VLA - VLBA Interference Memo No. 4

# Tests of the MIT 600 MHz Impulse Detector

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## Introduction:

Charlie Katz and Jackie Hewitt of MIT are planning a 600 MHz band impulse detector array with one of the detector systems to be located at VLBA Hancock. Additional detectors will be located at some distance from Hancock, possibly to include other NRAO locations, with the expectation that simultaneous events on the various detectors will be the result of some cosmological event rather than radio frequency interference (RFI). A prototype detector system was setup in the screen room at the AOC to measure potentially harmful interference that the equipment might radiate. This report describes the tests and the results and offers recommendations to reduce the potential of interference with the VLBA operation.

## The Equipment:

The impulse detector system shown in Figure 1 consists of an IBM compatible PC, a control box connected to the PC via both a serial and a parallel port, a GPS receiver housed in the control box, and a receiver back end all to be located in room 100 of the VLBA station building. Outside the building there will be the receiver front end and an antenna for the GPS receiver. A crossed dipole, a copy of the 50/90 cm LNA used in the VLBA design, and a noise source serve as the front end. Two coax cables and a control/power cable connect the two parts of the receiver. The control/power cable brings 15 VDC to the front end plus a low bandwidth logic level control line to the noise source. A third coax cable connects the GPS antenna to its receiver.

The computer is an Elite 486SX 33 MHz with color monitor, with Class B shielding under FCC Part 15. An Ethernet I/O is to be included later, but was not installed at the time of this test. Two local oscillators, 67 MHz and 541 MHz, are housed in the receiver back end as well as the filters and mixers to reduce the two total power channels from the front end to two 6 MHz baseband signals. Conversion to digital is done in the computer. Also in the receiver back end cabinet is the 15 VDC power supply.

All coax cables are double-shielded RG-223. The control/power cable is Alpha 6054, consisting of 22 AWG pairs with overall shield.

## The Test:

The primary concerns are that the VLBA antenna will see 1) radiation from the GPS receiver either through radiation back up through the antenna lead-in or by leakage out of the station building, 2) radiation from the detector receiver LO again either by radiation through the cable lead-ins or by leakage out of the building, and 3) radiation from the PC clock. Since the LO's are less than 1 GHz and the LO of the GPS is around 1400 MHz, the radiation from the 600 MHz impulse detector was measured over the range 100 MHz to 2 GHZ using the setup in Figure 2. The setup consisted of a discone antenna, two amplifiers, and a HP 8559 spectrum analyzer connected to a plotter. The antenna and amplifier 1 were located inside the screen room, while the remainder of the equipment was outside. For the region < 1 GHZ, the test equipment was an Archer 25 - 1300 MHz omnidirectional discone antenna with the first amplifier a Miteq 1108 and the second a Watkins Johnson 6201-49. From 1 GHz to 2 GHz, the antenna used was a Sigma Euro-com 300 - 2200 MHz omnidirectional discone, with the first amplifier the Miteq 1108, and the second an Avantek 8199. The Miteq amplifier is not specified for operation below 1.2 GHZ; however, its gain appears to roll off very little at the lower frequencies.

Various configurations of equipment under test inside and outside the screen room were measured to help isolate any potential problems:

1. The screen room background with nothing on -- Fig. 3 < 1 GHz and Fig. 12 > 1 GHz. (Tests 5 and 20)
2. The computer in the screen room -- Fig. 4 & 5 (Tests 1 & 21)
3. The GPS receiver in the screen room -- Fig. 6 & 7 (Tests 6 & 23)
4. The receiver back end in the screen room -- Fig. 8 & 9 (Tests 7 & 25)
5. All equipment on and in the screen room -- Fig. 10 (Test 11)
6. The GPS antenna in the screen room and the receiver outside -- Fig. 11 & 12 (Tests 12, 13, & 20)
7. The receiver front end in the screen room and all the back end equipment outside the screen room -- Fig. 13 & 14 (Tests 18 & 19)

Harmful levels:

That the detector system emits noise is to be expected. The basic problem is to determine what power density (PD) will be incident on the VLBA antenna as a result of the equipment radiation and to decide if that PD will be detectable by the VLBA. For equipment in the station building,

PR (dBW/m²) = SA (dBm) - 30 dB(dBm/dBw) - G1 (dB) - G2 (dB) + CA(dB) - GA (dBm²)

where,

PR = EIRP inside the station building

SA = peak radiation measured by spectrum analyzer

G1 = gain of amplifier 1

G2 = gain of amplifier 2

CA = cable attenuation during test, estimated to be 3 dB

GA = gain of discone antenna, assumed to be 3 dBi +

$10 \log (\lambda^2/4\pi)$ dB = -9 dB for 90 cm, -14 dB for 50 cm, and -22 dB for 20 cm.

The 3 dBi gain is the estimated gain caused by reflections and resulting concentration of power in the screen room.

The PD at the VLBA antenna as a result of radiation from the station building is then,

$$PD = PR - BA - 10 \log (4 \pi r^2) - 10 \log (RBW/20 \text{ kHz})$$

where,
PD = power density incident on VLBA in dB(W/$m^2$)
BA = attenuation of station building room 100 taken to be 35 dB, f < 2 GHz
r = distance of VLBA from radiation in meters taken to be 100 meters so that $10 \log (4 \pi r^2)$ is 51 dB($m^2$)
10 log (RBW/20 kHz) = conversion of SA measurements to 20 kHz for comparison with harmful levels or 12 dB for 300 kHz RBW and 17 dB for 1 MHz RBW,

and for equipment outside the station building PD = PD as above + BA (35 dB), so that one can expect the following power densities by wavelength. The harmful levels in the table (HPD) are thresholds where an interfering signal may begin to show up in the data and are derived from ITU Recommendation 769 (1992) for the worst case of 20 KHz bandwidth. A signal strength measured by the spectrum analyzer (SA) above the thresholds shown may exceed the HPD.

| Wave length (cm) | RBW | PD (dBW but SA in dBm) | Harmful level HPD RBW 20 kHz (dBW/$m^2$) | SA for PD > HPD radiation in station bldg. (dBm) | SA for PD > HPD radiation outside station bldg. (dBm) |
|---|---|---|---|---|---|
| 90 | 1 MHz | SA - 163 | -175 | -12 | -47 |
| 90 | 300 kHz | SA - 158 | -175 | -17 | -52 |
| 50 | 1 MHz | SA - 158 | -172 | -14 | -49 |
| 50 | 300 kHz | SA - 153 | -172 | -19 | -54 |
| 20 | 1 MHz | SA - 153 | -166 | -13 | -48 |
| 20 | 300 kHz | SA - 148 | -166 | -18 | -53 |

Conclusions:

The tests show measurable radiation from both the computer and the back end receiver of the detector system; however, in most cases the predicted power density incident on the VLBA antenna as a result of the radiation is less than harmful levels. Though the LO of the GPS receiver is 30 dB above the background noise, the resulting power density of the LO at the VLBA antenna is predicted to be below the harmful threshold.

No GPS LO radiation was detected from the GPS antenna. Radiation of spectra from the receiver front-end is detectable but is also expected to fall below harmful levels. The control/power cable that connects the front-end to the back-end of the receiver could not be fed thru the screen room wall, so that radiation back through this cable may add to the signal levels measured in the test.

There are uncertainties in the test. For example, the actual attenuation of room 100 of the station building at VLBA Hancock is assumed to be 35 dB up to 2 GHz, but has not been measured. As well, some of the gains and attenuations in the calculations are estimates; for instance, the VLBA antenna sidelobe gain is assumed to be 0 dBi in defining harmful levels.

Recommendations:

1. The computer and receiver back end must be operated in an area decoupled as much as possible from the VLBA antenna. According to VLBA Memo No 596, tests show that room 100 of the station building provides 35 dB of rejection from 100 MHz - 2 GHz.

2. Filtering the circuit outputs and gasketing the receiver cabinet will help reduce emissions by the receiver back end LO's. The power in the harmonics of the LO's should be reduced.

3. Gasketing the control cabinet may help to reduce the GPS LO radiation.

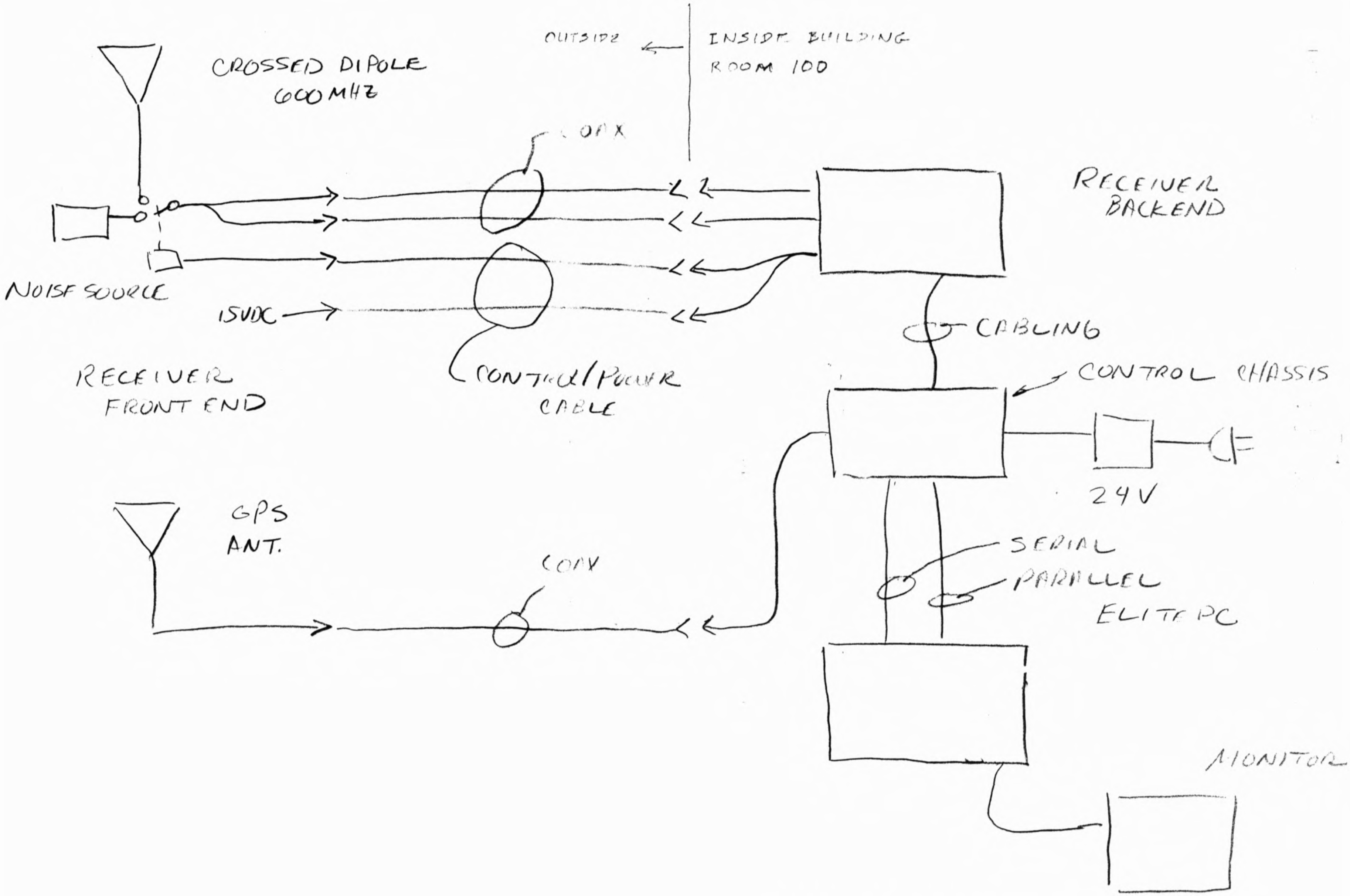
4. Since the control/power cable is used for DC power and a low bandwidth signal, I recommend filtering all the lines on this cable at the receiver back end cabinet.

5. Additional testing to insure radiation levels are below harmful levels should be performed after corrections are completed.

6. During initial tests at the VLBA antenna, tests should be performed using SPAN (SCREEN software) and/or a spectrum analyzer to look for interference in the VLBA IF that may result from operation of the 600 MHz impulse detector.

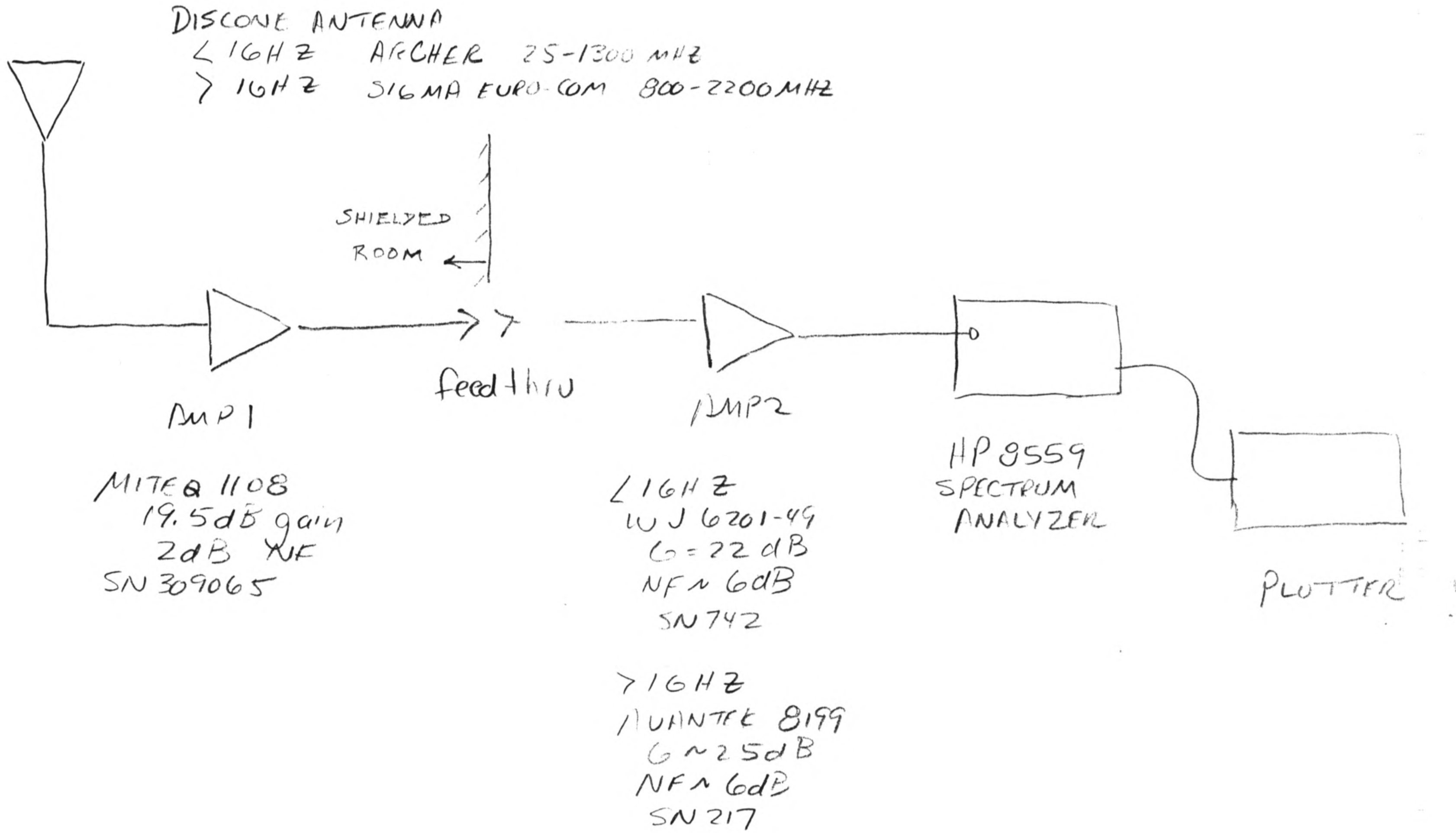
References:

VLBA memo no 596, Station Building RF Test, J. Oty, P. Rhodes, D. Ross, 1987




600MHZ IMPULSE DETECTOR

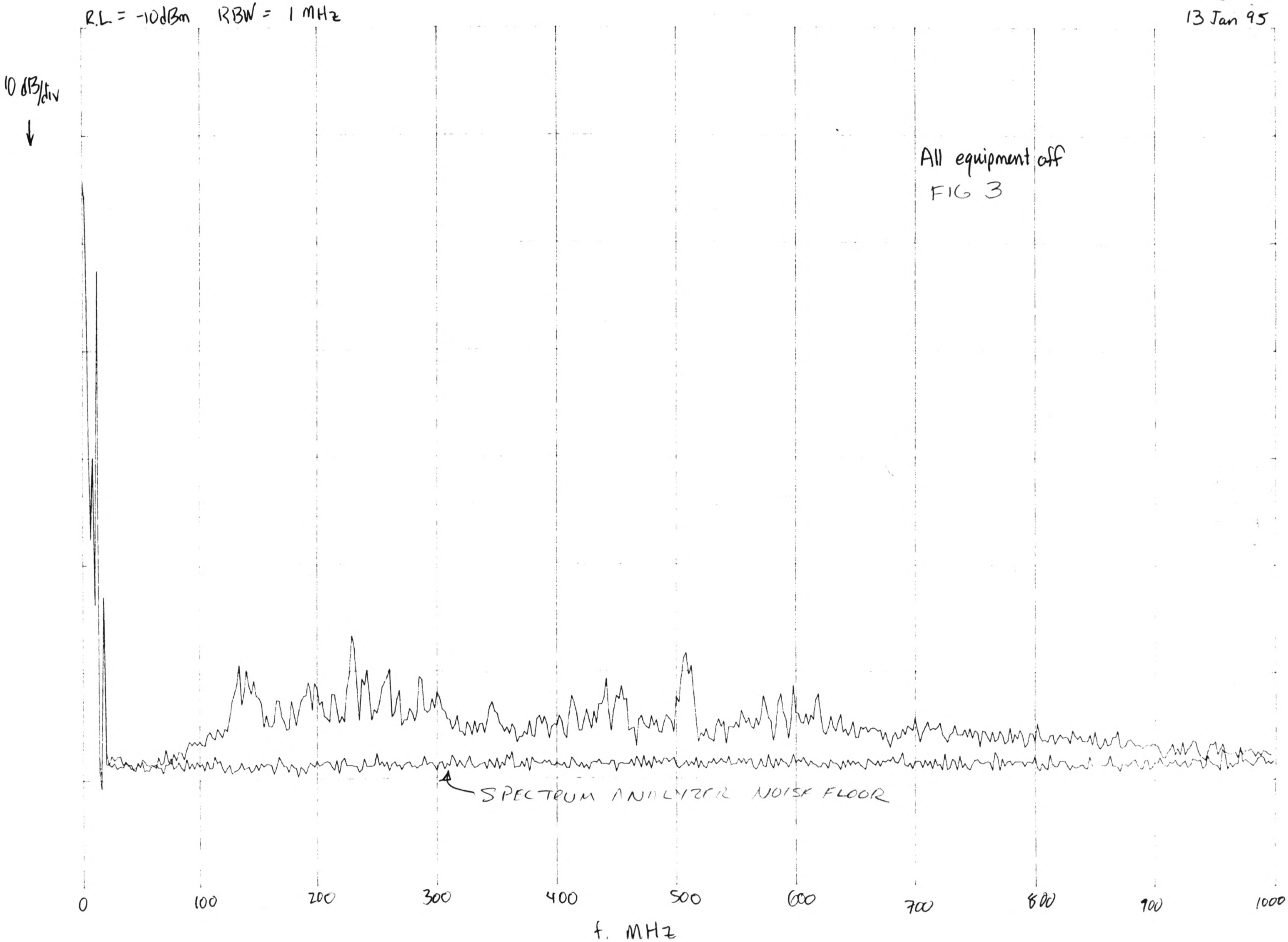
FIG 1 CJ

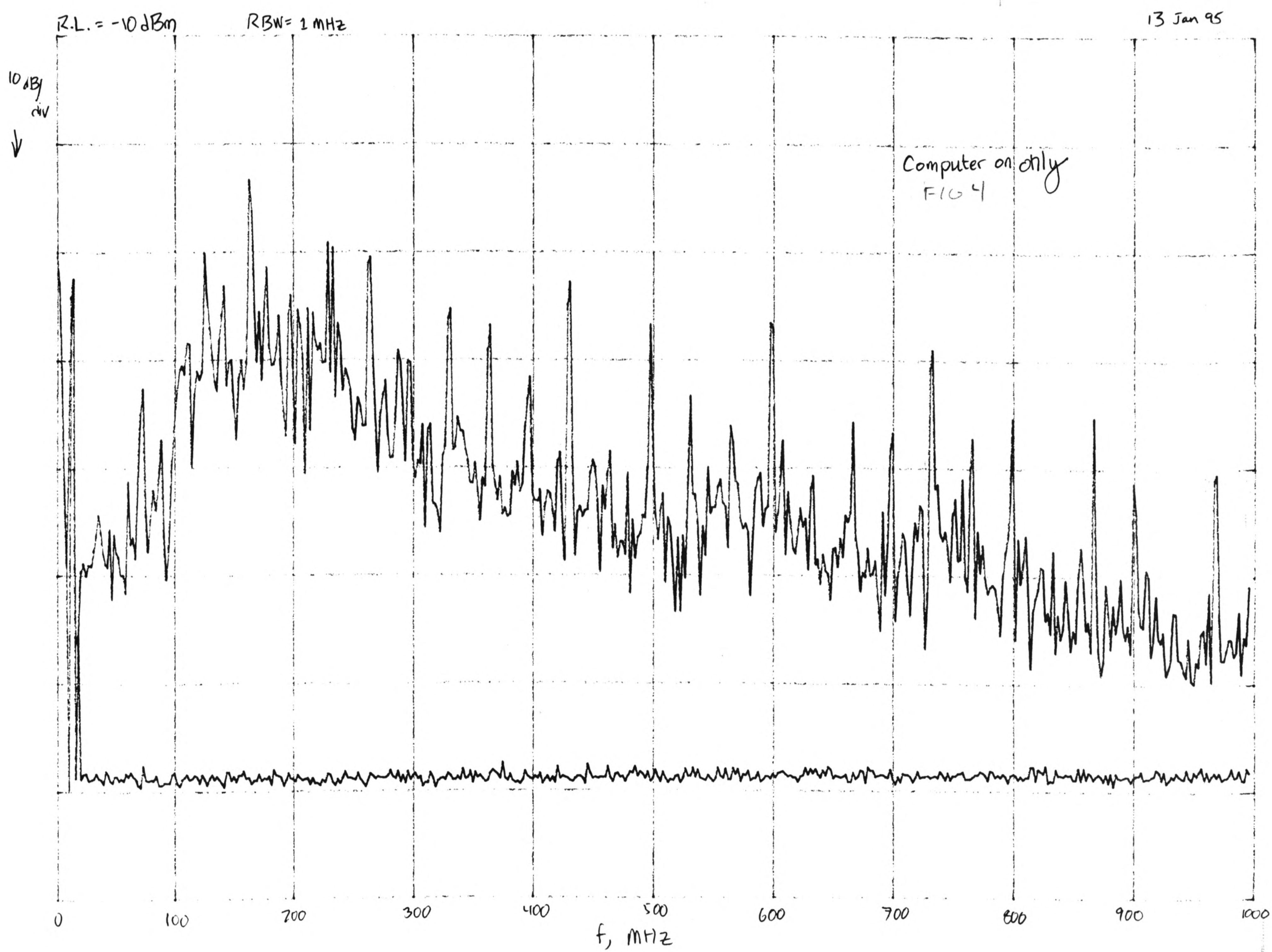


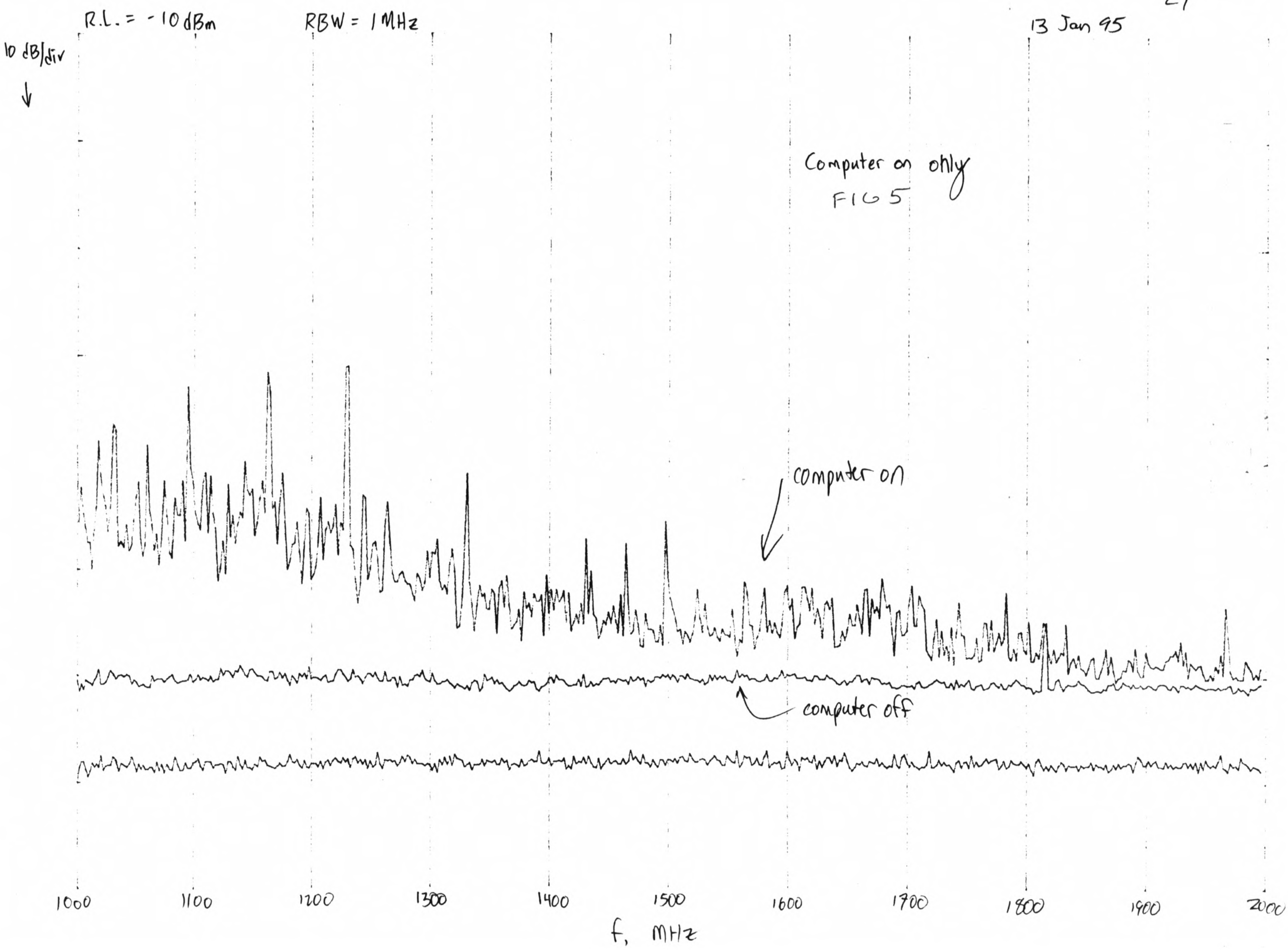

RF EMISSION TEST SETUP

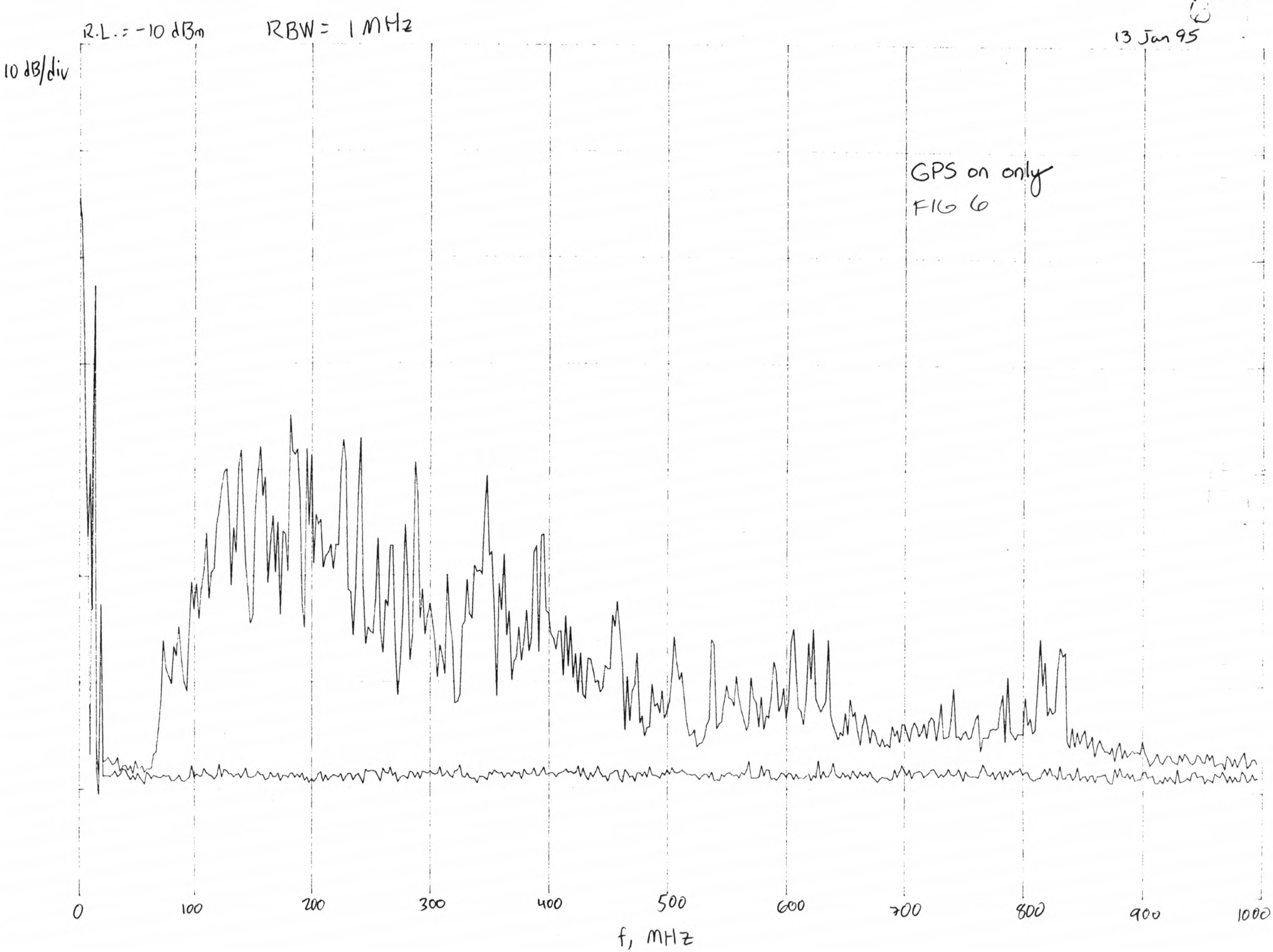
FIG 2 CJ

13 Jan 95


R.L = -10dBm RBW = 1 MHz
10 dB/div
All equipment off
FIG 3
SPECTRUM ANALYZER NOISE FLOOR
0
100
200
300
400
500
600
700
800
900
1000
f. MHz


R.L. = -10 dBm
RBW = 1 MHz
13 Jan 95
10 dB/div
Computer on only
FIG 4
0
100
200
300
400
500
600
700
800
900
1000
f, MHz


R.L. = -10 dBm
RBW = 1 MHz
13 Jan 95
10 dB/div
Computer on only
FIG 5
computer on
computer off
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
f, MHz



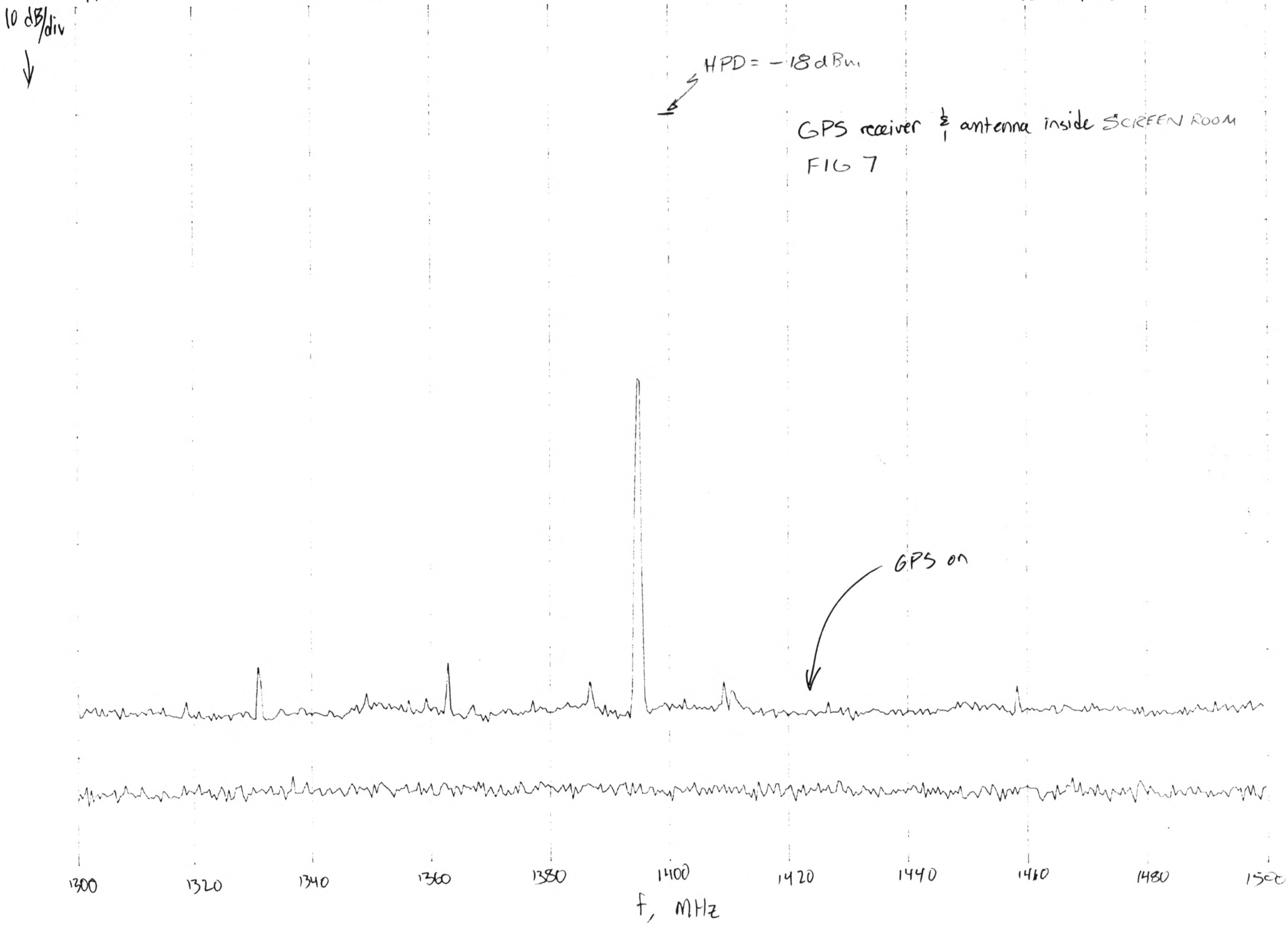
R.L. = -10 dBm
RBW = 1 MHz
13 Jan 95
10 dB/div
GPS on only
FIG 6
0
100
200
300
400
500
600
700
800
900
1000
f, MHz

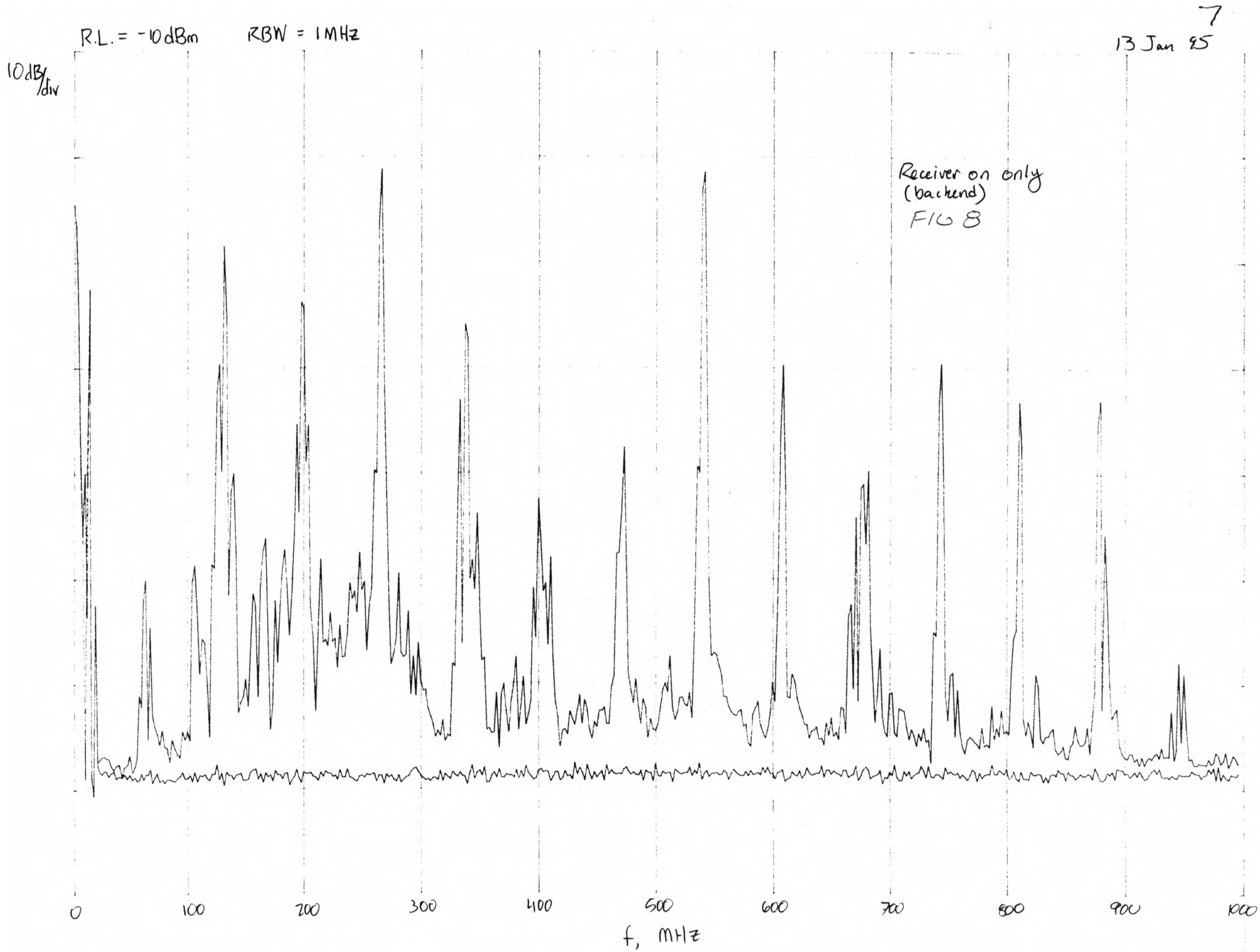
R.L. = -10 dBm    RBW = 300 kHz    13 Jan 95

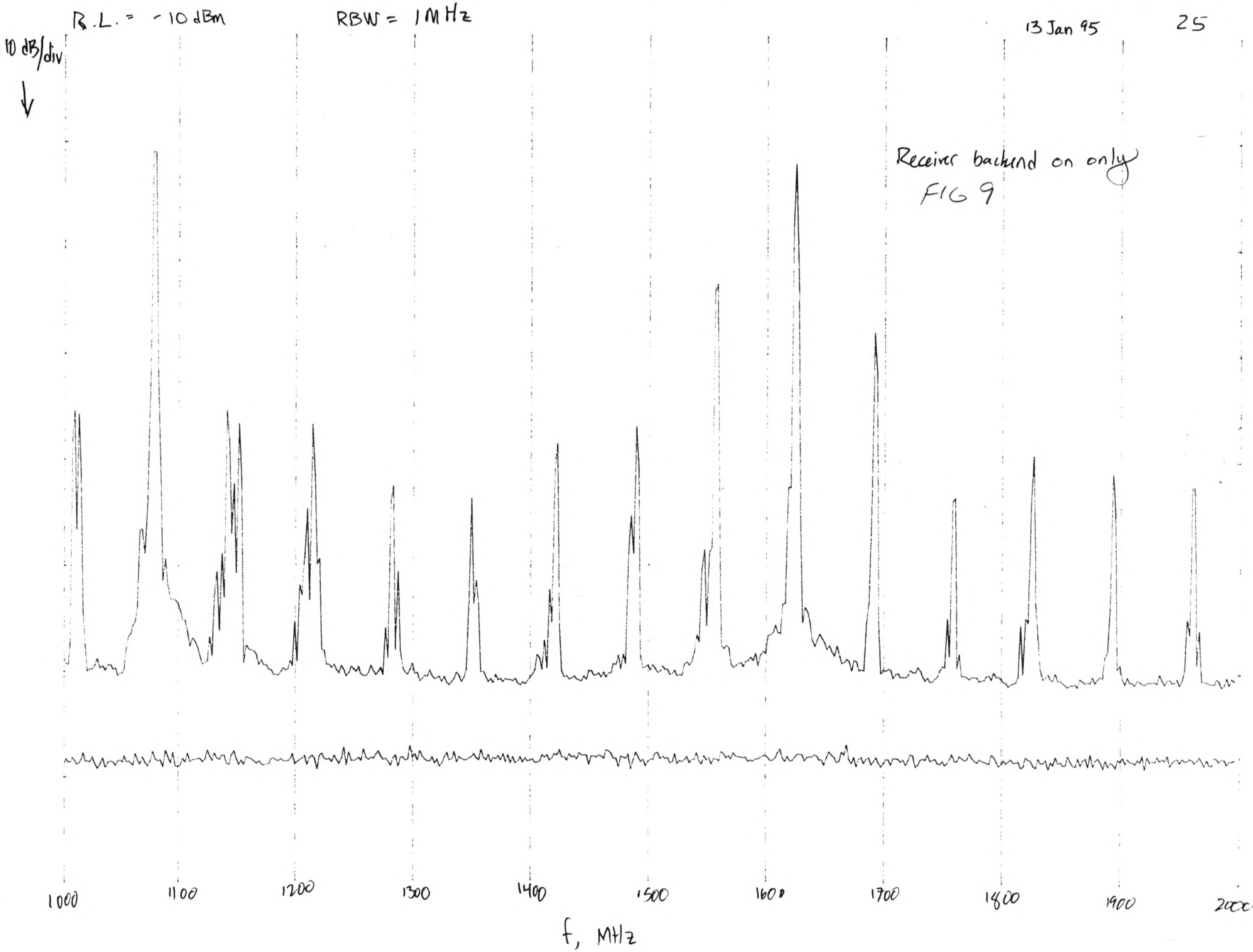


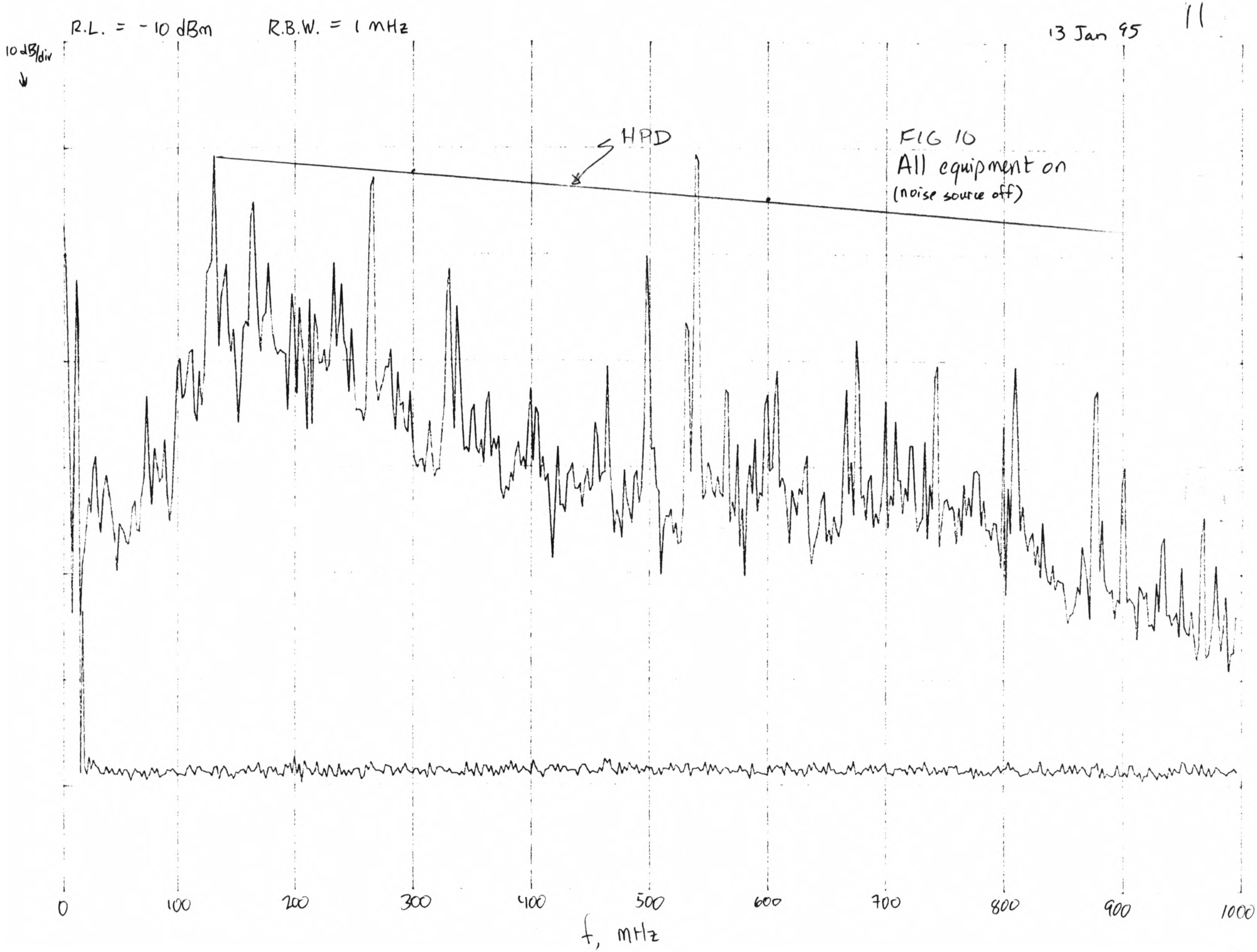
GPS receiver & antenna inside SCREEN ROOM

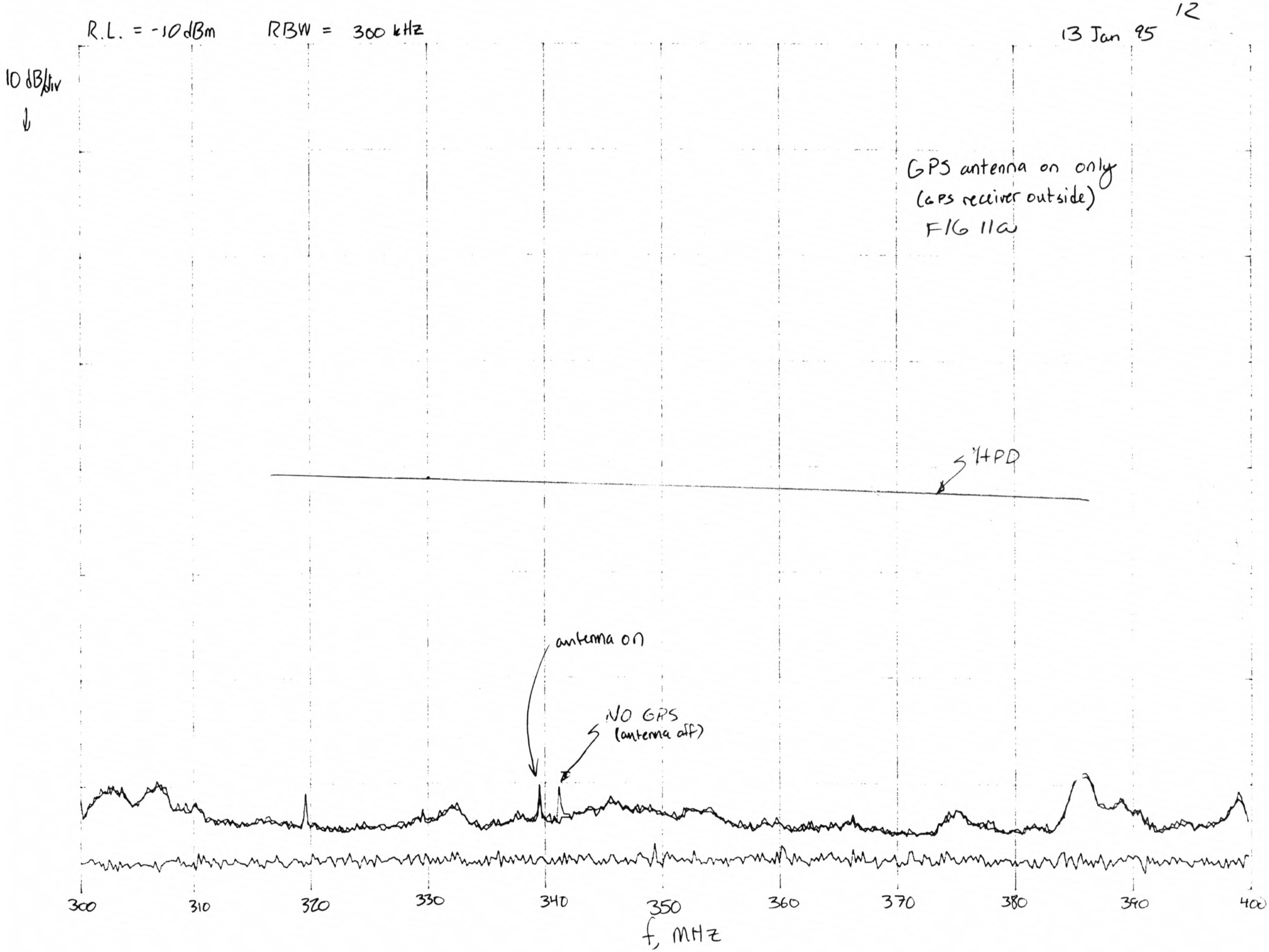
FIG 7

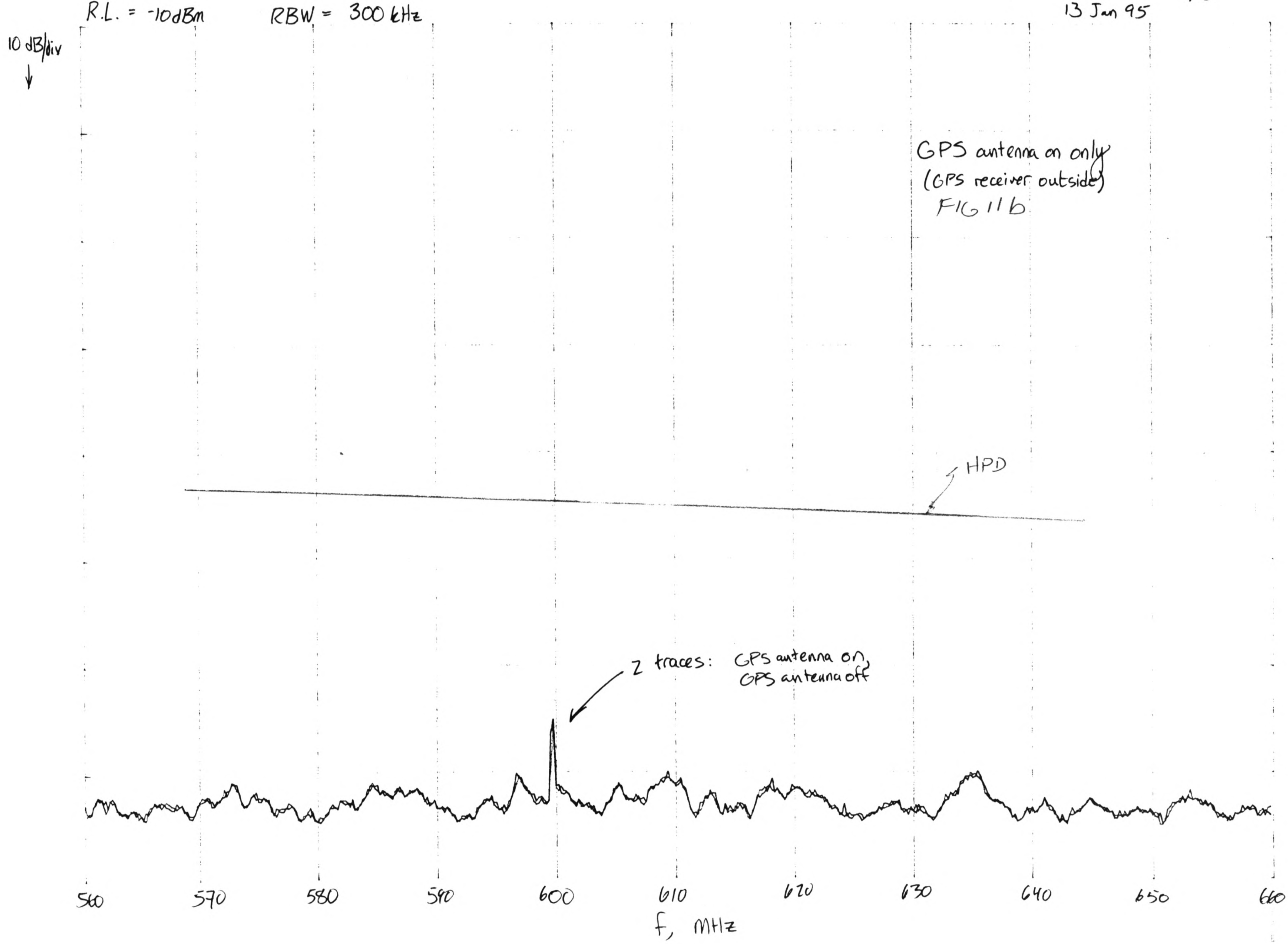


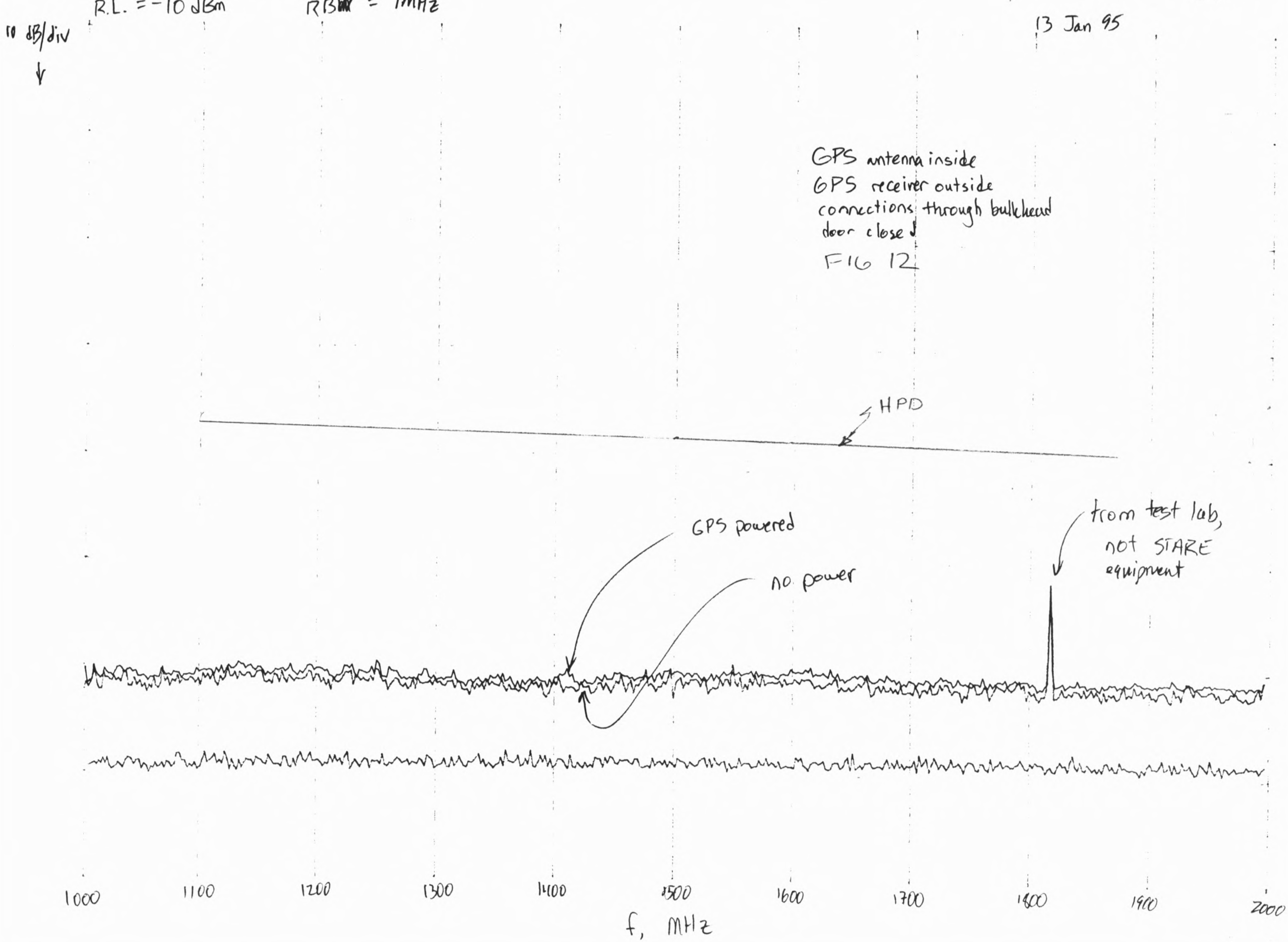

R.L. = -10dBm
RBW = 1MHz
7
13 Jan 85
10dB/div
Receiver on only
(backend)
FIG 8
0
100
200
300
400
500
600
700
800
900
1000
f, MHz

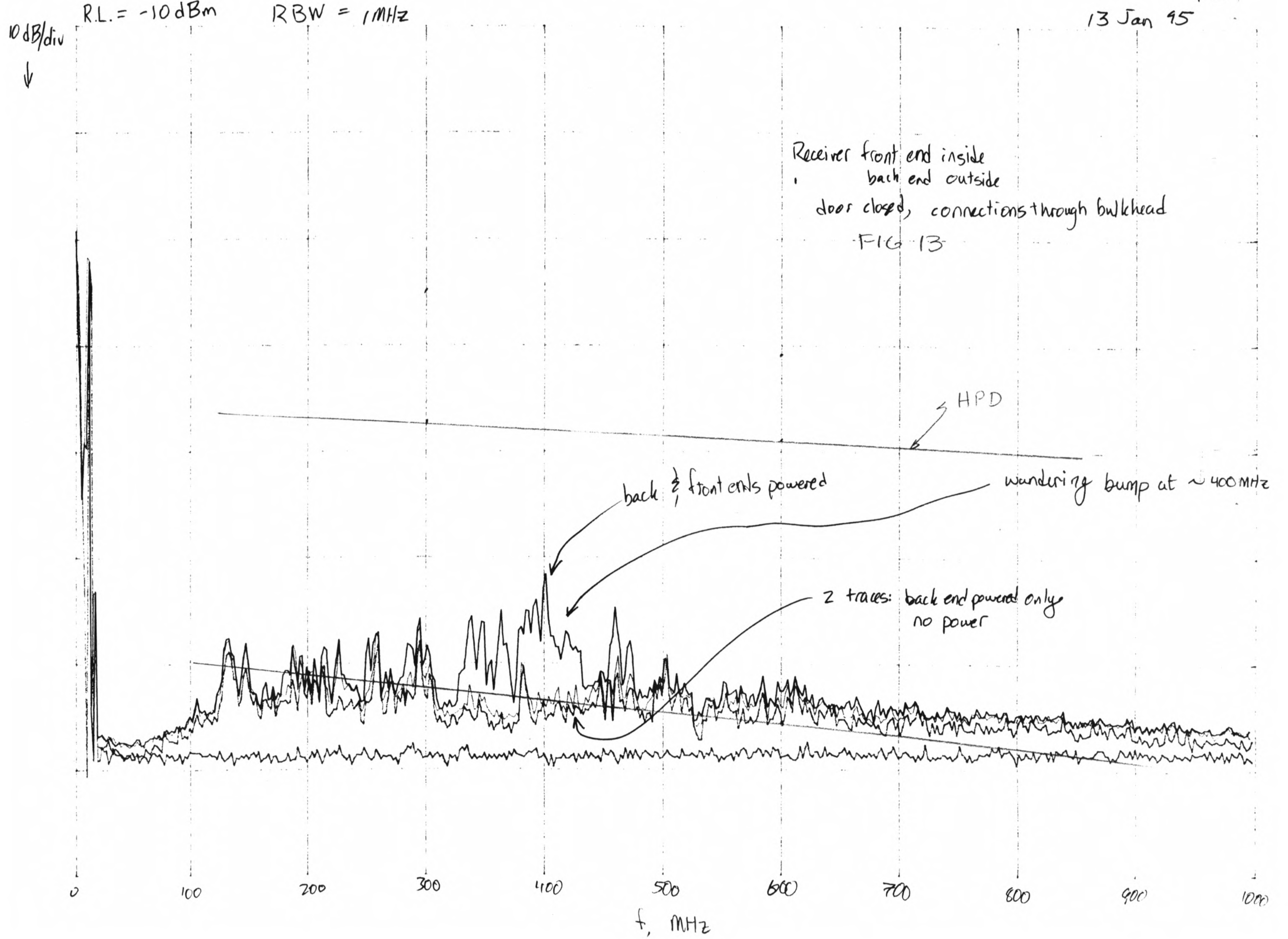

R.L. = -10 dBm
RBW = 1 MHz
13 Jan 95
10 dB/div
Receiver backend on only
FIG 9
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
f, MHz


R.L. = -10 dBm
R.B.W. = 1 MHz
13 Jan 95
10 dB/div
HPD
FIG 10
All equipment on
(noise source off)
0
100
200
300
400
500
600
700
800
900
1000
f, MHz


R.L. = -10 dBm
RBW = 300 kHz
13 Jan 95
10 dB/div
GPS antenna on only
(GPS receiver outside)
FIG 11a
S/4PD
antenna on
NO GPS
(antenna off)
300
310
320
330
340
350
360
370
380
390
400
f, MHz


R.L. = -10dBm
RBW = 300 kHz
13 Jan 95
10 dB/div
GPS antenna on only
(GPS receiver outside)
FIG 11b
HPD
2 traces: GPS antenna on,
GPS antenna off
560
570
580
590
600
610
620
630
640
650
660
f, MHz


R.L. = -10 dBm
RBW = 1MHz
10 dB/div
13 Jan 95
GPS antenna inside
GPS receiver outside
connections through bulkhead
door closed
FIG 12
HPD
GPS powered
no power
from test lab,
not STARE
equipment
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
f, MHz


R.L. = -10 dBm
RBW = 1 MHz
13 Jan 95
10 dB/div
Receiver front end inside
back end outside
door closed, connections through bulkhead
FIG 13
HPD
back & front ends powered
wandering bump at ~400 MHz
2 traces: back end powered only
no power
0
100
200
300
400
500
600
700
800
900
1000
f, MHz

R.L. = -10 dBm RBW = 1 MHz 13 Jan 95