NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

VLA ELECTRONICS MEMORANDUM NO. 187

SWEPT-FREQUENCY TESTS OF THE WAVEGUIDE COMMUNICATION CHANNELS

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1.0 INTRODUCTION

This report describes a method for measuring the flatness and stability of the VLA's waveguide communication channels from the antennas to the central electronics room. Four 50-MHz wide IF bands (containing the signals received by the antenna), local oscillator phase information and monitor data are sent from each antenna to the central electronics room along a waveguide trunk line (one line for each of the three arms of the array) for approximately 51 msec out of every 52.0833 msec transmission cycle. During the other approximately 1 msec, control data and local oscillator signals are sent out to each dish. A more detailed description of the system can be found in [1].

In order that only one waveguide per arm of the array is required, the signals from the nine antennas on each arm are frequency multiplexed. The carriers used in the eleven possible channels (two are kept as spares) lie in the range 26.41 to 50.41 GHz and only upper sidebands are detected (to avoid group delay problems). Before being modulated onto the carrier the signals described above are arranged to lie in the frequency range 1 to 2 GHz as shown in Figure 1. This signal is the input to the modems at each dish and the output of the modems in the central electronics room. It is the flatness and stability of this transmission system, shown in Figure 2, that was measured.

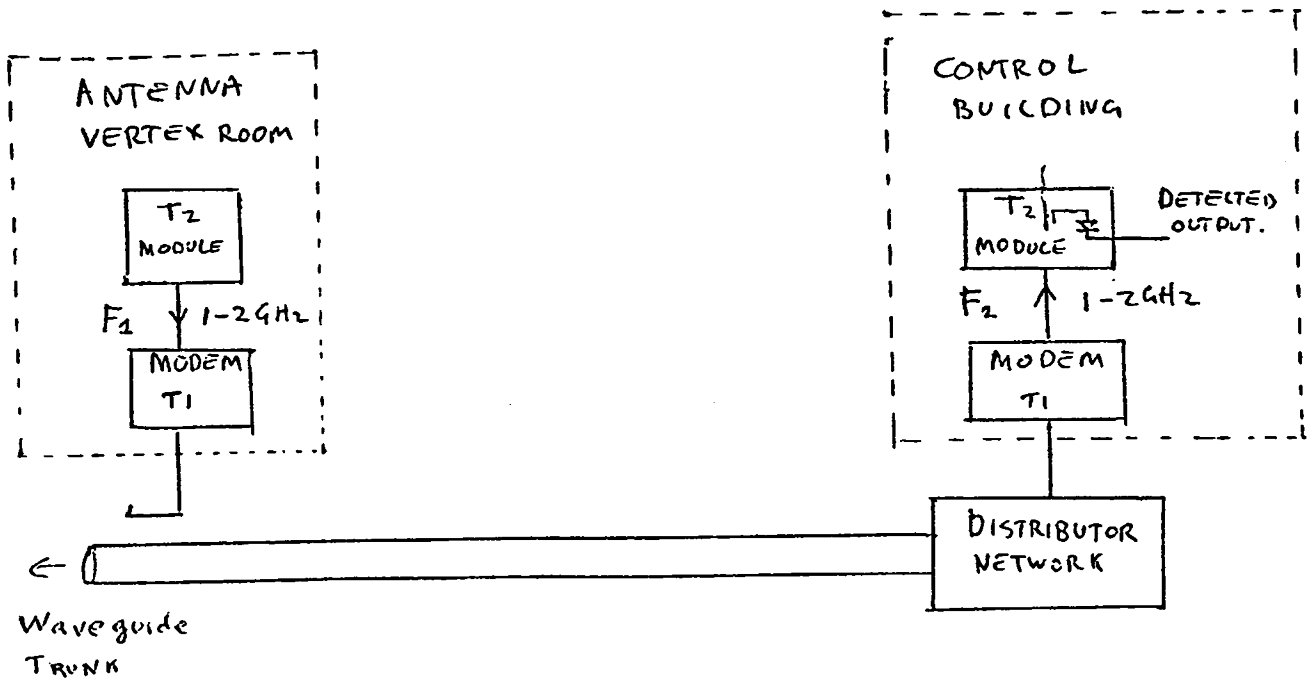

Figure 1

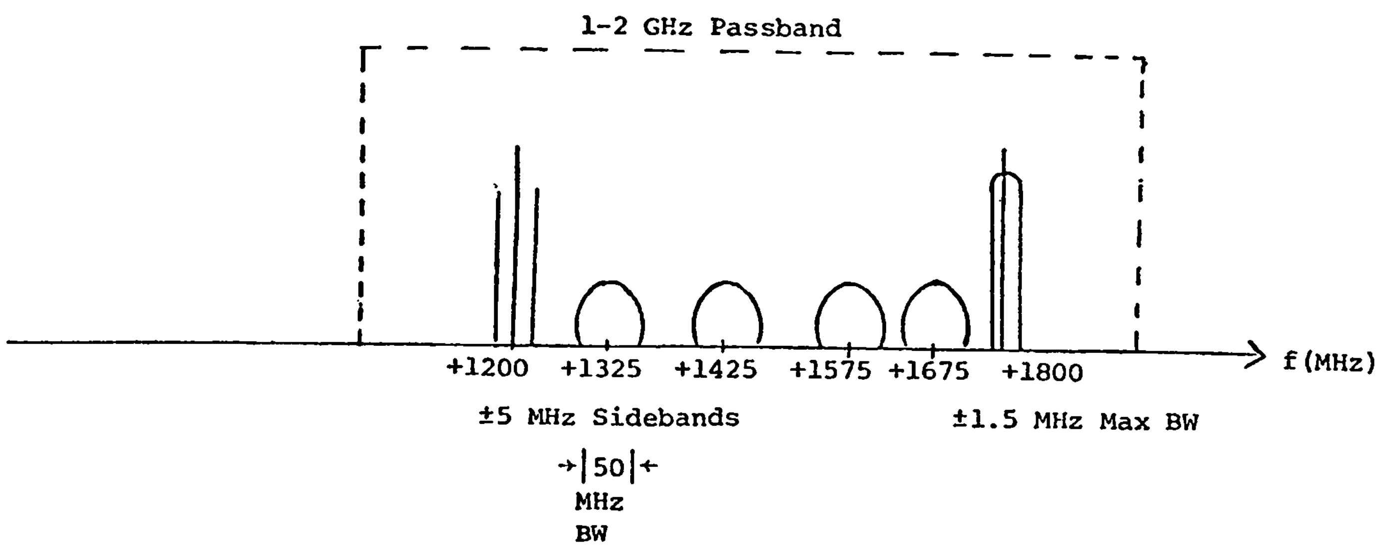

Figure 2

The stability and flatness of this system will become even more important when the spectral line processor becomes operational late in 1979 and the array is used for line observations. If at any frequency which lies in one of the four IF bands shown in Figure 1 the transmission system has a high (or low) amplitude response, a spurious emission (or absorption) line would appear to be present. If the transmission system were extremely stable such effects could be calibrated out by observing a source with a flat frequency spectrum to establish the response of the complete observing system. However, the waveguide trunk and the connections to each antenna vertex room (where the modem is located) are exposed to the extreme weather conditions experienced at the VLA Site, and as such any irregularities in the system response might be expected to vary, especially from day to night during spring and fall.

The waveguide response has also been measured using a sweeper in the range 26-50 GHz and measuring the response from the distribution network to the circular waveguide entering the antenna vertex room. This method has two disadvantages: it does not include the effects caused by mismatches at each modem; and the data cannot be recorded in a computer for manipulation as described later, but is instead recorded on a chart recorder.

The remainder of the VLA electronics is in a controlled environment and is expected to remain relatively stable. Another problem which irregularities in the waveguide system can cause, especially if they result in multiple signal reflections, are phase variations in the local oscillator at an antenna [2,3]. These reflections will also cause an irregularity in the amplitude response and may be detected by examining the response of the system.

2.0 TEST EQUIPMENT AND SETUP

The transmission system from modem-to-modem was swept from 1 to 2 GHz by a sweep generator placed at the antenna. The signal arriving at the central electronics room was detected in the IF combiner (T2) module and the amplitude recorded on magnetic tape by the digital communications system (DCS). The sweep generator is controlled remotely by the DCS through a special unit built by Mr. D. Morton in 1978. This unit replaces the T2 module at the antenna while the test is in progress and on receiving the appropriate commands from the DCS generates a ramp voltage which is connected to the external sweep of the generator. It also provides a front panel connection for the swept signal to be fed to the modem (F1 in Figure 2) as well as performing the receive function of the normal T2 to allow the local oscillator at that antenna and hence the modems local oscillator to remain phase locked.

2.1 The Special T2 Module

A block diagram of the special T2 module is shown in Figure 3. The ramp voltage is generated by a 12-bit digital-to-analog converter whose input is the output of a 12-bit binary counter which is clocked once every waveguide cycle (52 msec or 19.2 Hz).

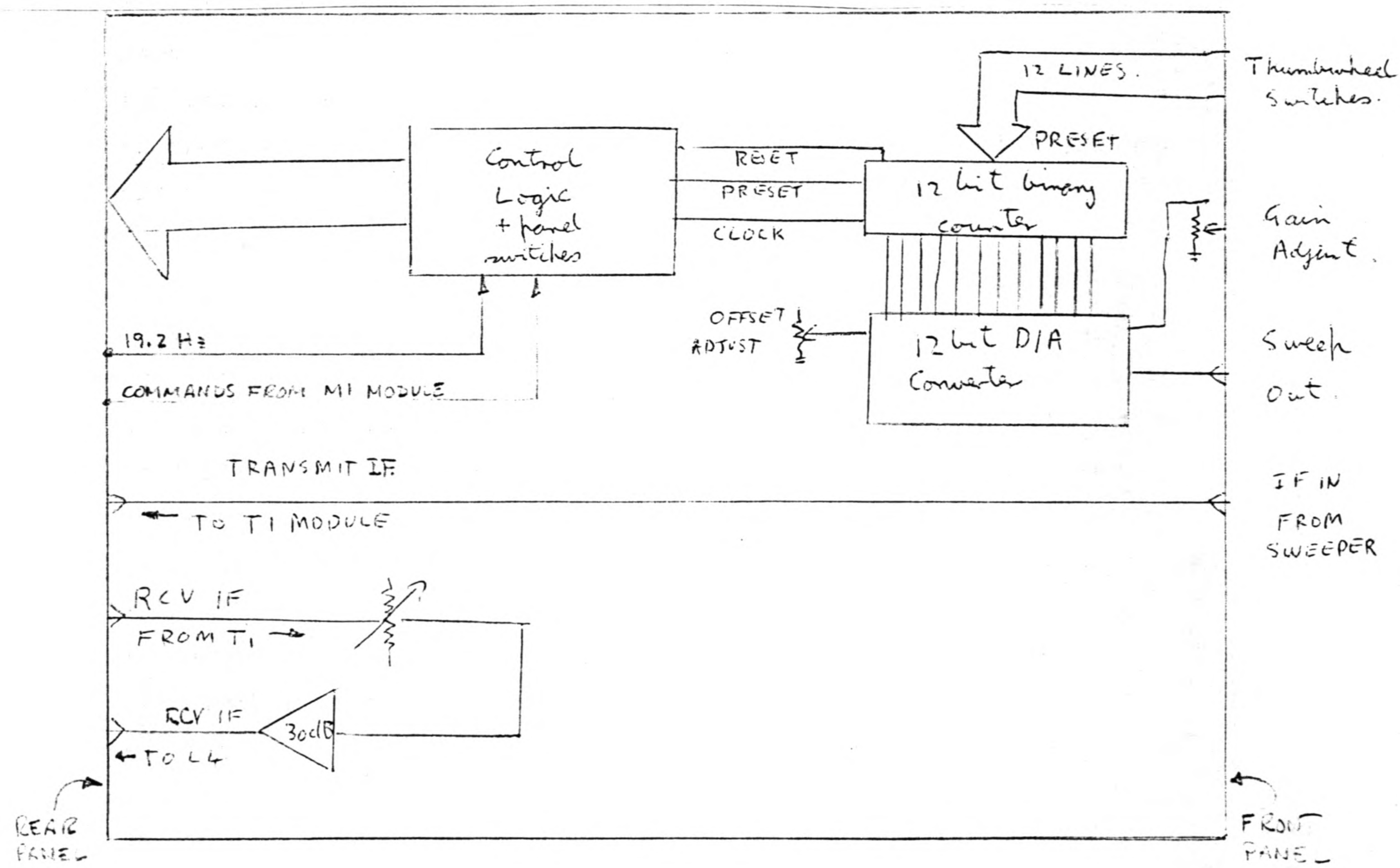

Figure 3: Special T2 module.

The ramp signal may be started and stopped either by a front panel switch or sending a command to that antenna, via the DCS to address 360_8 of data set 2 to start the sweep, or 361_8 to stop the sweep. Another front panel switch enables the ramp voltage to be set to zero (RESET position) or to a value corresponding to an octal number selected on a set of thumbwheel switches on the front panel (PRESET position). The PRESET condition may also be activated by sending a command to address 362_8. There are two other inputs to the digital-to-analog converter: an offset adjust which varies the lowest output voltage (nominally zero) and hence lowest frequency obtainable and a gain adjust available at the front panel (called RANGE) which varies the highest output voltage and hence highest frequency obtainable.

This unit also provides the receive function of the T2 module by providing an adjustable amount of gain for the received IF signals coming out of the T1 module (the modem), including the local oscillator signals and commands from the DCS. The gain adjustment is available at the front panel and must be set (as described later) at each antenna. Finally, a female BNC connector is provided at the front panel to connect the output of the sweep generator to the input of the modem.

2.2 Calibration of the Measuring System

As these waveguide sweep tests attempt to measure only the response of the waveguide system and the modems, the effects of variations in the responses of the sweep generator and detecting circuitry must be removed. The same T2 module was used in the central electronics room for every antenna and it was modified to minimize any possible reflections and hence variations in amplitude response. This was achieved by removing the four-way power divider and replacing it by a 6-dB attenuator and feeding this signal directly into the diode detector whose output was monitored by the DCS.

The response of the sweeper and the modified T2 was measured in the following way, using two D racks in the central electronics room as illustrated in Figure 4. The T1 and T2 modules in a D rack were removed and the modified T2 was placed in the appropriate section of the D rack. The output of the sweep generator was connected to the rack connector which would normally be T1's IF output (OMQ connector P15). The modified T2 was then placed in full receive mode by shorting pins S and T on the T1 modules amp connector in the D rack. The signal to control the sweeper was generated by inserting the special T2 module in the T2 position of another D rack (see Figure 4). The test was then run as if sweeping a waveguide channel, using slightly different DCS commands (explained in Appendix 1), giving a file on magnetic tape corresponding to the amplitude response of the test equipment. This could later be computationally removed from the data measured for each antenna.

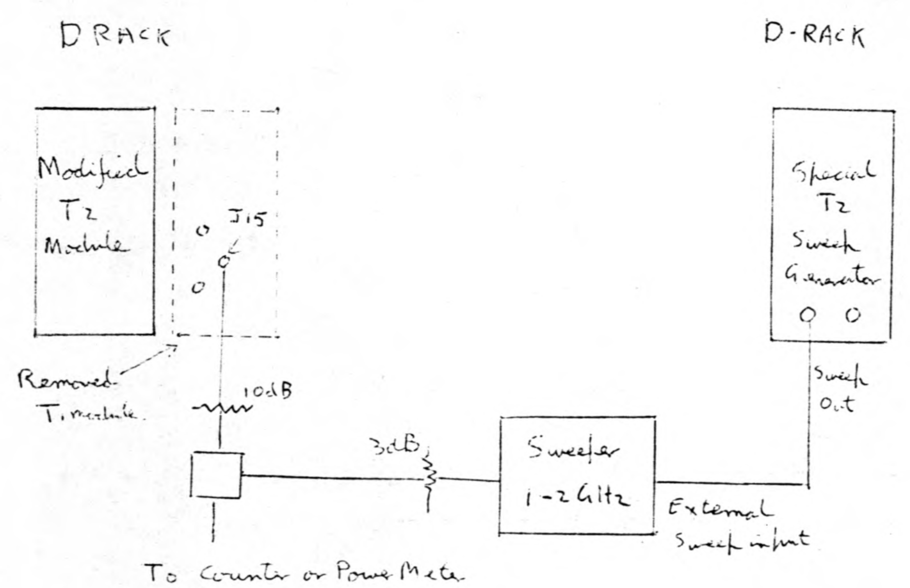

Figure 4: Calibration test setup.

2.3 Setting Up and Running the Sweep Tests

The modified T2 is inserted in the D rack associated with the antenna to be tested and the special T2 in the B rack (at the antenna). The sweeper is then connected to the special T2 as shown in Figure 5. The power level going into the special T2 should be set at -10 dBm and the frequency range adjusted in the following way: halt the sweep, dial up 7777 on the thumbwheel switches on the front panel. After pressing PRESET the frequency should be adjusted to 2.0 GHz. With 0000 selected the frequency should be 1.0 GHz. This can be adjusted by either the internal offset pot or slightly increasing the number selected on the switches as the sweep starts at the point selected. Before beginning the test the gain adjust on the special T2 should be set so that the local oscillator at the antenna is in lock. To do this the modem at the antenna should be in full receive and

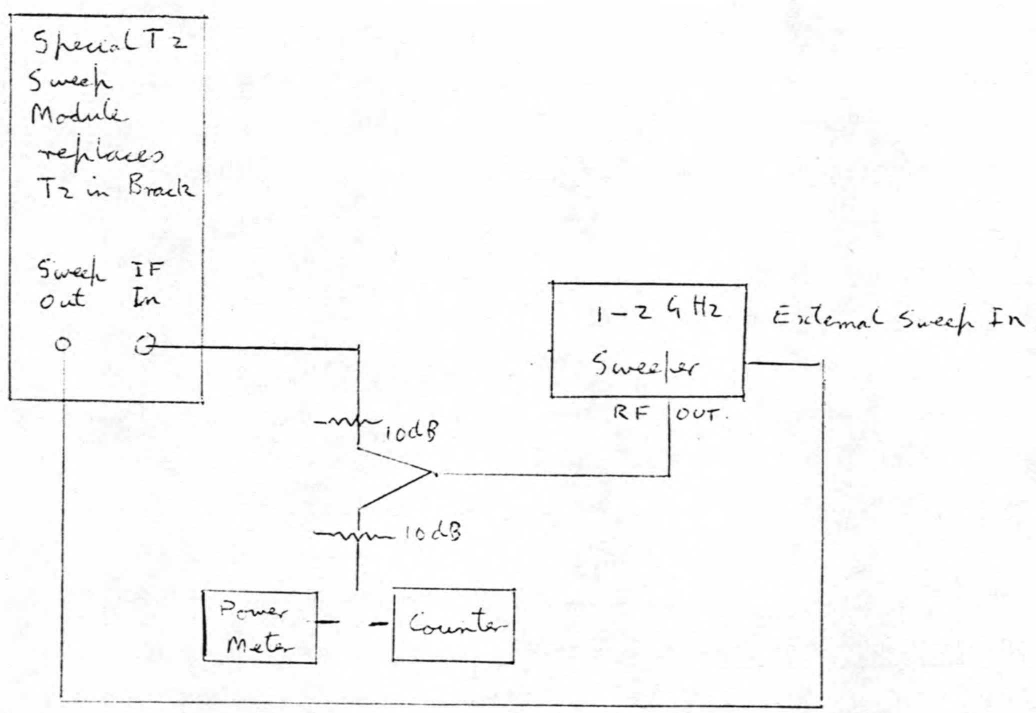

Figure 5: Test setup in antenna vertex room.

the modem in the central electronics room in full transmit and the gain adjusted to give the correct 1200-MHz and 1800-MHz levels as indicated on the L9 module's front panel meter in the B rack.

Taking the data requires the assistance of someone in the Control Building, such as the telescope operator. A list of instructions for the operator is given in Appendix 2. When the setup is complete, a set of commands must be transmitted via the DMT task in order to start the sweep and record the results. To maintain synchronism between the sweep and the data recording, these commands must be executed much faster than they can be manually typed; therefore, they are stored in a disk file and executed by assigning control of DMT to that file (step 7 in Appendix 2). The contents of the command file are listed and explained in Appendix 1.

The "select" command (line 8 in Appendix 1) has two effects. It causes the data set in D rack (DS 5) to transmit the value of a specified address (46_8, which is the detector in T2) every waveguide cycle, using Monitor Word 2. It also causes the software task called DCS to begin writing this data to a file called MDO, which we have assigned to the magnetic tape (step 4, Appendix 2).

2.4 Software For Analysis of Results

A program called WGSWEEP has been written to read the tape, to remove systematic effects using the calibration data, to make a line printer plot of the calibrated data with averaging options, and to compute and plot a discrete Fourier transform of the data. The latter should give us the equivalent of a time domain reflectometer. The program was written for the Modcomp computers, and is mostly in FORTRAN; but because it uses a fairly large amount of main memory, it currently can be run only on the computer called "Bacchus".

The remainder of this section assumes general familiarity with the operation of the Modcomps.

The program is normally run in the background. It reads from file BI, which should be assigned to the tape. Before each read operation, the program pauses to allow the user to position BI at the beginning of the desired file. For each file to be read, the program requests the complete address (antenna, data set, multiplex) of the data desired. The calibration file is read first, and it need only be read once. The first value in the calibration file calibrates the first one in each data file, etc., up to a maximum of 4096 values; normally this is the length of a sweep. The user is prompted for which of these values are to be used for plotting the frequency domain data, and for the averaging interval to be used. For reference, the sequence numbers of values at some useful frequencies are given below, assuming a 1.0 to 2.0 GHz sweep of 4096 points.

1.00 GHz		1
1.20	(LO carrier)	820
1.30-1.35	(Channel A)	1228-1433
1.40-1.45	(Channel B)	1638-1843
1.55-1.60	(Channel C)	2252-2457
1.65-1.70	(Channel D)	2662-2867
1.80	(LO carrier)	3277
2.00		4096

The program then computes the FFT of the entire data vector (4096 points), computes the magnitude of each point in the resulting 2048-point complex vector, and will plot any user-specified portion of the latter.

3.0 RESULTS OBTAINED USING THE SWEEP TEST SYSTEM

In August 1979 the sweep tests as described above were performed on VLA antenna numbers 2, 4, 6, 8, 9, 14, 15, 18, 19, 20, and 21 and the results recorded on two magnetic tapes. The files recorded on these tapes are listed in Table I(a) along with the antenna position

TABLE I

MEASUREMENTS MADE DURING 1979

	Antenna	Station	Channel	Address	CER T1-	VR T1-	Date	Tape/file(3)	Remarks
(a)		Calibration	-	21_8	-	-	8/14	1/1,V310/1	
	4	CW8	3	5	D35	D13	8/14	1/2,V310/2	
	6	AW3	8	10_8	D18	D16	8/16	1/3,V310/3	Peaks at 46,120 nsec (1)
	2	AW4	7	11_8	D14	D15	8/16	1/4,V310/4	
	8	AW5	2	6		D50	8/16	1/5,V310/5	
	9	AW6	1	4		D28	8/16	1/6,V310/6	
	14	AW7	4	3	D36	D39	8/16	1/7,V310/7	
	15	AW8	9	7	D19	D44	8/16	1/8,V310/8	
		Calibration	-	21_8	-	-	8/8	2/1,V310/9	
		Calibration	-	21_8	-	-	8/8	2/2,V310/10	
	20	DN2	1	26_8	D69	D66	8/13	2/3,V310/11	Peaks at 10,14 nsec (1,2)
	18	DN4	5	24_8	D62	D30	8/13	2/4,V310/12	
	19	DN6	4	25_8	D38	D60	8/13	2/5,V310/13	
	21	DN8	6	23_8	D40	D7	8/13	2/6,V310/14	
(b)		Calibration	-	21_8	-	-	10/10	3/1,V310/15	
	18	BE6	3	16_8	D10	D33	10/9	3/2,V310/16	
	16	CE9	7	22_8	D53	D11	10/9	3/3,V310/17	
	12	CE8	9	20_8	D45	D20	10/9	3/4,V310/18	
	13	CE6	2	17_8	D24	D63	10/9	3/5,V310/19	Large peak at 14 nsec (2)
	11	DE8	1	15_8	D68		10/9	3/6,V310/20	
	7	DE4	6	12_8	D42		10/9	3/7,V310/21	
	10	DE3	5	13_8	D32	D31	10/9	3/8,V310/22	Large peak at 108 nsec
	3	DE1	8	21_8	D17	D51	10/10	3/9,V310/23	Peak at 11 nsec
	5	DE2	4	14_8	D22	D64	10/10	3/10,V310/24	

(1) See Section 4.
(2) Variable pad in rectangular waveguide at D rack.
(3) Data was originally written on three different scratch tapes. It has now all been copied to tape V310.

at that time, the waveguide channel used, the antenna address, and the serial numbers of both modems. The results of all these tests were analyzed using program WGSWEEP, the calibration file was applied to each file and an amplitude plot and FFT plot of the data were produced. Some of the antennas showed a fairly flat amplitude response (especially antenna 14 and 15); others had slowly varying, but large, variations over the 1-2 GHz passband; and a few had fine scale ripples in the whole band, such as antennas 6 and 20 (reduced plots of these are shown in Figures 6 and 7 respectively). Fast Fourier transforms were done on all the data and the results for antennas 6 and 20 are shown in Figures 8 and 9 respectively. These outputs show that the ripples seen in antenna 6's response are periodic, as shown by the peaks occurring at around 45 nanoseconds and 120 nanoseconds, indicating possible reflections, whereas the FFT for antenna 20 is flat after 31 nanoseconds with values less than 0.005 indicating that the ripples are not caused by reflections. Note that 120 nanoseconds corresponds to a period in the frequency domain of 8.3 MHz and 45 nanoseconds corresponds to 22 MHz, and that the plots in Figures 6 and 14 show structure at these frequencies. For antenna 6 the waveguide frequency was 45 GHz, which in 20-mm waveguide has a group velocity of 2.74 x 10^8 m/sec, so 120 nanoseconds corresponds to 32.9 metres and 46 nanoseconds to 12.6 metres round-trip length or distances between reflections of 16.5 metres and 6.3 metres. The distance between the coupler and foundation waveguide is approximately 6 metres indicating that the foundation waveguide bend may be faulty. The 16.5 metres response may be another reflection or a mode conversion effect from the wave discontinuity.

To verify these results the A and C IF channels at the outputs of the T2 modules were examined with a spectrum analyzer and plots of these 50-MHz passbands were made. Although these plots would be affected by the front end band shapes and the filter band shapes, it is still possible to see some of the waveguide responses which have large variations affecting this band shape. The resulting plots for antennas 6 and 20 are shown in Figures 10, 12, 14, and 16. These plots were done with 300-kHz resolution and a 10-Hz video filter on the analyzer; the vertical scale is 2 dB per inch and 10 MHz per inch on the horizontal scale. To compare these easily a plot of the A and C channel frequency ranges was made with only 4 averages per plot point.

These plots for antennas 6 and 20 are shown in Figures 11, 13, 15, and 17. Considering the shape of the band-pass filter there is a definite likeness between these two measurements showing that the sweep system does measure the waveguide response. It is interesting to note that antennas 14 and 15 have the best responses and they are the antennas farthest away, suggesting that any waveguide reflections are attenuated by the long path length.

4.0 SUBSEQUENT INVESTIGATIONS

4.1 Antenna 6

The measurements reported in Section 3 above were made on August 13. Around September 22, there was a catastrophic loss of pressurization in the west arm waveguide which was traced to the elevation rotary joint of antenna 6: the bearings had seized, and one of the circular waveguide connections had finally unscrewed itself! The original failure of the joint had no doubt occurred long before the pressure loss, and the effects were seen in the swept measurement. A repeat of the swept measurement would now be interesting.

The ripple periods observed in the swept measurements do not imply reflections at the rotary joint, which is 9 m from the modem and 28 m from the 60-mm waveguide coupler.

Plots of the LO phase monitor data for the observing run just prior to the sweep test are given in Figures 18 (VR 5 MHz) and 19 (600 MHz round-trip). Similar plots from a run just after the rotary joint was repaired (October 1-7) are given in Figures 20 and 21.

4.2 Antenna 20

No further measurements have been made, but it should be noted that shortly before the sweep test of August 13 (namely on July 27) a variable attenuator was installed in the rectangular waveguide of D rack, and a wooden pad was removed from the 20-mm waveguide at the vertex room. The new attenuator is a prototype of those intended to be installed at all D racks for level setting. So far, the only other D rack so equipped is connected to antenna 13 (cf. Section 5.1 below).

5.0 ADDITIONAL SWEEP MEASUREMENTS, SOUTHEAST ARM

In October 1979 all channels on the southeast arm were swept using the methods described here. The relevant parameters are listed in Table I(b). (Data was taken on some of these during August, but it was accidentally overwritten.) The results have been analyzed in the same way, producing mostly normal spectra, but with the following interesting results.

5.1 Antenna 13

The FFT showed a large peak at 14 nsec, corresponding to a ripple of about 0.9 dB peak-to-peak. This is very similar to the result for antenna 20. Both antennas have variable attenuators in their D racks, and both are on low waveguide frequencies (channels 1 and 2). If due to two TE_{01} mode reflections in the 20-mm waveguide, the reflections are separated by about 1.6 m and the product of their reflection coefficients is -12.7 dB.

5.2 Antenna 10

This antenna shows an anomalously high peak at 108 nsec, with equivalent ripple 0.8 dB peak-to-peak. Reflections in the 20-mm guide would have to be 14.2 m apart and total -13.5 dB. This distance is comparable to that between the modem and the elevation rotary joint (about 16.8 m).

6.0 ACKNOWLEDGMENTS

The special T2 module was built by Doug Morton, who was an NRAO summer student during 1978. Ken Sowinski helped to acquaint us with the inner workings of Monty. Daryl Grant and Larry Beno assisted in carrying out the October sweep tests.

REFERENCES

[1] Thompson, A. R., "An Introduction to the VLA Electronics System", VLA Technical Report No. 29, March 1977.

[2] Ogai, M., "Attenuation, Ripple and Phase Stability in VLA Waveguide Transmission System", VLA Electronics Memorandum No. 154, March 1977.

[3] Archer, J. W., "Spurious Responses in the VLA Circular Waveguide System", VLA Electronics Memorandum No. 177, August 1978.

FIGURE 6

A#6 D18 D16 Ch8 AW3

[redacted]TENNA ADR = # 8
[redacted]TA SET 5
MUX ADR # 26

[redacted]EQ/GHZ	POWER	DB
1.004	1.447	-4.616
1.012	1.595	-4.194
1.020	1.549	-4.321
1.027	1.515	-4.416
1.035	1.608	-4.160
1.043	1.491	-4.488
1.051	1.440	-4.638
1.059	1.667	-4.001
1.067	1.540	-4.346
1.074	1.593	-4.199
1.082	1.828	-3.601
1.090	1.550	-4.319
1.098	1.700	-3.918
1.106	1.726	-3.852
1.113	1.662	-4.016
1.121	1.813	-3.639
1.129	1.722	-3.862
1.137	1.809	-3.647
1.145	1.782	-3.713
1.152	1.620	-4.128
1.160	1.797	-3.677
1.168	1.793	-3.687
1.176	1.748	-3.795
1.184	1.811	-3.641
1.192	1.754	-3.781
1.199	1.871	-3.501
1.207	2.027	-3.153
1.215	1.930	-3.365
1.223	1.985	-3.245
1.231	2.213	-2.771
1.238	2.073	-3.056
1.246	2.146	-2.906
1.254	2.116	-2.967
1.262	2.099	-3.002
1.270	2.364	-2.486
1.277	2.208	-2.781
1.285	2.284	-2.635
1.293	2.310	-2.585
1.301	2.364	-2.486
1.309	2.523	-2.203
1.317	2.460	-2.311
1.324	2.524	-2.201
1.332	2.547	-2.161
1.340	2.379	-2.458
1.348	2.500	-2.242
1.356	2.536	-2.180
1.363	2.315	-2.577
1.371	2.517	-2.213
1.379	2.484	-2.271
1.387	2.386	-2.444
1.395	2.588	-2.092
1.402	2.586	-2.096
1.410	2.443	-2.342
1.418	2.756	-1.820
1.426	2.682	-1.937
1.434	2.709	-1.894
1.442	2.768	-1.800

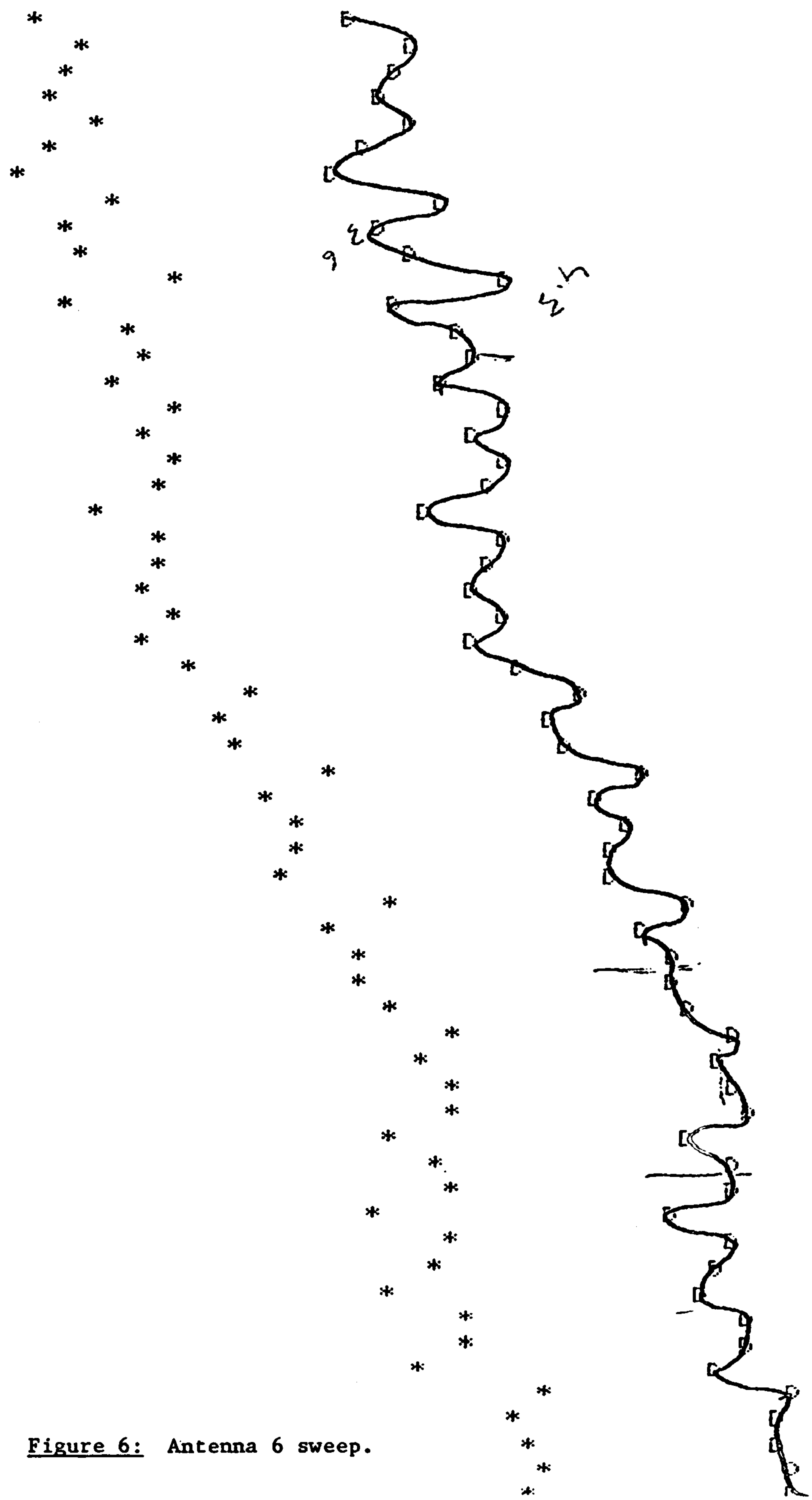

Figure 6: Antenna 6 sweep.

1.473	2.997	-1.455
1.481	3.144	-1.247
1.488	2.927	-1.558
1.496	3.014	-1.430
1.504	3.037	-1.397
1.512	2.841	-1.686
1.520	3.026	-1.412
1.527	3.083	-1.332
1.535	3.113	-1.290
1.543	3.249	-1.104
1.551	3.396	-0.912
1.559	3.472	-0.816
1.567	3.508	-0.771
1.574	3.432	-0.866
1.582	3.709	-0.529
1.590	3.681	-0.563
1.598	3.399	-0.908
1.606	3.569	-0.696
1.613	3.830	-0.390
1.621	3.568	-0.697
1.629	3.634	-0.618
1.637	3.758	-0.472
1.645	3.461	-0.829
1.652	3.477	-0.810
1.660	3.461	-0.829
1.668	3.313	-1.019
1.676	3.582	-0.680
1.684	3.563	-0.704
1.692	3.445	-0.850
1.699	3.525	-0.750
1.707	3.225	-1.137
1.715	3.009	-1.437
1.723	3.161	-1.223
1.731	2.949	-1.525
1.738	2.847	-1.678
1.746	3.028	-1.411
1.754	3.068	-1.354
1.762	3.035	-1.400
1.770	3.175	-1.204
1.777	2.890	-1.613
1.785	2.793	-1.761
1.793	2.842	-1.685
1.801	2.767	-1.802
1.809	2.975	-1.487
1.817	3.167	-1.215
1.824	3.117	-1.284
1.832	3.186	-1.189
1.840	3.384	-0.928
1.848	3.110	-1.294
1.856	3.241	-1.115
1.863	3.168	-1.214
1.871	3.044	-1.387
1.879	3.318	-1.013
1.887	3.616	-0.639
1.895	3.706	-0.532
1.902	3.549	-0.721
1.910	3.434	-0.864
1.918	3.220	-1.143
1.926	2.898	-1.601
1.934	2.599	-2.074
1.942	2.169	-2.859
1.949	1.871	-3.501
1.957	1.628	-4.106
1.965	1.321	-5.013

FIG. 6

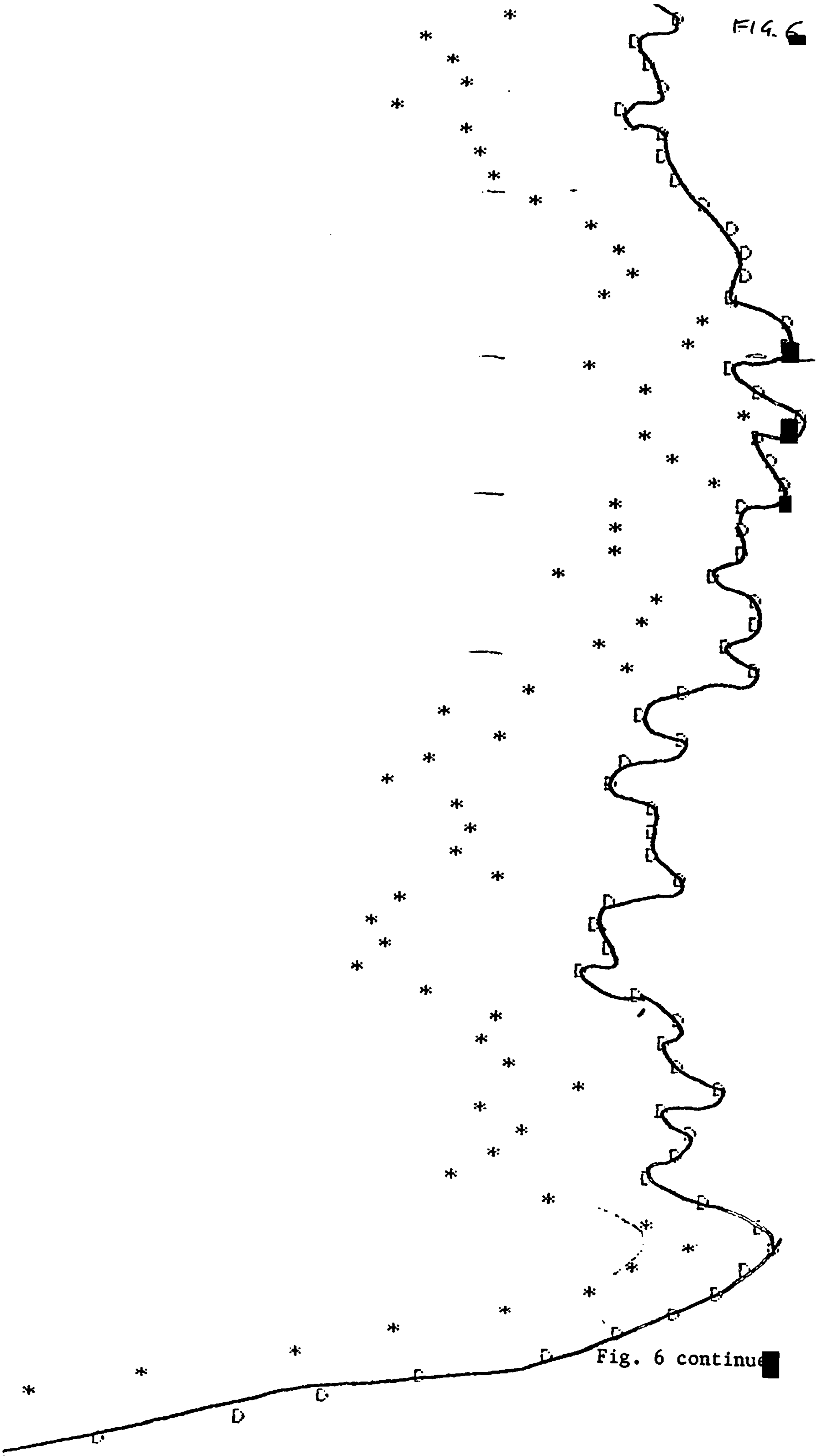

Fig. 6 continue[redacted]

i[redacted]ENNA ADR = # 16 A# 20 D69 D66 Ch1 DN2 FIGURE 7
+[redacted]A SET 5
IUX ADR # 26

F[redacted]Q/GHZ	POWER	DB
1.004	1.047	-3.441
1.012	0.996	-3.661
1.020	0.971	-3.768
1.027	1.005	-3.622
1.035	1.027	-3.527
1.043	1.023	-3.541
1.051	1.131	-3.106
1.059	1.218	-2.785
1.067	1.170	-2.960
1.074	1.175	-2.942
1.082	1.238	-2.713
1.090	1.262	-2.632
1.098	1.200	-2.849
1.106	1.183	-2.913
1.113	1.180	-2.922
1.121	1.133	-3.100
1.129	1.146	-3.050
1.137	1.223	-2.767
1.145	1.208	-2.820
1.152	1.212	-2.807
1.160	1.278	-2.577
1.168	1.292	-2.530
1.176	1.345	-2.356
1.184	1.420	-2.118
1.192	1.446	-2.041
1.199	1.513	-1.844
1.207	1.459	-2.000
1.215	1.457	-2.008
1.223	1.531	-1.793
1.231	1.611	-1.570
1.238	1.645	-1.479
1.246	1.560	-1.710
1.254	1.403	-2.172
1.262	1.383	-2.234
1.270	1.480	-1.939
1.277	1.556	-1.722
1.285	1.636	-1.504
1.293	1.746	-1.221
1.301	1.811	-1.062
1.309	1.853	-0.963
1.317	1.930	-0.786
1.324	1.914	-0.822
1.332	1.940	-0.763
1.340	1.884	-0.890
1.348	1.823	-1.035
1.356	1.745	-1.224
1.363	1.650	-1.467
1.371	1.622	-1.542
1.379	1.743	-1.230
1.387	1.805	-1.077
1.395	1.703	-1.330
1.402	1.624	-1.535
1.410	1.550	-1.738
1.418	1.564	-1.701
1.426	1.620	-1.546
1.434	1.643	-1.486
1.442	1.720	-1.286
[illegible]	[illegible]	[illegible]

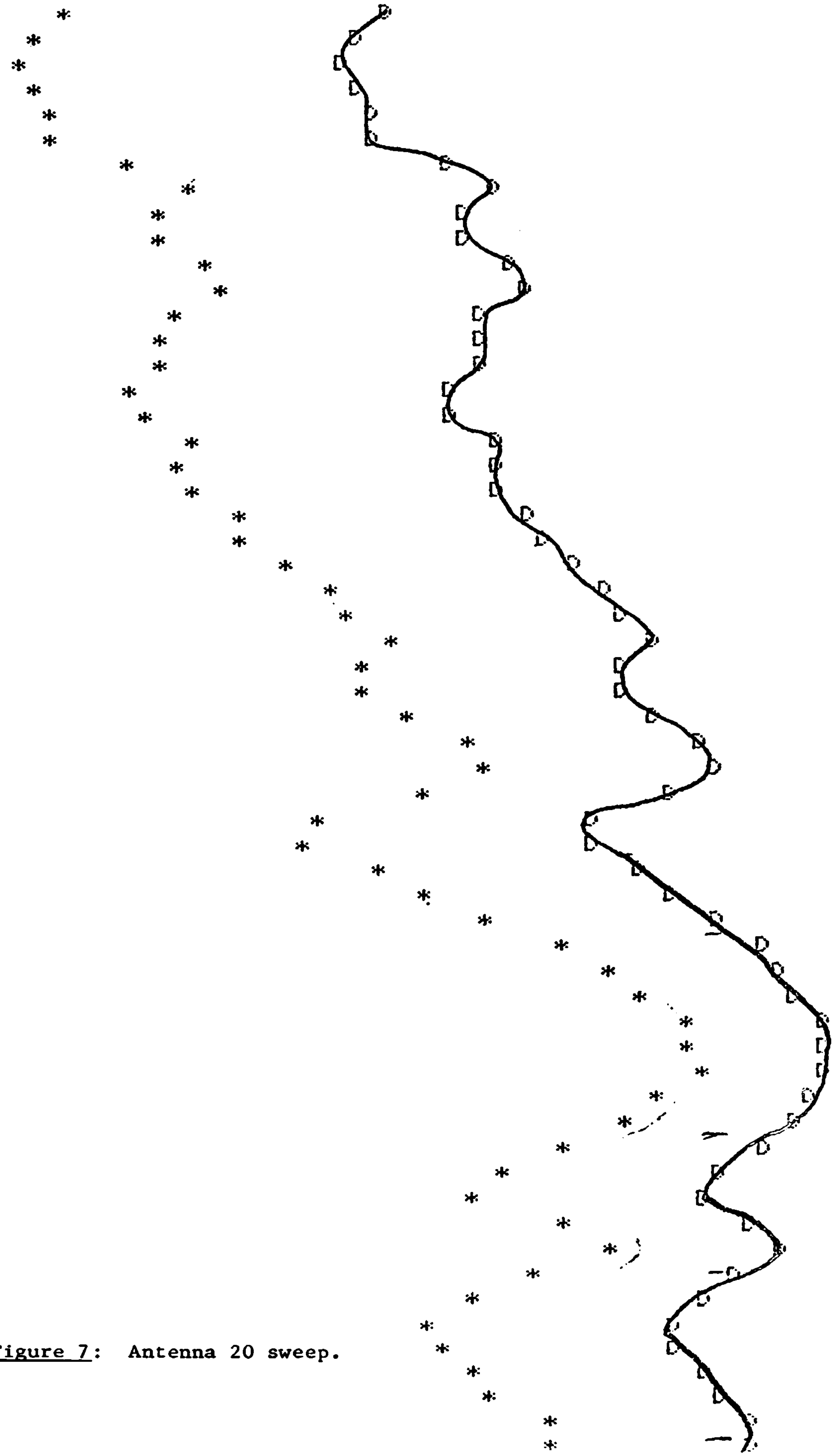

__Figure 7__: Antenna 20 sweep.

1. 473	[illegible]	[illegible]
1. 481	1. 837	-1. 001
1. 488	1. 791	-1. 112
1. 496	1. 838	-0. 999
1. 504	1. 865	-0. 936
1. 512	1. 809	-1. 068
1. 520	1. 720	-1. 286
1. 527	1. 650	-1. 468
1. 535	1. 692	-1. 357
1. 543	1. 925	-0. 799
1. 551	2. 115	-0. 389
1. 559	2. 118	-0. 382
1. 567	2. 187	-0. 244
1. 574	2. 193	-0. 231
1. 582	2. 032	-0. 563
1. 590	1. 845	-0. 981
1. 598	1. 694	-1. 352
1. 606	1. 745	-1. 224
1. 613	1. 829	-1. 020
1. 621	1. 834	-1. 009
1. 629	1. 726	-1. 273
1. 637	1. 697	-1. 345
1. 645	1. 842	-0. 988
1. 652	1. 906	-0. 840
1. 660	1. 838	-0. 998
1. 668	1. 753	-1. 203
1. 676	1. 678	-1. 394
1. 684	1. 593	-1. 621
1. 692	1. 544	-1. 756
1. 699	1. 565	-1. 698
1. 707	1. 619	-1. 549
1. 715	1. 553	-1. 729
1. 723	1. 409	-2. 154
1. 731	1. 283	-2. 559
1. 738	1. 243	-2. 697
1. 746	1. 284	-2. 558
1. 754	1. 246	-2. 687
1. 762	1. 175	-2. 942
1. 770	1. 144	-3. 057
1. 777	1. 128	-3. 117
1. 785	1. 216	-2. 792
1. 793	1. 273	-2. 594
1. 801	1. 316	-2. 449
1. 809	1. 278	-2. 576
1. 817	1. 241	-2. 705
1. 824	1. 319	-2. 439
1. 832	1. 298	-2. 509
1. 840	1. 300	-2. 503
1. 848	1. 274	-2. 589
1. 856	1. 224	-2. 764
1. 863	1. 181	-2. 918
1. 871	1. 205	-2. 832
1. 879	1. 345	-2. 353
1. 887	1. 455	-2. 013
1. 895	1. 637	-1. 501
1. 902	1. 794	-1. 104
1. 910	1. 812	-1. 061
1. 918	1. 823	-1. 034
1. 926	1. 855	-0. 958
1. 934	1. 865	-0. 936
1. 942	1. 836	-1. 002
1. 949	1. 780	-1. 138
1. 957	1. 771	-1. 159
1. 965	1. 783	-1. 130
[illegible]	[illegible]	[illegible]

FIG. 7

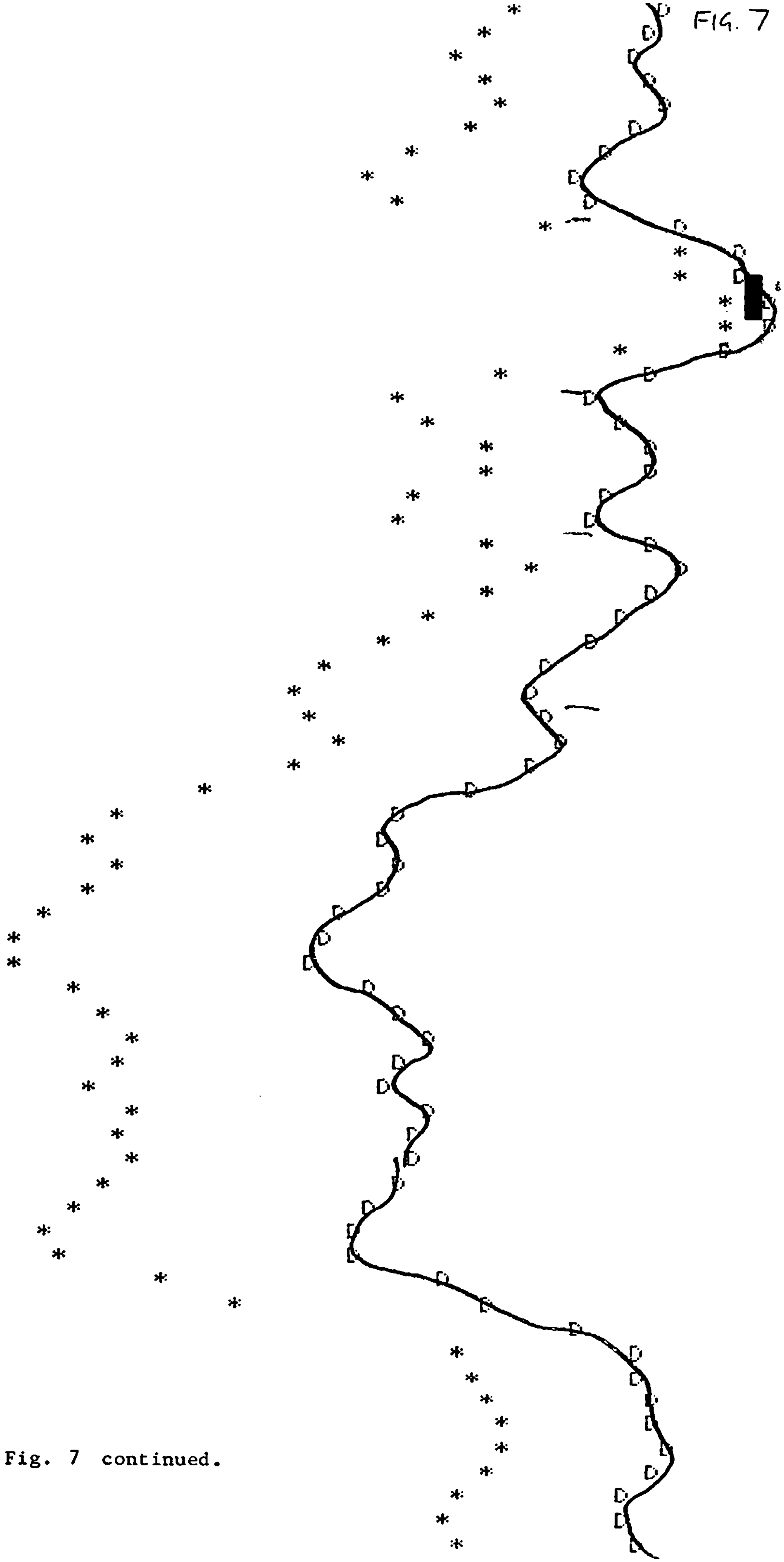

Fig. 7 continued.

```
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T=0. 20E+01
T=0. 30E+01
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T=0. 50E+01                                *
T=0. 60E+01                                *
T=0. 70E+01                        *
T=0. 80E+01             *
T=0. 90E+01             *
T=0. 10E+02        *
T=0. 11E+02           *
T=0. 12E+02       *
T=0. 13E+02    *
T=0. 14E+02   *
T=0. 15E+02    *
T=0. 16E+02    *
T=0. 17E+02    *
T=0. 18E+02   *
T=0. 19E+02 *
T=0. 20E+02<
T=0. 21E+02 *
T=0. 22E+02<
T=0. 23E+02<
T=0. 24E+02<
T=0. 25E+02<
T=0. 26E+02<
T=0. 27E+02<
T=0. 28E+02  *
T=0. 29E+02<
T=0. 30E+02<
T=0. 31E+02 *
T=0. 32E+02<
T=0. 33E+02<
T=0. 34E+02<
T=0. 35E+02<
T=0. 36E+02<
T=0. 37E+02 *
T=0. 38E+02 *
T=0. 39E+02<
T=0. 40E+02<
T=0. 41E+02<
T=0. 42E+02<
T=0. 43E+02  *
T=0. 44E+02 *
T=0. 45E+02    *
T=0. 46E+02  *
T=0. 47E+02   *
T=0. 48E+02   *
T=0. 49E+02    *
T=0. 50E+02    *
T=0. 51E+02<
T=0. 52E+02<
T=0. 53E+02<
T=0. 54E+02<
T=0. 55E+02 *
T=0. 56E+02 *
T=0. 57E+02<
T=0. 58E+02<
T=0. 59E+02<
T=0. 60E+02<
T=0. 61E+02<
T=0. 62E+02<
```

<u>Figure 8</u>: Antenna 6, time domain (FFT of sweep).

A#6 continued FIGURE 8

```
T=0. 66E+02<
T=0. 67E+02<
T=0. 68E+02<
T=0. 69E+02<
T=0. 70E+02<
T=0. 71E+02<
T=0. 72E+02<
T=0. 73E+02<
T=0. 74E+02<
T=0. 75E+02<
T=0. 76E+02<
T=0. 77E+02<
T=0. 78E+02<
T=0. 79E+02<
T=0. 80E+02 *
T=0. 81E+02 *
T=0. 82E+02<
T=0. 83E+02<
T=0. 84E+02<
T=0. 85E+02 *
T=0. 86E+02  *
T=0. 87E+02  *
T=0. 88E+02 *
T=0. 89E+02<
T=0. 90E+02 *
T=0. 91E+02 *
T=0. 92E+02   *
T=0. 93E+02 *
T=0. 94E+02<
T=0. 95E+02<
T=0. 96E+02<
T=0. 97E+02<
T=0. 98E+02<
T=0. 99E+02<
T=0. 10E+03 *
T=0. 10E+03 *
T=0. 10E+03<
T=0. 10E+03<
T=0. 10E+03<
T=0. 10E+03 *
T=0. 11E+03   *
T=0. 11E+03     *
T=0. 11E+03     *
T=0. 11E+03     *
T=0. 11E+03 *
T=0. 11E+03<
T=0. 11E+03 *
T=0. 11E+03     *
T=0. 11E+03     *
T=0. 11E+03         *
T=0. 12E+03         *
T=0. 12E+03            *
T=0. 12E+03 *
T=0. 12E+03  *
T=0. 12E+03          *
T=0. 12E+03      *
T=0. 12E+03   *
T=0. 12E+03   *
T=0. 12E+03     *
T=0. 13E+03   *
T=0. 13E+03      *
T=0. 13E+03    *
T=0. 13E+03 *
```

Fig. 8 continued.

A 20 FIGURE 9

```
SCALE = 0.50E+00
T=0. 10E+01
T=0. 20E+01
T=0. 30E+01                               *
T=0. 40E+01             *
T=0. 50E+01                             *
T=0. 60E+01        *
T=0. 70E+01           *
T=0. 80E+01    *
T=0. 90E+01     *
T=0. 10E+02           *
T=0. 11E+02  *
T=0. 12E+02  *
T=0. 13E+02<
T=0. 14E+02          *
T=0. 15E+02<
T=0. 16E+02  *
T=0. 17E+02    *
T=0. 18E+02<
T=0. 19E+02 *
T=0. 20E+02<
T=0. 21E+02  *
T=0. 22E+02 *
T=0. 23E+02   *
T=0. 24E+02  *
T=0. 25E+02<
T=0. 26E+02<
T=0. 27E+02 *
T=0. 28E+02<
T=0. 29E+02 *
T=0. 30E+02<
T=0. 31E+02 *
T=0. 32E+02<
T=0. 33E+02<
T=0. 34E+02<
T=0. 35E+02<
T=0. 36E+02<
T=0. 37E+02<
T=0. 38E+02<
T=0. 39E+02<
T=0. 40E+02<
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T=0. 42E+02<
T=0. 43E+02<
T=0. 44E+02<
T=0. 45E+02<
T=0. 46E+02<
T=0. 47E+02<
T=0. 48E+02<
T=0. 49E+02<
T=0. 50E+02<
T=0. 51E+02<
T=0. 52E+02<
T=0. 53E+02<
T=0. 54E+02<
T=0. 55E+02<
T=0. 56E+02<
T=0. 57E+02<
T=0. 58E+02<
T=0. 59E+02<
T=0. 60E+02<
T=0. 61E+02<
T=0. 62E+02<
```

Figure 9: Antenna 20, time domain (FFT of sweep).

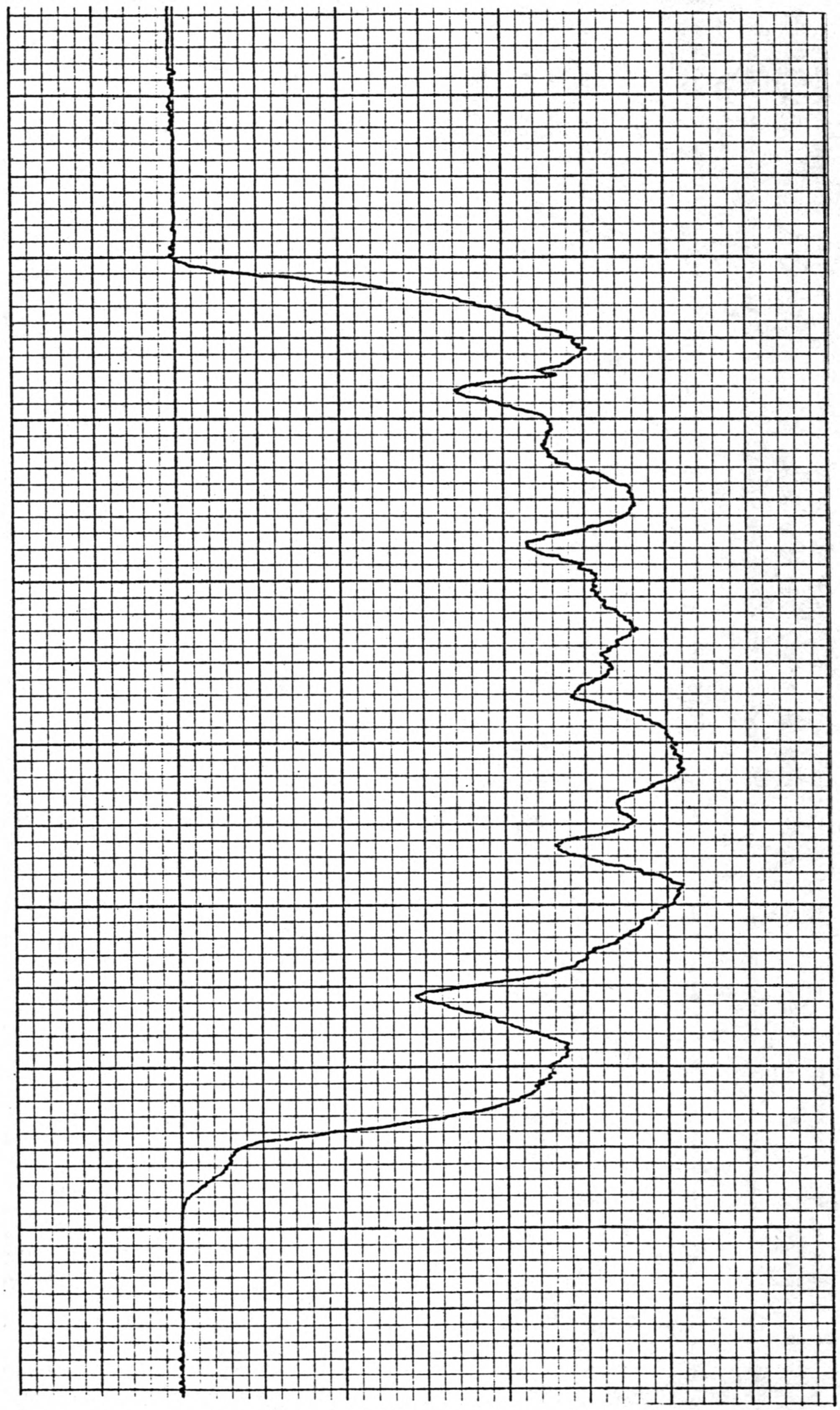


Figure 10: Spectrum analyzer trace, T2-RCV IF, Antenna 6, Channel A.

ANTENNA ADR = # 8.　　　A 6
D[redacted]TA SET 5
[redacted]X ADR # 26

FREQ/GHZ	POWER	DB
1.300	2.136	-1.287
1.301	2.436	-0.717
1.302	2.631	-0.382
1.303	2.634	-0.377
1.304	2.583	-0.462
1.305	2.657	-0.340
1.306	2.733	-0.217
1.307	2.257	-1.048
1.308	1.884	-1.832
1.309	2.280	-1.004
1.310	2.769	-0.161
1.311	2.771	-0.157
1.312	2.781	-0.141
1.313	2.788	-0.131
1.314	2.766	-0.165
1.315	2.601	-0.431
1.316	2.261	-1.041
1.317	1.961	-1.658
1.318	2.367	-0.841
1.319	2.601	-0.432
1.320	2.434	-0.720
1.321	2.505	-0.595
1.322	2.730	-0.223
1.323	2.587	-0.455
1.324	2.490	-0.621
1.325	2.399	-0.784
1.326	2.179	-1.202
1.327	2.534	-0.546
1.328	2.709	-0.255
1.328	2.639	-0.369
1.329	2.769	-0.160
1.330	2.833	-0.060
1.331	2.640	-0.368
1.332	2.479	-0.640
1.333	2.276	-1.013
1.334	2.159	-1.241
1.335	2.578	-0.471
1.336	2.661	-0.333
1.337	2.664	-0.328
1.338	2.698	-0.273
1.339	2.646	-0.358
1.340	2.384	-0.810
1.341	2.254	-1.054
1.342	2.022	-1.525
1.343	1.864	-1.878
1.344	2.113	-1.334
1.345	2.419	-0.746
1.346	2.544	-0.527
1.347	2.546	-0.526
1.348	2.611	-0.415
1.349	2.685	-0.294
1.350	2.266	-1.031

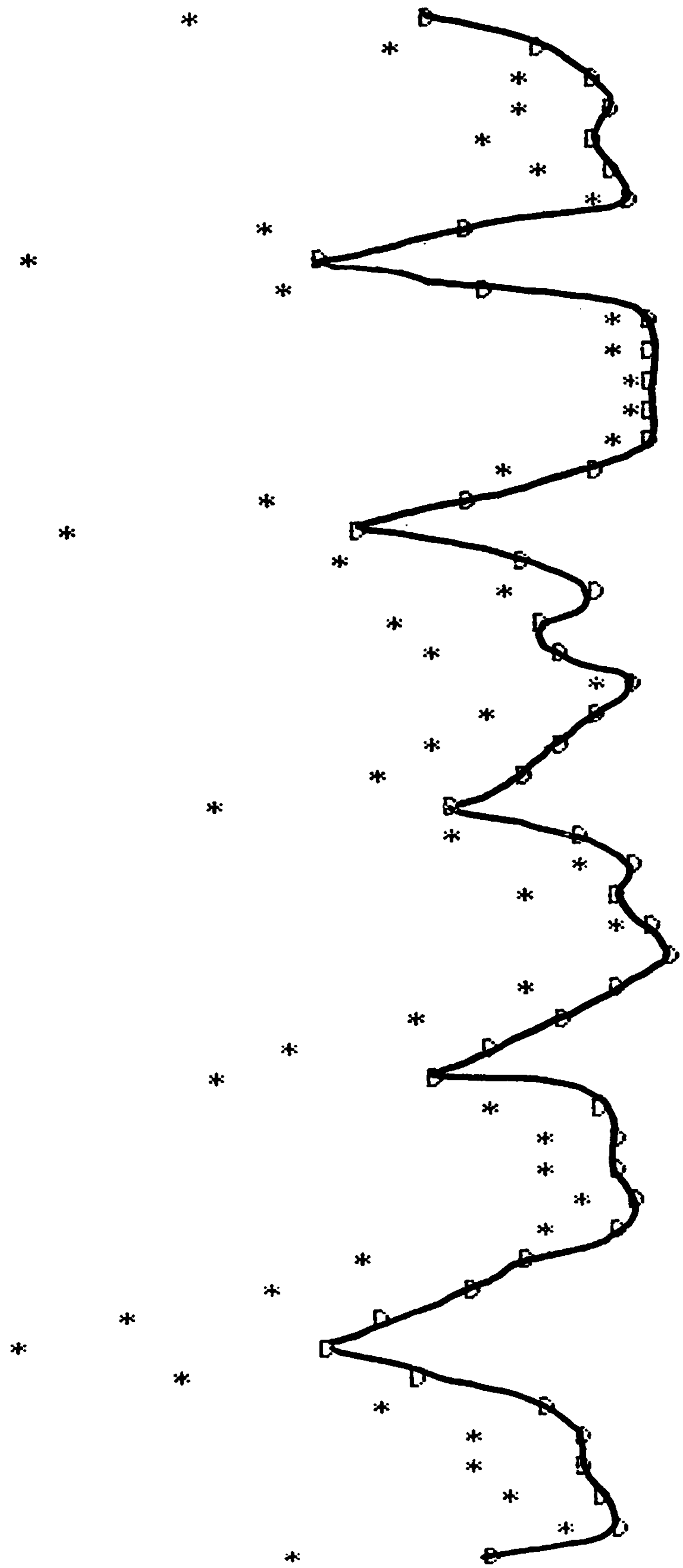


Figure 11: Antenna 6 sweep, expanded to show channel A; cf. Fig 10.

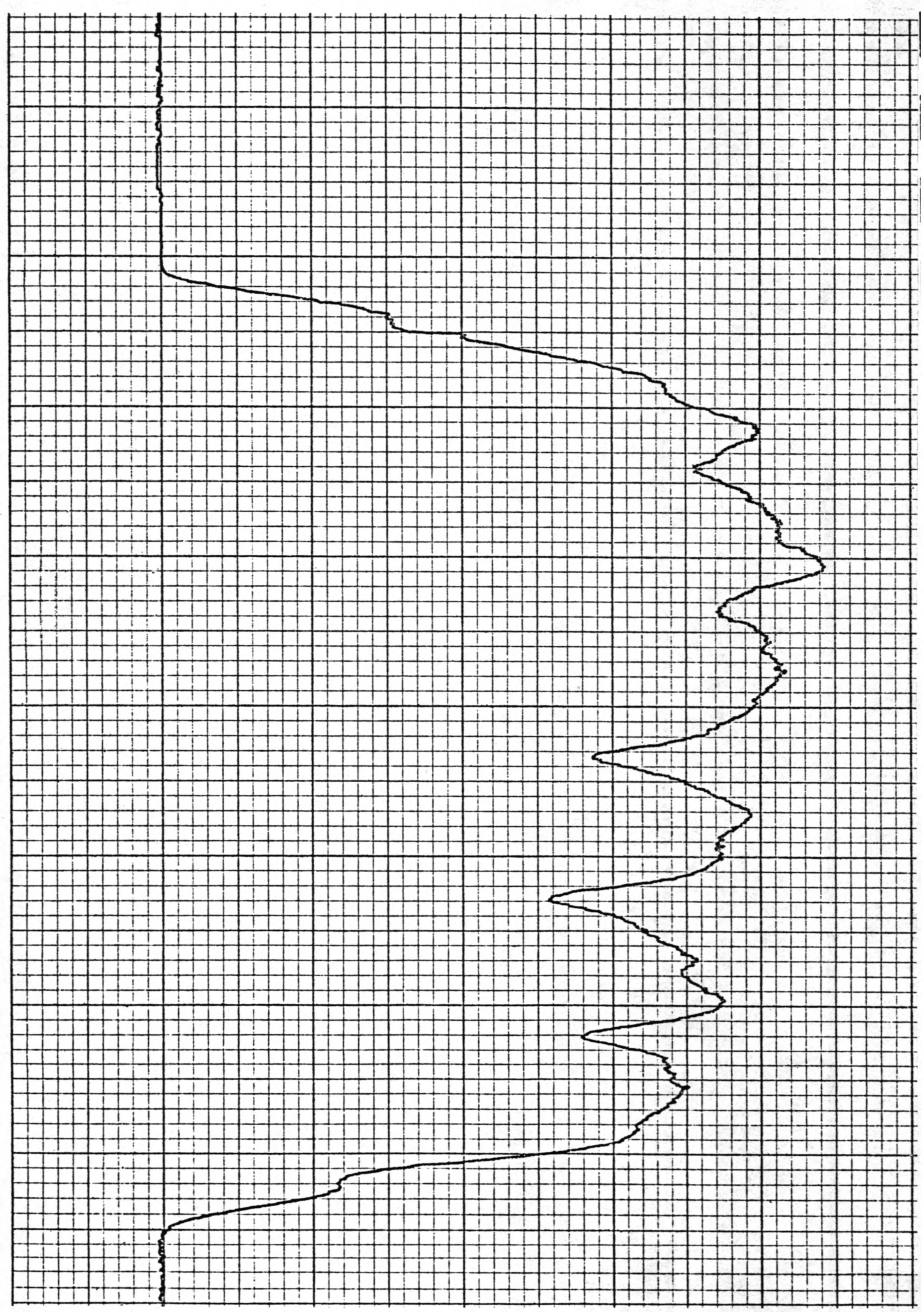


Figure 12: Spectrum analyzer trace, T2-RCV IF, Antenna 6, Channel C.

C 6

ANTENNA ADR = # 8
[redacted]TA SET 5
[redacted]X ADR # 26

[redacted]EQ/GHZ	POWER	DB
1.550	3.682	-0.546
1.551	3.675	-0.553
1.552	3.393	-0.901
1.553	3.026	-1.397
1.554	2.732	-1.842
1.555	2.991	-1.449
1.556	3.288	-1.038
1.557	3.485	-0.784
1.558	3.702	-0.522
1.559	3.647	-0.587
1.560	3.697	-0.528
1.561	3.618	-0.622
1.562	3.326	-0.987
1.563	2.865	-1.636
1.564	3.219	-1.129
1.565	3.450	-0.828
1.566	3.770	-0.443
1.567	3.686	-0.541
1.568	3.675	-0.554
1.569	3.779	-0.433
1.570	3.540	-0.717
1.571	3.089	-1.309
1.572	3.278	-1.051
1.573	3.434	-0.849
1.574	3.646	-0.589
1.575	3.559	-0.693
1.576	3.419	-0.868
1.577	3.596	-0.649
1.578	3.449	-0.829
1.578	2.990	-1.450
1.579	3.054	-1.358
1.580	3.590	-0.655
1.581	3.846	-0.356
1.582	3.980	-0.208
1.583	3.959	-0.230
1.584	4.024	-0.160
1.585	4.068	-0.113
1.586	3.480	-0.791
1.587	2.807	-1.723
1.588	3.142	-1.235
1.589	3.894	-0.302
1.590	3.961	-0.229
1.591	4.038	-0.145
1.592	4.083	-0.097
1.593	4.007	-0.178
1.594	3.791	-0.419
1.595	3.334	-0.976
1.596	2.776	-1.772
1.597	3.055	-1.357
1.598	3.255	-1.081
1.599	3.376	-0.922
1.600	4.024	-0.160

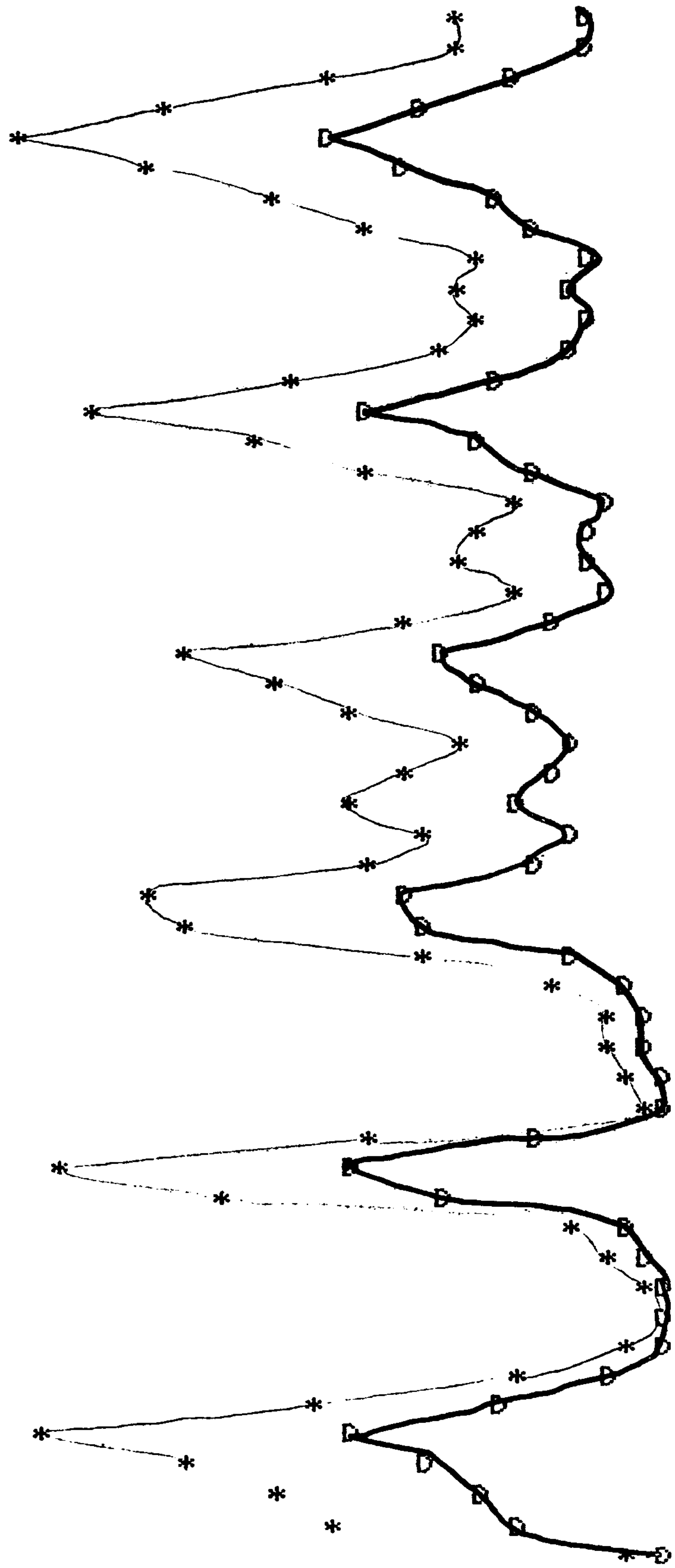


Figure 13: Antenna 6 sweep, expanded to show channel C; cf. Fig. 12.

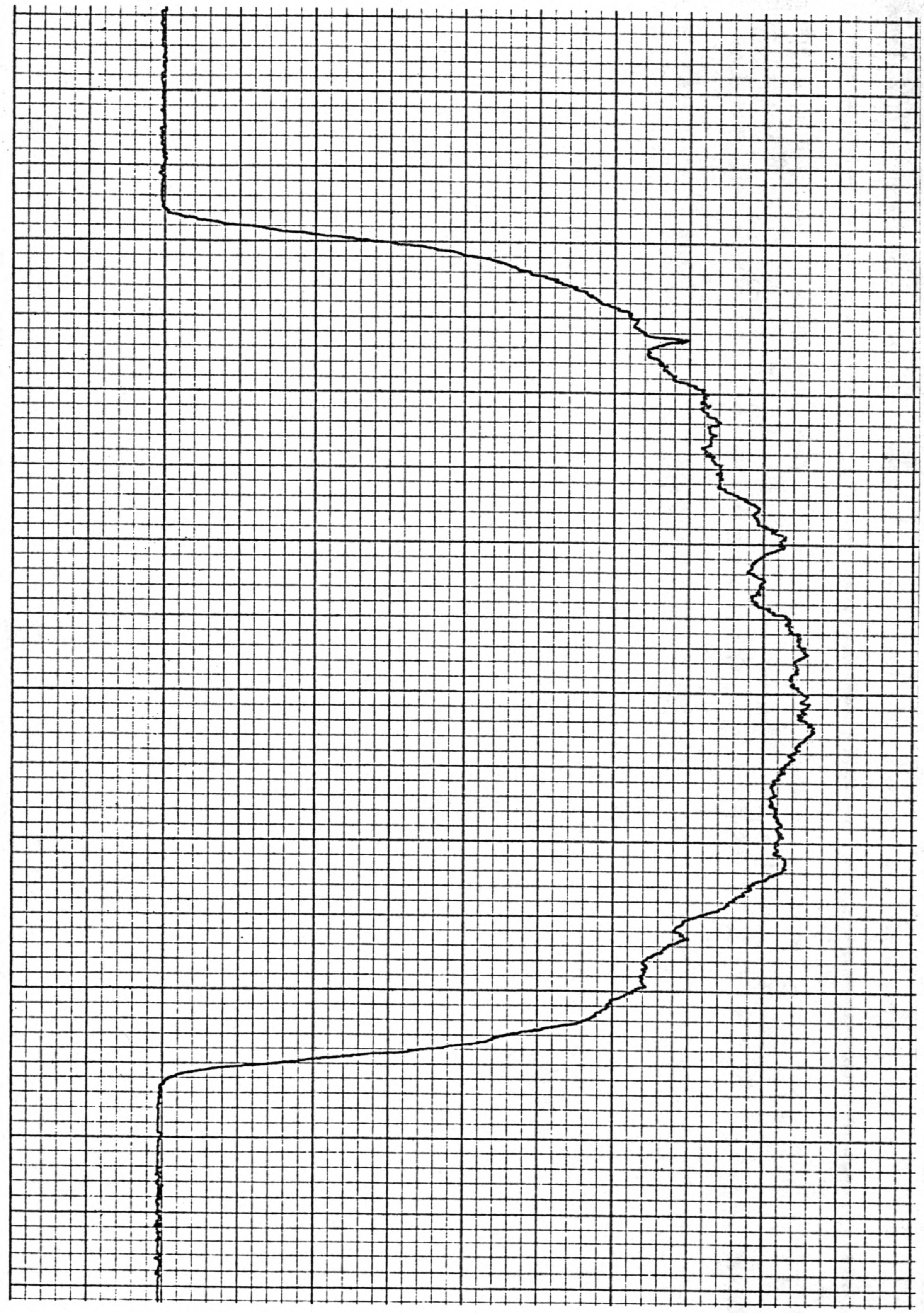


Figure 14: Spectrum analyzer trace, T2-RCV IF, Antenna 20, Channel A.

A20

ANTENNA ADR = # 16
DATA SET 5
MUX ADR # 26

FREQ/GHZ	POWER	DB
1.300	1.854	-0.465
1.301	1.855	-0.463
1.302	1.845	-0.486
1.303	1.851	-0.472
1.304	1.793	-0.611
1.305	1.773	-0.658
1.306	1.773	-0.658
1.307	1.771	-0.663
1.308	1.912	-0.331
1.309	1.930	-0.291
1.310	1.904	-0.349
1.311	1.900	-0.359
1.312	1.854	-0.464
1.313	1.803	-0.586
1.314	1.870	-0.427
1.315	1.836	-0.508
1.316	1.931	-0.289
1.317	2.010	-0.114
1.318	1.992	-0.153
1.319	2.030	-0.071
1.320	1.958	-0.228
1.321	1.816	-0.555
1.322	1.844	-0.488
1.323	1.834	-0.511
1.324	1.837	-0.504
1.325	1.960	-0.223
1.326	2.038	-0.055
1.327	2.016	-0.101
1.328	1.945	-0.257
1.328	1.904	-0.349
1.329	1.889	-0.384
1.330	1.890	-0.382
1.331	1.932	-0.285
1.332	1.985	-0.169
1.333	1.990	-0.157
1.334	1.990	-0.156
1.335	1.943	-0.262
1.336	1.924	-0.304
1.337	1.919	-0.316
1.338	1.860	-0.451
1.339	1.888	-0.385
1.340	1.901	-0.356
1.341	1.824	-0.535
1.342	1.918	-0.318
1.343	1.871	-0.425
1.344	1.806	-0.579
1.345	1.862	-0.445
1.346	1.798	-0.598
1.347	1.820	-0.545
1.348	1.860	-0.450
1.349	1.829	-0.523
1.350	1.458	-1.510

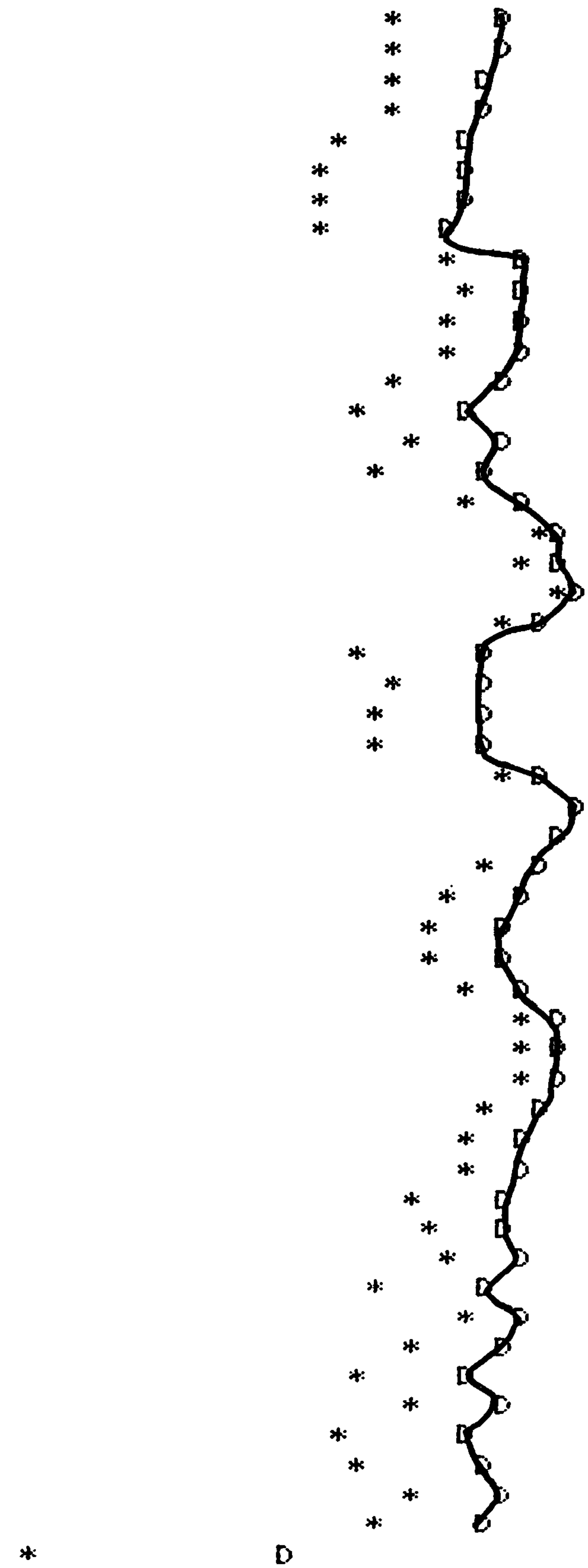


Figure 15: Antenna 20 sweep, expanded to show channel A; cf. Fig. 14.

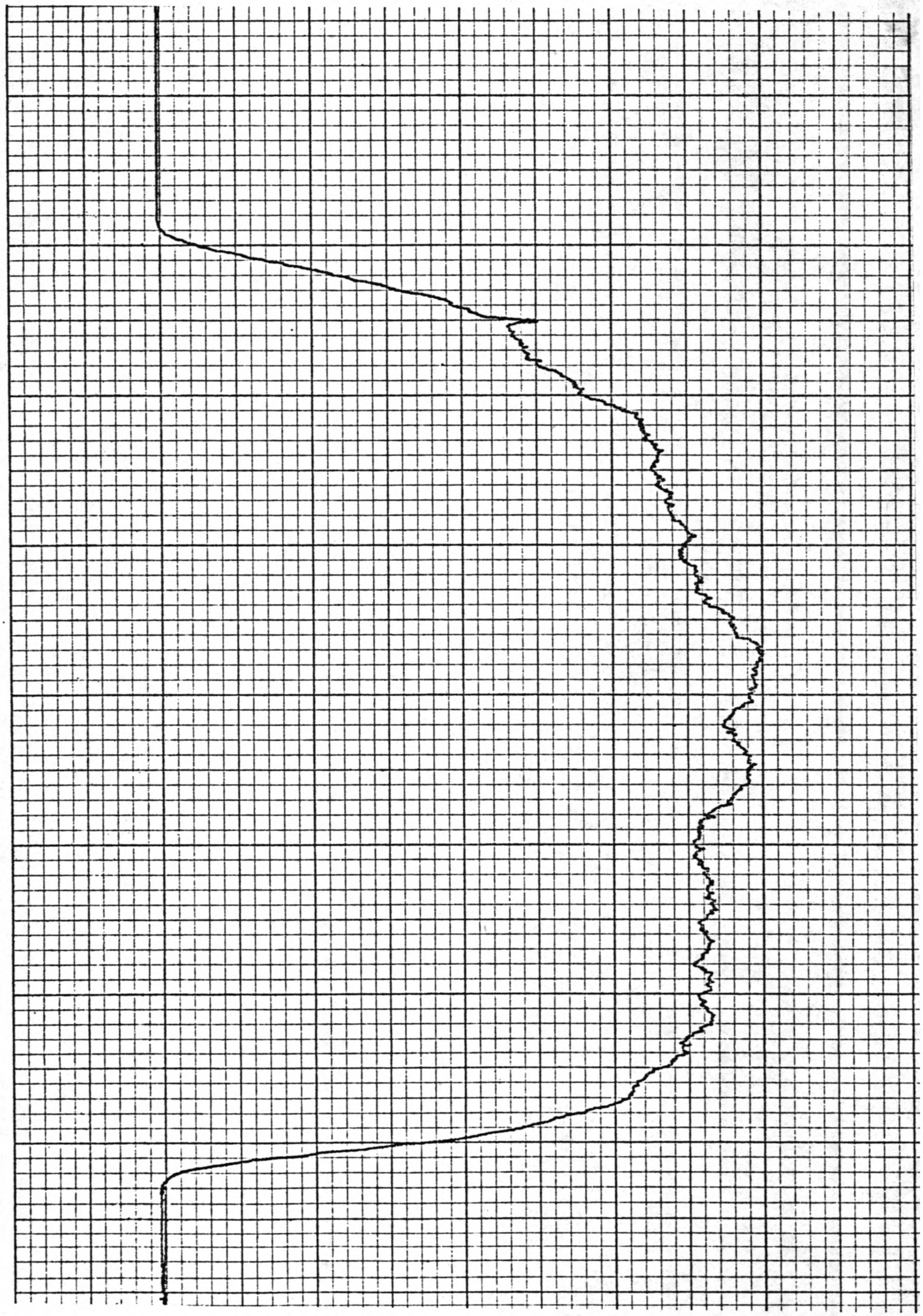


Figure 16: Spectrum analyzer trace, T2-RCV IF, Antenna 20, Channel C.

ANTENNA ADR = # 16

DATA SET 5

AUX ADR # 26

C20

FREQ/GHZ	POWER	DB
1.578	2.023	-0.583
1.578	2.046	-0.533
1.578	2.054	-0.516
1.578	2.151	-0.315
1.578	2.199	-0.219
1.578	2.132	-0.353
1.578	2.110	-0.400
1.578	2.009	-0.612
1.578	2.023	-0.581
1.578	2.051	-0.523
1.578	2.140	-0.338
1.578	2.260	-0.101
1.578	2.204	-0.210
1.578	2.213	-0.191
1.578	2.179	-0.260
1.578	2.136	-0.346
1.578	2.188	-0.241
1.578	2.187	-0.242
1.578	2.239	-0.141
1.578	2.194	-0.229
1.578	2.172	-0.274
1.579	2.166	-0.286
1.579	2.154	-0.310
1.579	2.198	-0.221
1.579	2.246	-0.127
1.579	2.281	-0.061
1.579	2.244	-0.131
1.579	2.182	-0.252
1.579	2.097	-0.425
1.579	2.062	-0.498
1.579	1.973	-0.690
1.579	1.990	-0.654
1.579	2.125	-0.369
1.579	2.132	-0.354
1.579	2.107	-0.405
1.579	2.046	-0.532
1.579	1.866	-0.933
1.579	1.890	-0.877
1.579	1.845	-0.983
1.579	1.842	-0.989
1.579	1.928	-0.791
1.580	1.843	-0.987
1.580	1.870	-0.923
1.580	1.812	-1.059
1.580	1.761	-1.184
1.580	1.730	-1.261
1.580	1.691	-1.359
1.580	1.733	-1.253
1.580	1.715	-1.299
1.580	1.727	-1.270
1.580	1.671	-1.412
1.580	1.849	-0.972

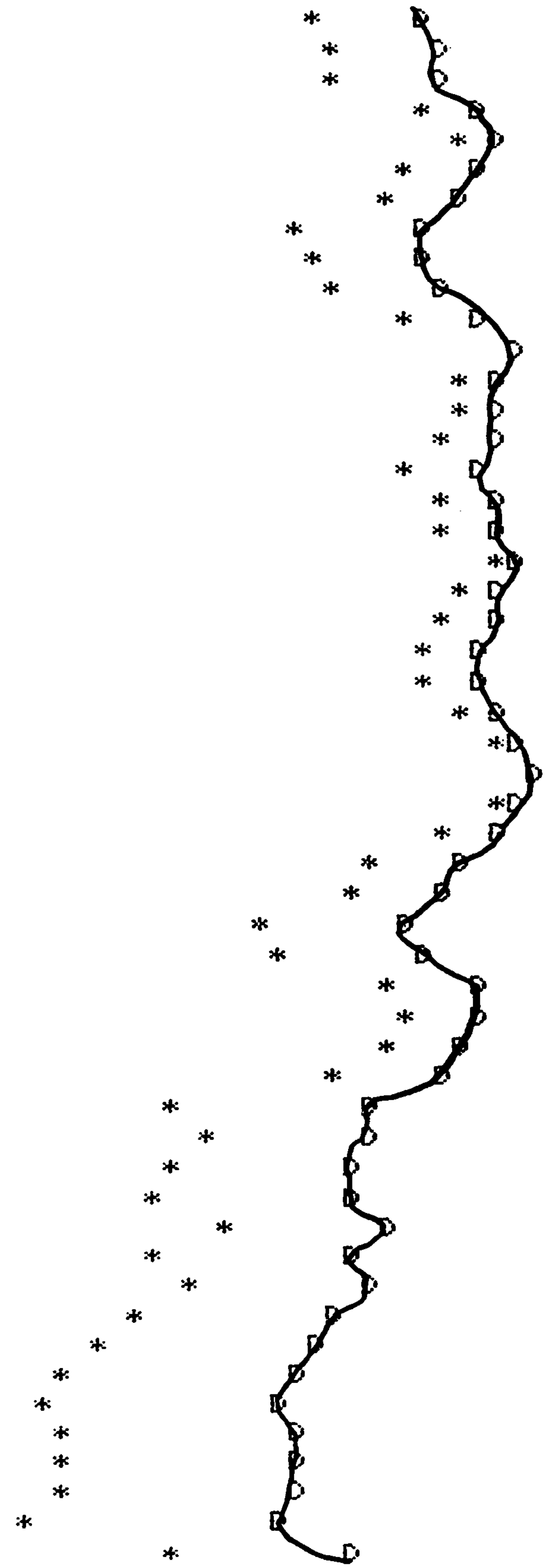
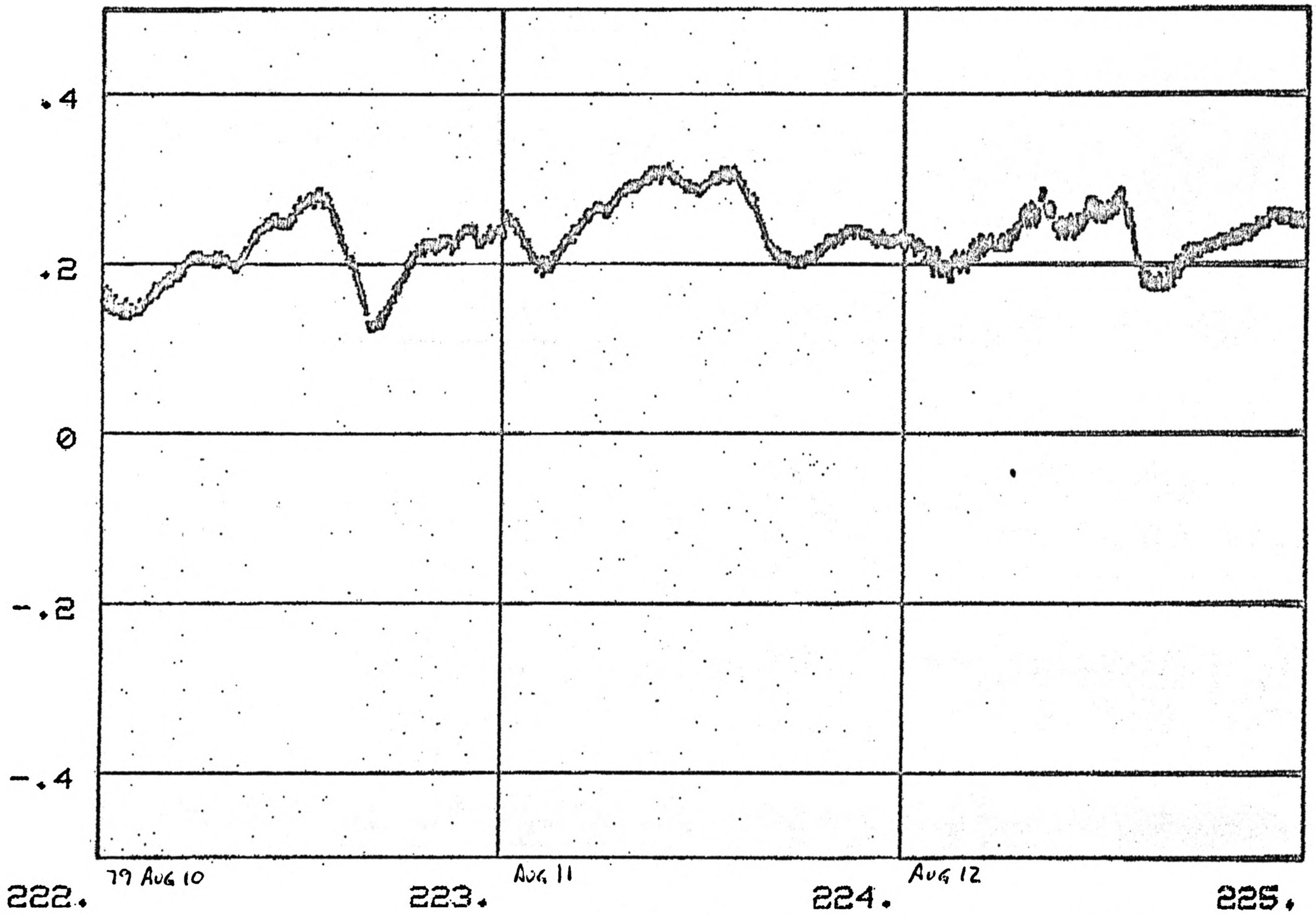


Figure 17: Antenna 20 sweep, expanded to show channel C; cf. Fig. 16.

Monitor Data

Monitor Point Value



Time (IAT, day number within 1979)

MAUG06[11,1]
1 Antennas: 6 DCSaddress: 2:024 Datatype: VALUE
Yaxis: -.5000000 .5000000 Skipfactor: 1

Figure 18: 5 MHz phase at antenna 6 just before waveguide sweep test.

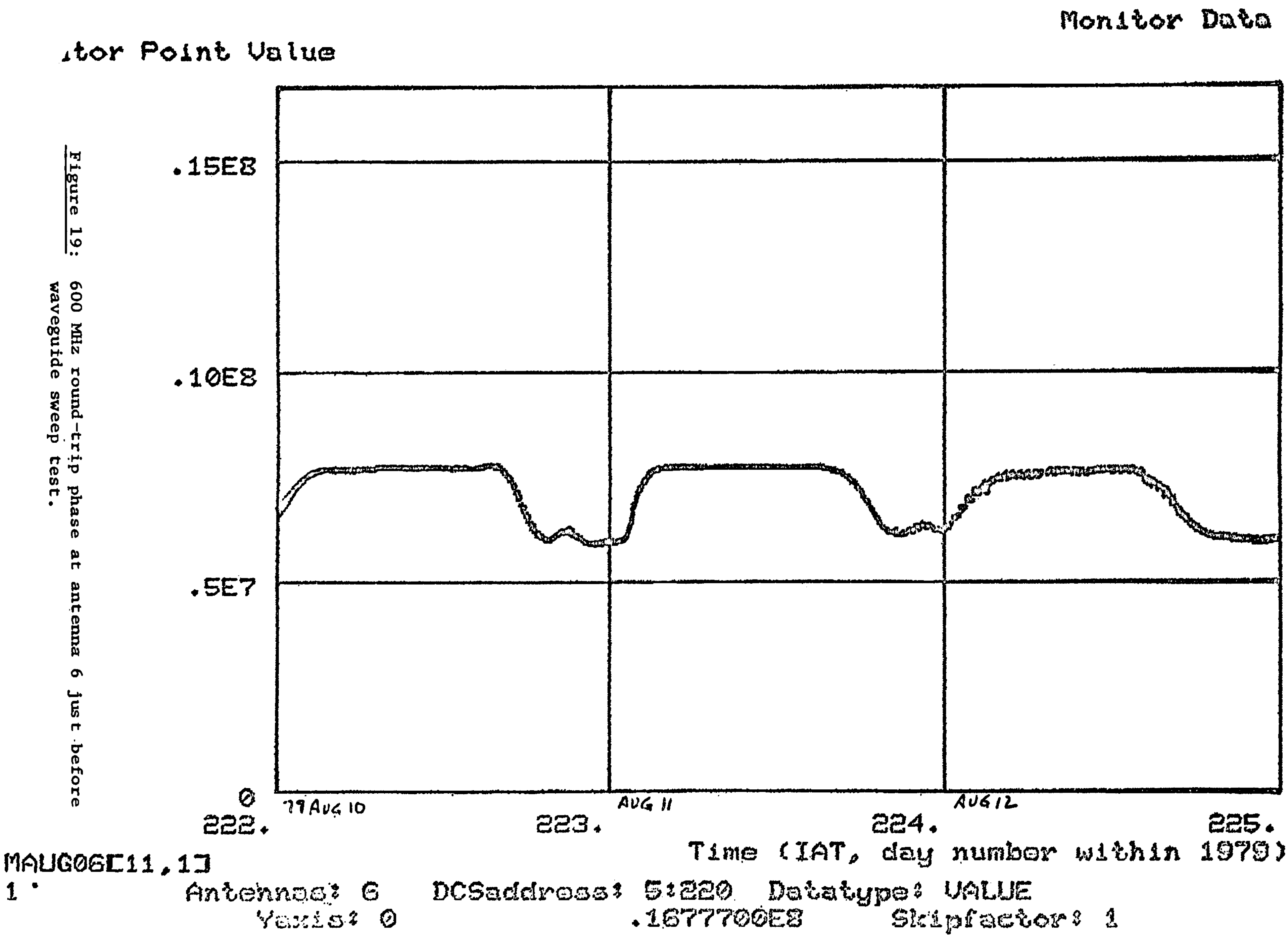
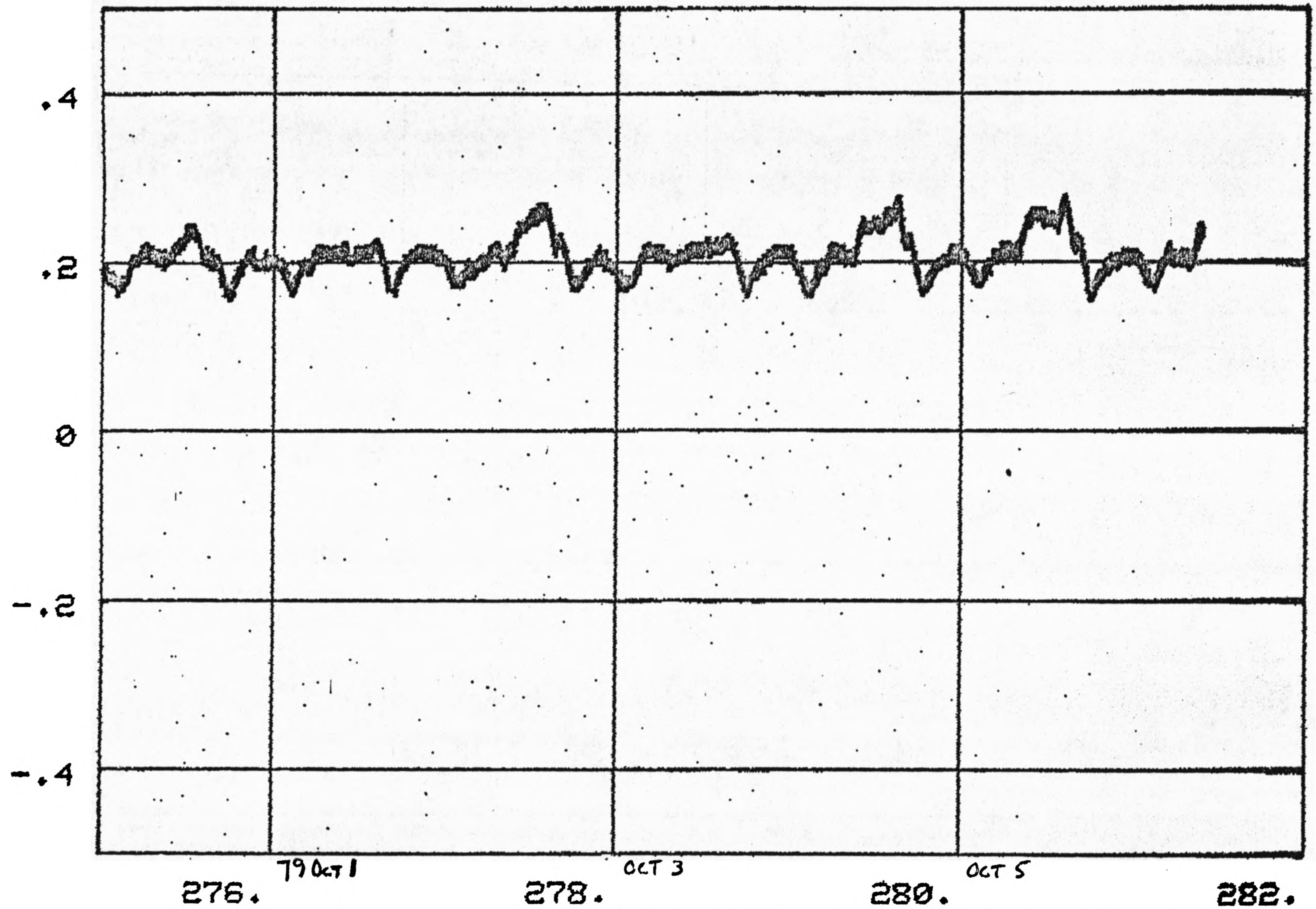


Figure 19: 600 MHz round-trip phase at antenna 6 just before waveguide sweep test.

Monitor Data

cor Point Value



Time (IAT, day number within 1979)

MOCT01[11,1]
1 Antennas: 6 DCSaddress: 2:024 Datatype: VALUE
Yaxis: -.5000000 .5000000 Skipfactor: 1

Figure 20: 5 MHz phase at antenna 6 after repair of faulty elevation rotary joint.

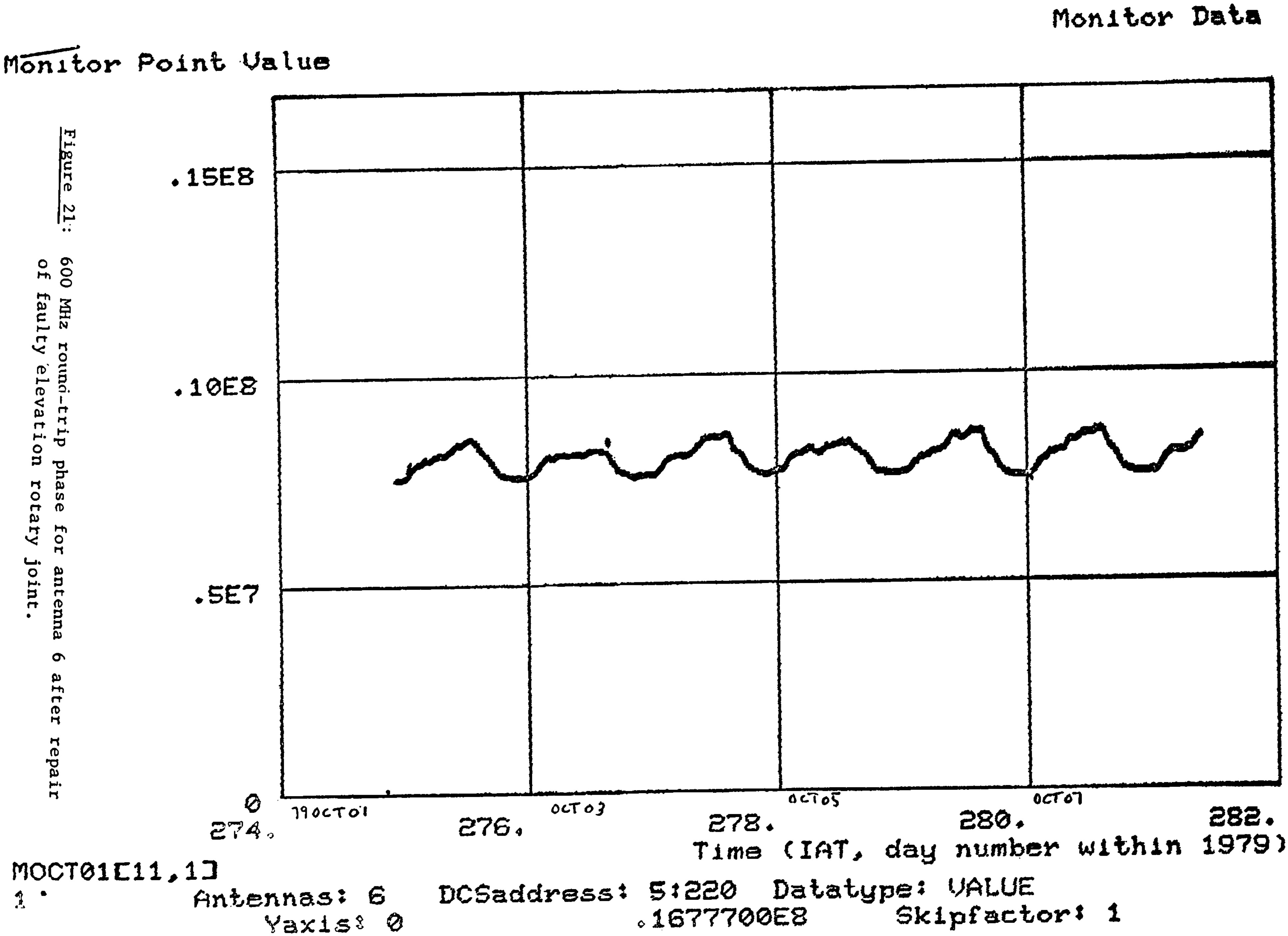


Figure 21: 600 MHz round-trip phase for antenna 6 after repair of faulty elevation rotary joint.

APPENDIX 1

A listing of the DMT control file used for waveguide sweeps (called DMTSWEEP) is shown below:

```
 1  T
 2  CS '46,'300,5
 3  Z M #3219 96
 4  Z M #30B9 0
 5  Z M #30C9 0
 6  CS 0,'361,2
 7  CS 0,'362,2
 8  S '46 5
 9  CS 0 '360,2
10  DELAY 216
11  F 5
12  ASSIGN
```

Line 2 is a single-shot command to cause the data set to select address '46 for Monitor Word 2.

Line 3-5 are a core patch required by a peculiarity of the DCS task in MONTY.

Line 6 halts the sweep.

Line 7 PRESETS sweep (to number selected on front panel).

Line 8 saves the data in address octal 46 (hex 26) every waveguide cycle.

Line 9 starts the sweep.

Line 10 is a delay lasting the length of the sweep.

Line 11 RESETS the data set.

Line 12 returns control to the terminal.

A listing of the calibration control file, DMTSWCAL, is given below:

```
 1  T
 2  CS '46,'300,5
 3  Z M #3219 96
 4  Z M #30B9 0
 5  Z M #30C9 0
 6  CS 0,'361,5,'14
 7  CS 0,'362,5,'14
 8  S '46 5
 9  CS 0 '360,5,'14
10  DELAY 216
11  F 5
12  ASSIGN
```

The commands are the same as for DMTSWEEP except that the commands to the special T2 have an address corresponding to the D rack where the special T2 was located during the calibration run (in this case 14_8). These commands are normally sent to the address defaulted before commencing the sweep (see Appendix 2). During the tests carried out in July and August 1979, the files DMTSWEEP and DMTSWCAL were stored in partitions DDD and DDC on "Boss'" disk. The core patches may change as the system is changed.

APPENDIX 2

Instructions for telescope operators when running sweep tests on waveguide system and modems.

A special T2 module will be placed in both the B and D racks of the antenna being tested.

I will call from the antenna and ask you to:

(1) Turn receive/transmit switch on that antenna's T1 module from "AUTO" to "XMT".

(2) Soon after I will ask you to return it to "AUTO".

(3) In DMT, type I G look for xm instead of X. If xm appears, someone else is selecting monitor data and I cannot carry out the test until they stop.

(4) If (3) is clear, assign monitor data output to my mag tape: In Monty's OC

    /DCS/ASS MDO MTn (where n is 1 or 2)
    //R.

(5) Give control of that antenna to SB6 (or any convenient DMT terminal).

(6) Make sure antenna is taken.

(7) On SB6: N A 'n (n is octal address for antenna).
    ASS DDD.

This command starts the sweep which lasts for 216 seconds during which time SB6 is "incommunicado".

(8) I will call back when sweep has finished and ask if mag tape has been moving.

(9) If all went well I will ask for end of file to be written on mag tape in Monty OC. (e.g., F7 on SB5).

    /DCS/WEOF MDO
    /ASS MDO MDO
    //H.

(10) Next antenna.