National Radio Astronomy Observatory
Socorro, New Mexico

VLA Test Memorandum No. 185

Interference at 1330 MHz

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The Problem

This report gives the results of an EMC investigation made in response to E. Brinks who had noticed severe levels of interference during a run on 16th January 1994; i.e., day 56076 at LST 0 - 2 hours (IAT 23h 26m - 1h 26m). The array was in D-configuration.

Identification of the Interfering Source

The investigation described in this report was done during a second run by E. Brinks, with an identical set-up to the January run. The observing date and time was 21 March 1994; day 56140 at LST 2 - 8 hours (IAT 21h 12m - 3h 13m). This time the array was in A-configuration. The project was a spectral line experiment using mode 4, Hanning smoothing and a 10 sec integration time. IF AC was at 1.5 MHz and 64 channels, IF BD at 3.25 MHz and 32 channels. The sky frequency of the center of the band was near 1325.1 MHz (redshifted HI at 21525 km/s). Also, 25 MHz front-end filters were in place to try to cut down on interference.

During the observation, the Tektronix 2710 Spectrum Analyzer was connected to the Receive Signal output on the T2 module for antenna 22. The antenna was selected arbitrarily. At this connection, the four intermediate frequencies, IFA, IFB, IFC, and IFD are present between the carriers at 1200 MHz and 1800 MHz.

Figure 1 shows 12dB of interference on both IFA and IFB at 30 KHz resolution bandwidth. In the case of IFA, the interference emission appears at an IF of 1320 MHz. The sky frequency of the interference can be determined from the formula:

Sky Frequency = IF3 - F8 + L6 - 3200

where IF3 is the frequency of the interference in the IF,
F8 is 300 for IFA, 400 for IFB, 550 for IFC, 650 for IFD,
L6 was read from the VL screen and is peculiar to the observation.

The sky frequency of the interference determined from this formula is: Sky frequency = 1320 - 300 + 3510 - 3200 = 1330 MHz.

A high resolution spectral plot of the interference (Figure 2) shows a waveform characteristic of a pulse-modulated radar emission. The pulse appeared very regularly every 12 seconds, 5 times per minute, when timed with a second hand.

The L-Band Syslquick RFI plot (Figure 3) shows an interference emission at 1330 MHz, identified by W. Brundage as an Albuquerque radar. Data for the L-Band RFI plot are taken periodically on a routine basis. The emission at 1330 MHz is also apparent in a plot (Figure 4) from the RFI monitor taken during the observation. For this test, the RFI monitor was configured with a discone antenna, two amplifiers with a system gain of about 44 dB, a band pass filter, and a Tektronix 8559 Spectrum Analyzer. The large non-repeating peaks in the plot are thought to be local interference; the same effect was repeated when an observatory vehicle passed by the monitor location.

P. Lilie monitored Peak Detector and Automatic Level Control (ALC) Integrator outputs from the F4 module during the observation using the VLA Monitor System. The F4 module monitors the output of the detectors at the antenna front end. A linear plot of the Peak Detector voltage (Figure 5) shows a peak every minute. The sample time for the monitor data is 5 seconds and the radar pulse occurs every 12 seconds but is presumed to be less than 2 seconds wide, so that the radar pulse and the monitor sample coincide only once per minute. The voltage level for the Peak Detector is 0.1 v with the normal operating power input of -22dBm, so that the radar appears to be introducing peaks 60 times the normal system temperature. Figure 5 also shows that the Peak Detector is apparently not recovering to the 0.1 v level between radar pulses; an earlier plot of the same voltage level taken during an X Band observation showed no excursions above the threshold.

Peaks in the ALC plot (Figure 6) coincide with the pulses in the Peak Detector plot. The pulses appear to be caused by the Fast Limiter which is coupled to the ALC output through a variable resistor; the Fast Limiter threshold is set at 0.2 volts, a level exceeded during the radar pulses by 30 times according to the Peak Detector plots. Otherwise, the ALC level appears to be normal.

Effect of RFI on Astronomical Data

The data were filled by E. Brinks using quasi real time filling and inspected with the AIPS task TVFLG. At the very beginning of the run, all data for all antennae were flagged bad by the ModComp on-line computer (ModComp flags). This lasted for about 20 minutes. After that, the data look remarkably good, given the severe RFI present. Figure 7 shows the data for IF B in the way TVFLG puts up the data on a monitor. The x-axis gives baselines of ANT i with ANT j (j>i). The black wide bands correspond to antennae missing for part or all of the observation (e.g. ANT 6 which was out until IAT 23h and ANT 17 which was in the AAB). The y-axis corresponds to time, increasing upwards. Data on calibrator sources (light gray horizontal bands) and target object are interleaved. The time range of the data shown here is from IAT 22h - 24h, or about 2 hours near the beginning of the run. Black dots and horizontal stripes indicate data flagged bad by the ModComp. As can be seen, most samples are deemed okay with occasional data being flagged for a few antennae and a few times when the entire array drops out. Still 90 to 95%

of the data are estimated to be useful.

The calibrator bands are lighter because they represent a higher flux level than the target source. The presence of the RFI is less evident while observing the calibrator source.

The 16 January run has in the meantime been calibrated and mapped. Basically, a TVFLG shows the same level of drop-outs as in the 21 March run. In both runs interference seems particularly bad in some 15 min time spans with lots of ModComp flags, and much more reasonable at other intervals which can last up to 45 min. The calibration proceeded without any major problems and the map of the target object resulted in a source at the right spot and expected amplitude in the map. Also the noise in the final map was much as expected.

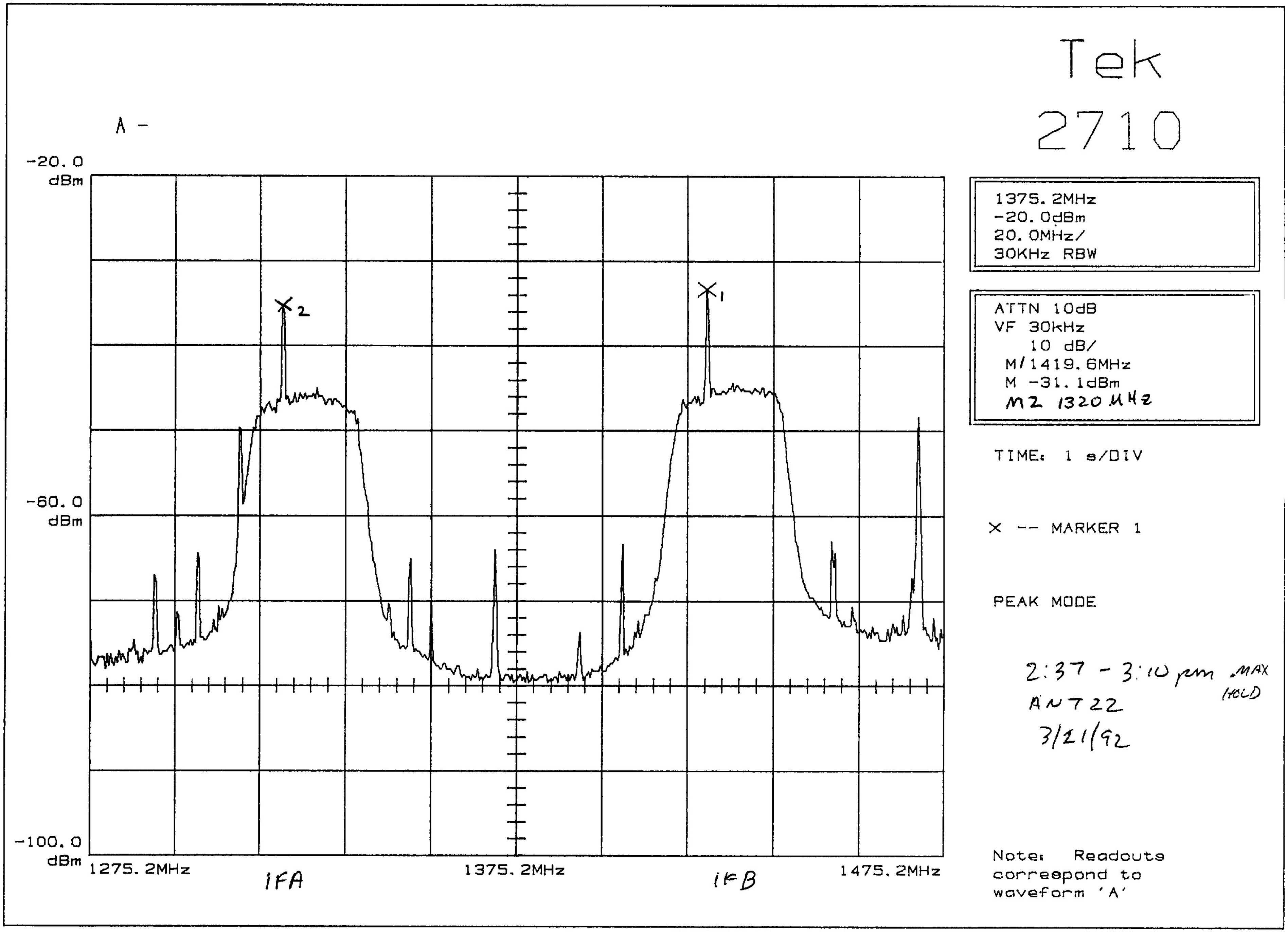
Alternate L6's and Front End Bandpass Filters

The L6 and filter selections available at the VLA lacked the flexibility to avoid interference present at both ends of the observing bandpass. Either part of the band of interest would fall outside the passband, or the passband would have included an interfering signal. For example, in this experiment an L6 of 3510 MHz was the closest available to the desired center frequency of 1325 MHz, and the 25 MHz filter the smallest bandpass available. The L6 may be tuned to (n * 50 MHz) + or - 10 MHz, so that the L6 could have been tuned to 3490 MHz instead of 3510 MHz. The bandpass filter would then have been 50 MHz to include the desired observing bandpass, and would then have included a different radar signal present at 1310 MHz.

Conclusion:

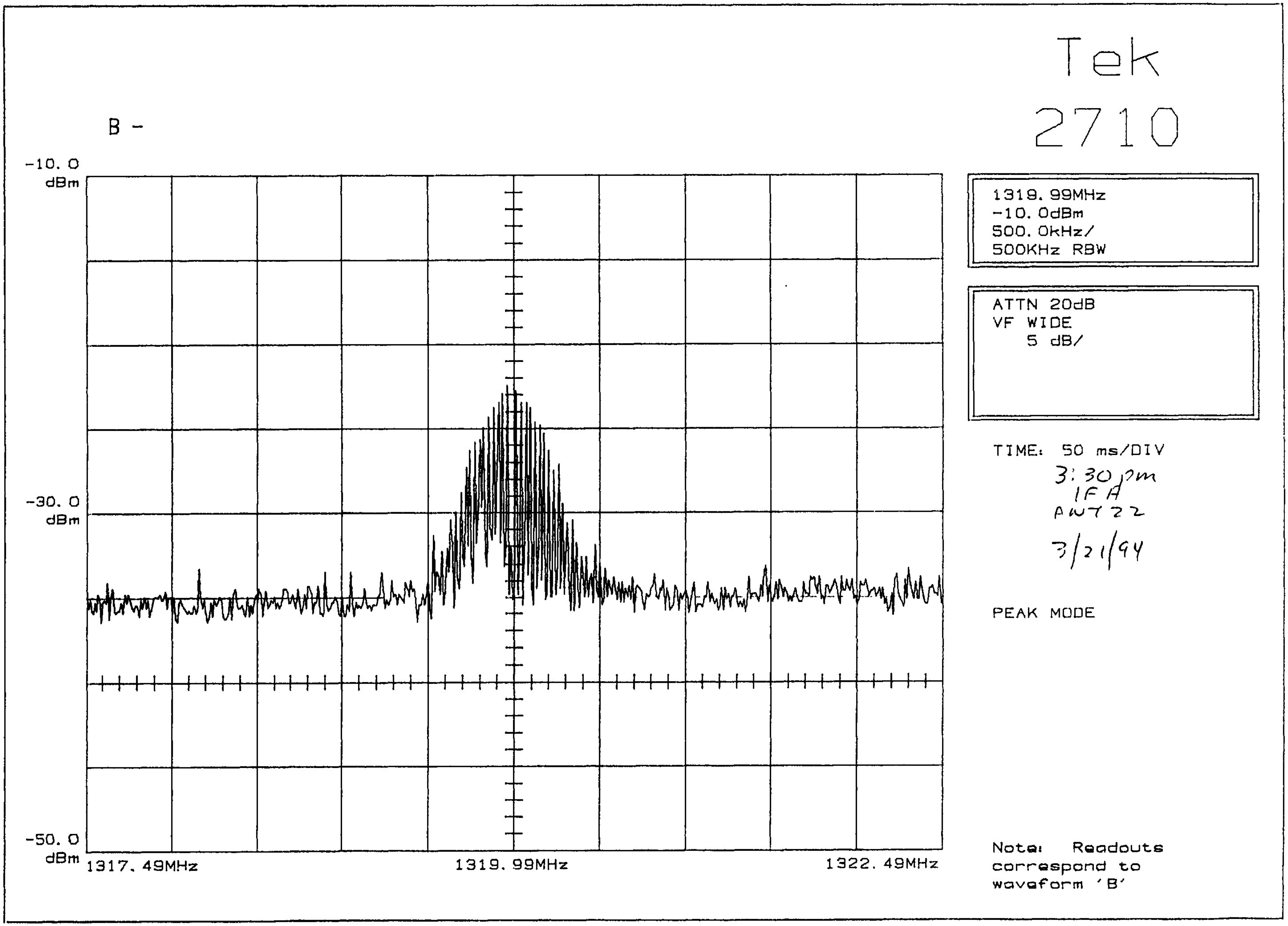
It appears that a radar transmission near Albuquerque is the source of the L-band interference at 1330 MHz. Though the observations might not have been compromised, the efficiency was reduced. A more definite statement will have to await the calibration and mapping of the 21 March observations.

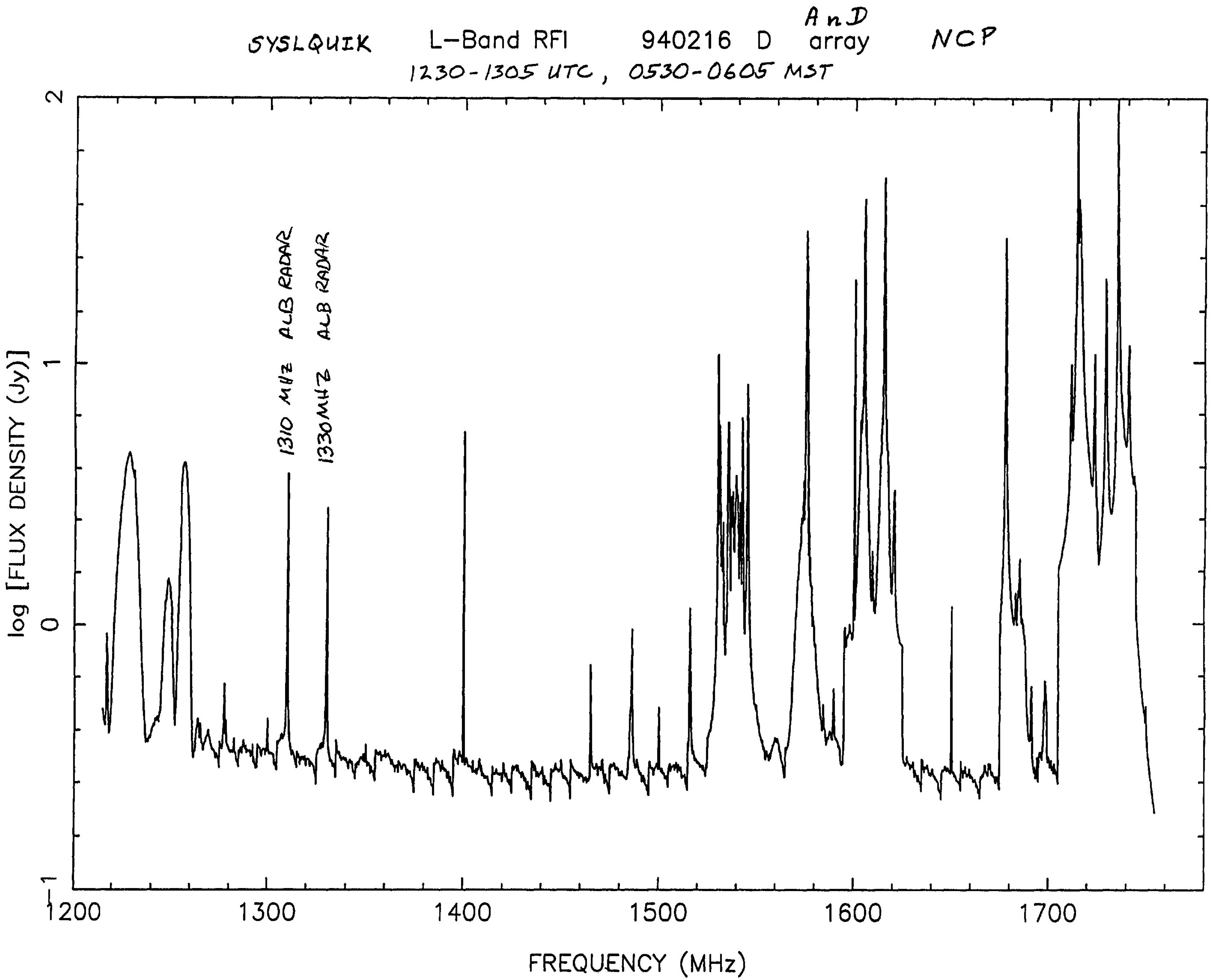
Since the radar is most likely used as a navigation aide, requesting that the emissions be blanked in the VLA sector is not a realistic approach to the problem. As part of the VLA upgrade proposal, recommendations are planned to enhance operation in the presence of RFI. Blanking for short time scales with the current VLA correlator design is not practical, but frequency excision may be a possibility. Also, a more flexible LO chain and a suite of narrow band FE filters might help squeeze the desired bandpass between known interfering sources.



Tek
2710
A -
-20.0
dBm
-60.0
dBm
-100.0
dBm
1275.2MHz
1375.2MHz
1475.2MHz
1FA
IFB
1375.2MHz
-20.0dBm
20.0MHz/
30KHz RBW
ATTN 10dB
VF 30kHz
10 dB/
M/1419.6MHz
M -31.1dBm
M2 1320 MHz
TIME: 1 s/DIV
X -- MARKER 1
PEAK MODE
2:37 - 3:10 pm MAX HOLD
ANT22
3/21/92
Note: Readouts correspond to waveform 'A'

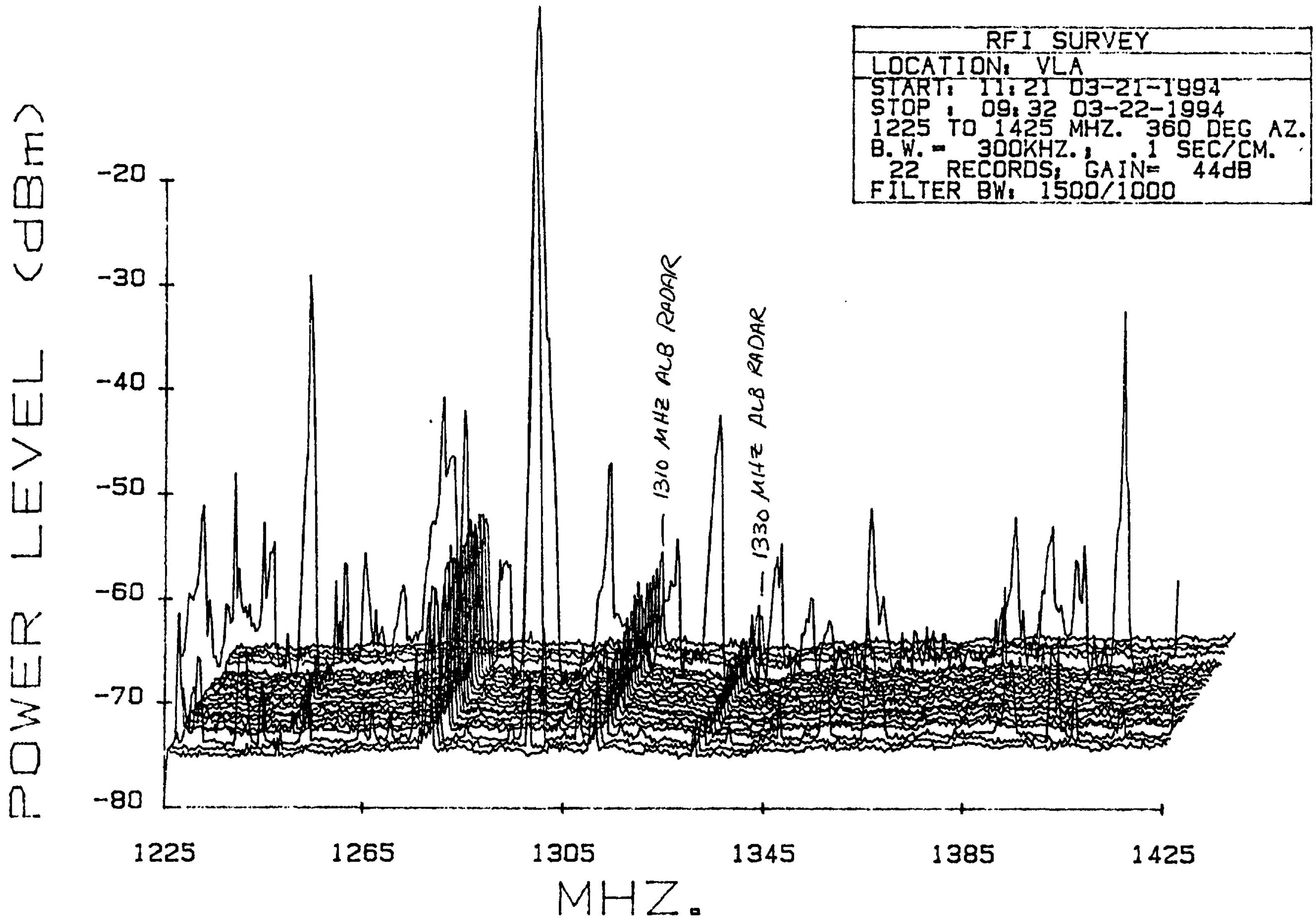
FIG 1

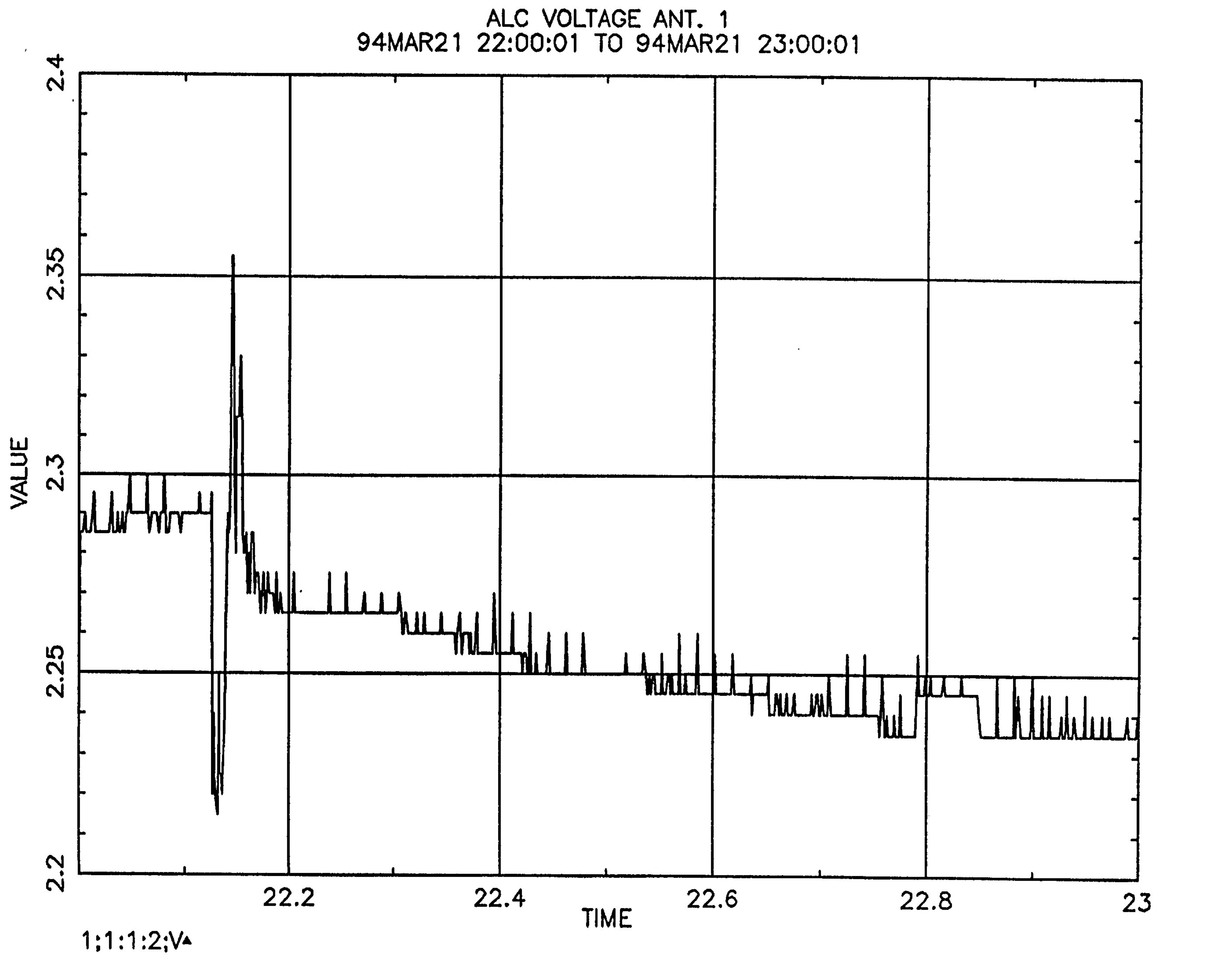

Tek
2710
B -
-10. 0
dBm
-30. 0
dBm
-50. 0
dBm
1317. 49MHz
1319. 99MHz
1322. 49MHz
1319. 99MHz
-10. 0dBm
500. 0kHz/
500KHz RBW
ATTN 20dB
VF WIDE
5 dB/
TIME: 50 ms/DIV
3:30 pm
IF A
AW722
3/21/94
PEAK MODE
Note: Readouts correspond to waveform 'B'



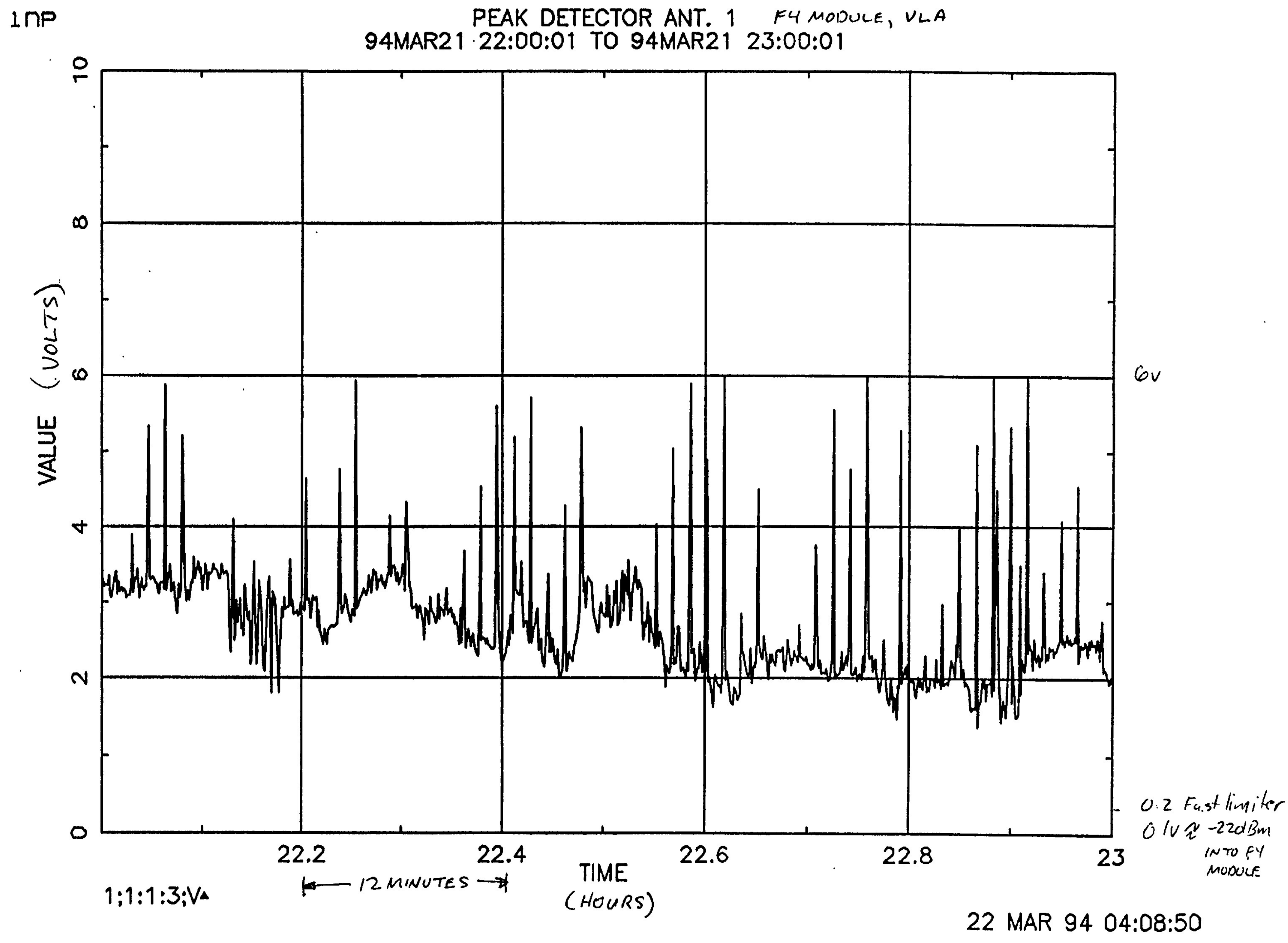
SYSLQUIK L-Band RFI 940216 D AnD array NCP
1230-1305 UTC, 0530-0605 MST
log [FLUX DENSITY (Jy)]
2
1
0
-1
1200
1300
1400
1500
1600
1700
FREQUENCY (MHz)
1310 MHz ALB RADAR
1330 MHz ALB RADAR

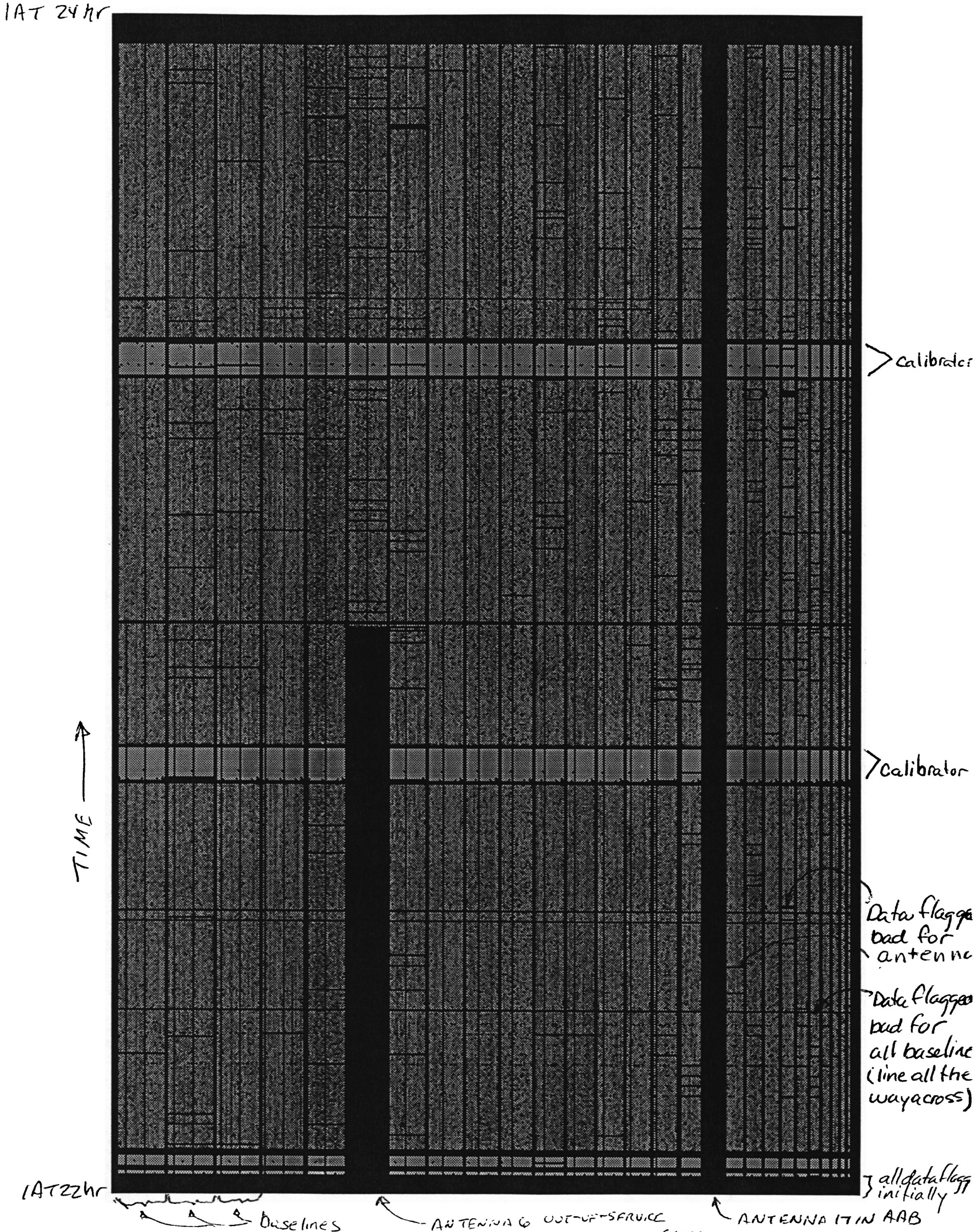
FIG 3


RFI SURVEY
LOCATION: VLA
START: 11:21 03-21-1994
STOP : 09:32 03-22-1994
1225 TO 1425 MHZ. 360 DEG AZ.
B.W.= 300KHZ.; .1 SEC/CM.
22 RECORDS; GAIN= 44dB
FILTER BW: 1500/1000
POWER LEVEL (dBm)
-20
-30
-40
-50
-60
-70
-80
1310 MHZ ALB RADAR
1330 MHZ ALB RADAR
1225
1265
1305
1345
1385
1425
MHZ.



OUTPUT OF ALC INTEGRATOR
NORMALLY 1-5V. FIG 5


1ΠP
PEAK DETECTOR ANT. 1 F4 MODULE, VLA
94MAR21 22:00:01 TO 94MAR21 23:00:01
VALUE (VOLTS)
10
8
6
4
2
0
6v
22.2
22.4
22.6
22.8
23
TIME
(HOURS)
12 MINUTES
0.2 Fast limiter
0.1V ≈ -22dBm
INTO F4
MODULE
1;1:1:3;V▲
22 MAR 94 04:08:50



TVFLG DATA FOR MARCH 17, 1994
SHOWING INCIDENCE OF FLAGGED DATA

FIGURE 7