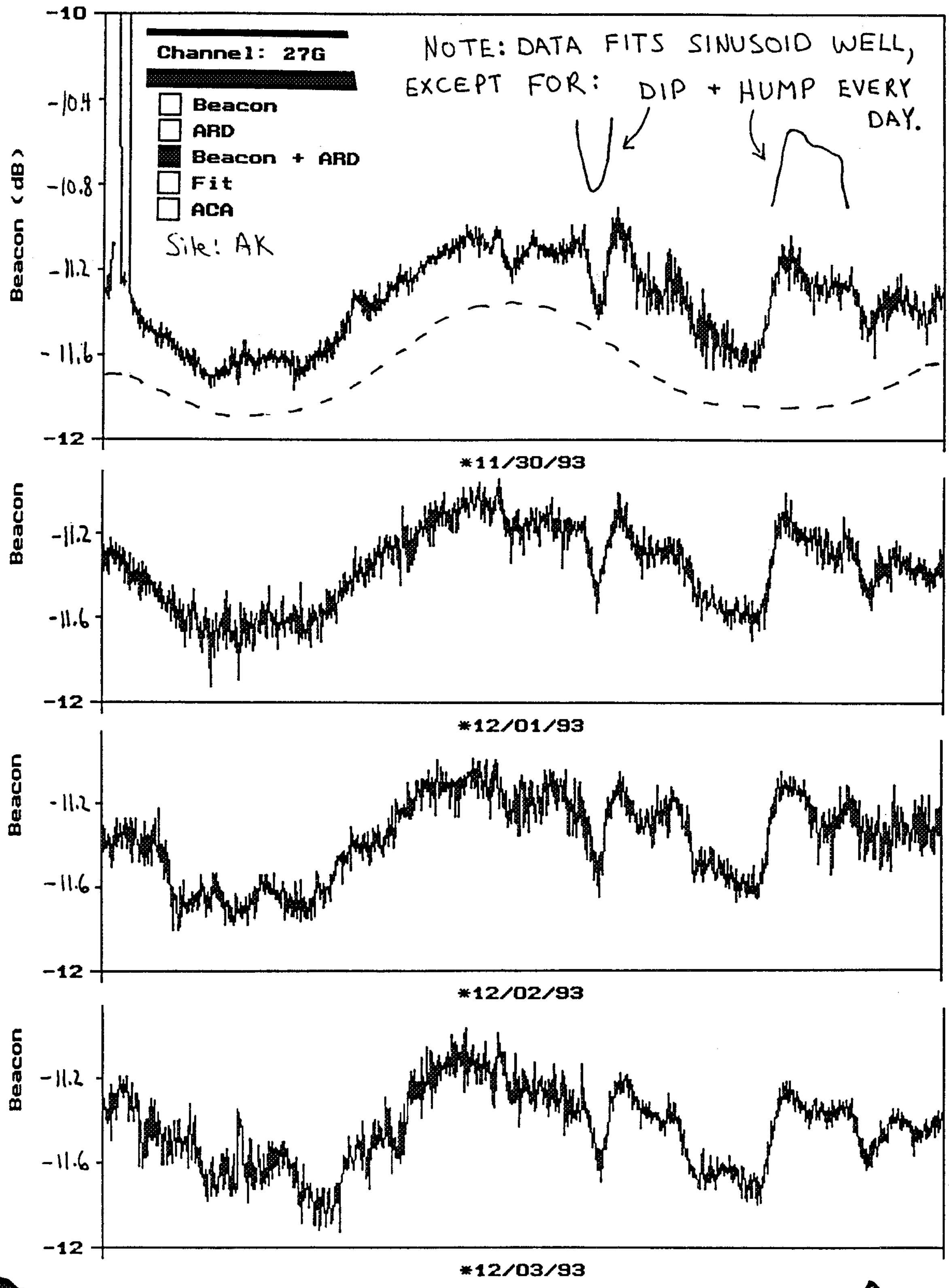

SATELLITE TO EARTH GEOMETRY
Fairbanks, Latitude 64.9°N, Longitude 147.8°W
ACTS
Geosynchronous
Satellite, 100°W
25,500 miles
4,000 miles
22,235 miles
Earth
1 Atmospheric Depth
7 Atmospheric Depths
Path to ACTS
Atmosphere
8°
Earth
Fairbanks
Alaska ACTS Propagation


DYNAMIC RANGE OF APT
RF BLOCK
70 MHZ OUT
IF ATTN
IF AMP CHAIN
RF IN
SIGNAL OUT
455 KHZ TO ADC
RECEIVER 1 DB COMPRESSION LEVEL
POWER LEVEL
NOMINAL CLEAR SKY SIGNAL LEVEL
DYNAMIC RANGE
RECEIVER NOISE FLOOR
Alaska ACTS Propagation

ACTS 20 GHz EIRP Contours

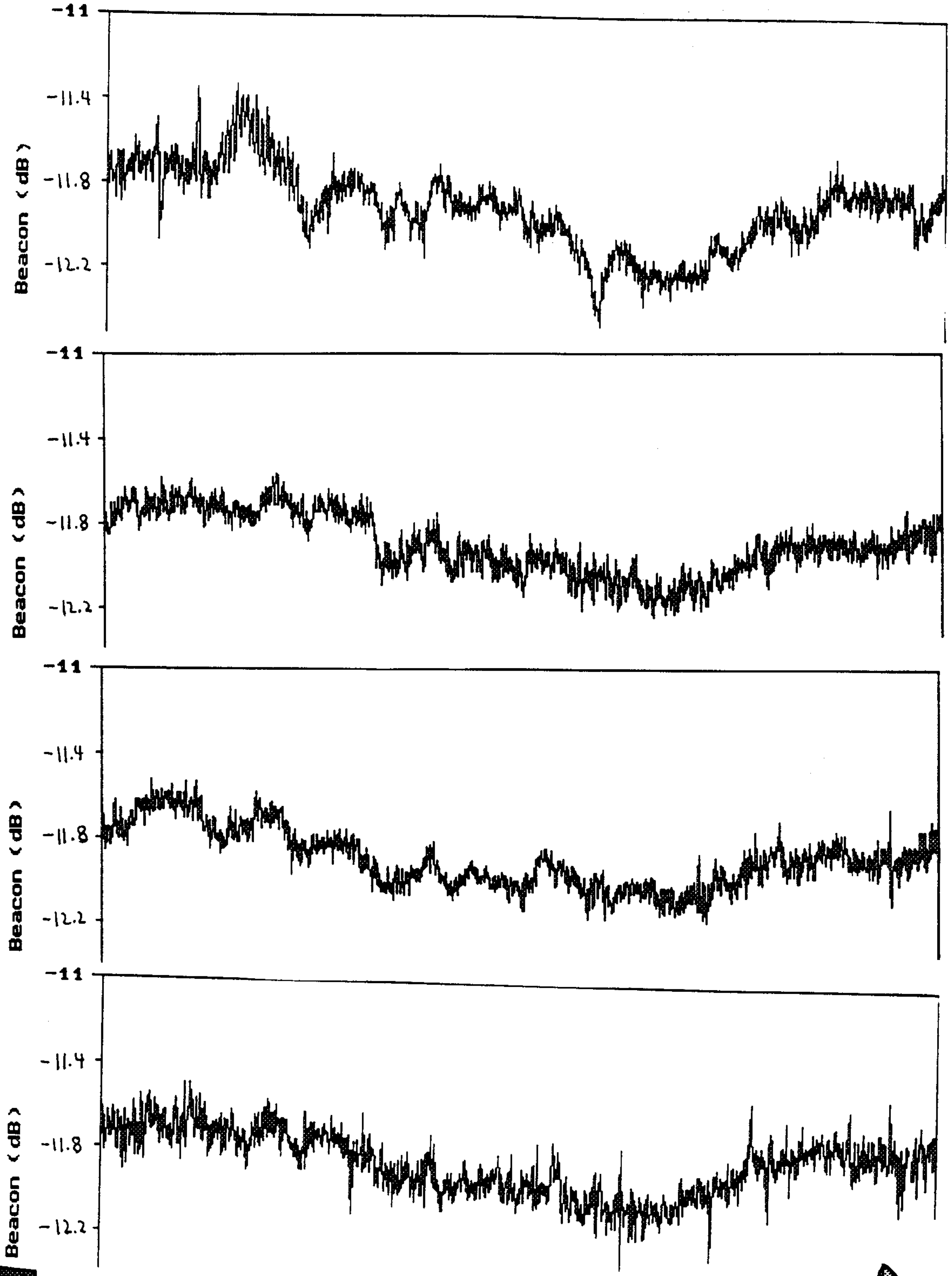


Alaska ACTS Propagation

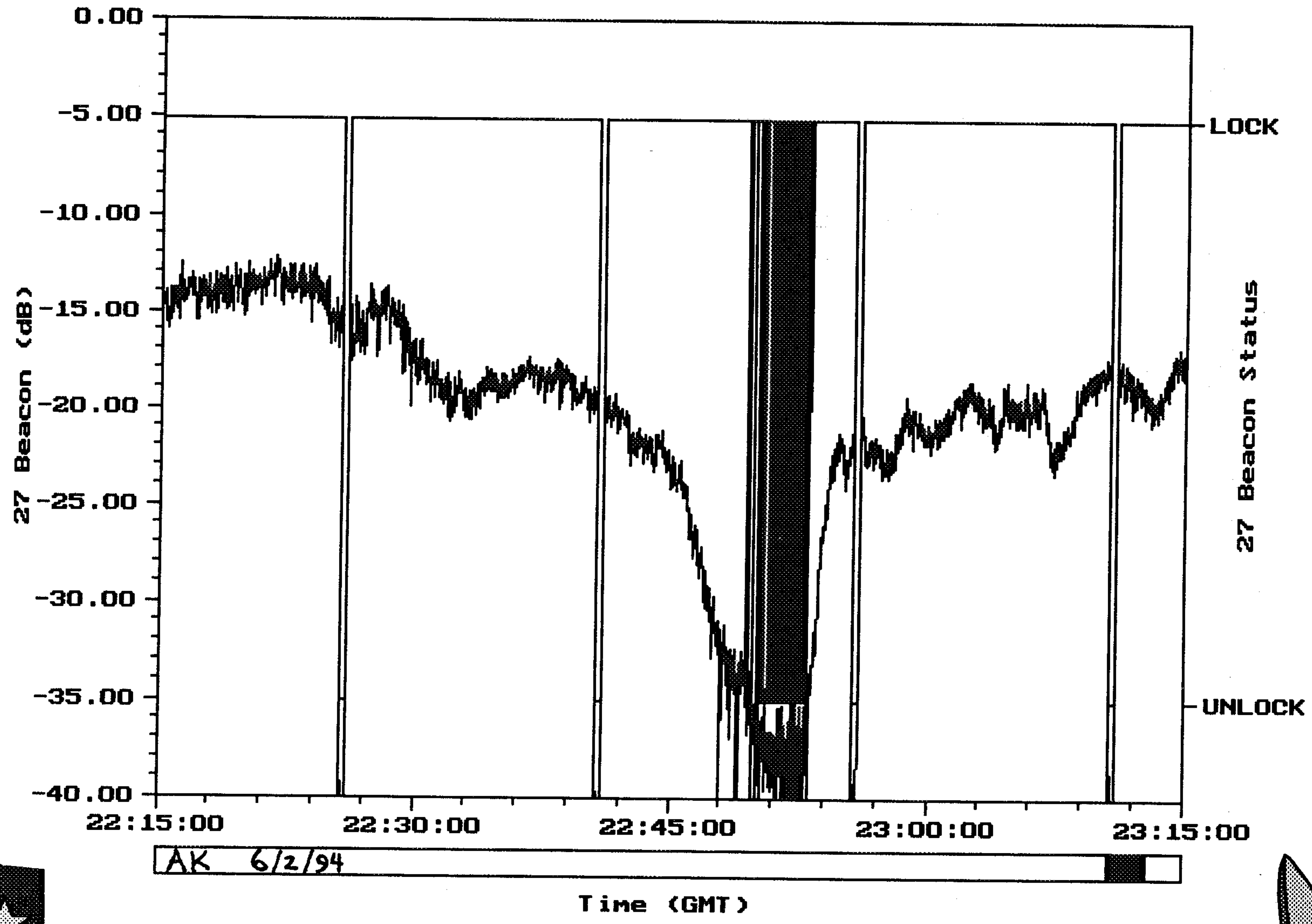


Alaska ACTS Propagation

27 GHz Beacon + ARD 2/20-23/94
0.4 dB/tick mark Site: AK

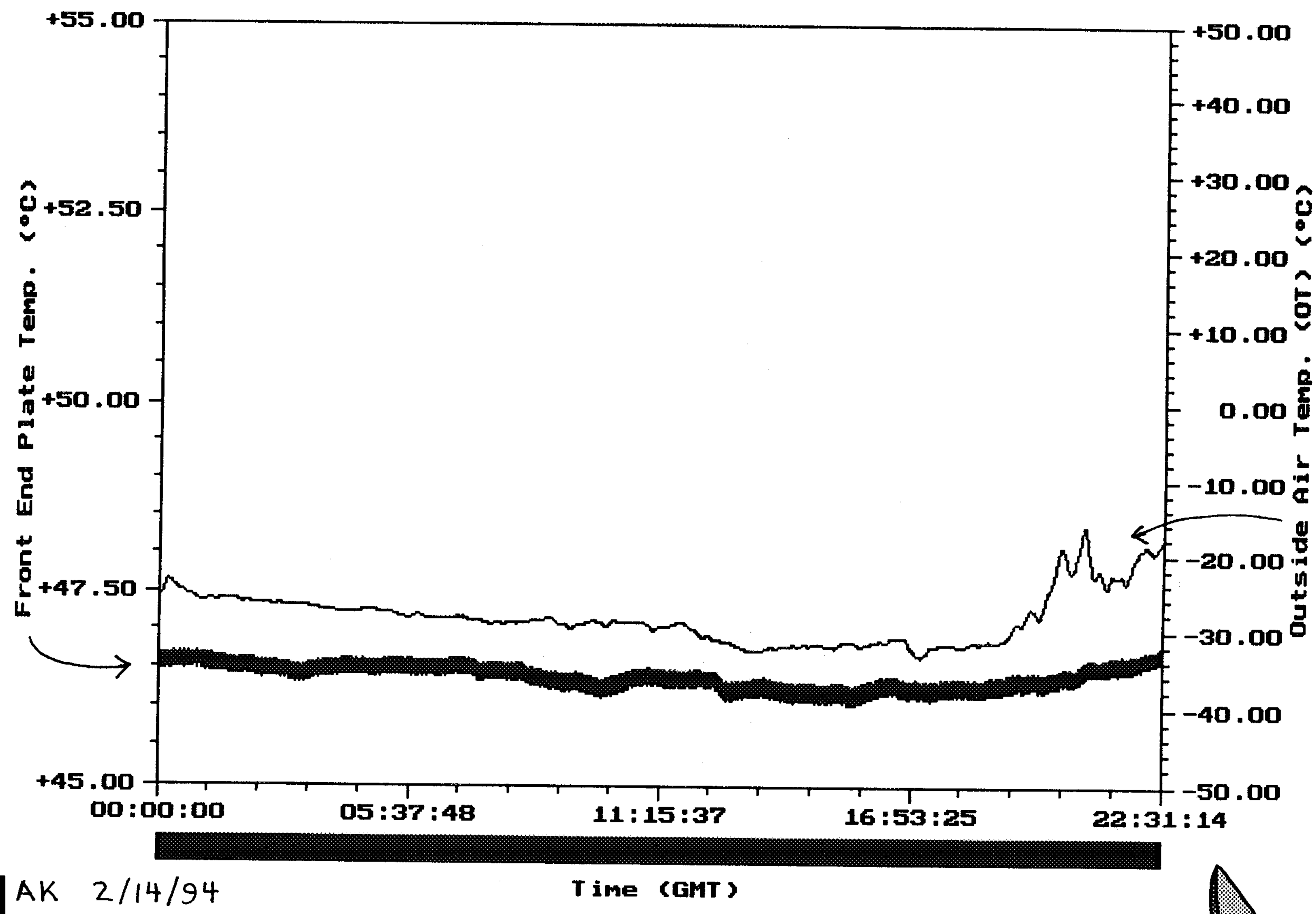


AK Dynamic Range Limitation



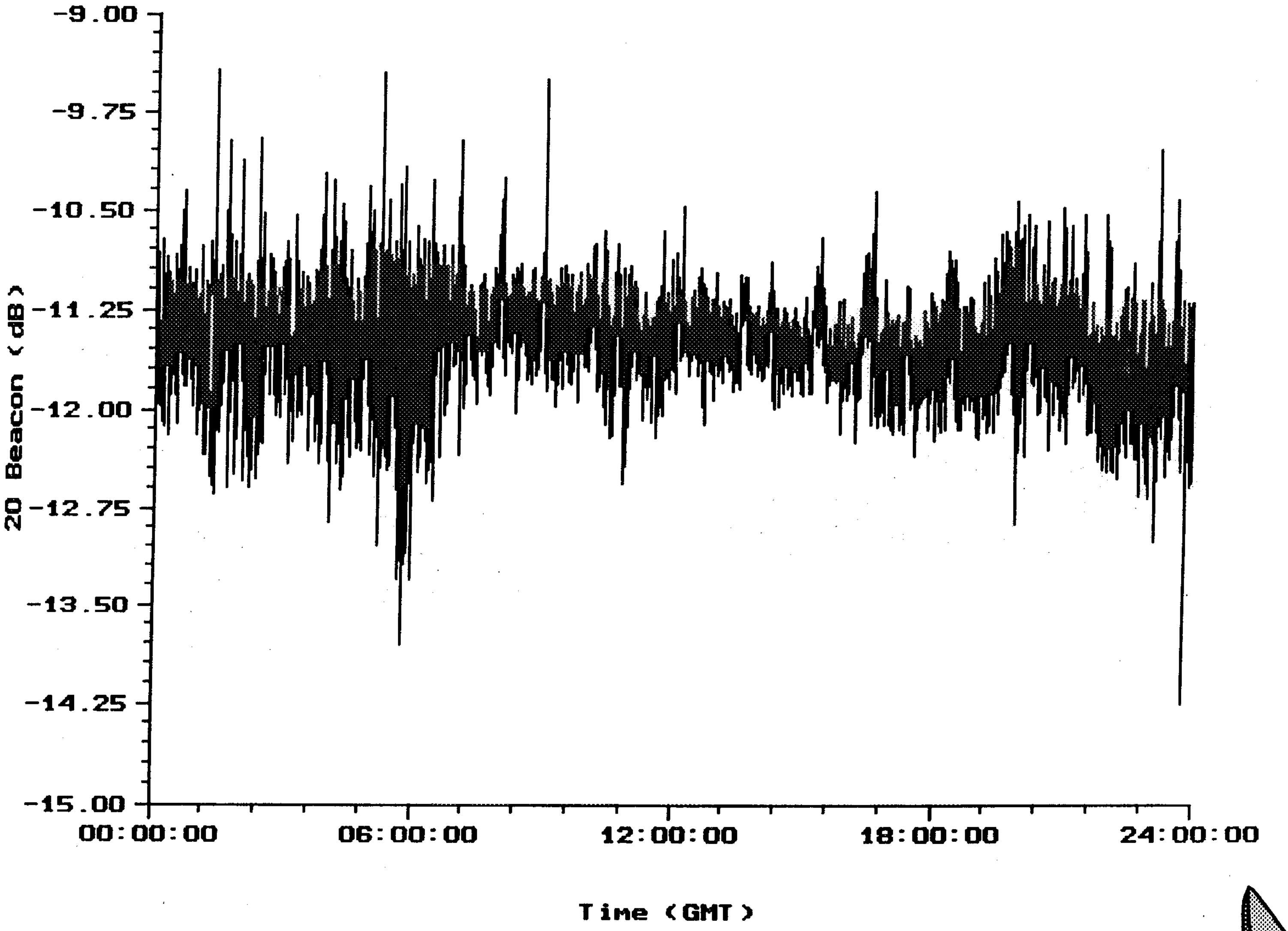
Alaska ACTS Propagation

Outside Air and Front End Plate Temperatures

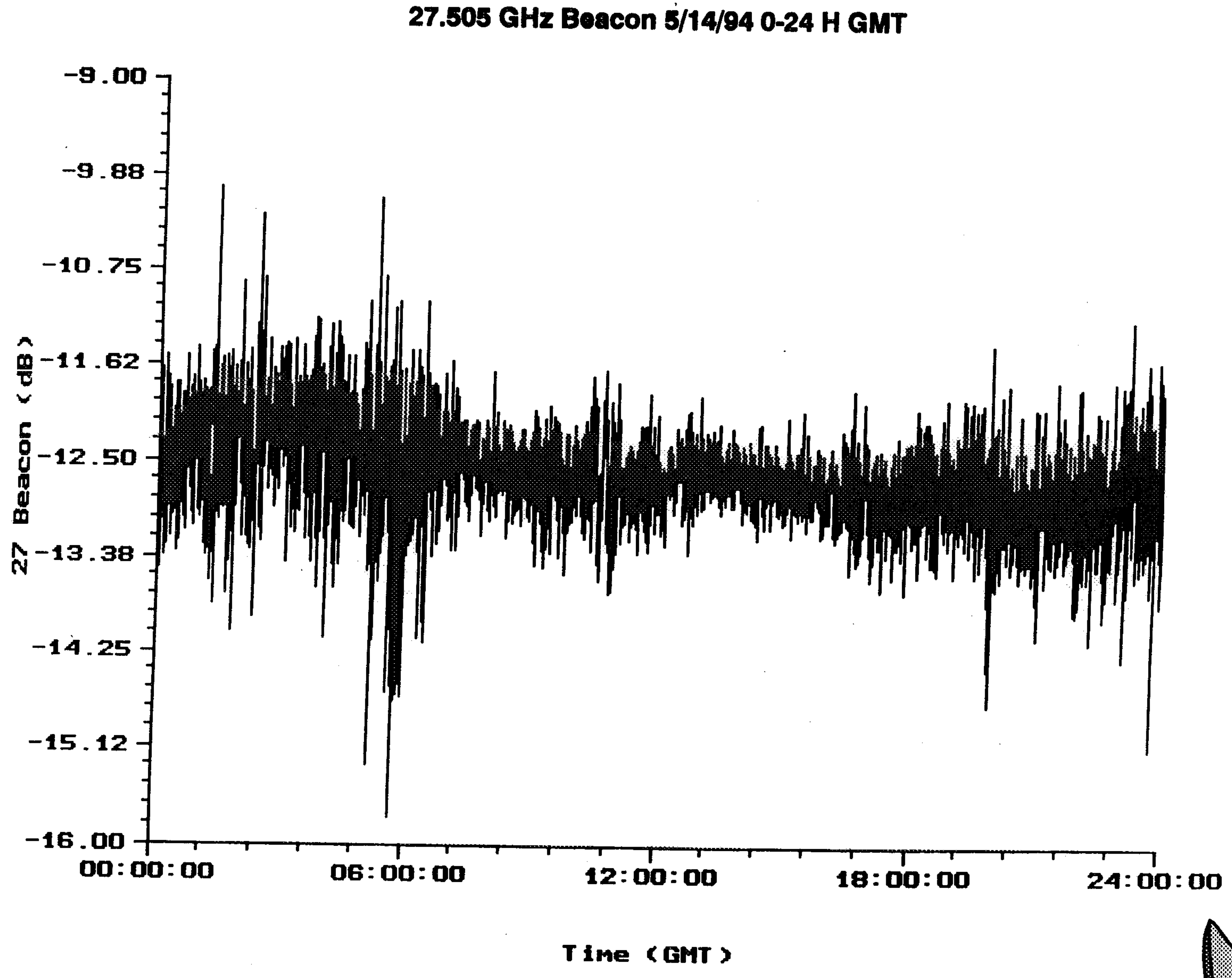


Alaska ACTS Propagation

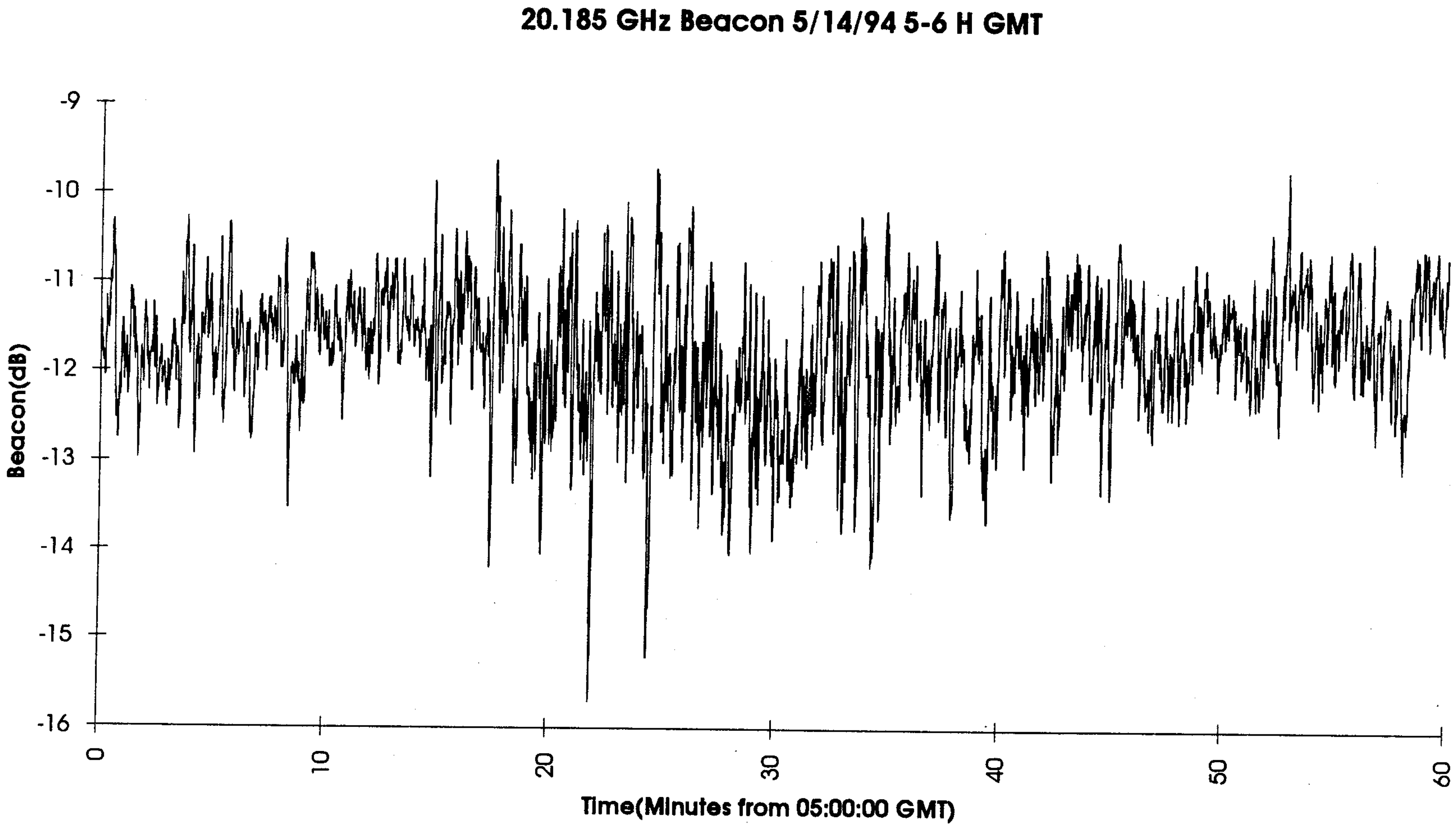
20.185 GHz Beacon 5/14/94 0-24 H GMT



Alaska ACTS Propagation

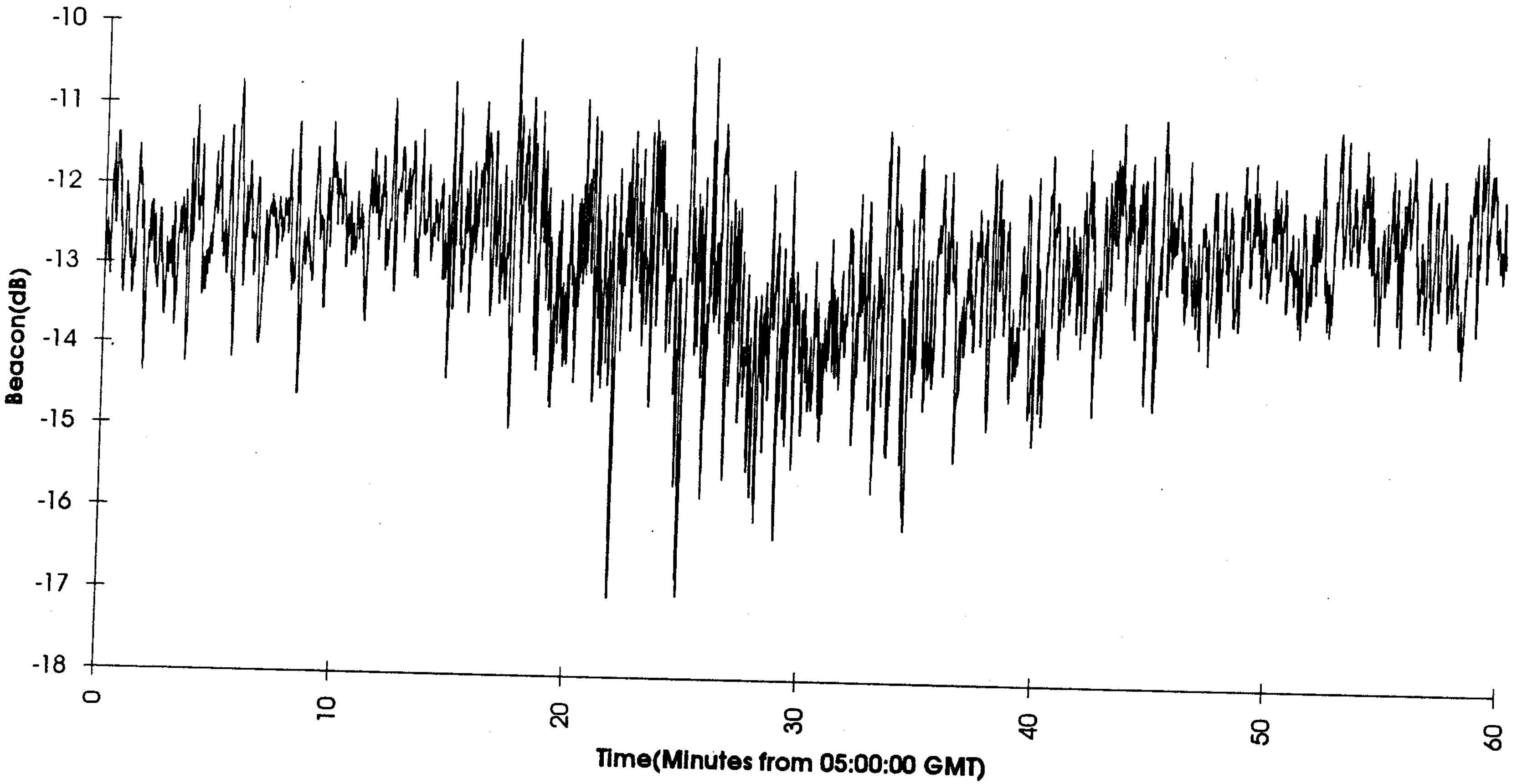


Alaska ACTS Propagation



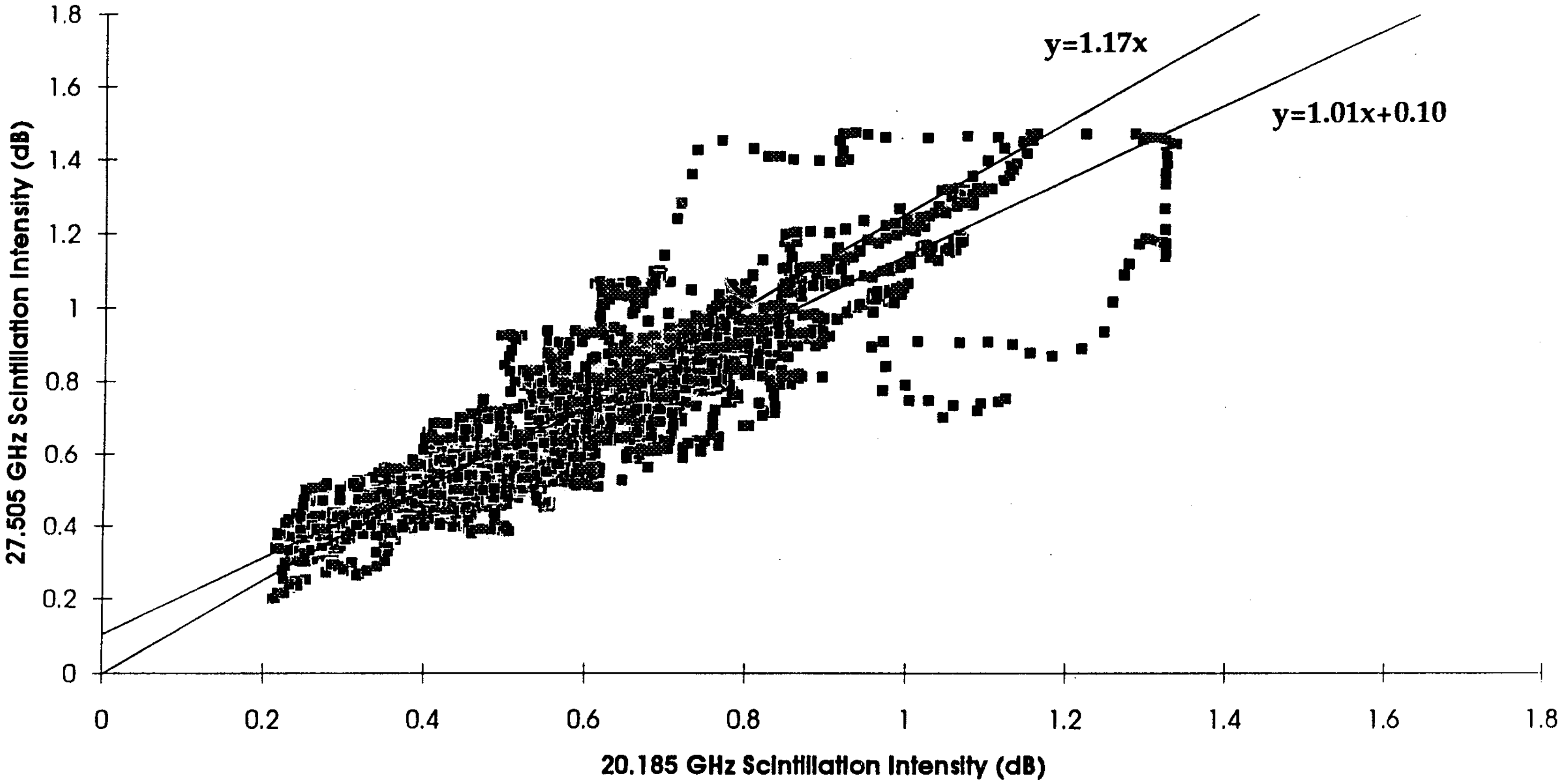
Alaska ACTS Propagation

27.505 GHz Beacon 5/14/94 5-6 H GMT

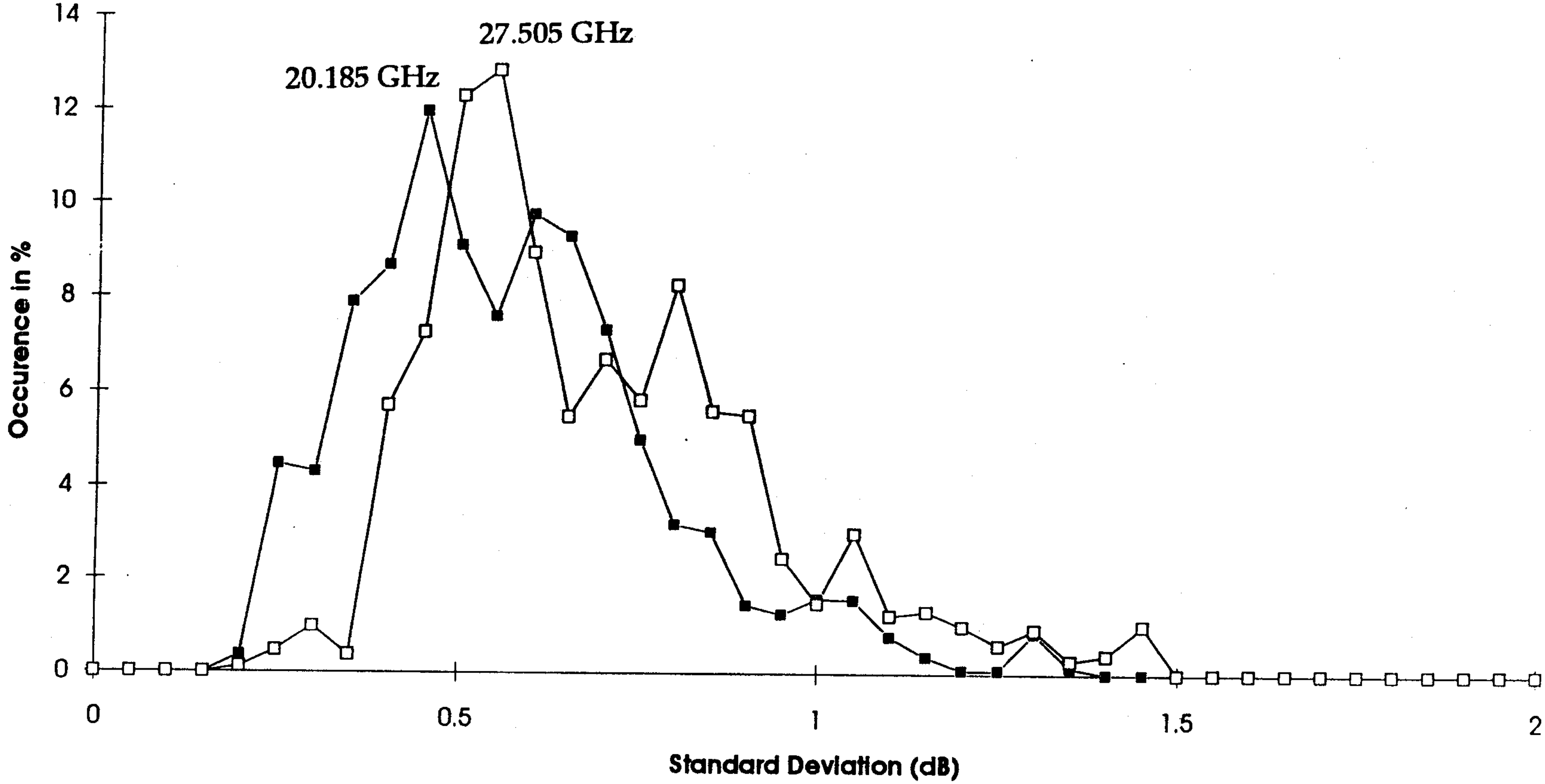


Alaska ACTS Propagation

Scatter Plot of Scintillation Intensity 5/14/94 5-6 H GMT



Measured p.d.f. 5/14/94 5-6 H GMT



Alaska ACTS Propagation

SCINTILLATION RATIO PREDICTIONS

- FREQUENCY RATIO, 27.5/20.2 GHZ
  - FOR 1.22-M ANTENNA
    - » 1.19
- ANTENNA SIZE RATIO, 1.5"/1.22-M
  - FOR 20.2 GHZ FREQUENCY
    - » 1.03
- USED CCIR/CRANE MODEL

Alaska ACTS Propagation

III. FUTURE PLANS

- INSURE INTEGRITY OF DATA
- RAIN SEASON
- SCINTILLATION SEASON
- CONTINUE ANALYSES
- CLOUD EFFECTS
- DEVELOP MODELS OF PROPAGATION PHENOMENA

Alaska ACTS Propagation

U.B.C. ACTS PROPAGATION EXPERIMENT

By:

I. Dommel
R. Hulays
M. Kharadly

Electrical Engineering Department
University of British Columbia

June 16, 1994

OUTLINE

- STATUS
- SOME PROBLEMS
- SOME OBSERVATIONS
- PRESENT AND FUTURE WORK

STATUS

- LATEST DACS SOFTWARE UPDATE INSTALLED ON JUNE 7, 1994
- RAW DATA, PRE-PROCESSED DATA AND EVENT AND FAULT LOGS UP TO, AND INCLUDING APRIL 1994 WERE SENT TO ACTS DATA CENTER. MAY DATA IS NOW COMPLETE
- ELEVATION TILT SCAN
  - ◊ Weather has not been cooperative!
  - ◊ No local sounding stations. The closest stations are:

* Quillayute (Olympic peninsula): 220 km, S.W.
* Port Hardy (Northern Vancouver island): 360 km, N.W.
* Vernon (Okanagan): 300 km, E.

◊ Possibility of interpolating between the three sounding sites

◊ Results thus obtained may not be valid at our site up to a height of 2 km.

◊ Attempting to arrange for a sounding on Campus

- HYDROPHOBIC PAINT TEST
  - ◊ This has been tested, loss is hardly measurable, less than 0.1 dB signal loss at 29.6 GHz
  - ◊ Has not yet been applied to antenna
- SURVEILLANCE CAMERA AND TIME-LAPSE RECORDER
  - ◊ Installed to keep track of antenna surface conditions (e.g., Icing) and weather conditions (e.g., Rain, Snow)
  - ◊ Records are obtained every 8 seconds with tape lasting 40 days

ADDITIONAL RESOURCE

- AIRPORT WEATHER STATION
  - ◊ Approx. 8 km from APT site
  - ◊ Close to propagation path
  - ◊ Will use their monthly statistics to compare to ours

SOME PROBLEMS

- 27 GHz RADIOMETER STEPS CAUSING RADIOMETER RESTARTS, Fig. 1

- RADIOMETERS VOLTAGE DRIFT, Fig. 2

  ◊ A manual reboot, at times, corrects the problem

- ACTSEDIT PROBLEMS

  ◊ Inability of software to remove certain spikes (e.g. Fig. 3)

◊ This causes error in the attenuation cumulative distribution function plots (Fig. 4)

- DR. CRANE'S EDITING PROGRAM

  ◊ We have not yet been able to make it work

SOME OBSERVATIONS

- TYPICAL FADES AT VANCOUVER, Figs. 5 and 6
  - ◊ Long duration
  - ◊ Low fade
  - ◊ Radiometer-derived attenuation generally agrees with Beacon-derived attenuation

- ATYPICAL FADES AT VANCOUVER, Figs. 7 and 8
  - ◊ Strong fade - System lost lock
  - ◊ Radiometer-derived attenuation does not agree with Beacon-derived attenuation (Radiometer saturates at 10 dB?)
  - ◊ 20 GHz attenuation > 27 GHz attenuation, Fig. 9
    - * Some snow-fall was recorded
    - * Possible cause (defocusing due to snow layer on antenna surface?)

- MONTHLY ATTENUATION STATISTICS
    - ◊ For the Month of January, Figs. 10 and 11
    - ◊ For the Month of March, Figs. 12 and 13
        - ⇒ 20 GHz attenuation reaches higher values than 27 GHz attenuation!
- SCINTILLATIONS
    - ◊ Clear weather, Fig. 14
    - ◊ Rain, Fig. 15

PRESENT AND FUTURE WORK

- ANALYSIS PACKAGE
  - ◊ Exceedance statistics
  - ◊ 27 GHz attenuation vs 20 GHz attenuation
  - ◊ Fade-duration statistics
  - ◊ Fill in missing data

- MELTING LAYER
  - ◊ Estimation of the excess attenuation caused by the presence melting layer

335

- SCINTILLATIONS

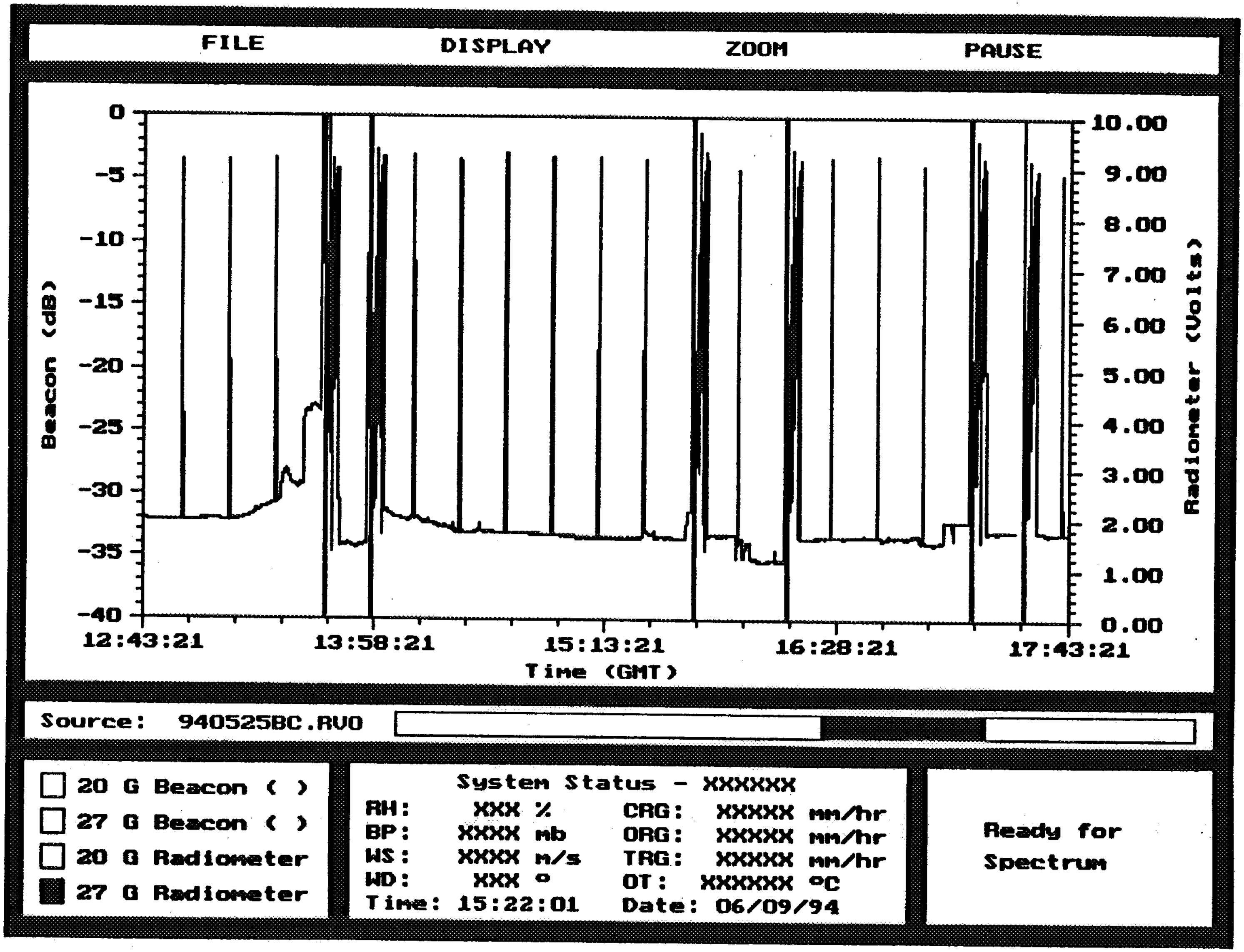


Fig.1: Typical 27 GHz radiometer steps causing automatic restart

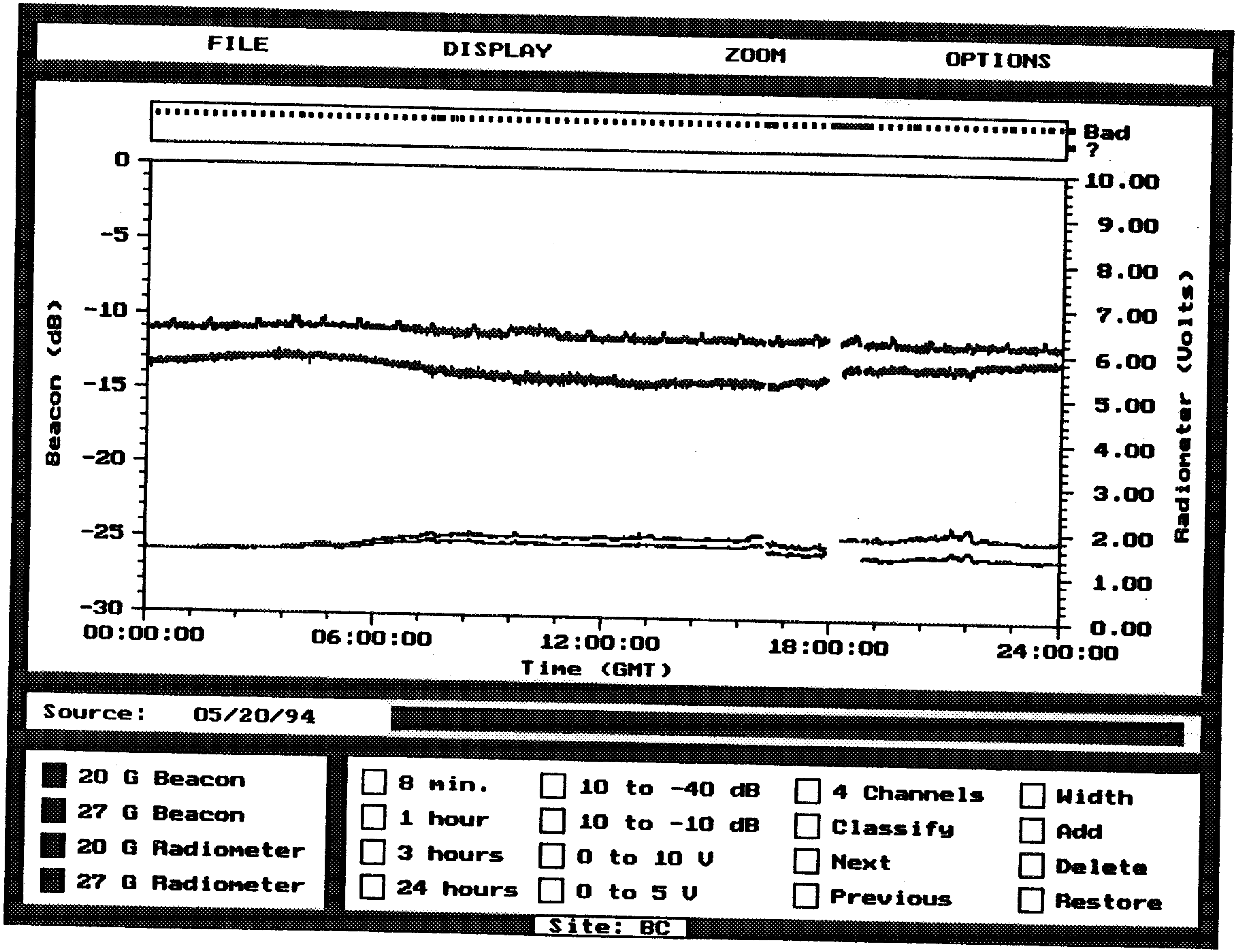


Fig. 2: Radiometer voltage drift

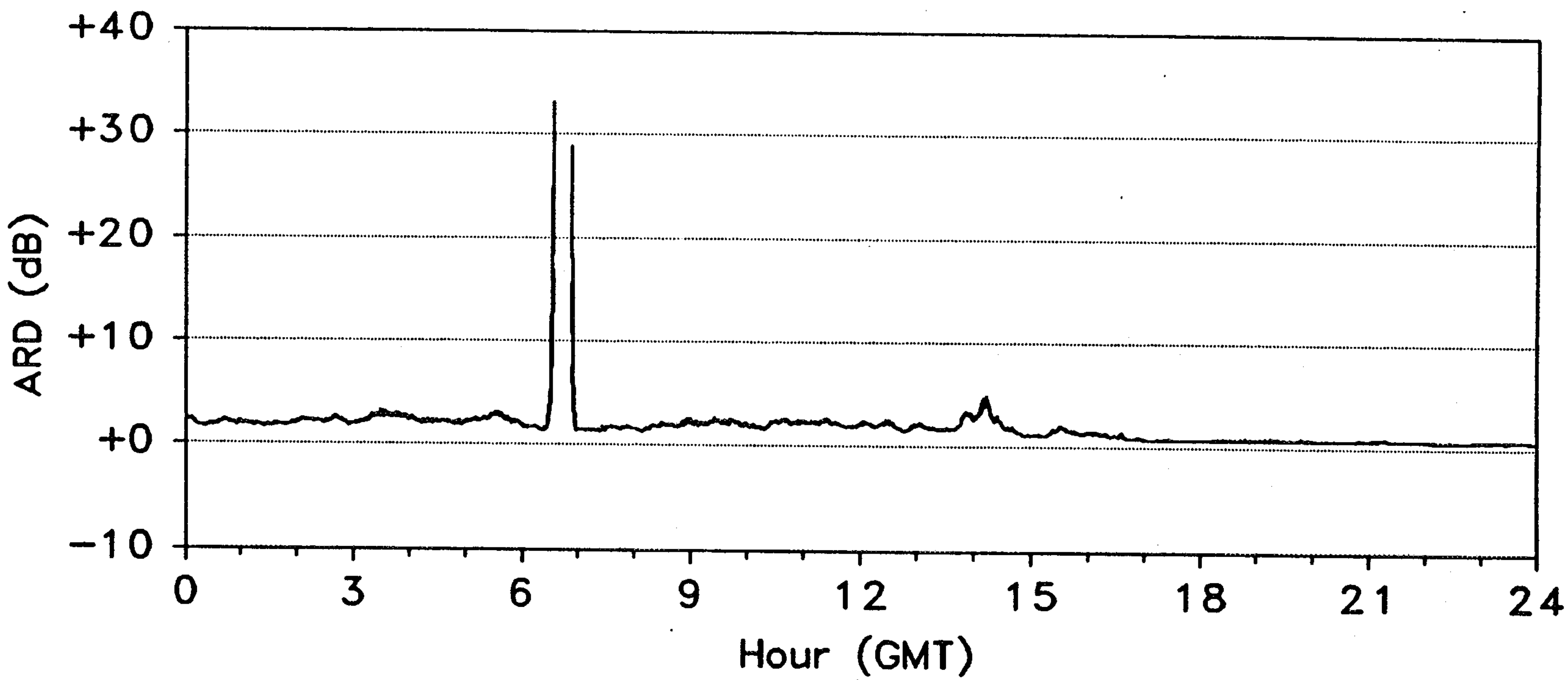


Fig. 3: Pre-processing software was unable to remove spike in 27 GHz radiometer-derived attenuation

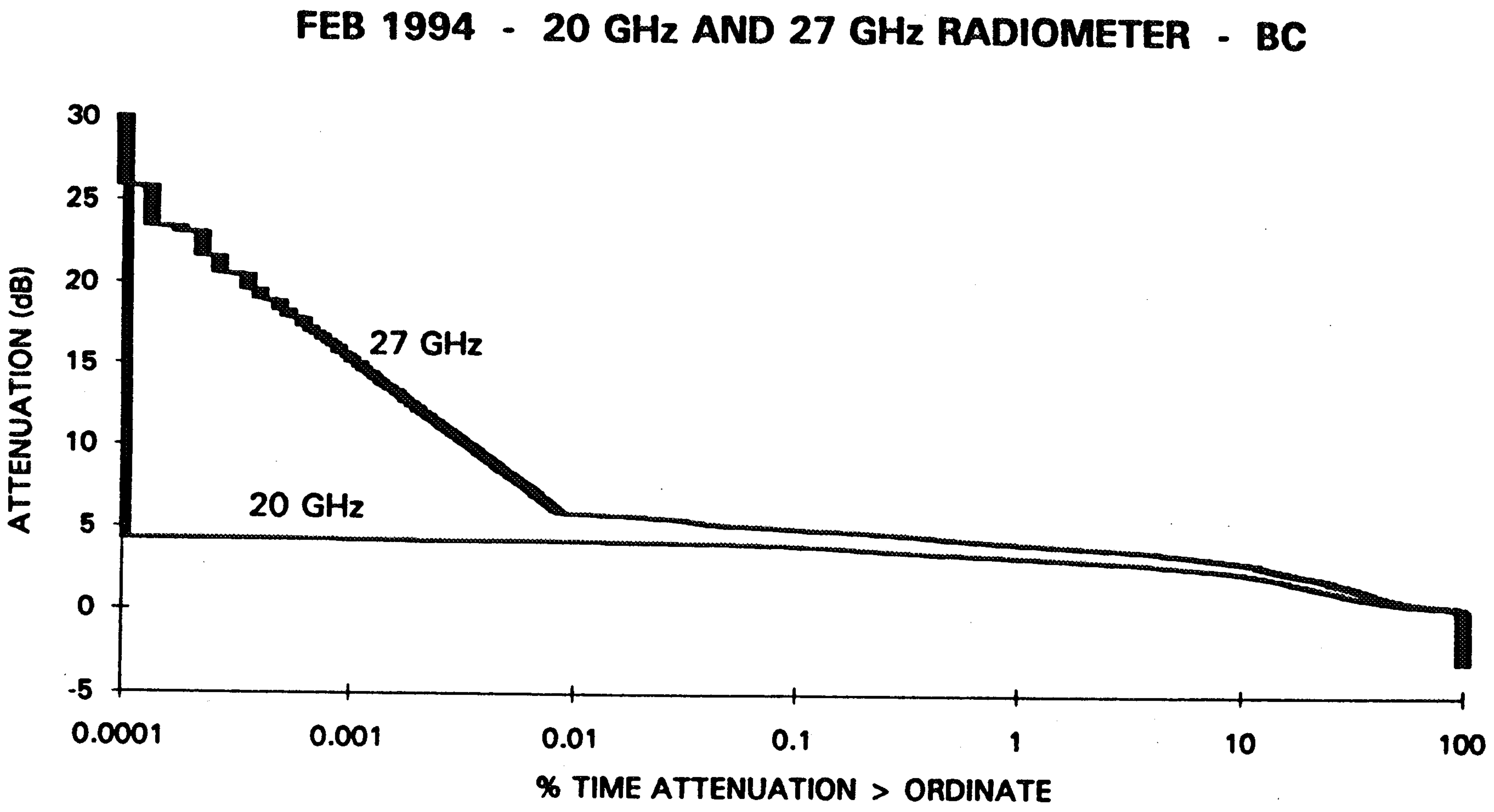


Fig. 4: Effect of the spike in Fig. 3 on the Cumulative Distribution Function of the 27 GHz radiometer-derived attenuation

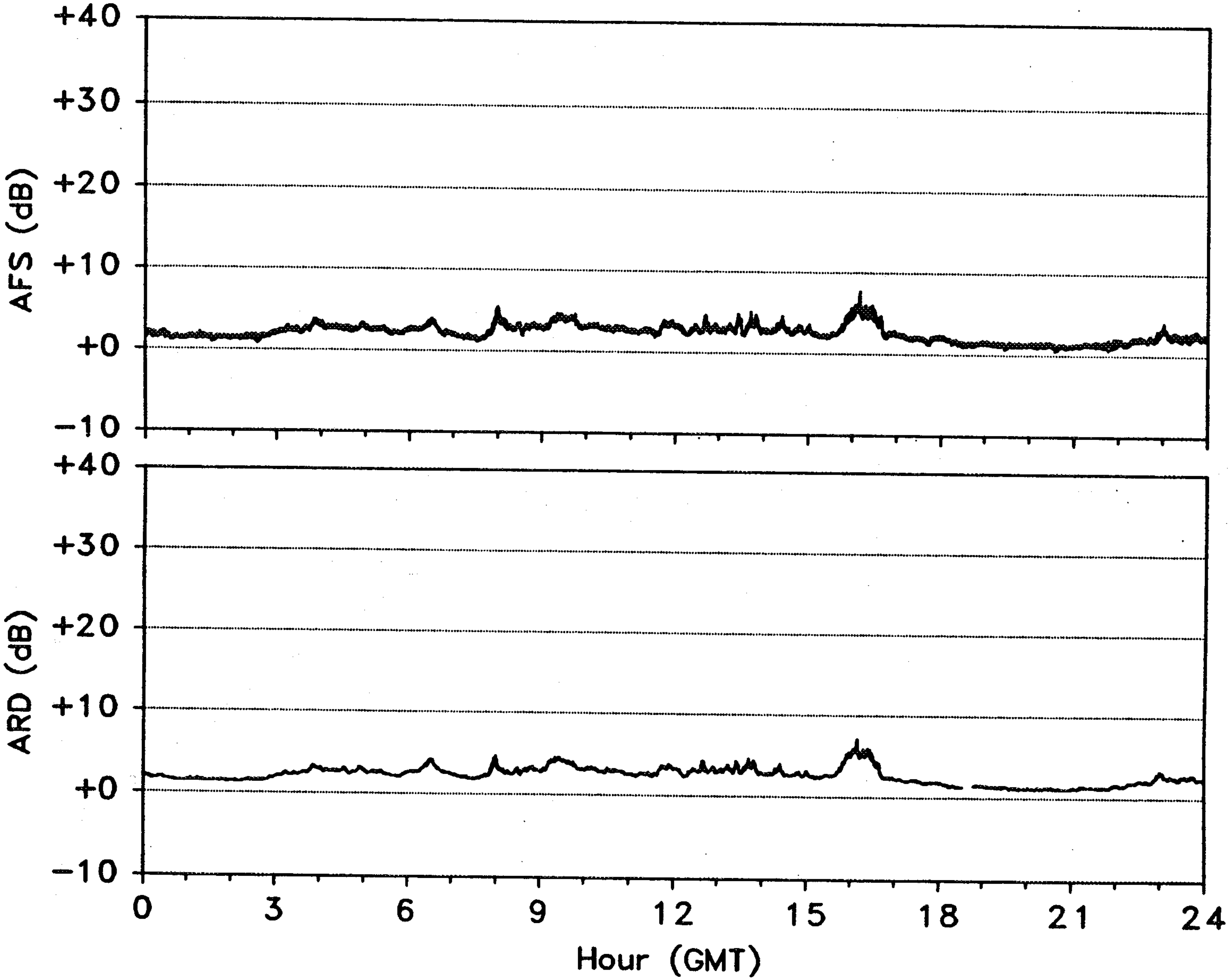


Fig. 5: 20 GHz attenuation for March 1, 1994

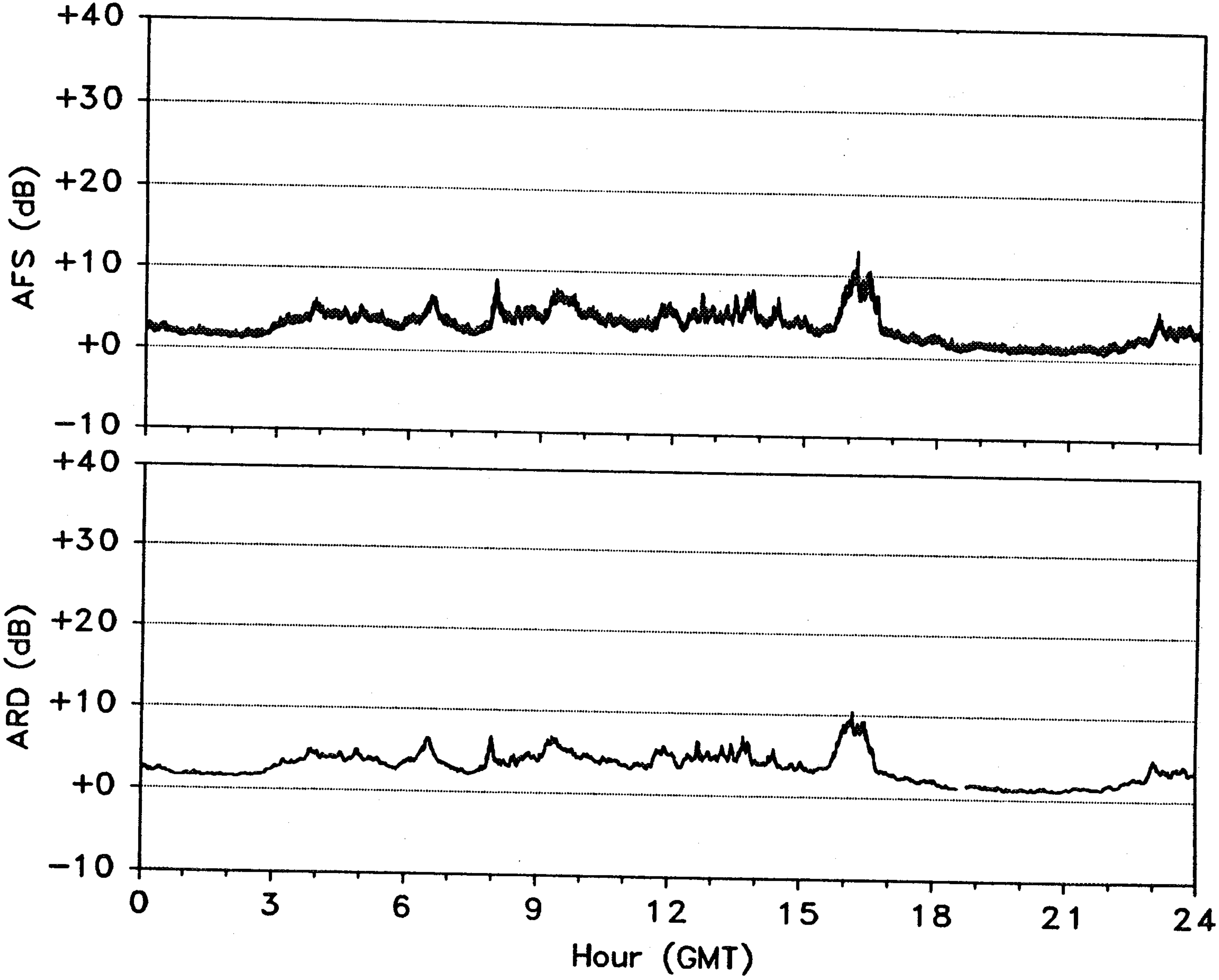


Fig. 6: 27 GHz attenuation for March 1, 1994

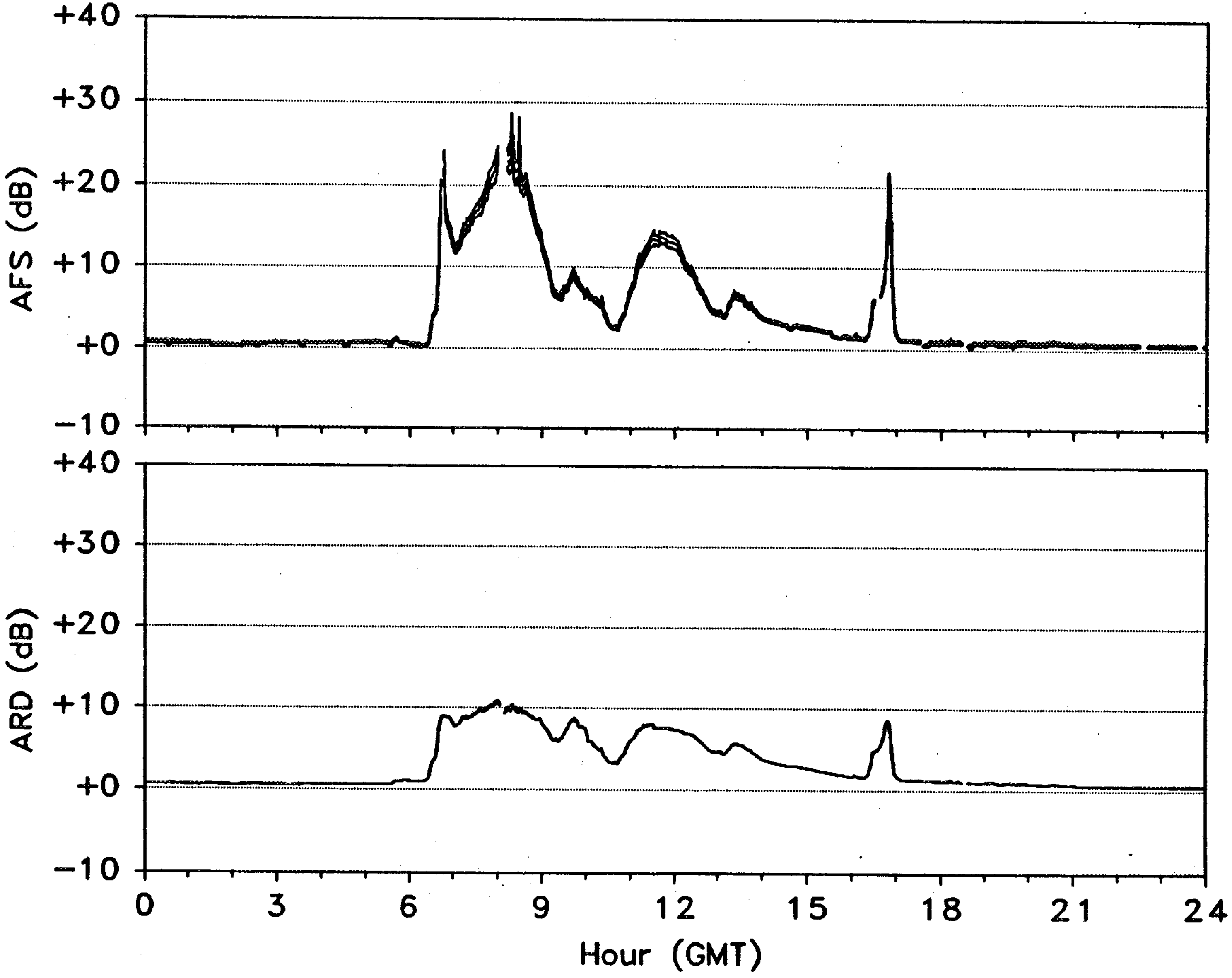


Fig. 7: 20 GHz attenuation for March 22, 1994

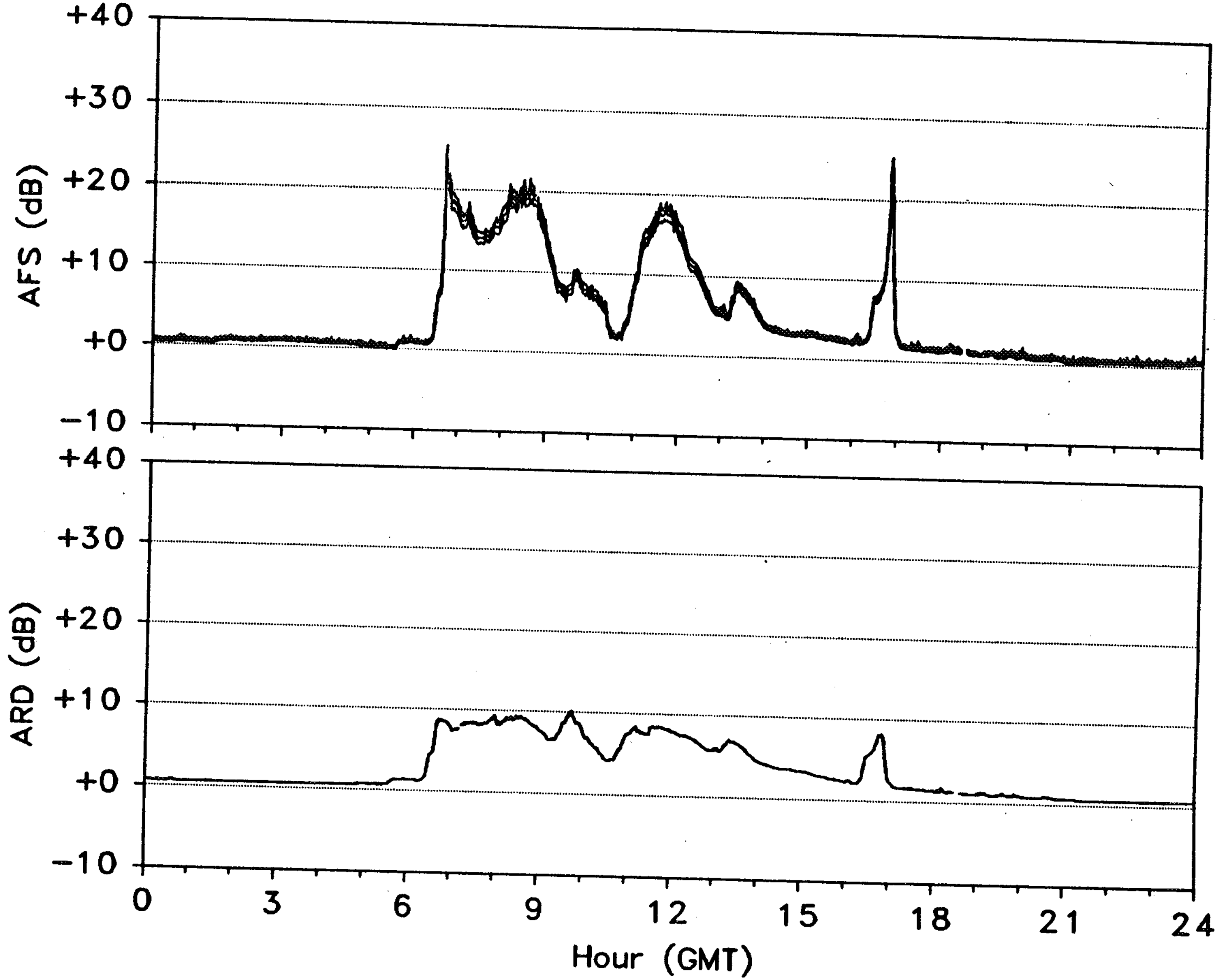


Fig. 8: 27 GHz attenuation for March 22, 1994

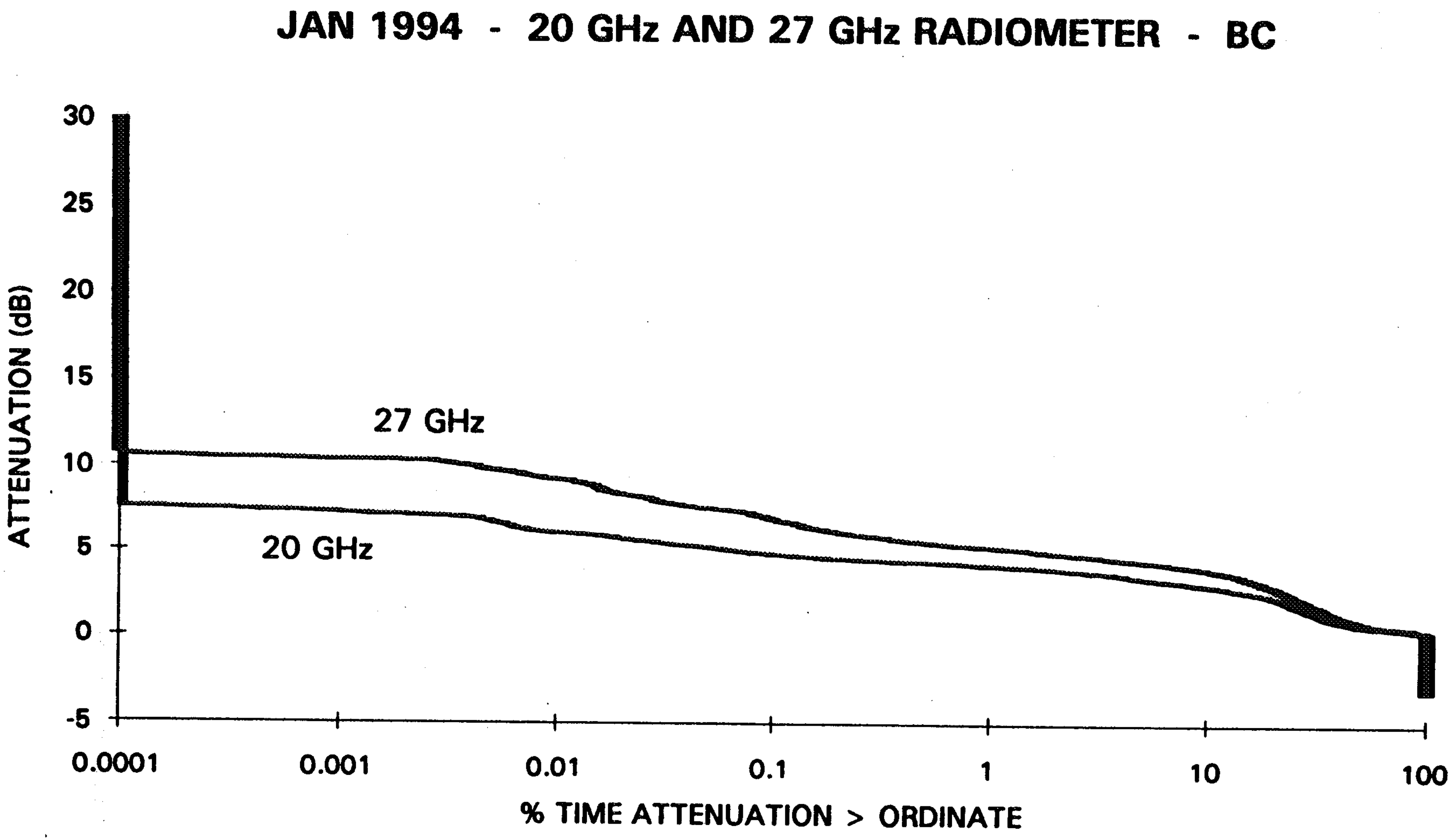


Fig. 11: Cumulative distribution functions of the 20 and 27 GHz radiometer-derived attenuation for the month of January, 1994

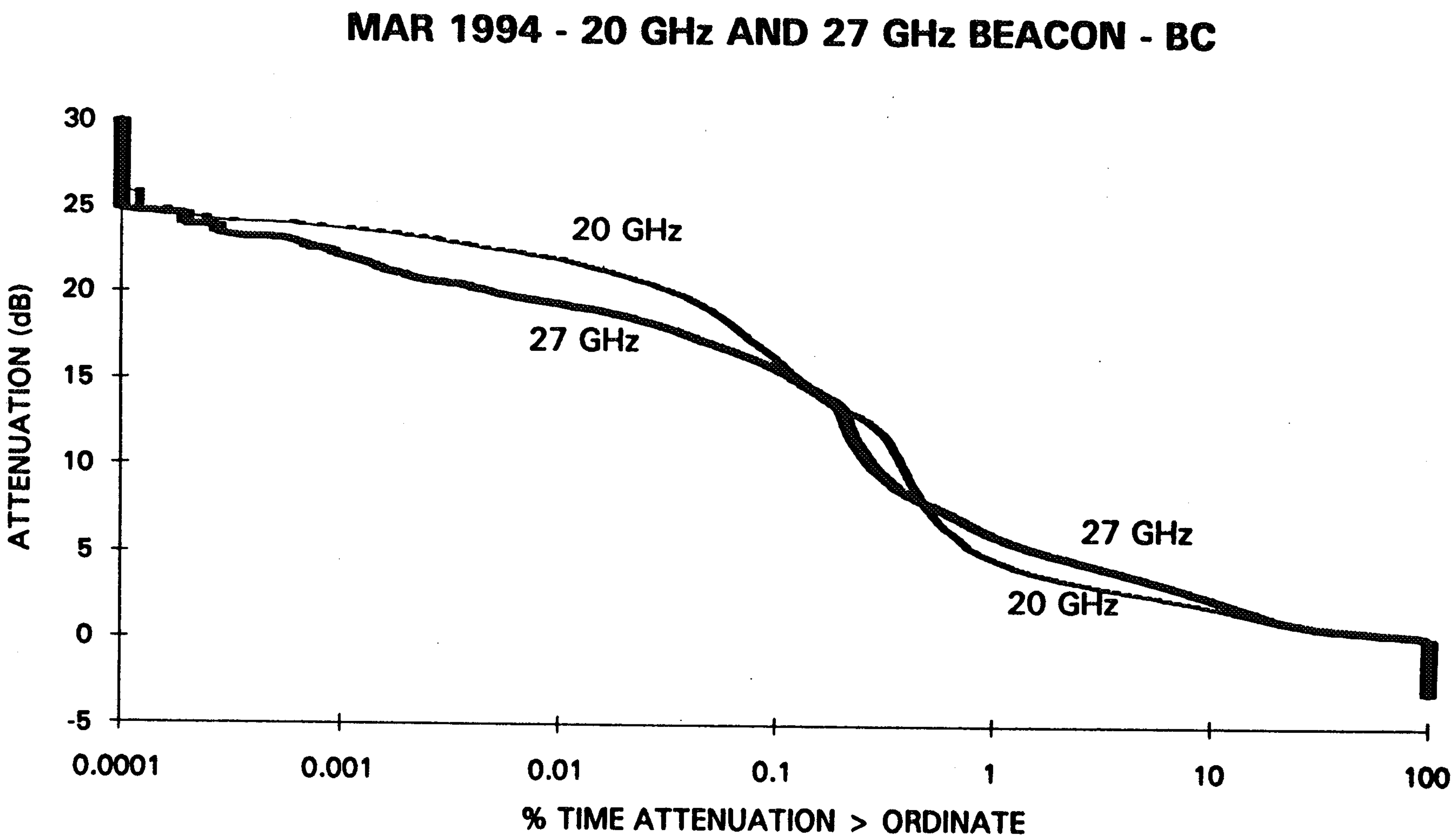


Fig. 12: Cumulative distribution functions of the 20 and 27 GHz beacon-derived attenuation for the month of March, 1994

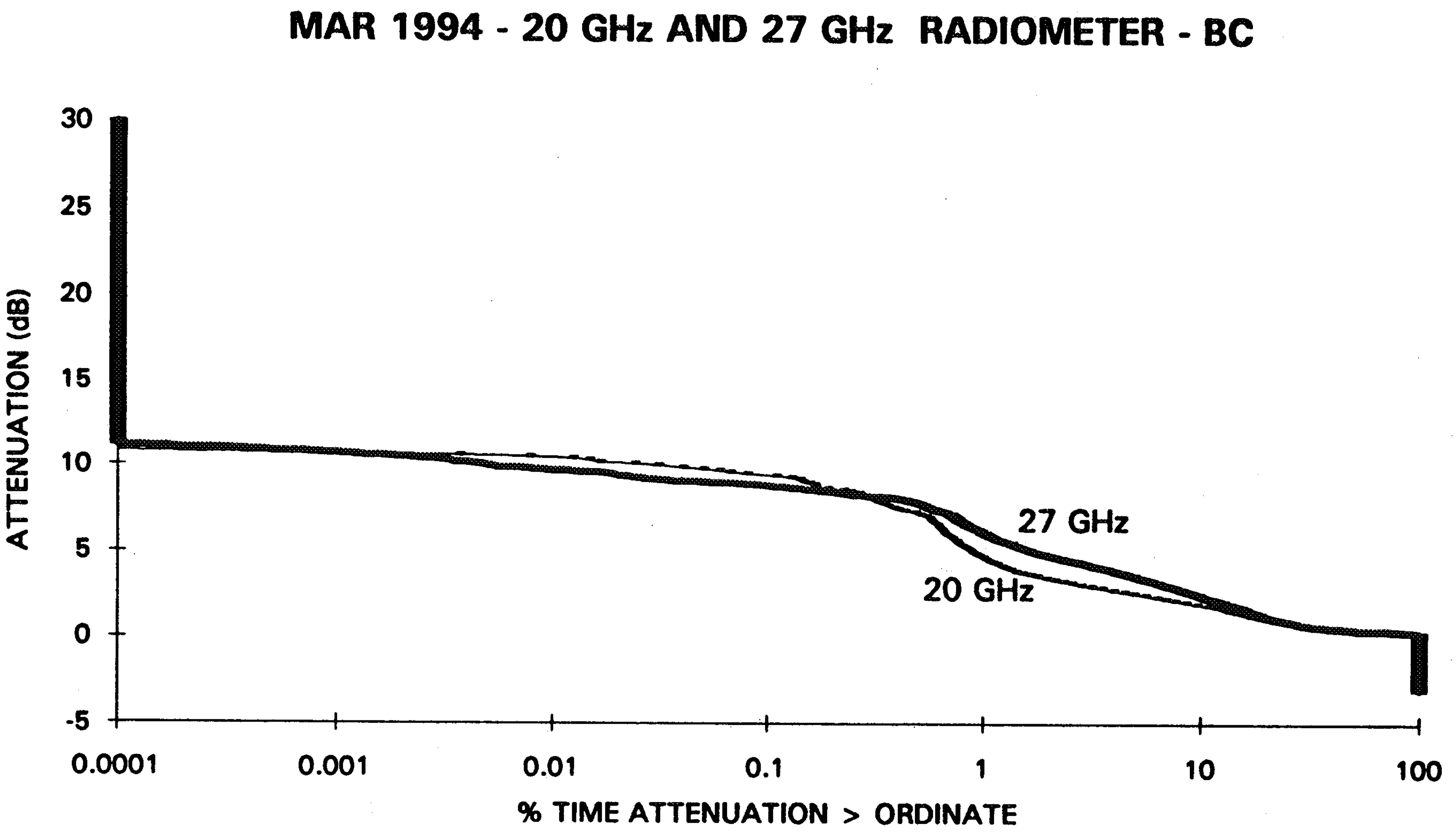


Fig. 13: Cumulative distribution functions of the 20 and 27 GHz radiometer-derived attenuation for the month of March, 1994

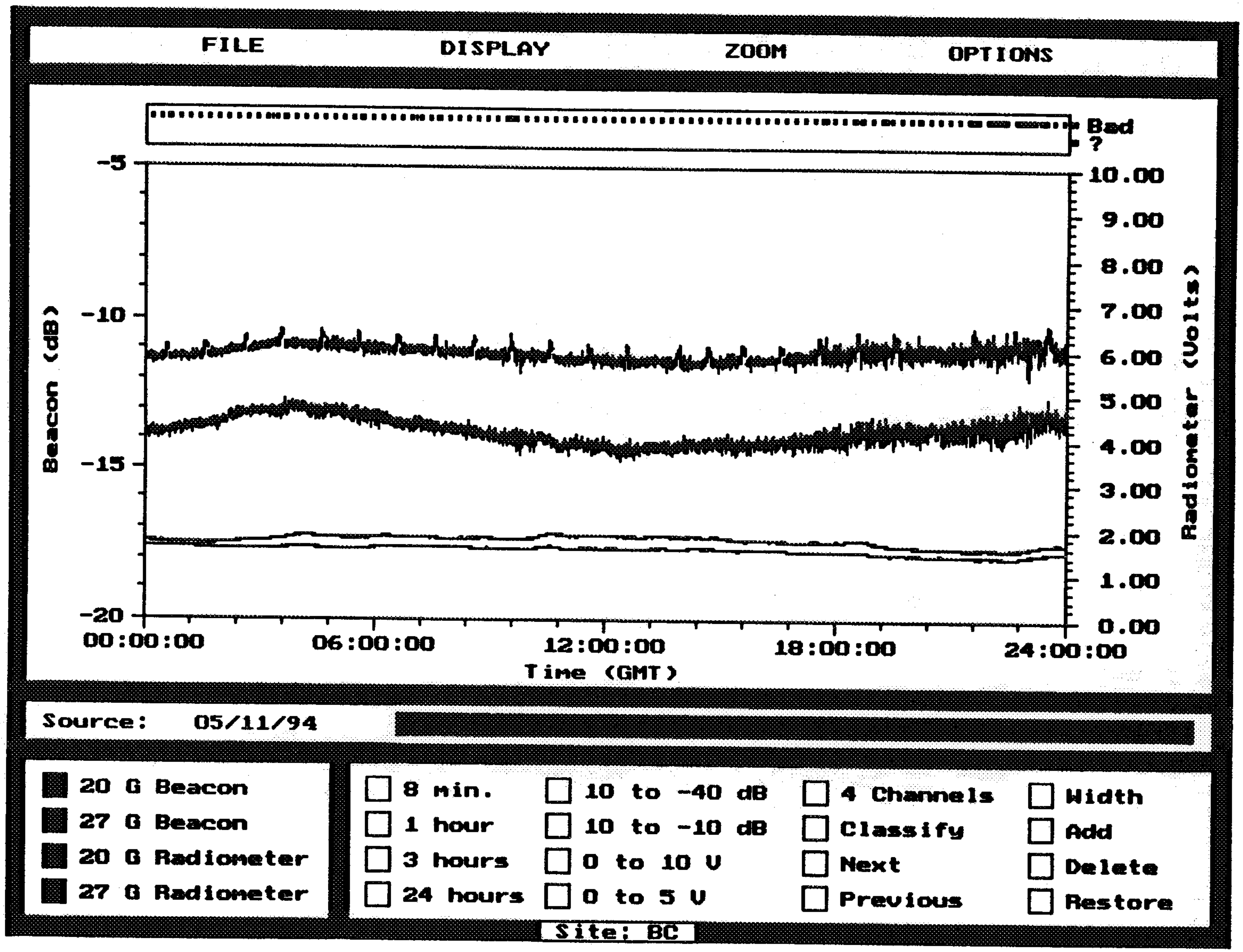


Fig. 14: Clear air scintillation on May 11, 1994

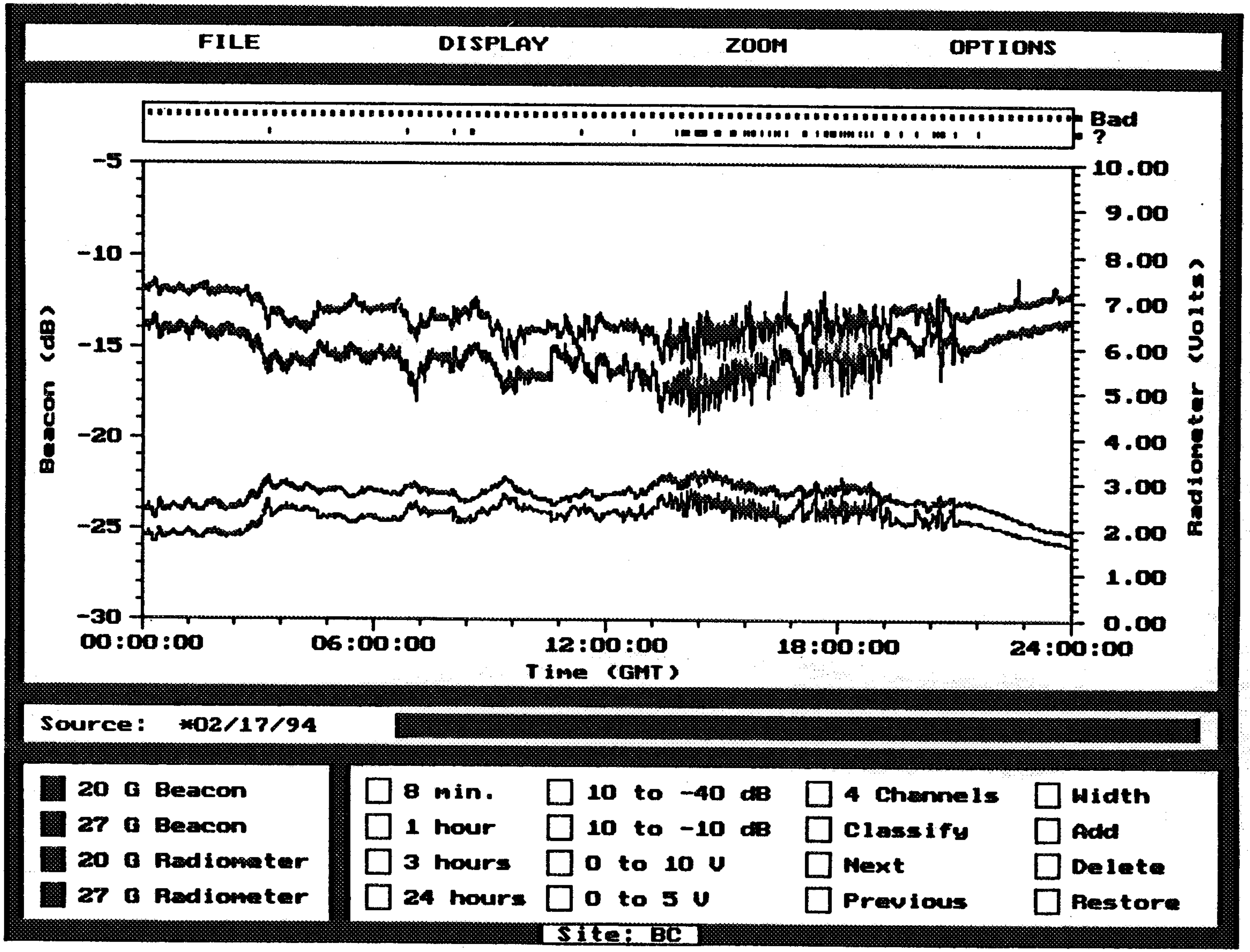


Fig. 15: Rainy weather scintillation on February 17, 1994

Ka-band Propagation Measurements Using the ACTS Propagation Terminal and the CSU-CHILL Multiparameter Radar

Experimenters

Colorado State University
Department of Electrical Engineering
Ft. Collins, CO 80523

Investigators

V.N. Bringi, Professor
John Beaver, Ph.D. Candidate
Joseph Turk, Research Associate

ACTS Propagation Studies Mini-Workshop
June 16, 1994

$\boxed{\textbf{Outline}}$

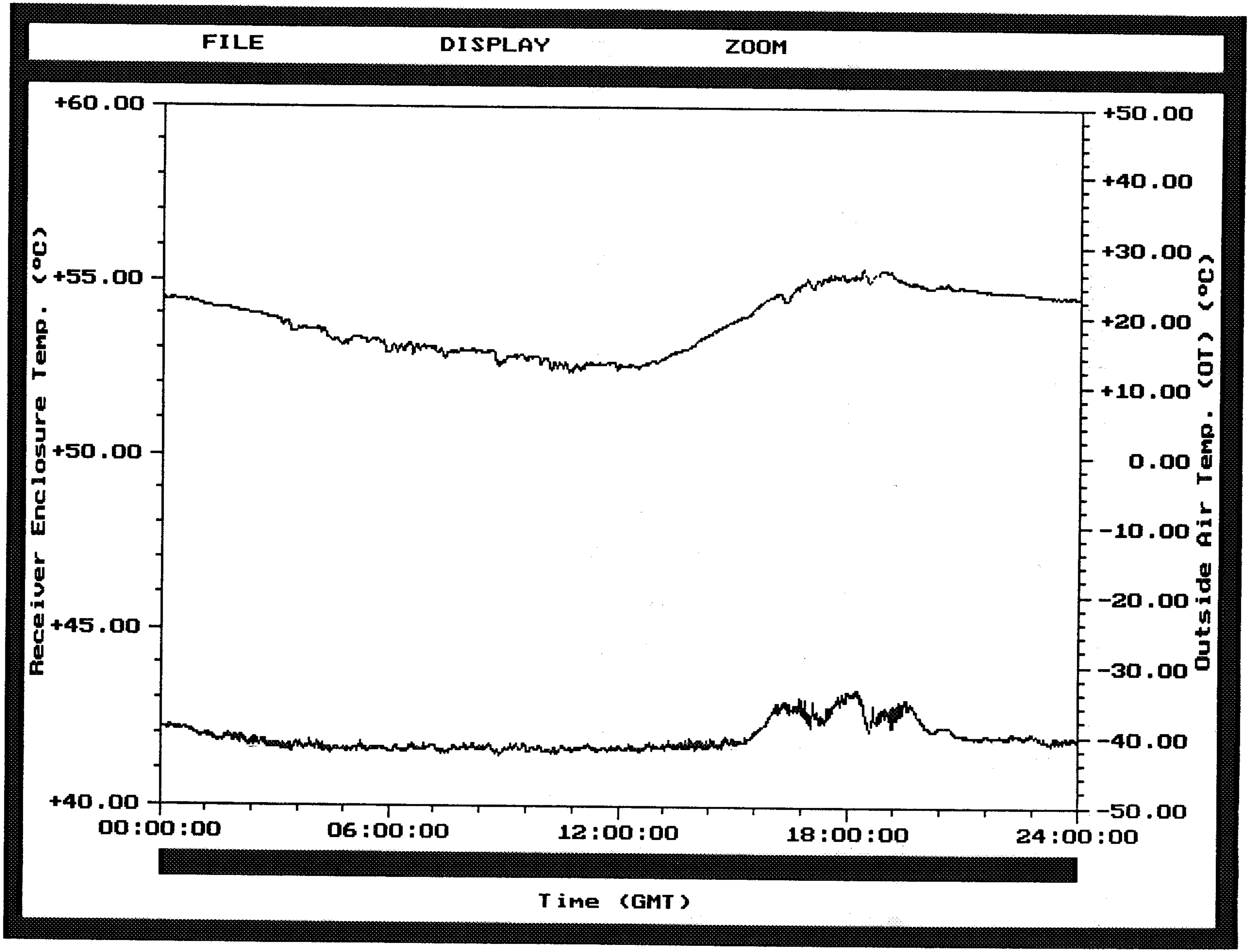
- CSU – ACTS Propagation Terminal Status
  - Hardware Problems and Solutions
  - Software Discussion

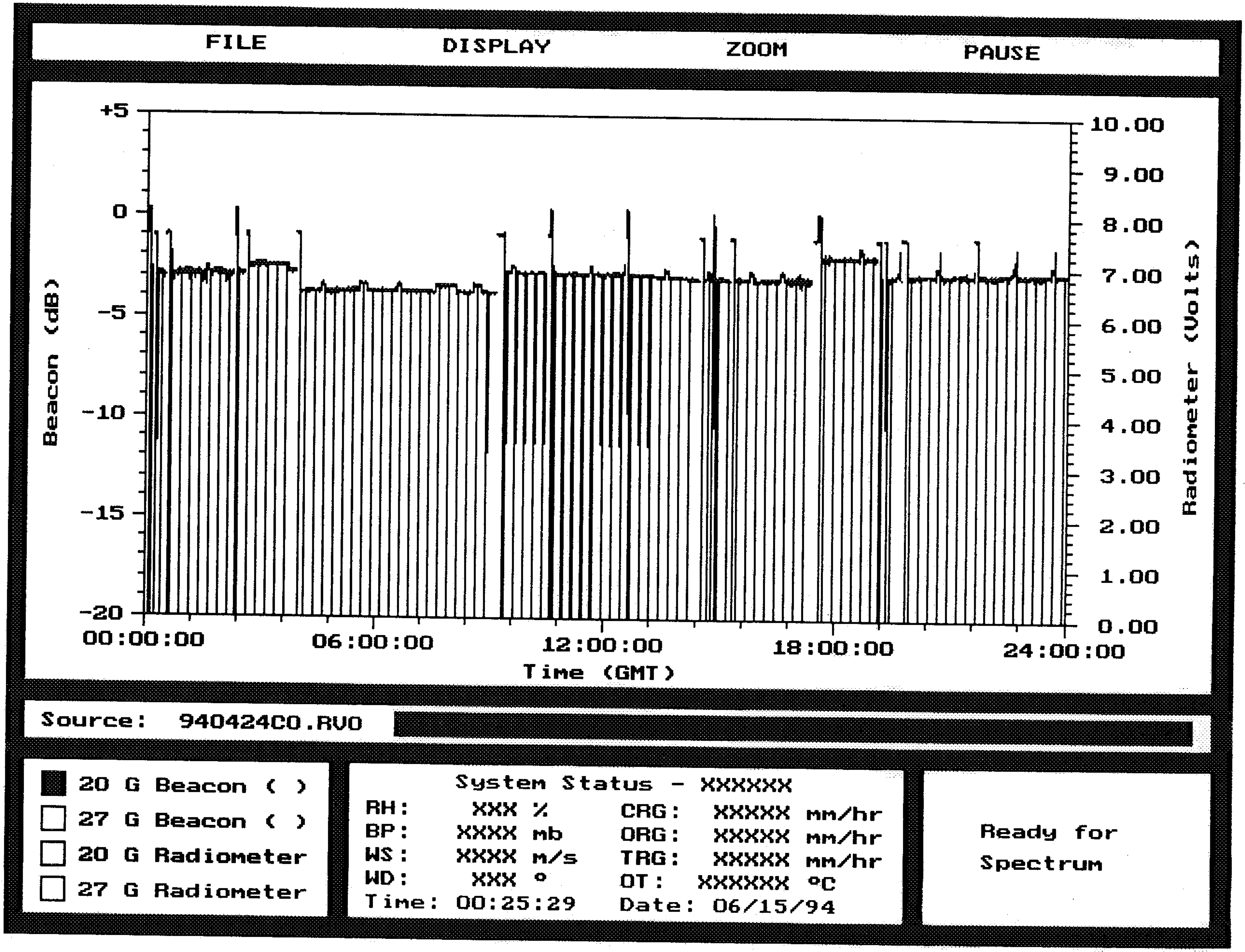
- ACTS Propagation Measurements
  - ACTS and CSU – CHILL measurements

- Modelling Efforts

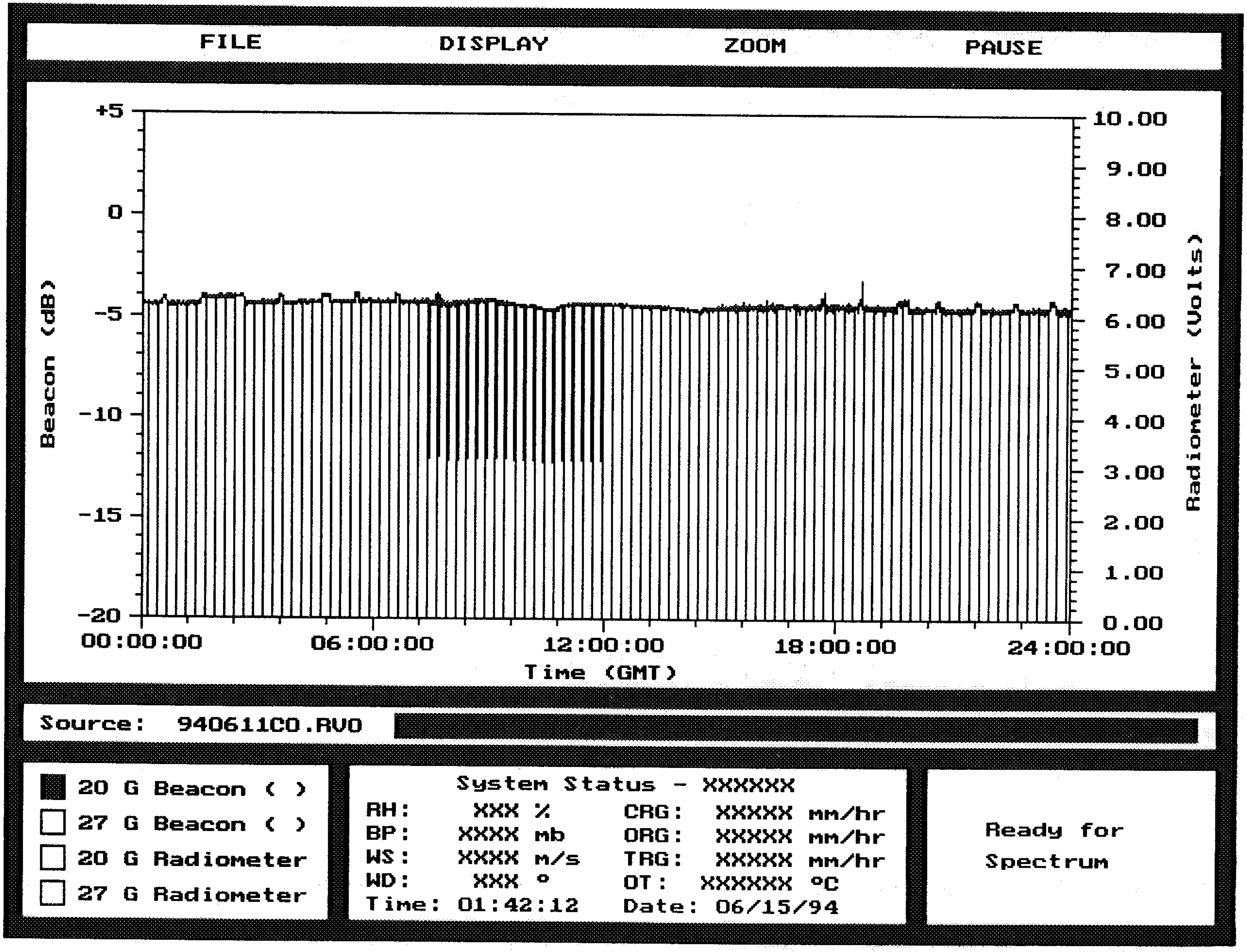
Hardware Problems and Solutions

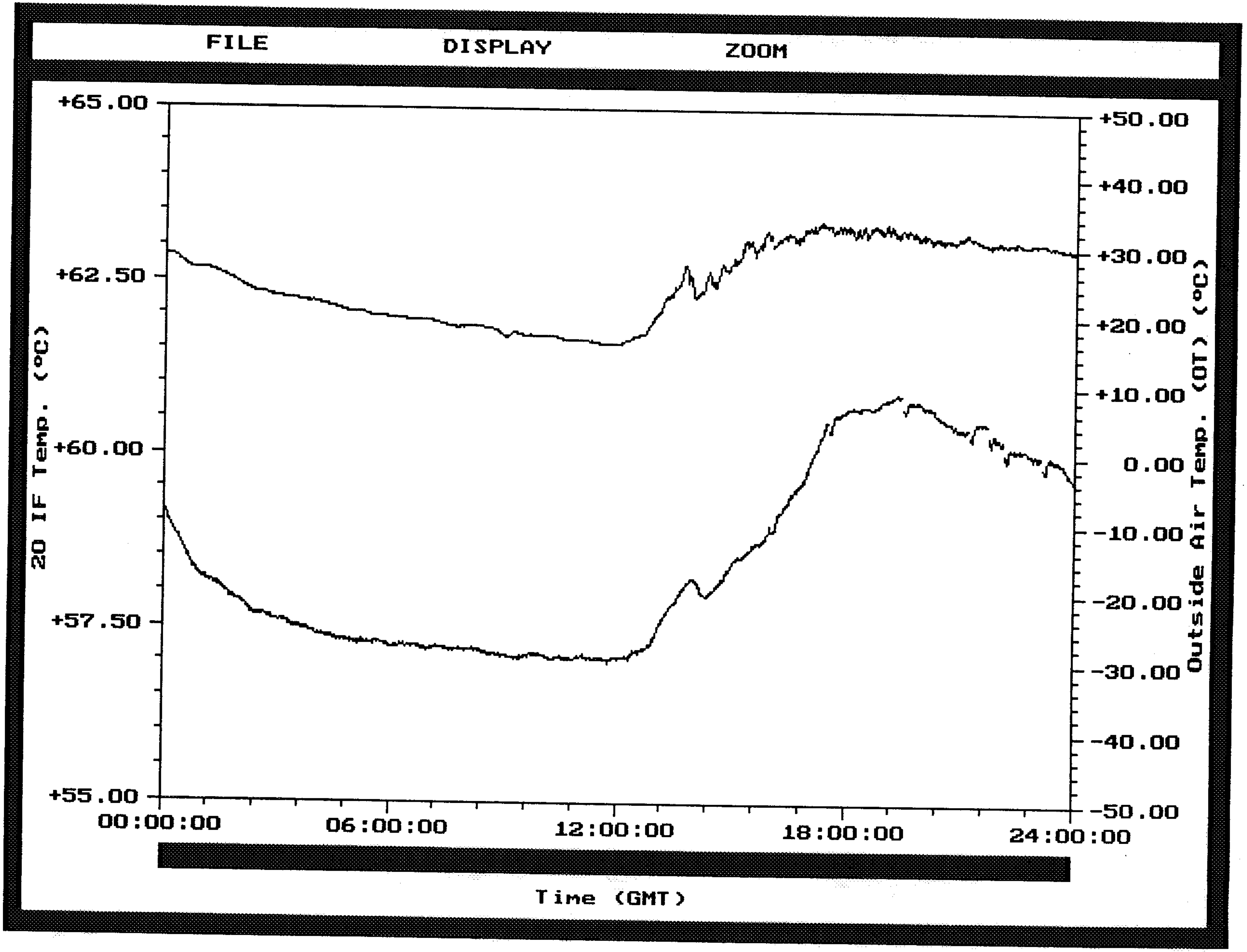
- Snow accumulation on the antenna surface
  - Installed a heating unit on the back surface of antenna
- Frequent system crashes and reboots
  - Reduced the receiver enclosure temperature to 40^o Celcius
- Loss of 27GHz beacon signal
  - Lost lock on February 28, 1994.
  - After retuning the Master Oscillator, reacquired signal on March 4.


FILE
DISPLAY
ZOOM
+60.00
+55.00
+50.00
+45.00
+40.00
Receiver Enclosure Temp. (°C)
+50.00
+40.00
+30.00
+20.00
+10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
Outside Air Temp. (OT) (°C)
00:00:00
06:00:00
12:00:00
18:00:00
24:00:00
Time (GMT)



FILE
DISPLAY
ZOOM
PAUSE
+5
0
-5
-10
-15
-20
Beacon (dB)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Radiometer (Volts)
00:00:00
06:00:00
12:00:00
18:00:00
24:00:00
Time (GMT)
Source: 940424C0.RV0
20 G Beacon ( )
27 G Beacon ( )
20 G Radiometer
27 G Radiometer
System Status - XXXXXX
RH: XXX %
BP: XXXX mb
WS: XXXX m/s
WD: XXX °
Time: 00:25:29
CRG: XXXXX mm/hr
ORG: XXXXX mm/hr
TRG: XXXXX mm/hr
OT: XXXXXX °C
Date: 06/15/94
Ready for
Spectrum


FILE
DISPLAY
ZOOM
PAUSE
+5
0
-5
-10
-15
-20
Beacon (dB)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Radiometer (Volts)
00:00:00
06:00:00
12:00:00
18:00:00
24:00:00
Time (GMT)
Source: 940611C0.RV0
20 G Beacon ( )
27 G Beacon ( )
20 G Radiometer
27 G Radiometer
System Status - XXXXXX
RH: XXX %
BP: XXXX mb
WS: XXXX m/s
WD: XXX °
Time: 01:42:12
CRG: XXXXX mm/hr
ORG: XXXXX mm/hr
TRG: XXXXX mm/hr
OT: XXXXXX °C
Date: 06/15/94
Ready for
Spectrum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DISPLAY
ZOOM
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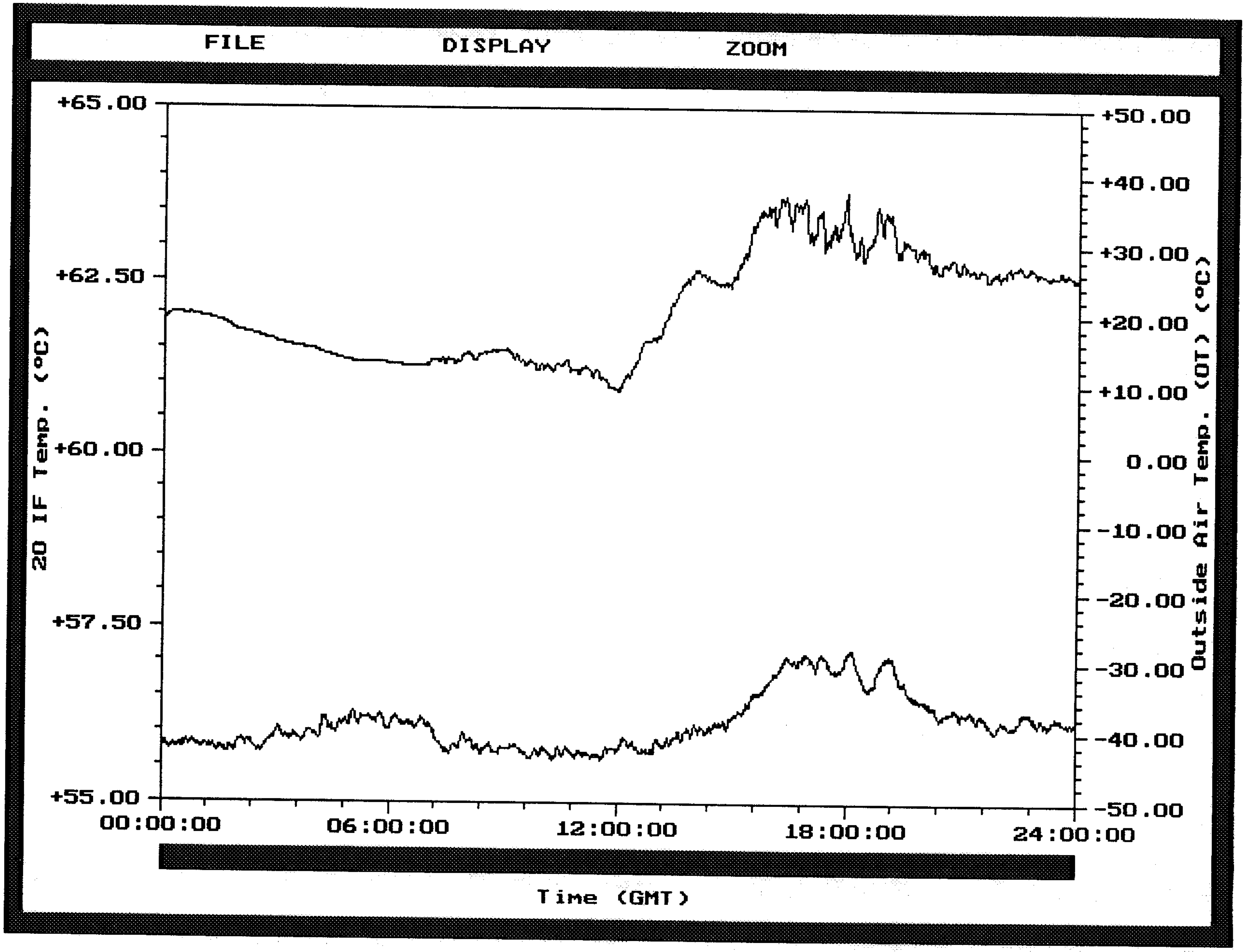
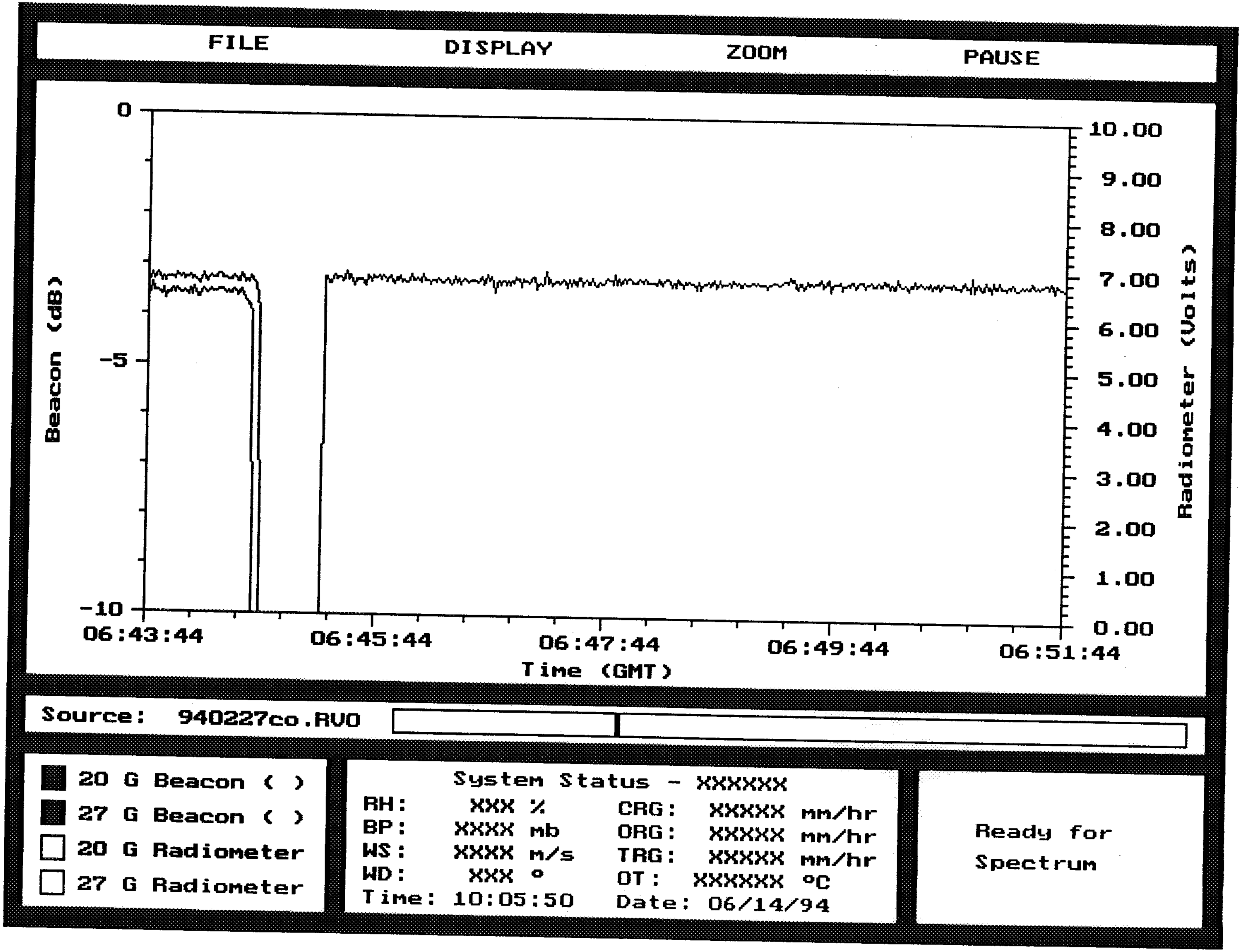
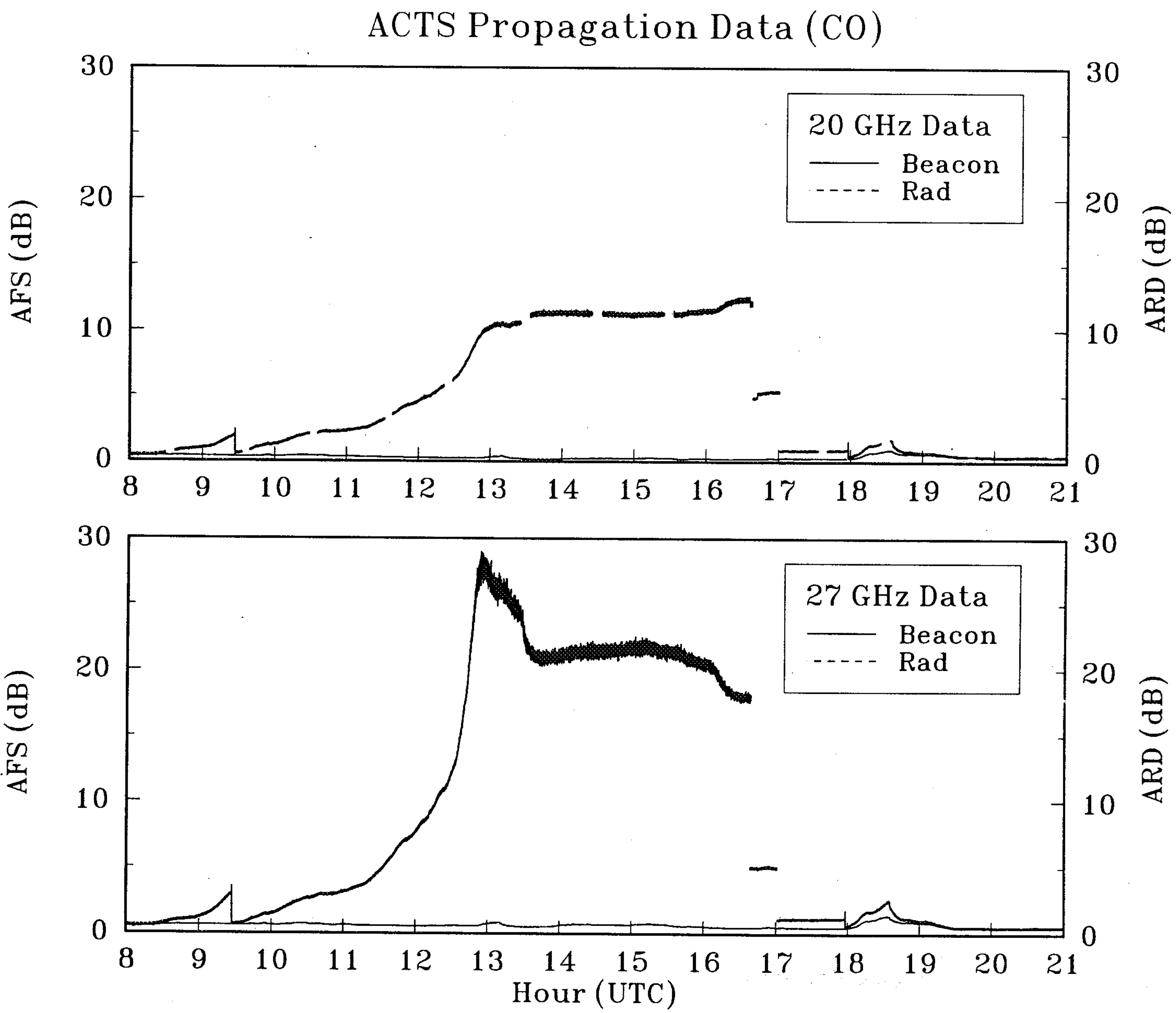
+62.50
+60.00
+57.50
+55.00
20 IF Temp. (°C)
+50.00
+40.00
+30.00
+20.00
+10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
Outside Air Temp. (OT) (°C)
00:00:00
06:00:00
12:00:00
18:00:00
24:00:00
Time (GMT)


FILE
DISPLAY
ZOOM
+65.00
+62.50
+60.00
+57.50
+55.00
20 IF Temp. (°C)
+50.00
+40.00
+30.00
+20.00
+10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
Outside Air Temp. (OT) (°C)
00:00:00
06:00:00
12:00:00
18:00:00
24:00:00
Time (GMT)


FILE
DISPLAY
ZOOM
PAUSE
Beacon (dB)
0
-5
-10
Radiometer (Volts)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
06:43:44
06:45:44
06:47:44
06:49:44
06:51:44
Time (GMT)
Source: 940227co.RVO
20 G Beacon ( )
27 G Beacon ( )
20 G Radiometer
27 G Radiometer
System Status - XXXXXX
RH: XXX %
BP: XXXX mb
WS: XXXX m/s
WD: XXX °
Time: 10:05:50
CRG: XXXXX mm/hr
ORG: XXXXX mm/hr
TRG: XXXXX mm/hr
OT: XXXXXX °C
Date: 06/14/94
Ready for Spectrum

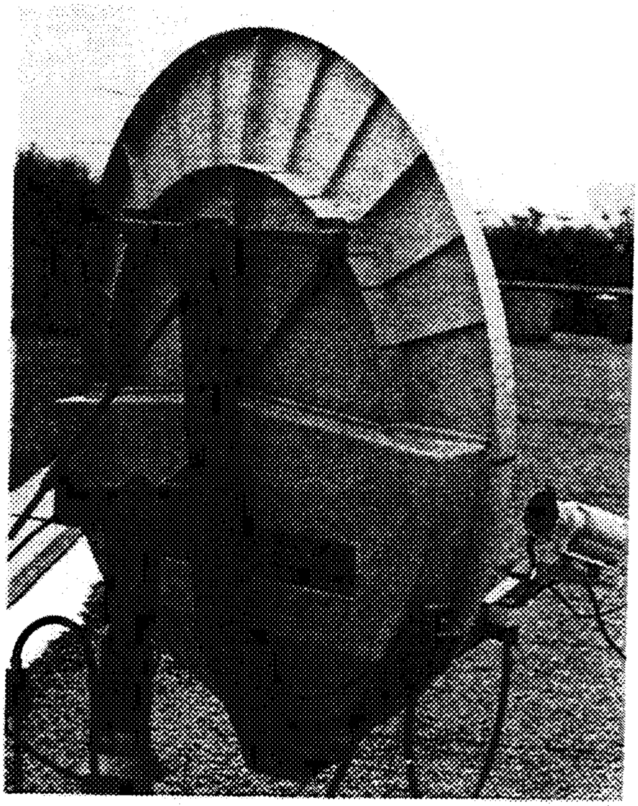
Snow Accumulation on Antenna Surface



Raychem

SoftHeat Radiant® Anti-Icing Systems

For Prodelin 1.2m,1.8m and 2.4m Earth Stations



Model RAD-P18H-1-S-53 mounted on Prodelin 1.8m Reflector

The SoftHeat Radiant Anti-Icing System family comprises models for the Prodelin 1.2m, 1.8m, and 2.4m reflectors. Field installation is simple, making them ideal for either initial installation or subsequent retrofit applications. Through the use of self-regulating heating elements, sufficient thermal power is delivered to the front surface of the antenna for effective anti-icing, while the uniform radiant heat minimizes reflector distortion.

Self-Regulating Performance

The polymer heater element used in SoftHeat Radiant Anti-Icing Systems is self regulating, allowing the thermal power delivered to the antenna to vary depending on the environmental conditions the antenna experiences: as ambient temperature decreases, heat output increases.

Radiant Heating Simplicity

Radiant heat transfer, as applied to antenna anti-icing, provides special benefits due to its inherent uniformity. Furthermore, SoftHeat Radiant systems respond differently to varying heat transfer conditions across the reflector surface, so that no mechanical means are required for even heat distribution. Thus the system has no moving parts other than controller contacts.

Ease of Installation

The SoftHeat Radiant Anti-Icing System is designed for quick and simple installation. It is complete and ready for installation as shipped, requiring no special structural adaptations or additional framing.

High Thermal Flux

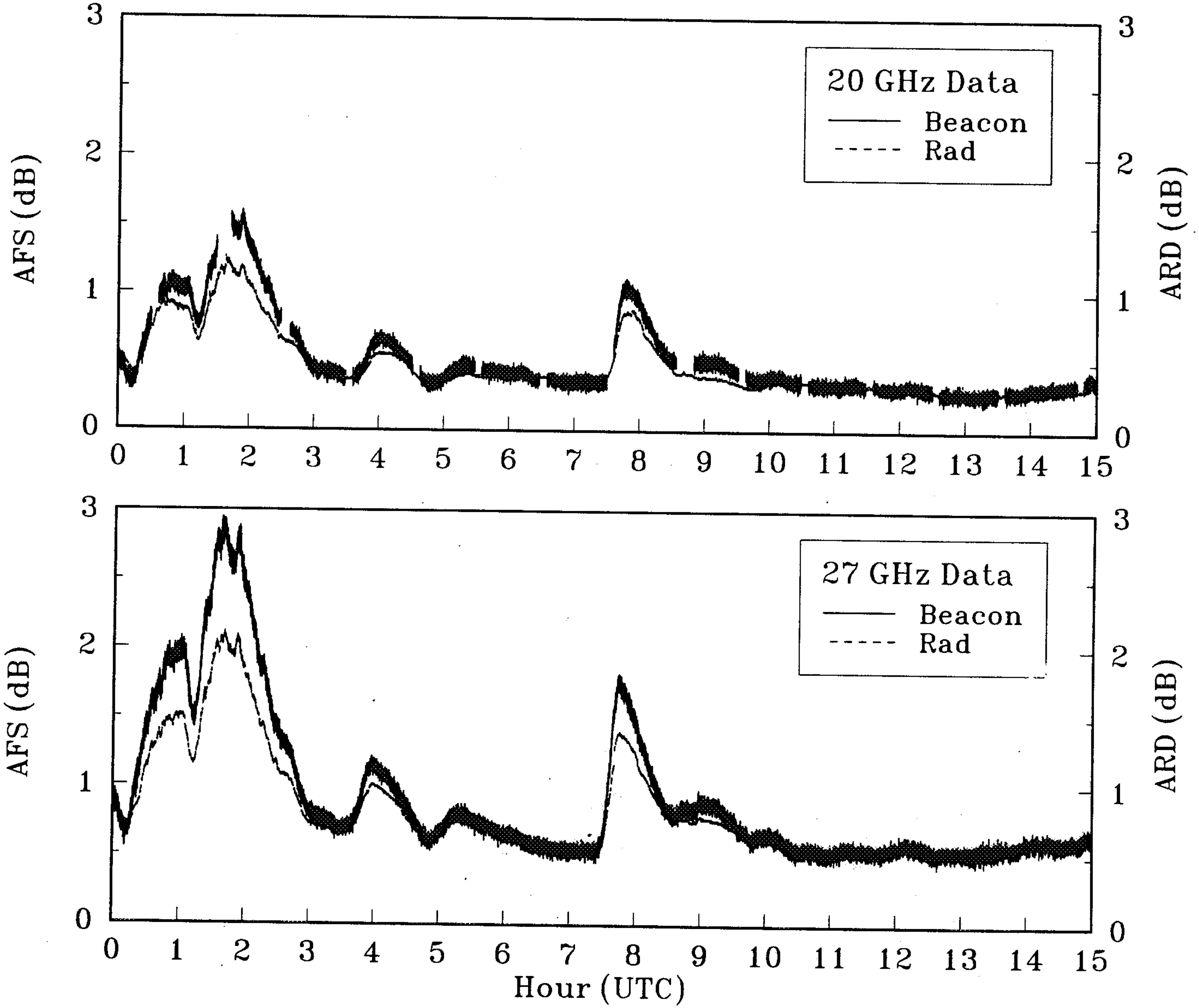
SoftHeat Radiant Anti-Icing Systems provide a high thermal flux, strongly biased **forward**, where snow and ice accumulation can cause severe signal attenuation. SoftHeat/Prodelin systems have demonstrated greater than 85% thermal efficiency toward the front of the antenna.

Features

SoftHeat Radiant Anti-Icing Systems are designed specifically for Prodelin 1.2m,1.8m, or 2.4m reflectors. All systems operate on 120 volt A.C.; power connection for 1.2m and 1.8m systems uses a simple plug and cord. A feedhorn heating system reduces outages from ice and snow accumulation in the critical feedhorn window. An advanced solid state moisture/temperature sensor reduces energy consumption on 1.8m and 2.4m systems.

Measured Snow Event after De–Icing Unit was Installed

ACTS Propagation Data (CO)

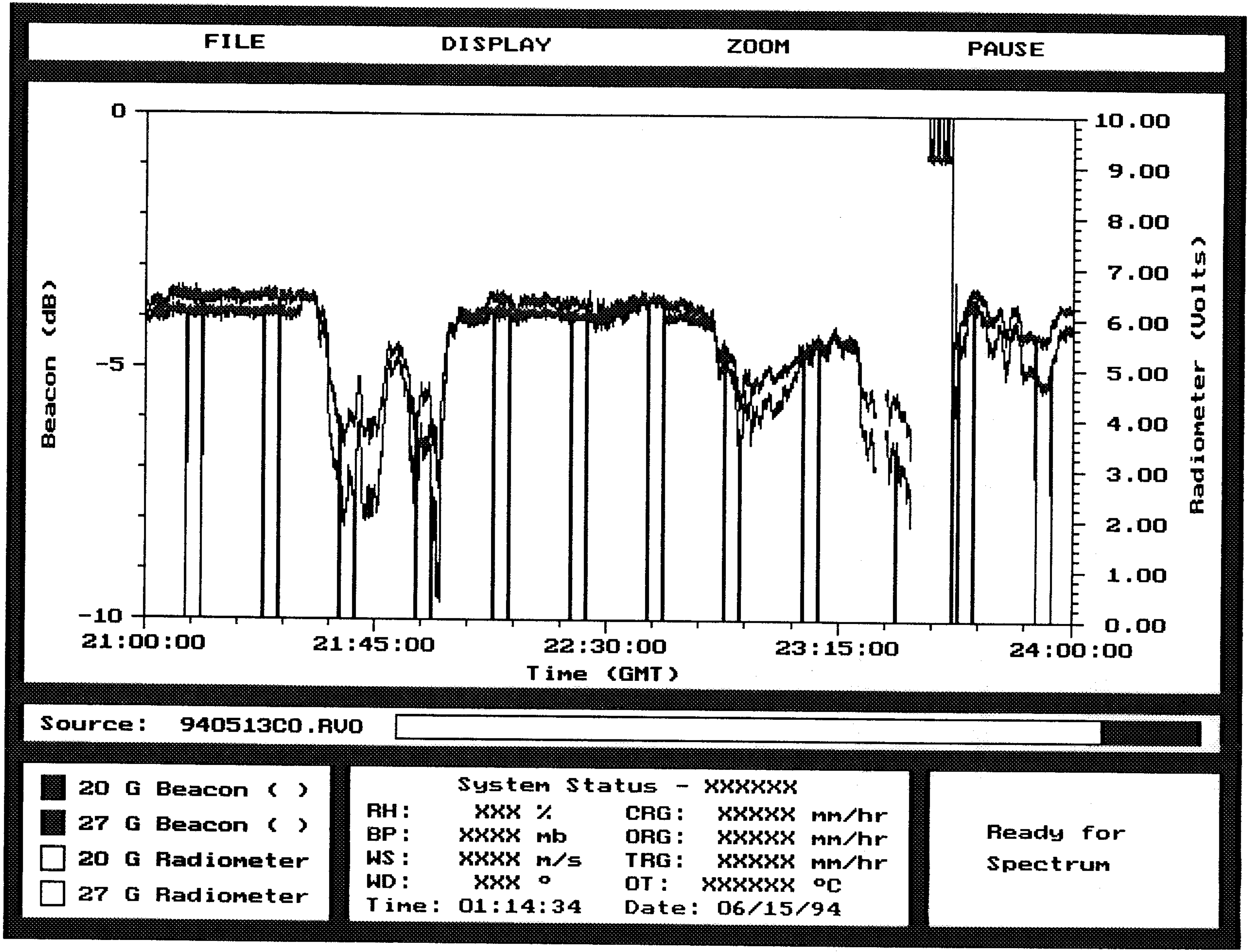


Software Discussion

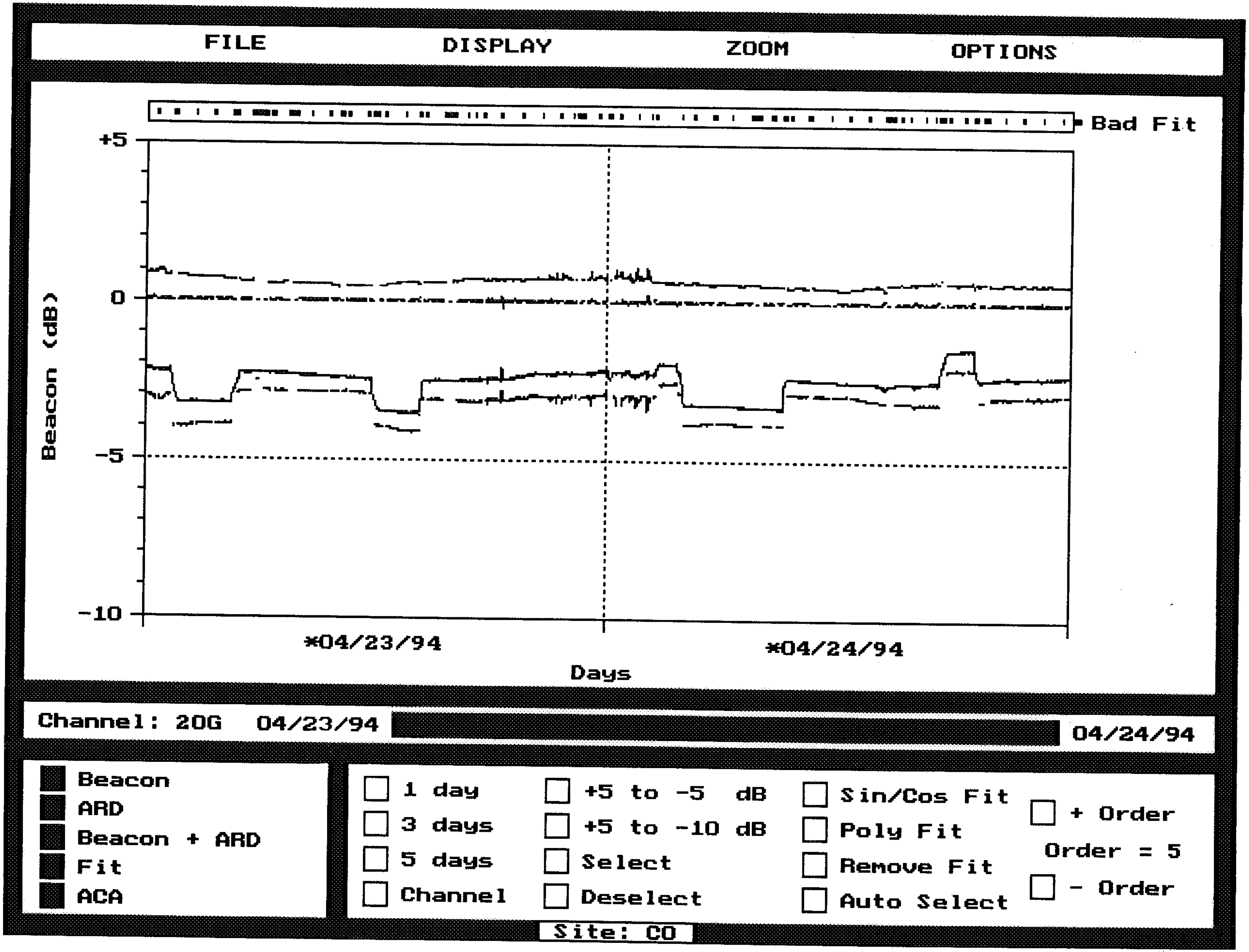
- Shorter set up times

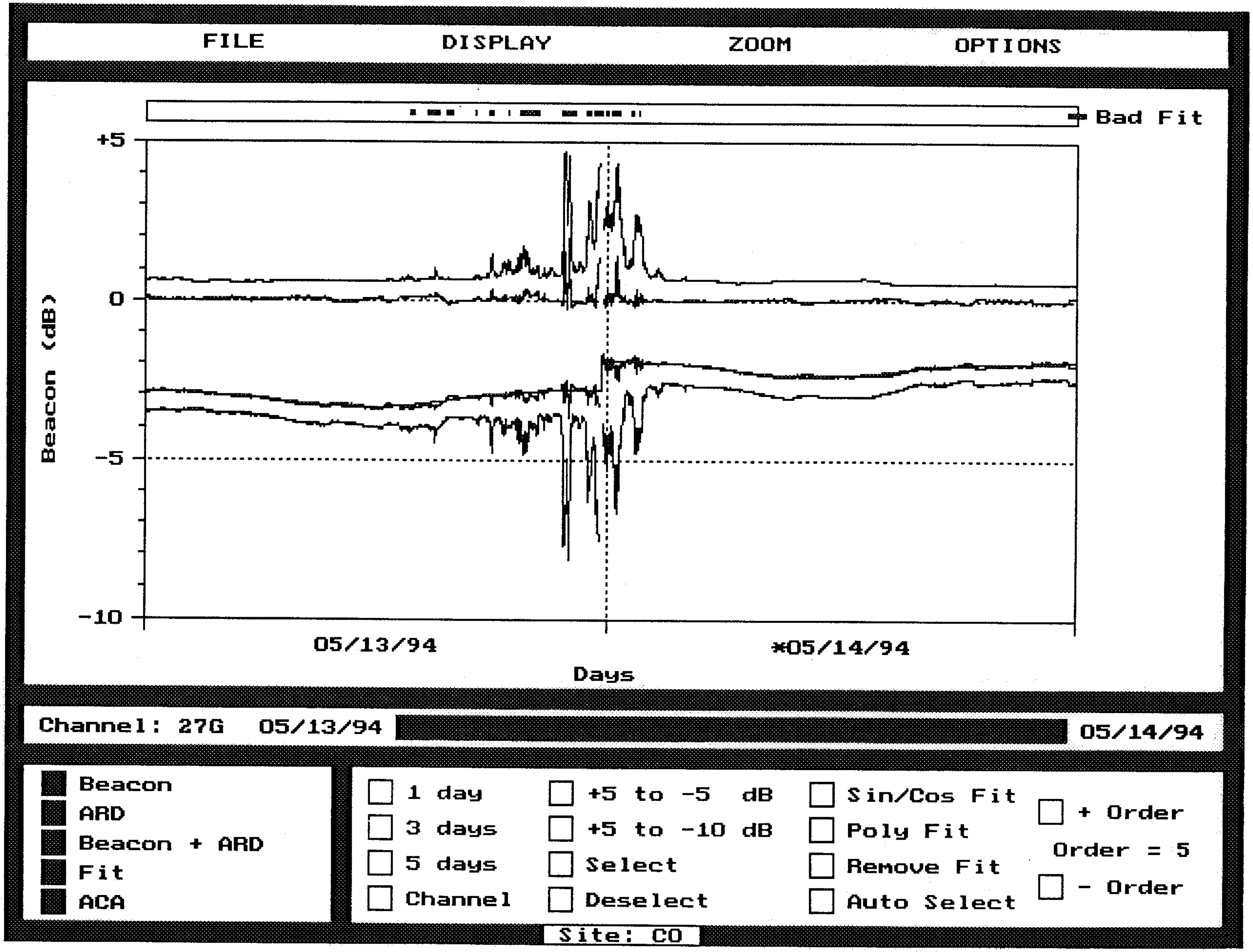
- Level shifts in data after set ups

- Time axis in bias removal



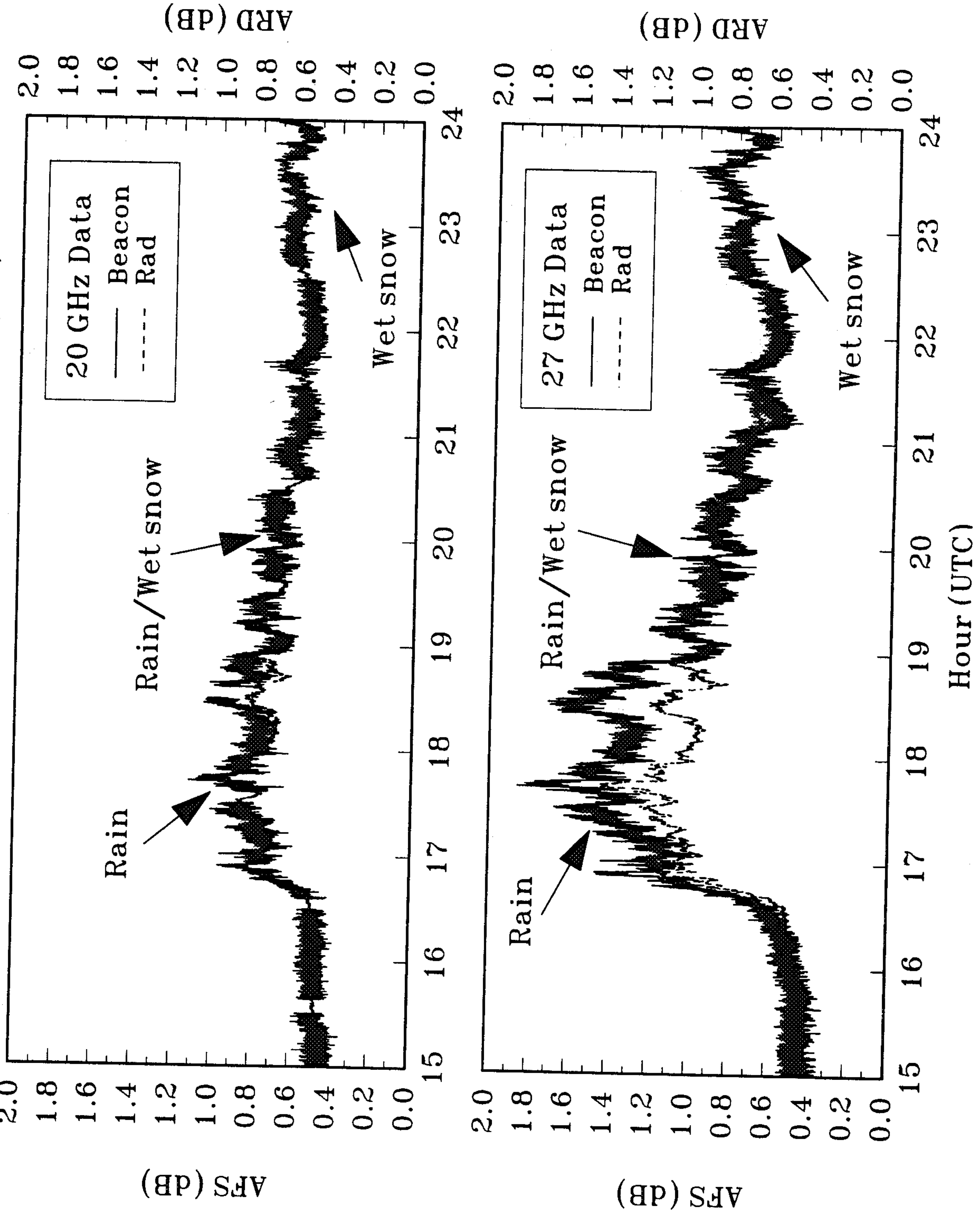
FILE
DISPLAY
ZOOM
PAUSE
0
-5
-10
Beacon (dB)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Radiometer (Volts)
21:00:00
21:45:00
22:30:00
23:15:00
24:00:00
Time (GMT)
Source: 940513C0.RV0
20 G Beacon ( )
27 G Beacon ( )
20 G Radiometer
27 G Radiometer
System Status - XXXXXX
RH: XXX %
BP: XXXX mb
WS: XXXX m/s
WD: XXX °
Time: 01:14:34
CRG: XXXXX mm/hr
ORG: XXXXX mm/hr
TRG: XXXXX mm/hr
OT: XXXXXX °C
Date: 06/15/94
Ready for
Spectrum


FILE
DISPLAY
ZOOM
OPTIONS
Bad Fit
+5
0
-5
-10
Beacon (dB)
*04/23/94
*04/24/94
Days
Channel: 20G 04/23/94
04/24/94
Beacon
ARD
Beacon + ARD
Fit
ACA
1 day
3 days
5 days
Channel
+5 to -5 dB
+5 to -10 dB
Select
Deselect
Sin/Cos Fit
Poly Fit
Remove Fit
Auto Select
+ Order
Order = 5
- Order
Site: CO


FILE
DISPLAY
ZOOM
OPTIONS
Bad Fit
+5
0
-5
-10
Beacon (dB)
05/13/94
*05/14/94
Days
Channel: 27G
05/13/94
05/14/94
Beacon
ARD
Beacon + ARD
Fit
ACA
1 day
3 days
5 days
Channel
+5 to -5 dB
+5 to -10 dB
Select
Deselect
Sin/Cos Fit
Poly Fit
Remove Fit
Auto Select
+ Order
Order = 5
- Order
Site: CO

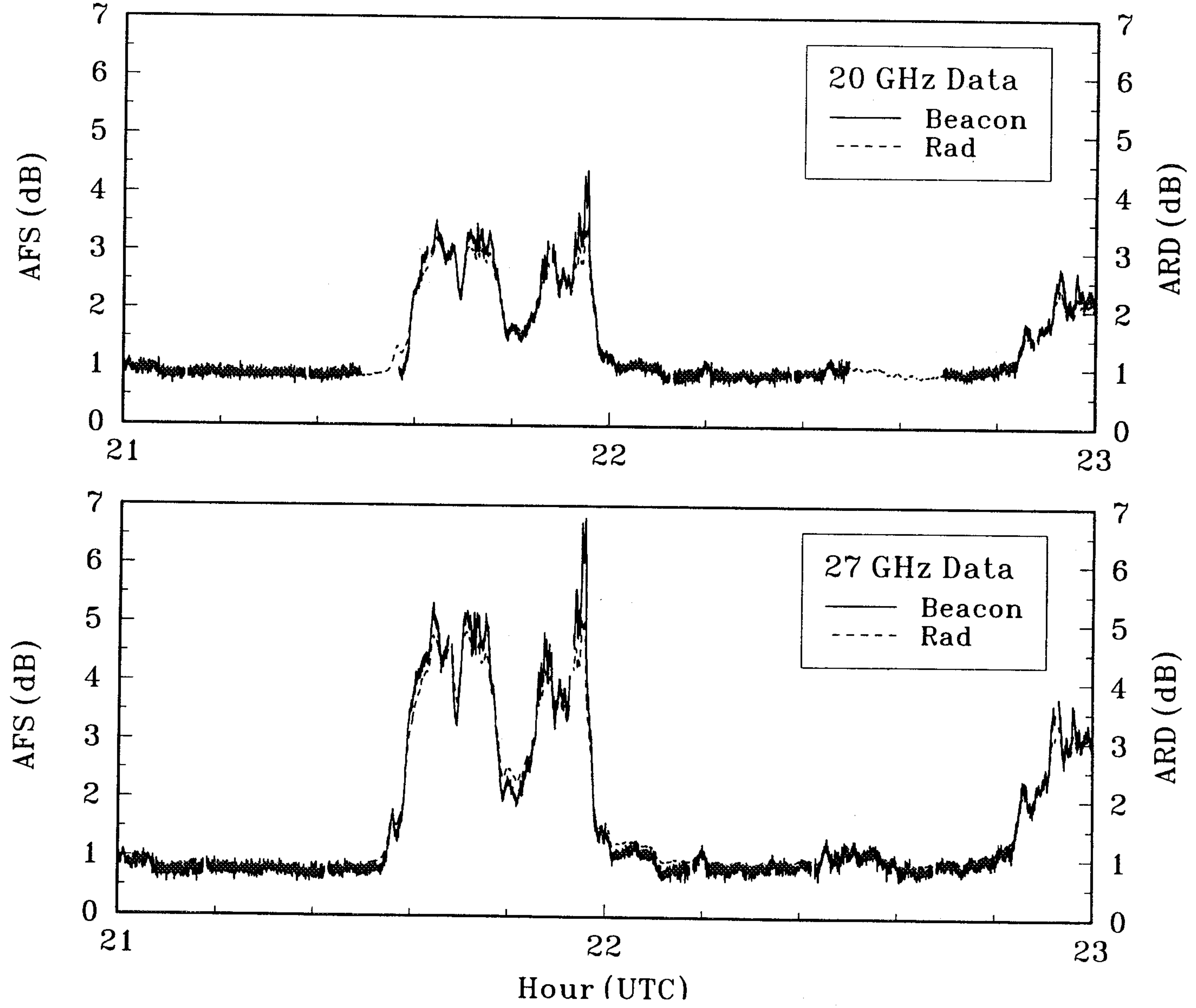
Rain / Wet Snow Event

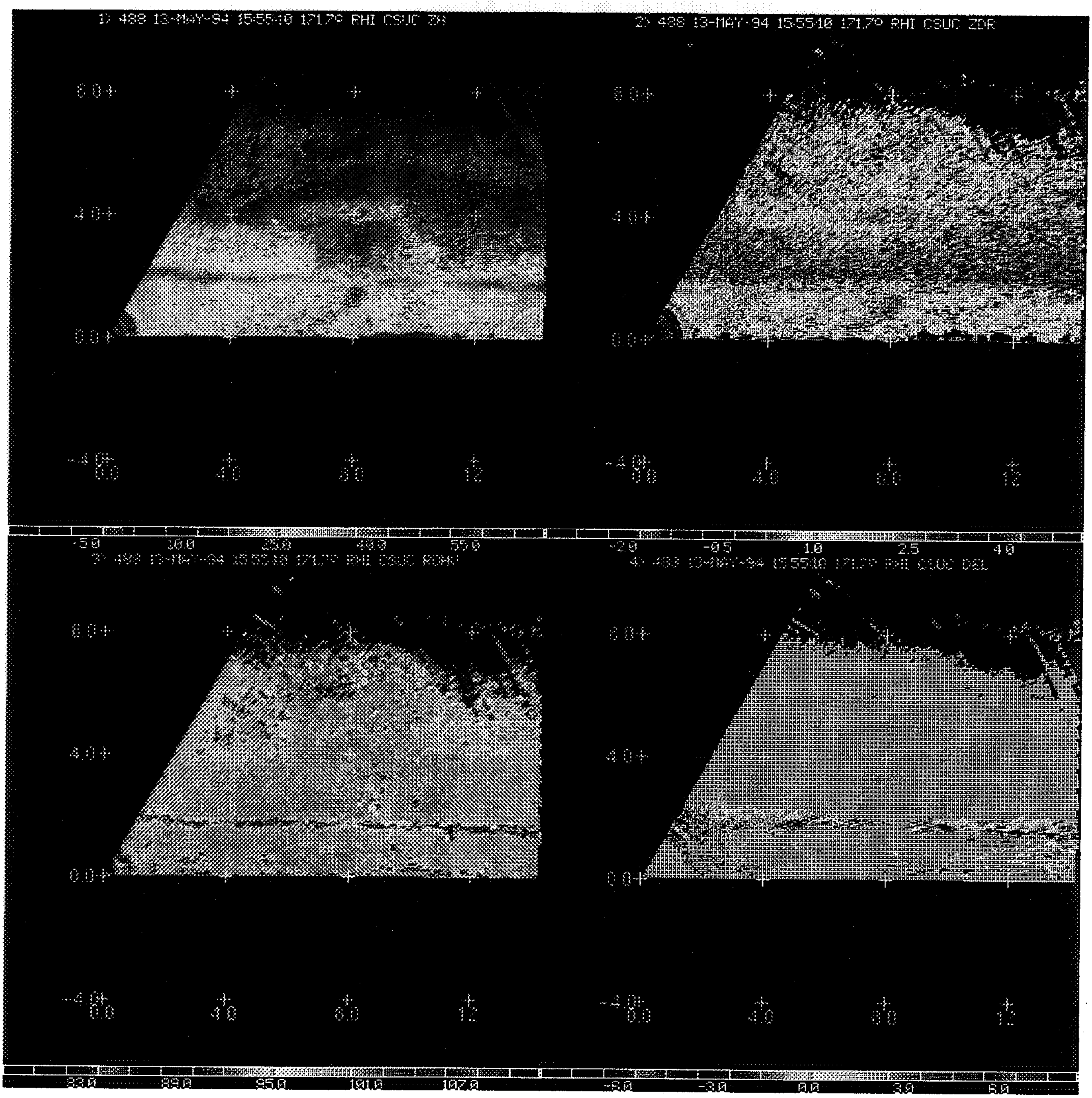
4/9/94 ACTS Propagation Data (CO)

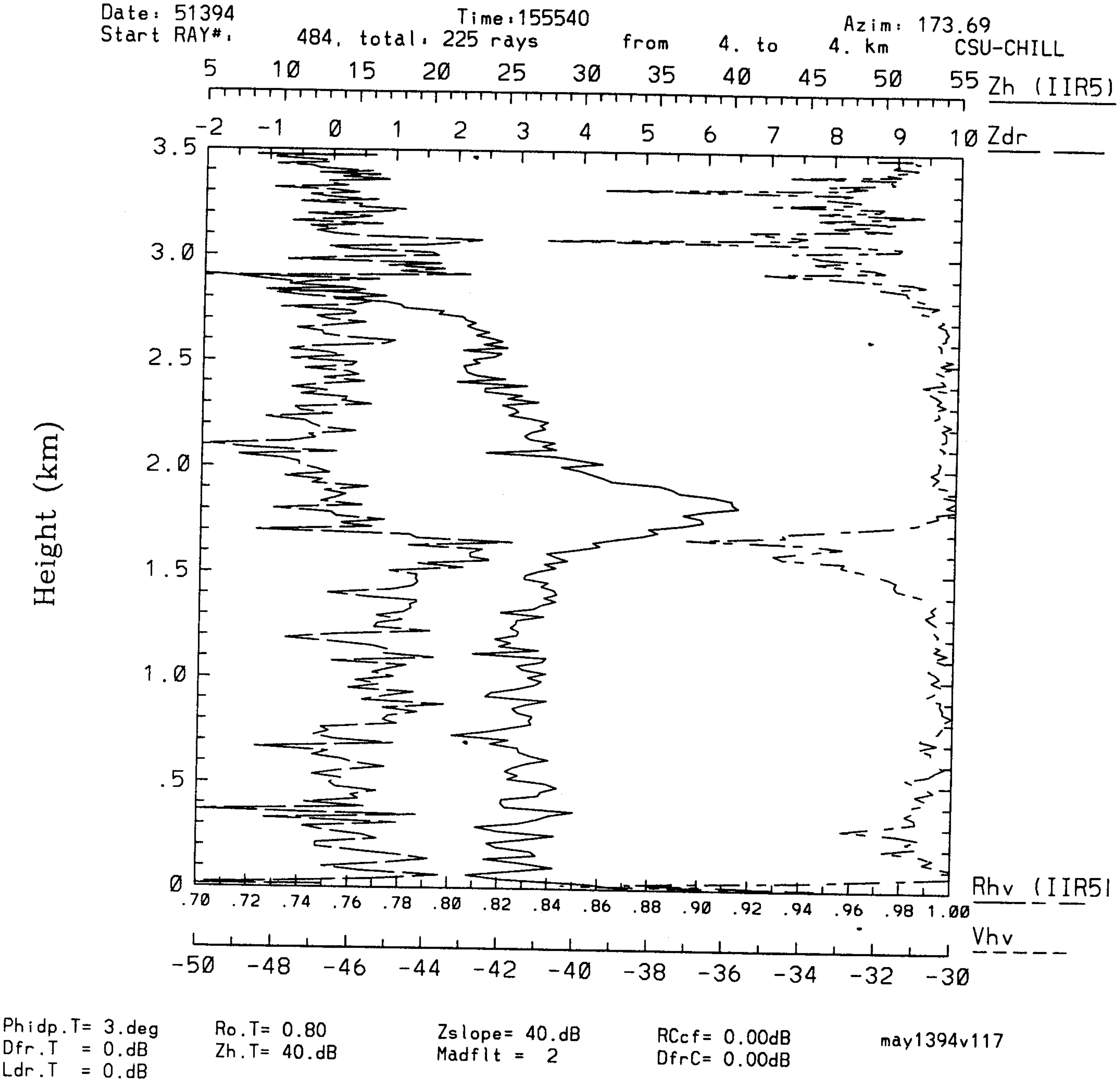


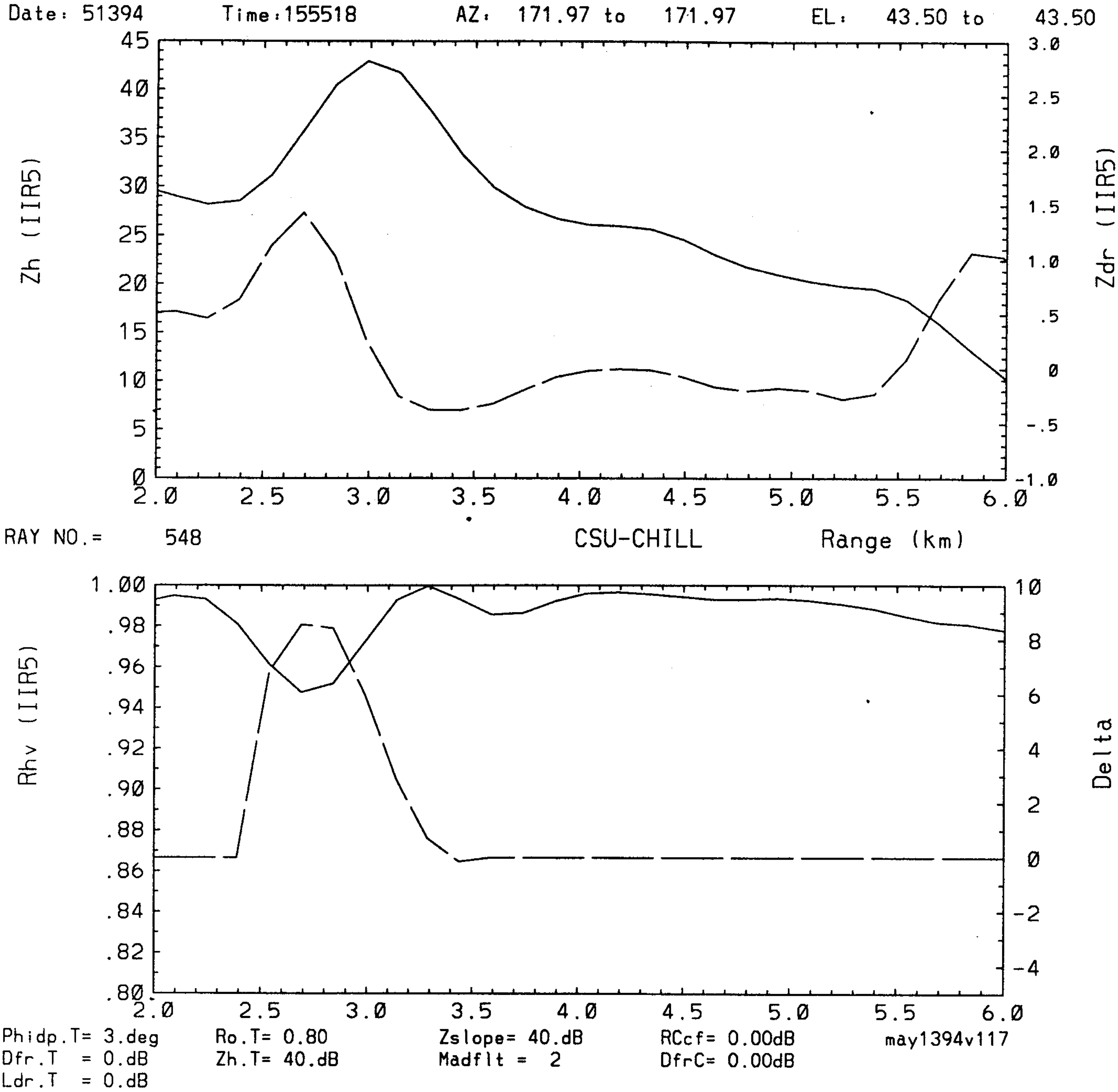
ACTS/CSU CHILL Data (Bright Band Case)

5/13/94 ACTS Propagation Data (CO)



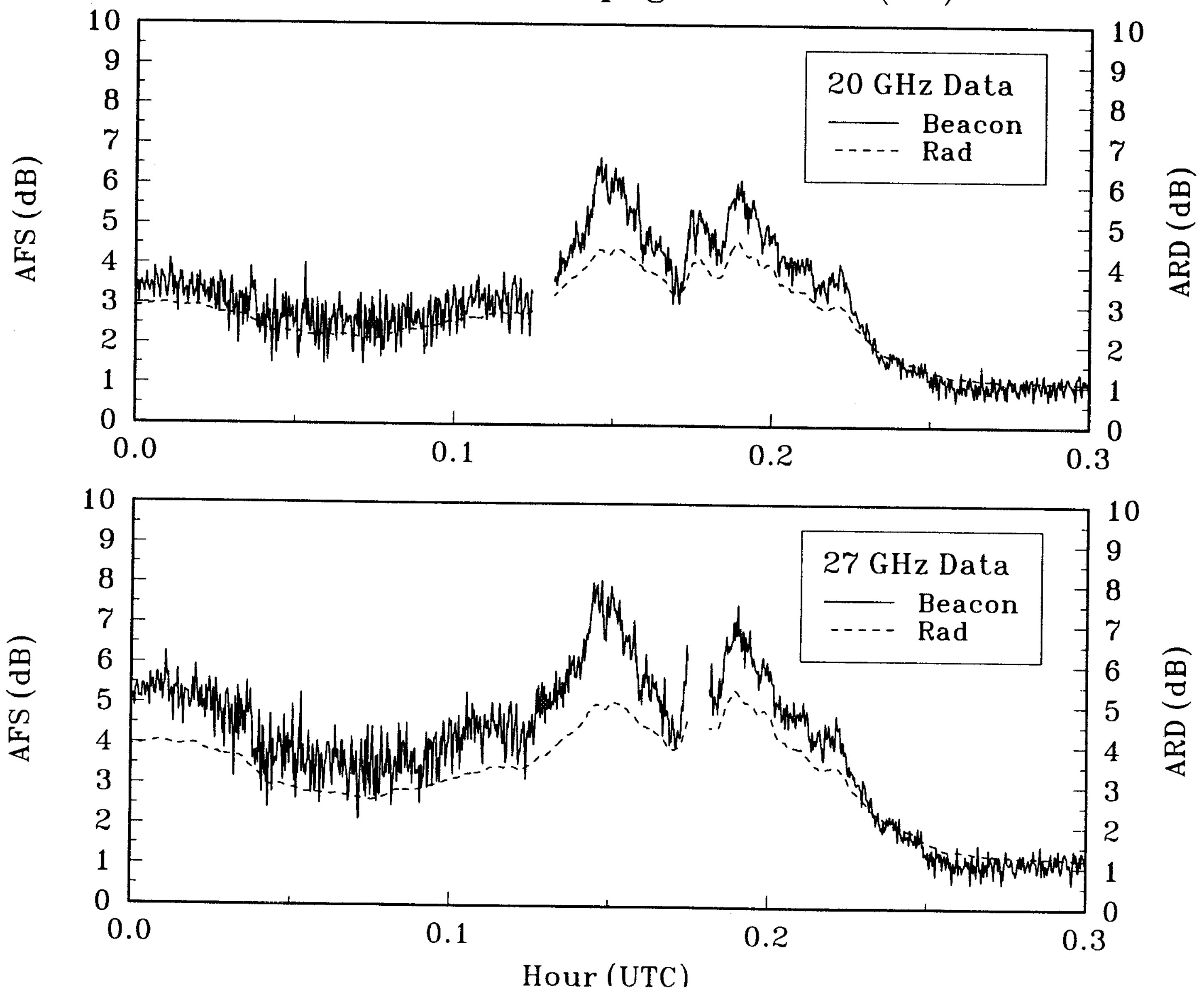

1) 488 13-MAY-94 15:55:10 171.7° RHI CSUC ZH
2) 488 13-MAY-94 15:55:10 171.7° RHI CSUC ZDR
3) 488 13-MAY-94 15:55:10 171.7° RHI CSUC RDHV
4) 488 13-MAY-94 15:55:10 171.7° RHI CSUC DEL

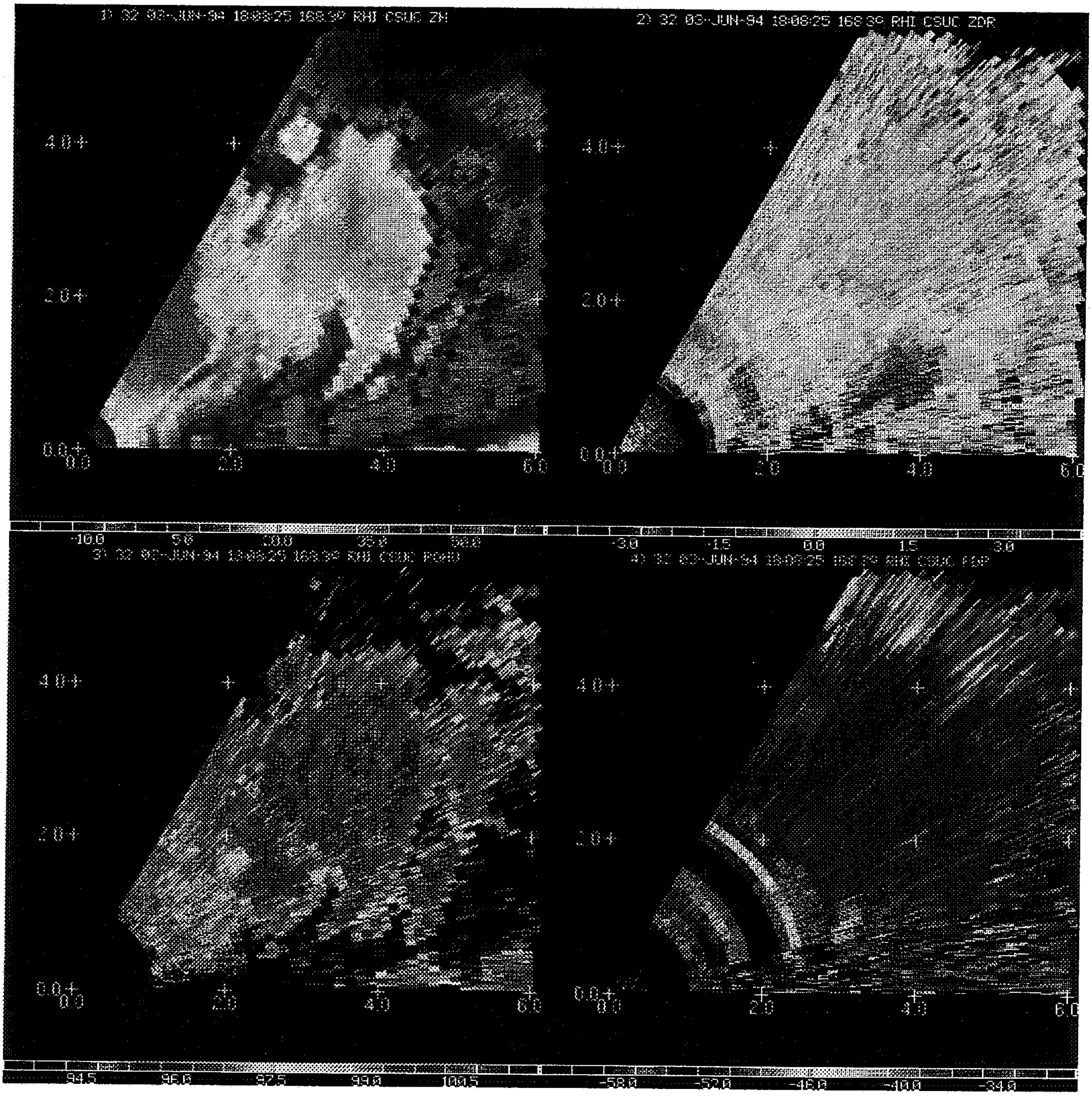

Date: 51394
Time:155540
Azim: 173.69
Start RAY#: 484, total: 225 rays from 4. to 4. km
CSU-CHILL
5 10 15 20 25 30 35 40 45 50 55 Zh (IIR5)
-2 -1 0 1 2 3 4 5 6 7 8 9 10 Zdr
3.5 3.0 2.5 2.0 1.5 1.0 .5 0
Height (km)
.70 .72 .74 .76 .78 .80 .82 .84 .86 .88 .90 .92 .94 .96 .98 1.00 Rhv (IIR5)
-50 -48 -46 -44 -42 -40 -38 -36 -34 -32 -30 Vhv
Phidp.T= 3.deg
Dfr.T = 0.dB
Ldr.T = 0.dB
Ro.T= 0.80
Zh.T= 40.dB
Zslope= 40.dB
Madflt = 2
RCcf= 0.00dB
DfrC= 0.00dB
may1394v117


Date: 51394 Time:155518 AZ: 171.97 to 171.97 EL: 43.50 to 43.50
Zh (IIR5)
Zdr (IIR5)
45
40
35
30
25
20
15
10
5
0
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
RAY NO.= 548
CSU-CHILL
Range (km)
Rhv (IIR5)
Delta
1.00
.98
.96
.94
.92
.90
.88
.86
.84
.82
.80
10
8
6
4
2
0
-2
-4
2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Phidp.T= 3.deg
Dfr.T = 0.dB
Ldr.T = 0.dB
Ro.T= 0.80
Zh.T= 40.dB
Zslope= 40.dB
Madflt = 2
RCcf= 0.00dB
DfrC= 0.00dB
may1394v117

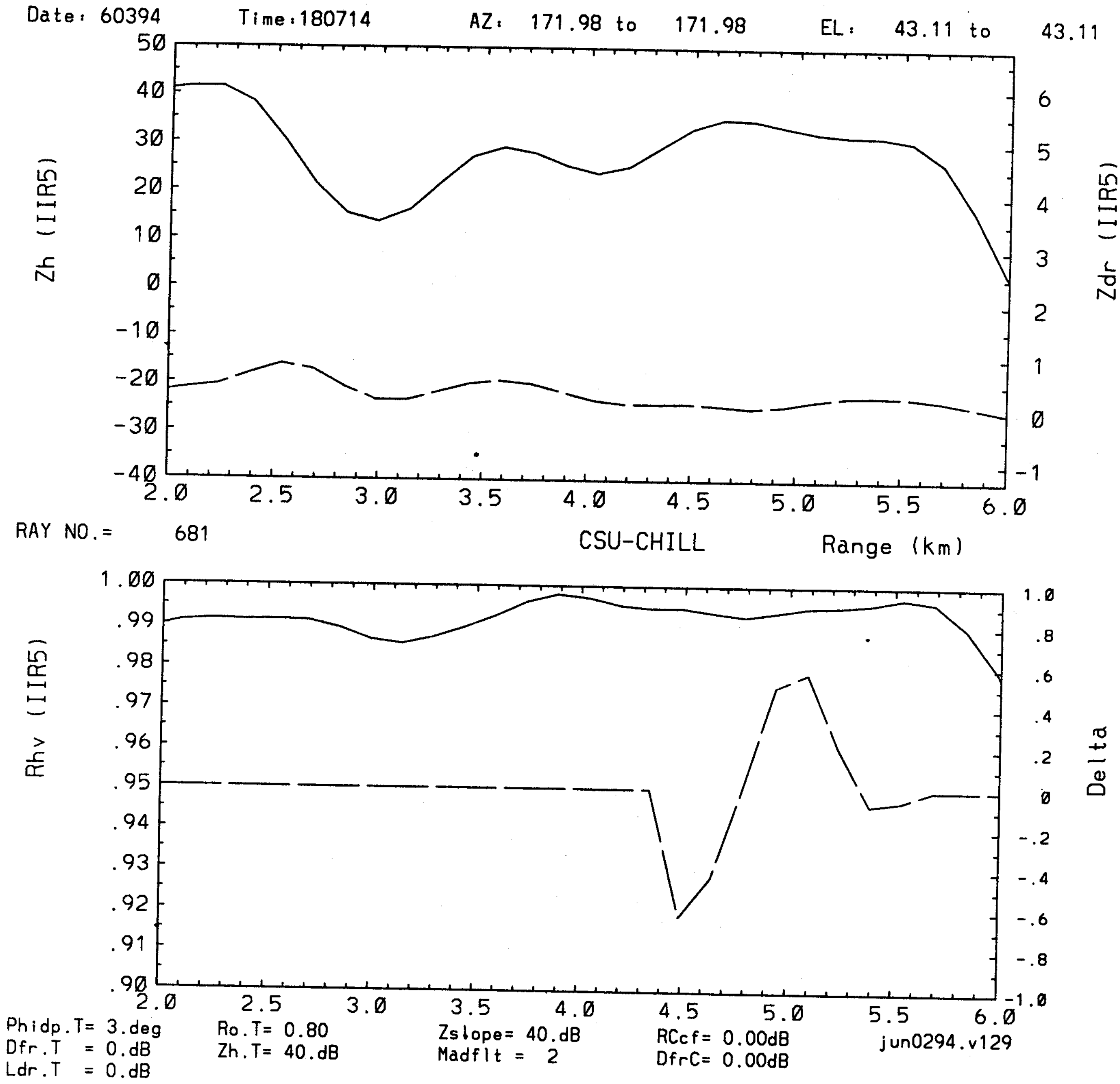
ACTS/CSU CHILL Data (Convective Case)

6/3/94 ACTS Propagation Data (CO)





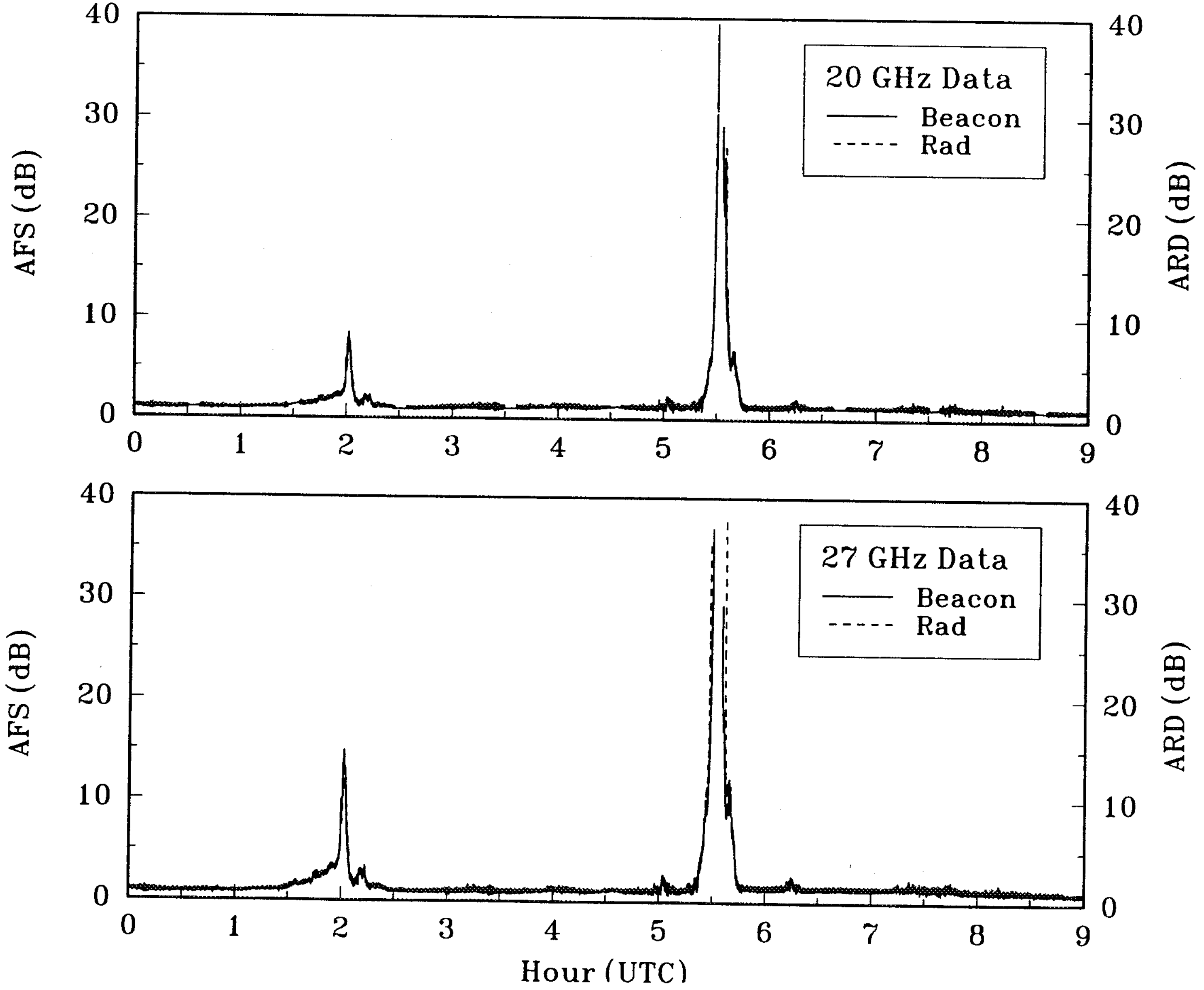
2) 32 03-JUN-94 18:08:25 168.3° RHI CSUC ZDR
-10.0
5.0
20.0
35.0
50.0
-3.0
-1.5
0.0
1.5
3.0
94.5
96.0
97.5
99.0
100.5
-58.0
-52.0
-46.0
-40.0
-34.0
4.0
2.0
0.0
6.0



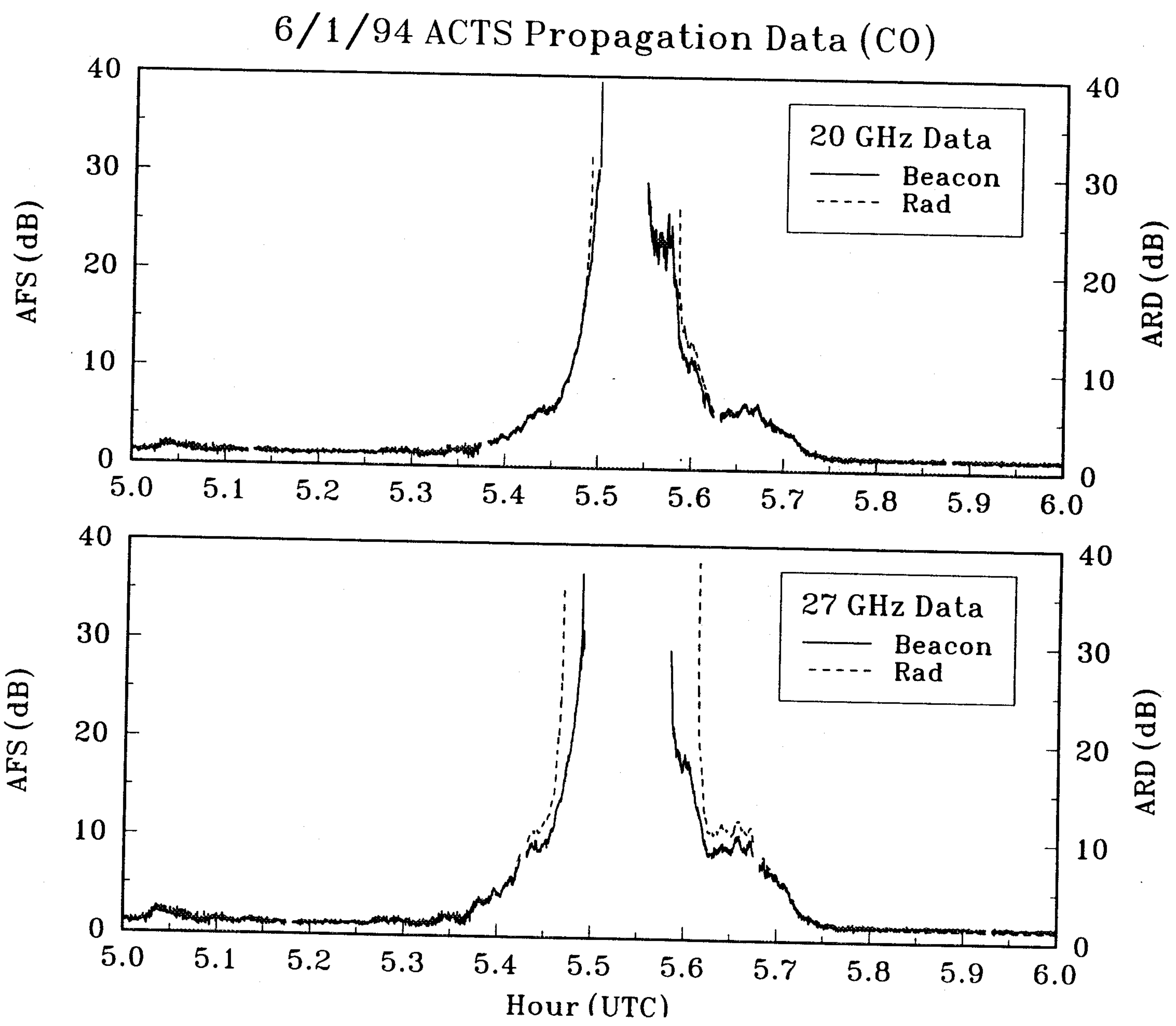
Date: 60394
Time:180714
AZ: 171.98 to 171.98
EL: 43.11 to 43.11
Zh (IIR5)
Zdr (IIR5)
RAY NO.= 681
CSU-CHILL
Range (km)
Rhv (IIR5)
Delta
Phidp.T= 3.deg
Dfr.T = 0.dB
Ldr.T = 0.dB
Ro.T= 0.80
Zh.T= 40.dB
Zslope= 40.dB
Madflt = 2
RCcf= 0.00dB
DfrC= 0.00dB
jun0294.v129

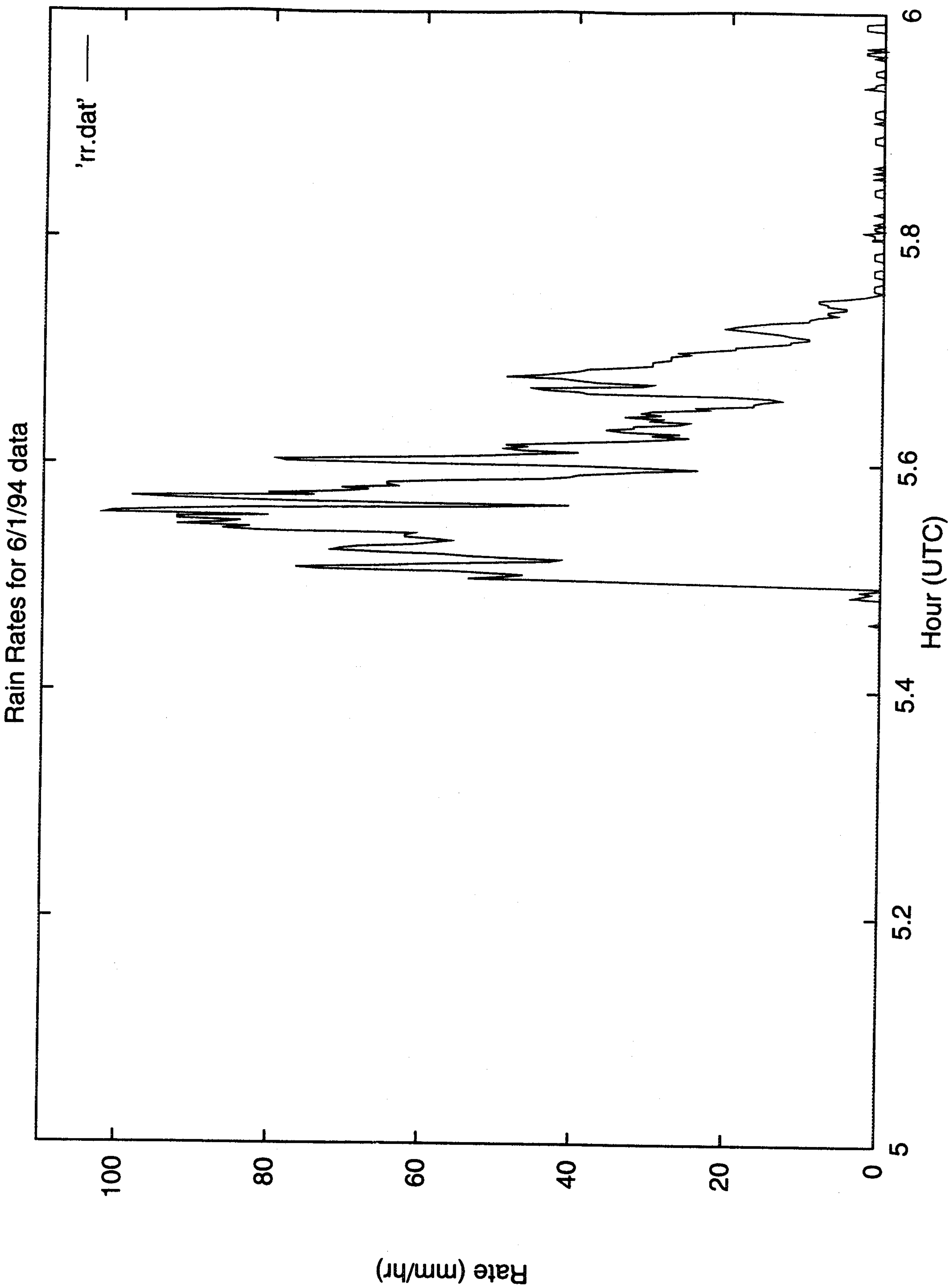
Loss of Both Signals due to Rain Event

6/1/94 ACTS Propagation Data (CO)



Loss of Both Signals due to Rain Event





Rain Rates for 6/1/94 data
'rr.dat'
Rate (mm/hr)
Hour (UTC)
0
20
40
60
80
100
5
5.2
5.4
5.6
5.8
6

0.5

$\boxed{\textbf{Propagation Models}}$

- Mueller Propagation Model (Wayne Adams, NCAR)
  - The variation of the electric field along the propagation path is given by

$$\frac{dE_v}{ds} = (ik + M_{vv})E_v + M_{vh}E_h$$

$$\frac{dE_h}{ds} = M_{hv}E_v + (ik + M_{hh})E_h$$

where

$$M_{ij} = \Sigma_p n_p \frac{2\pi i}{k} f_{ij}(\hat{k})$$

→ f_{ij} are the forward scattering amplitudes
→ n_p is the number concentration

Propagation Models

– The equations for the variation of the electric field along the propagation path can be used to obtain differential equations in terms of the modified Stokes parameters

$$\frac{dI_v}{ds} = 2Re(M_{vv})I_v + Re(M_{vh})U + Im(M_{vh})V$$

$$\frac{dI_h}{ds} = 2Re(M_{hh})I_h + Re(M_{hv})U - Im(M_{hv})V$$

$$\frac{dU}{ds} = 2Re(M_{hv})I_v + 2Re(M_{vh})I_h + [Re(M_{vv}) + Re(M_{hh})]U - [Im(M_{vv}) - Im(M_{hh})]V$$

$$\frac{dV}{ds} = -2Im(M_{hv})I_v + 2Im(M_{vh})I_h + [Im(M_{vv}) - Im(M_{hh})]U + [Re(M_{vv}) + Re(M_{hh})]V$$

where

$$I_v = \frac{|E_v|^2}{\eta}$$

$$I_h = \frac{|E_h|^2}{\eta}$$

$$U = \frac{2Re(E_v E_h^*)}{\eta}$$

$$V = \frac{2Im(E_v E_h^*)}{\eta}$$

Propagation Models

– Solutions of the four differential equations yield four eigenvalues and eigenvectors

$$\beta(\hat{s}) = \begin{bmatrix} \beta_1(\theta,\phi) \\ \beta_2(\theta,\phi) \\ \beta_3(\theta,\phi) \\ \beta_4(\theta,\phi) \end{bmatrix} = \begin{bmatrix} 2ImK_1 \\ iK_2^* - iK_1 \\ iK_1^* - iK_2 \\ 2ImK_2 \end{bmatrix}$$

where

$$K_1 = k - \tfrac{i}{2}\left[M_{vv} + M_{hh} + r\right]$$
$$K_2 = k - \tfrac{i}{2}\left[M_{vv} + M_{hh} - r\right]$$

and

$$r = \left[(M_{vv} - M_{hh})^2 + 4M_{hv}M_{vh}\right]^{\frac{1}{2}}$$

Propagation Models

The eigenmatrix is given by

$$\mathbf{H} = \begin{bmatrix} 1 & |b_2|^2 & b_2 & b_2^* \\ |b_1|^2 & 1 & b_1^* & b_1 \\ 2Re(b_1) & 2Re(b_2) & 1 + b_1^* b_2 & 1 + b_1 b_2^* \\ -2Im(b_1) & 2Im(b_2) & i(1 - b_1^* b_2) & -i(1 - b_1 b_2^*) \end{bmatrix}$$

where

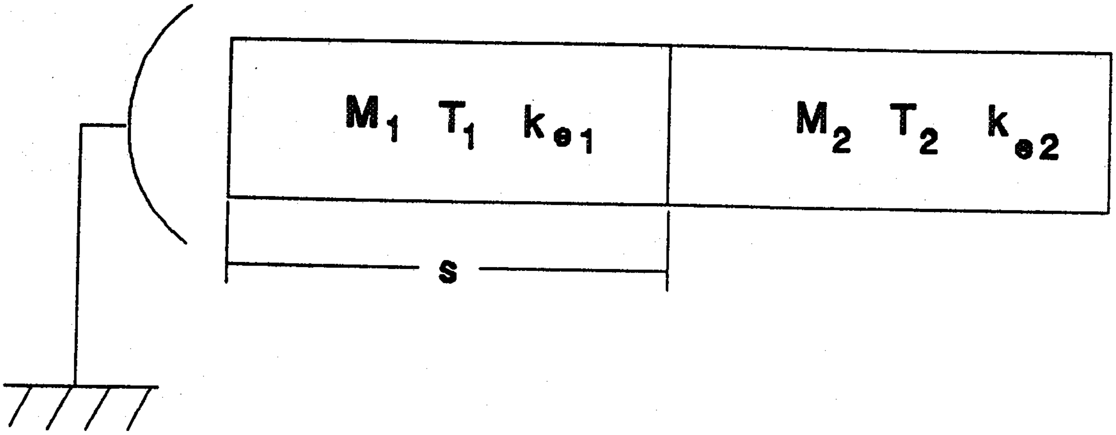
$$b_1 = \frac{2M_{hv}}{M_{vv} - M_{hh} + r}$$

$$b_2 = \frac{2M_{vh}}{-M_{vv} + M_{hh} + r}$$

The extinction matrix is defined as

$$\kappa_{\mathbf{e}} = \begin{bmatrix} -2Re(M_{vv}) & 0 & -Re(M_{vh}) & -Im(M_{vh}) \\ 0 & -2Re(M_{hh}) & -Re(M_{hv}) & Im(M_{hv}) \\ -2Re(M_{hv}) & -2Re(M_{vh}) & -(ReM_{vv} + ReM_{hh}) & (ImM_{vv} - ImM_{hh}) \\ 2Im(M_{hv}) & -2Im(M_{vh}) & -(ImM_{vv} - ImM_{hh}) & -(ReM_{vv} + ReM_{hh}) \end{bmatrix}$$

Propagation Models



The transmission matrix $\mathbf{T_1}$ is given by

$$\mathbf{T_1} = \mathbf{H}\mathbf{P}\mathbf{H}^{-1}$$

where

$$\mathbf{P} = \begin{bmatrix} e^{-\beta_1 s} & 0 & 0 & 0 \\ 0 & e^{-\beta_2 s} & 0 & 0 \\ 0 & 0 & e^{-\beta_3 s} & 0 \\ 0 & 0 & 0 & e^{-\beta_4 s} \end{bmatrix}$$

Propagation Models

- The Mueller matrix in resolution volume 2 is then modified to take into account the propagation effects of resolution volume 1.

$$\mathbf{M}_2' = \mathbf{T}_1^{\dagger}\mathbf{M}_2\mathbf{T}_1$$

- Radar parameters that are normally computed using the Mueller matrix, can now be computed with the new Mueller matrix ($\mathbf{M}_2'$).

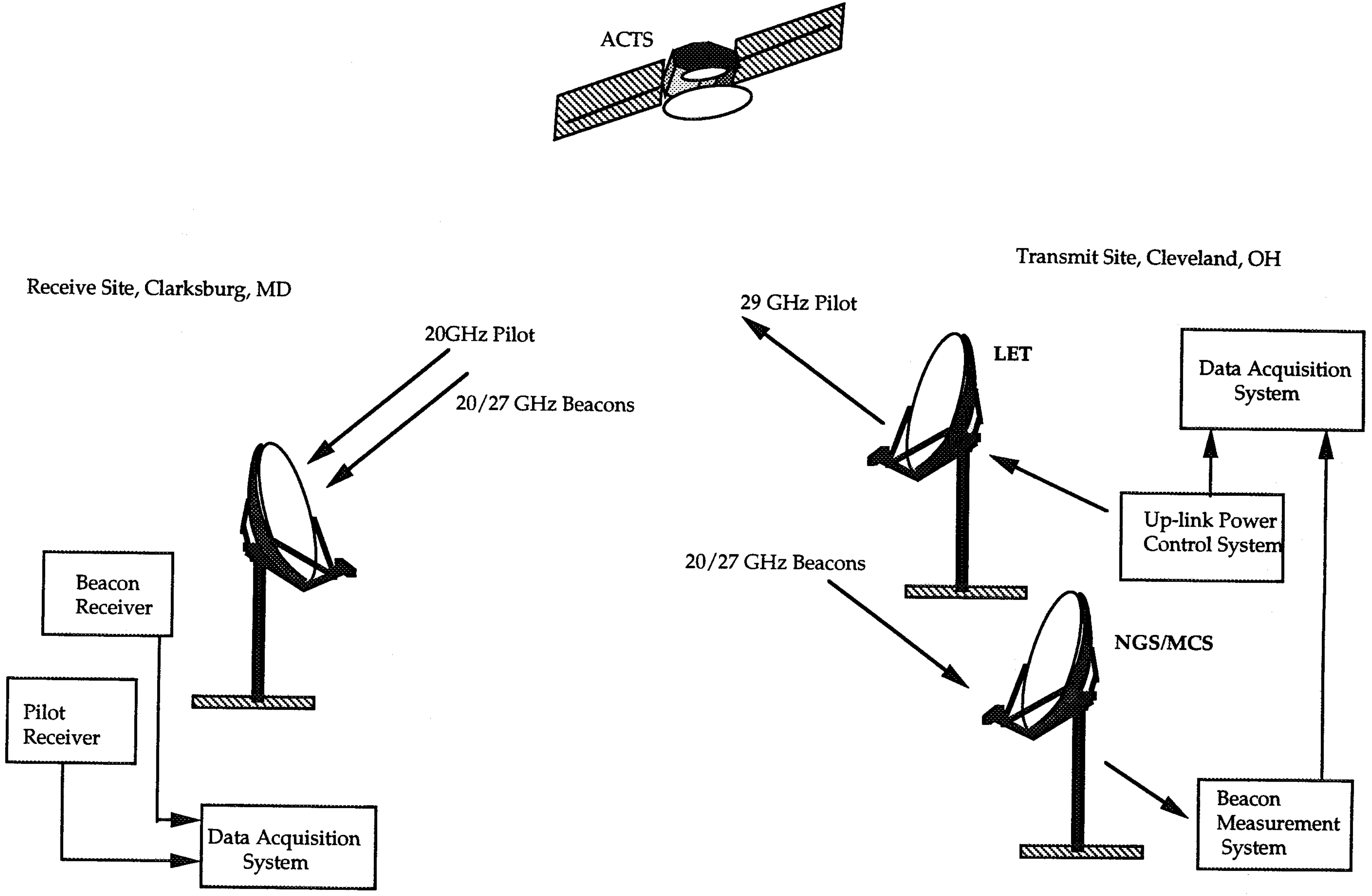
ACTS Up-link Power Control Experiment

A. Dissanayake

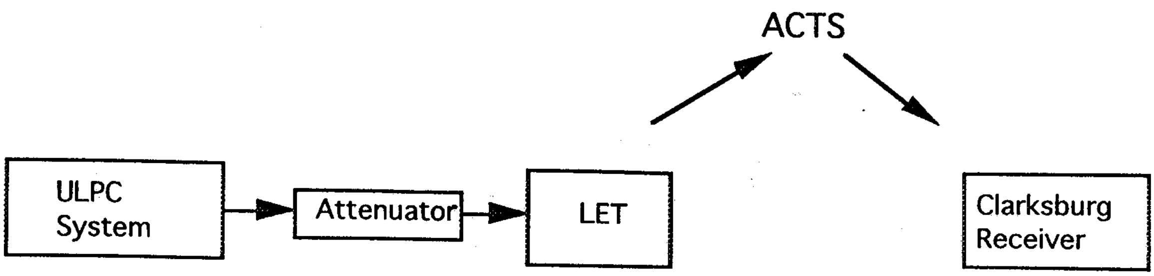
June 16, 1994

Ka-band Up-link Power Control

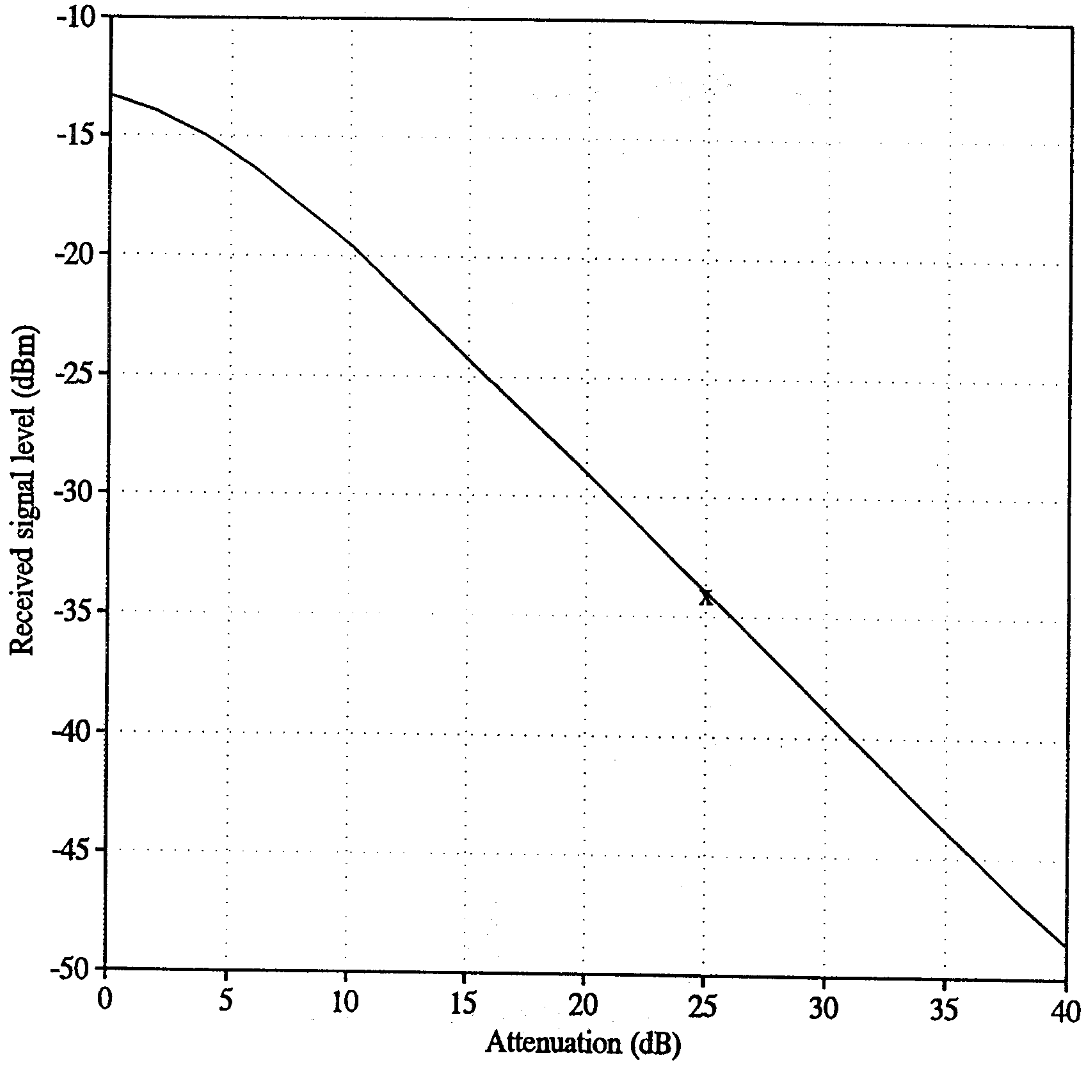
* Power control carried out using a 27 GHz pilot carrier transmitted from the LET at Lewis Center in Cleveland; transponded carrier received at Clarksburg.
* Power control based on down-link attenuation measurements at 20 GHz
* Beacon reception and pilot transmission are done on separate antennas; antenna separation ~ 15 ft.
* Control applied at IF; power control resolution: 0.2 dB; update rate 5 Hz
* Maximum power control range: 25 dB; however, investigation will be limited to a control range of 15 dB.
* Several safety features incorporated into the power controller design to protect space segment



ACTS Up-link Power Control Experiment Configuration



Measurement Configuration



Transponder/LET linearity test; attenuator setting vs. signal strength received at Clarksburg
x - nominal operating point

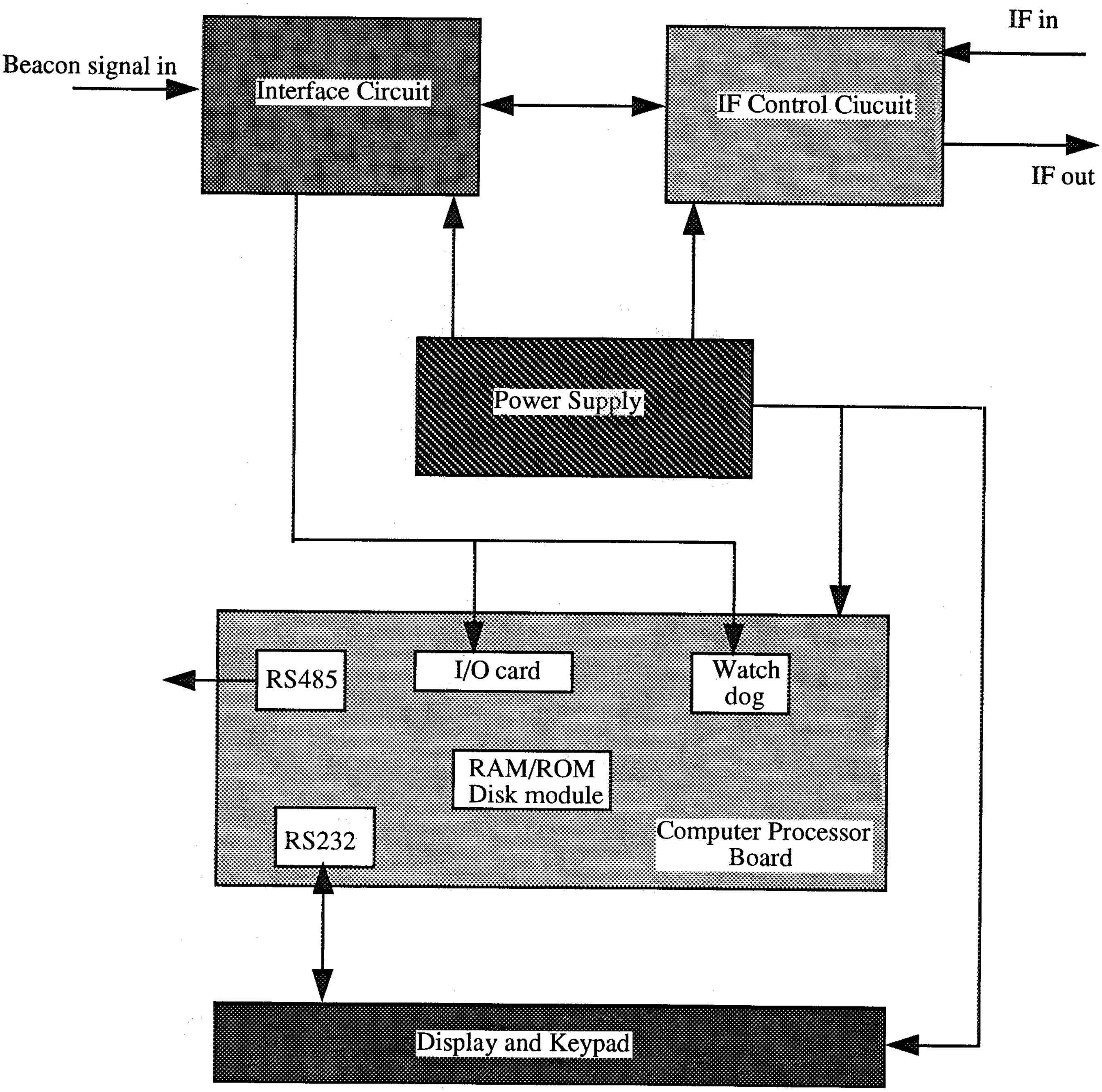
Power Control System

* Power control applied via a linearized PIN attenuator

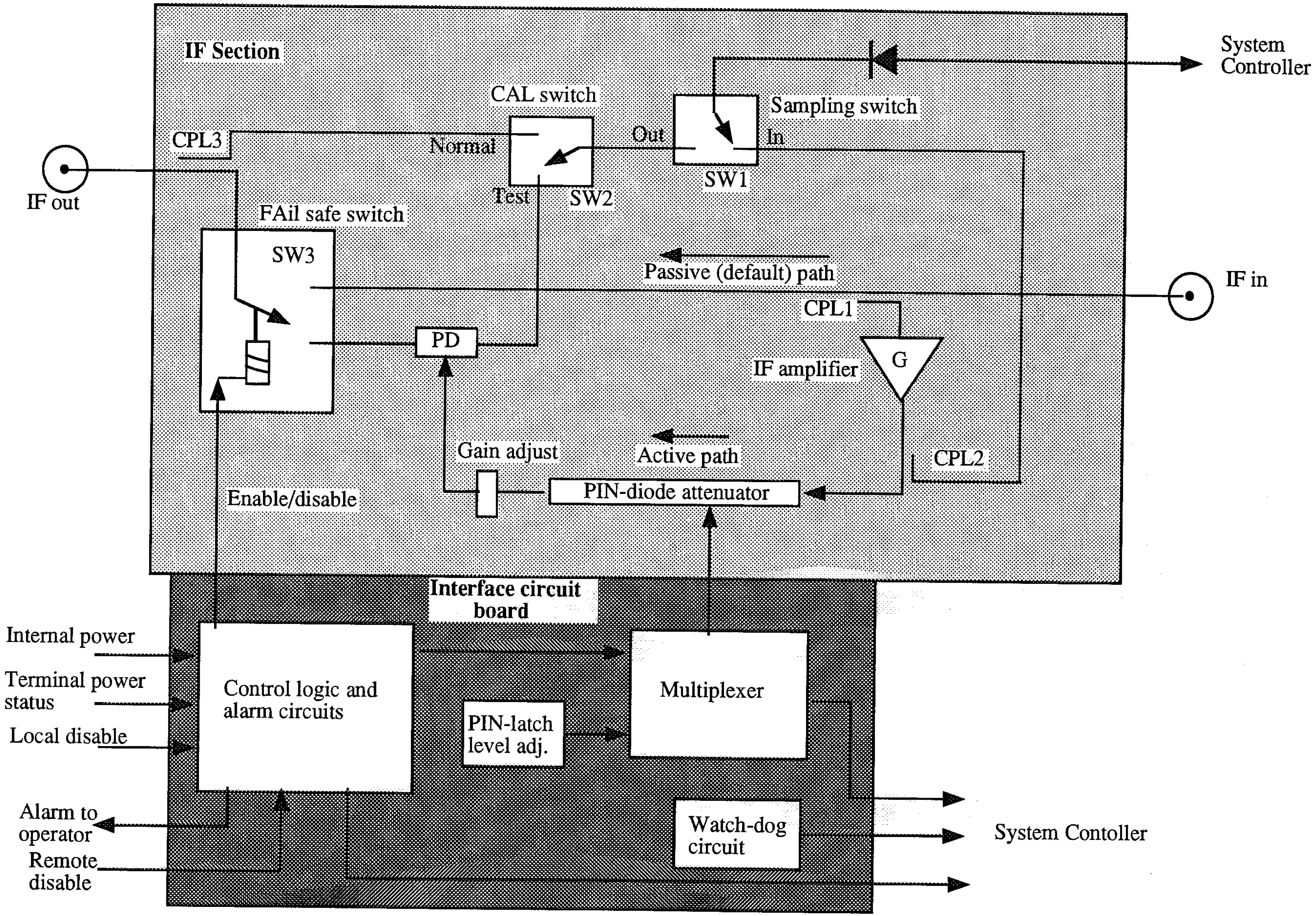
* A default path without power control available in case of a system failure; this path is also activated under exceptional conditions (beacon failure, beacon level jump or unacceptable drift)

* Intel 386 based PC used as the system controller; system controller and control circuitry housed in a standard rack unit.

* Controller parameters programmed through a front panel keypad and display.



Functional Block Diagram of the Up-link Power Controller



Contol and Interface Circuits

Power Control Algorithm

* Detect down-link fade after establishing the reference level; reference level based on long-term observations using an adaptive filter with a time constant of the order of 1 hour

* Down-link fade separated in to rain fade and scintillation components; n averaging time of 20 sec. used in estimating the rain fade.

* Current level of rain fade predicted using an adaptive filter

* Frequency scaling of rain and scintillation fades to 27 GHz

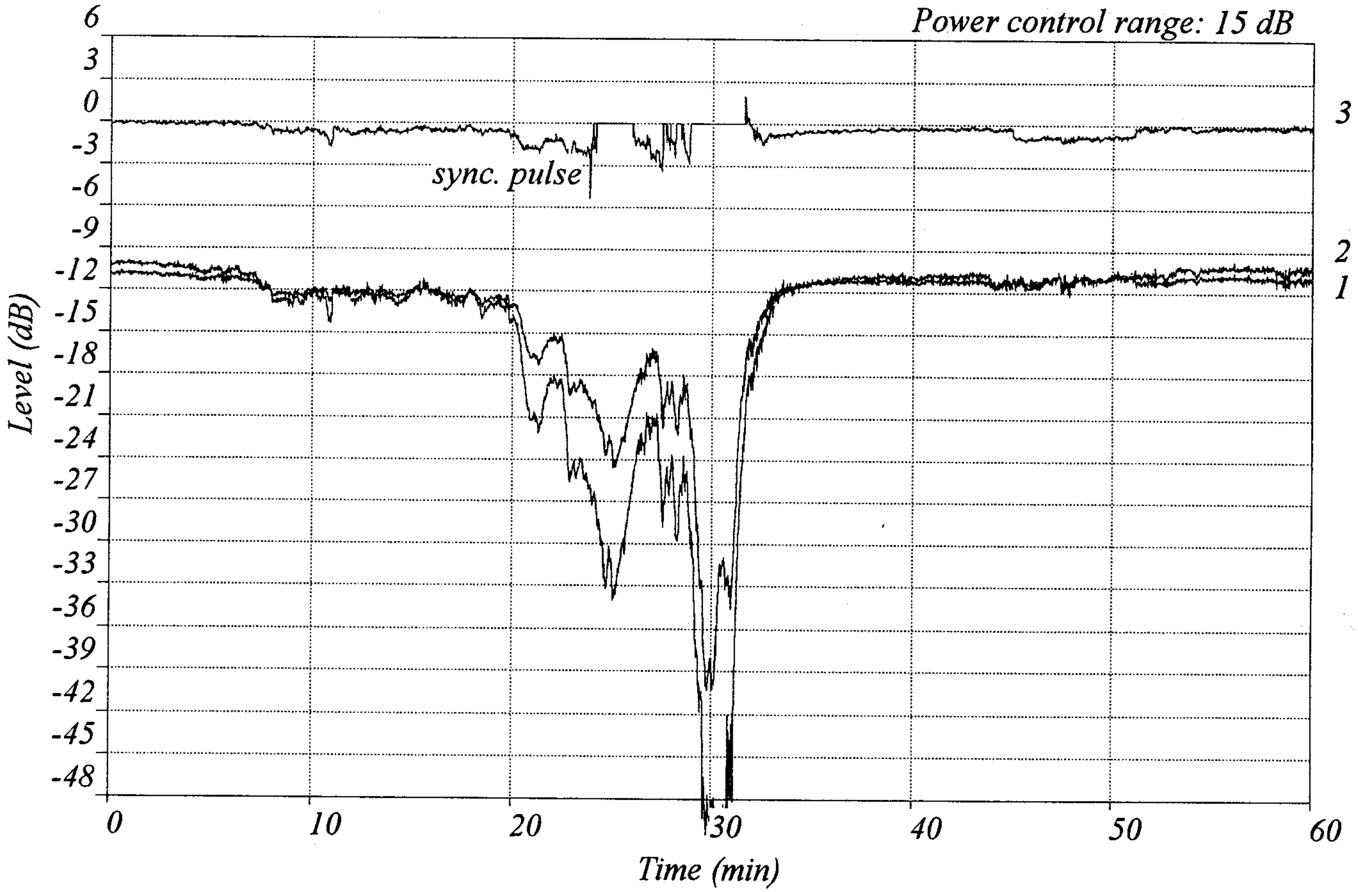
Initial Results

* Separate transmit and receive antennas do not allow meaningful investigation of scintillation compensation.

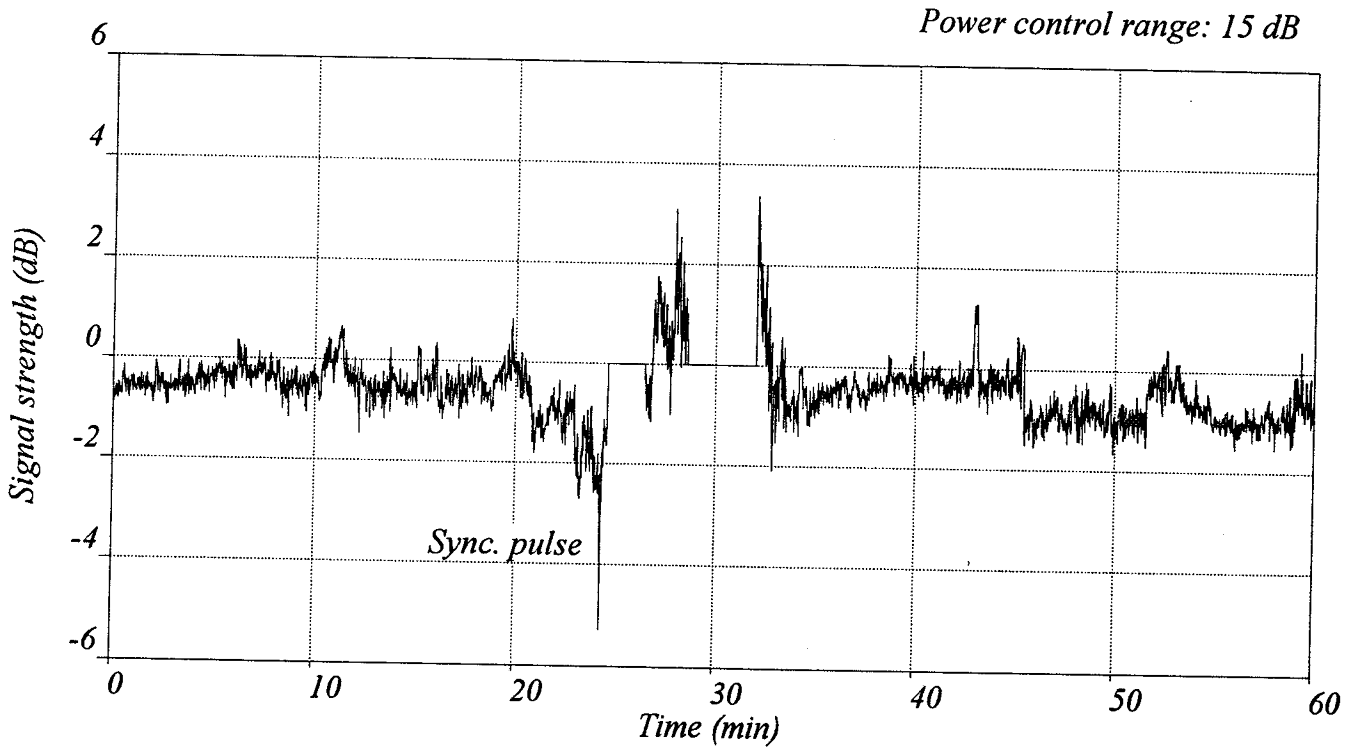
* Approximately 24 hours of pilot transmissions completed; three severe rainstorms encountered during this period.

* Algorithm appears to underestimate the up-link fade.

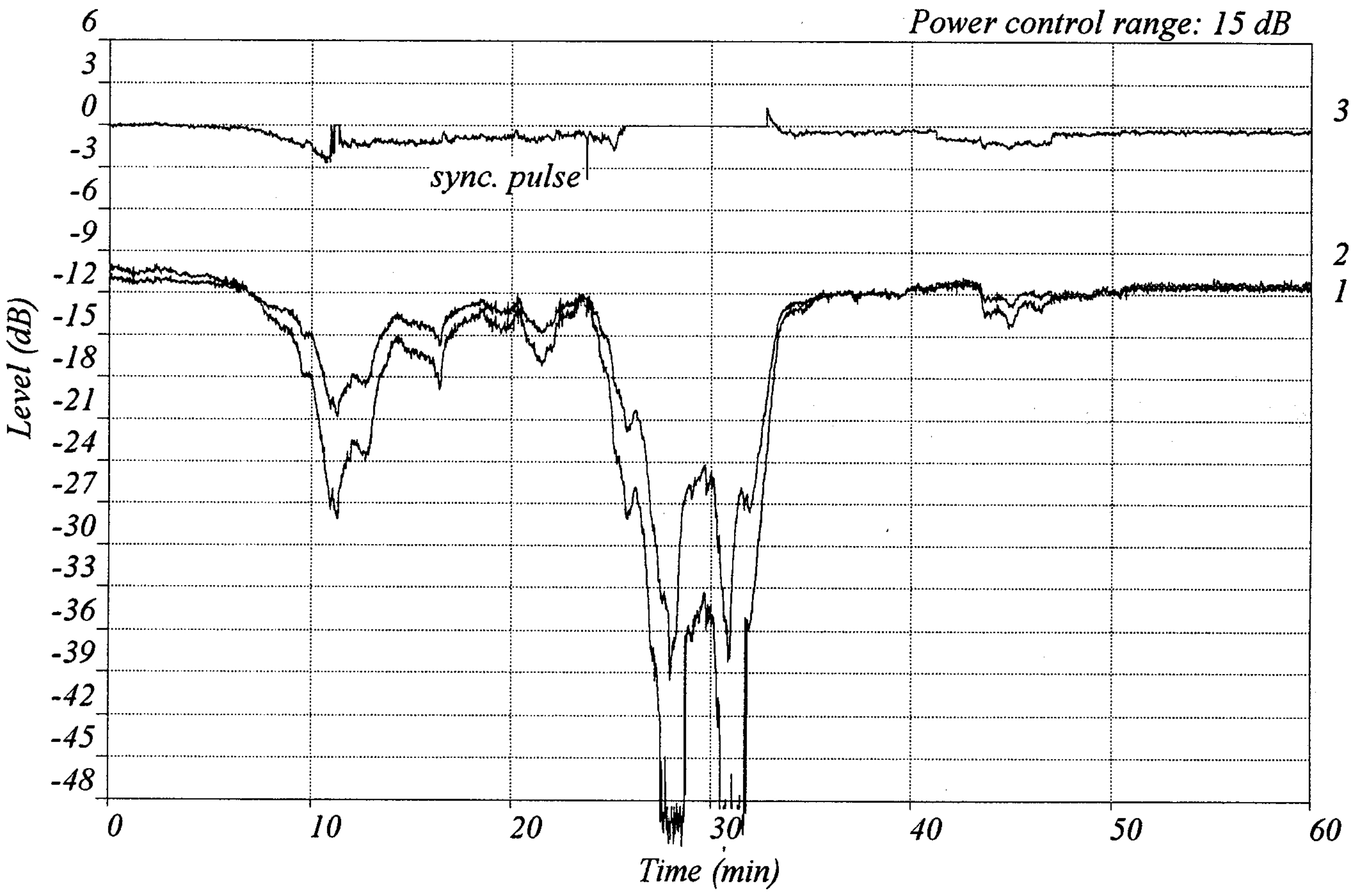
* When restricted to a power control range of 15 dB, the control accuracy can be maintained within ±3 dB.



ACTS up-link power control experimnet
Rain event 1 on 31 May, 1994; 1: 20GHz, 2: 30GHz, 3: control error

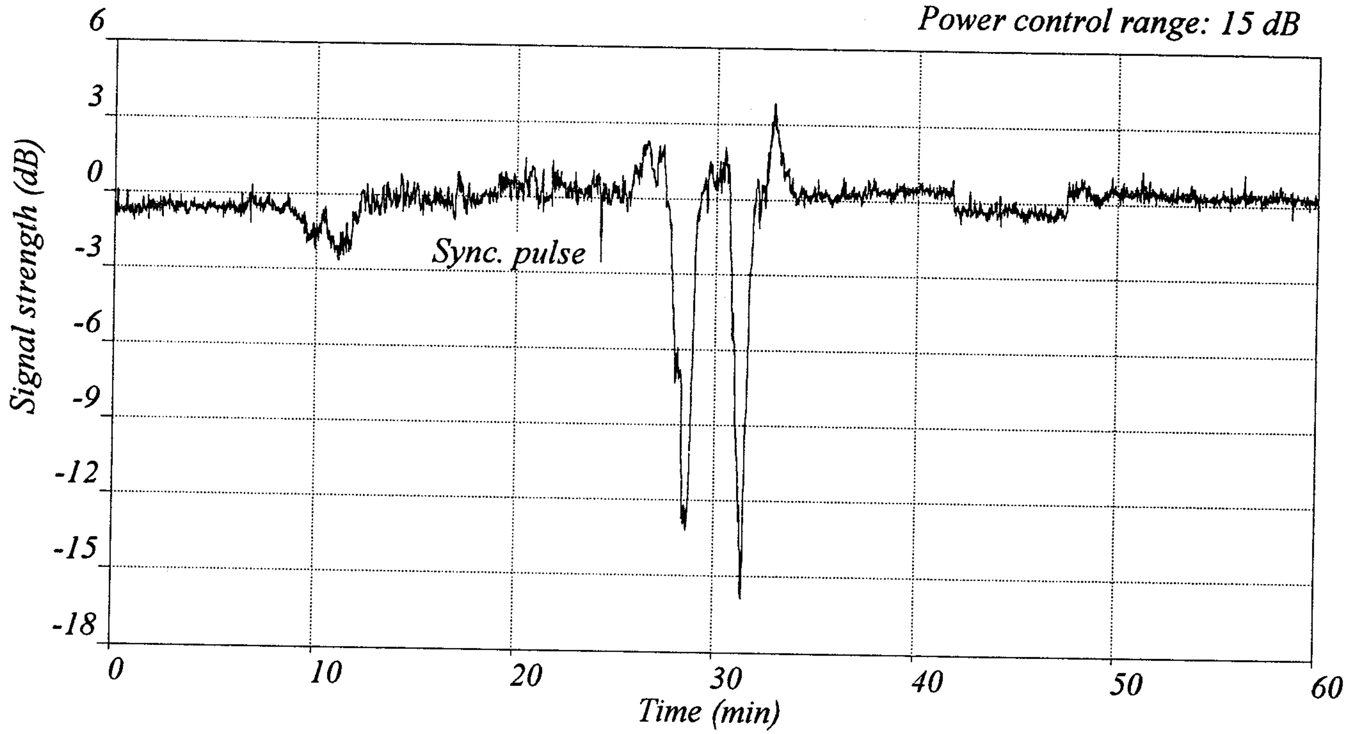


ACTS up-link power control experimnet
Rain event 1 on 31 May, Pilot level at Clarksburg



ACTS up-link power control experimnet

Rain event 2 on 31 May, 1994; 1: 20GHz, 2: 30GHz, 3: control error



ACTS up-link power control experimnet
Rain event 2 on 31 May, Pilot level at Clarksburg