National Radio Astronomy Observatory
Socorro, NM

VLA TEST MEMO. 194

SYSTEM GENERATED RFI IN THE VLA AT L-BAND

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21July1995

1. INTRODUCTION

The L-band RFI to observations with the VLA is periodically monitored by observing the North Celestial Pole using the array. This is to (1) warn observers about frequencies at which interference persists, and (2) locate sources of RFI and take appropriate steps to minimize them. Fig 1 (from VLA System Tests) shows a typical RFI plot made in early 1993. In the plot there are three types of RFI signals:
(1) External RFI,
(2) Spurious signals caused by the IF conversion scheme used by the VLA, and
(3) System generated RFI signals caused by the local oscillator system.

The problem of spurious signals due to signals in image around 1600MHz is caused by the RF signals beating with the second harmonic of the first LO (i.e. 3200*2-f_r), and can be minimised by changing the frequency conversion scheme (VLA Electronics Memo. No. 223). A much simpler and cheaper method of reducing the spurious signals, by phase switching the first local oscillator at 3200MHz instead of the present scheme of phase switching the signals from 2-4 GHz Synthesizers (L6 Modules), was suggested in VLA Electronics Memo. No. 224. The scheme was tried using a $\lambda/2$ cable in the path of 200MHz signal going to A-rack. The 200MHz is 180° phase switched, instead of the phase of the 2-4 GHz Synthesizer signals, using Walsh function phase switching signals, in antennas 7, 19, and 23. The 200MHz signals are used for generating the 3200MHz first LO for upconverting the L-band RF signals. The scheme is quite effective in reducing these spurious signals and also reduces considerably one of the strongest system generated RFI signal at 1400MHz as shown in this memo. Also in this memo we consider sources of RFI signals at other harmonics of 50MHz and how they can be minimised.

2. STRONG RFI AT HARMONICS OF 200MHz

The RFI at 1400MHz and 1600MHz is caused by 7th and 8th harmonics of 200MHz, generated by balanced mixers used as phase detectors at 200MHz in the phase lock loops of the 3200MHz LO (F2 Module), 17-20 GHz LO (F3 Module), and 12-15 GHz LO (F12 Module). The RFI signals from these mixers are radiated and probably picked up by the feed in each antenna.

With the 200MHz signals to A-rack phase switched, using Walsh Functions, in antennas 7, 19, and 23, it was possible to verify this hypothesis. We disconnected the 200MHz signal going from B-rack to F12 Module in these 3 antennas. The 1400MHz RFI, because of the 7th harmonic of 200MHz from phase detectors in F2 and F3 Modules, should be incoherent between these three antennas and rest of the array, because of 180° phase switching of the 200MHz signals (going to phase detectors) using Walsh functions. Spectrum in Fig. 2 shows a strong RFI signal at 1400MHz between all antennas (Antennas=*-7,19,23,2,20,28) which donot have phase switching at 200MHz (antennas 2, 20, and 28 were not used in these tests). In the spectrum for antennas 7, 19, and 23 (with 200MHz phase swiching) shown in Fig. 3 we do not see any RFI at 1400MHz. In Fig. 4 a plot of AMPSCALAR sum of products between Antennas (*-7,19,23,2,20,28) with (7,19,23) is shown. It shows that the 1400MHz RFI in these 3 antennas is reduced by a factor of about 200 (46dB), and supports our hypothesis of the cause of the 1400MHz RFI. Also it shows that during the tests the error of the 180° phase switching for the three antennas at 1400MHz was $\lesssim 0.7°$or $\lesssim 0.1° at 200MHz$.

3. RFI AT HARMONICS OF OFFSET LOs

RFI signals at other harmonics of 50MHz, between 1250MHz and 1750 MHz, are shown in spectra plotted in Fig. 5. From these spectra we see moderate RFI signals at 1300MHz, 1500MHz, and 1650MHz. (RFI at 1750MHz is spread over more than one channel and is caused by something other than LO system or is external). Somewhat weaker RFI signals are seen at other harmonics of 50MHz (1250MHz, 1550MHz, and 1700MHz). The RFI signals at 1300MHz, 1500MHz, and 1650MHz are probably due to harmonics of the offset LOs at 650MHz, 300MHz, and 550MHz respectively, used for converting 1025MHz IF signals to IFs D, A, and C respectively in F8 Modules. Other harmonics of 50MHz are probably due to radiation of the 50MHz comb picked up by the feed. It is possible that the radiation is caused by 50MHz comb in A-rack because recent shielding of the B-racks has not noticably reduced these RFI signals.

4. RFI DUE TO 50MHz COMB OUTSIDE B-RACK

To check that 50MHz comb going to the A-rack is causing the RFI, we added another 1050MHz low pass filter in the L2 Modules of antennas 7, 19, and 23 (50MHz comb coming out of the L2 Modules already have a 1050MHz low pass filter). Figs. 6,7, and 8 show 0.78MHz, 512 channel spectra at 1250MHz, 1350MHz, 1450MHz, 1550MHz, 1700MHz, and 1750MHz. The spectra in Fig. 6 are for baselines formed by all antennas (antennas 3 and 10 were not used in these tests because they didnot have B-rack shield or FO link for connections between B-rack and A-rack). Note that RFI at 1750MHz is over morethan one channel and therefore is not LO related and is possibly external. RFI at other harmonics of 50MHz is present but is somewhat stronger at 1550 and 1700MHz, than at 1250, 1350, and 1450MHz. The spectra in Fig. 7 are between baselines formed by antennas (*-3,10,7,19,23) with antennas (7,19,23) with no phase switching of 200MHz signals. RFI signals at 1250, 1350, and 1450MHz are below detection limit and at 1550MHz and 1700MHz are considerably reduced. The spectra in Fig. 8 are with the same baselines as in Fig. 7 but with phase switching at 200MHz in antennas 7,19,and 23. We do not see any RFI even at 1550 and 1700 MHz in the spectra of Fig. 8. This suggests that the RFI at 1550 and 1700 MHz in Fig. 7 were due to image of 1650MHz and 1500MHz respectively around 1600MHz, which disappear when phase switching is introduced in the first LO at 3200MHz. From the spectra in Figs. 6-8 it is deduced that 50MHz comb out side B-rack causes weak RFI at all harmonics of 50MHz in L-band, and this can be reduced considerably by putting a low pass filter in the comb coming out of the B-rack.

5. BROADBAND IF NOISE RADIATION CAUSING INCREASE IN T_{SYS}

Harmonics of 300MHz, 550MHz and 650MHz are radiated from F8 Modules and cause RFI. Assuming these harmonics are generated in the mixers, the power generated in the harmonics should be several tens of dBs below the broadband noise IF output of -20dBm at the output of these mixers. The broadband noise may be getting picked up in the same way as the harmonics of the offset LOs. Any pickup of these broadband noise signals will not contribute to visibility measurements, because most of the noise is due to system noise from each antenna and the signals are already phase switched, but may cause increase in the system temperature. To check this the following observations were done looking at the North Celestial Pole. Coherent 1400MHz RFI appears at 1410.1MHz (using L6 frequency of 3589.9 MHz) in the output of IF B mixer in F8 Module. If we disable phase switching, the 1410.1MHz will be coherent between various antennas. Observations in IF A at 1410.1MHz in spectral line mode should show a line at 1410.1MHz, and the line should disappear when IF B frontend filter is opened (bandwidth code=4). Plots in Fig. 9 show these measurements made with a bandwidth of 3.125 MHz, 256 channels, Mode=1A. Fig. 9a shows spectrum with center freq=1400MHz. Fig. 9b shows spectrum at 1410.1MHz with frontend filter for IF B having 50 MHz bandwidth, and Fig. 9c shows the spectrum at 1410.1 with the Frontend filter for IF B opened. From these plots it appears that the 1410.1MHz RFI is due to 1400 MHz picked up, and the picked up signal is about 1-2 % of the original signal. It means the L-band system temperature is effected at this level due to the broadband noise raditing from F8 mixers or beyond.

6. CONCLUSIONS

We have identified three types of system generated RFI signals causing interference to observations with the VLA at L-band:
(1) Strong RFI at harmonics of 200MHz. Of these 1400MHz RFI is most serious and can be reduced considerably or eliminated by phase switching 200MHz signals from L2 Modules (Figs. 2-4). These can also be reduced by reducing the harmonics of 200MHz in F2, F3 and F12 Modules, but that may require considerable work.
(2) Moderate RFI is caused by harmonics of offset LOs at 300MHz, 550MHz, and 650MHz used in F8 Modules (Fig. 5). These signals are serious for sensitive spectral line work and it may be important to reduce or eliminate the RFI atleast at 1300MHz because of the observations of red shifted HI. We should investigate means of reducing these RFI signals. One way will be to switch off 650MHz LO during any sensitive spectral line work at 1300MHz and use only AC IFs for the observations.

(3) Weak RFI signals at all harmonics of 50MHz are caused by 50MHz comb coming out of the B-rack shield. These RFI signals can be considerably reduced by putting an additional low pass filter in the path of the 50MHz comb (there is already one 1050MHz LPF in the L2 Module) before it comes out of the B-rack shield (Figs. 6-7).

ACKNOWLEDGEMENTS

The tests described in this memo have been possible with the enthusiastic help from Paul Lilie, Larry Beno, and their groups.

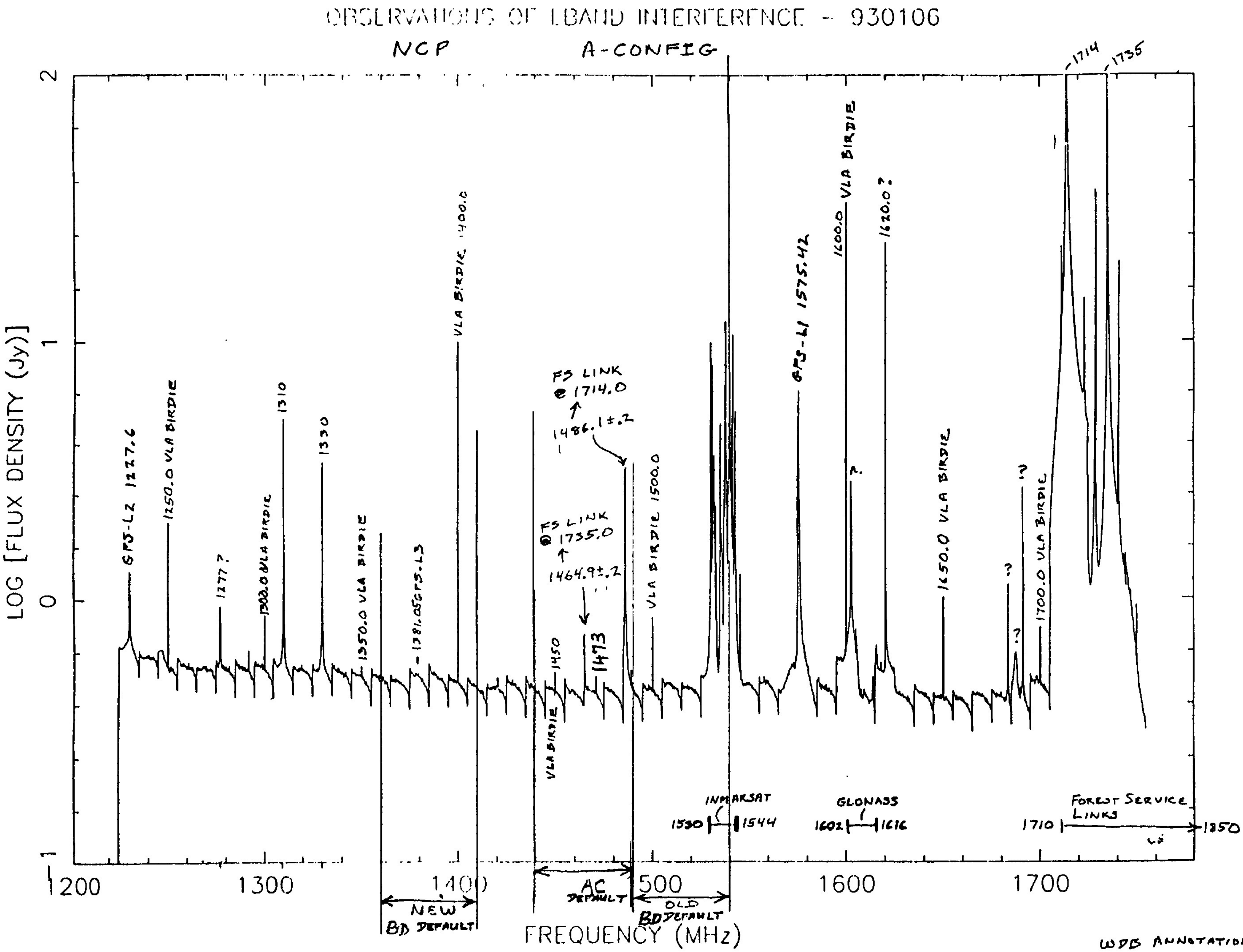


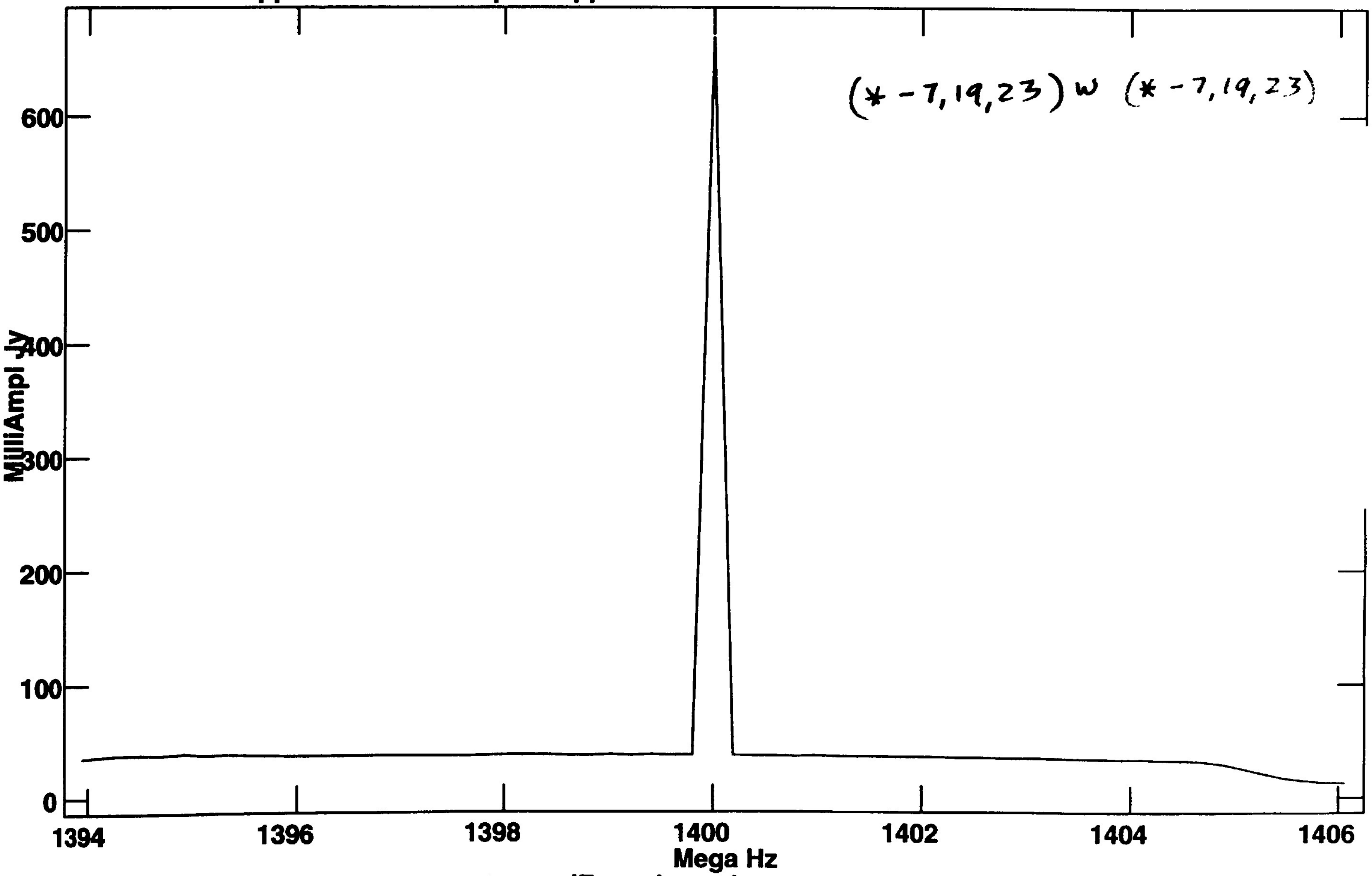
FIG 1

WDB ANNOTATIONS 93/02/17

VLA

FIG - VLA L-BAND RFI SURVEY LOOKING TOWARDS THE NORTH CELESTIAL POLE

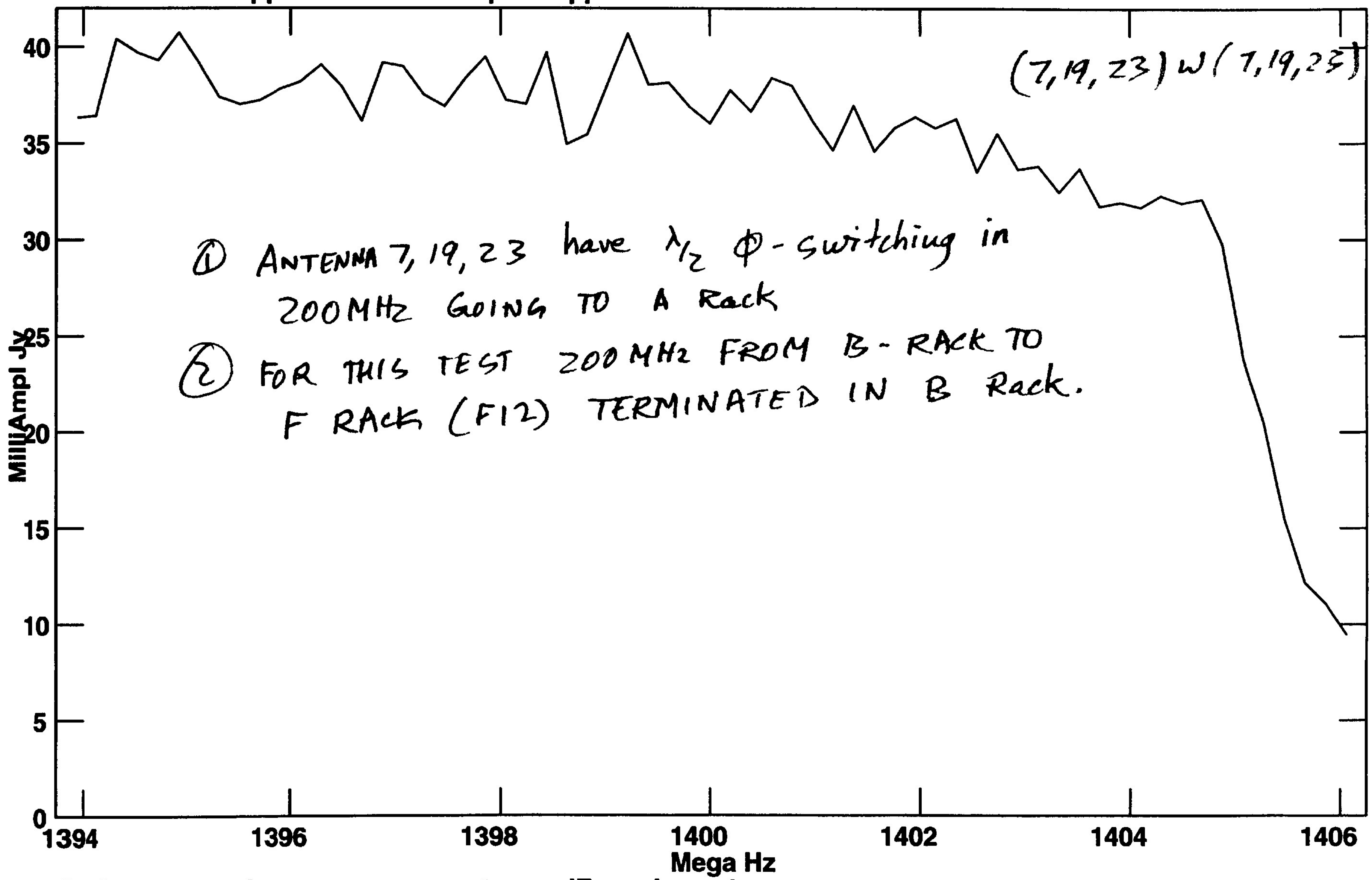
Plot file version 2 created 28-JUN-1995 10:20:11
NPOLE VLA950627.LINE.1
Freq = 1.4000 GHz, Bw = 12.500 MHz
No calibration applied and no bandpass applied



Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:03:00 to 00/21:21:14
Baseline: Several averaged Stokes: RR

FIG. 2

Plot file version 3 created 28-JUN-1995 10:20:52
NPOLE VLA950627.LINE.1
Freq = 1.4000 GHz, Bw = 12.500 MHz
No calibration applied and no bandpass applied



Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:03:00 to 00/21:21:14
Baseline: Several averaged Stokes: RR

FIG. 3

Plot file version 1 created 28-JUN-1995 10:18:20
NPOLE VLA950627.LINE.1
Freq = 1.4000 GHz, Bw = 12.500 MHz
No calibration applied and no bandpass applied

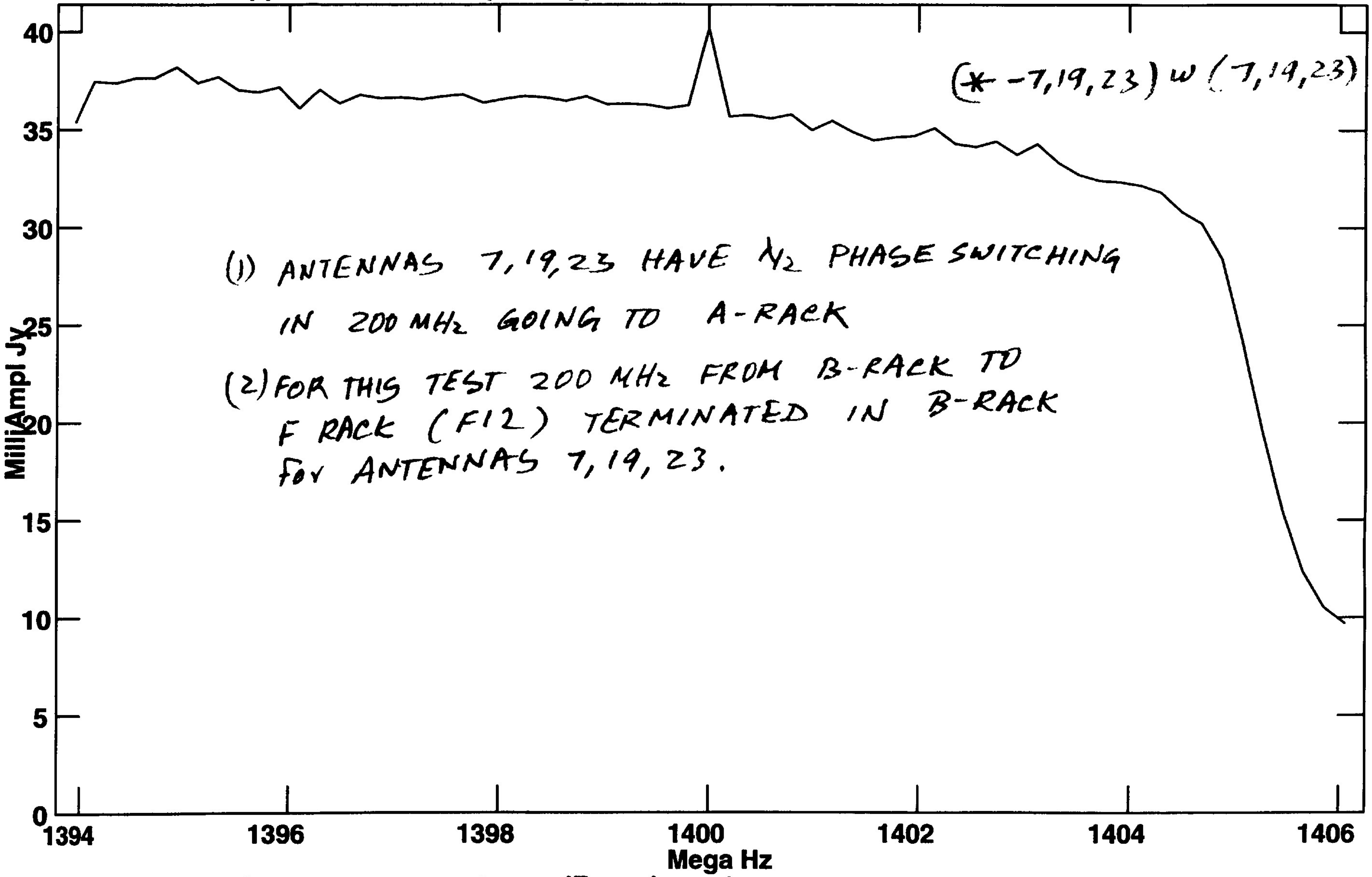


FIG. 4

Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:03:00 to 00/21:21:14
Baseline: Several averaged Stokes: RR

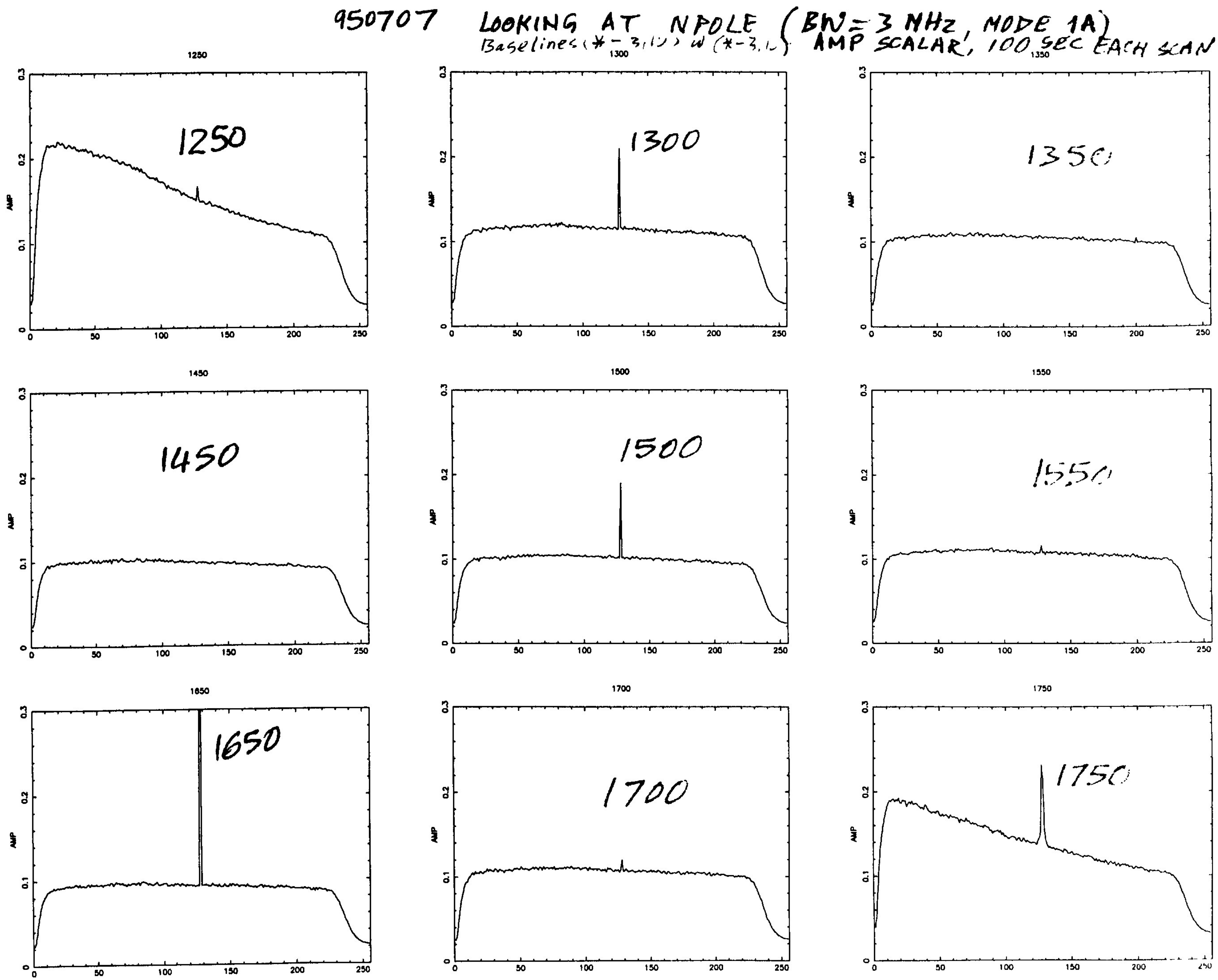

950707 LOOKING AT NPOLE (BW = 3 MHz, MODE 1A)
AMP SCALAR, 100 SEC EACH SCAN
1250
1300
1350
1450
1500
1550
1650
1700
1750
AMP
0
0.1
0.2
0.3
50
100
150
200
250

FIG. 5

950713 NPOLE (BW=0.8MHz, MODE 1A, AMPSCALAR,
BASELINES (* -3,10) W (* -3,10)

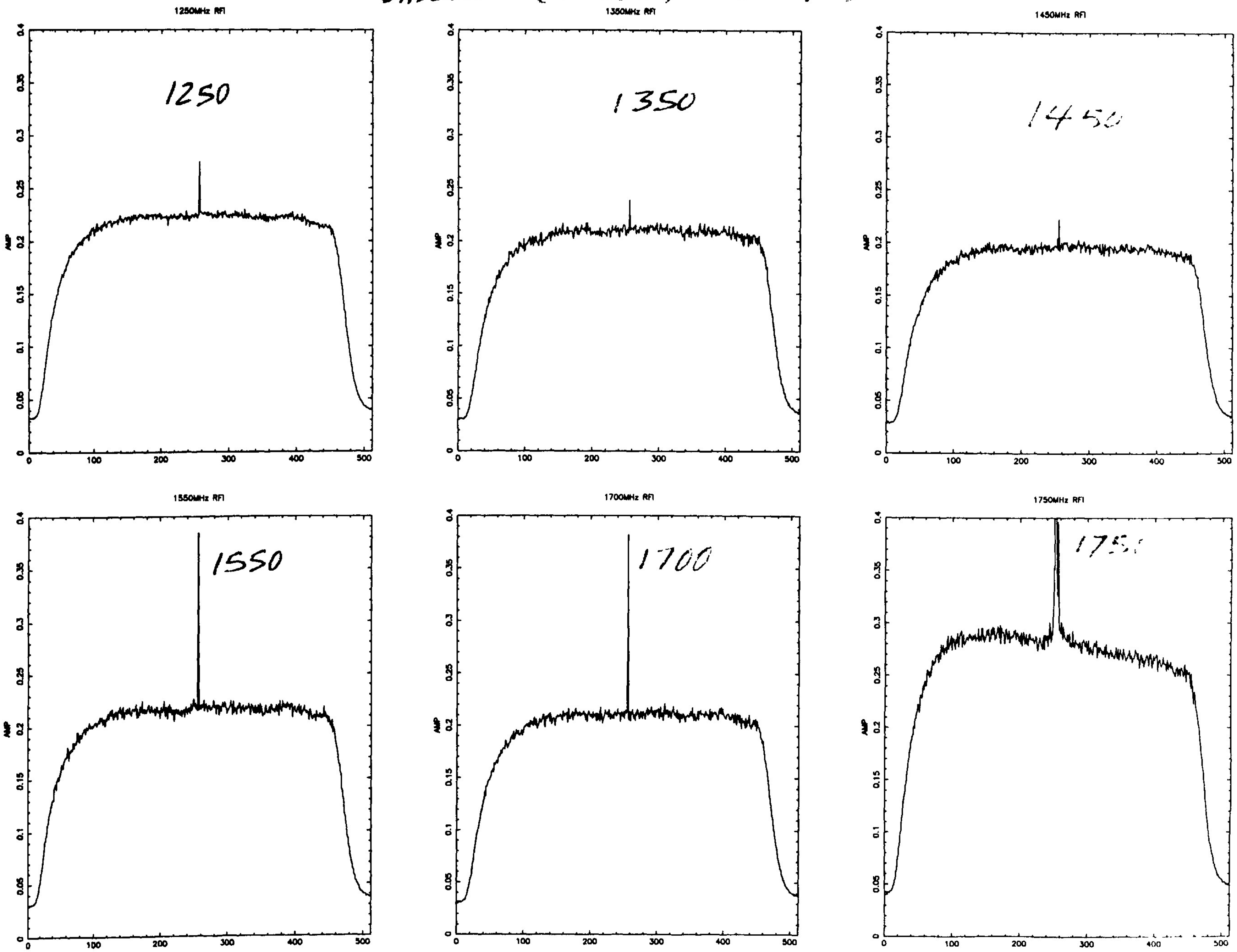


FIG. 6

950713 N POLE (BW=0.8MHz, IA MODE, AMP SCALAR, τ ≈ 100 s
BASELINES: (*-3,10,7,19,23) w' (7,19,23). NO φ s/w 2.0 MHz

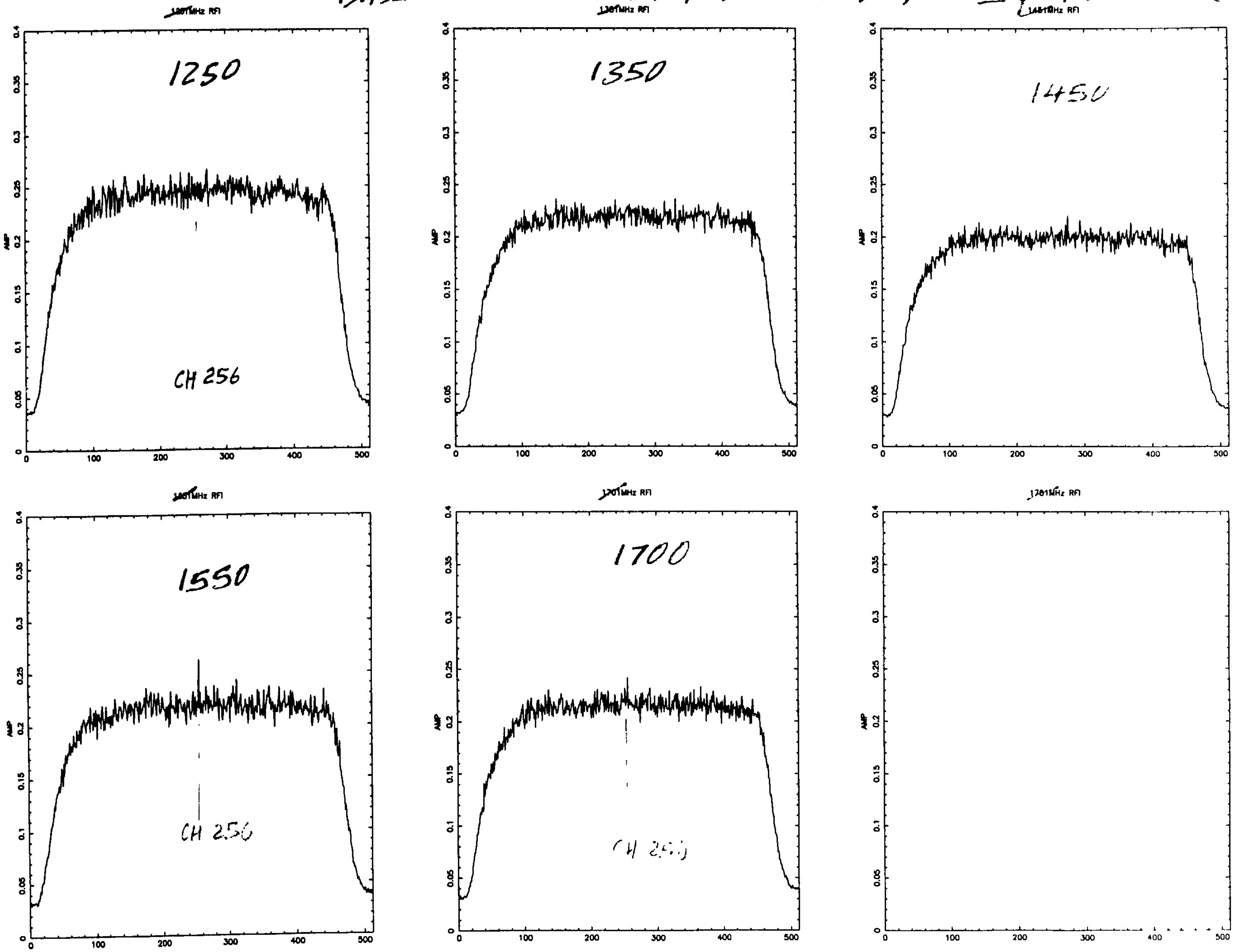


FIG. 7

950713 N POLE (BW=0.8 MHz, MODE 1A, AMPSCALAR, $\tau \sim 100$s
BASELINES: (*-3, 10, 7, 19, 23) w (7, 19, 23) ϕ s/w 200MHz in 7, 19, 23

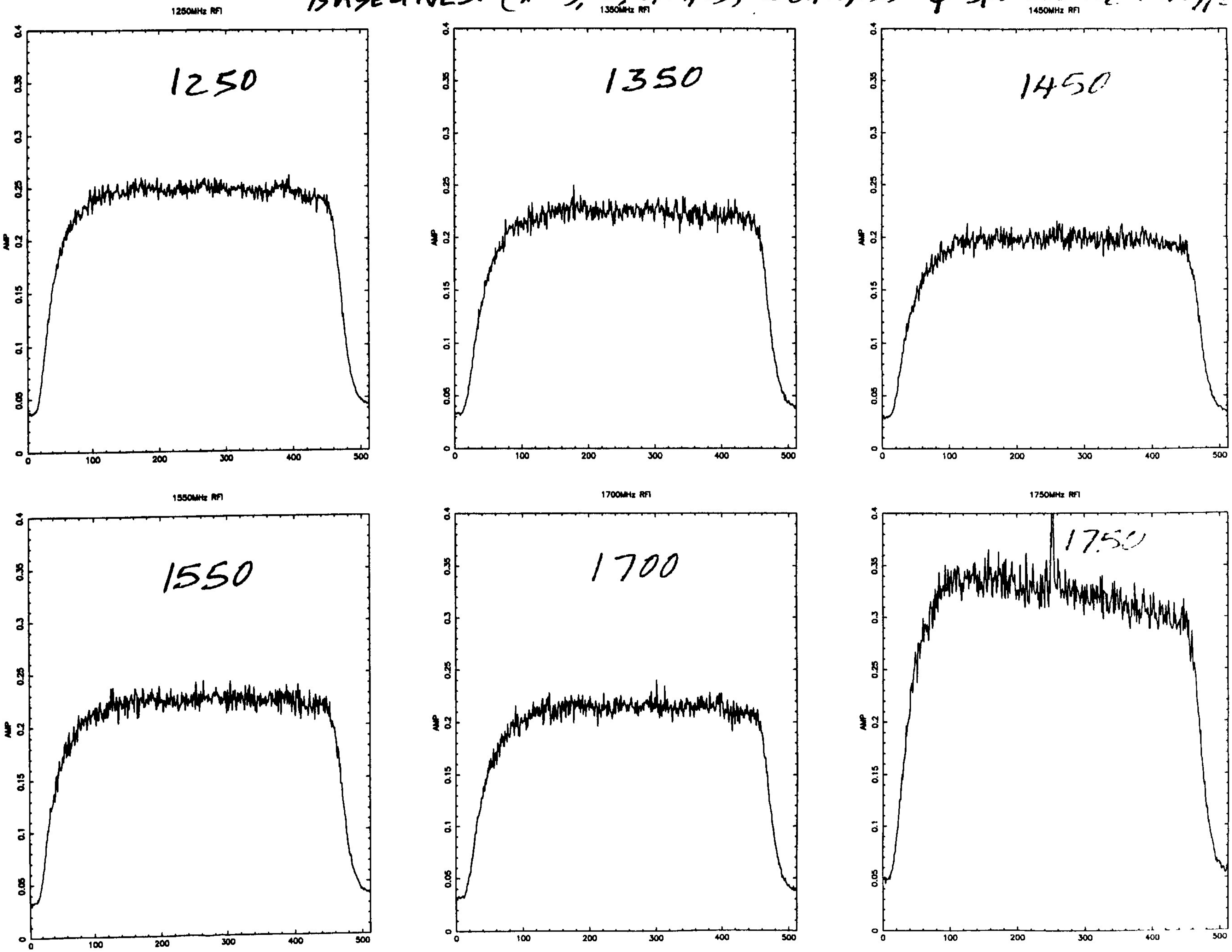


FIG. 8

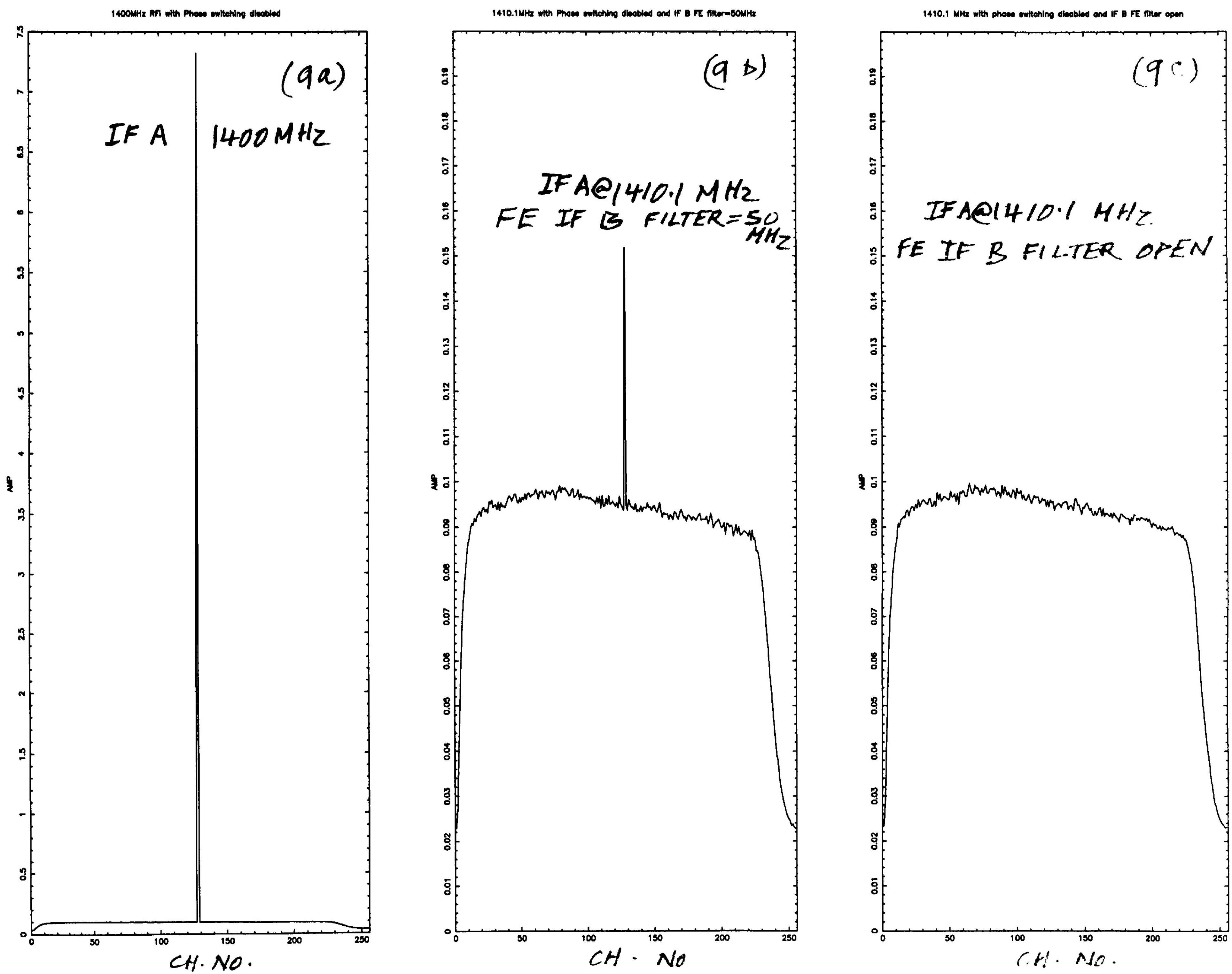

1400MHz RFI with Phase switching disabled
(9a)
IF A 1400MHz
AMP
CH. NO.
1410.1MHz with Phase switching disabled and IF B FE filter=50MHz
(9b)
IFA@1410.1 MHz
FE IF B FILTER=50 MHz
AMP
CH. NO
1410.1 MHz with phase switching disabled and IF B FE filter open
(9c)
IFA@1410.1 MHz
FE IF B FILTER OPEN
AMP
CH. NO.

Fig 9