

# Report on RFI Survey of Charlottesville NTC Laboratories

December 16 & 17 2004

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On December 16 and 17, 2004, we visited the New Technology Center of the NRAO in Charlottesville, VA to conduct an RFI survey at three locations in the labs. A central concern is whether RFI produced by the ALMA correlator will interfere with SIS mixer testing and other sensitive receiver measurements being made in the labs. At the time of this survey, only ¼ of the card slots in 1 quadrant of the correlator rack was populated; the intent is to perform the survey again when the correlator is completely installed.

The survey at each location is comprised of sweeps that collectively span 20 MHz to 18 GHz. Antennas were fixed at a specified azimuth and elevation angle and in a selected polarity at each survey location. To achieve equal dwell time per bandwidth, the spectrum analyzer adjusts the sweep time according to span. Since our amplifiers and antennas cover different spans, test time was adjusted to keep the number of sweeps the same for any given span. All plots are peak hold representations of the interference encountered during the test. A measurement worksheet, plots for each location, and a comprehensive equipment list can be found in the appendices.

The first survey location was on the 3<sup>rd</sup> floor of building 4, in lab 302 B where sideband response testing of SIS mixers was being conducted. The ALMA correlator is located roughly 25m due North and 9m below this location in the classroom building. Antennas were positioned with the main lobes pointing due North and a vertical tilt of roughly -20° (where applicable), roughly at rooftop air ducts from the correlator's AC unit. In the first set of measurements, the correlator was powered off, and the wireless LAN was operating. In the second set of measurements, the correlator was powered on in a test mode, and the wireless LAN was off.

The difference between the two sets of measurements is minimal. It is possible to pick out the 125 MHz correlator clock and two of its harmonics (250 MHz and 875 MHz) that appear in the second set of measurements and were absent in the first. However, these signals are not the dominant features of the plots, showing up 20 to 25 dB lower than the strongest signals measured in this range. Additionally, the broadband noise from the correlator which underlies its 125 MHz harmonics fell below the general noise level already present in the lab; this level was not obviously increased by powering on the correlator. It is unclear why only the 1<sup>st</sup> and 6<sup>th</sup> harmonics showed up; the later survey at 4m distance from the correlator shows a typical "comb" of harmonics that eventually falls below the noise floor of the measurement system around 6.7 GHz. We suspect random reflective surfaces are responsible for the seemingly arbitrary appearance of selected harmonics. Reflection and absorption attenuated the signal seen at 125 MHz by 13 dB beyond what one would expect from line-of-sight free space loss. We suspect that reflection off the roofing material of the B building (the building housing the correlator) was responsible for much of this loss. We can only guess that ambient interference (cell phone, perhaps?) or additive moding is responsible for the fact that the signal at 875 MHz measured 4 dB higher than free space loss predicts.

Three channels of WIFI around 2.4 GHz, occupying almost 100 MHz of BW each, are evident in both plots, although in the second survey, when the in-house WIFI was supposed to be powered down, the lowest channel was absent until the scan was about halfway finished; perhaps the purpose of shutting down the system was not communicated to all concerned parties? Anyway, it was possible to pick up WIFI from at least two other access points than the one that was temporarily powered down for the purposes of our test. A very strong, relatively narrow band signal which appeared on both plots at 2.730 GHz may have been Instructional Television Fixed Service (ITFS) or Multipoint Distribution Service (MDS) a.k.a. "wireless cable TV", although a search of the FCC database does not reveal any licensing at that frequency in the Charlottesville area. At the high end of this test range one can see the sideband source for the SIS mixer test operating between 4.270 and 4.405 GHz. We were set up very close to the SIS test rack, although that noise must be relatively attenuated as it was positioned (intentionally) out of the main beam of the horn antenna. During the first measurements, which were taken during working hours, there was a surprising amount of intermittent noise in the 5 – 8 GHz span. The only signals that persisted and were present after 4:30 PM, when the second set of measurements were taken, appeared at 5.470 GHz and may have been radiolocation out of the Charlottesville Airport, roughly 10 Km away to the North East. Everything above that was intermittent, including a very strong spike which showed up at 9.373 GHz during the second measurement set. This also falls in a radionavigation band and may have been coming from the airport. The highest frequency at which anything at all was seen was a small spike at 13.91 GHz, possibly earth to satellite radiolocation.

The second survey location was inside the 12' x 8' x 8' shielded chamber on the first floor of building 4. The intent of this survey was to provide information about the shielding effectiveness of that chamber. The antenna was polarized vertically (to line up with the door aperture) about 1m inside the door, and a scan was taken with the door open, and with the door closed. A few limitations of this method must be noted: 1) Signal moding inside a reflective chamber ensures that the level read at the antenna is going to be different when the door is open vs. when the door is closed, even if the signal source were inside the chamber. 2) Since the ambient signals are constantly changing, we can't be sure that attenuation is caused by the chamber or a change in the signal. 3) The direction of the source relative to a breach in the chamber factors into the attenuation. Keeping these items in mind, all we can say if we see signals with the door shut is that the chamber is leaky at that frequency and probably for some bandwidth around that frequency. Still, in contrasting the before/after plots, it is tempting to say that we appear to be getting about 20dB of attenuation across the range of test. At the very least, it is obvious that the chamber is providing some attenuation more than 10dB, less than 40dB, and certainly its effectiveness varies with frequency. To improve the shielding effectiveness and usefulness of the enclosure, we make the following recommendations:

- 1) Fix the holes. I noticed at least 4 holes (3) about 3/16" diameter and one about 3/4" diameter. Remove the paint around them with a dremel tool and then provide a conductive seal with copper tape.
- 2) It is unclear whether the "hat and flat" panel junctions are actually making conductive contact with the panels. In some areas (like where there is a gap) it clearly is not. These panel connectors may be able to be loosened without disassembling the chamber, I don't know, but in any case it is necessary to clean paint, oxidation, etc. from them where they contact the panels. Additionally, copper wool should be stuffed into any crevice big enough for it to fit, especially the corner junctions which have large gaps. If you're very serious about improving the chamber, I recommend a complete disassembly, cleaning, and reassembly.
- 3) The spring fingers around the door appear to be very old and worn, and some of them are missing. I would replace all of them. Also, the addition of a latching mechanism that holds the door tightly closed is recommended.
- 4) I noticed that some test equipment was running inside the chamber. I powered it off during our test, and used the bulkhead connection on the rear wall of the chamber to connect to our test equipment outside the enclosure. (The only active device in there was the linear power supply for the preamplifier which has been tested and shown to be quiet.) In a small, reflective chamber the test equipment should be isolated from the receiver under test as much as possible, running coaxial cables through a bulkhead connector and filtering other cable connections to the outside world wherever possible.

If a restoration effort demands a more quantitative assessment of the chamber, we could conduct shielded effectiveness (SE) testing with methods adapted from the IEEE 299 standard. This method of SE testing has proven helpful in assessing the condition of the large shielded areas in the Jansky lab and in the Education and Visitor Center here at Green Bank.

The third survey location was in the B building at a 4m distance from the correlator rack, with about 1/16 of the cards installed and running a "L501 test" continually during test. The purpose of this survey is to profile the RFI generated by the correlator. One feature of the resultant profile is the harmonics of the correlator's 125 MHz clock which extend to 6.75 GHz before fading below the noise floor of the measurement system. In addition to these harmonics, we note a roughly 20 dB shift in the noise floor from the start of our measurements at 20 MHz all the way up to 3.2 GHz, where it starts to roll off, dropping into the noise at about 7 GHz. One of the biggest broadband noise sources I have ever seen, but not too surprising, given that I was set up 4m away from a device dissipating 8725W. Should the dissipated power be linearly proportional to the number of cards installed, and should the radiated power be similarly proportional to dissipated power, I would expect to see our measurements increase by 12 dB when we return to measure the fully installed correlator, and higher harmonics would be expected to emerge from the noise.

From the 4m data, we can make some predictions about the field strength at 25m from the correlator, using our "RFI analysis" spreadsheet. Bear in mind that these predictions do not account for absorption and reflection losses from the buildings, foliage, etc.

1 – Frequency of three signals of interest<sup>1</sup> (MHz):

125	875	6750
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2 – Predicted Field Strength in Lab 302B:

-130.67	-128.17	-161.58	dBW/m <sup>2</sup> /Hz
8.57E+12	1.52E+13	6.95E+09	Jy

3 – Field Strength in Lab 302 B as measured:

-143.45	-123.75	N/A	dBW/m <sup>2</sup> /Hz
4.52E+11	4.22E+13	N/A	Jy

It is up to the reader to decide to what extent the ITU-R limits apply in this situation: They represent the sensitivity of a RA receiver, with its attached feed, to sky frequency. Our highest measured signal is in the frequency range of the ALMA IF, not in the range of the ALMA sky frequencies (which our group has no equipment to measure). The sensitivity of the SIS mixers to IF interference may not be well modeled by the ITU-R limits.

4 – Exceeds ITU-R Line Limit by (dB):

88.13	84.40	37.77
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<sup>1</sup> The first two “signals of interest” were chosen because we were able to measure their levels at both locations (despite reflective losses and obscuring ambient noise in lab 203 B), and the last because it is in the middle of the IF range, as well as being the highest harmonic of the 125 MHz clock that we were able to see.

# Appendix A: Measurement Worksheet

## Tracking Information...

Device Under Test: 1/16 of ALMA Correlator  
 Date of Test: 12/17/04  
 Tested By: C. Beaudet and G. Watts

## Test Parameters and Measurement Results...

Observed RFI Feature	1	2	3
<b>Measured Frequency ( MHz )</b>	<b>125</b>	<b>875</b>	<b>6750</b>
Corresponding Wavelength ( meters )	2.40	0.34	0.04
Measured Peak Power ( dBm )	7.7	-5.5	-62.5
Spectrum Analyzer Resolution Bandwidth ( MHz )	0.010	0.010	0.010
Measured Half-Power Bandwidth ( MHz )	0.010	0.010	0.010
Signal Characteristics	CW	CW	CW
<b>Measured Power Per Unit Resolution Bandwidth ( dBW/Hz )</b>	<b>-62.30</b>	<b>-75.50</b>	<b>-132.50</b>

## Test Setup and Total Radiated Power Per Unit RBW Measured During Test...

Test Antenna Gain ( dBi )	-2.86	5.84	10.50
Equivalent Test Antenna Collecting Area ( m*m )	0.237	0.036	0.002
Total Transmission Line Loss ( dB ) (modify if different cables used)	0.1	2.1	4.3
Preamplifier Gain ( dB )	58.8	53.3	45.0
Distance From DUT to Test Antenna ( meters )	4.0	4.0	4.0
Calculated Test Setup Space Loss ( dB )	29.28	37.48	50.57
<b>Total Radiated Power Per Unit RBW Measured During Test ( dBW/Hz )</b>	<b>-91.72</b>	<b>-89.22</b>	<b>-122.63</b>

## Predicted Field Strength at Target Distance...

Distance to Lab 302B ( meters )	25	25	25
<b>Calculated Field Strength at Target Distance ( dBW/m*m/Hz )</b>	<b>-130.67</b>	<b>-128.17</b>	<b>-161.58</b>
<b>Calculated Field Strength at Target Distance ( Jy )</b>	<b>8.57E+12</b>	<b>1.52E+13</b>	<b>6.95E+09</b>

## Predicted Impact on RA Observations...

### Predictions for SPECTRAL LINE OBSERVATIONS

Corresponding Target RA SPECTRAL LINE Bandwidth ( MHz )	1.00	8.00	32.00
Corresponding Target RA SPECTRAL LINE Limit ( dBW/m*m/Hz )	-238.80	-241.60	-234.40
Calculated Field Strength Per Unit SPECTRAL LINE Bandwidth ( dBW/m*m/Hz )	-150.67	-157.20	-196.63
Calculated Field Strength Per Unit SPECTRAL LINE Bandwidth ( Jy )	8.57E+10	1.91E+10	2.17E+06
<b>Feature Exceeds Target SPECTRAL LINE Limit By... ( dBW/m*m/Hz )</b>	<b>88.13</b>	<b>84.40</b>	<b>37.77</b>

## Appendix B: Equipment List

<b>Equipment:</b>	<b>Frequency Range</b>
<b>Receiver</b>	
HP 8563E Spectrum Analyzer	9 kHz - 26.5 GHz
<b>Antennas</b>	
EM-6912 Biconical	20 MHz - 300 MHz
EM-6950 Log Periodic	200 MHz - 1 GHz
EM-6961 Ridged Guide Horn	1 GHz - 18 GHz
<b>Amplifiers</b>	
AU-1519-N-1306/E	1 MHz - 300 MHz
AM-4A-0000110-N-1306/E	1 MHz - 1 GHz
AM-5A-1020-N-1306/E	1 GHz - 2 GHz
AWT-8036	2 GHz - 8 GHz
AMT-12435	8 GHz - 12 GHz
AMT-18038	12 GHz - 18 GHz
<b>Cables</b>	
"CH5" (3' OGDT9)	(loss accounted for )
"CH2" (15' Belden 7809A)	(loss accounted for )

## Appendix C: Survey Plots

### Location 1: Lab 302 B

Plots are presented in pairs covering the same frequency range. The first of each pair was taken with the site WIFI ON, and the 1/16 Correlator OFF. The second plot in each pair was taken with the site WIFI OFF<sup>2</sup>, and the 1/16 Correlator ON.

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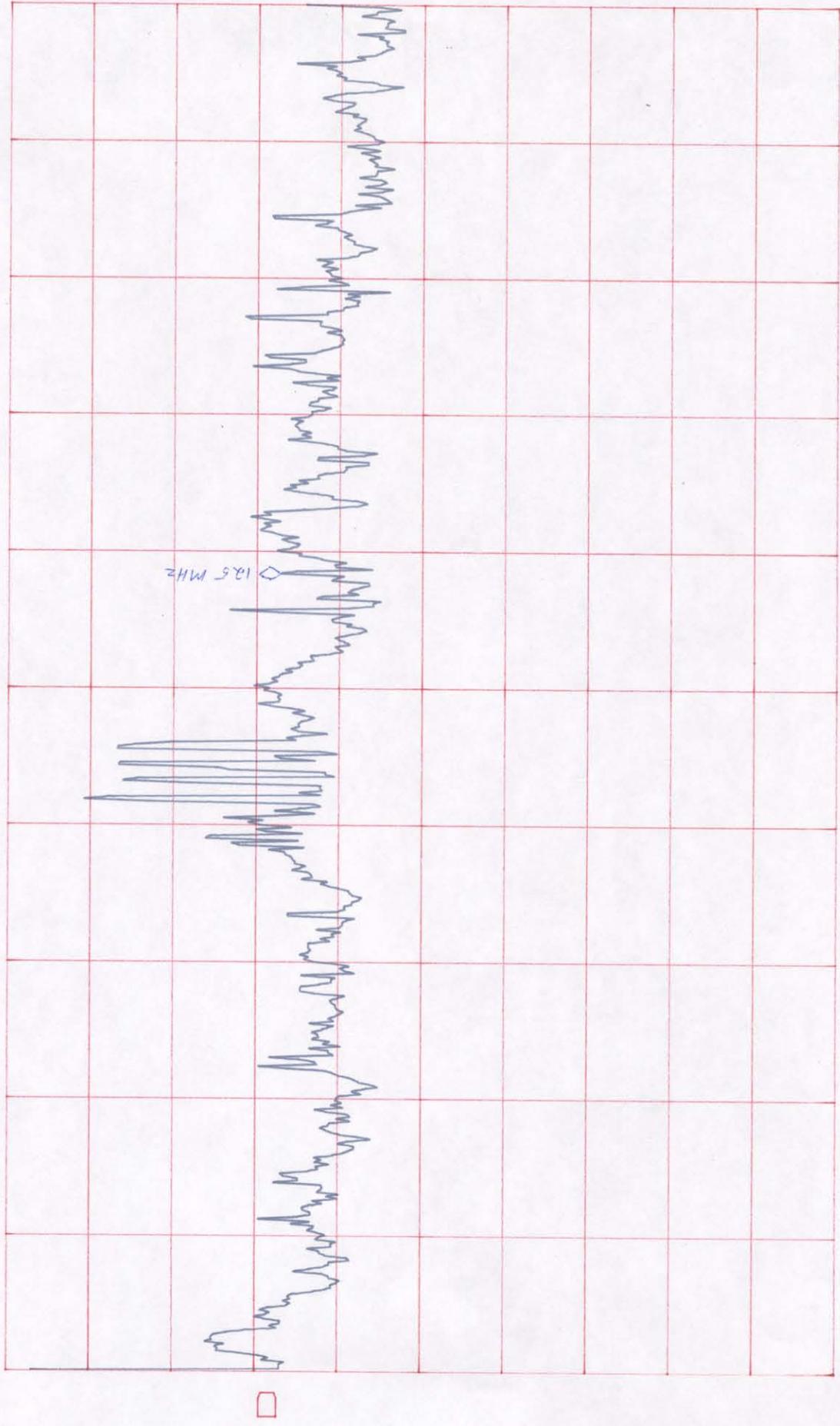
<sup>2</sup> The NRAO WIFI was turned back on in the middle of the sweep that covered its range, so the plot does not reflect its OFF state.

1409 11:55  
(917)

ATTEN 20dB

RL 10.0dBm

10dB/



D

START 20.0MHz

\*RBW 100kHz

VBW 100kHz

STOP 200.0MHz

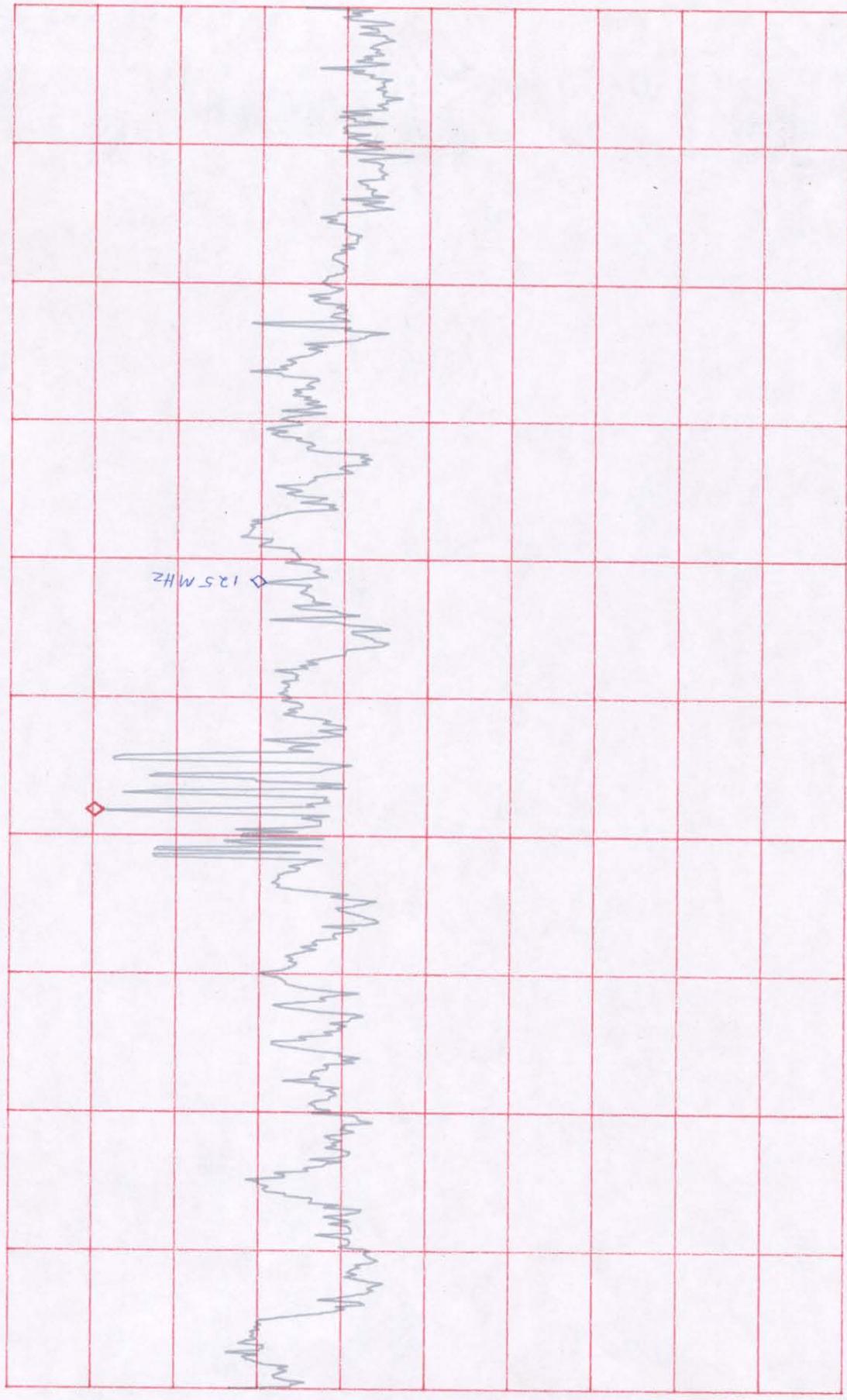
SWP 50.0ms

1568

ATTN 20dB  
RL 10.0dBm

MKR -1.17dBm  
95.3MHz

10dB/

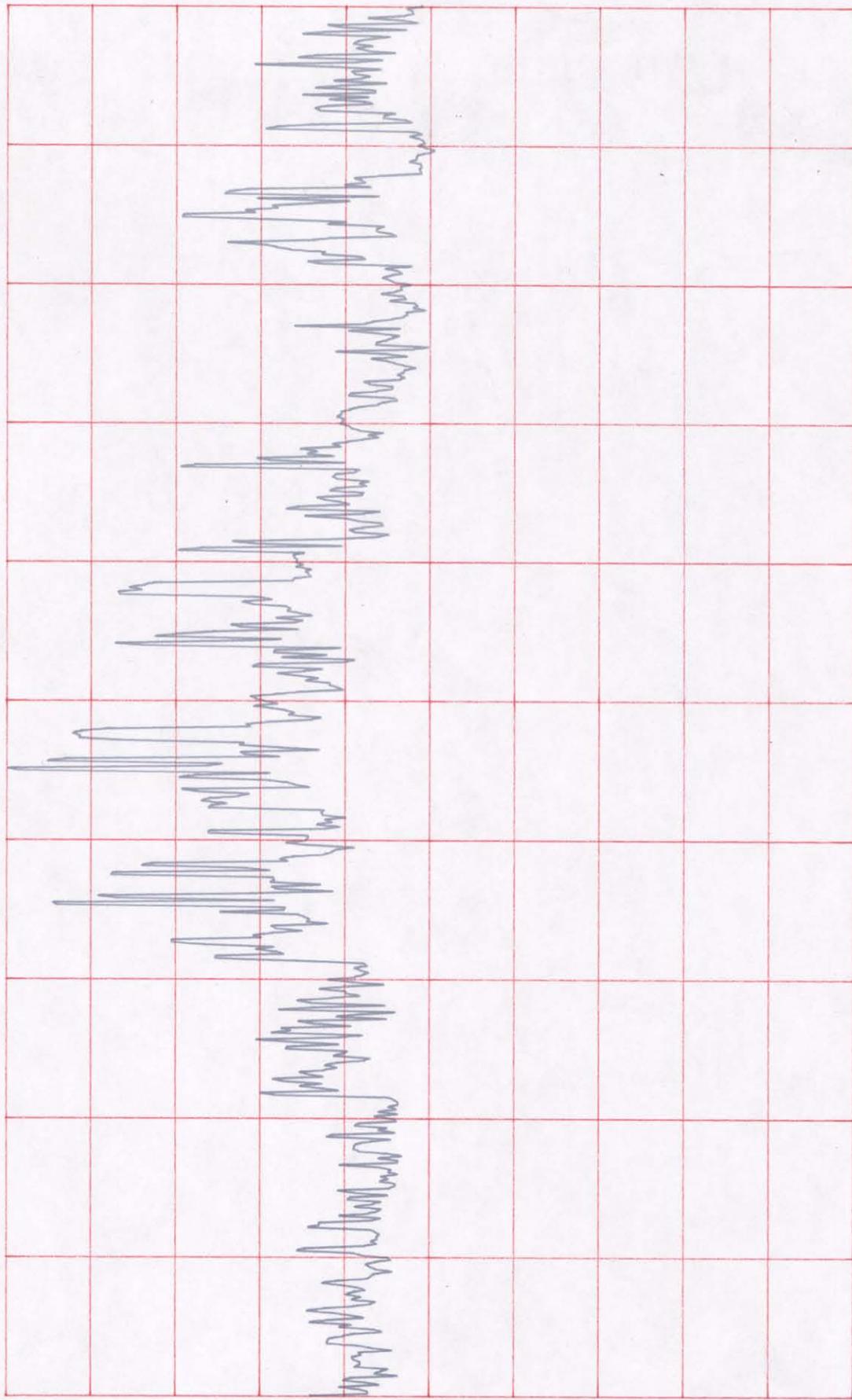


□

START 20.0MHz STOP 200.0MHz  
\*RBW 100kHz VBW 100kHz SWP 50.0ms

ATTEN 20dB  
RL 10.0dBm

10dB/



□

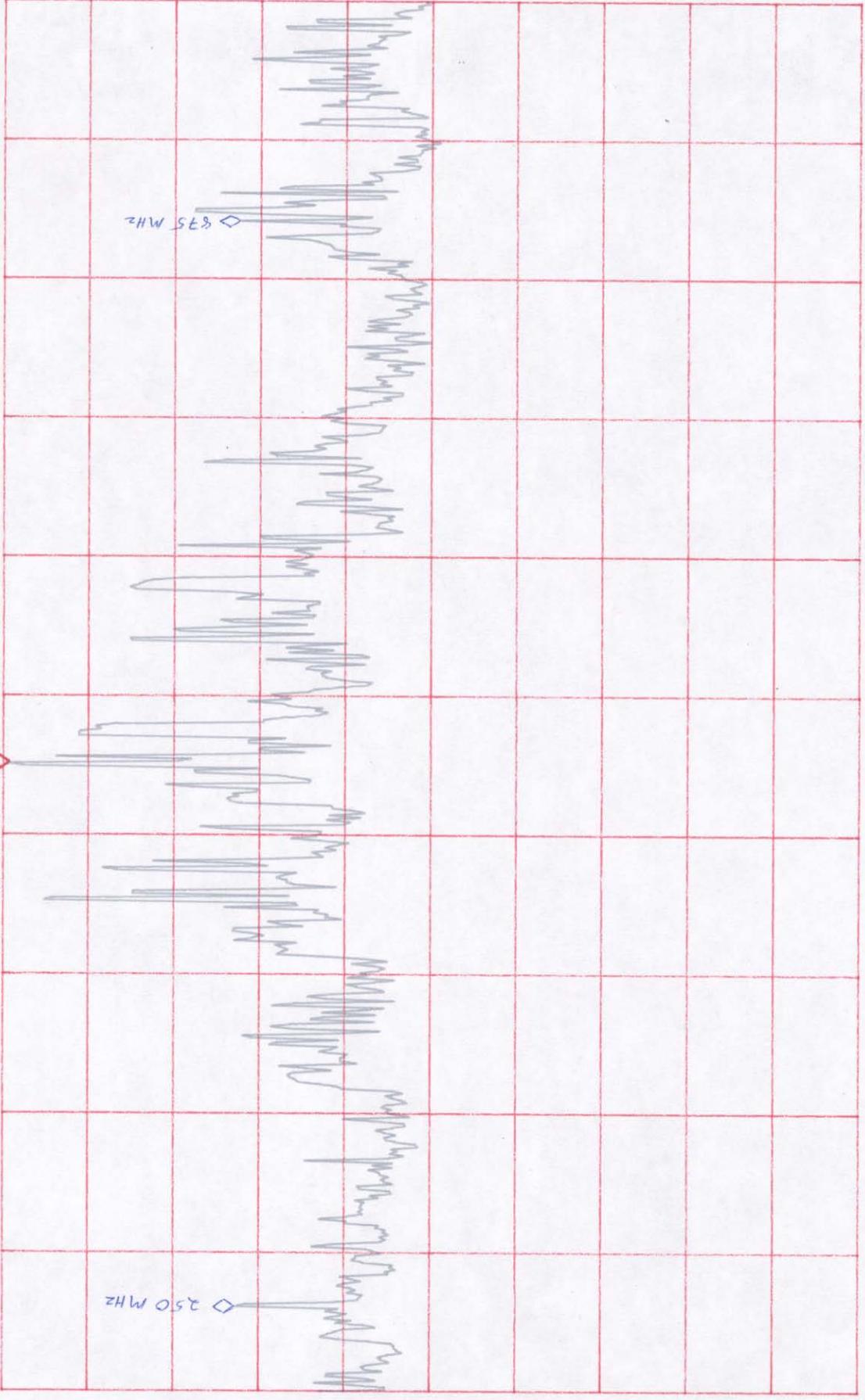
START 200.0MHz      STOP 1.0000GHz  
\*RBW 100kHz      VBW 100kHz      SWP 200ms

595T

ATTEN 20dB  
RL 10.0dBm

MKR 9.33dBm  
561.3MHz

10dB/



◇ 250 MHz

◇ 875 MHz

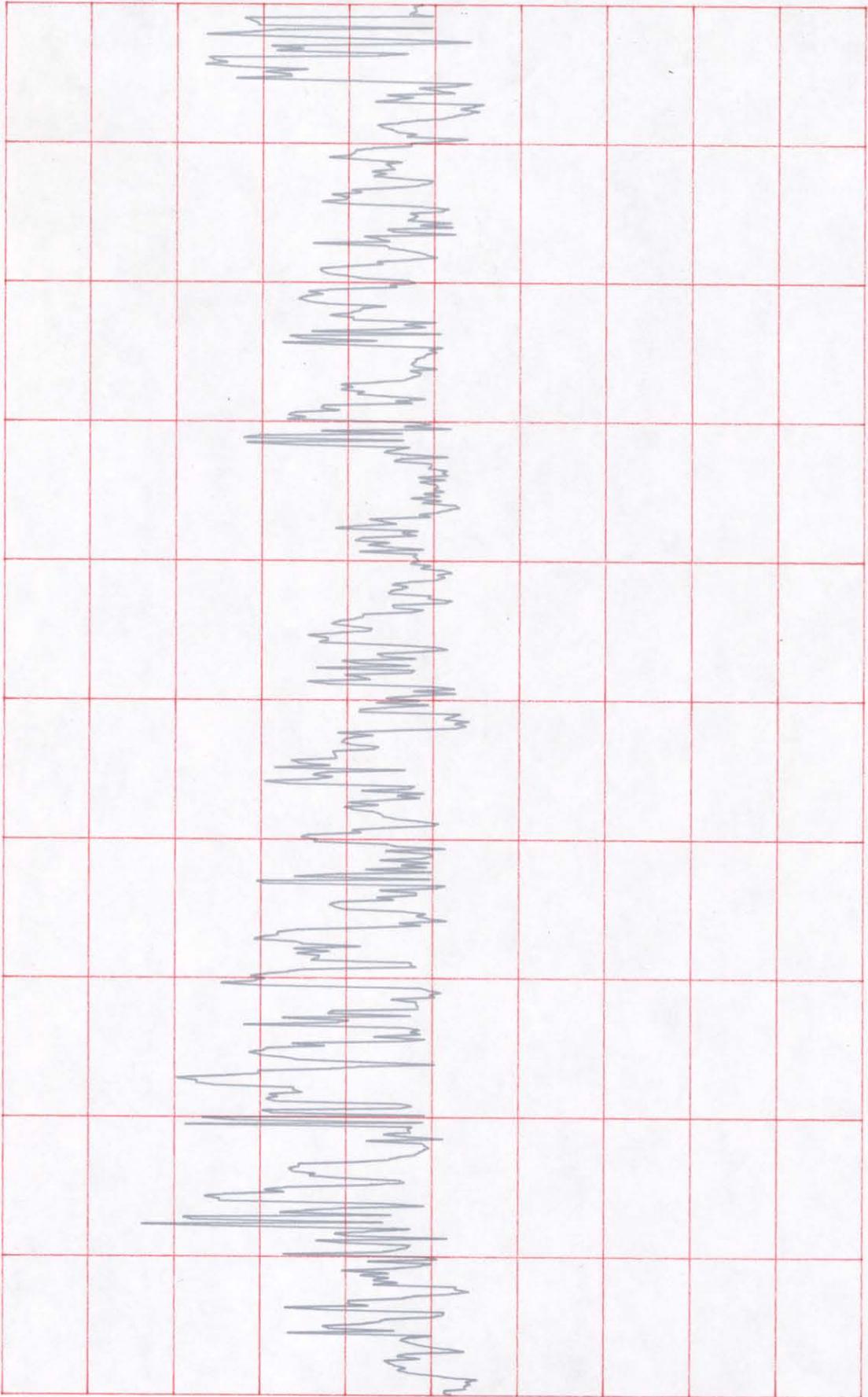
START 200.0MHz  
RBW 100kHz

STOP 1.0000GHz  
SWP 200ms

VBW 100kHz

ATTEN 20dB  
RL 10.0dBm

10dB/



□

START 1.000GHZ  
\*RBW 100KHZ

STOP 2.000GHZ  
SWP 250ms  
VBW 100KHZ

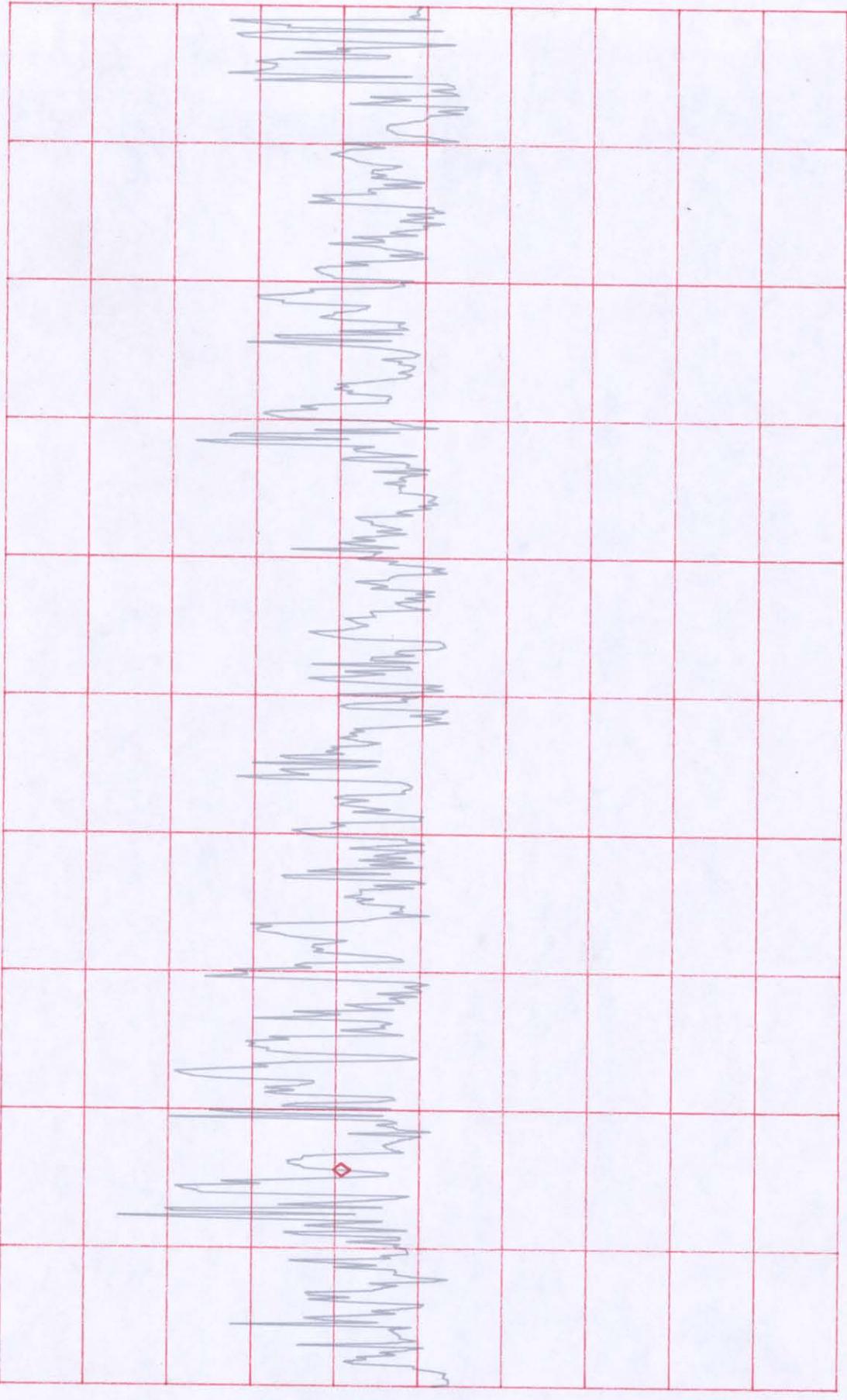
2023/11/20

ATTEEN 20dB  
RL 10.0dBm  
MKR -31.67dBm  
1.157GHz

10dB/

START 1.000GHz  
\*RBW 100kHz

STOP 2.000GHz  
VBW 100kHz  
SWP 250ms

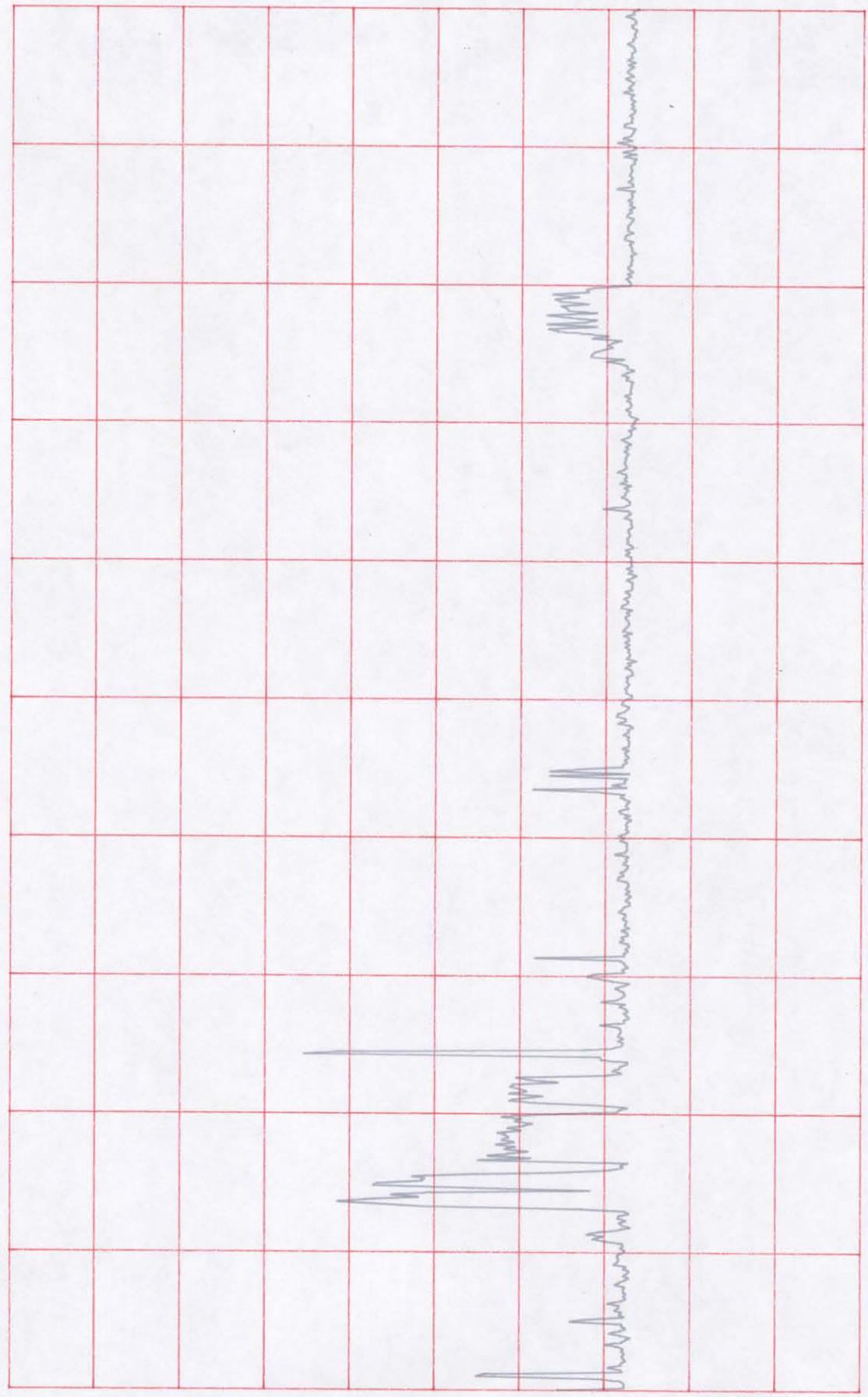


D

1991

ATTEN 20dB  
RL 10.0dBm

10dB/



0

START 2.000GHZ      STOP 5.000GHZ  
\*RBW 100kHz      VBW 100kHz      SWP 750ms

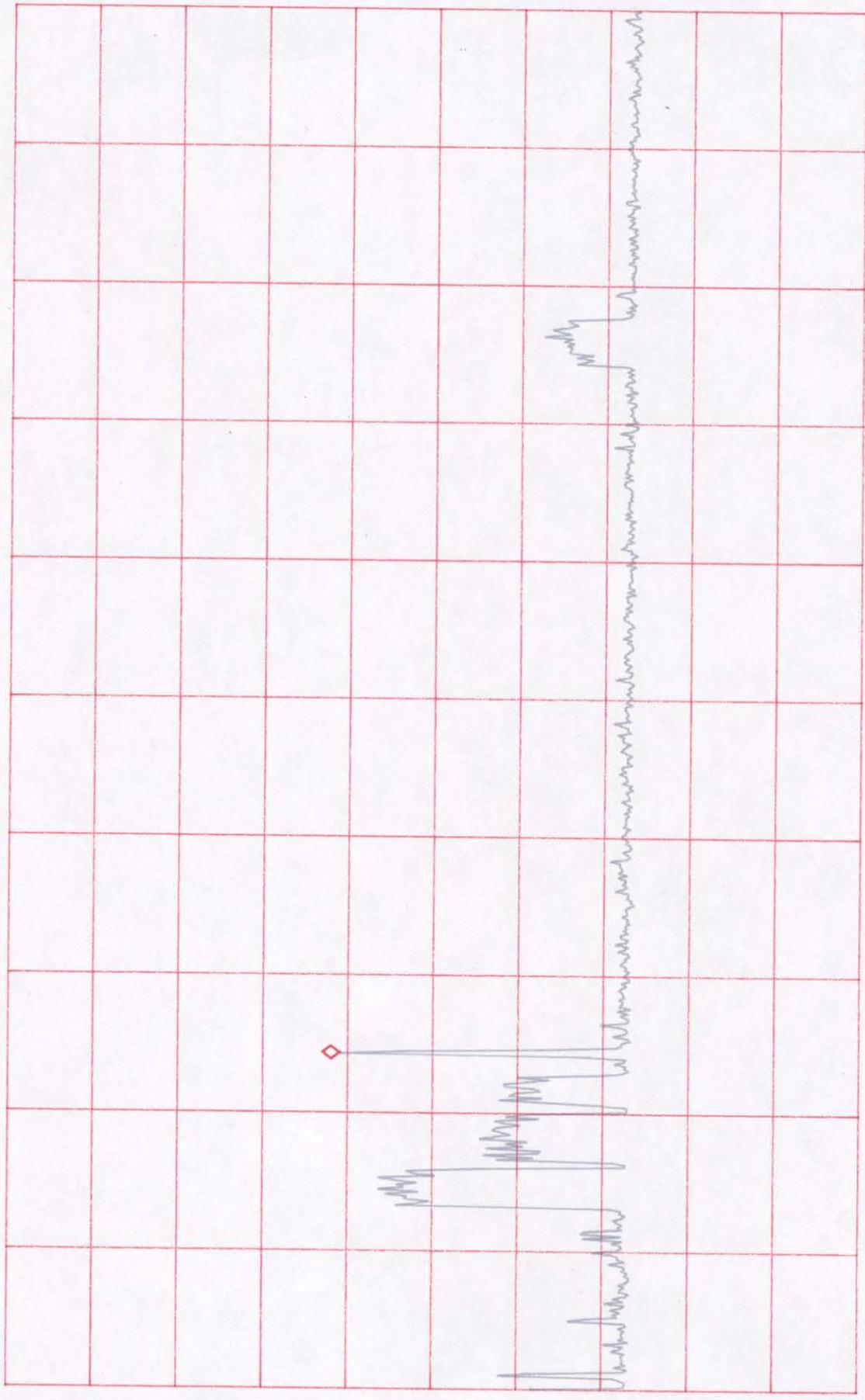
1987

ATTEEN 20dB  
RL 10.0dBm  
MKR -29.00dBm  
2.730GHZ

10dB/

START 2.000GHZ  
\*RBW 100kHz

STOP 5.000GHZ  
VBW 100kHz  
SWP 750ms



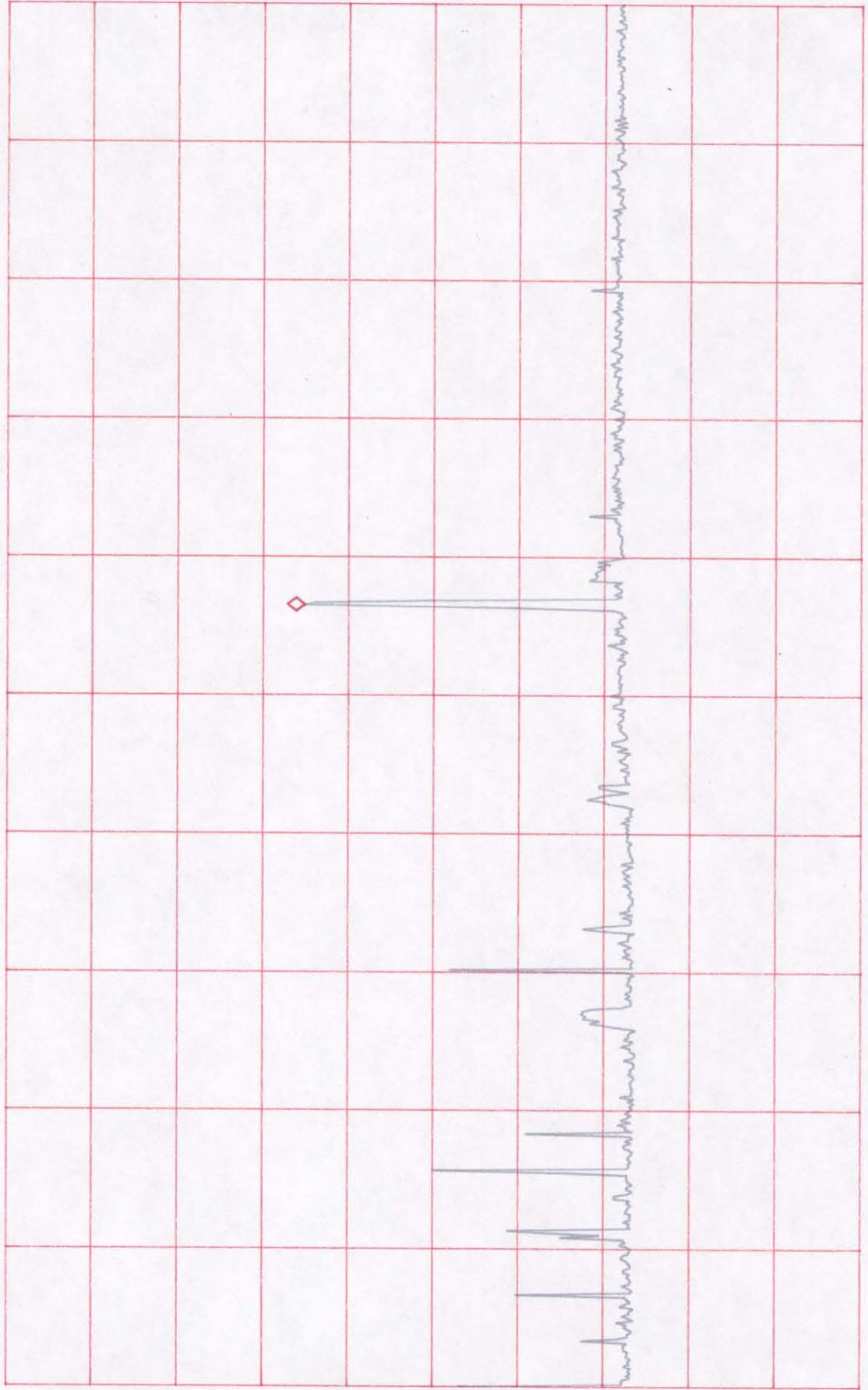
D

cont

ATTEN 20dB  
RL 10.0dBm

MKR -24.83dBm  
6.695GHZ

10dB/



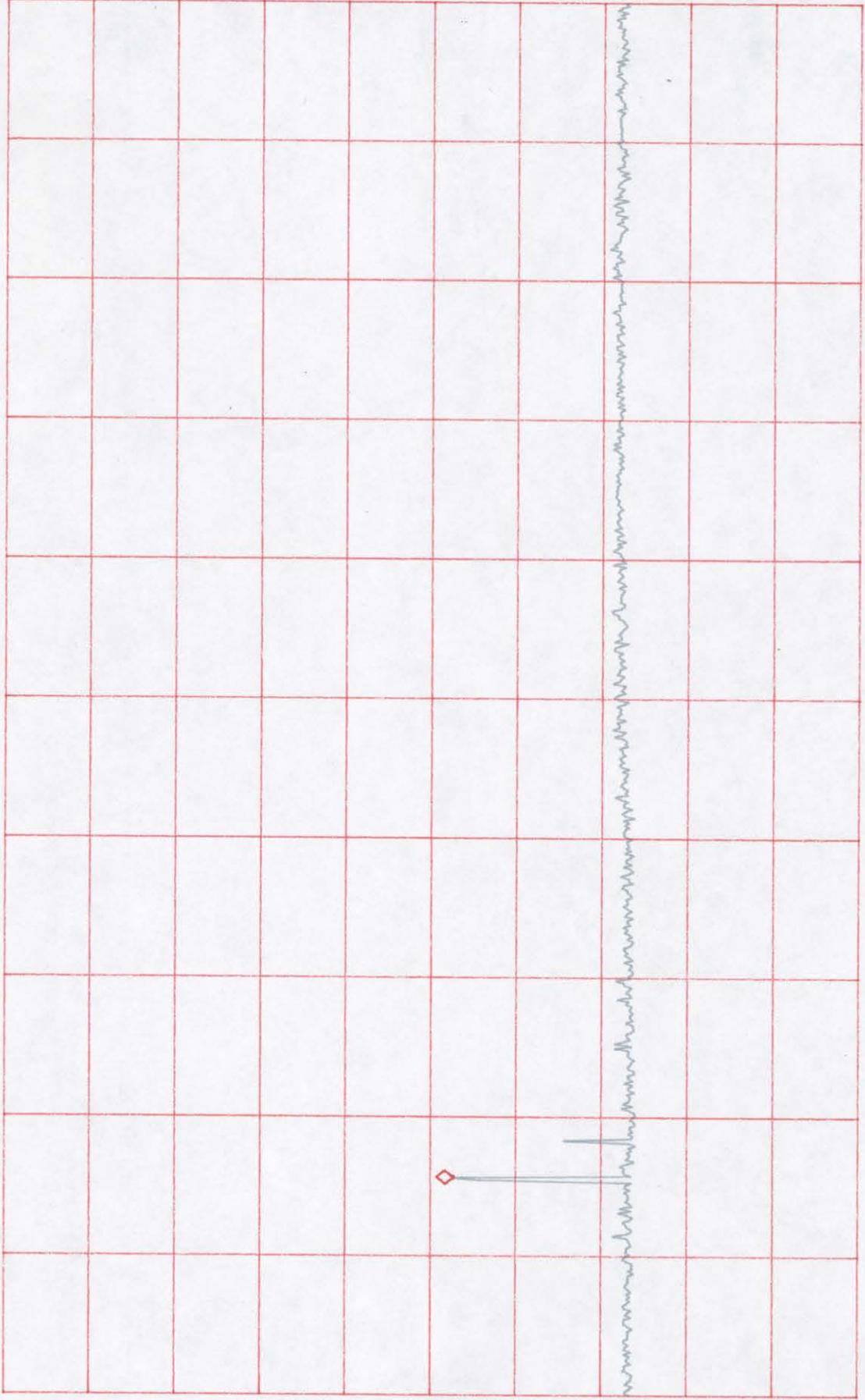
D

START 5.000GHZ      STOP 8.000GHZ  
 \*RBW 100kHz      VBW 100kHz      SWP 750ms

ATTEN 20dB  
RL 10.0dBm

MKR -42.67dBm  
5.470GHz

10dB/



D

START 5.000GHz

STOP 8.000GHz

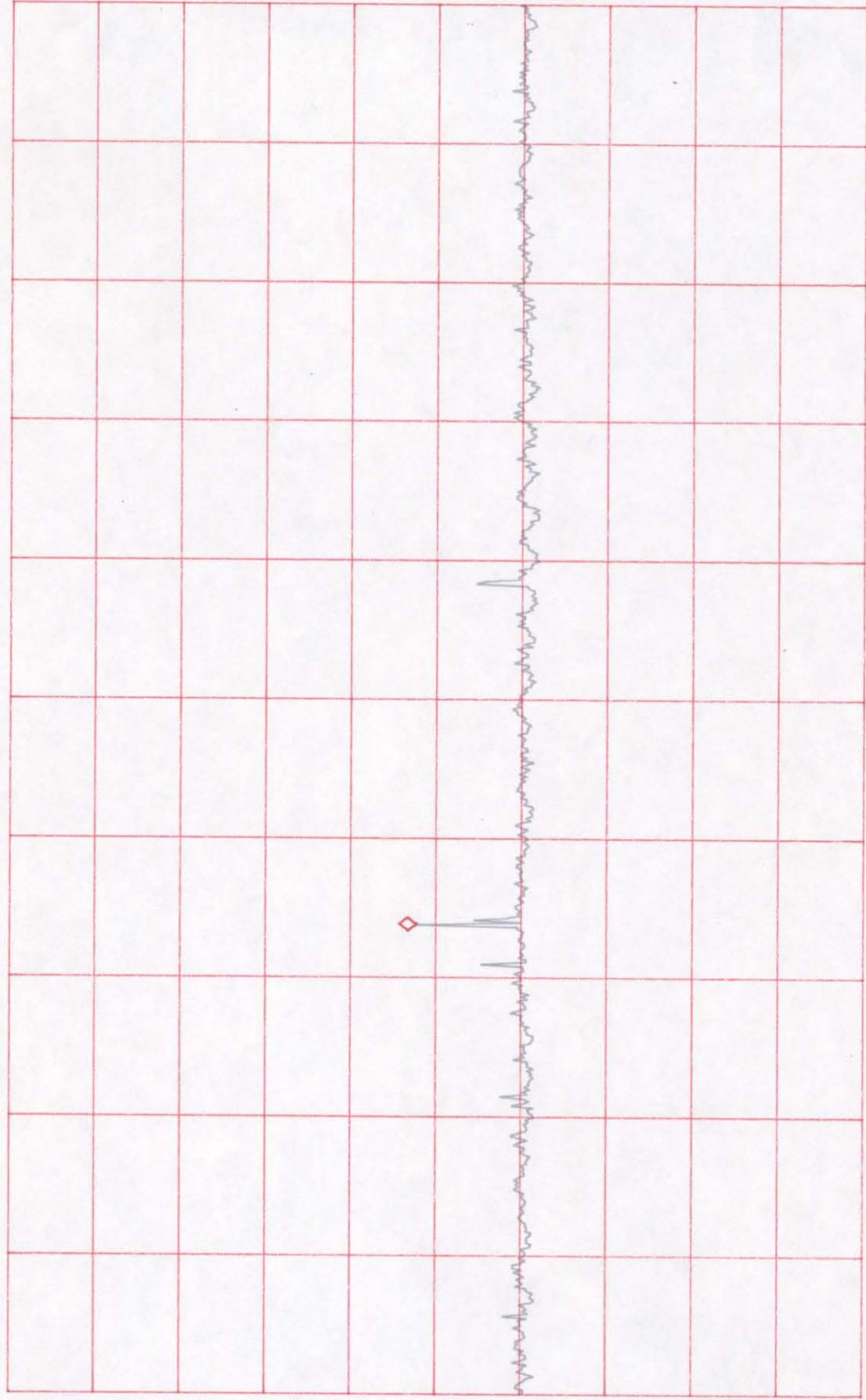
\*RBW 100kHz

VBW 100kHz

SWP 750ms

01917

\*ATTEN 0dB  
MKR -57.67dBm  
RL -10.0dBm  
9.353GHz  
10dB/

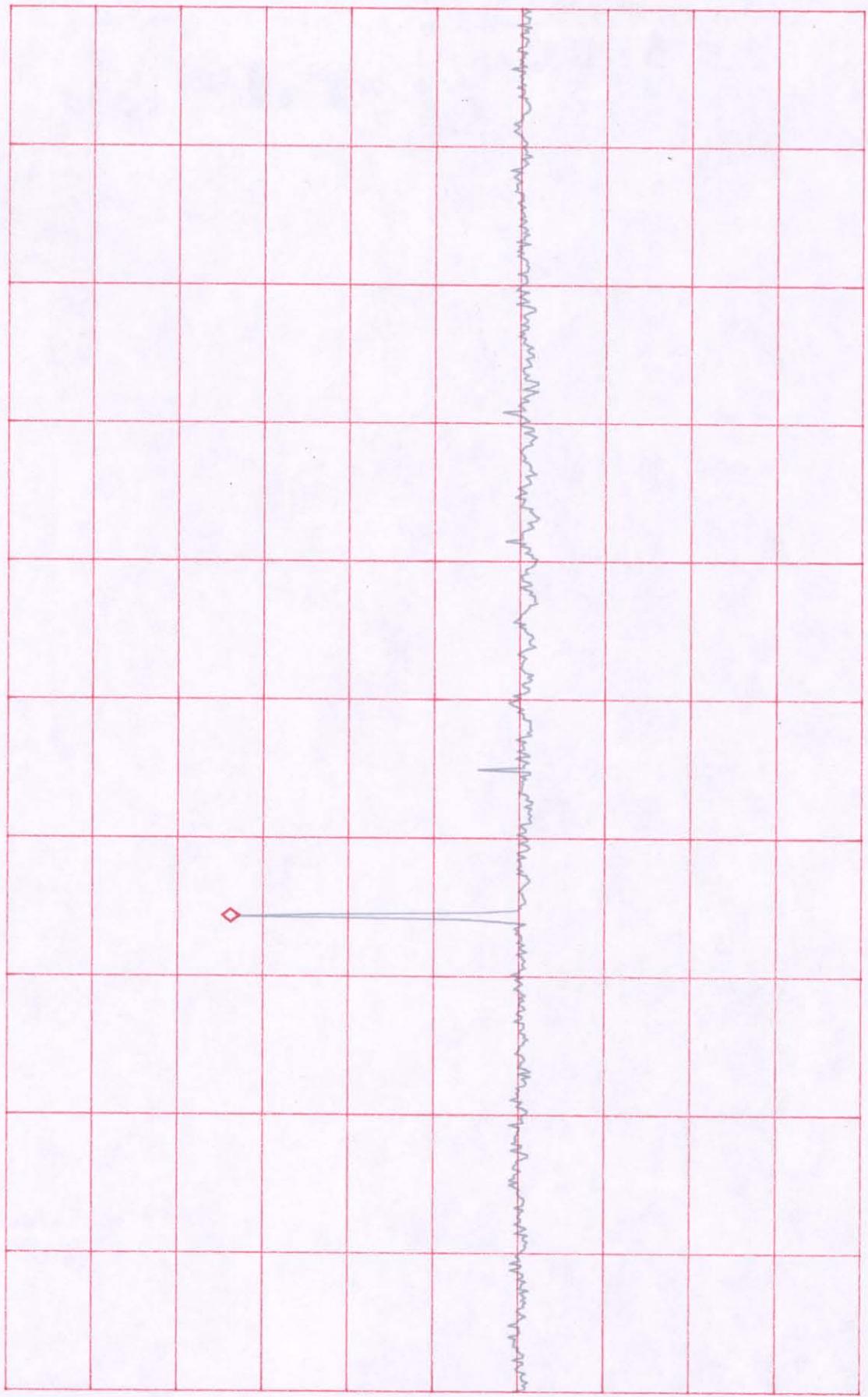


START 8.000GHz  
\*RBW 100kHz  
STOP 12.000GHz  
VBW 100kHz  
SWP 1.00sec

D

195T

\*ATTEN 0dB  
MKR -37.17dBm  
RL -10.0dBm  
9.373GHz  
10dB/



D

START 8.000GHz  
\*RBW 100kHz  
STOP 12.000GHz  
VBW 100kHz  
SWP 1.00sec

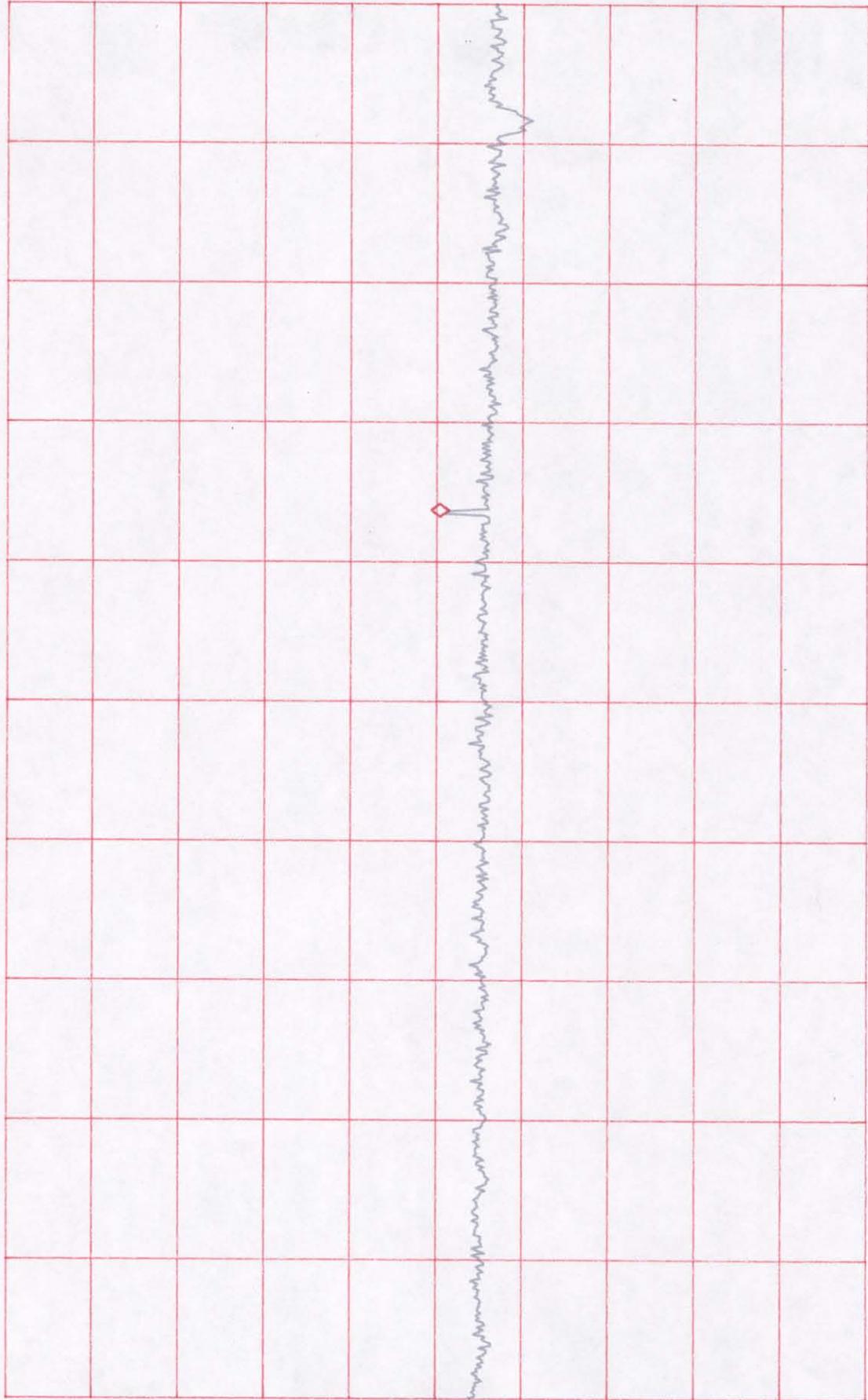
\*ATTEN 0dB

RL -10.0dBm

10dB/

MKR -61.33dBm

13.910GHz



START 12.000GHz

STOP 15.000GHz

\*RBW 100kHz

VBW 100kHz

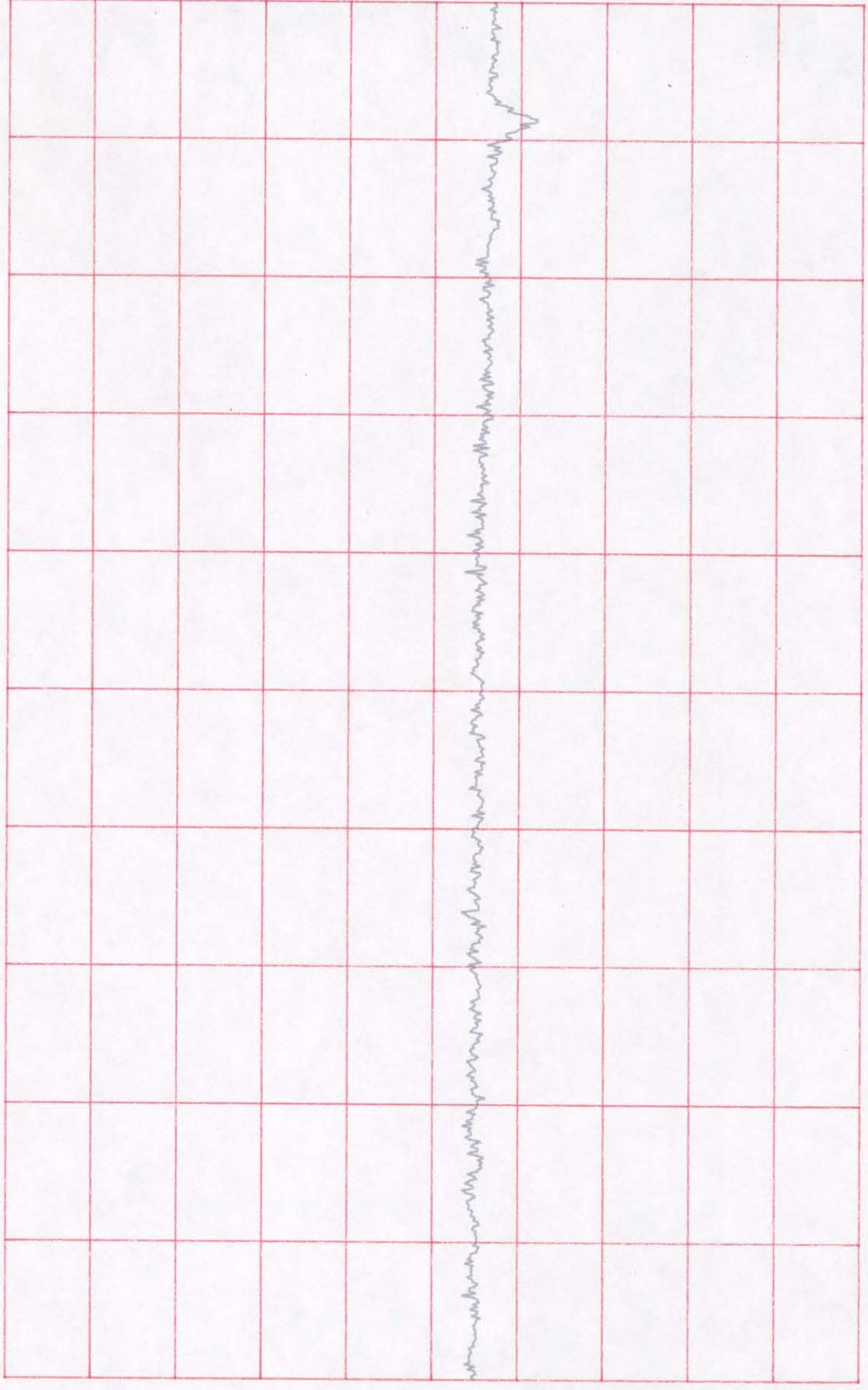
SWP 750ms

D

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

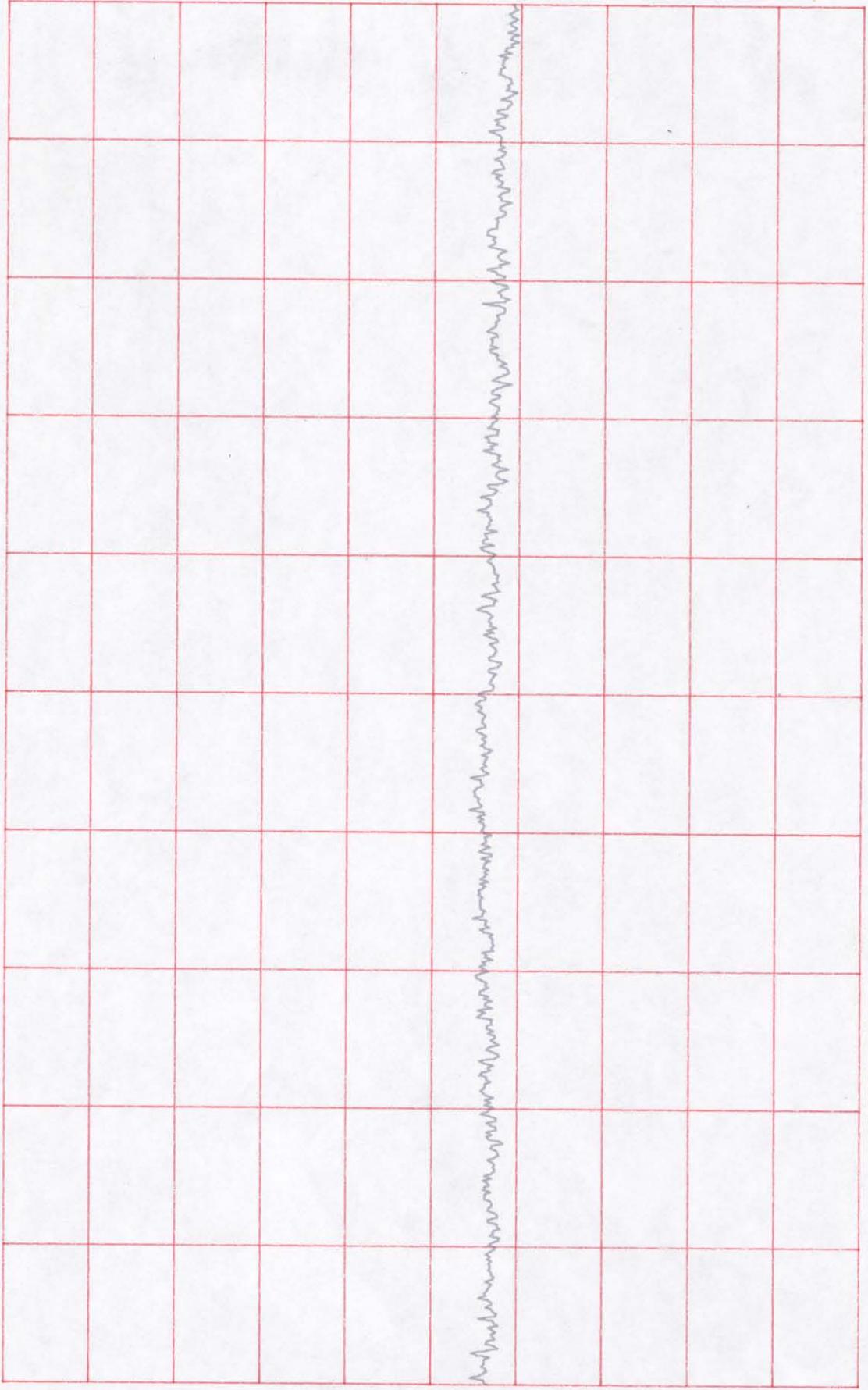
START 12.000GHZ STOP 15.000GHZ

\*RBW 100kHz VBW 100kHz SWP 750ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

START 15.000GHZ

STOP 18.000GHZ

\*RBW 100KHZ

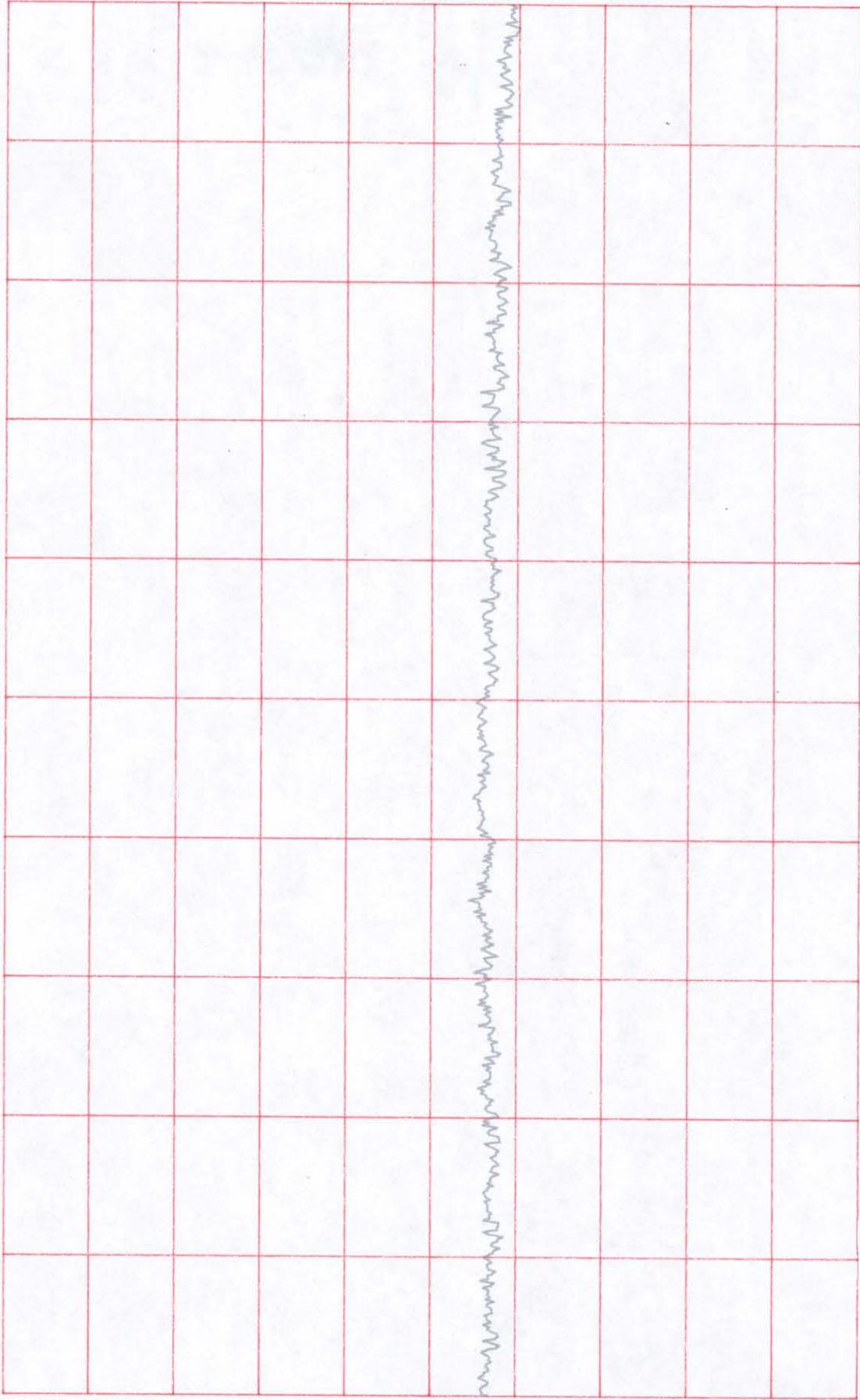
VBW 100KHZ

SWP 750ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

START 15.000GHZ

STOP 18.000GHZ

\*RBW 100kHz

VBW 100kHz

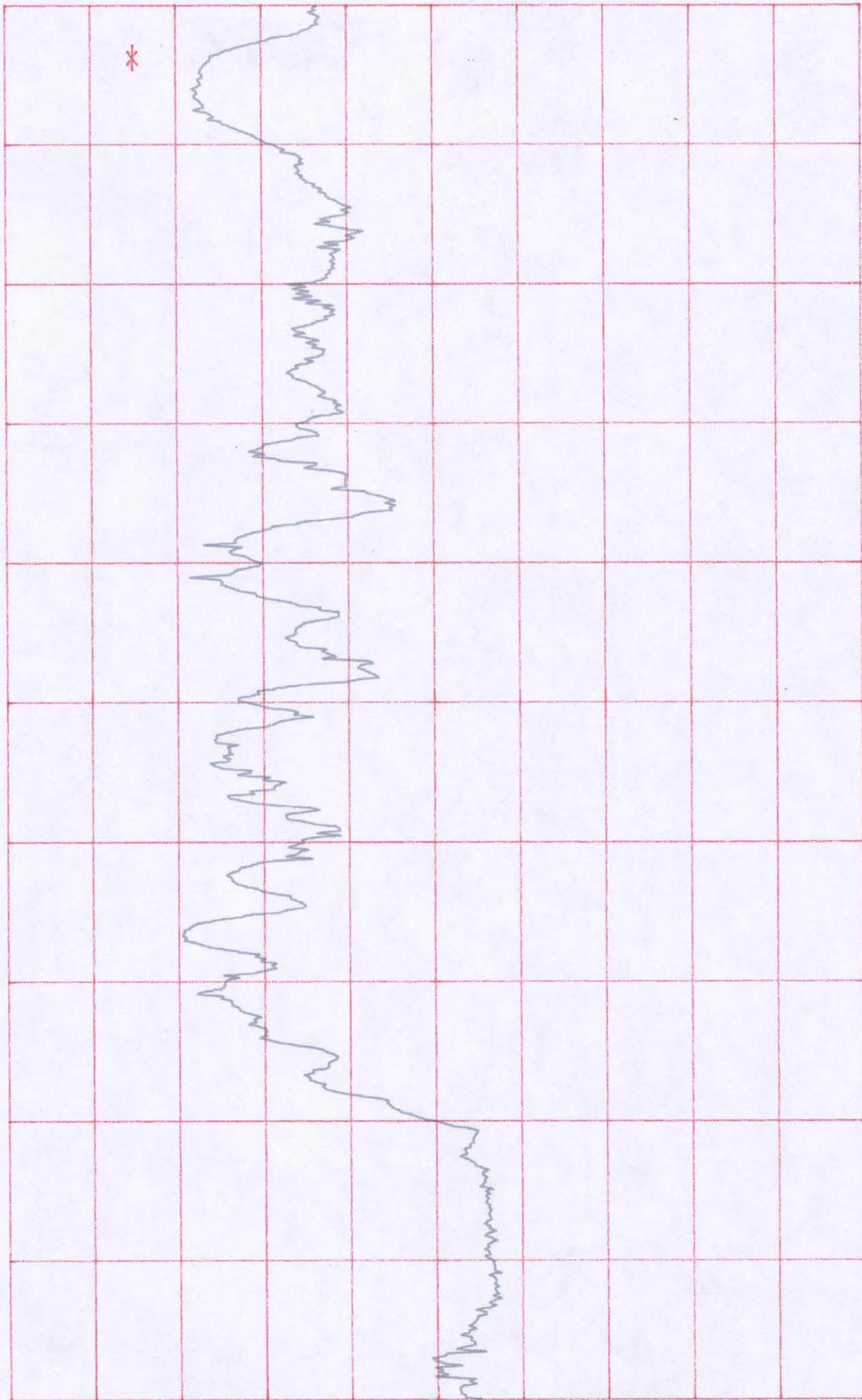
SWP 750ms

## **Location 2: Shielded Room**

Plots are presented in pairs covering the same frequency range. The first plot in each pair was taken with the door OPEN, and the second plot was taken with the door CLOSED.

ATTEN 20dB  
RL 10.0dBm

10dB/



□

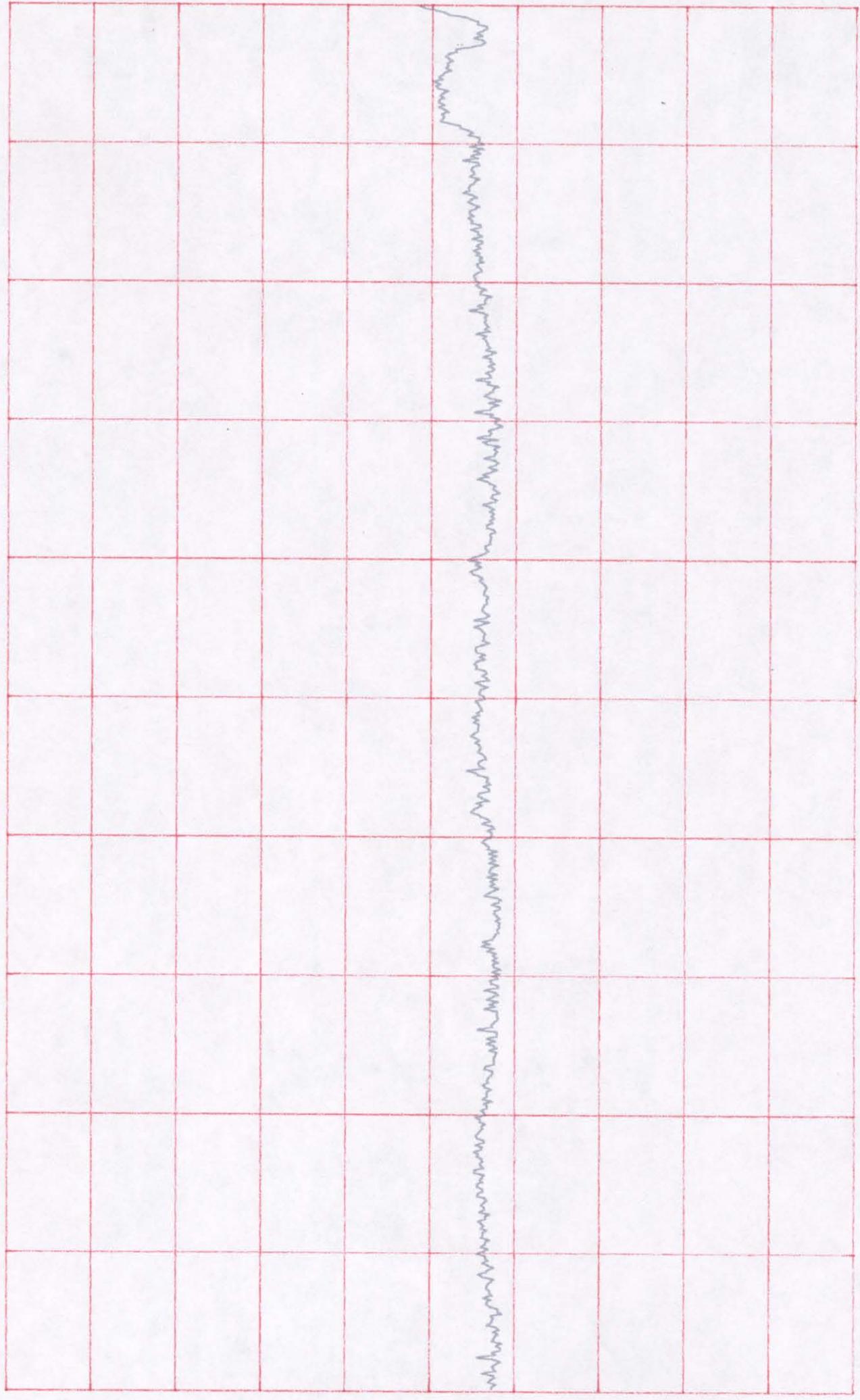
START 20.0MHz      STOP 200.0MHz  
RBW 1.0MHz      VBW 1.0MHz      SWP 50.0ms

89.57

ATTEN 20dB

RL 10.0dBm

10dB/



D

START 20.0MHz

RBW 1.0MHz

STOP 200.0MHz

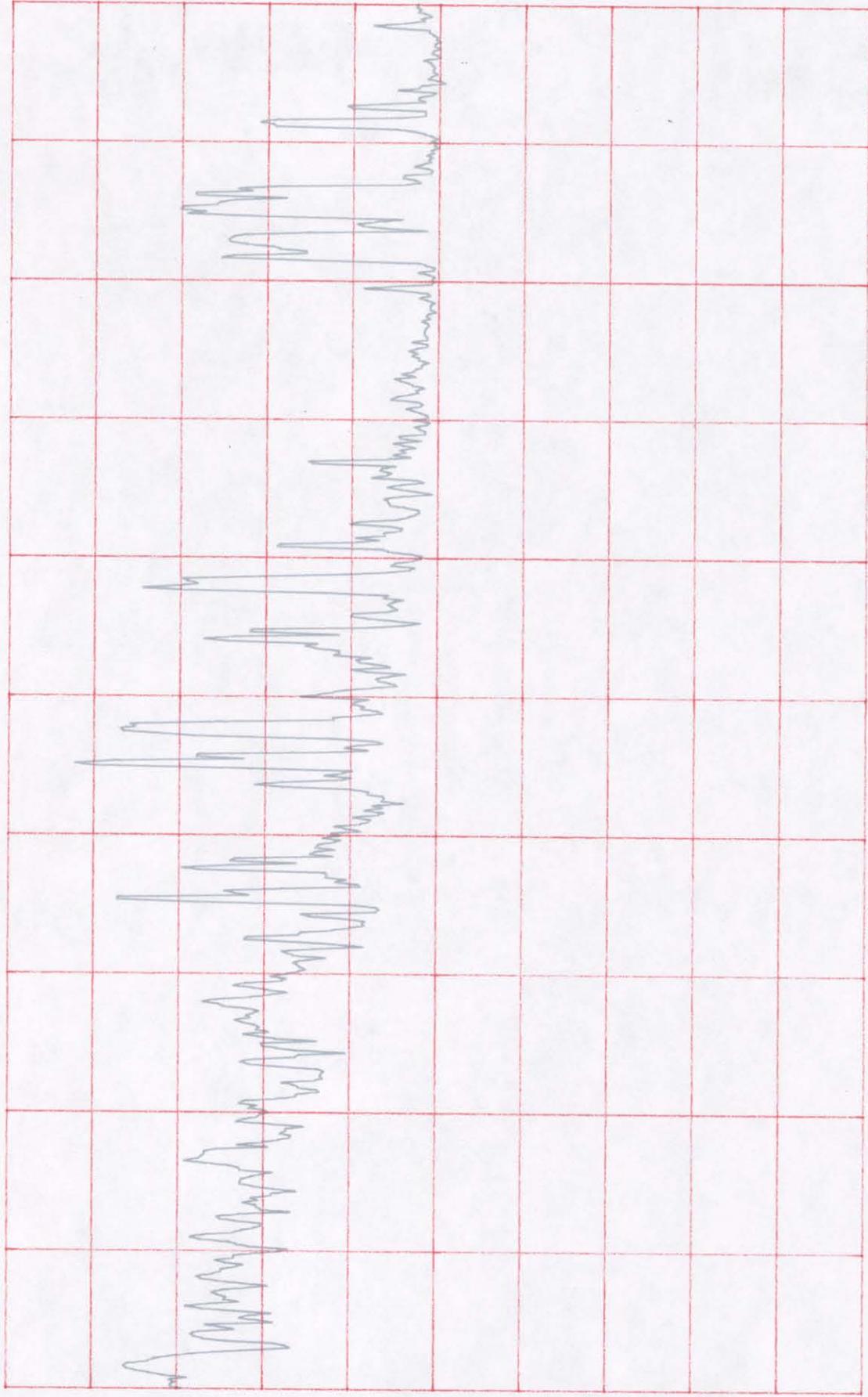
VBW 1.0MHz

SWP 50.0ms

ATTEN 10dB

RL 0dBm

10dB/



D

START 200.0MHz

RBW 1.0MHz

VBW 1.0MHz

STOP 1.0MHz

SWP 50.0ms

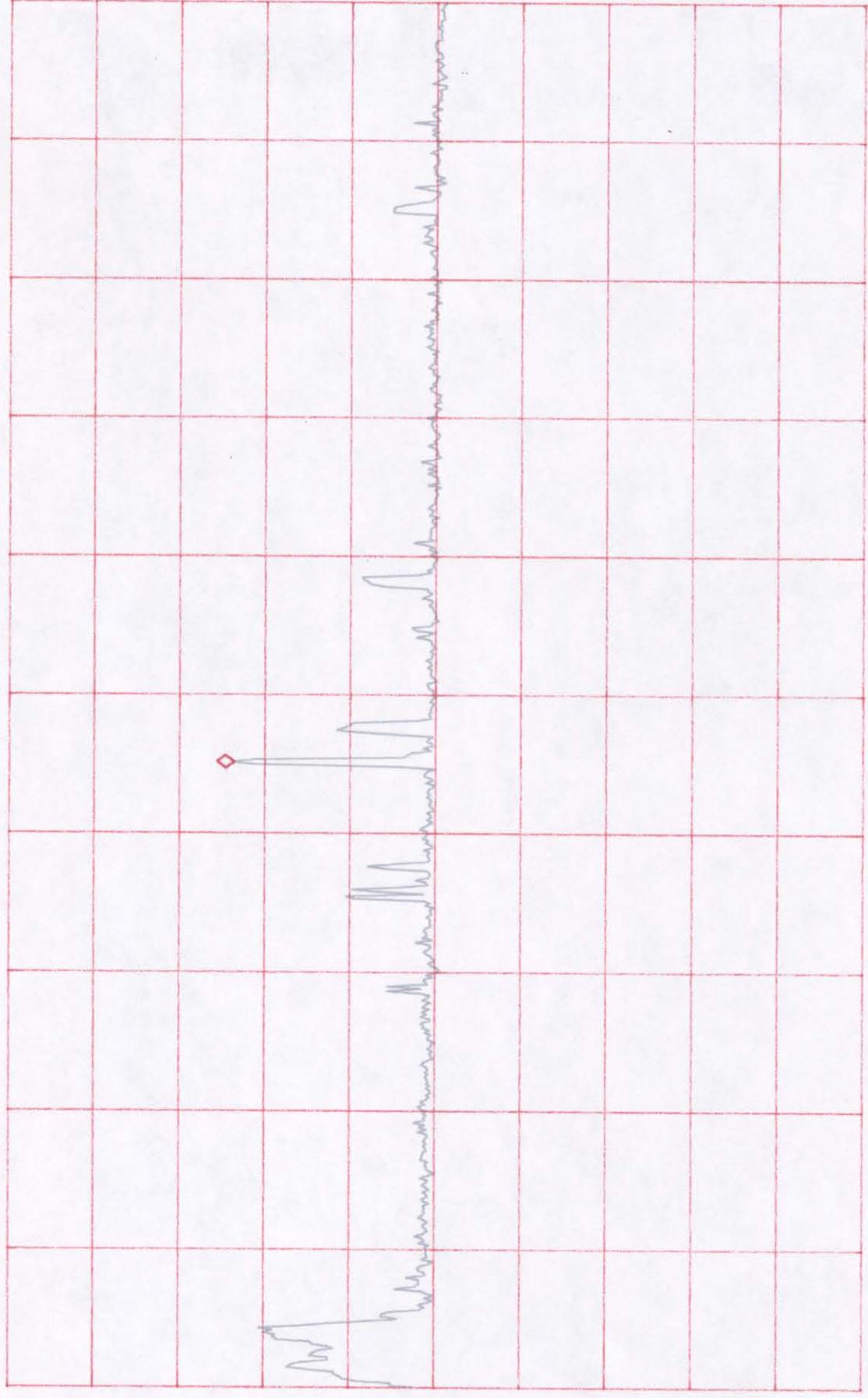
ATTEN 10dB

1356

ATTEN 10dB  
RL 0dBm

MKR -26.33dBm  
561.3MHz

10dB/



D

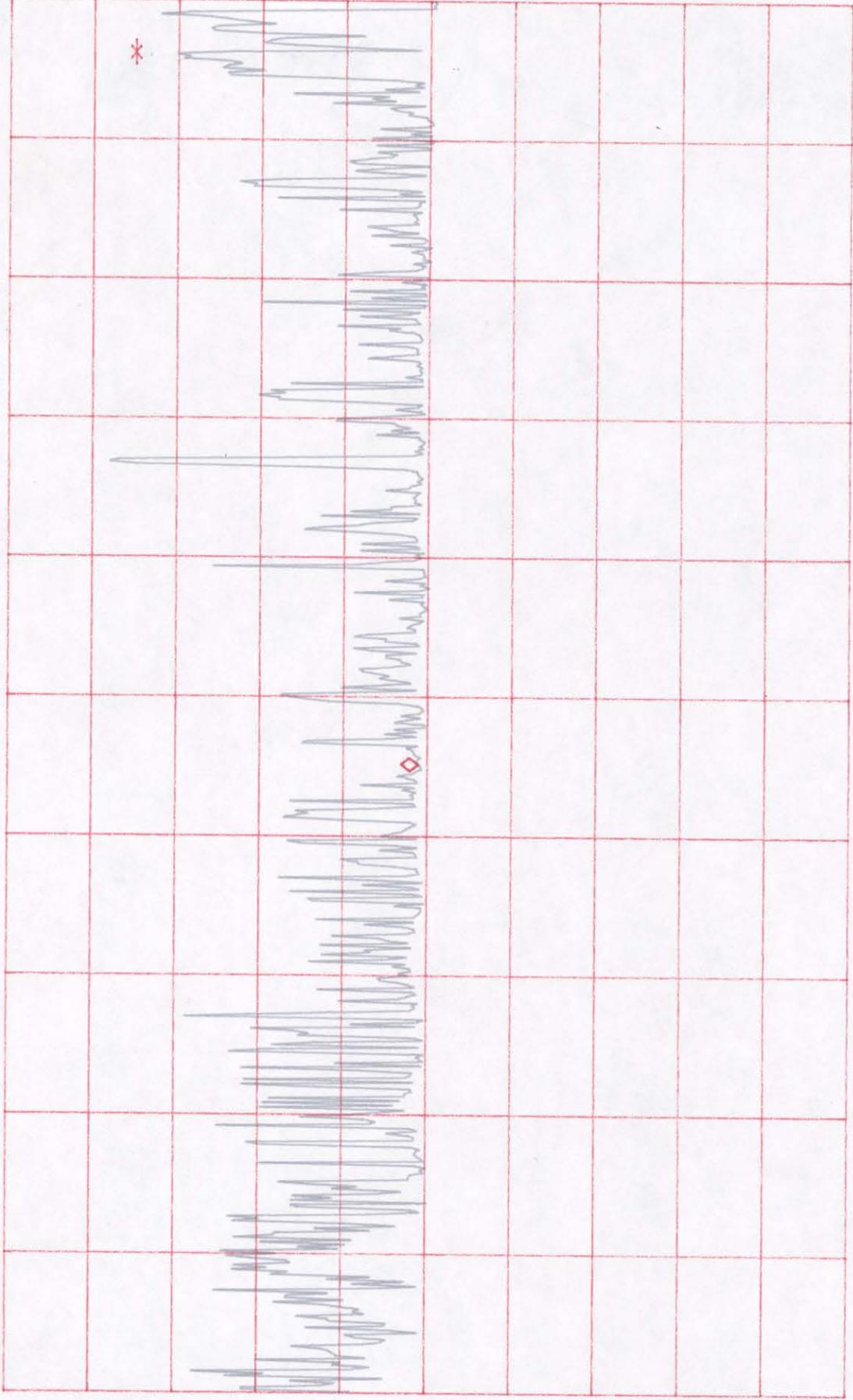
START 200.0MHz RBW 1.0MHz  
STOP 1.0000GHz VBW 1.0MHz SWP 50.0ms

2985

ATTEN 10dB  
RL 0dBm

MKR -48.83dBm  
1.452GHz

10dB/

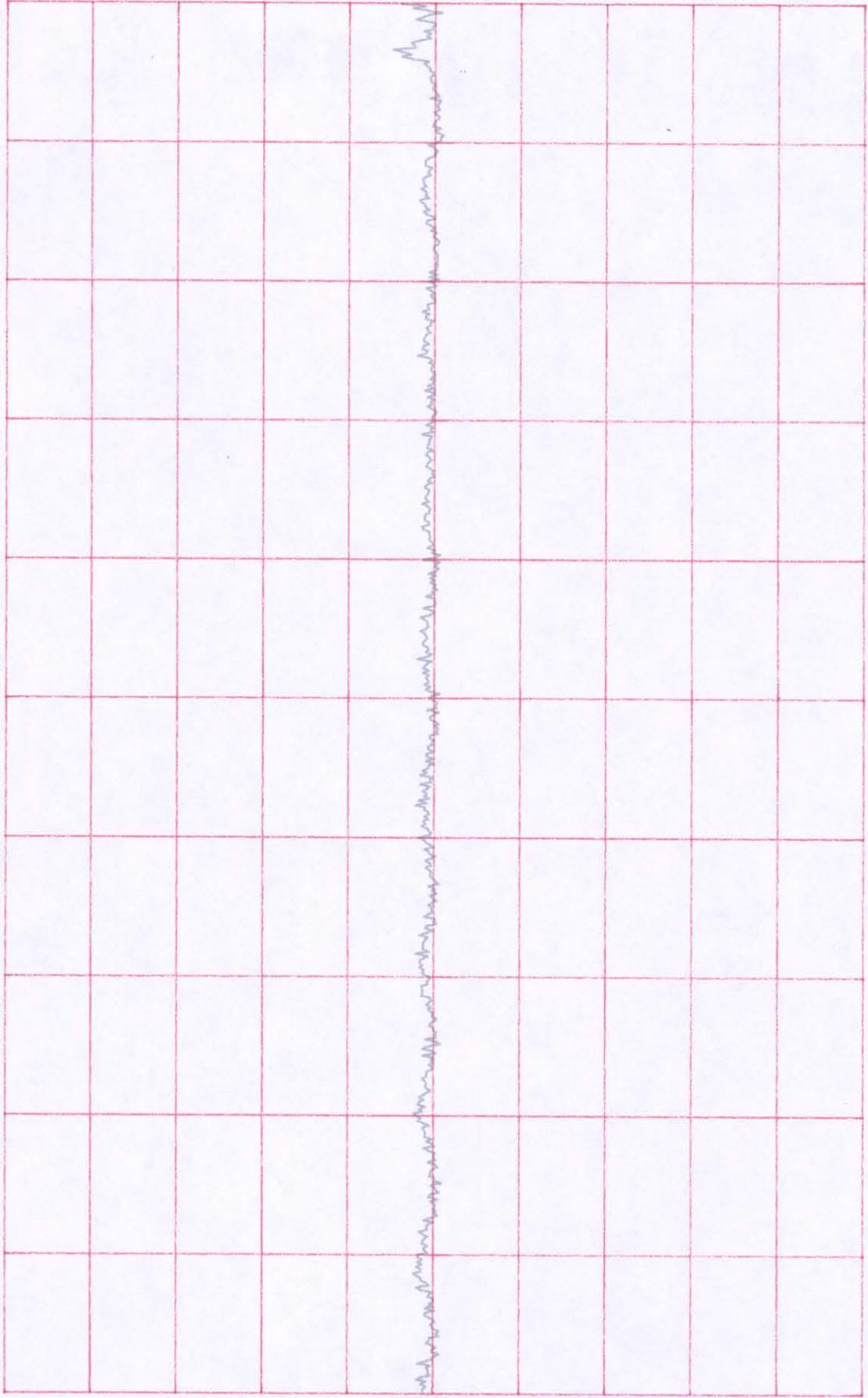


D

START 1.0000GHZ      STOP 1.9900GHZ  
 RBW 1.0MHZ      VBW 1.0MHZ      SWP 50.0ms

ATTEN 10dB  
RL 0dBm

10dB/

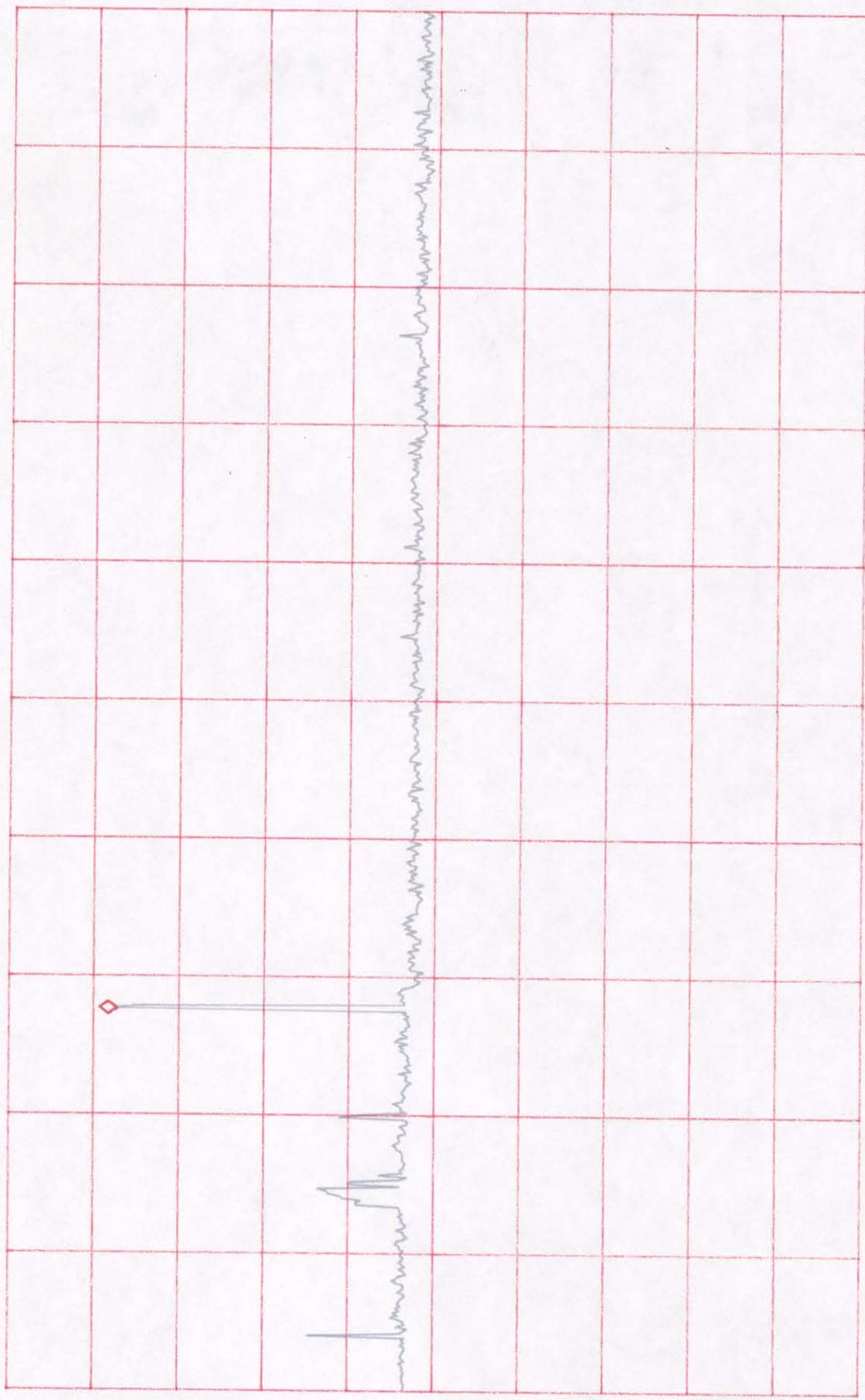


D

START 1.000000GHZ      STOP 1.99000GHZ  
RBW 1.0MHZ      VBW 1.0MHZ      SWP 50.0ms

548T

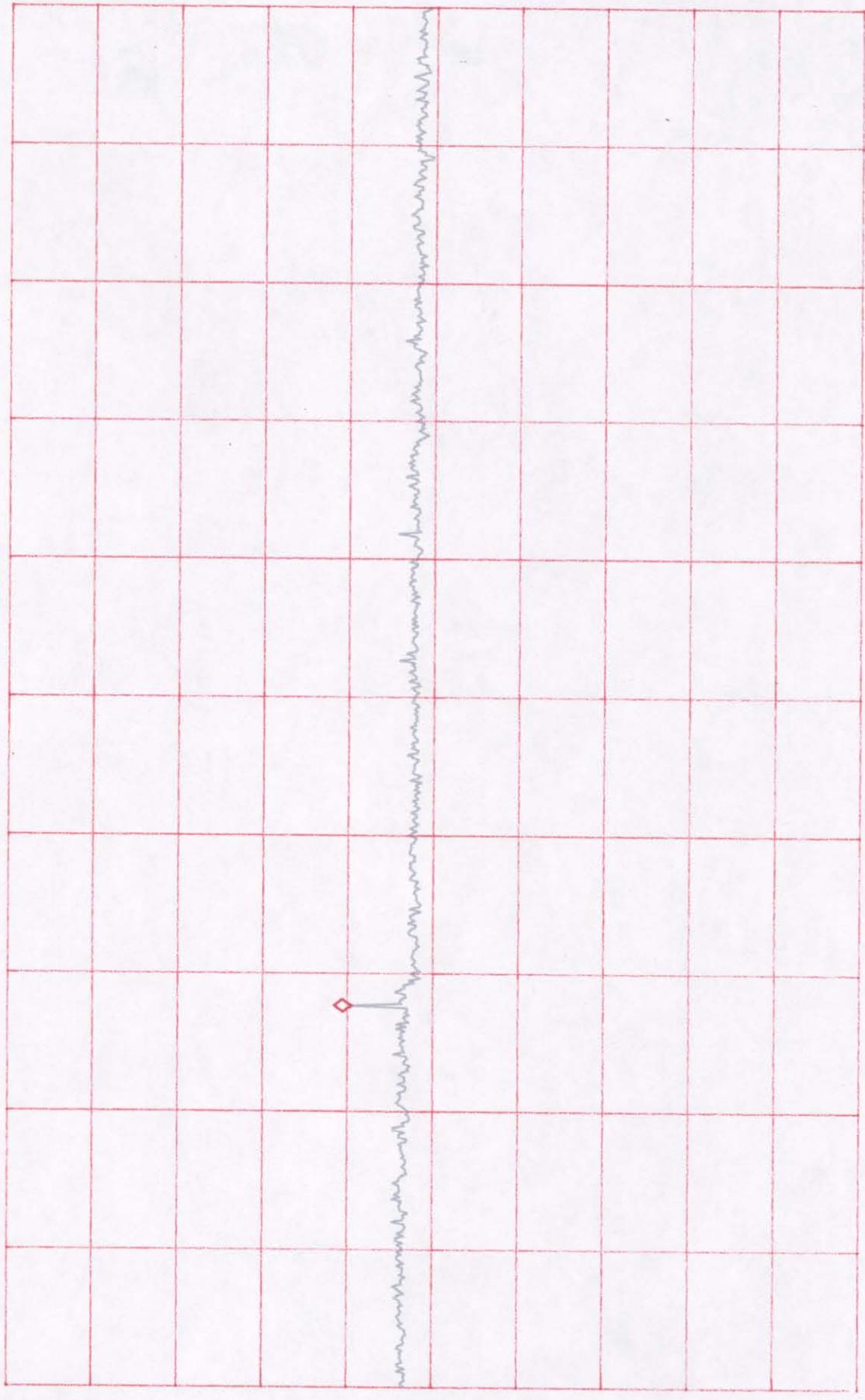
\*ATTEN 0dB  
RL -10.0dBm  
MKR -22.67dBm  
2.830GHZ  
10dB/



D

START 2.000GHZ  
RBW 1.0MHz  
STOP 5.000GHZ  
VBW 1.0MHz  
SWP 60.0ms

\*ATTEN 0dB  
RL -10.0dBm  
MKR -50.33dBm  
2.830GHZ  
10dB/



0

START 2.000GHZ  
RBW 1.0MHz  
STOP 5.000GHZ  
VBW 1.0MHz  
SWP 60.0ms

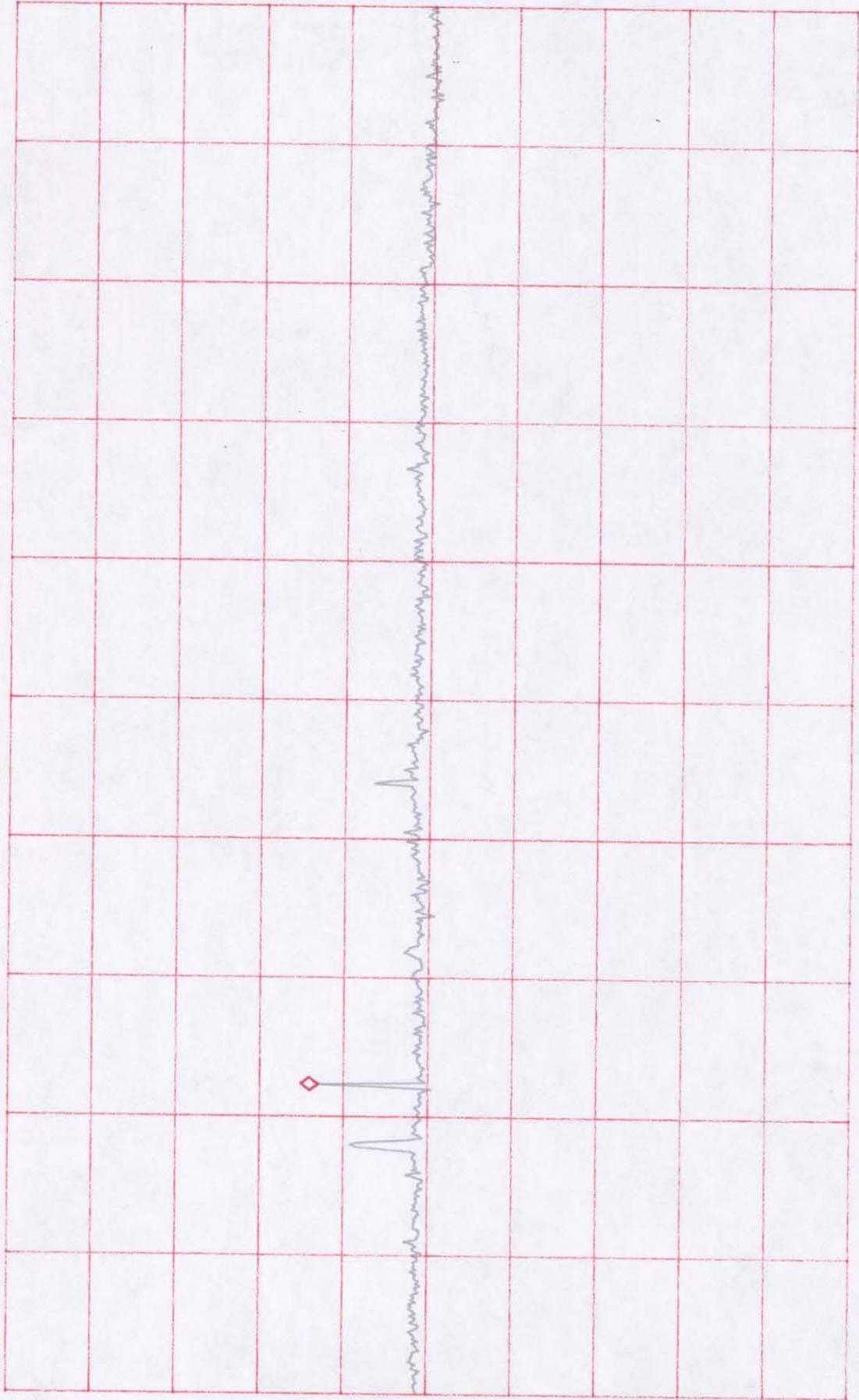
\*ATTEN 0dB

RL -10.0dBm

10dB/

MKR -46.83dBm

5.670GHZ



D

START 5.000GHZ

RBW 1.0MHz

VBW 1.0MHz

STOP 8.000GHZ

SWP 60.0ms

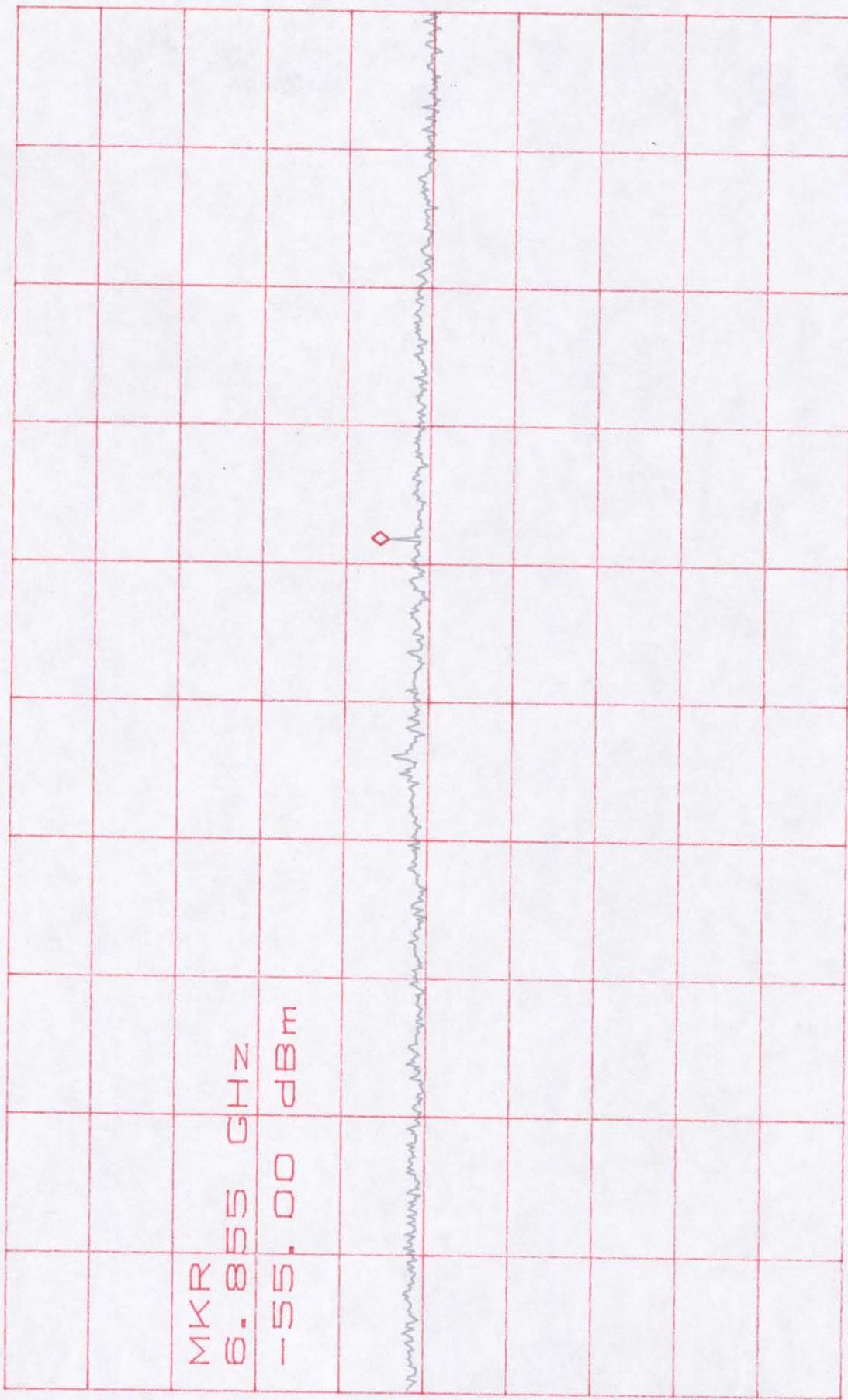
\*ATTEN 0dB

RL -10.0dBm

10dB/

MKR -55.00dBm

6.855GHZ



MKR  
6.855 GHZ  
-55.00 dBm

START 5.000GHZ

RBW 1.0MHz

VBW 1.0MHz

STOP 8.000GHZ

SWP 60.0ms

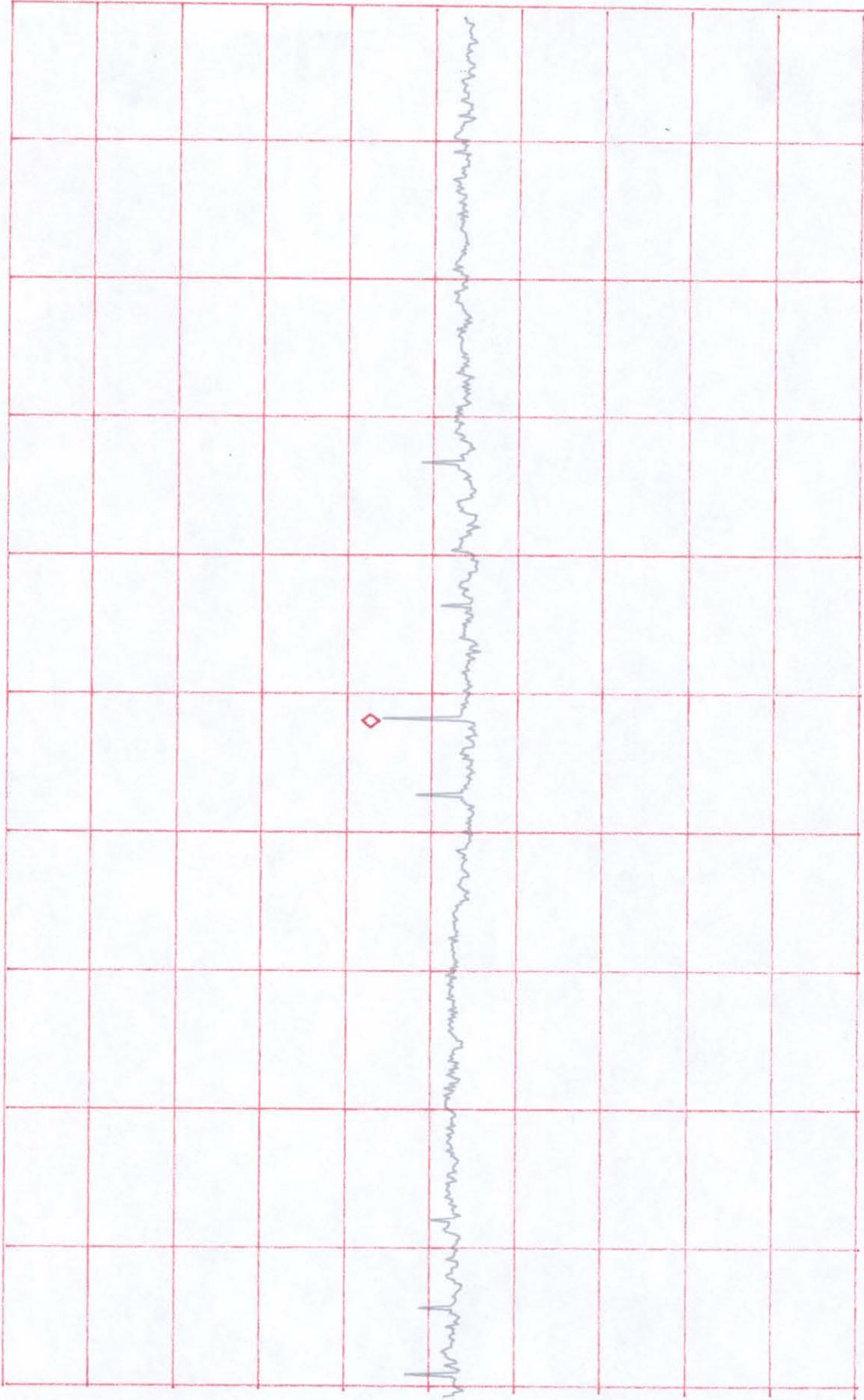
\*ATTEN 0dB

RL -10.0dBm

MKR -53.67dBm

9.960GHz

10dB/



D

START 8.000GHz

RBW 1.0MHz

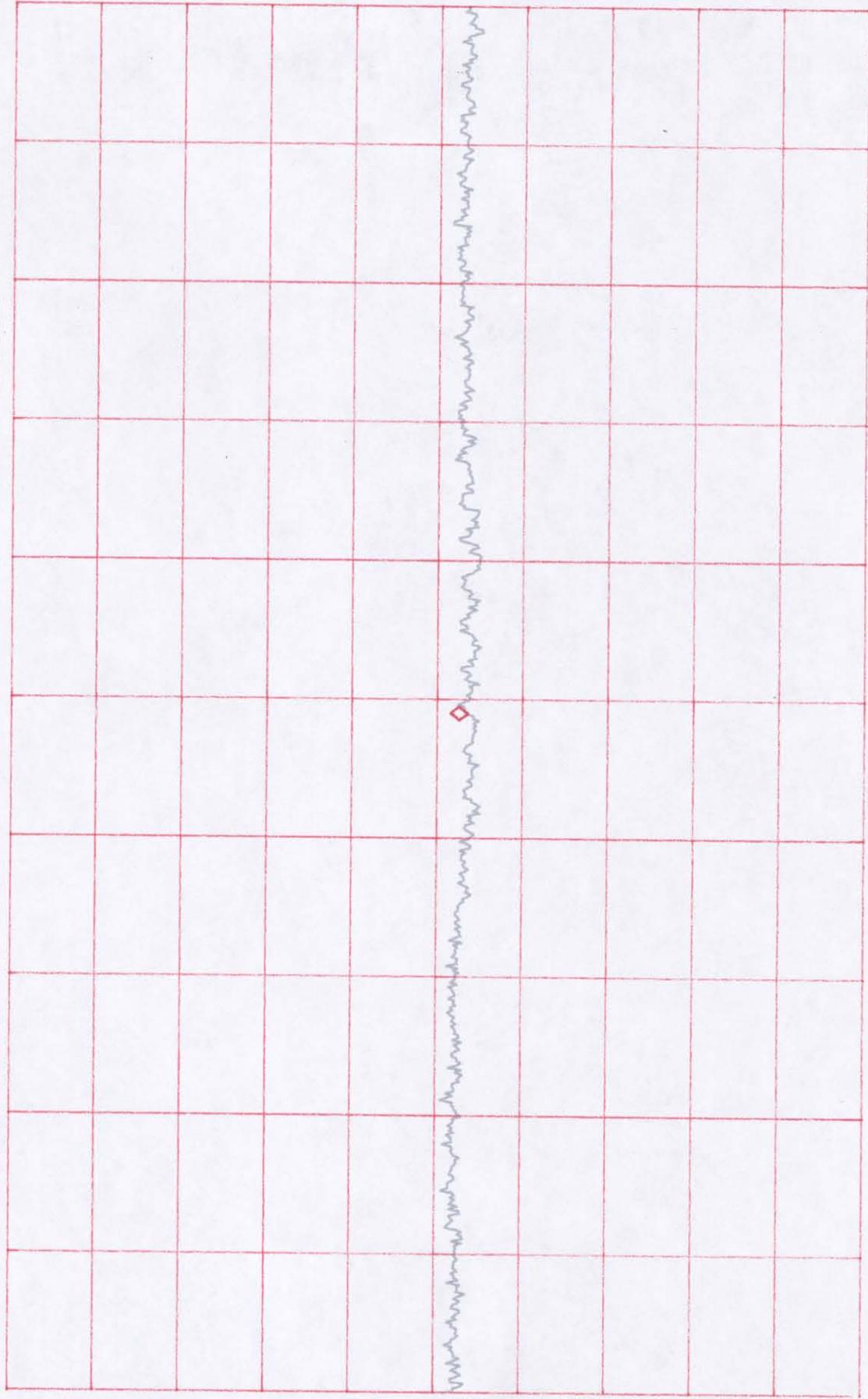
STOP 12.000GHz

VBW 1.0MHz

SWP 80.0ms

41957

\*ATTEN 0dB  
RL -10.0dBm  
MKR -63.50dBm  
9.960GHZ  
10dB/



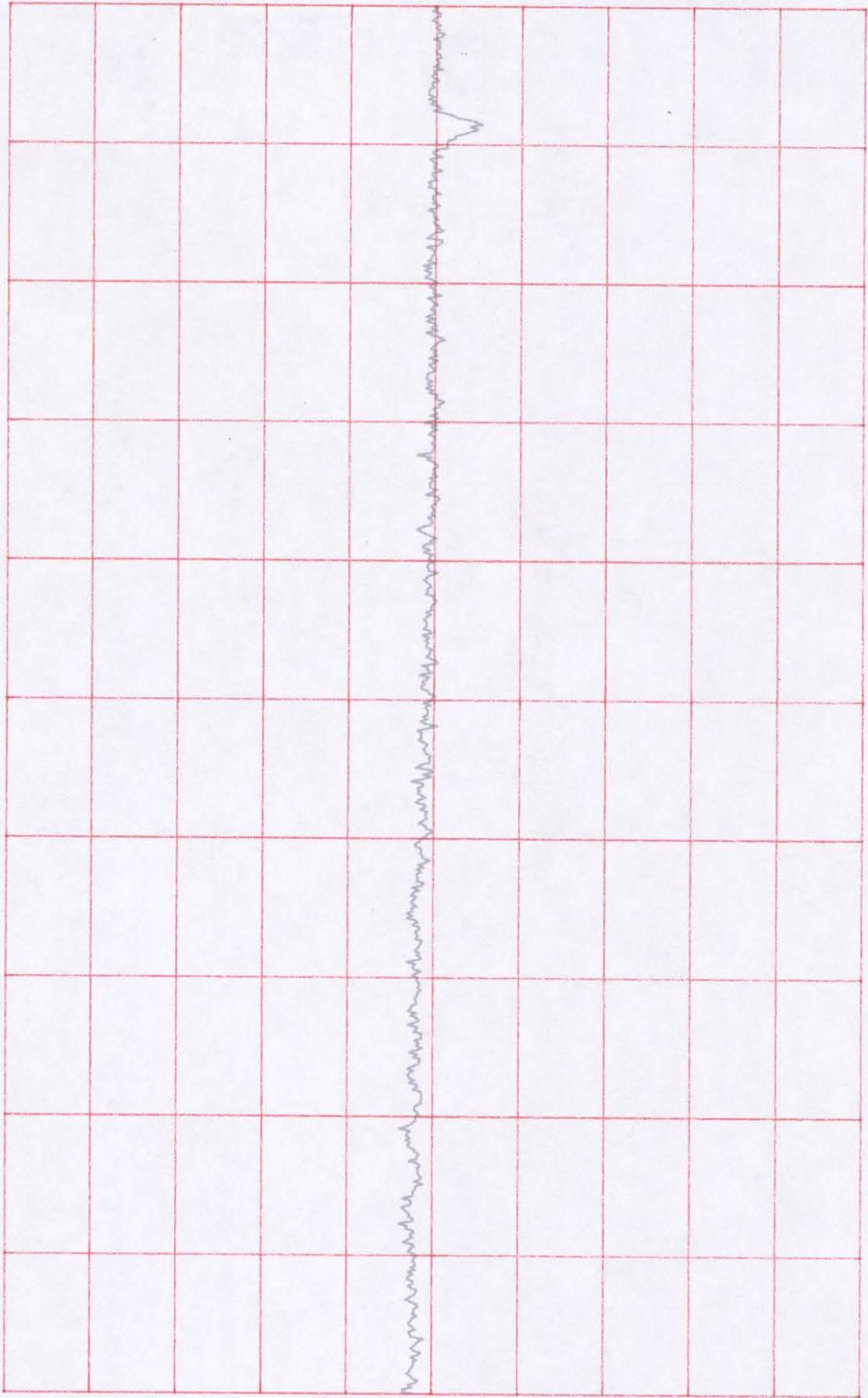
D

START 8.000GHZ  
RBW 1.0MHz  
VBW 1.0MHz  
STOP 12.000GHZ  
SWP 80.0ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

START 12.000GHZ

RBW 1.0MHZ

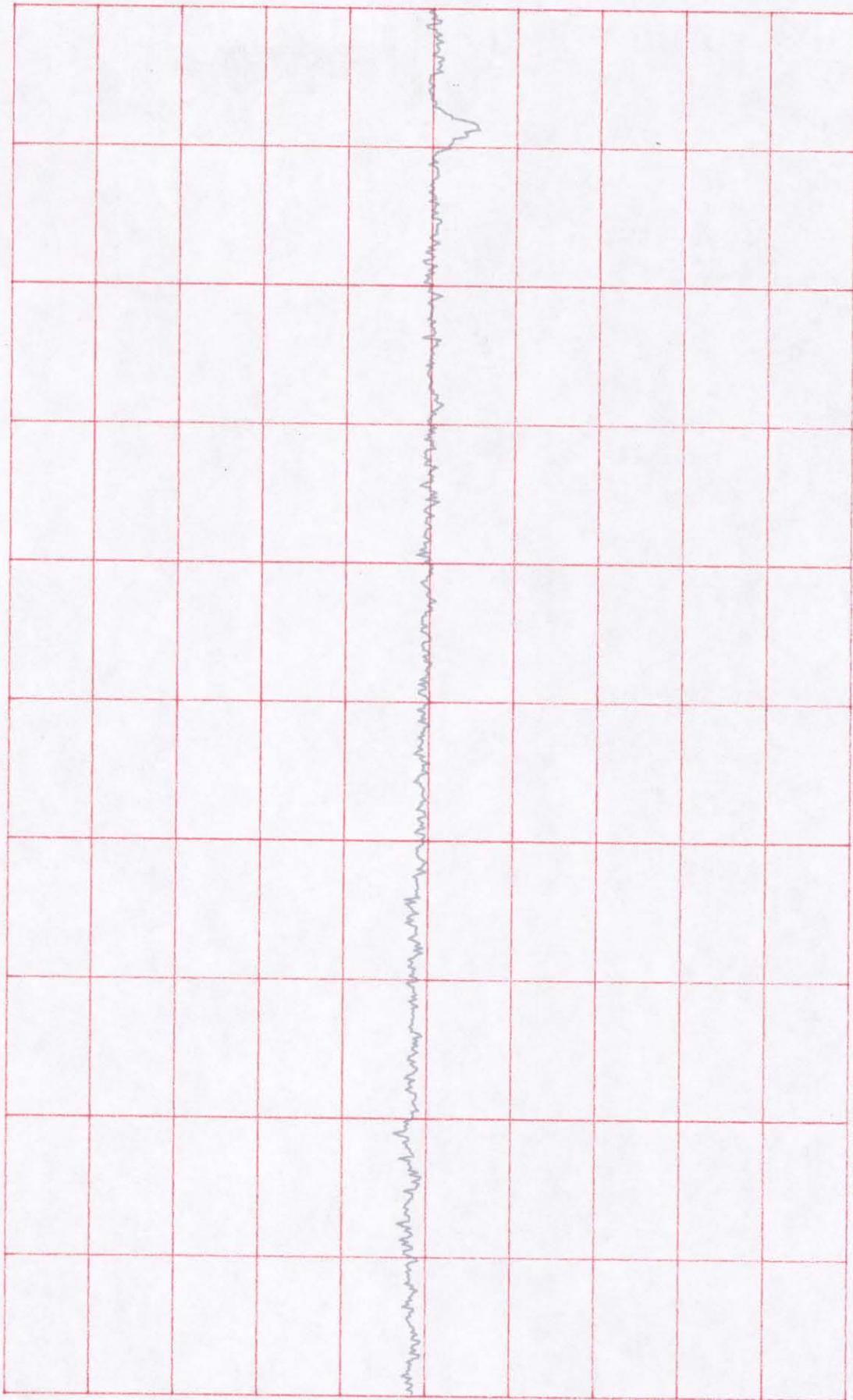
VBW 1.0MHZ

STOP 15.000GHZ

SWP 60.0ms

4987

\* ATTN 0dB  
RL -10.0dBm 10dB/



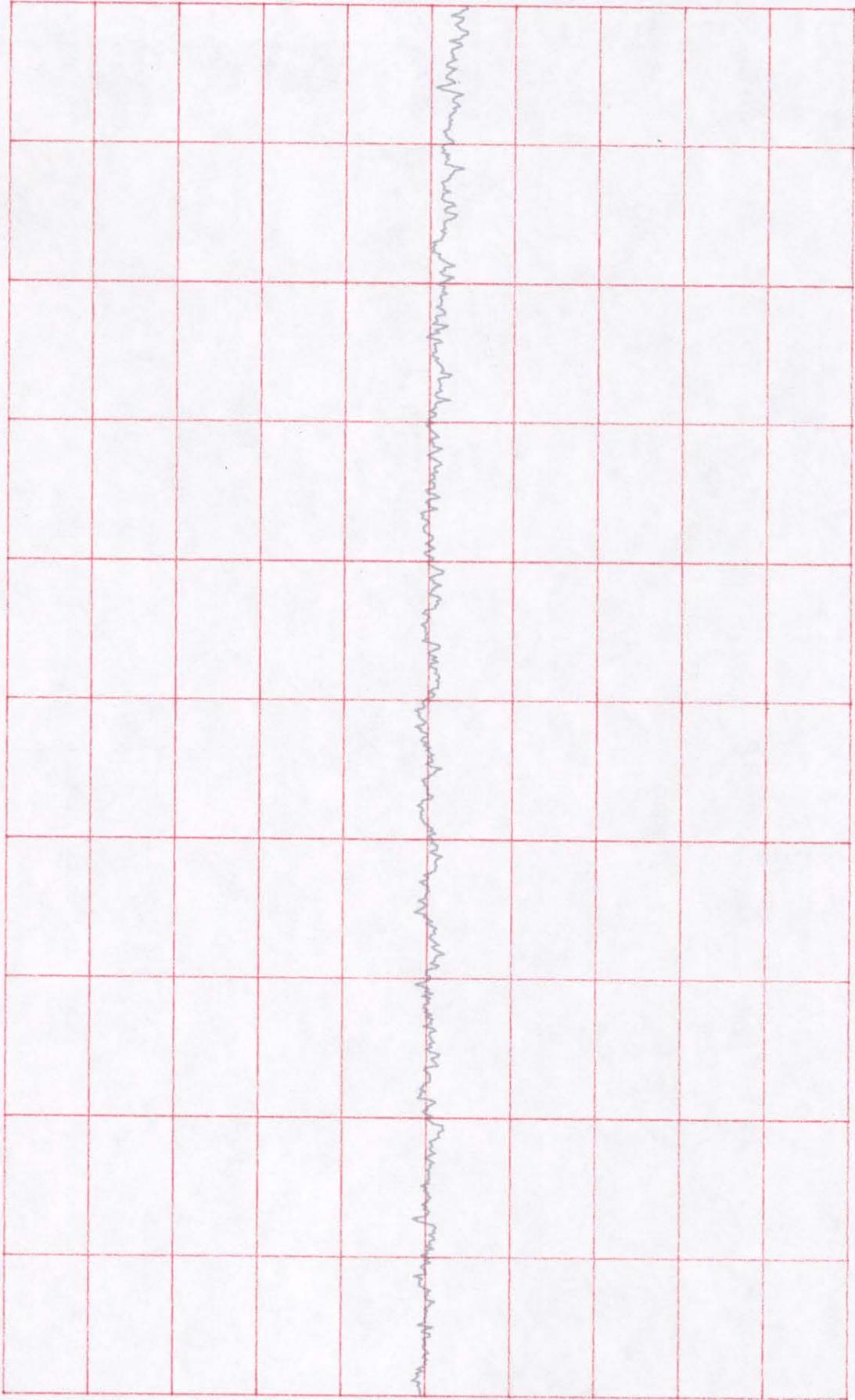
D

START 12.000GHZ STOP 15.000GHZ  
RBW 1.0MHZ VBW 1.0MHZ SWP 60.0ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



START 15.000GHZ

RBW 1.0MHZ

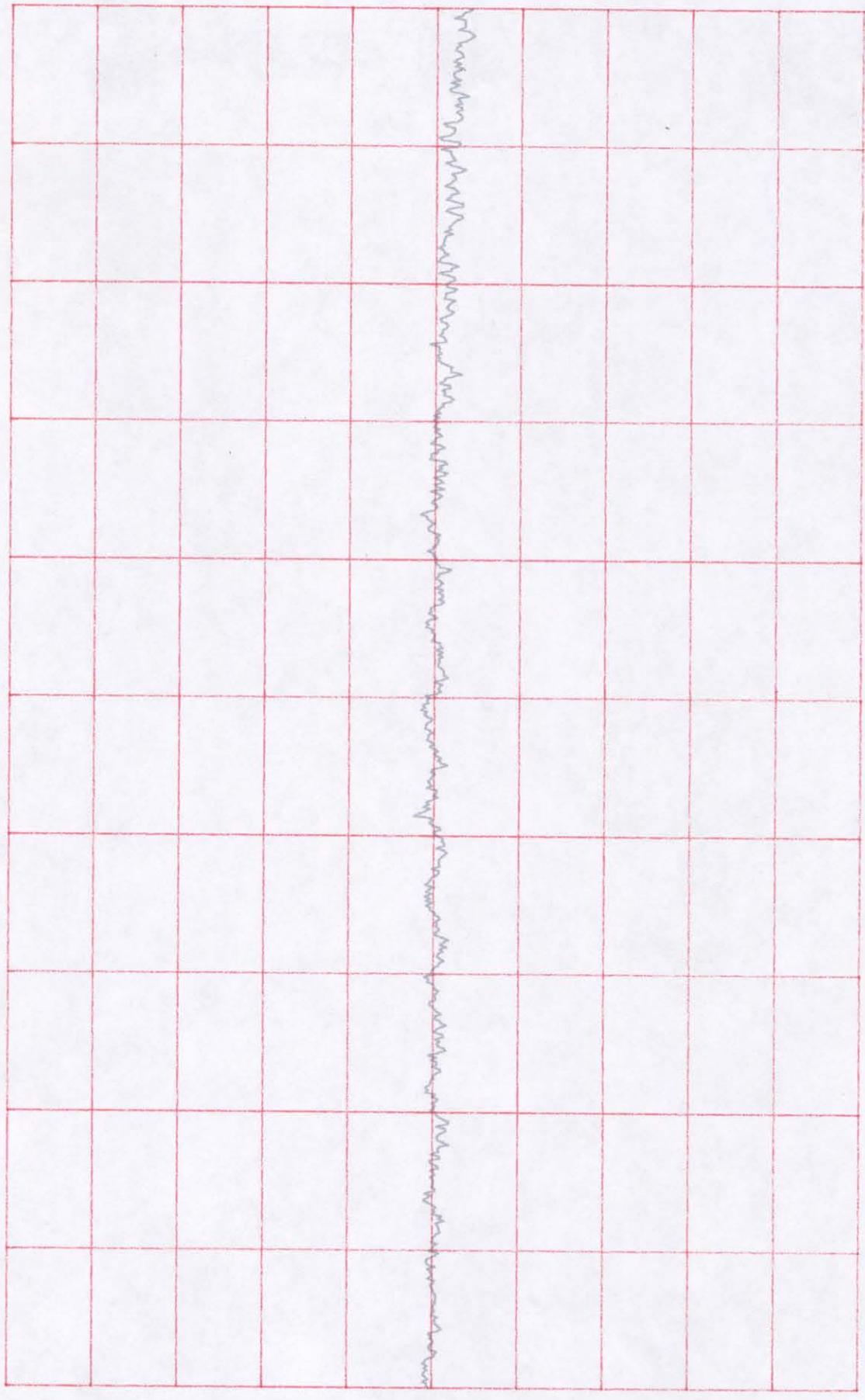
VBW 1.0MHZ

STOP 18.000GHZ

SWP 60.0ms

131618

\*ATTEN 0dB  
RL -10.0dBm 10dB/



D

START 15.000GHZ STOP 18.000GHZ  
RBW 1.0MHZ VBW 1.0MHZ SWP 60.0ms

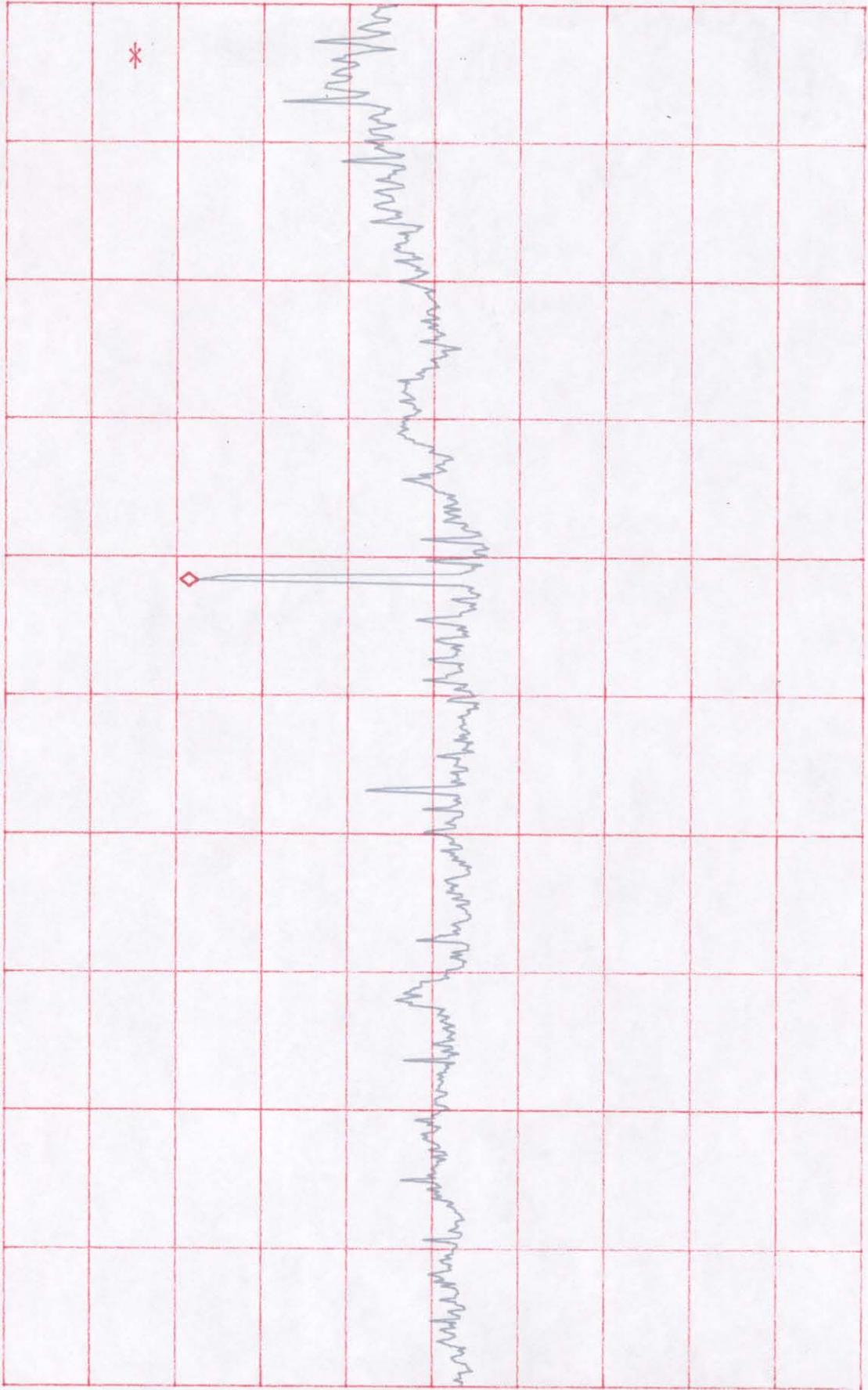
### **Location 3: 4m from the 1/16 ALMA Correlator**

Plots are presented in pairs covering the same frequency range. The first plot in each pair was taken with the 1/16 ALMA Correlator ON, and the second plot was taken with the 1/16 ALMA Correlator OFF.

ATTEN 40dB  
RL 30.0dBm

MKR 7.67dBm  
125.0MHz

10dB/



START 20.0MHz

STOP 200.0MHz

\*RBW 100kHz

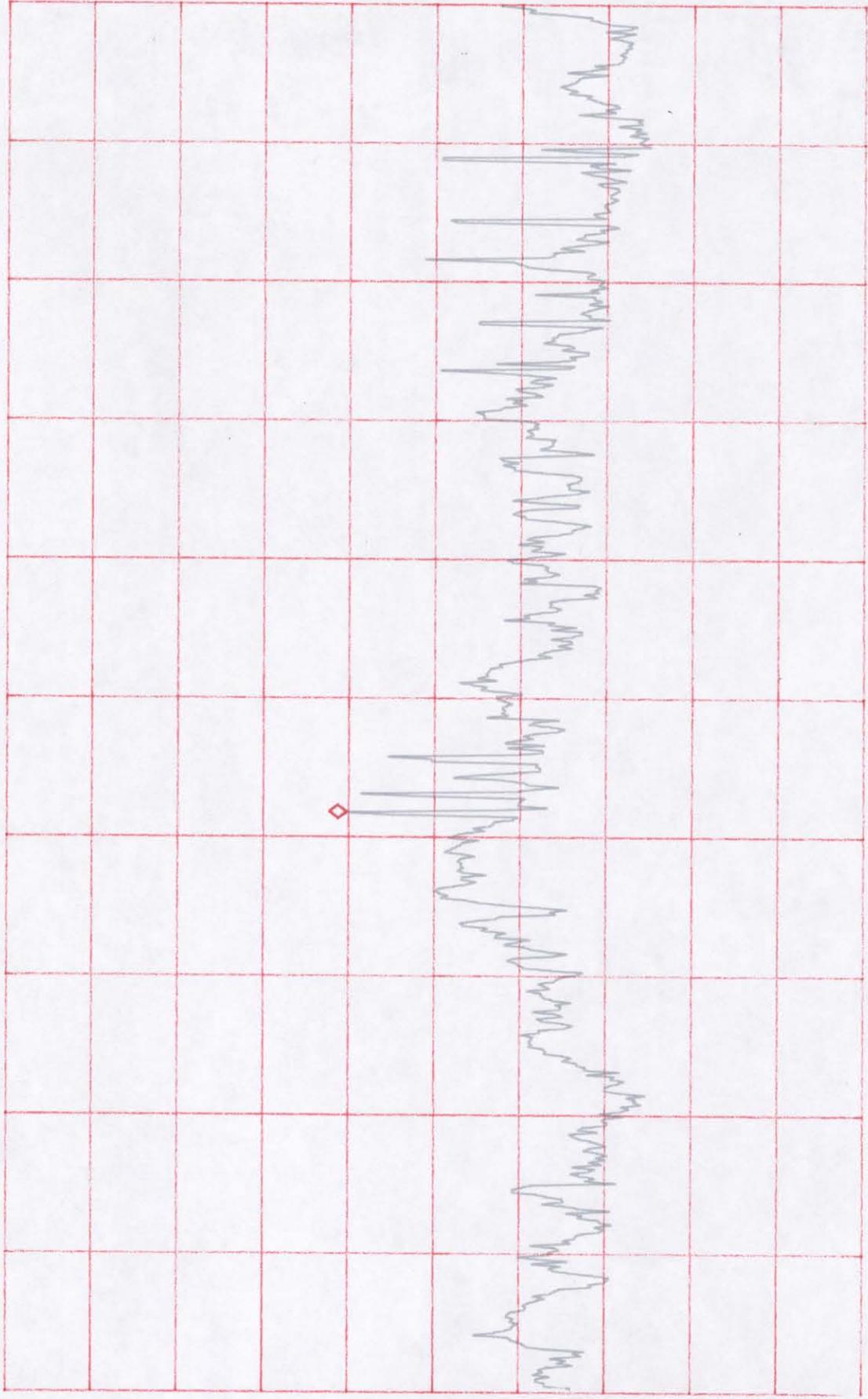
VBW 100kHz

SWP 50.0ms

\*ATTEN 40dB  
RL 30.0dBm

MKR -9.67dBm  
95.3MHz

10dB/



0

START 20.0MHz

STOP 200.0MHz

\*RBW 100kHz

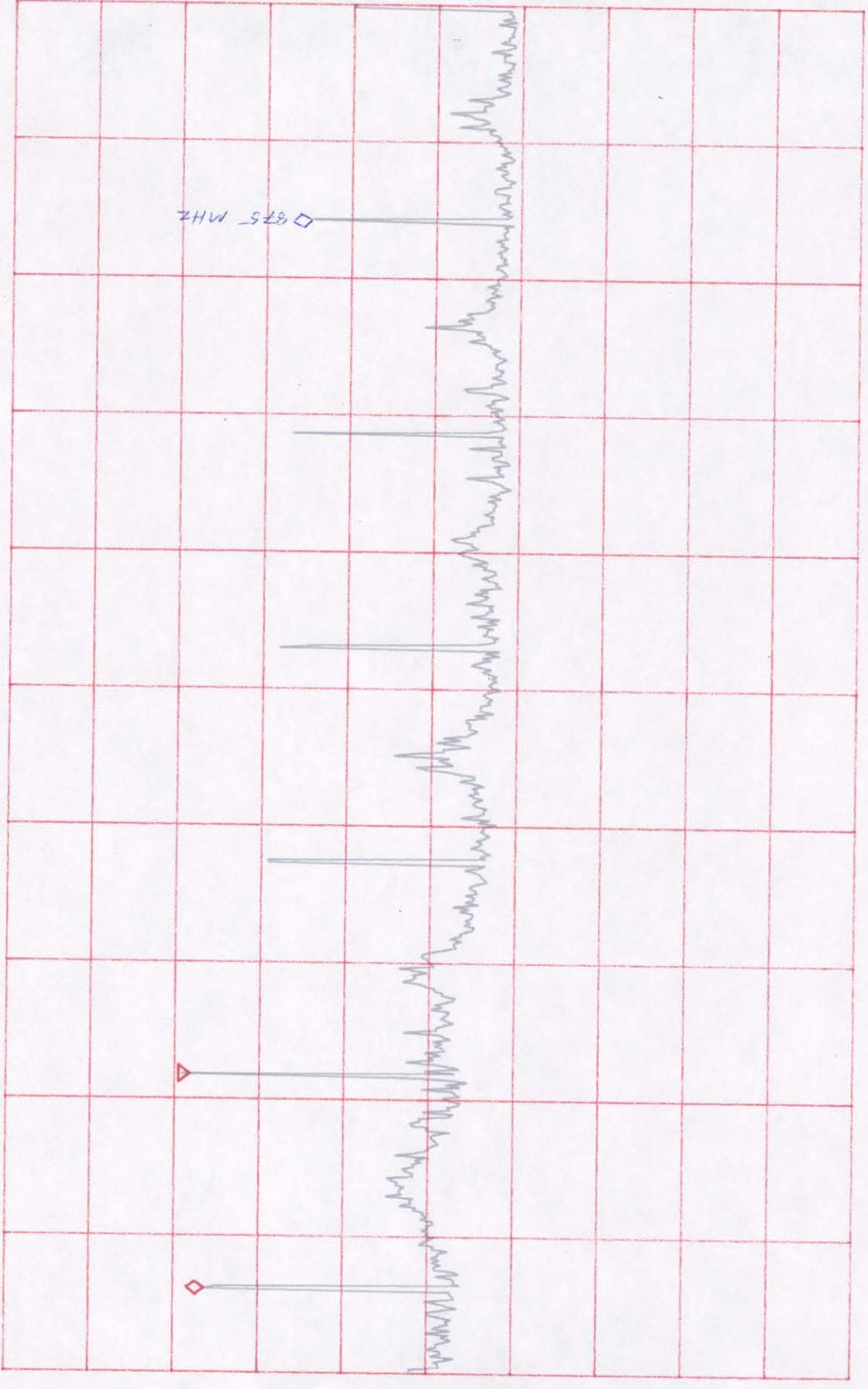
VBW 100kHz

SWP 50.0ms

ATTEN 40dB  
RL 30.0dBm

ΔMKR -1.83dB  
-125.3MHz

10dB/



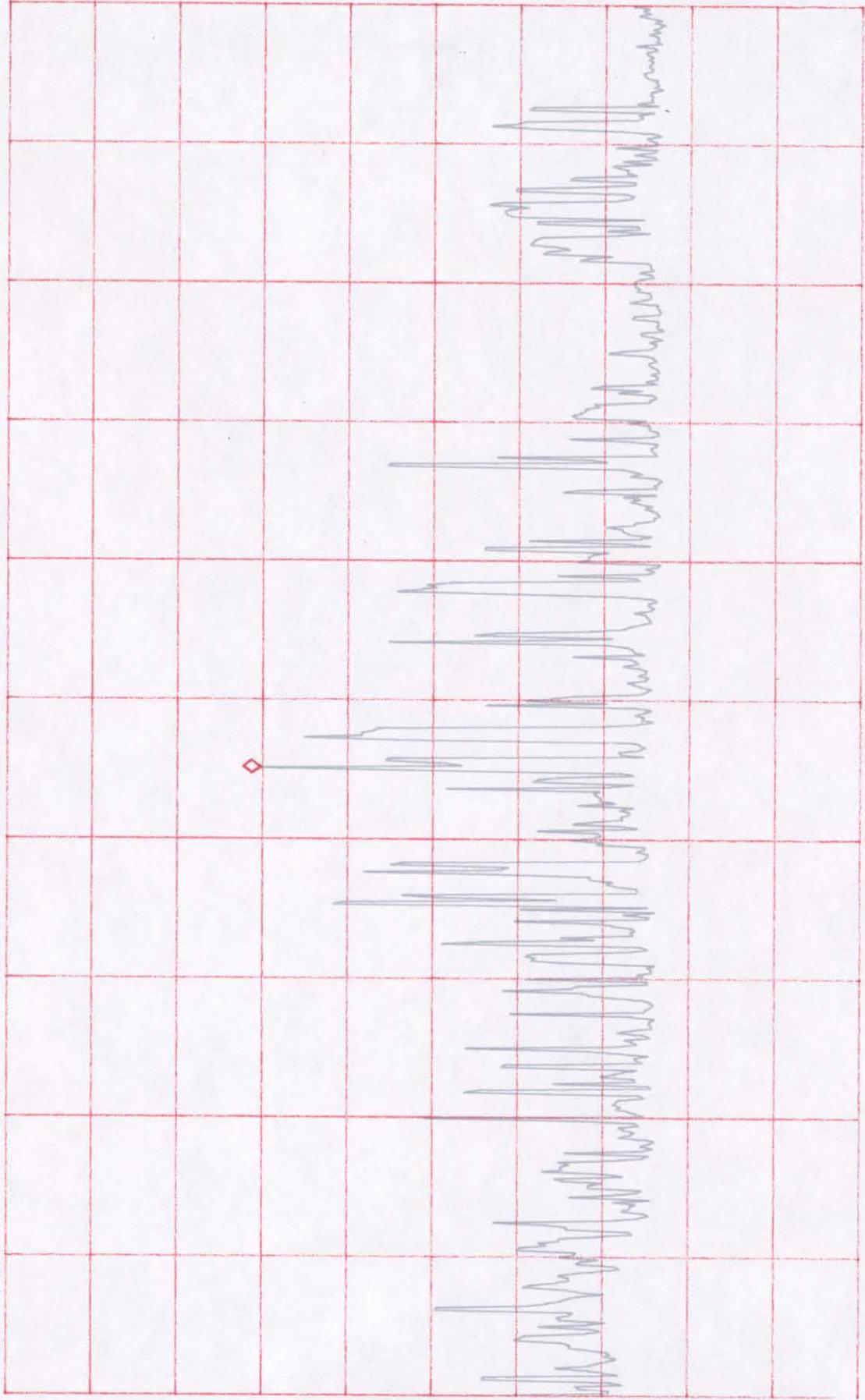
D

START 200.0MHz STOP 1.000GHz  
\*RBW 100kHz VBW 100kHz SWP 200ms

\*ATTEN 40dB  
RL 30.0dBm

MKR . 33dBm  
561.3MHz

10dB/



D

START 200.0MHz

\*RBW 100kHz

VBW 100kHz

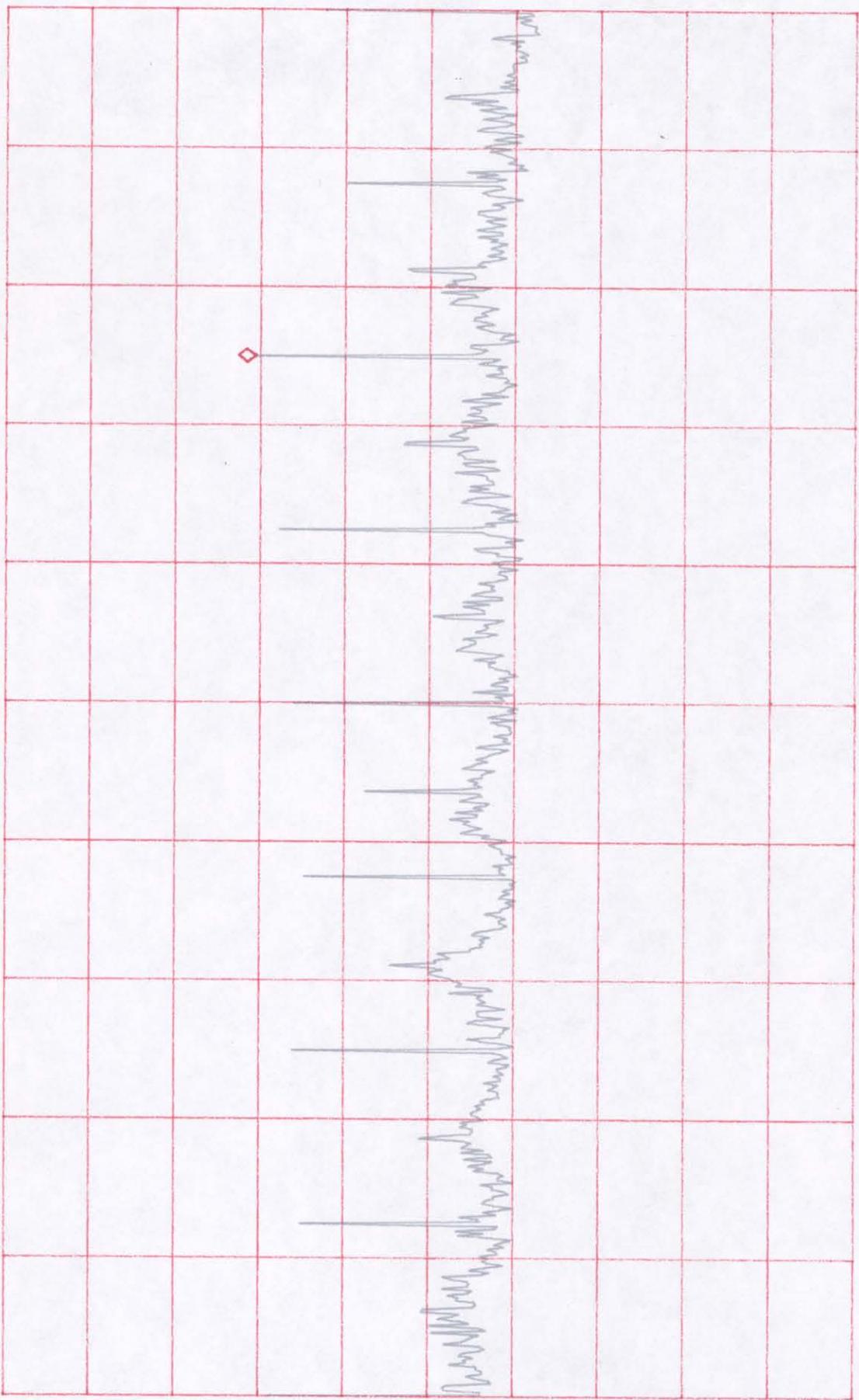
STOP 1.0000GHz

SWP 200ms

ATTEN 40dB  
RL 30.0dBm

MKR .67dBm  
1.750GHZ

10dB/



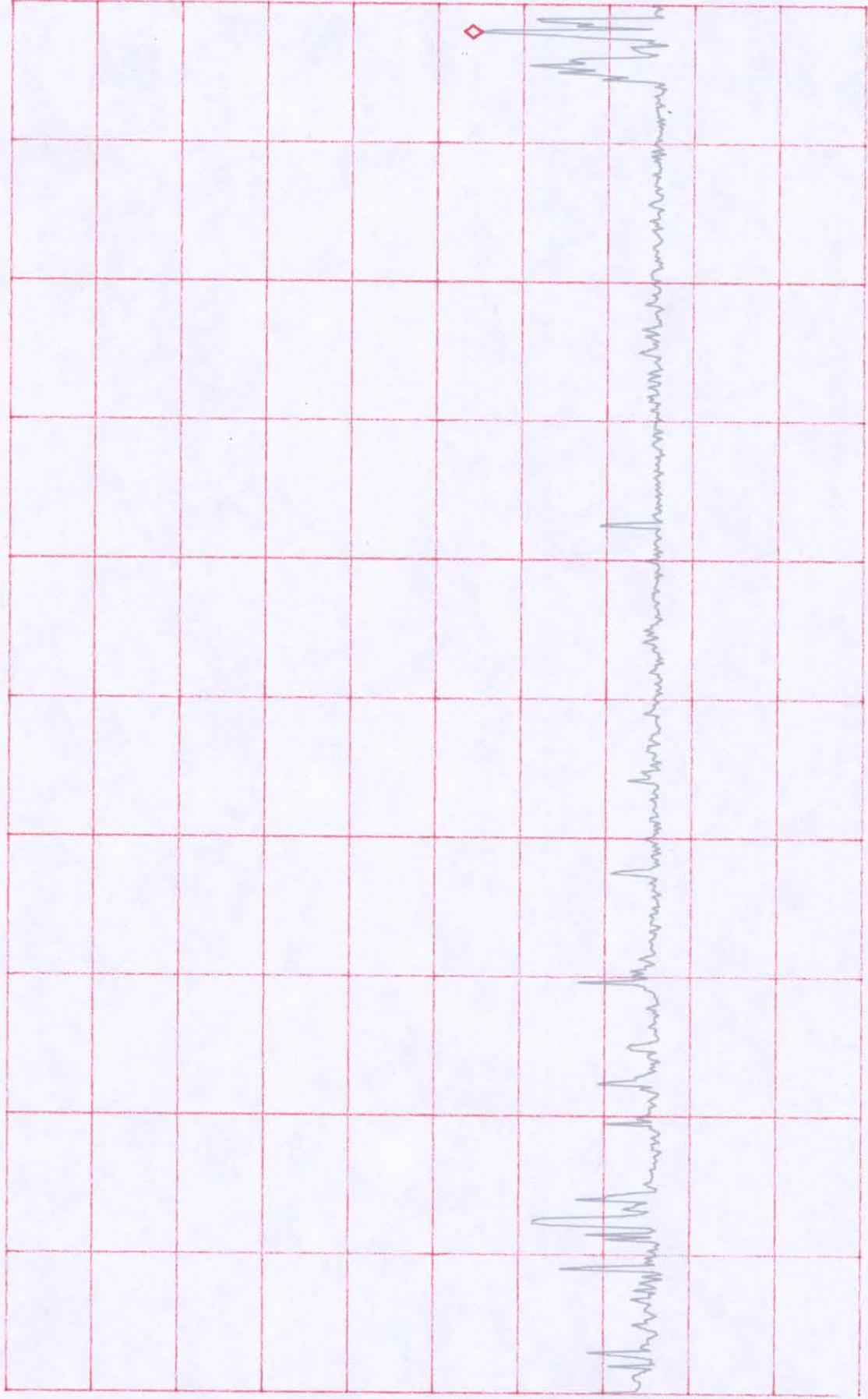
D

START 1.000GHZ      STOP 2.000GHZ  
\*RBW 100kHz      VBW 100kHz      SWP 250ms

\*ATTEN 40dB  
RL 30.0dBm

MKR -25.00dBm  
1.980GHZ

10dB/



D

START 1.000GHZ

STOP 2.000GHZ

\*RBW 100kHz

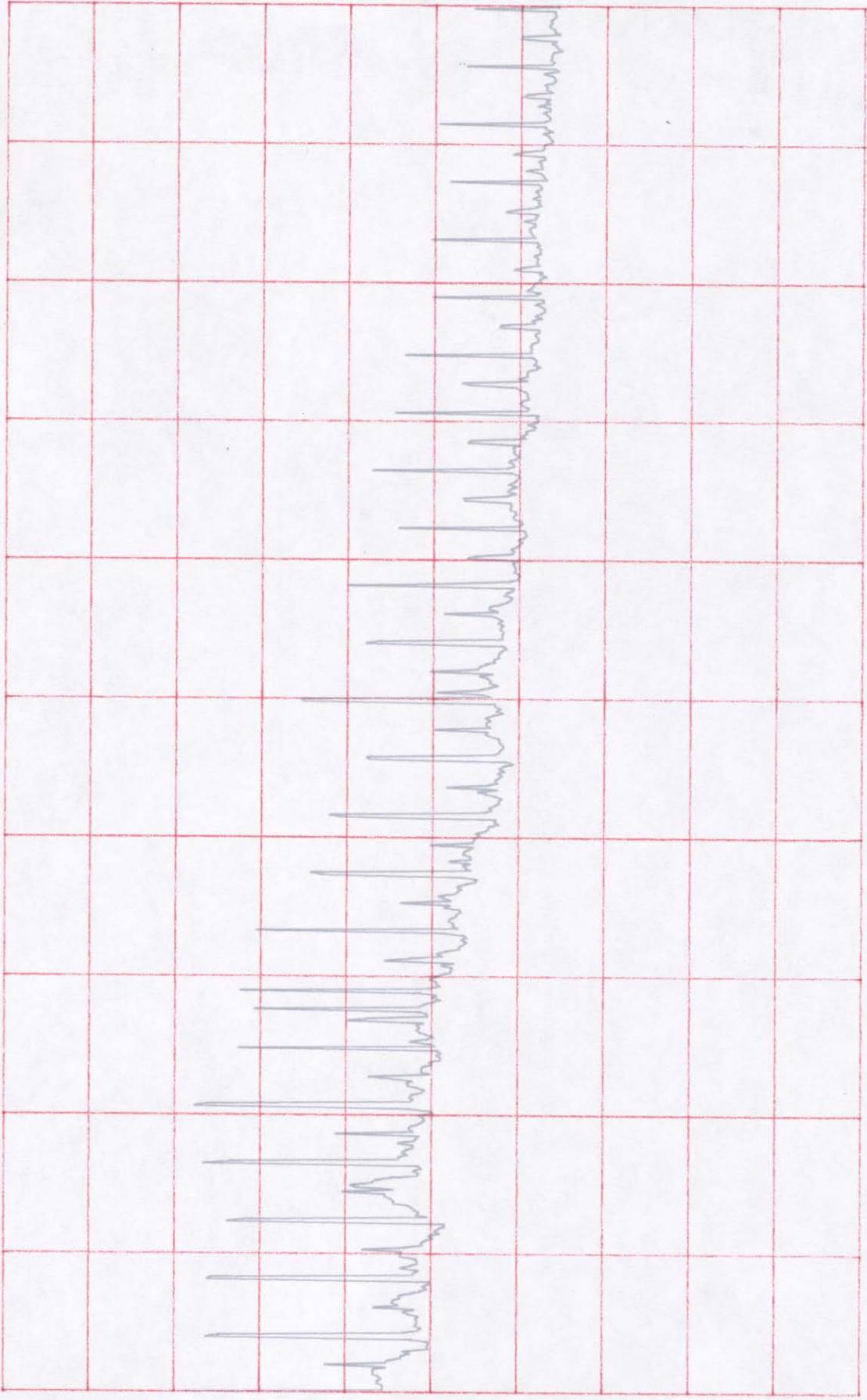
VBW 100kHz

SWP 250ms

ATTEN 10dB

RL 0dBm

10dB/



START 2.000GHZ

RBW 100kHz

VBW 100kHz

STOP 5.000GHZ

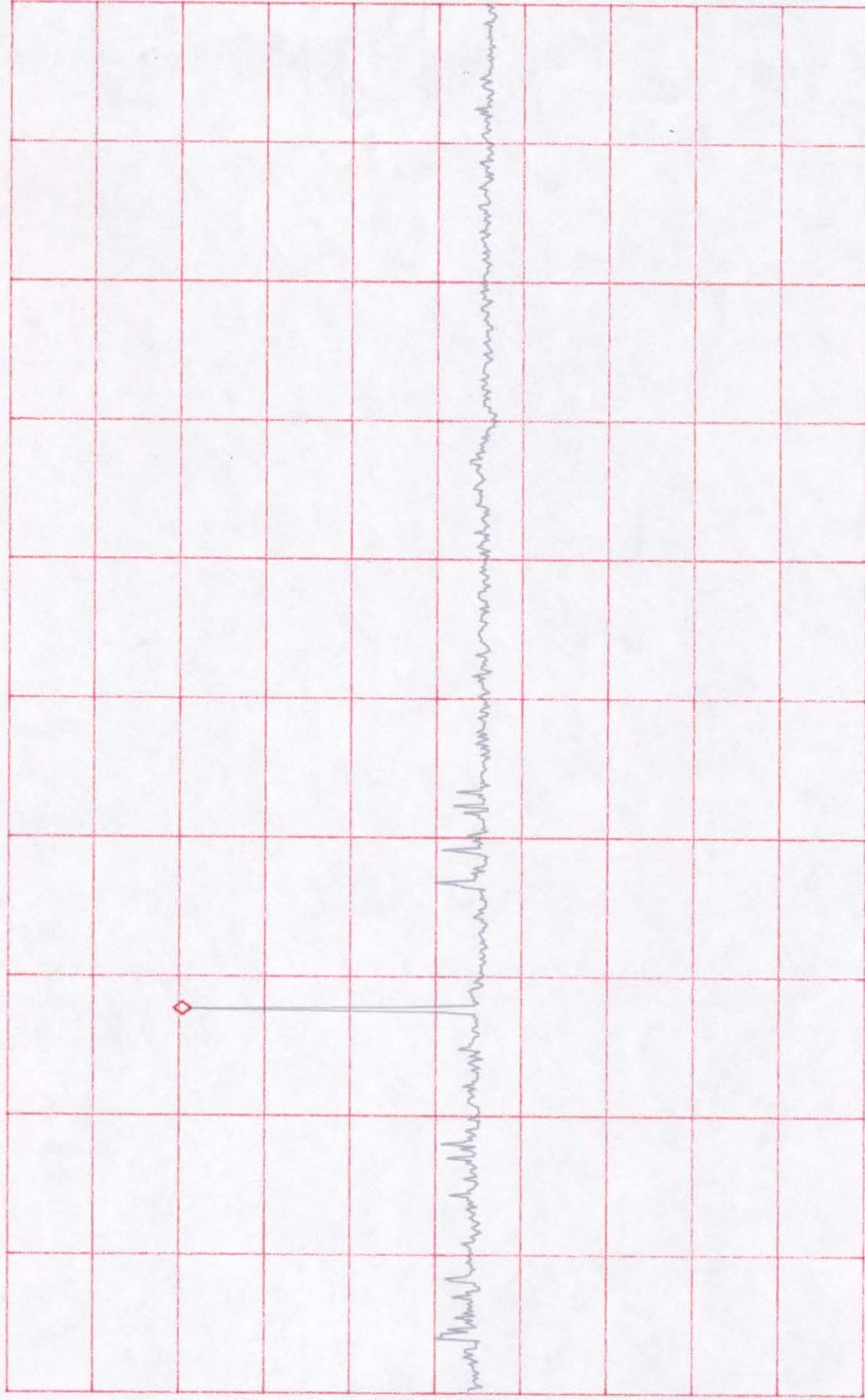
SWP 750ms

\*ATTEN 10dB

RL -10.0dBm

MKR -31.33dBm

10dB/  
2.830GHZ



D

START 2.000GHZ

\*RBW 100kHz

VBW 100kHz

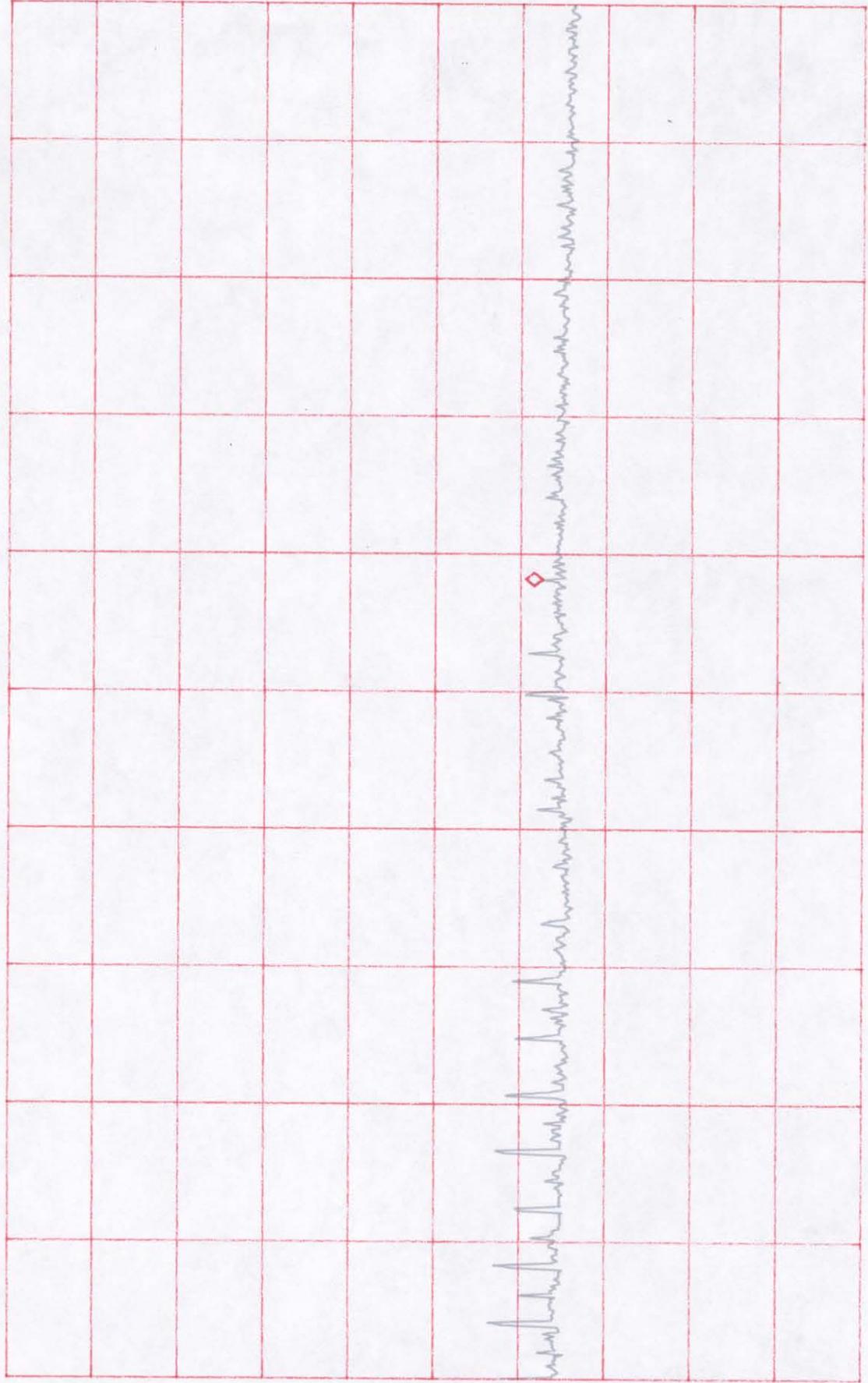
STOP 5.000GHZ

SWP 750ms

ATTEN 10dB  
RL 0dBm

MKR -62.50dBm  
6.745GHz

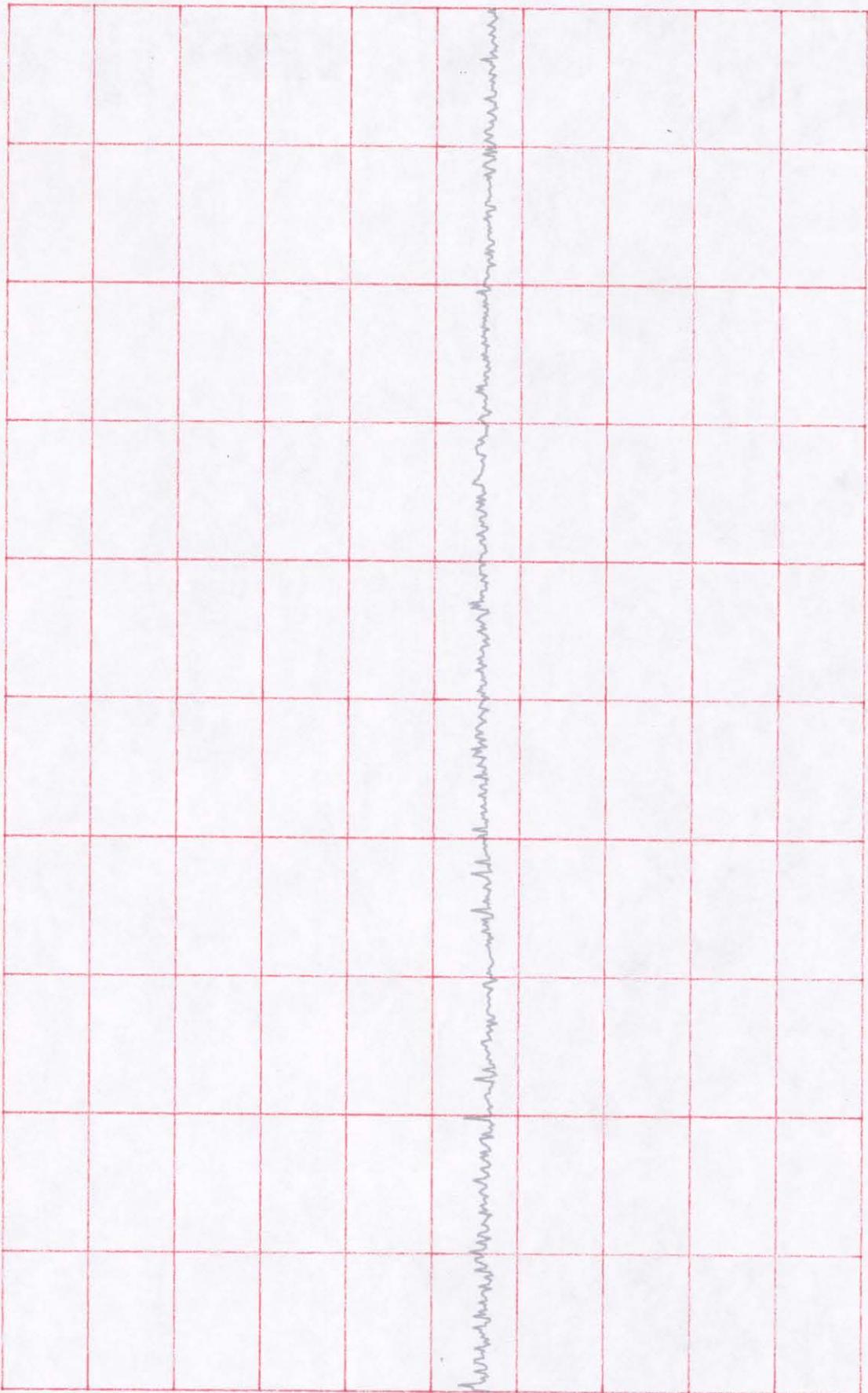
10dB/



D

START 5.000GHz      STOP 8.000GHz  
\*RBW 100kHz      VBW 100kHz      SWP 750ms

\*ATTEN 10dB  
RL -10.0dBm 10dB/



□

START 5.000GHZ      STOP 8.000GHZ  
\*RBW 100kHz      VBW 100kHz      SWP 750ms

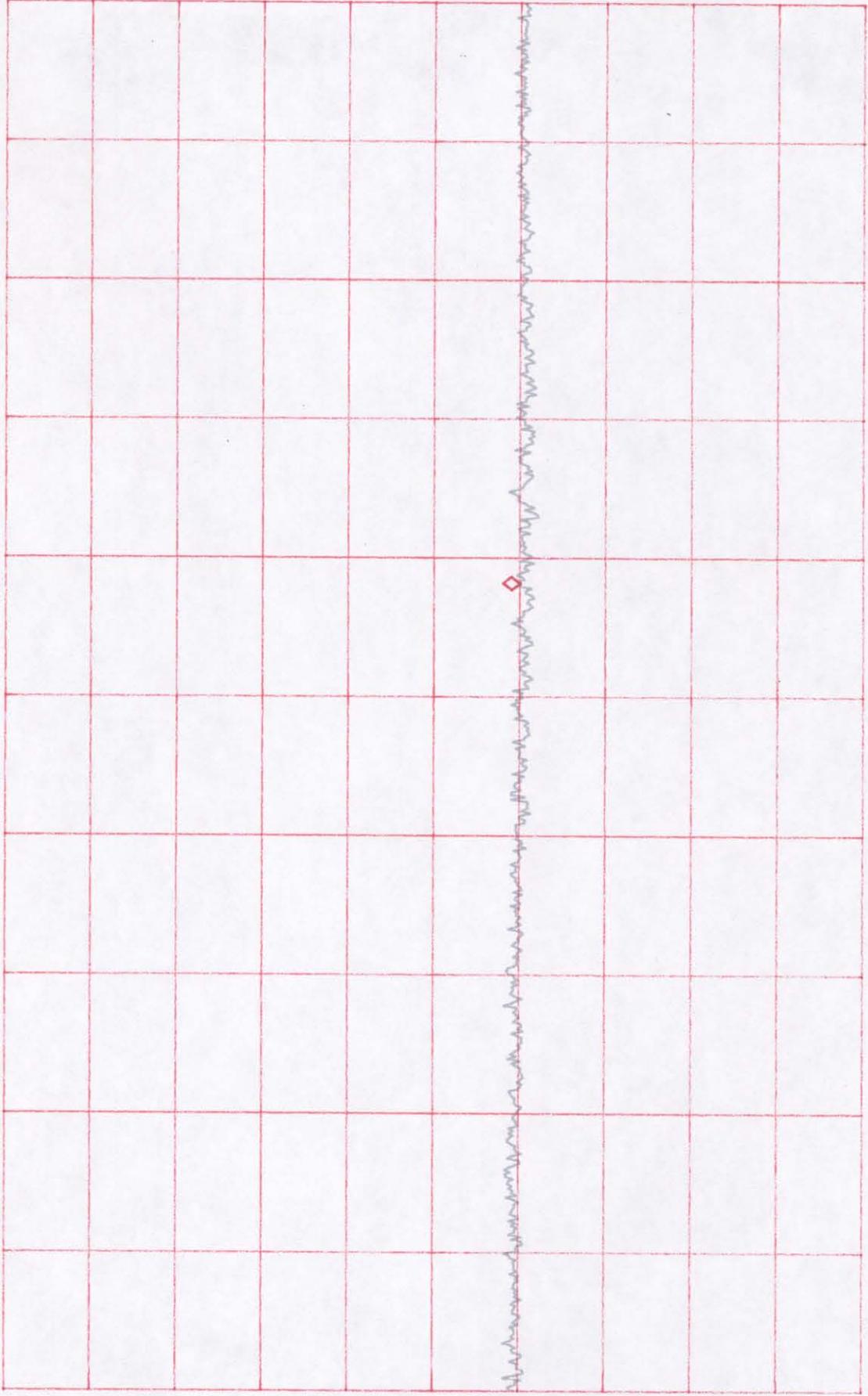
\*ATTEN 0dB

RL -10.00dBm

10dB/

MKR -70.00dBm

10.327GHZ



0

START 8.000GHZ

\*RBW 100kHz

VBW 100kHz

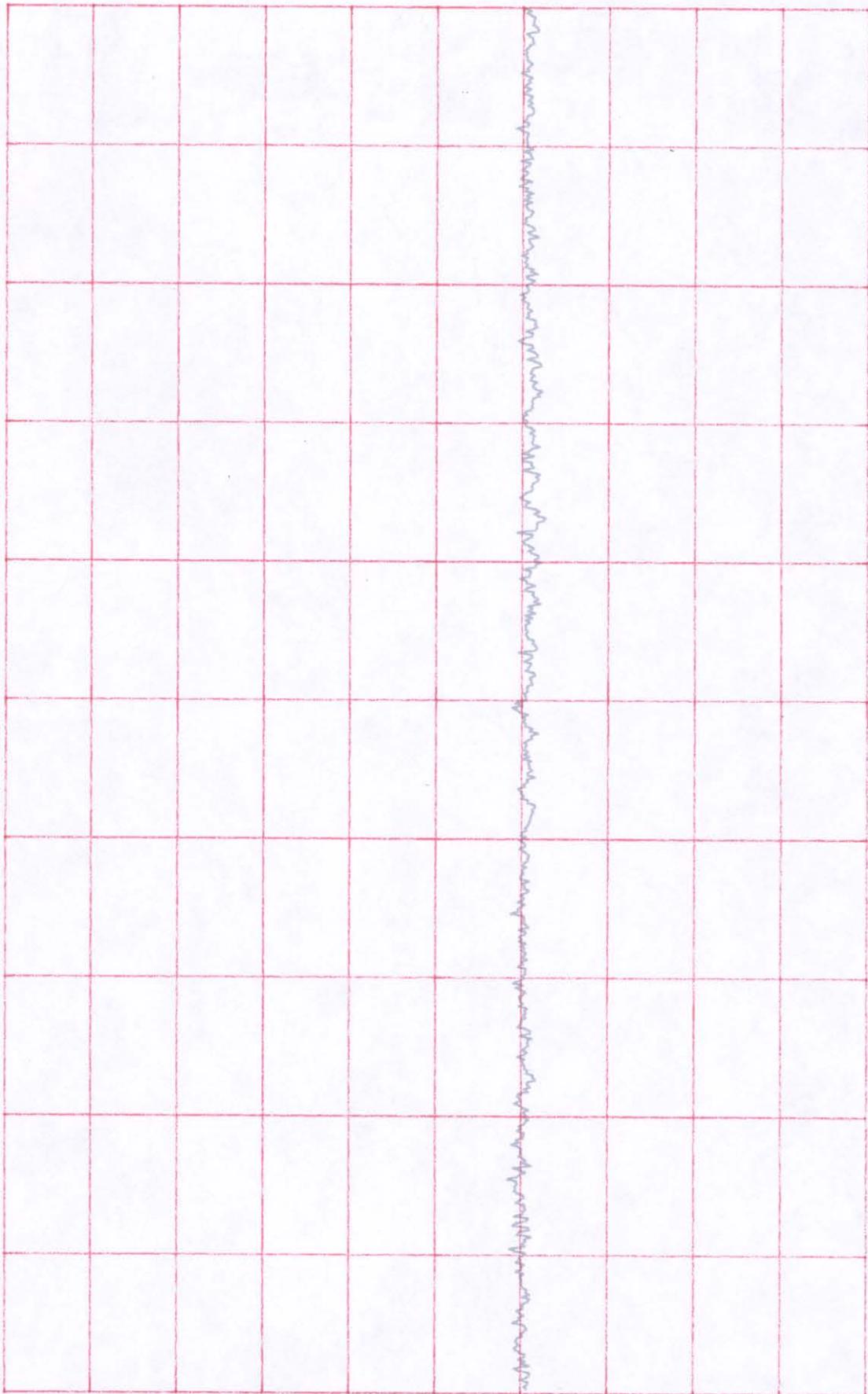
STOP 12.000GHZ

SWP 1.00sec

\*ATTEN 0dB

RL -10.0dBm

10dB/



START 8.000GHZ

\*RBW 100kHz

VBW 100kHz

STOP 12.000GHZ

SWP 1.00sec

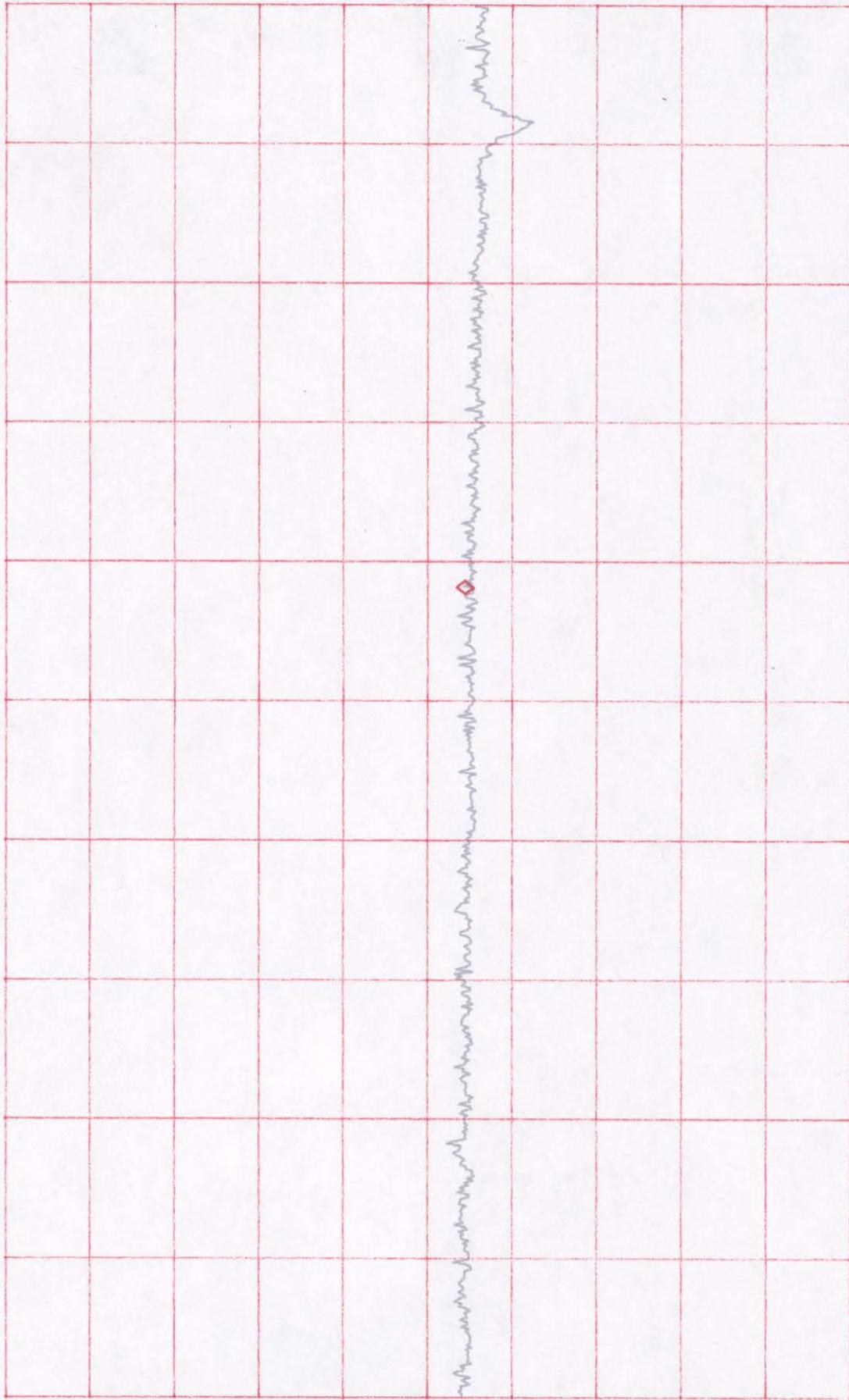
\*ATTEN 0dB

MKR -65.33dBm

RL -10.0dBm

13.745GHz

10dB/



D

START 12.000GHz

STOP 15.000GHz

\*RBW 100kHz

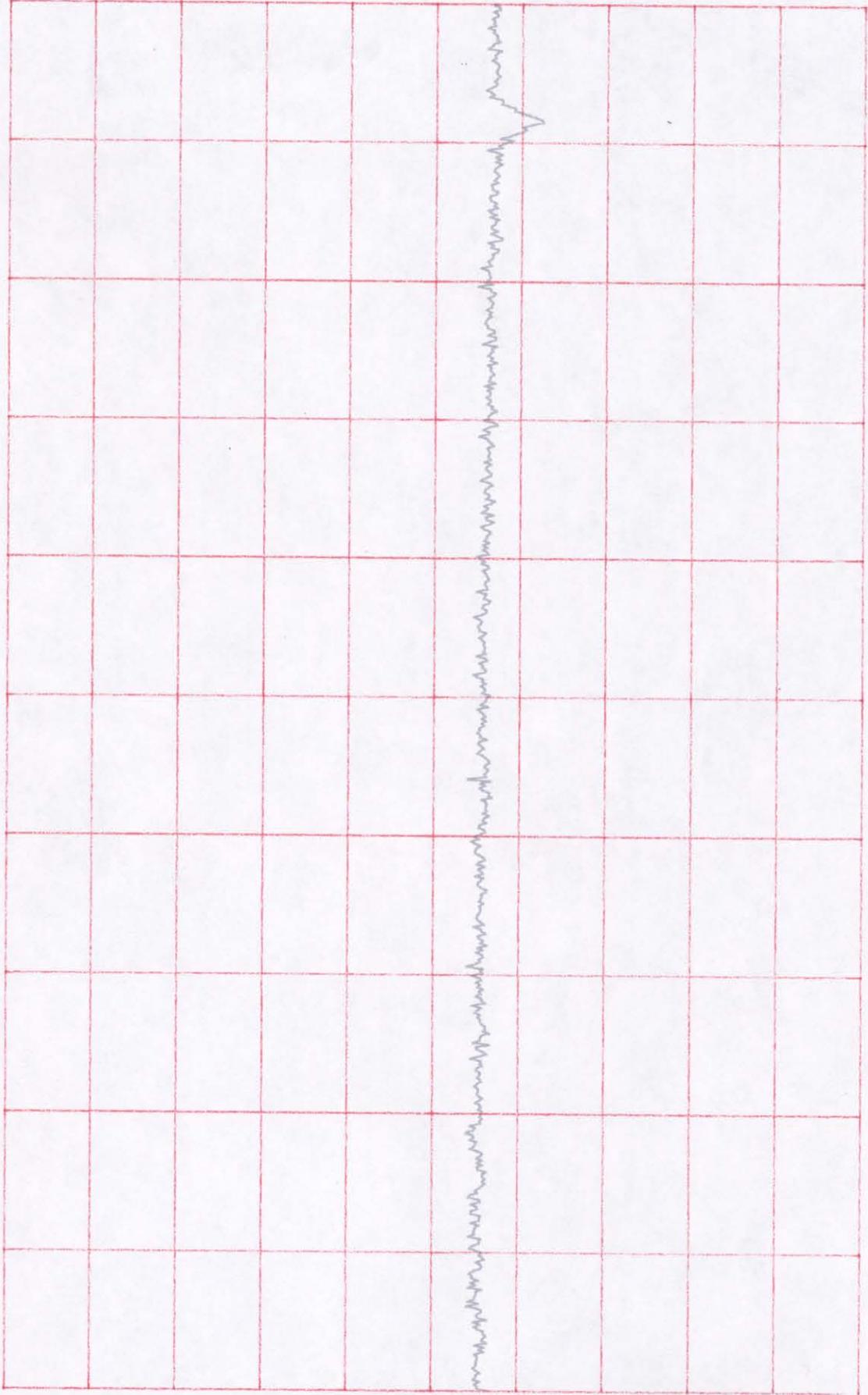
VBW 100kHz

SWP 750ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

START 12.000GHZ

STOP 15.000GHZ

\*RBW 100kHz

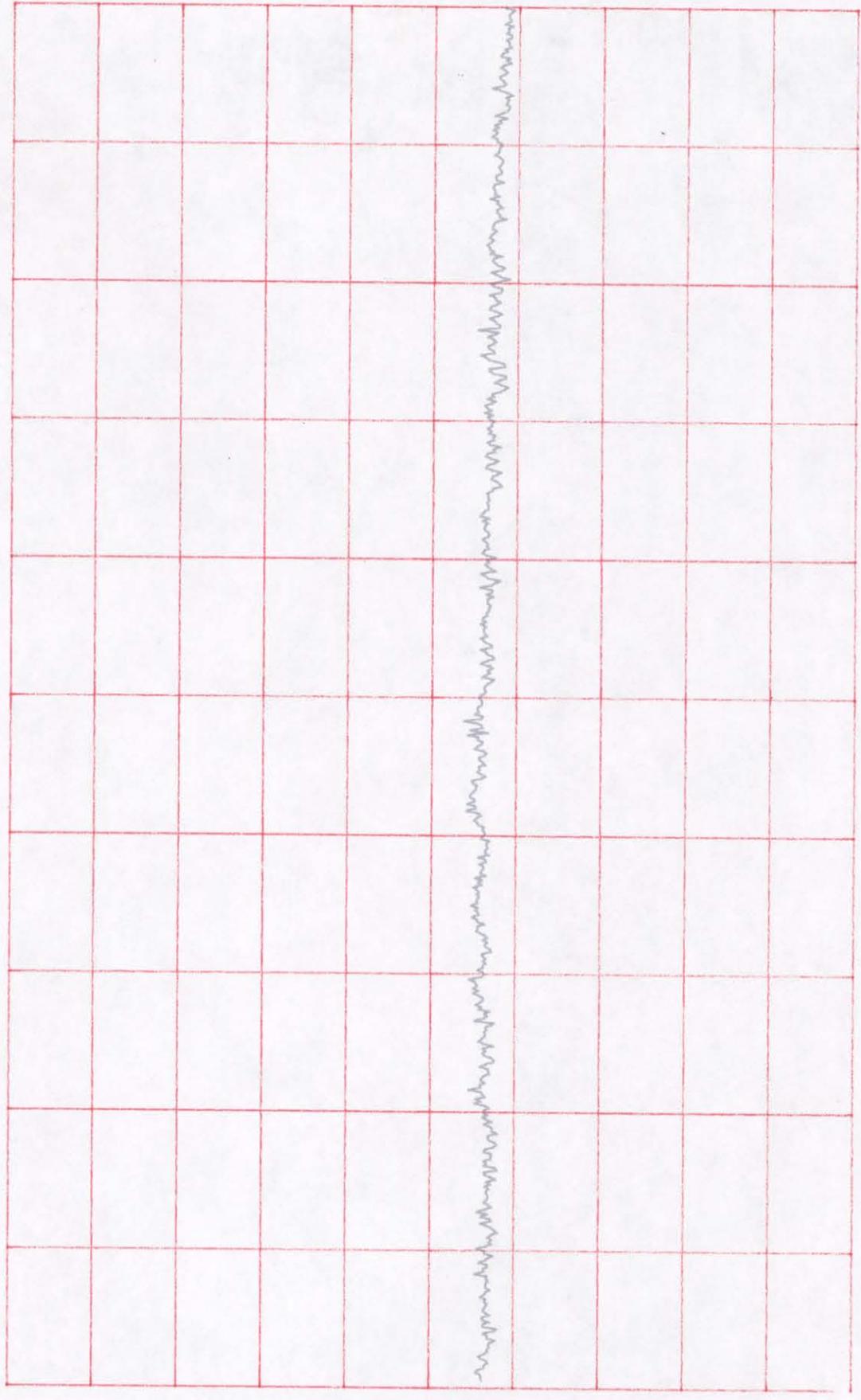
VBW 100kHz

SWP 750ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

START 15.000GHZ

STOP 18.000GHZ

\*RBW 100kHz

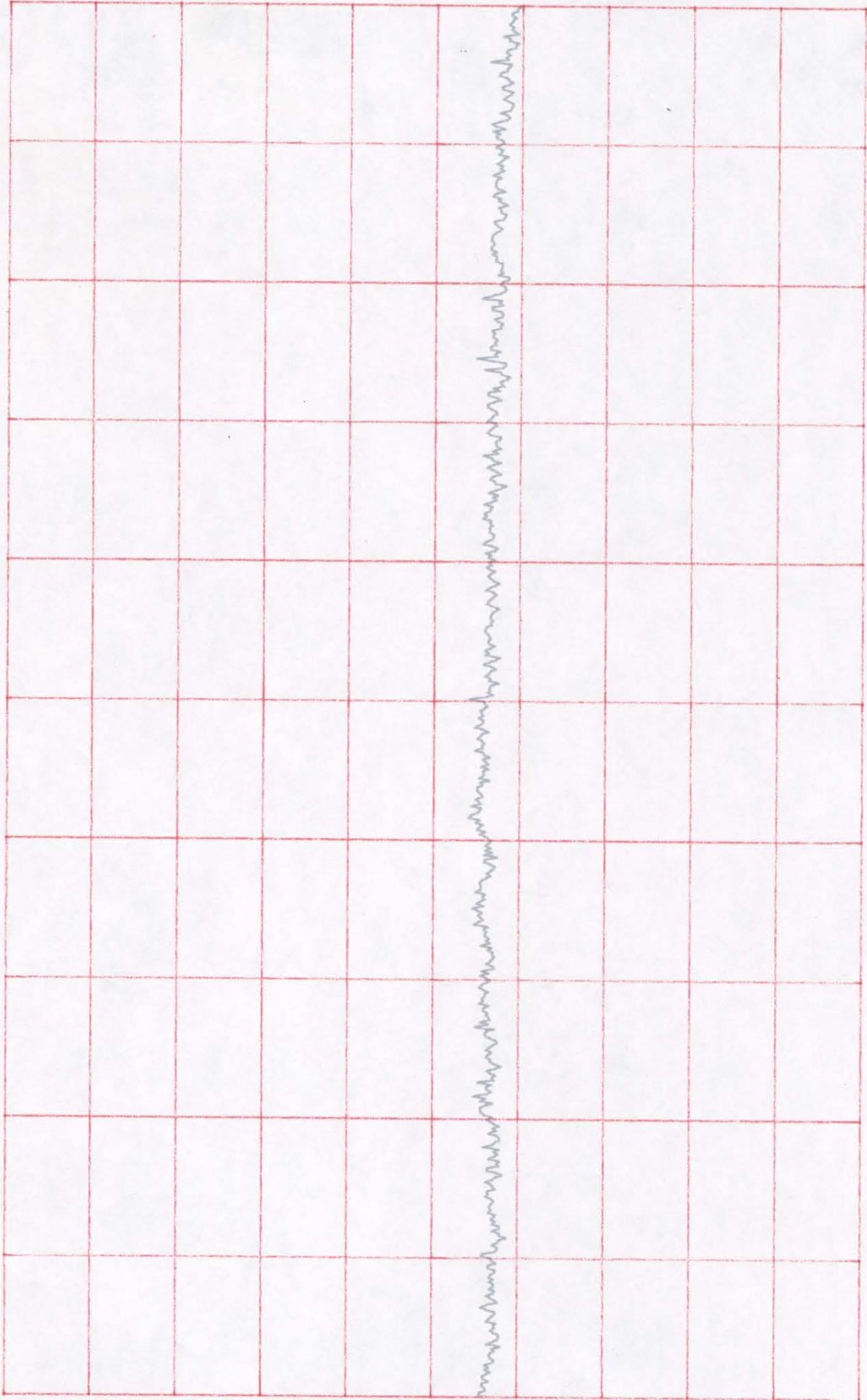
VBW 100kHz

SWP 750ms

\*ATTEN 0dB

RL -10.0dBm

10dB/



D

START 15.000GHZ

\*RBW 100KHZ

VBW 100KHZ

STOP

18.000GHZ

SWP 750ms

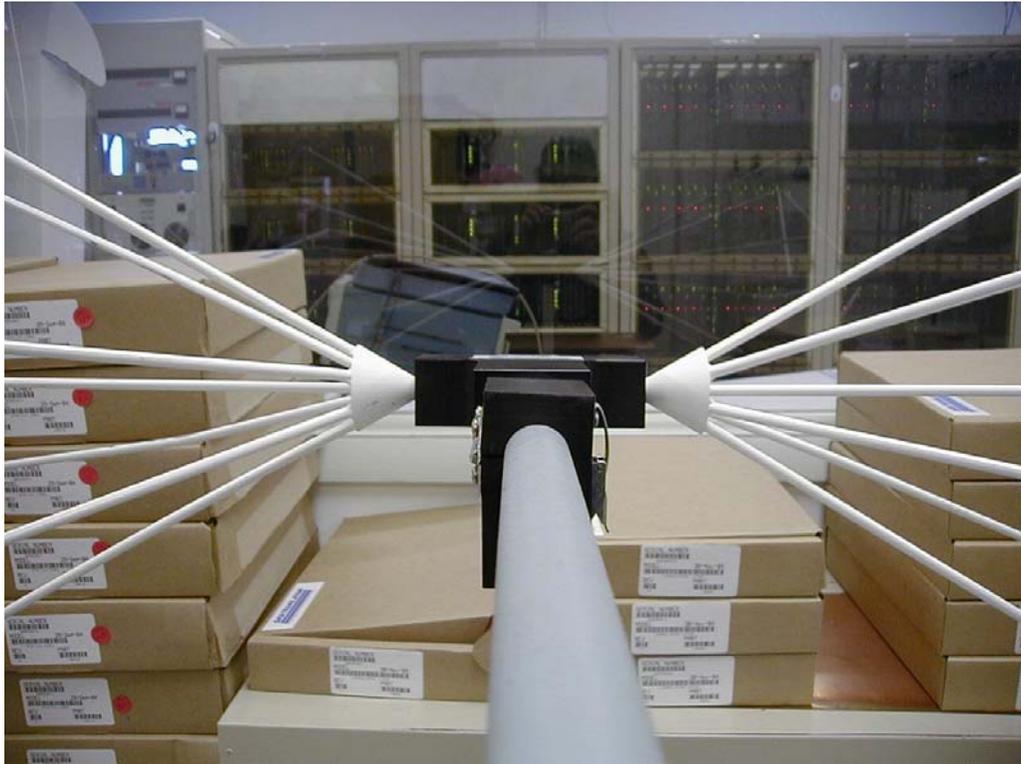
## Appendix D: Survey Photographs



Figure 1: Ridged Guide Horn Antenna in Lab 302B



Figure 2: Log Periodic Antenna in Shielded Room



**Figure 3: Biconical Antenna 4m from Correlator**



**Figure 4: Horn Antenna 4m from Correlator**