$\bar{p}$ Note #414

REPORT ON FURUKAWA COAX #1

26 November 1984

David W. Peterson

INTRODUCTION :

This report contains the results of measurements performed on sample coax #1 from the Furukawa Cable Co. of Japan. Time domain reflectometer (TDR) and RLC measurements were made at room temperature and superconducting. Network analyzer measurements of S11 and S21 were made for the superconducting coax.

COAX CHARACTERISTICS :

Production No. CH-60058
Piece No. 1

TEST ITEM	SPECIFICATION	TEST RESULT
Inner cond. diam.	0.460 +/- 0.001 mm	0.458 mm
Dielectric diam.	1.57 +/- 0.01 mm	1.567 mm
Inner diam. of outer conductor	1.60 +/- 0.01 mm	1.594 mm
Polyethylene terphthalate film	0.025 mm Thick 9 mm Wide	0.023 mm 9.0 mm
Overall diam.	1.85 +/- 0.1 mm	1.90 mm
Characteristic impedance at -196 C	----	52.6 Ohms

(The above information was furnished by the manufacturer.)

TDR MEASUREMENTS :

The following figures show TDR measurements of the coax at room temperature and at superconducting temperature. The center horizontal line in each photo is the 50 Ohm reference level and each vertical division is 2 Ohms. The horizontal axis in each picture is 2 nSec per division.

Note the discontinuities at the junction to the sample cable in the photos of the warm test and those at the junctions at the top of the dewar and at the coax sample in the superconducting tests.

The TDR photos show that the warm cable has an impedance of roughly 56 Ohms at the end on the inside of the spool and 54 Ohms at the end on the outside of the spool.

For the superconducting cable the impedance at both ends is betwwen 51 and 52 Ohms, on the average being about 51.5 Ohms.

RLC MEASUREMENTS :

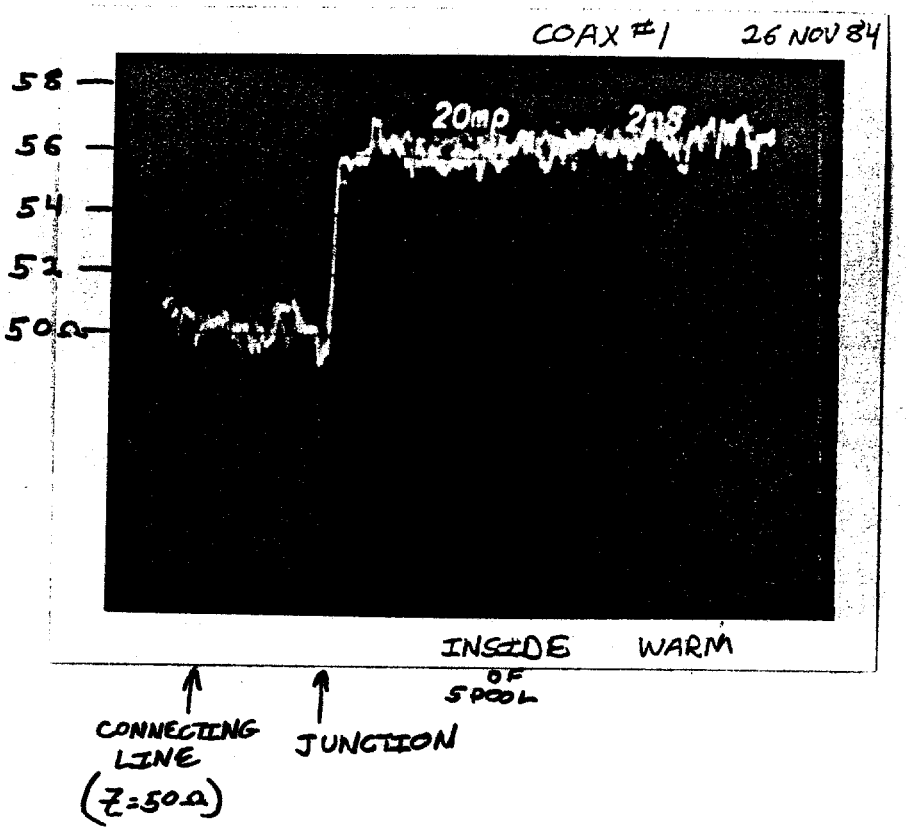
Measurements of resistance, inductance and capacitance of the sample were made at room temperature and superconducting. The results are shown in the following table.

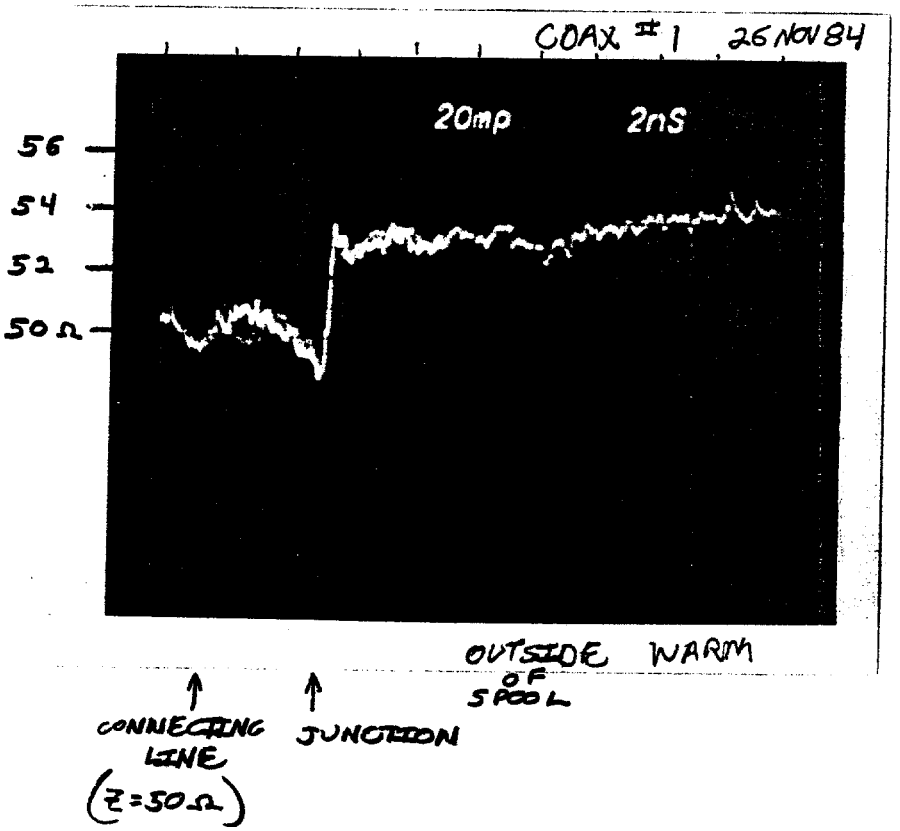
			Measured	Expected
Warm:	Resistance -	inner cond.	44.0 Ohms	40.81 Ohms
		outer cond.	14.1 Ohms	11.76 Ohms
	Capacitance -		36.22 nF	35.99 nF
		dissipation factor	0.0045	0.0065
	Inductance -		200.0 uH	119.96 uH
		Q	0.022	0.013
Superconducting:		(feedlines subtracted)		
	Resistance -	inner cond.	0.0 Ohms	0 Ohms
		outer cond.	0.0 Ohms	0 Ohms
	Capacitance -		36.60 nF	37.02 nF
		dissipation factor	0	0
	Inductance -		98.6 uH	97.53 uH
		Q (feed included)	1.1	
	Calculated characteristic impedance		51.9 Ohms	51.33 Ohms

Assuming Z=50 Ohms, epsilon=2.1, L=390 m and coax dimensions as measured by manufacturer.

* Measured using a General Radio Company Type 1656 Impedance Bridge.

TDR MEASUREMENTS (WARM)

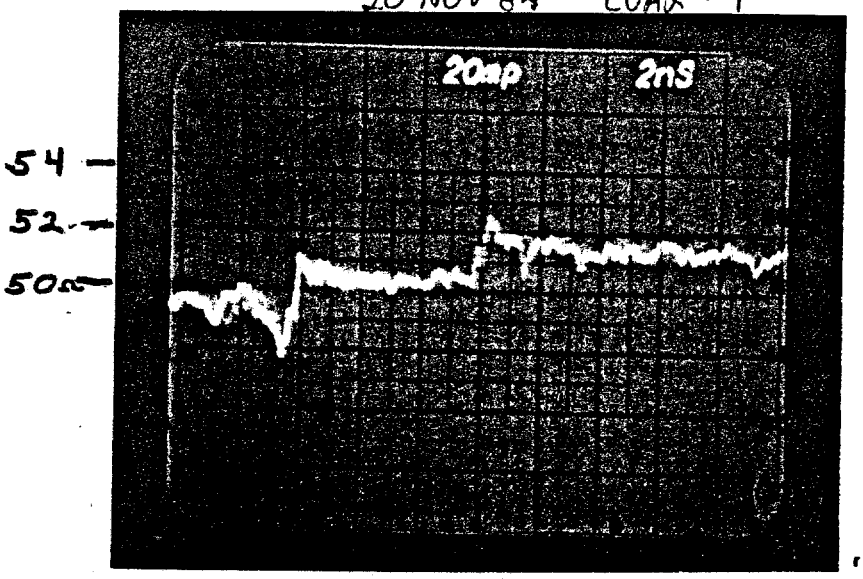




TDR MEASUREMENTS

(SUPERCONDUTING)

20 NOV 84 COAX #1

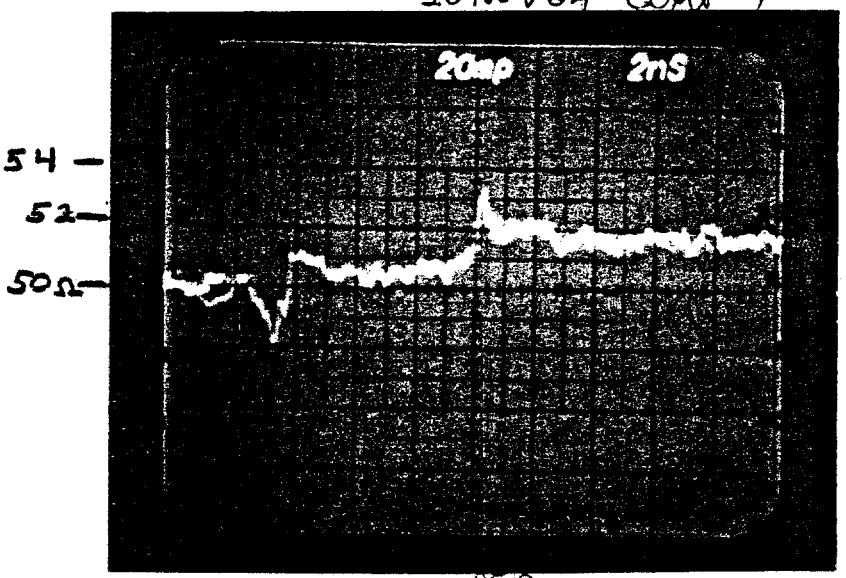


DEWAR TOP

SUPER LINE START

NEAR (INNER) LAYER OF SPOOL

20 NOV 84 COAX #1



DEWAR TOP

SUPER LINE START

FAR (OUTER) LAYER OF SPOOL

S-PARAMETER MEASUREMENTS :

The following plots are for the superconducting coax #1 as measured by a Hewlett-Packard 8410C automated network analyzer. Shown are S11, S21 and S21 with feedlines subtracted for the following ranges;

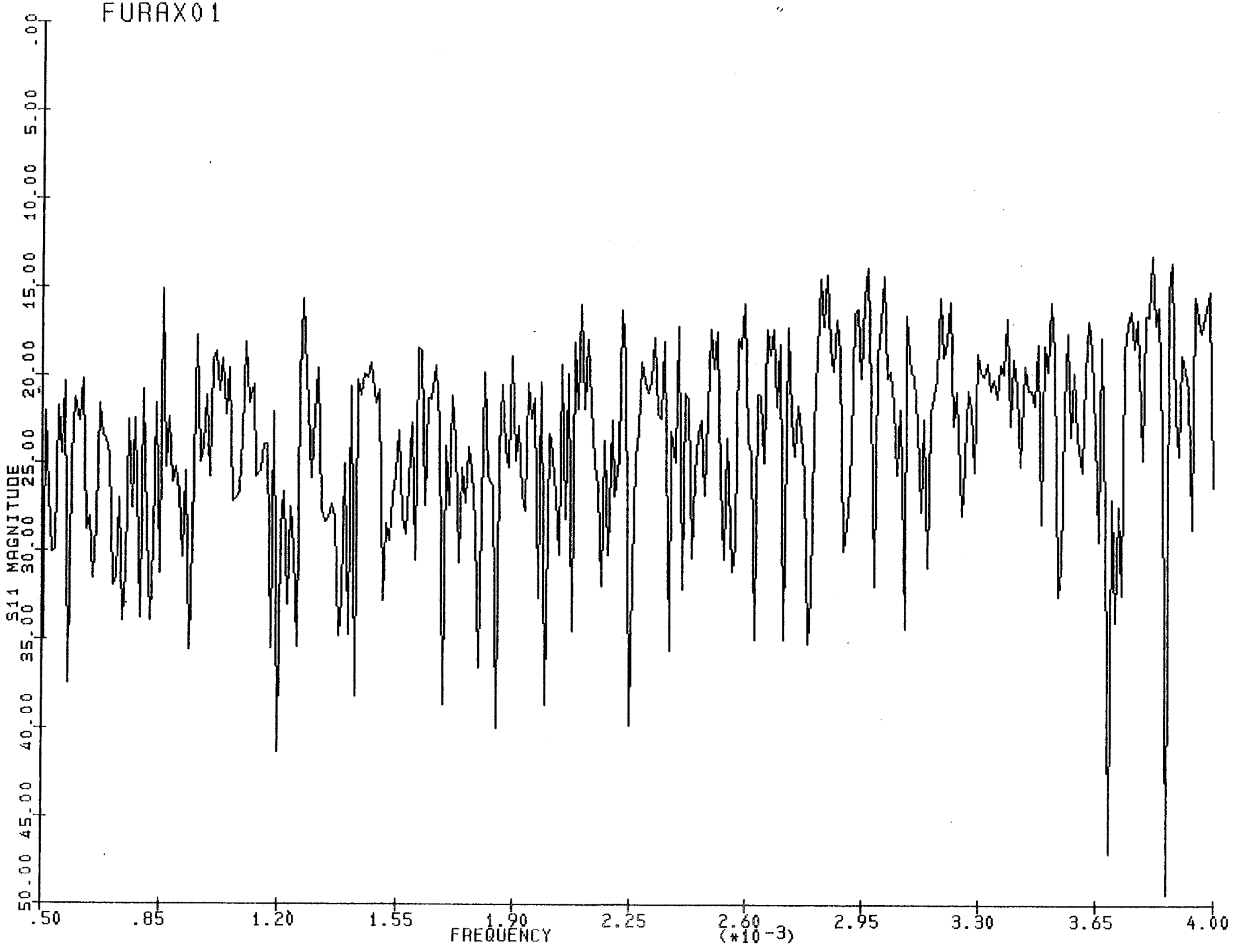
NAME	START (MHz)	STOP (MHz)	STEP (MHz)
FURAX01	500	4000	10
FURAX02	4000	8000	10
FURAX03	800	1500	2
FURAX04	1500	2200	2
FURAX05	1500	3000	5
FURAX06	3000	4500	5
FURAX07	1400	1500	0.25
FURAX08	1500	1600	0.25
FURAX09	1490	1500	0.025
FURAX10	1500	1510	0.025
FURAX11	1500	1501	0.0025

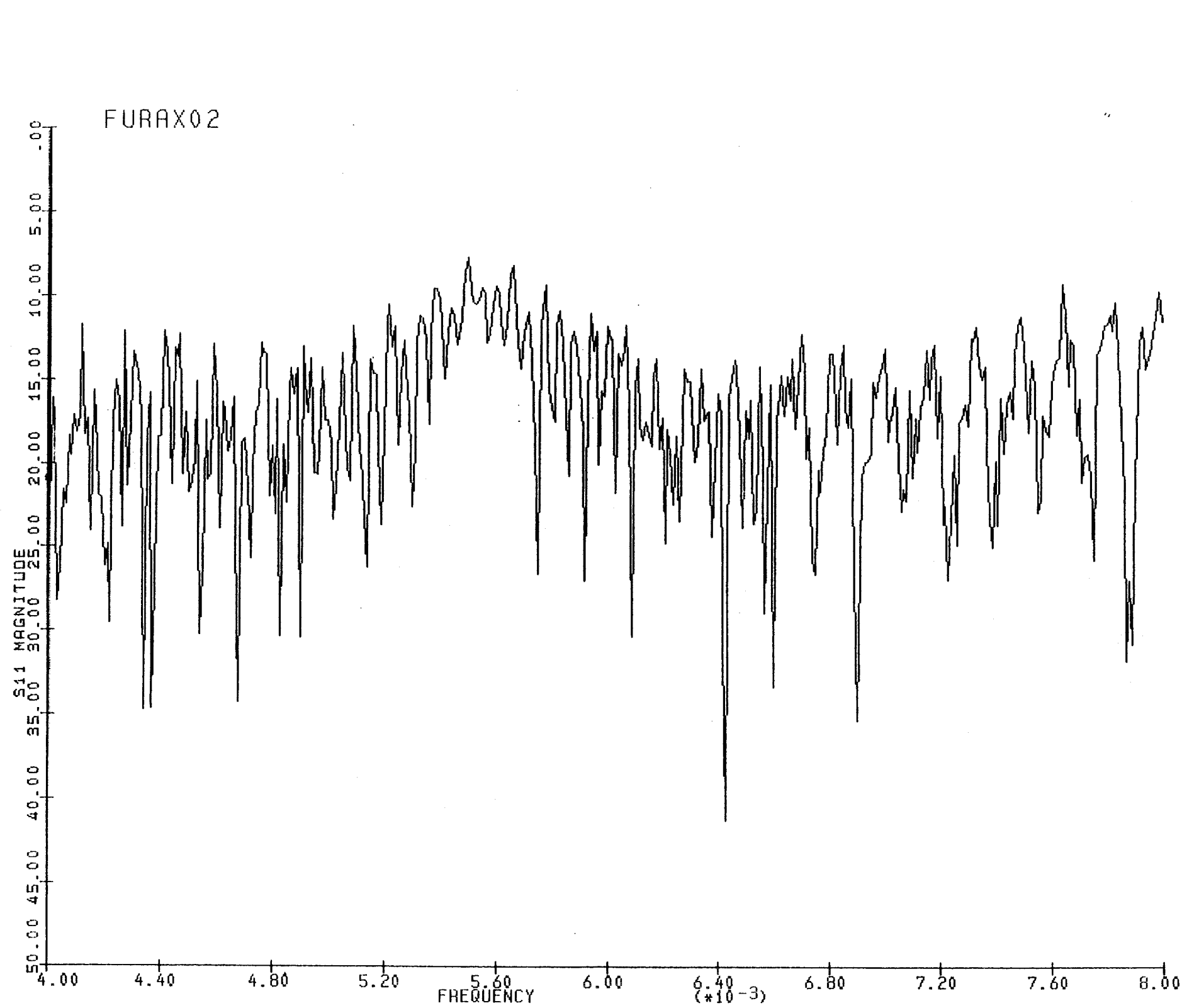
The plots of S11 show the periodic nature of the coax characteristics, particularly FURAX11 which has the greatest resolution. The plots of the corrected S21 have the effect of the stainless steel feedlines subtracted out using the model of the stainless line as

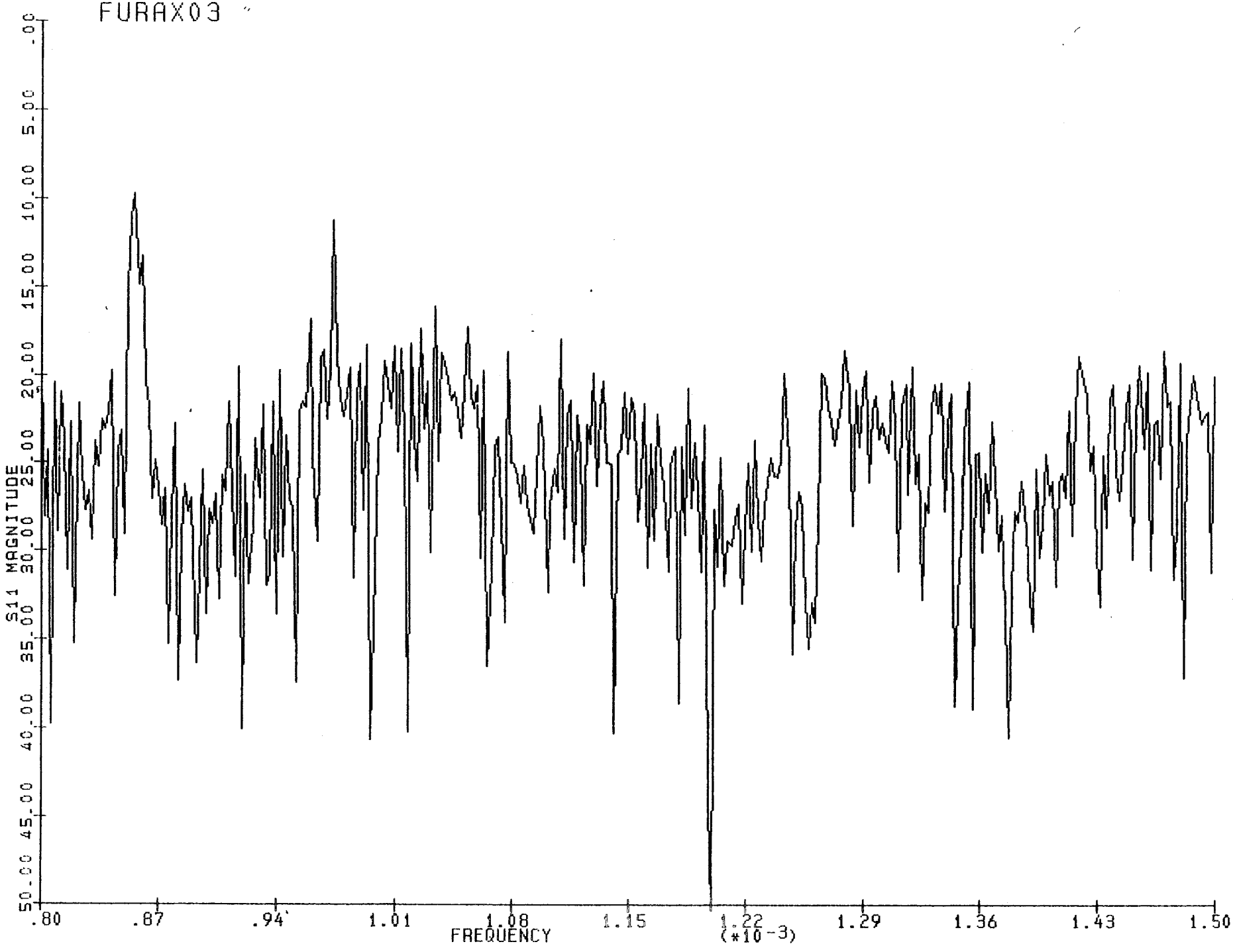
attenuation of stainless line (dB) = .81 + Freq (MHZ)x 0.00056394

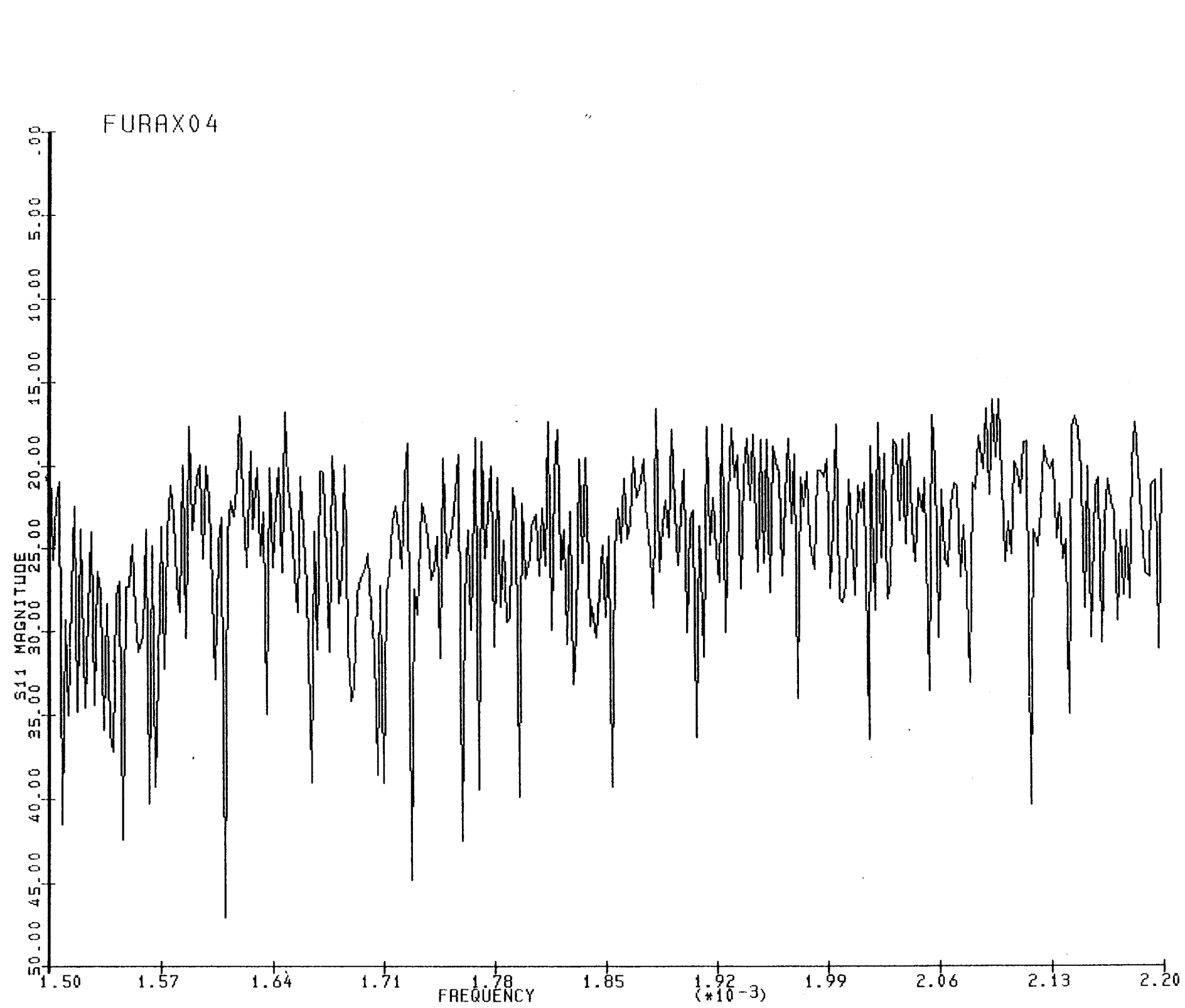
This model is from data taken on typical stainless steel transition lines used in other tests.

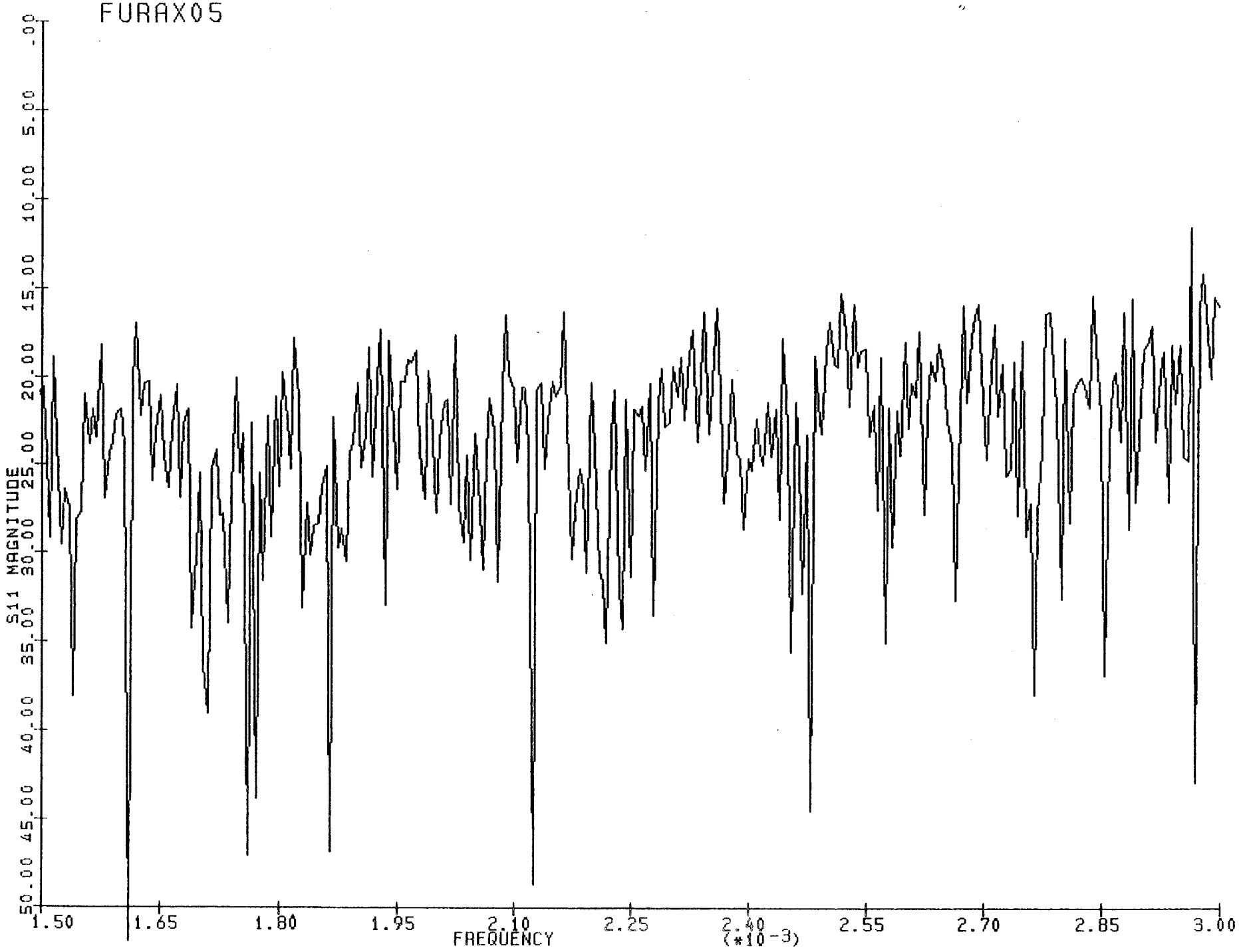
Areas of note are in the S21 plot FURAX02 which shows a resonance at 5.5 GHZ and the plot of FURAX03 which shows two spikes below 1 GHz.

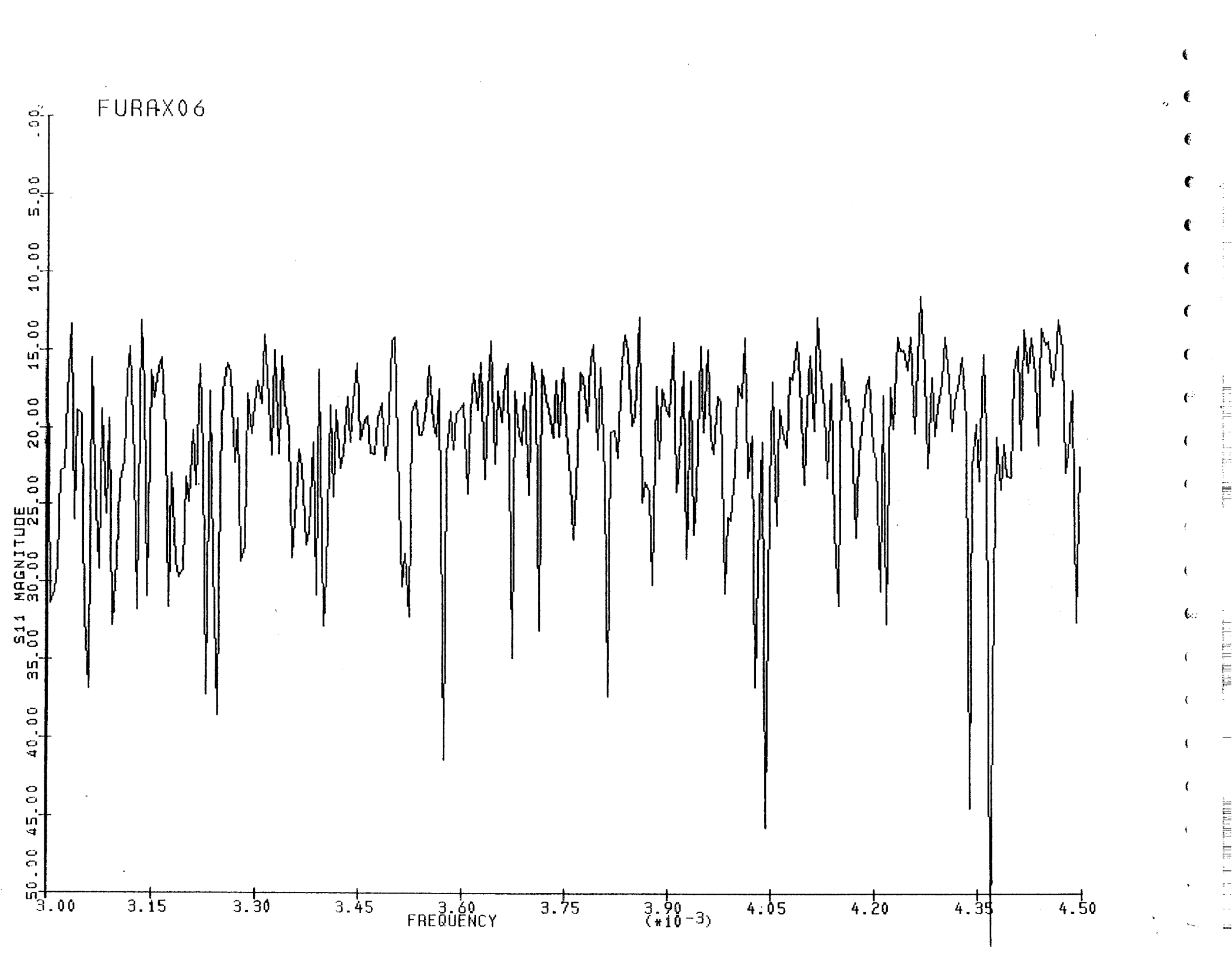

FURAX01
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
.50
.85
1.20
1.55
1.90
2.25
2.60
2.95
3.30
3.65
4.00
FREQUENCY
(*10-3)

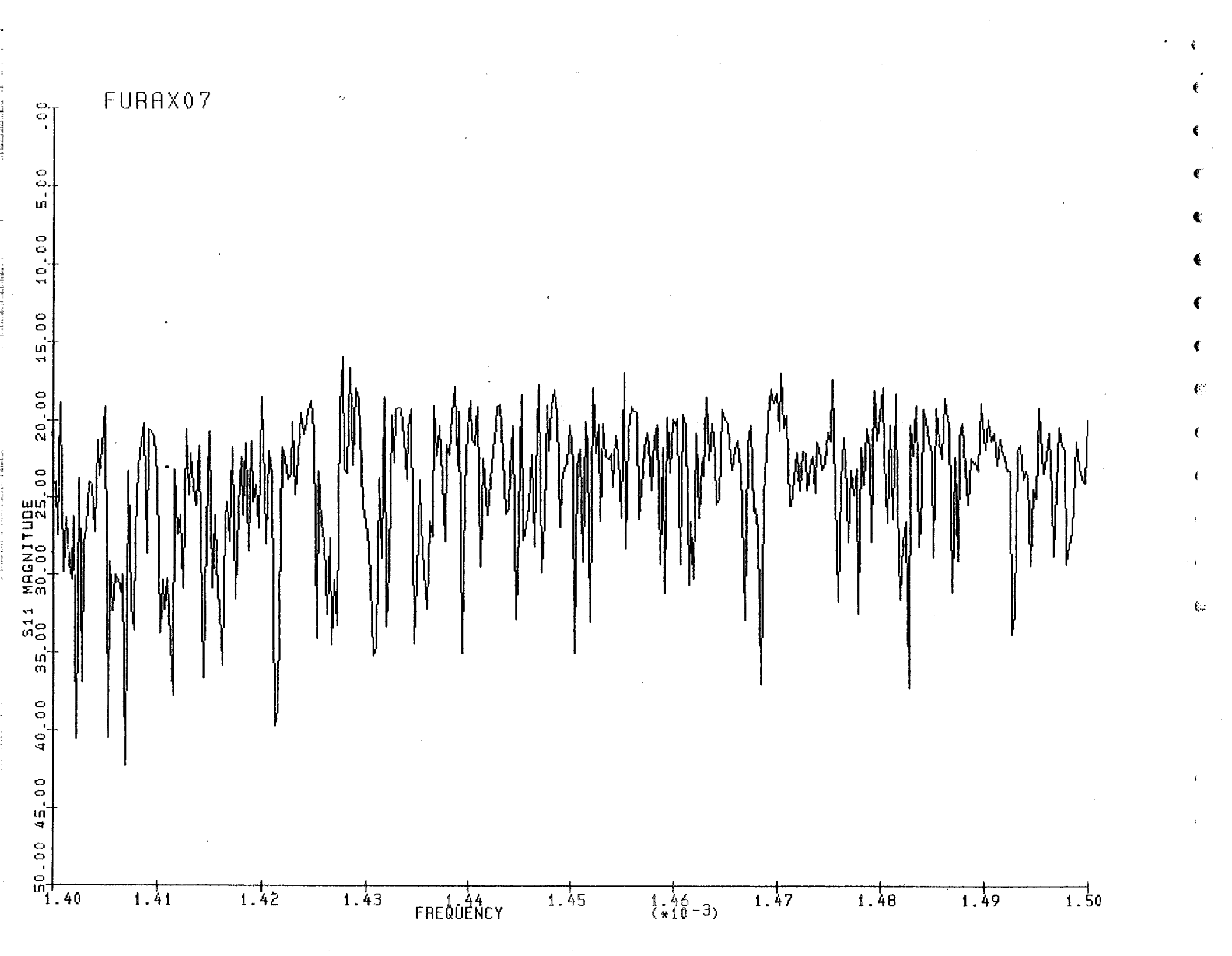

FURAX02
S11 MAGNITUDE
-.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
4.00
4.40
4.80
5.20
5.60
6.00
6.40
6.80
7.20
7.60
8.00
FREQUENCY
(*10-3)

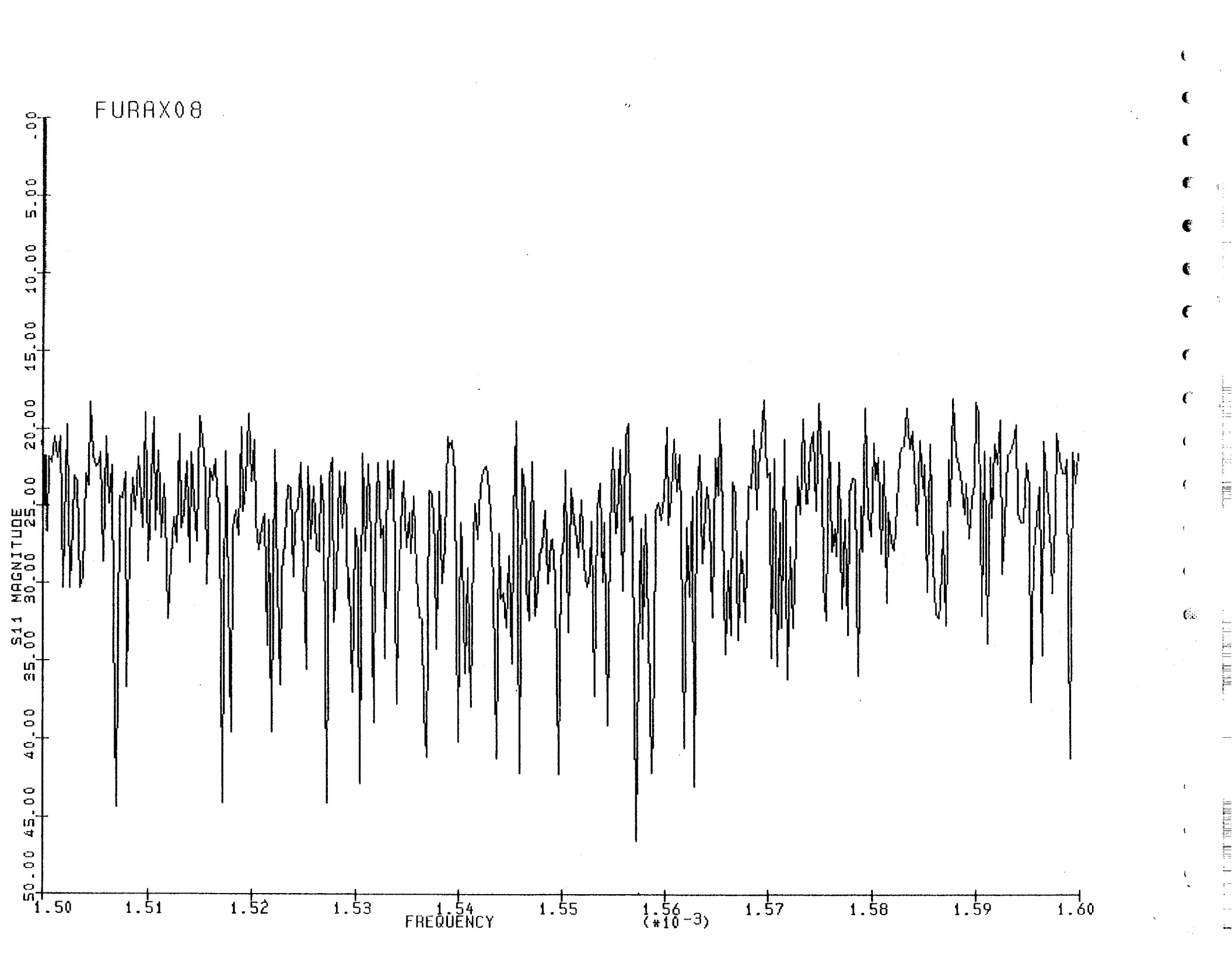

FURAX03
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
.80
.87
.94
1.01
1.08
1.15
1.22
1.29
1.36
1.43
1.50
FREQUENCY
(*10-3)

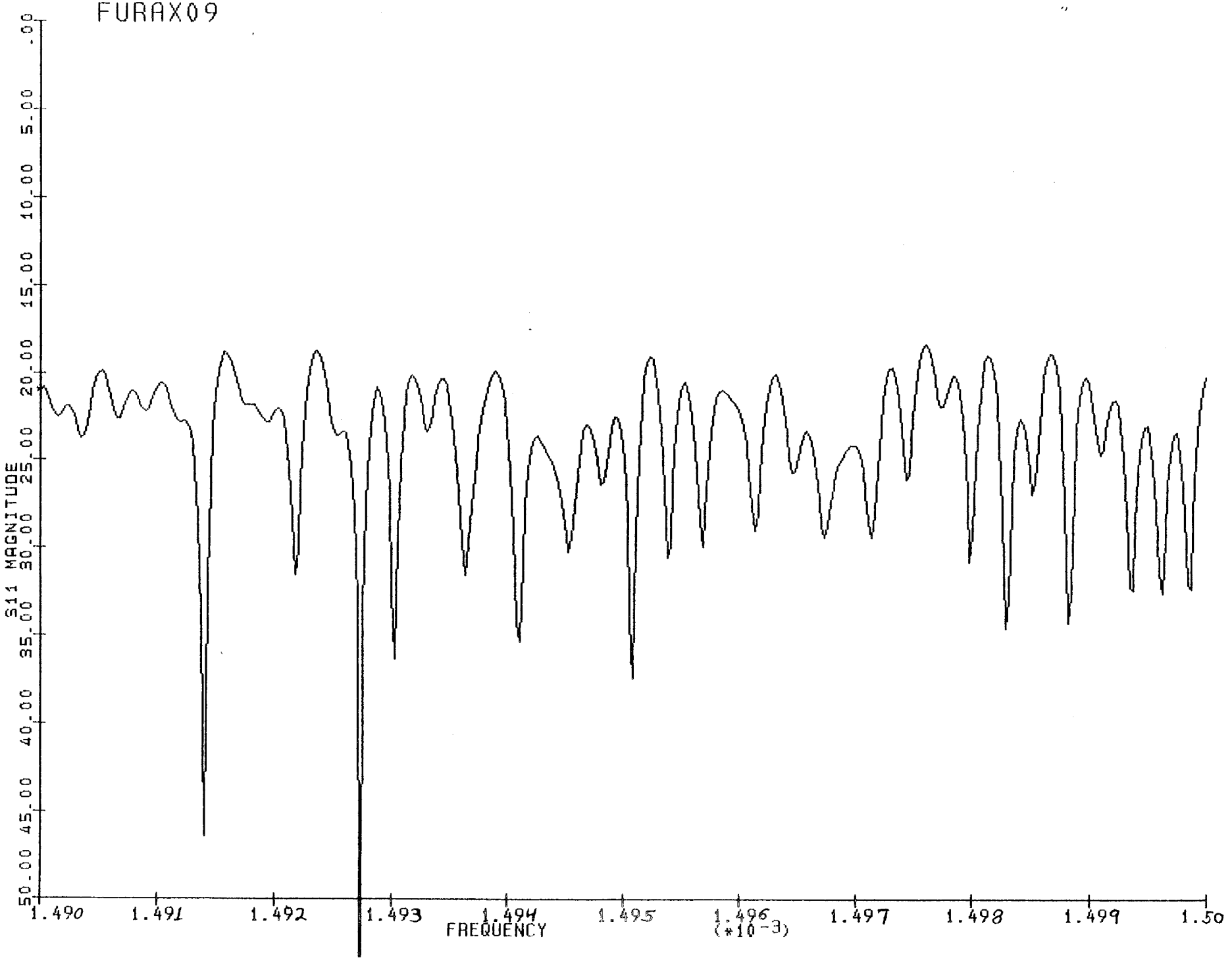

FURAX04
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.50
1.57
1.64
1.71
1.78
1.85
1.92
1.99
2.06
2.13
2.20
FREQUENCY
(*10-3)

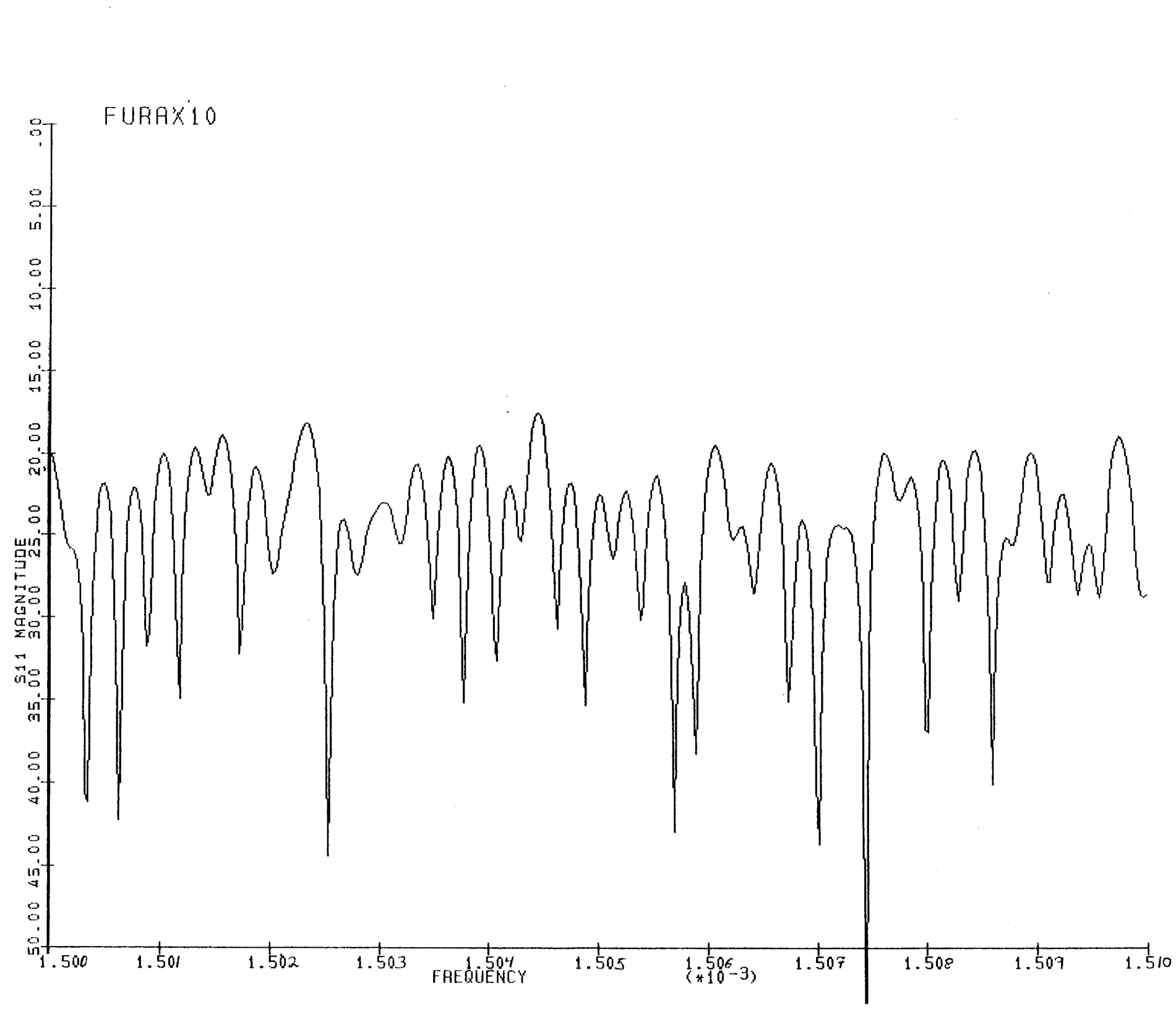

FURAX05
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.50
1.65
1.80
1.95
2.10
2.25
2.40
2.55
2.70
2.85
3.00
FREQUENCY
(*10-3)

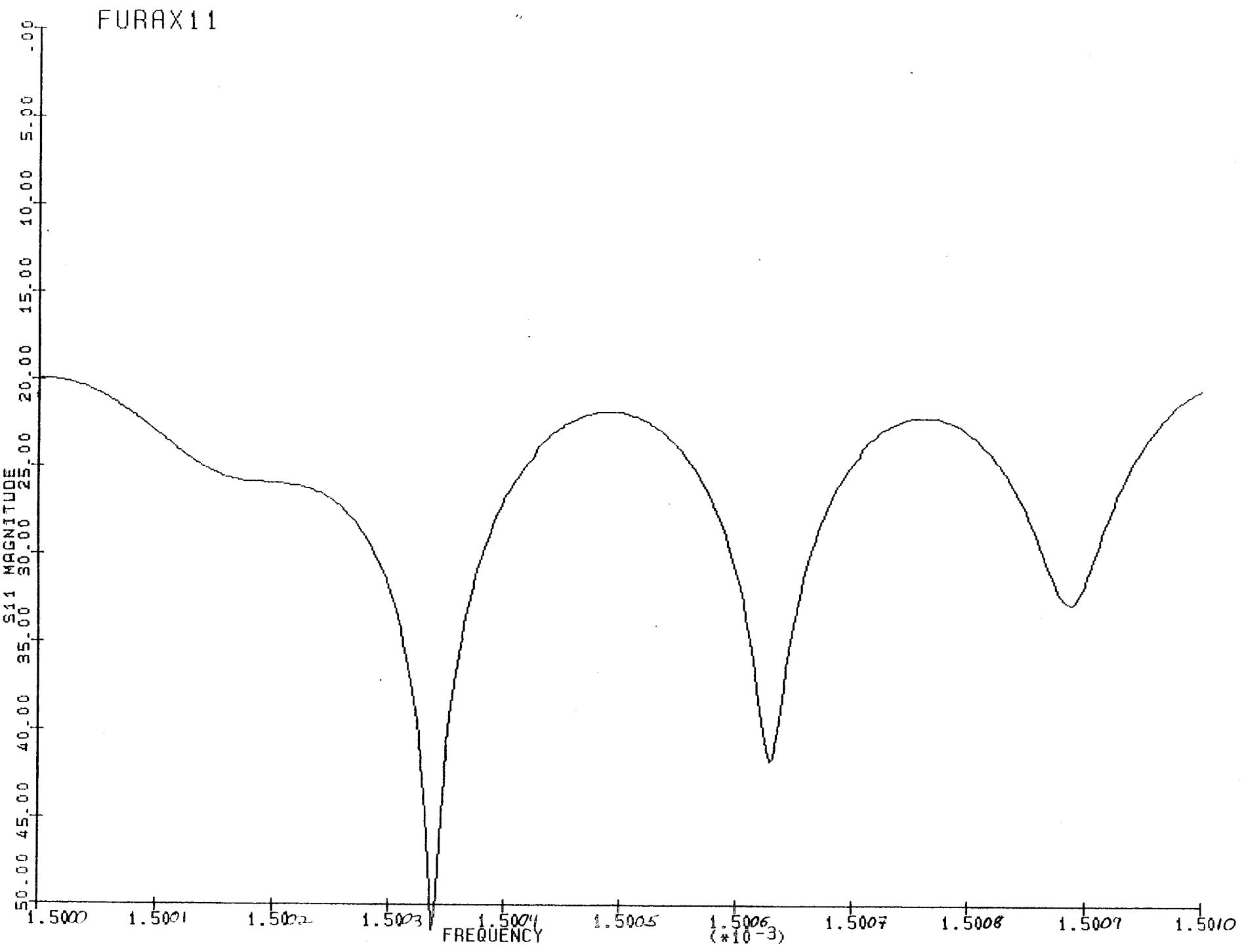

FURAX06
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
3.00
3.15
3.30
3.45
3.60
3.75
3.90
4.05
4.20
4.35
4.50
FREQUENCY
(*10-3)

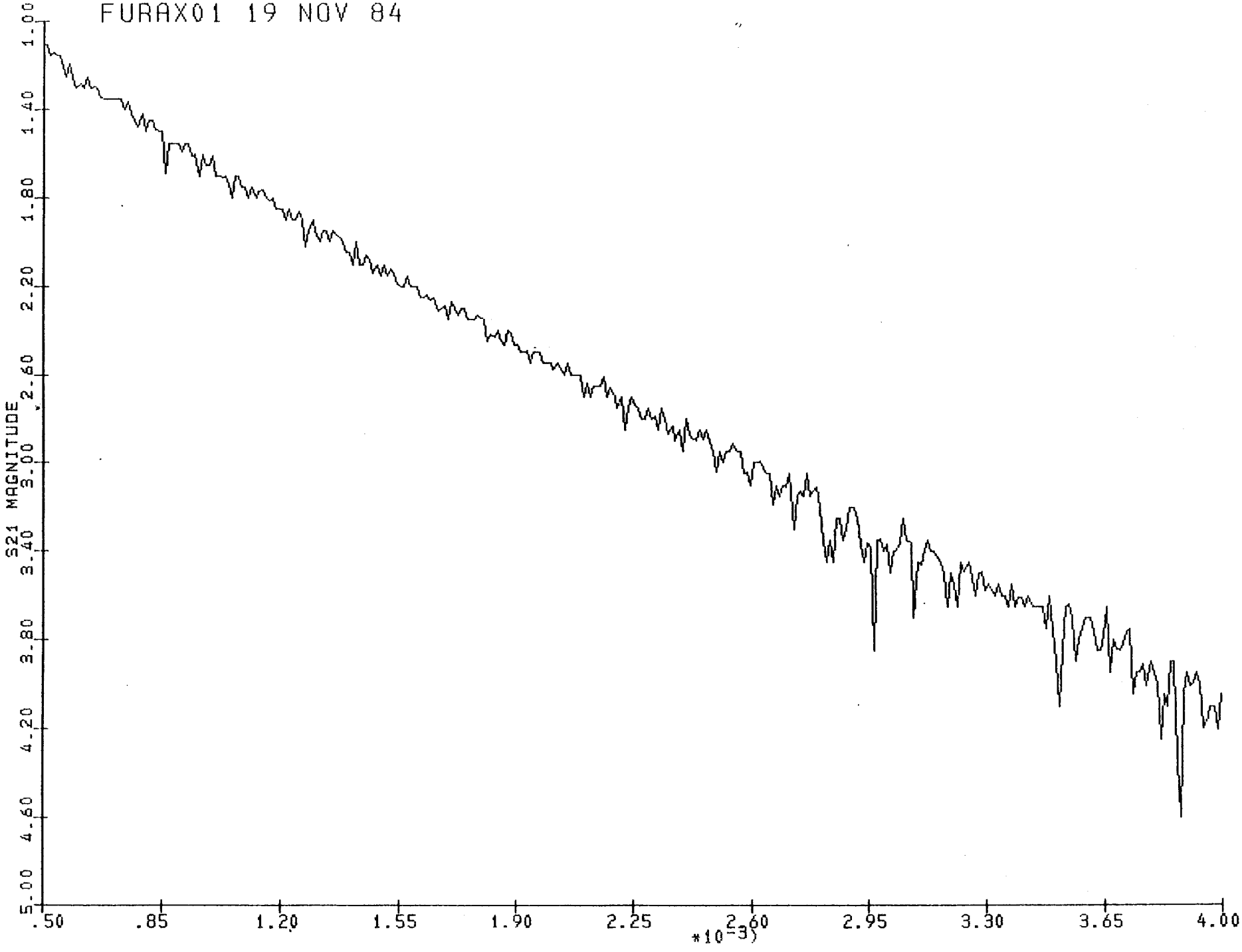

FURAX07
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.40
1.41
1.42
1.43
1.44
1.45
1.46
1.47
1.48
1.49
1.50
FREQUENCY
(*10-3)

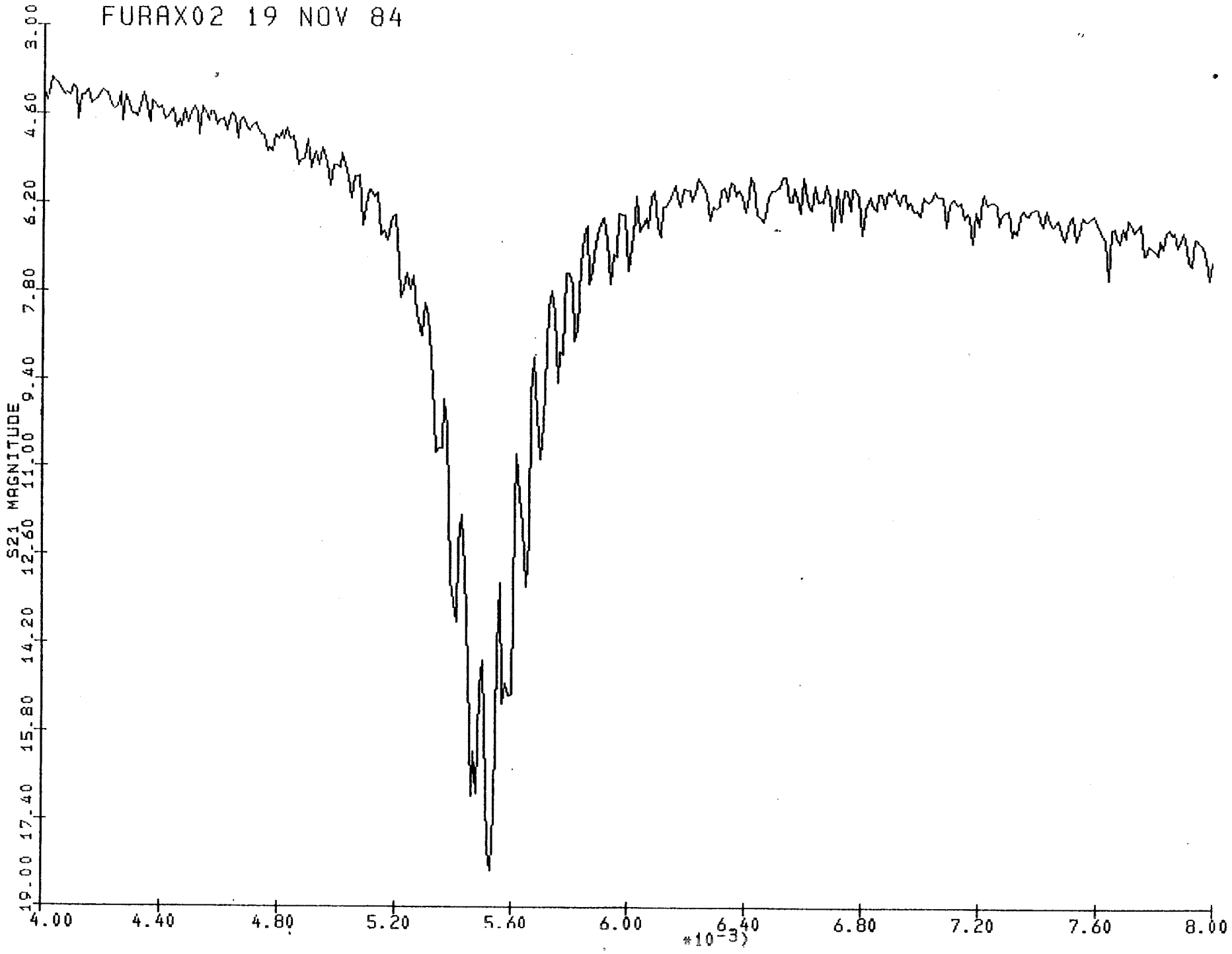

FURAX08
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.50
1.51
1.52
1.53
1.54
1.55
1.56
1.57
1.58
1.59
1.60
FREQUENCY
(*10-3)

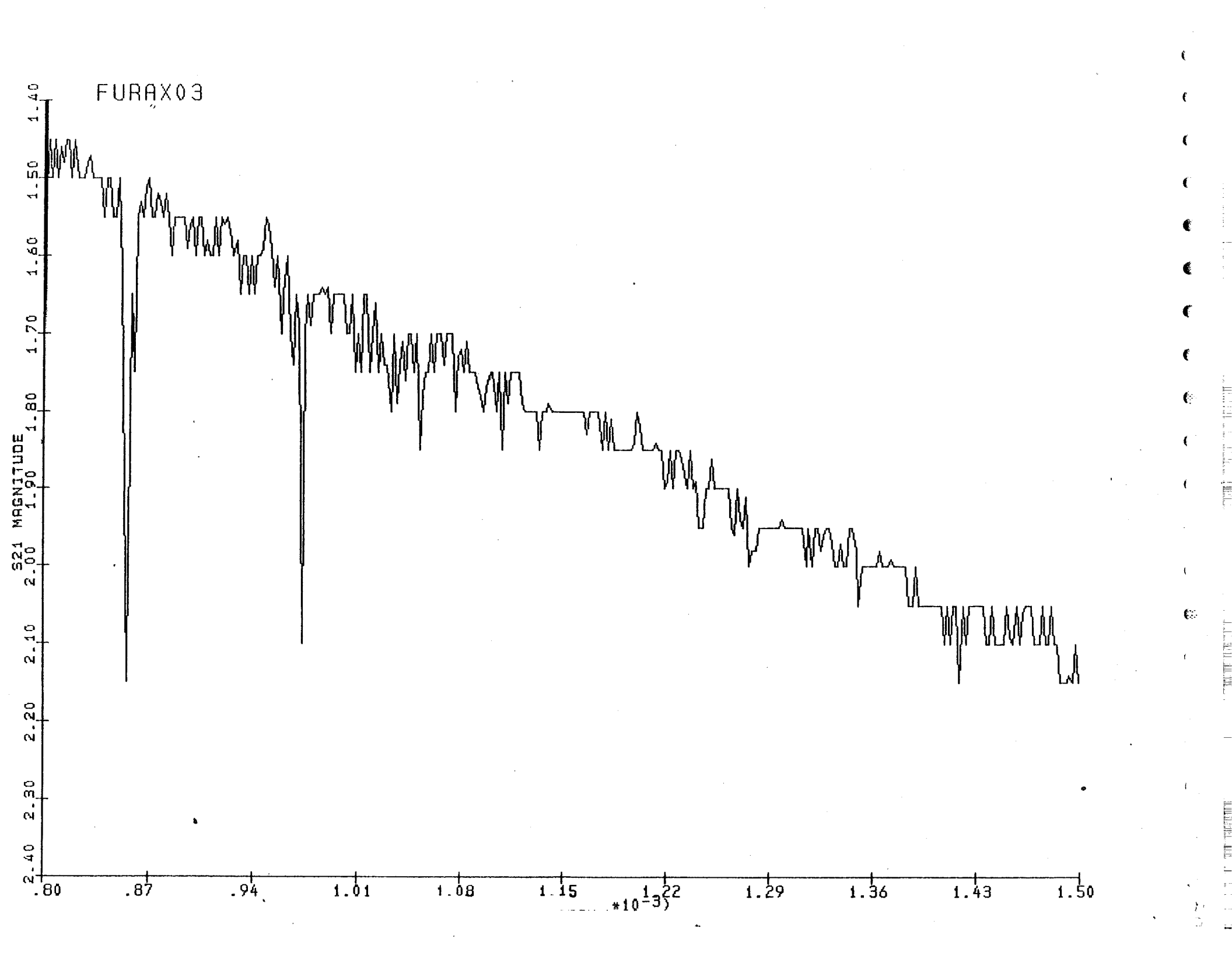

FURAX09
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.490
1.491
1.492
1.493
1.494
1.495
1.496
1.497
1.498
1.499
1.50
FREQUENCY
(*10-3)

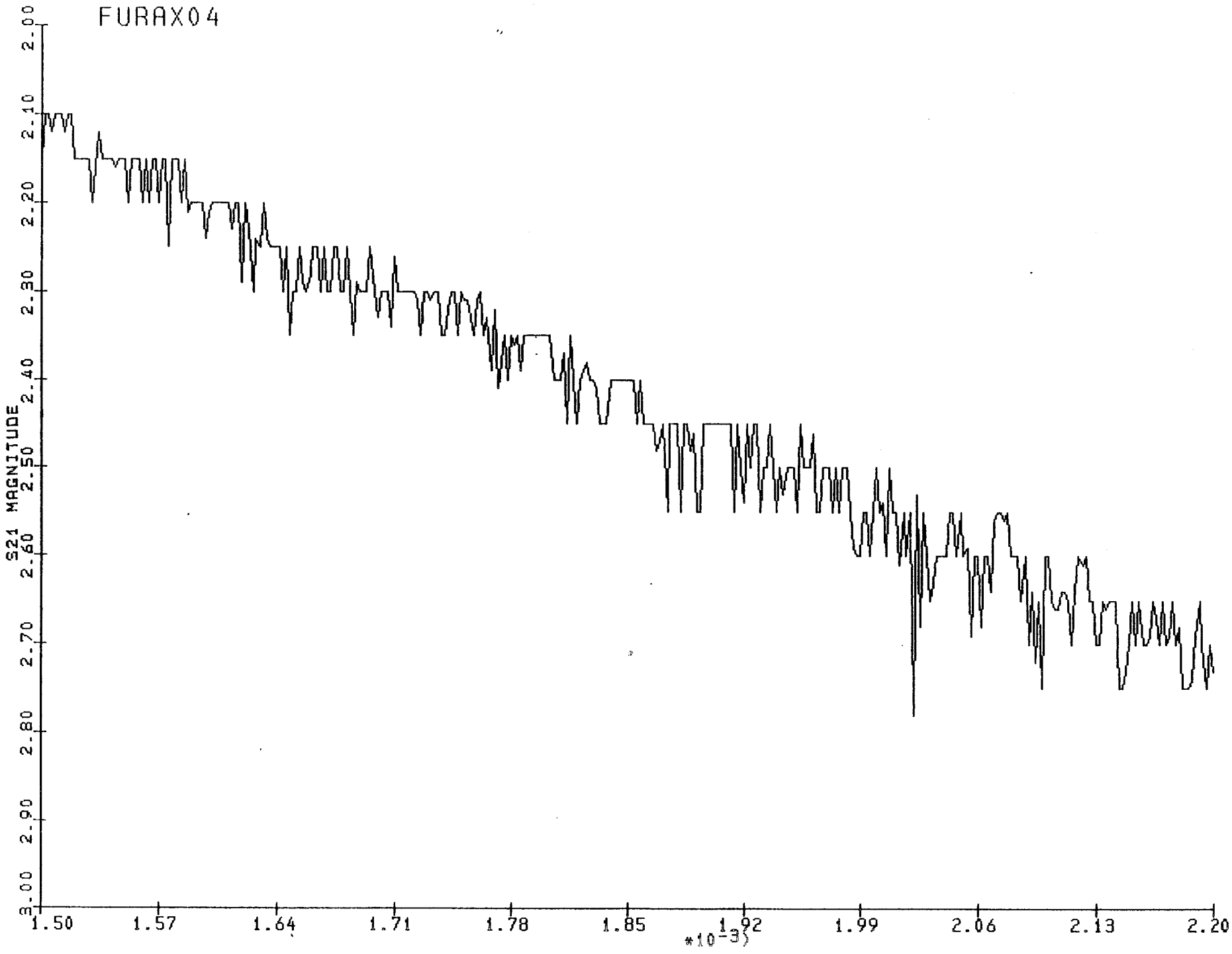

FURAX10
S11 MAGNITUDE
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.500
1.501
1.502
1.503
1.504
1.505
1.506
1.507
1.508
1.509
1.510
FREQUENCY
(*10-3)

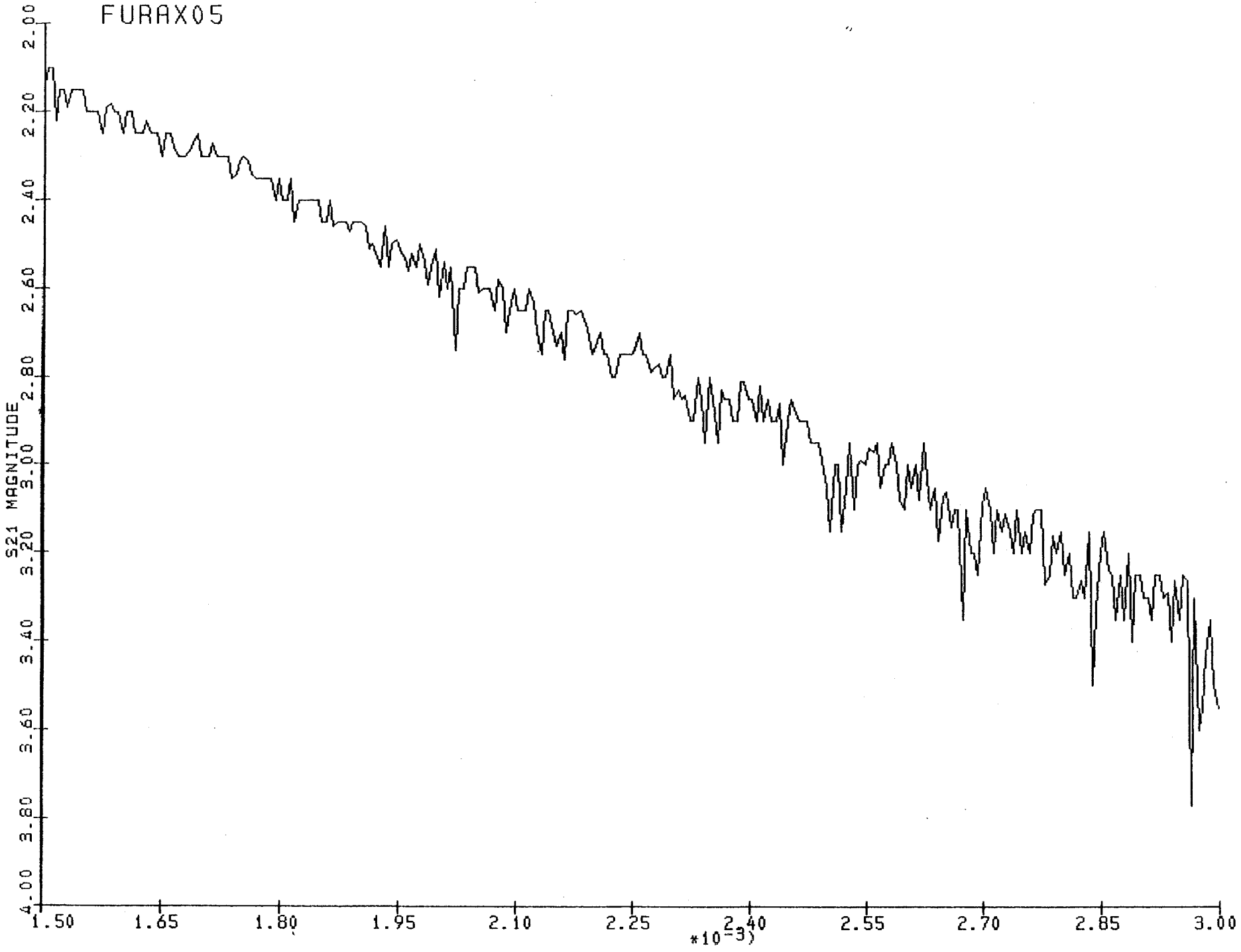

FURAX11
S11 MAGNITUDE
-.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
1.5000
1.5001
1.5002
1.5003
1.5004
1.5005
1.5006
1.5007
1.5008
1.5009
1.5010
FREQUENCY
(*10-3)

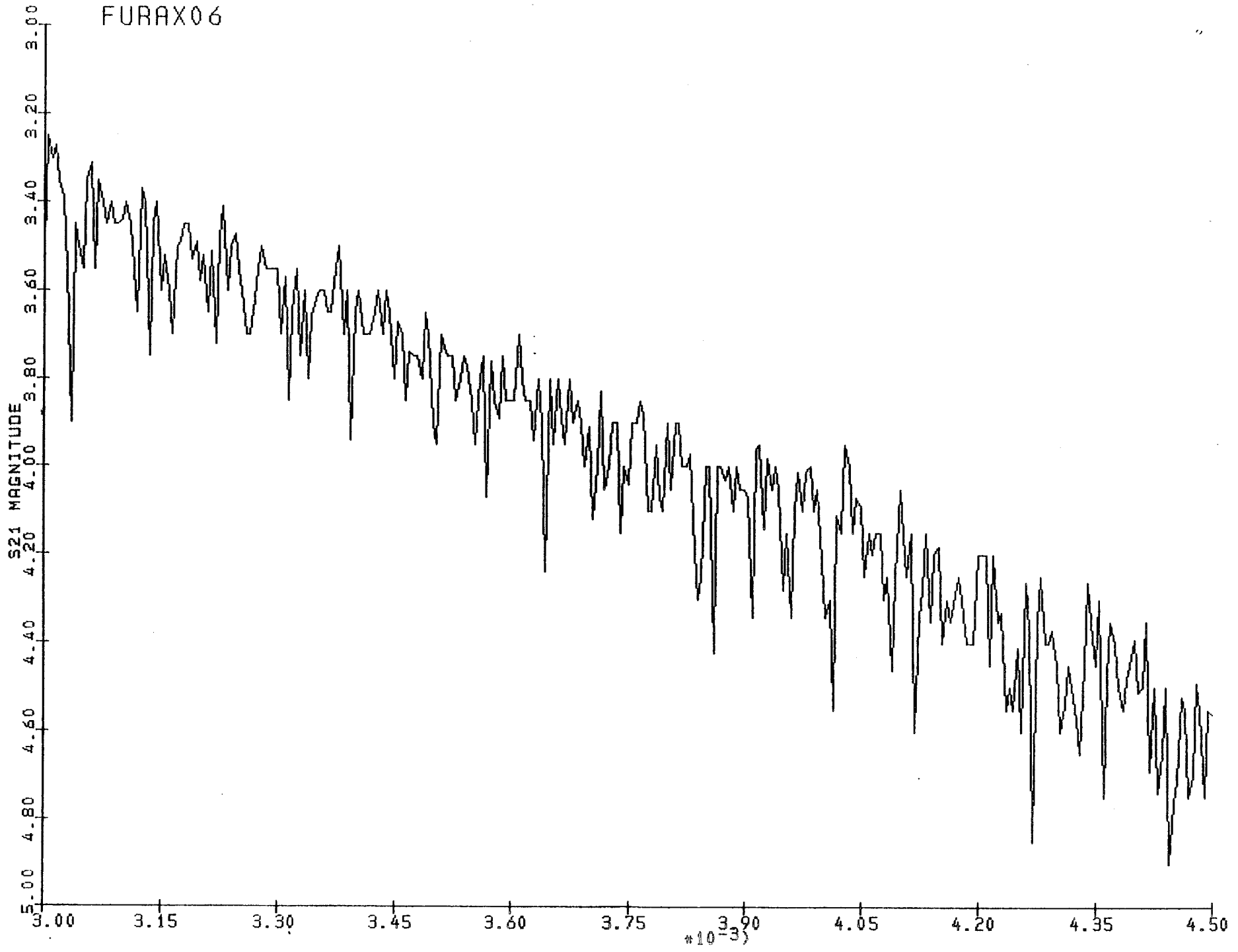

FURAX01 19 NOV 84
S21 MAGNITUDE
1.00
1.40
1.80
2.20
2.60
3.00
3.40
3.80
4.20
4.60
5.00
.50
.85
1.20
1.55
1.90
2.25
2.60
2.95
3.30
3.65
4.00
*10**3)

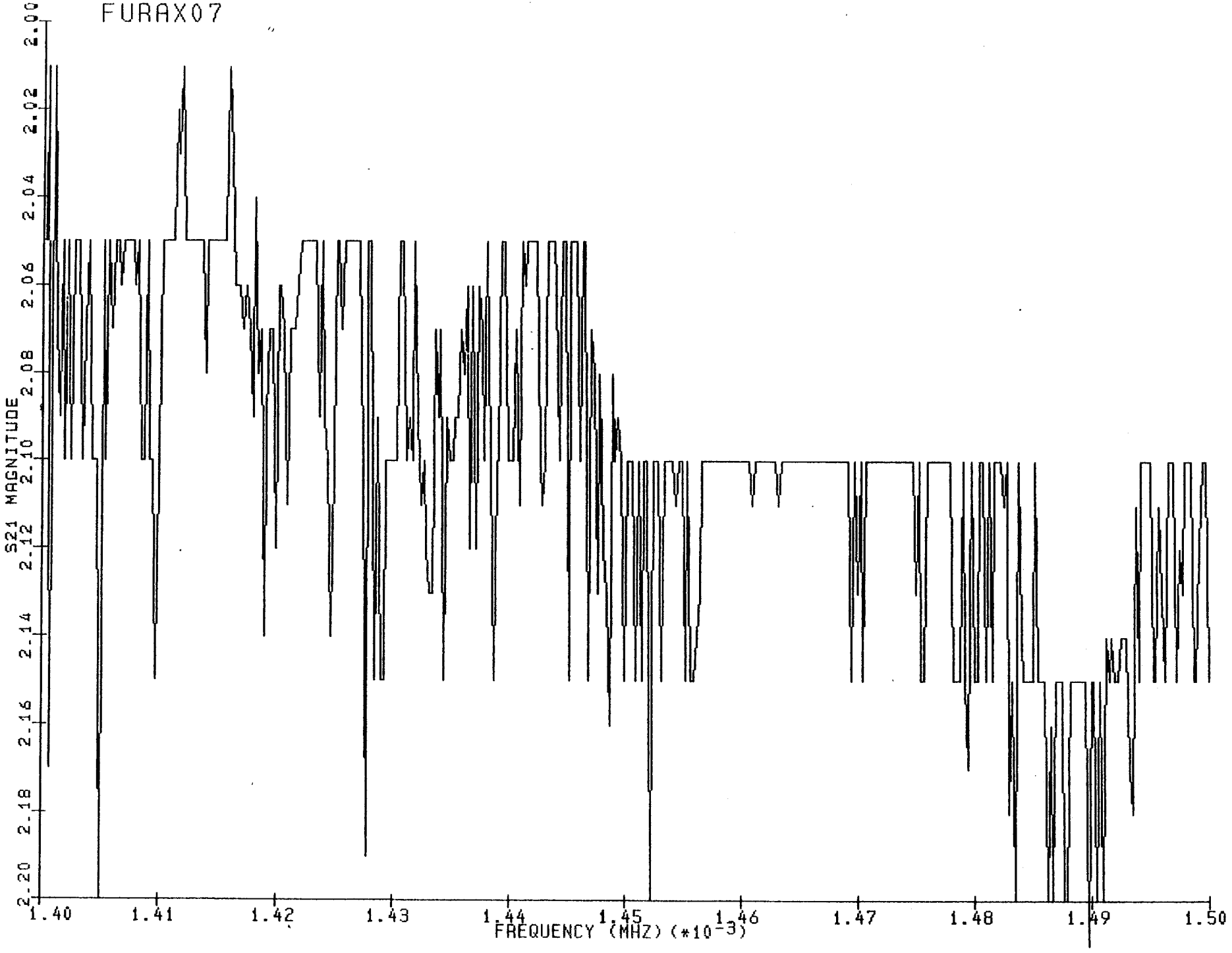

FURAX02 19 NOV 84
S21 MAGNITUDE
3.00
4.60
6.20
7.80
9.40
11.00
12.60
14.20
15.80
17.40
19.00
4.00
4.40
4.80
5.20
5.60
6.00
6.40
6.80
7.20
7.60
8.00
*10^-3)

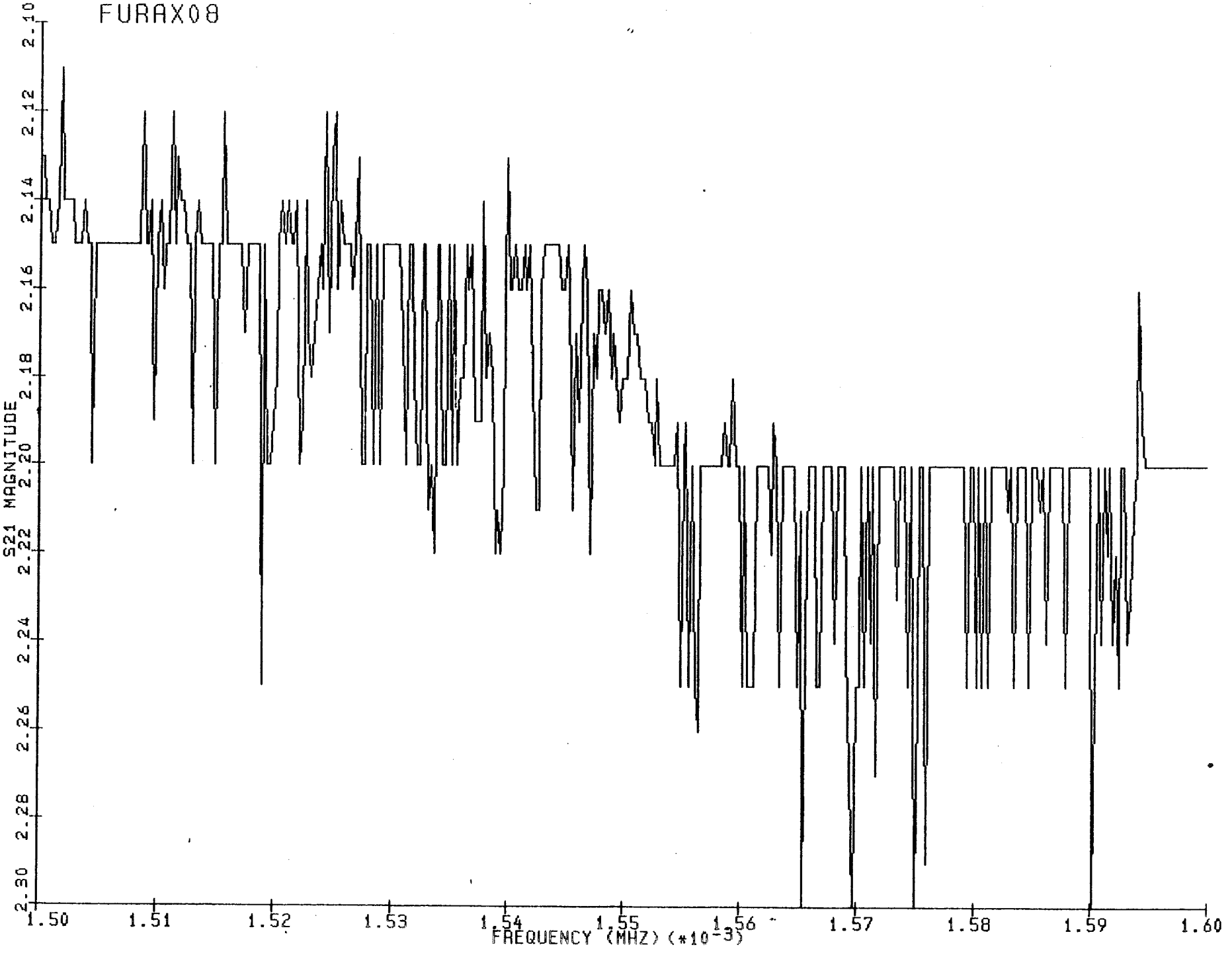

FURAX03
S21 MAGNITUDE
1.40
1.50
1.60
1.70
1.80
1.90
2.00
2.10
2.20
2.30
2.40
.80
.87
.94
1.01
1.08
1.15
1.22
1.29
1.36
1.43
1.50
*10^-3)

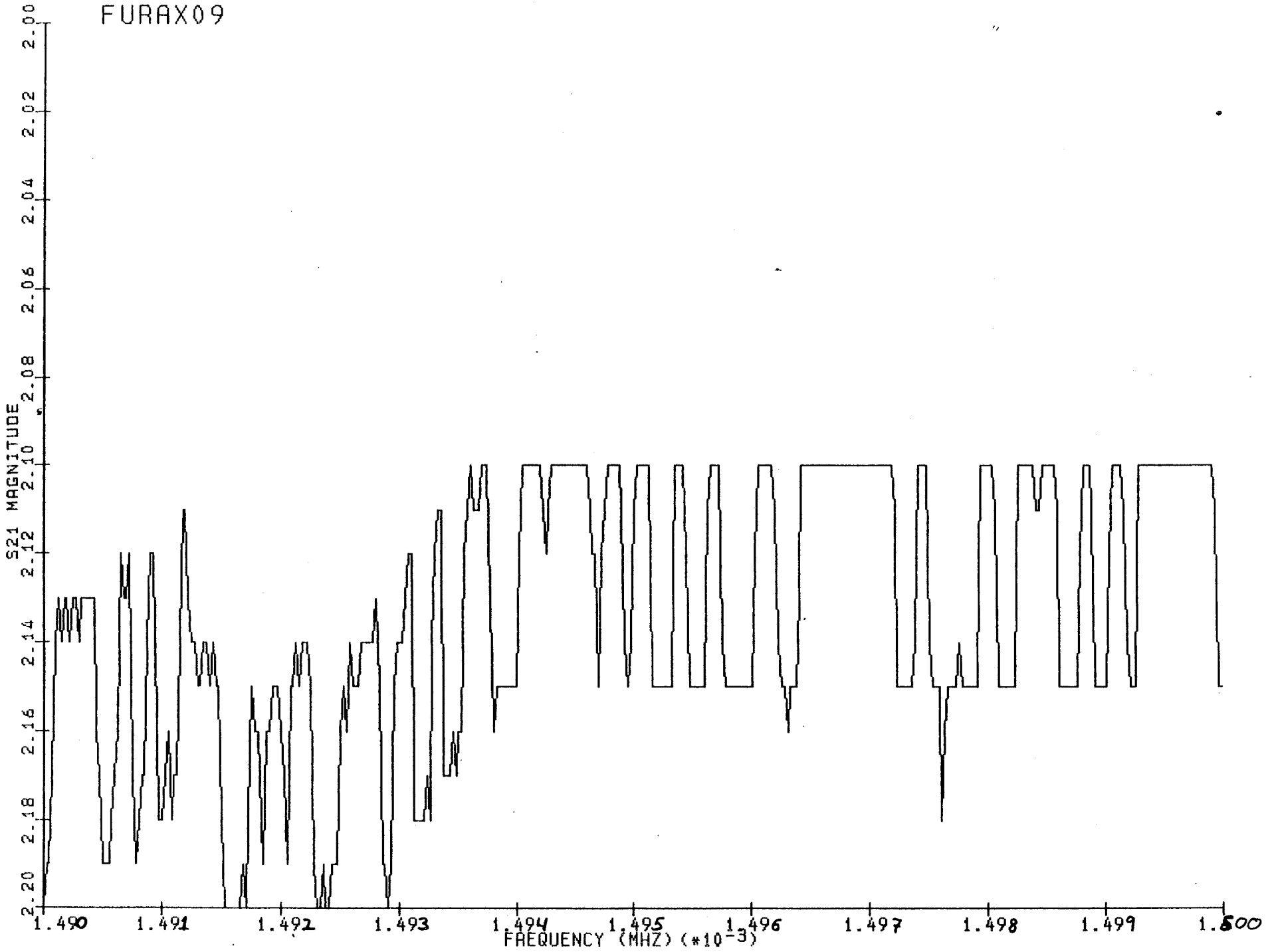

FURAX04
S21 MAGNITUDE
2.00
2.10
2.20
2.30
2.40
2.50
2.60
2.70
2.80
2.90
3.00
1.50
1.57
1.64
1.71
1.78
1.85
1.92
1.99
2.06
2.13
2.20
*10^-3)

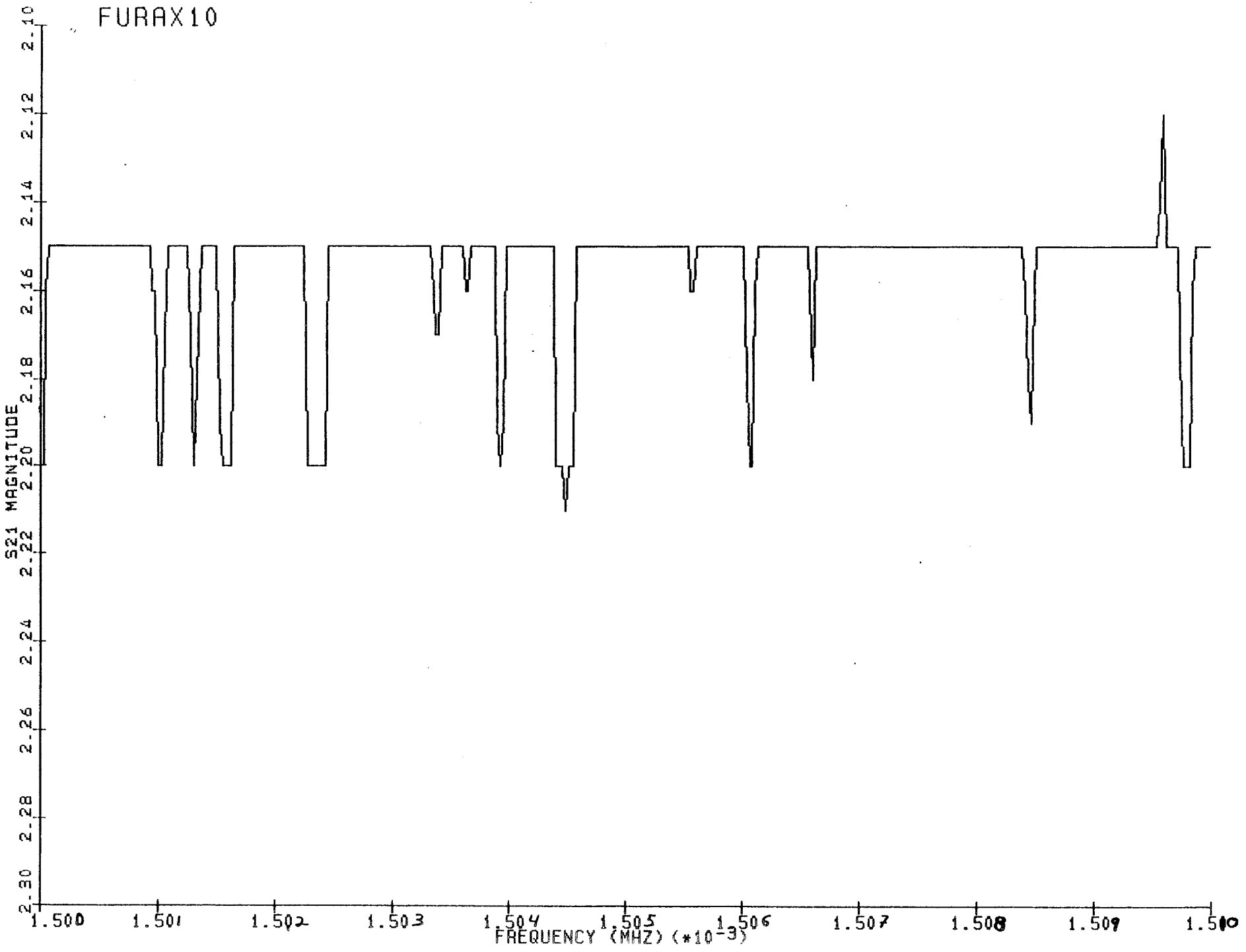

FURAX05
S21 MAGNITUDE
2.00
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
1.50
1.65
1.80
1.95
2.10
2.25
2.40
2.55
2.70
2.85
3.00
*10**3)

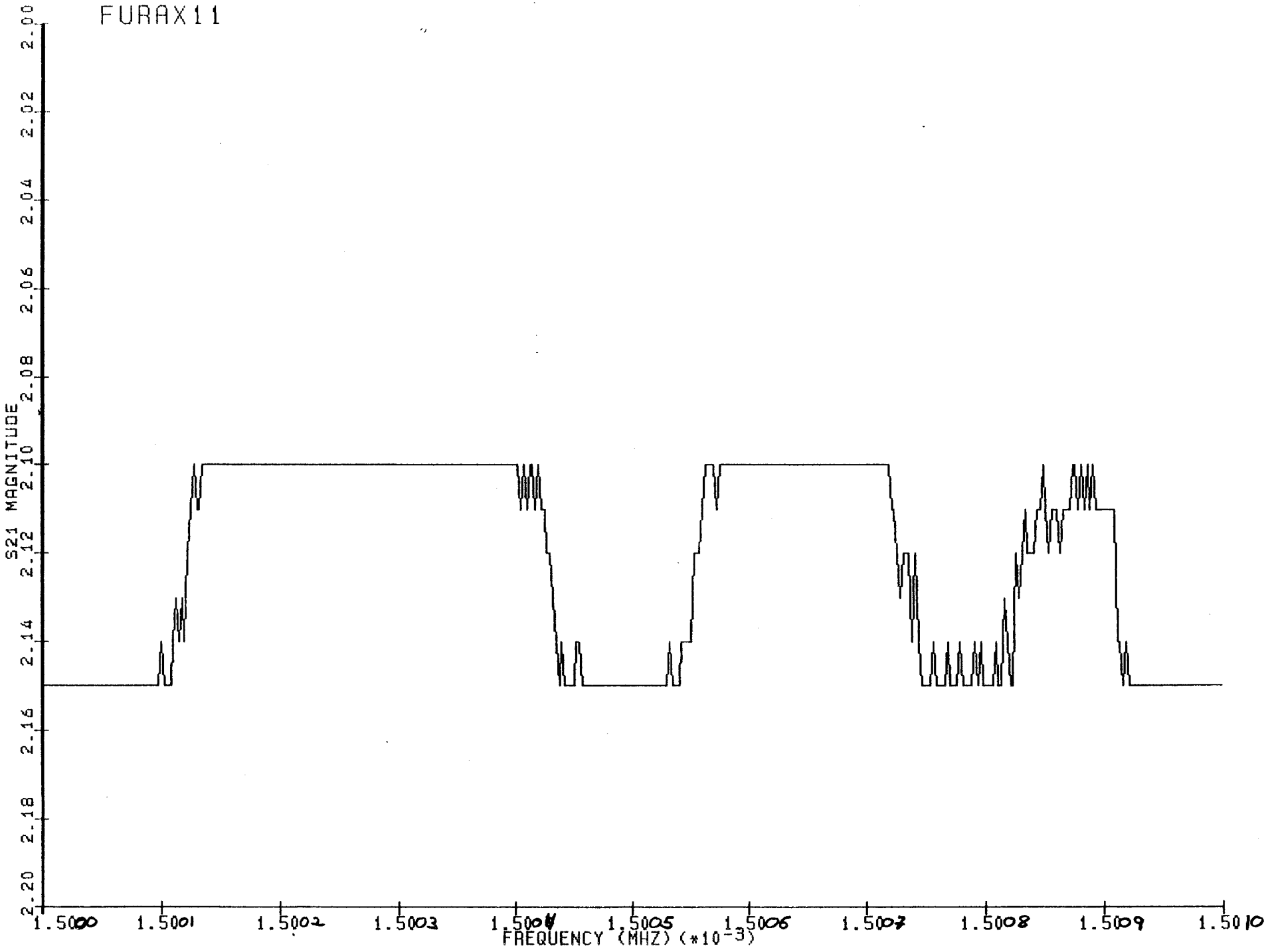

FURAX06
S21 MAGNITUDE
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
3.00
3.15
3.30
3.45
3.60
3.75
3.90
4.05
4.20
4.35
4.50
*10^-3)

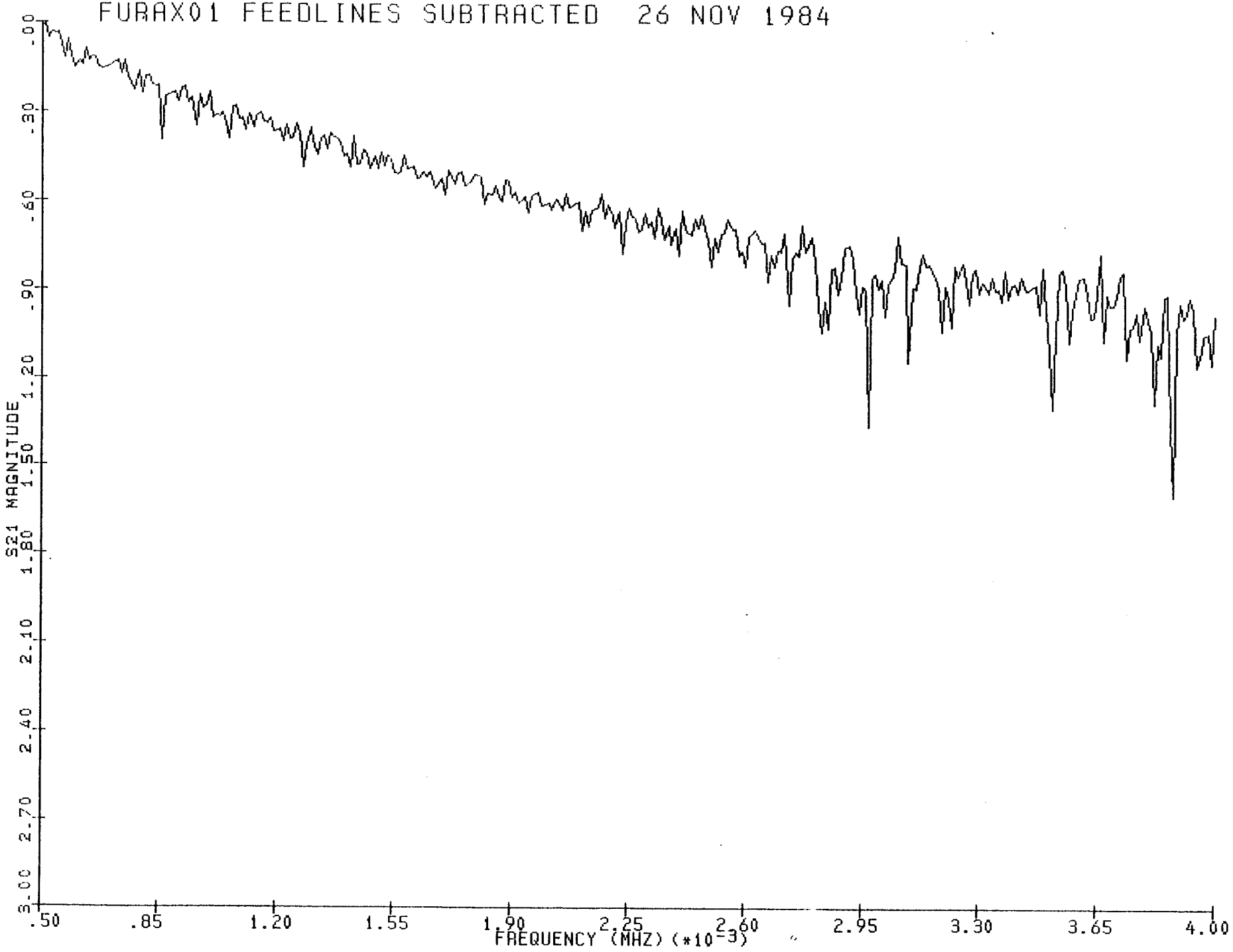

FURAX07
S21 MAGNITUDE
2.00
2.02
2.04
2.06
2.08
2.10
2.12
2.14
2.16
2.18
2.20
1.40
1.41
1.42
1.43
1.44
1.45
1.46
1.47
1.48
1.49
1.50
FREQUENCY (MHZ) (*10^-3)

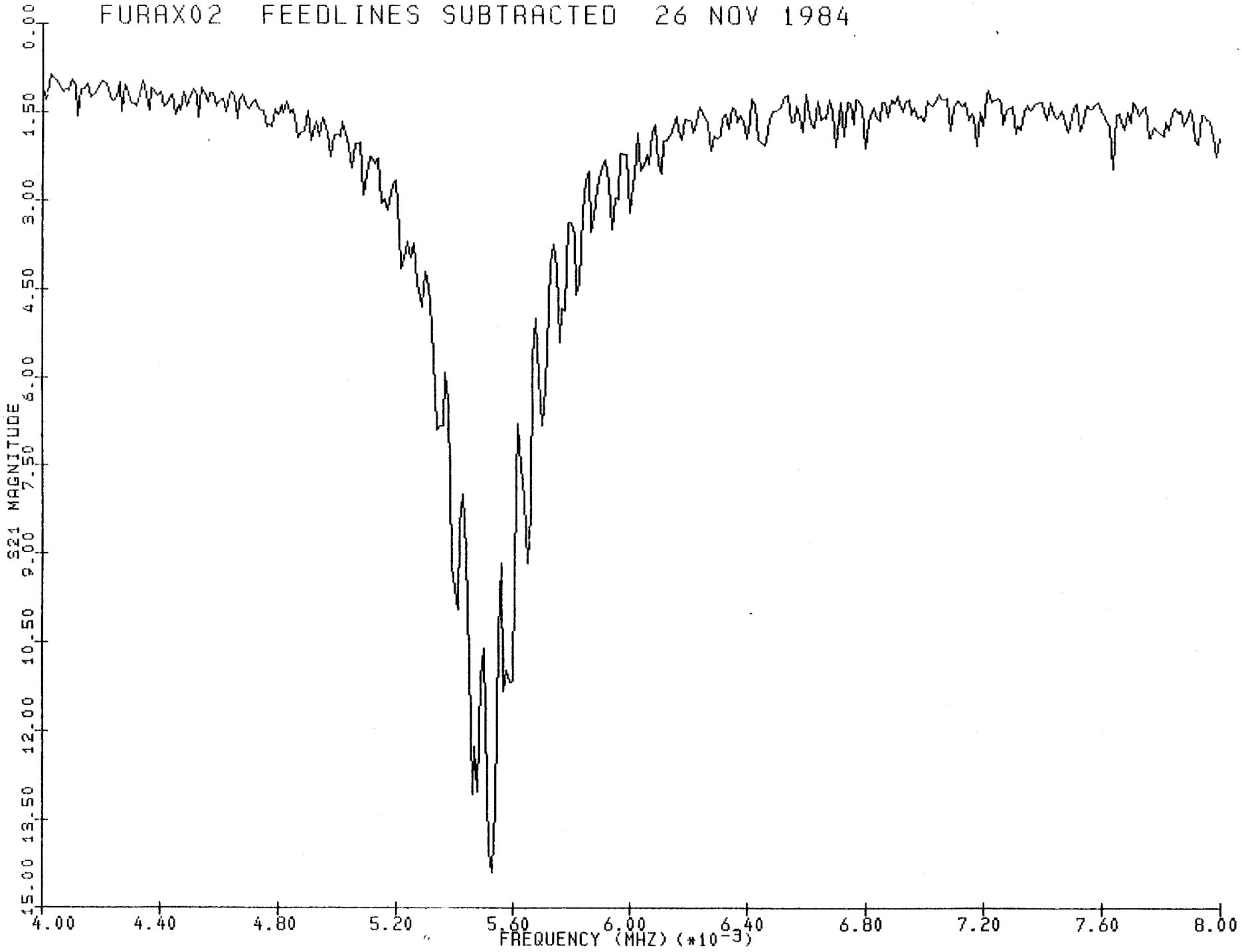

FURAX08
S21 MAGNITUDE
2.10
2.12
2.14
2.16
2.18
2.20
2.22
2.24
2.26
2.28
2.30
1.50
1.51
1.52
1.53
1.54
1.55
1.56
1.57
1.58
1.59
1.60
FREQUENCY (MHZ) (*10^-3)

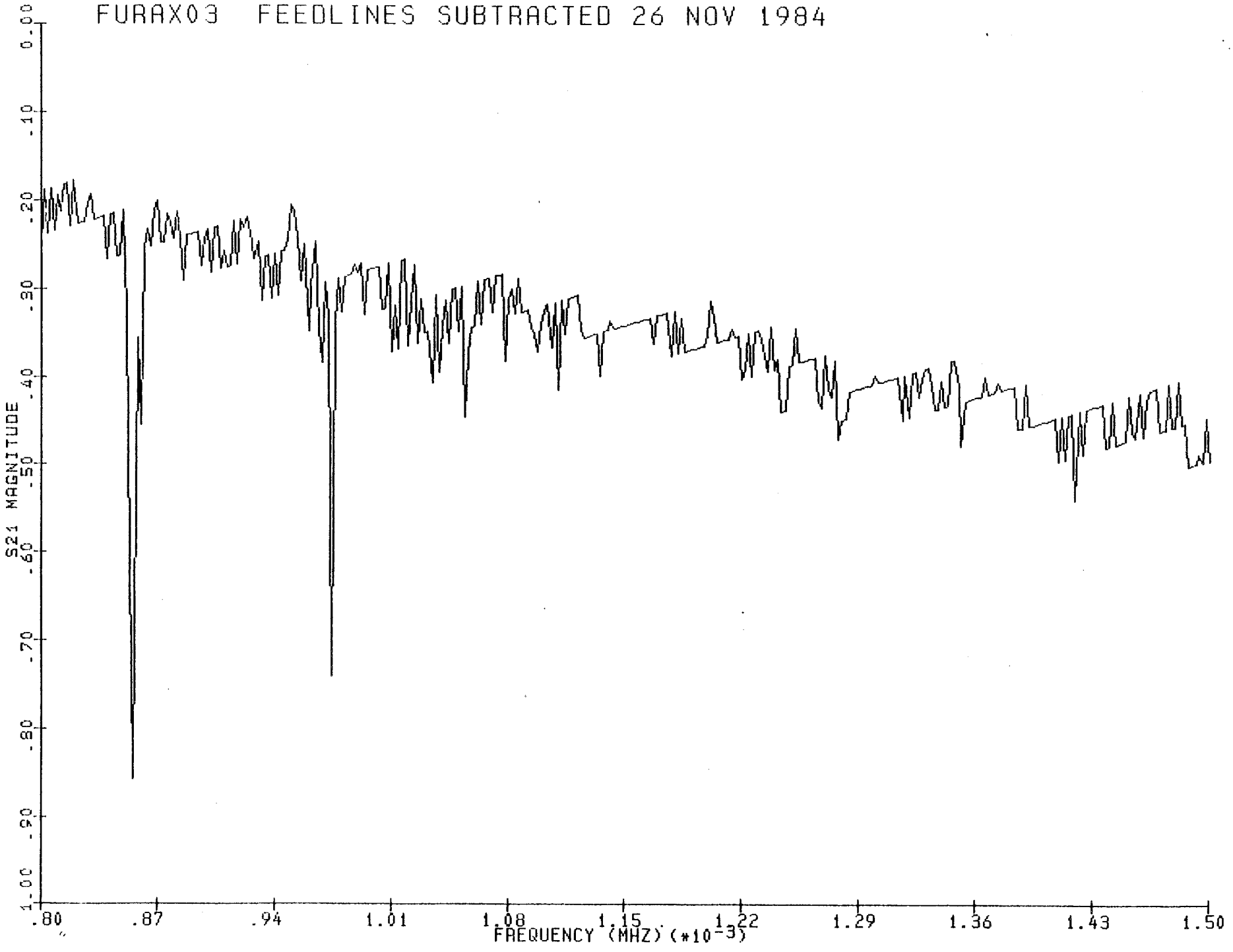

FURAX09
S21 MAGNITUDE
2.00
2.02
2.04
2.06
2.08
2.10
2.12
2.14
2.16
2.18
2.20
1.490
1.491
1.492
1.493
1.494
1.495
1.496
1.497
1.498
1.499
1.500
FREQUENCY (MHZ) (*10^-3)

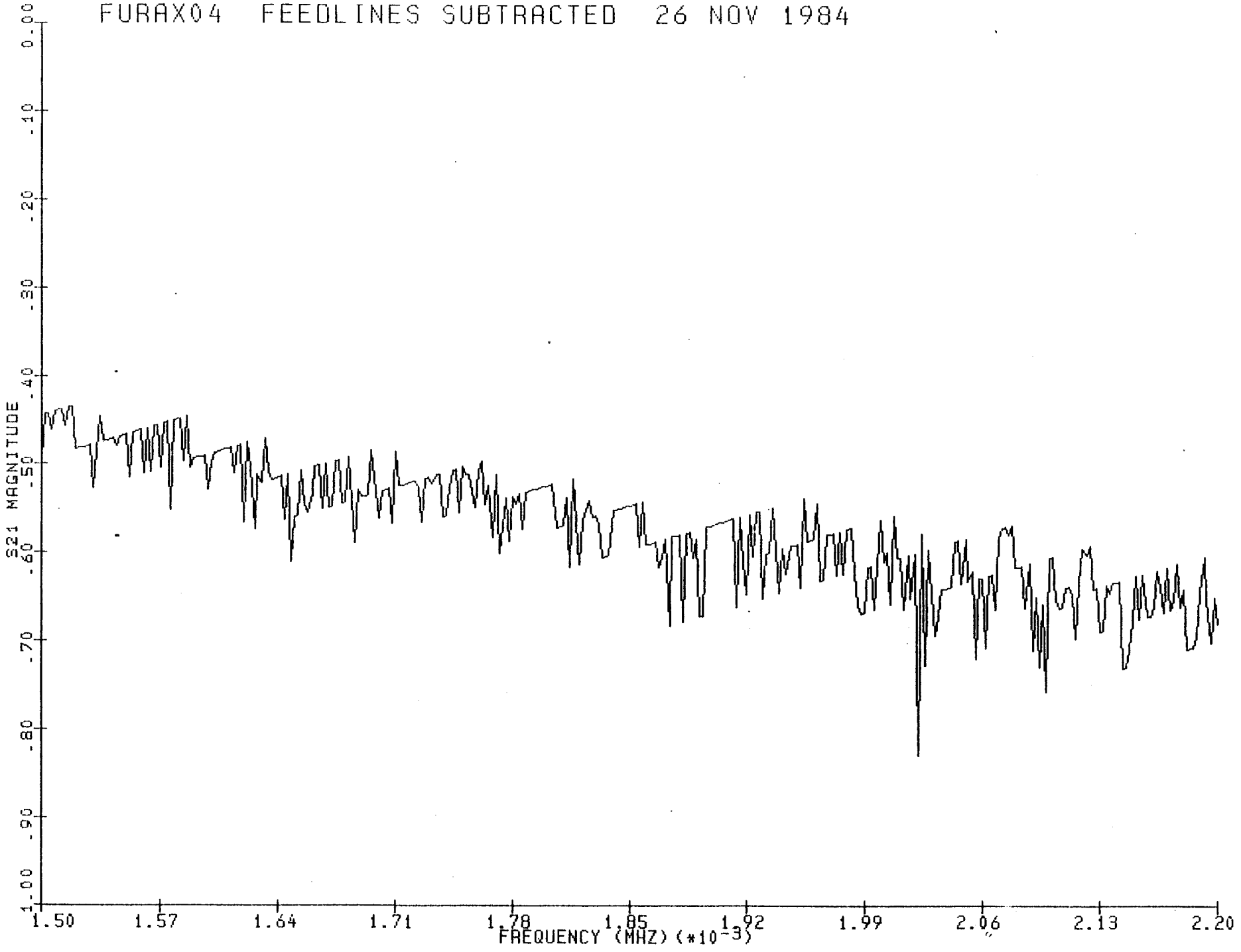

FURAX10
S21 MAGNITUDE
2.10
2.12
2.14
2.16
2.18
2.20
2.22
2.24
2.26
2.28
2.30
1.500
1.501
1.502
1.503
1.504
1.505
1.506
1.507
1.508
1.509
1.510
FREQUENCY (MHZ) (*10^-3)

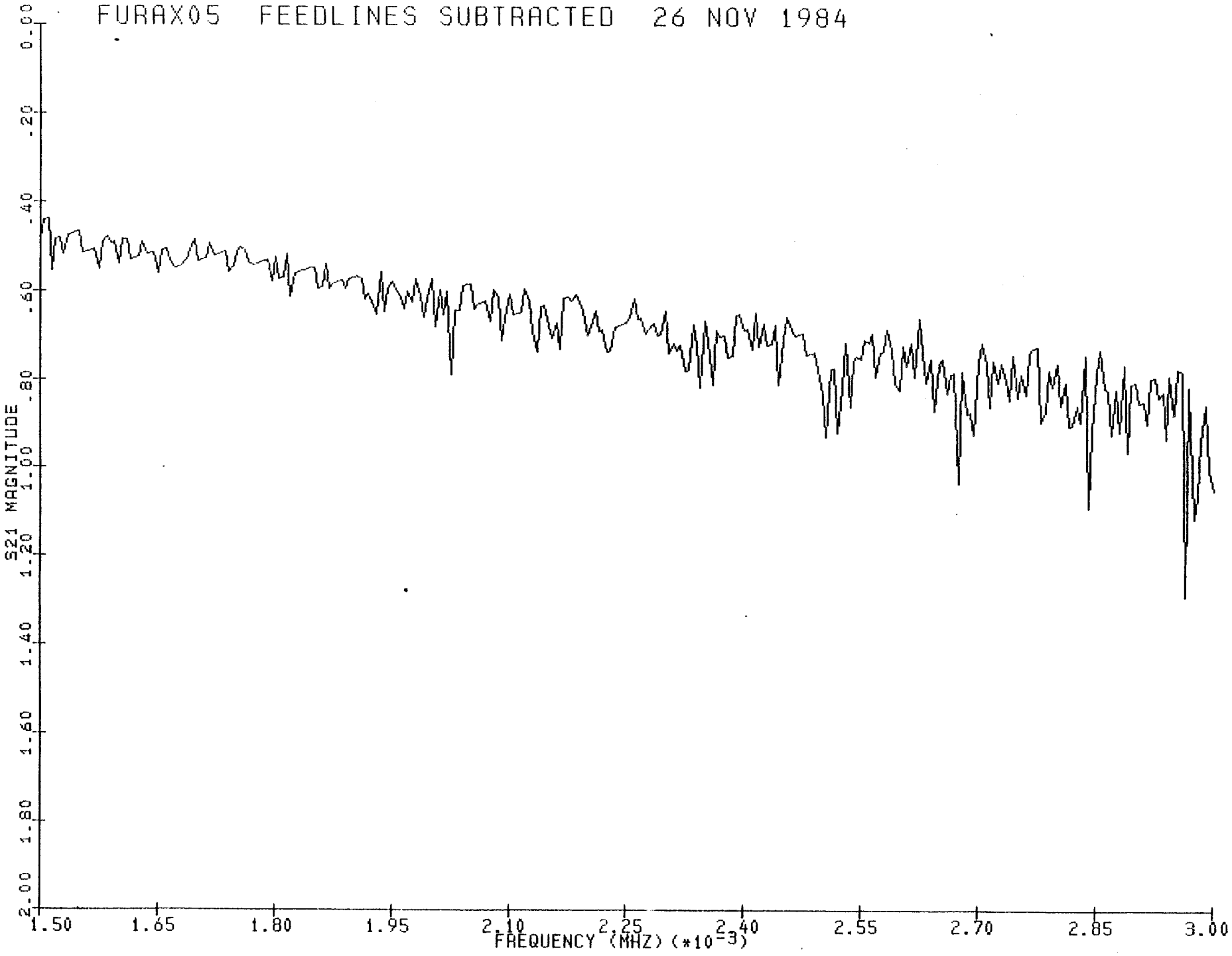

FURAX11
S21 MAGNITUDE
2.00
2.02
2.04
2.06
2.08
2.10
2.12
2.14
2.16
2.18
2.20
1.5000
1.5001
1.5002
1.5003
1.5004
1.5005
1.5006
1.5007
1.5008
1.5009
1.5010
FREQUENCY (MHZ) (*10^-3)

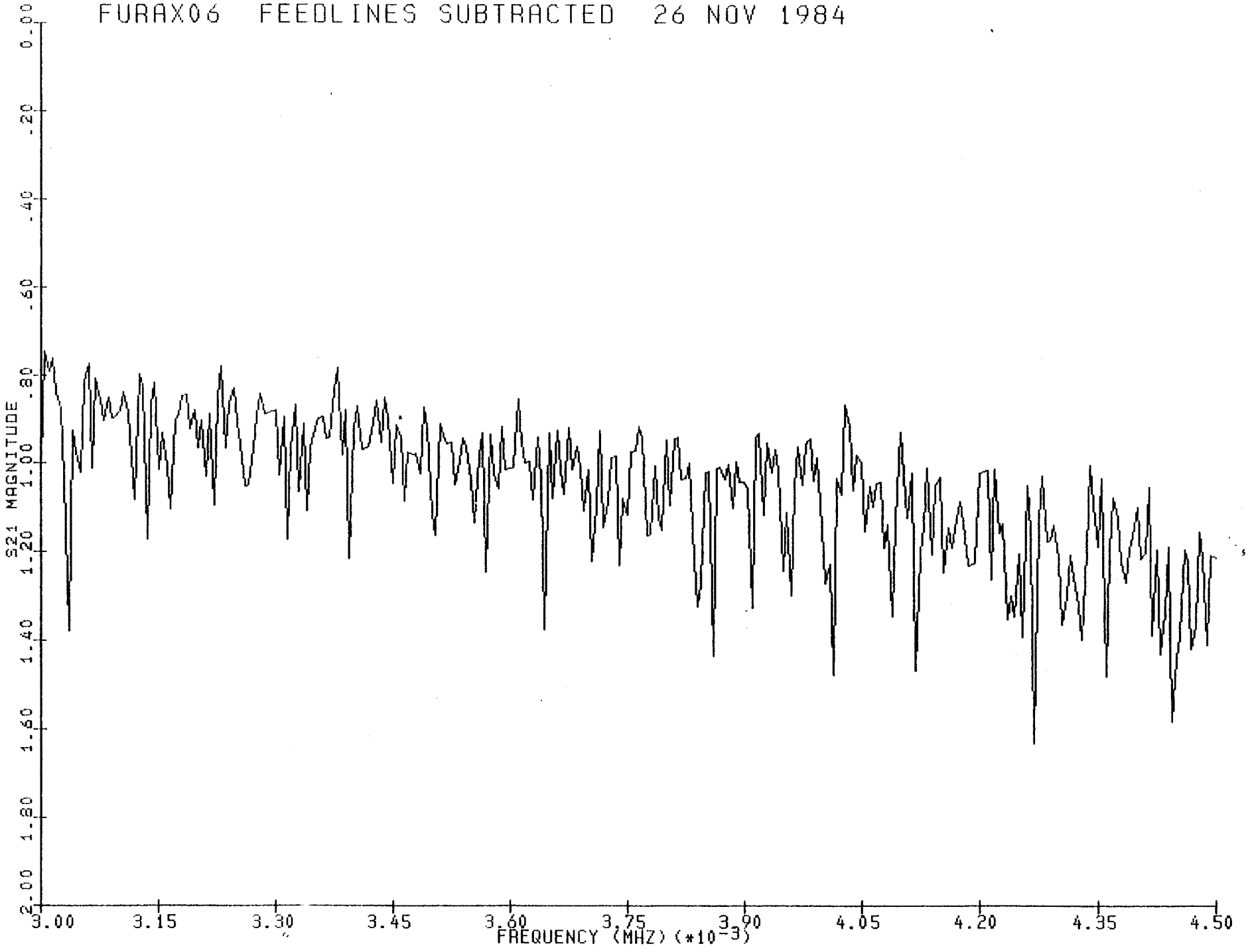

FURAX01 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
.00
.30
.60
.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
.50
.85
1.20
1.55
1.90
2.25
2.60
2.95
3.30
3.65
4.00
FREQUENCY (MHZ) (*10^-3)

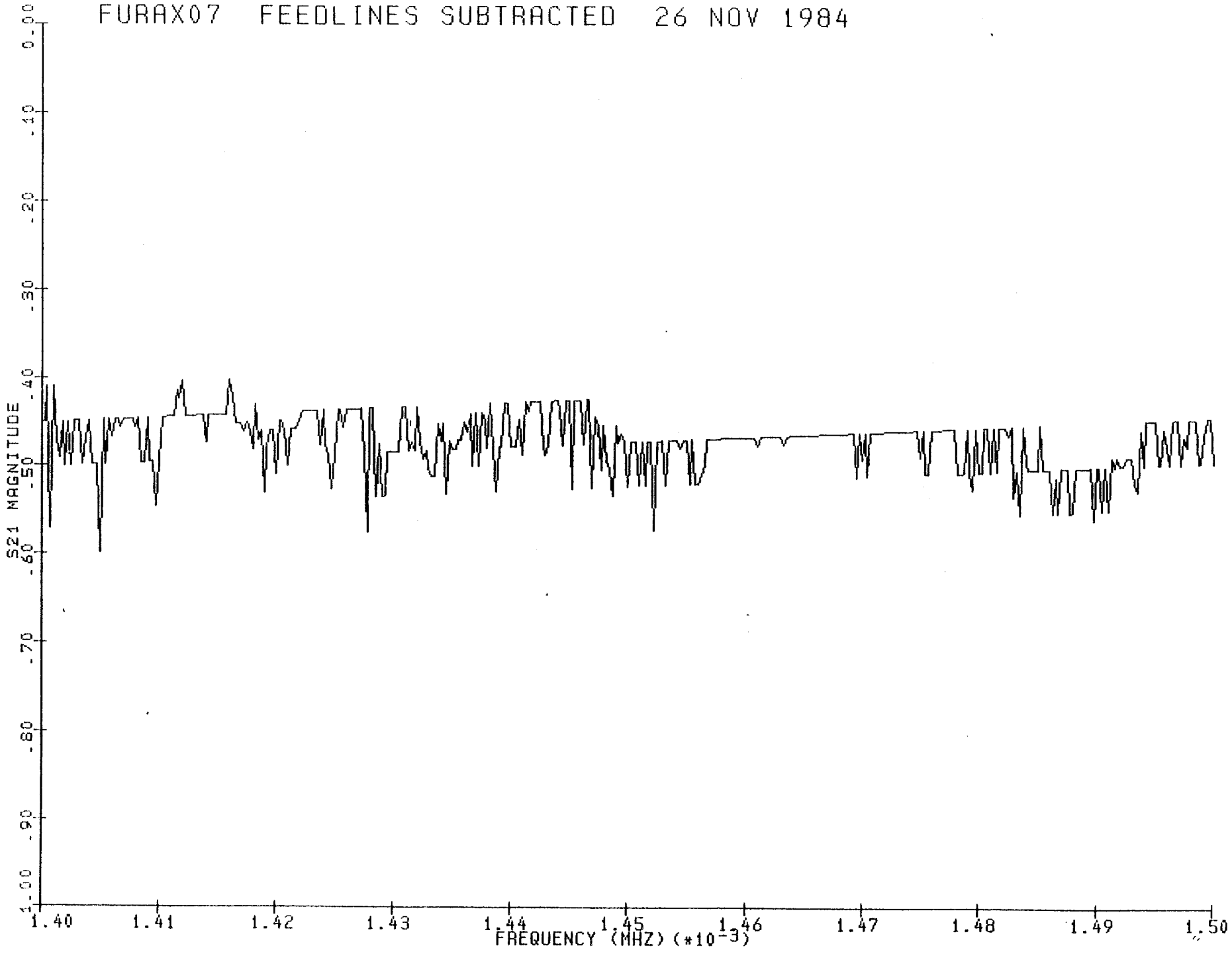

FURAX02 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
1.50
3.00
4.50
6.00
7.50
9.00
10.50
12.00
13.50
15.00
4.00
4.40
4.80
5.20
5.60
6.00
6.40
6.80
7.20
7.60
8.00
FREQUENCY (MHZ) (*10^-3)

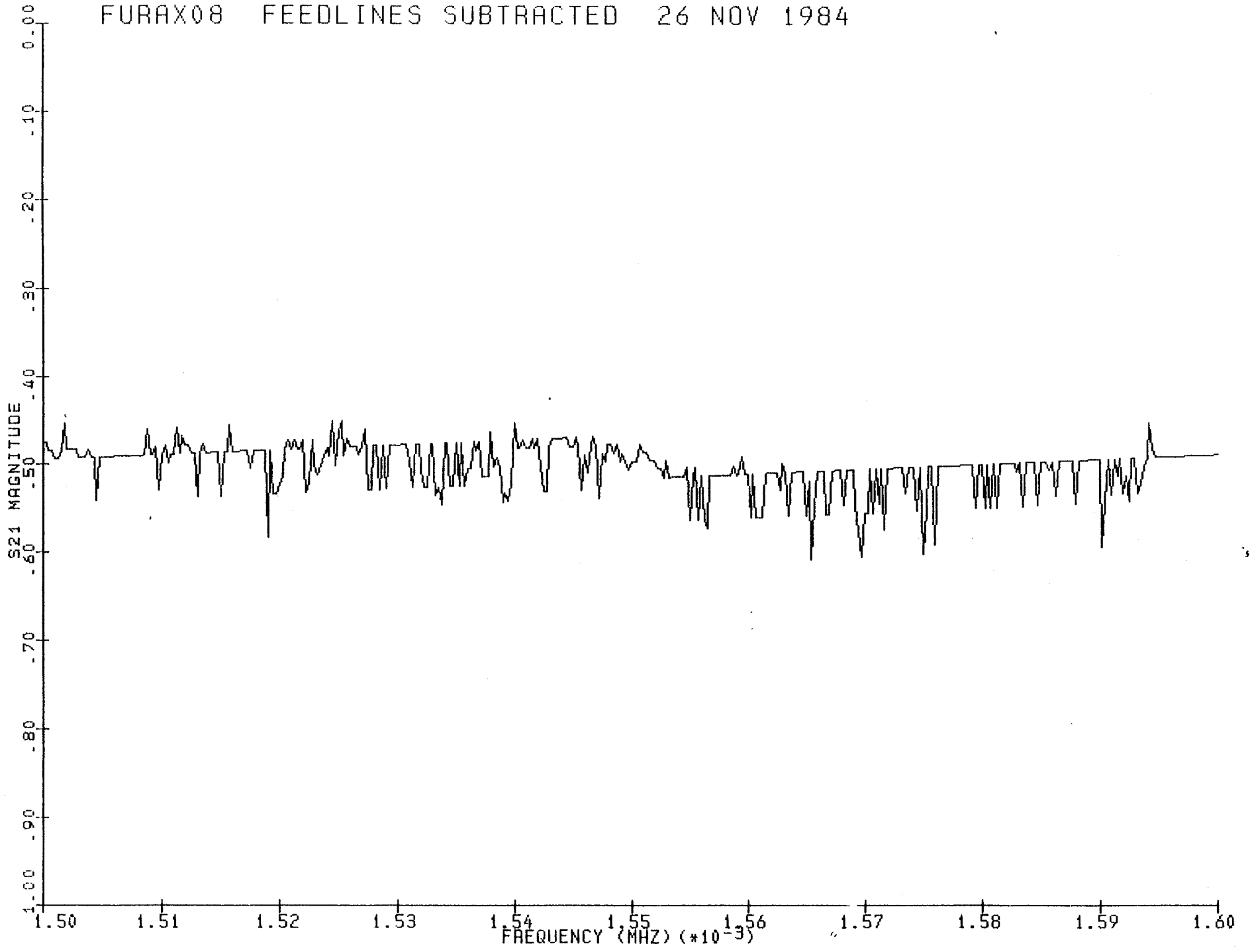

FURAX03 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
.80
.87
.94
1.01
1.08
1.15
1.22
1.29
1.36
1.43
1.50
FREQUENCY (MHZ) (*10-3)

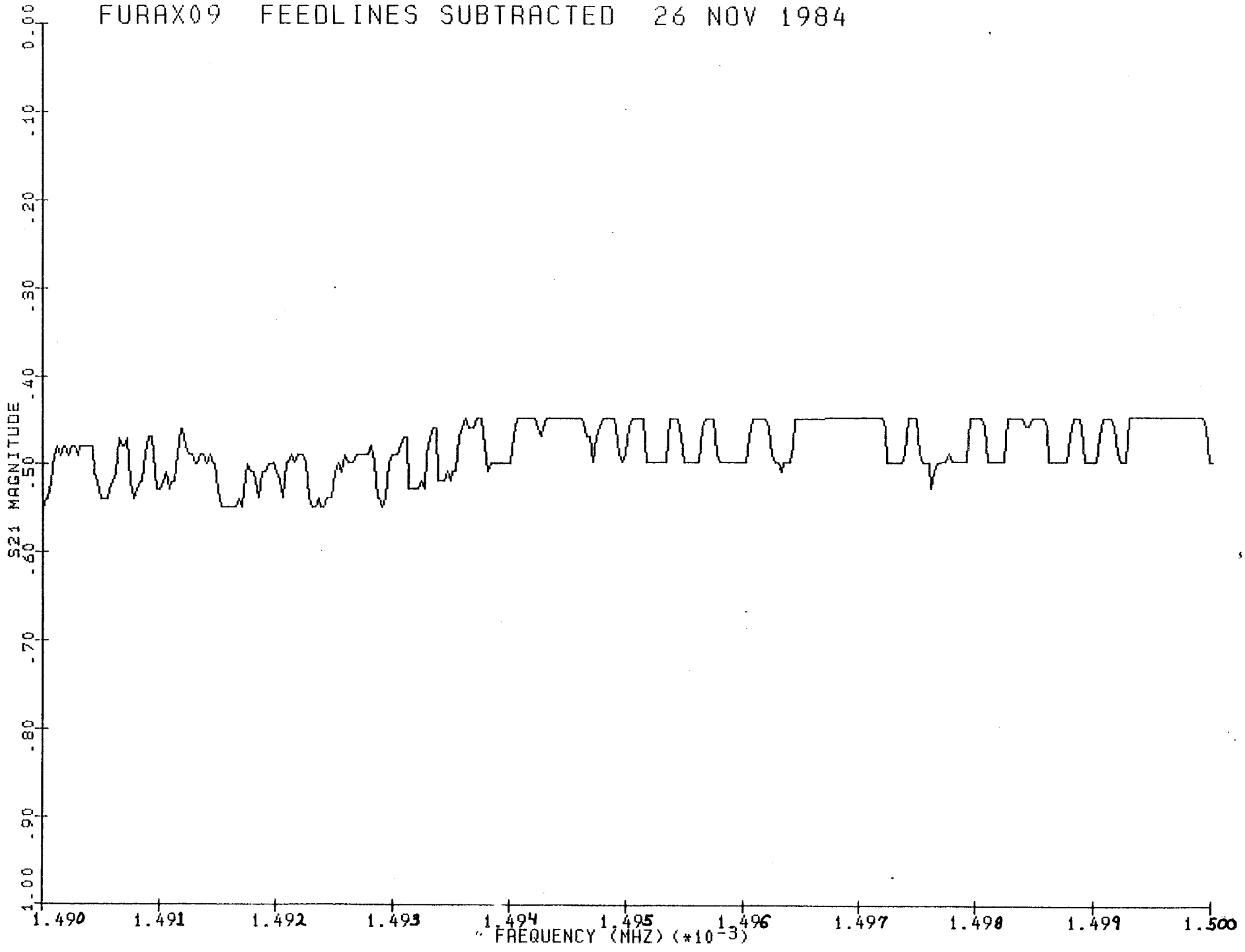

FURAX04 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
1.50
1.57
1.64
1.71
1.78
1.85
1.92
1.99
2.06
2.13
2.20
FREQUENCY (MHZ) (*10-3)

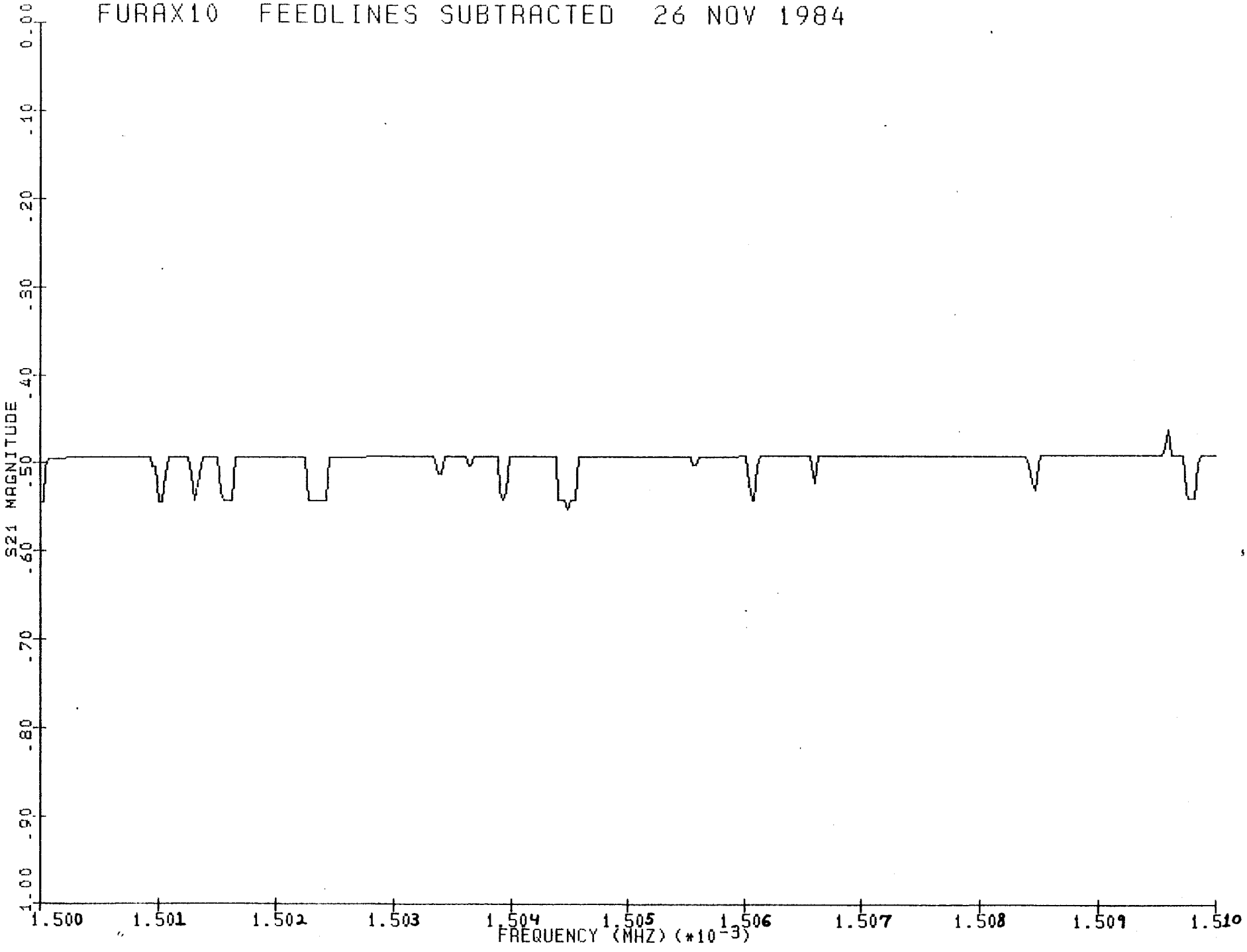

FURAX05 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
1.50
1.65
1.80
1.95
2.10
2.25
2.40
2.55
2.70
2.85
3.00
FREQUENCY (MHZ) (*10-3)

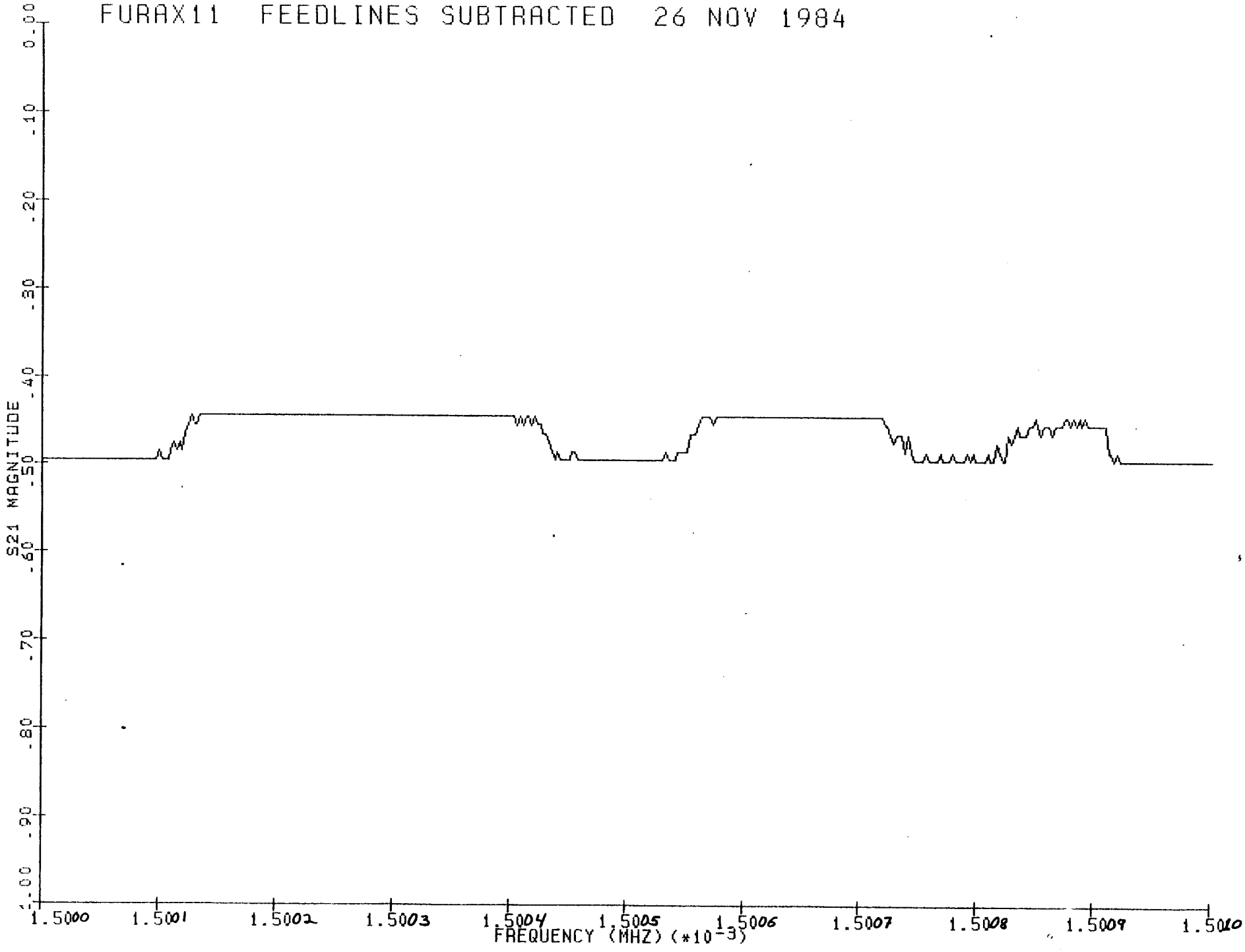

FURAX06 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.20
-.40
-.60
-.80
1.00
1.20
1.40
1.60
1.80
2.00
3.00
3.15
3.30
3.45
3.60
3.75
3.90
4.05
4.20
4.35
4.50
FREQUENCY (MHZ) (*10^-3)


FURAX07 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
1.40
1.41
1.42
1.43
1.44
1.45
1.46
1.47
1.48
1.49
1.50
FREQUENCY (MHZ) (*10-3)


FURAX08 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
1.50
1.51
1.52
1.53
1.54
1.55
1.56
1.57
1.58
1.59
1.60
FREQUENCY (MHZ) (*10^-3)


FURAX09 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
1.490
1.491
1.492
1.493
1.494
1.495
1.496
1.497
1.498
1.499
1.500
FREQUENCY (MHZ) (*10-3)


FURAX10 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
1.500
1.501
1.502
1.503
1.504
1.505
1.506
1.507
1.508
1.509
1.510
FREQUENCY (MHZ) (*10-3)


FURAX11 FEEDLINES SUBTRACTED 26 NOV 1984
S21 MAGNITUDE
0.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
-1.00
1.5000
1.5001
1.5002
1.5003
1.5004
1.5005
1.5006
1.5007
1.5008
1.5009
1.5010
FREQUENCY (MHZ) (*10-3)

CONCLUSIONS :

The results of the tests on Furukawa Coax #1 show that the coax performs well in the superconducting state. TDR measurements show an impedance change from 56 Ohms at room temperature to 51.5 Ohms when superconducting. The major measurable discontinuities are due to connectors. RLC measurements of inductance and capacitance yield values of characteristic impedance very close to the TDR values. The large difference between theoretical and measured warm inductances still needs to be understood. Network analyzer plots of S11 and S21 show some periodic structure but the effects are small for short periods and the major effects are due to end reflections at the connectors.

FUTURE TESTS :

Forthcoming will be the test of Furukawa Coax #2 and an investigation into the possibility of using the superconducting coax as the warm to cold transition line.

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