National Radio Astronomy Observatory
Socorro, NM

VLA TEST MEMO. 200

REDUCTION OF 1400 MHz RFI IN THE VLA

D.S.Bagri
1996 OCT 27

ABSTRACT

This memorandum explains a source of strong coherent 1400 MHz RFI in the VLA. Two recent modifications have reduced the 1400 MHz RFI by about 30 dB. Modifications are: (1) to 200 MHz phase detector in the X-band LO (F12 Module), and (2) $\lambda/2$ phase switching of 200 MHz reference for generating first LO instead of 180° phase switching of 10.1 MHz signal from Fringe Generator (L7). The reduction in the RFI is seen in tests on five antennas already modified. These modifications, when completed on all antennas, should allow continuum observations with narrow bandwidths containing 1400 MHz RFI and spectral line observations around 1400 MHz by excising the channel containing the 1400 MHz residual RFI.

INTRODUCTION

The actual cause of the 1400 MHz birdie in the VLA was not known until the middle of 1995. While testing the concept of using phase switching at the 200 MHz reference frequency to improve the L-band image rejection (Bagri 1995 VLA Electronics Memo. 224), I realized that 7^{th} and 8^{th} harmonics of 200 MHz were dominant sources of strong birdies at 1400 and 1600 MHz in the VLA.

To understand the source of the strong 1400 MHz birdie and how it can be reduced, it is helpful to review the basic system. A simplified block diagram of the VLA electronics, Fig. 1, shows conversion of the L-band RF signals to the 4.5 to 5 GHz first IF and then to second IF of 1000-1050 MHz. This uses a first LO at 3200 MHz which is generated in the F2 Module by mixing 3200 MHz VCO with 3000 MHz. The difference signal is phase detected with the 200 MHz reference and the output is used to phase lock the VCO. The second LO in the 2-4 GHz range is generated by combining 2400 or 3000 MHz with harmonics of 50 MHz, and the 10.1 MHz from the Fringe Generator (L7 Module). The 10.1 MHz has fringe rotation and 180° phase switching. For image rejection improvements we are now phase switching the 200 MHz reference instead of the 10.1 MHz signal. The LO signal for converting the X-band RF signals is generated in F12 Module by mixing a YIG oscillator output with harmonics of 600 MHz. The difference signal is phase detected with the 200 MHz reference and the output is used to phase lock the YIG oscillator. Similarly the 17-20 GHz (F3) LO signal, used for high frequency bands, employs 600 MHz harmonics and a phase detector at either 100 or 200 MHz to phase lock the YIG oscillator in the 17-20 GHz range. These phase detectors, used in F2, F12 and F3 modules, are balanced mixers which generate harmonics which could radiate into antenna feeds if not contained properly.

If the 200 MHz reference signal going to these phase detectors are 180° phase switched using different Walsh function signal for each antenna, then the 7^{th} harmonic at 1400 MHz radiated from the phase detectors will also have 180° phase switching, and will be incoherent from one antenna to another. For practical reasons we are using a $\lambda/2$ cable at 200 MHz to introduce the phase shift which may not be exact 180°. Any deviation from exact 180° and amplitude unbalance of the 200 MHz between 0° and 180° states will cause residual 1400 MHz coherent signal.

MEASUREMENTS AND RESULTS

We tested for the 1400 MHz RFI in antennas 7,19 and 23, which had $\lambda/2$ phase switching on the 200 MHz signal going to the F2. For this test we terminated the 200 MHz going to F3 and F12 modules. Fig. 2 shows results of these tests. The 1400 MHz birdie in the baselines formed by these three antennas with the remaining antennas was at least 30-40 dB lower than the average over the rest of the array.

Further tests indicated, as shown in Fig. 3, that the 1400 MHz birdie varied by more than 30 dB from antenna to antenna. A careful examination of old data going over more than 12 years and further testing established that the strong 1400 MHz birdie was caused by the 7^{th} harmonic of 200 MHz from the phase detector in the X-band LO (F12 Module).

Suppressing the 1400 MHz radiation from the F12 Module by improving the 200 MHz phase detector circuitry has reduced the 1400 MHz birdie considerably. Fig. 4 shows a comparision of the 1400 MHz birdie in data from 1995 and recent tests with 21 antennas which have the modified F12 Modules. This shows a reduction of the 1400 MHz birdie from last year by about 18 dB. Fig. 5 shows the 1400 MHz birdie in baselines formed by antennas 3,5,8,12 and 24 which have the 200 MHz phase switching and the F12 Module modifications. The 1400 MHz birdie seems to be further reduced by about 12 dB.

CONCLUSIONS

Overall it seems that the recent modifications in the F12 Module and phase switching at 200 MHz (which was primarily intended for L-band image rejection improvements) have reduced the 1400 MHz birdie by about 30 dB. At this stage it seems that the 1400 MHz birdie is tolerable for spectral line observations around this frequency using the VLA. However, the particular spectral channel containing the 1400 MHz frequency or additional couple of channels around this frequency may have to be excluded (excised) from data.

ACKNOWLEDGEMENTS

I thank Ken Sowinski and Paul Lilie for helpful discussions and the FE and LO-IF groups for the modifications and for help in conducting various tests. I also thank Bill Brundage for his helpful comments on improving the clarity of this report.

FIGURE CAPTIONS

Fig. 1: A simplified block diagram of the VLA electronics showing how the L-band RF signal is first converted to 4.5 to 5 GHz, by mixing with 3200 MHz first LO, and then to 1000-1050 MHz IF by mixing with 2-4 GHz LO. How the LO signals are derived and how the 1400 MHz RFI is generated can be understood using this block diagram.

Fig. 2: Amplitude of the 1400 MHz RFI in June 1995 as a function of frequency for (a) baselines formed by all antennas except antennas 7,19 and 23 (b) baselines formed by antennas 7,19 and 23

with all other antennas. Antennas 7,19 and 23 had phase switching at 200 MHz for signal going to F2. Amplitude of the 1400 MHz birdie is about 40 dB lower in (b) than in (a).

Fig. 3: Amplitude of the 1400 MHz birdie for various antennas (from CALIB on the RFI channel). There is more than 30 dB variation in strength of 1400 MHz RFI between various antennas. This shows the range of 1400MHz leakage from F12 Modules.

Fig. 4: Amplitude of the 1400 MHz birdie for 0.781 MHz/512 channel observations (a) for baselines formed by all antennas in June 1995 (b) for baselines formed by 23 antennas with modified F12 Modules. Comparision shows reduction of about 18 dB by F12 modifications.

Fig. 5: Amplitude of the 1400 MHz birdie for 0.781 MHz/512 channel observations for all baselines formed by antennas 3,5,8,12 and 24. These antennas have F12 modifications as well as phase switching at 200 MHz during these measurements.

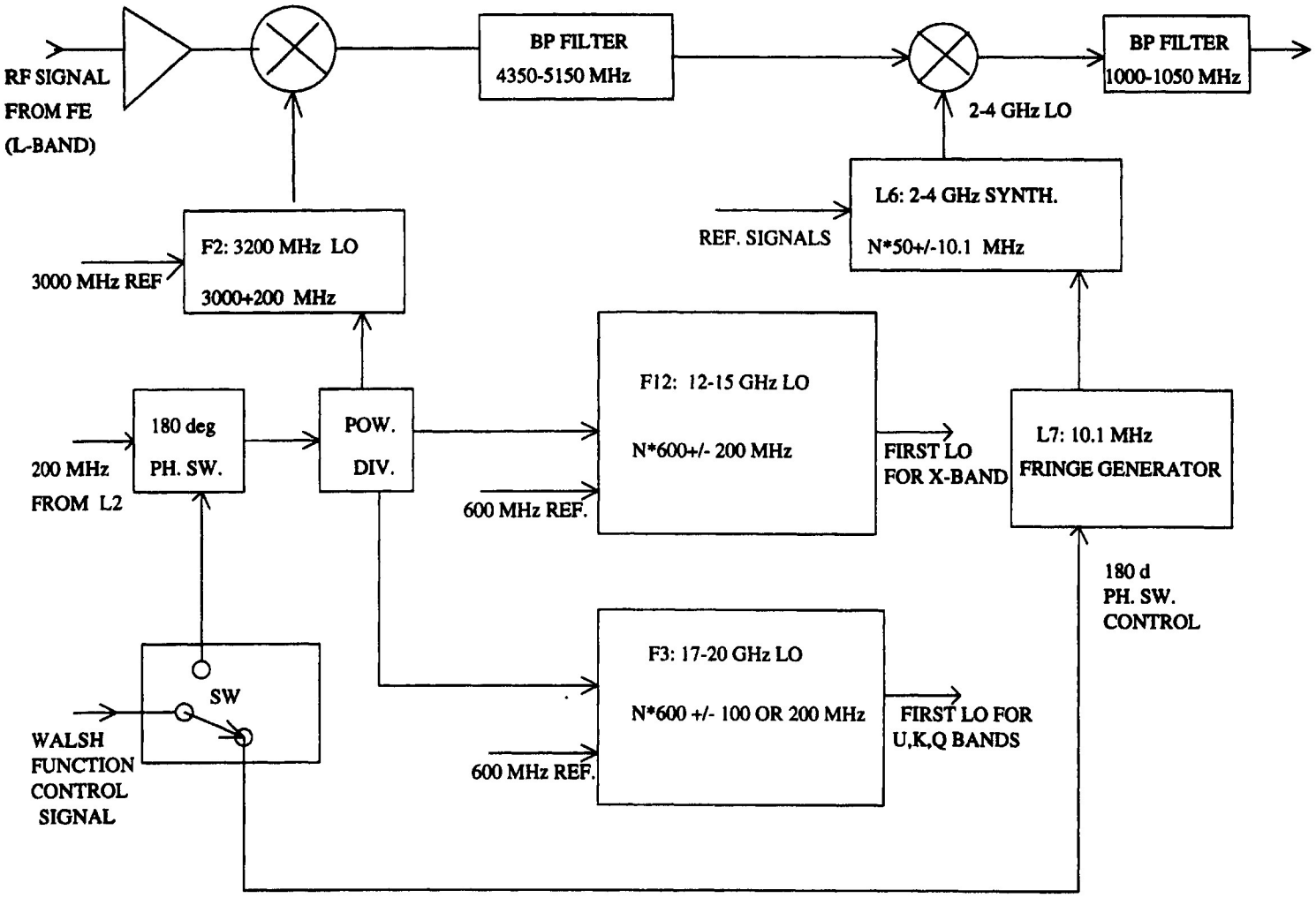

RF SIGNAL
FROM FE
(L-BAND)
BP FILTER
4350-5150 MHz
BP FILTER
1000-1050 MHz
2-4 GHz LO
L6: 2-4 GHz SYNTH.
N*50+/-10.1 MHz
REF. SIGNALS
F2: 3200 MHz LO
3000+200 MHz
3000 MHz REF
F12: 12-15 GHz LO
N*600+/- 200 MHz
FIRST LO
FOR X-BAND
L7: 10.1 MHz
FRINGE GENERATOR
180 deg
PH. SW.
POW.
DIV.
200 MHz
FROM L2
600 MHz REF.
180 d
PH. SW.
CONTROL
F3: 17-20 GHz LO
N*600 +/- 100 OR 200 MHz
FIRST LO FOR
U,K,Q BANDS
SW
WALSH
FUNCTION
CONTROL
SIGNAL
600 MHz REF.

FIGURE 1

FIG. 2a

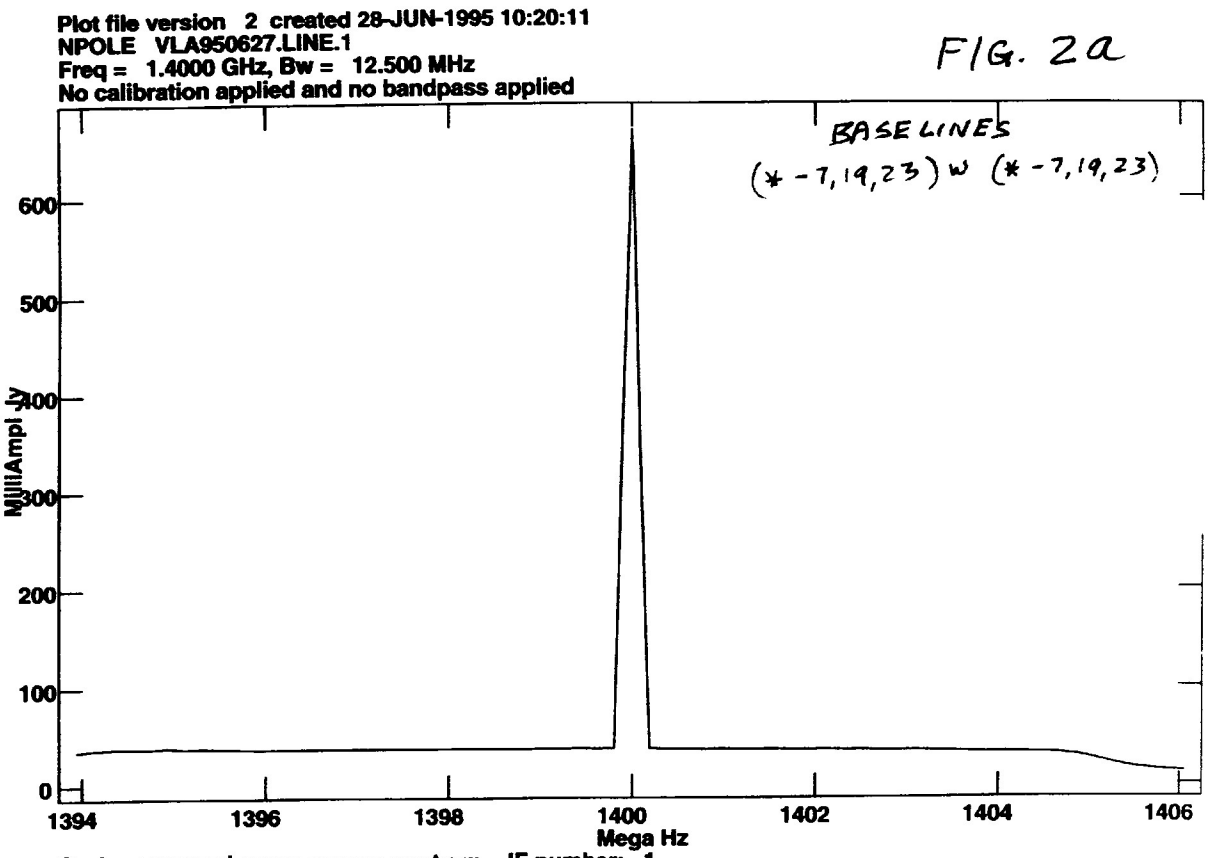
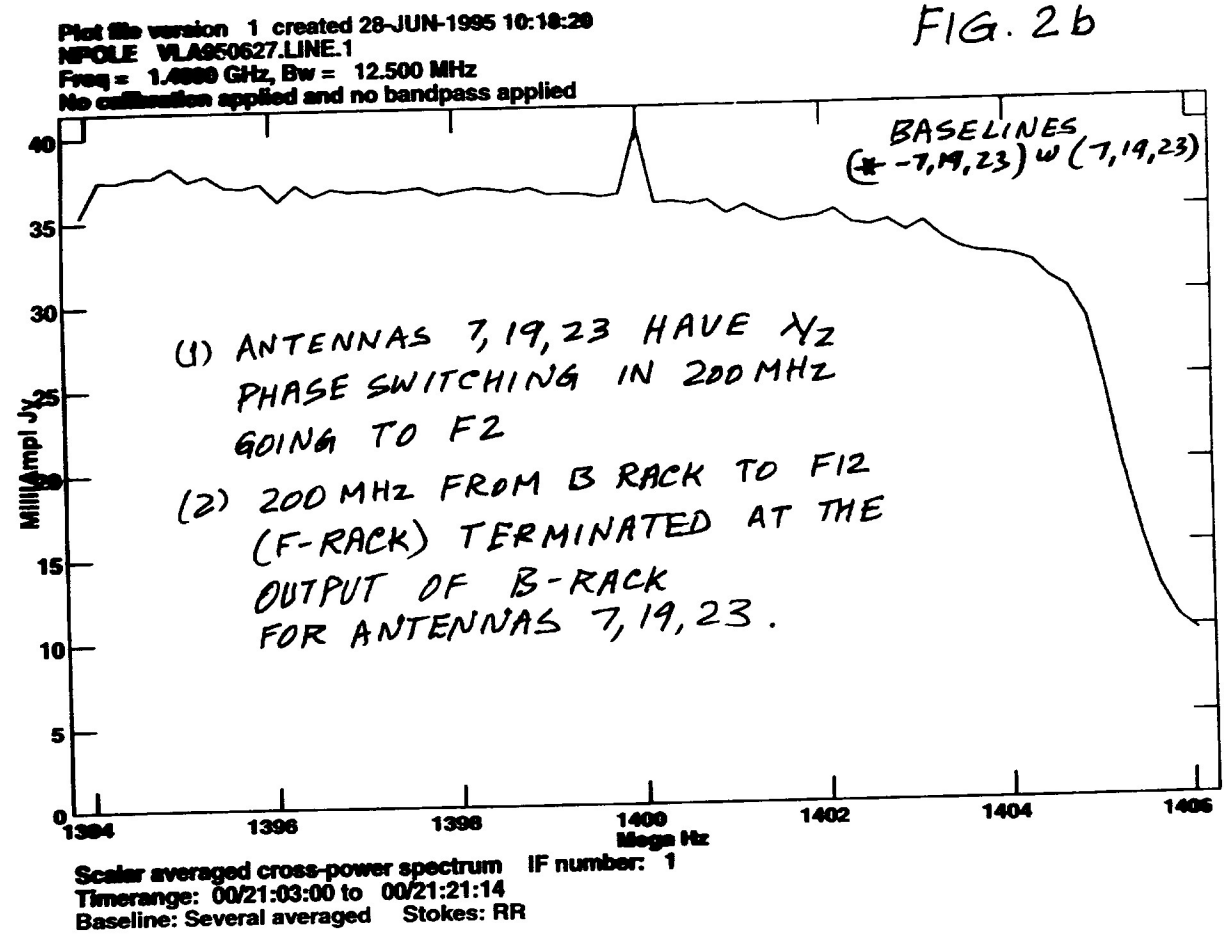

Plot file version 2 created 28-JUN-1995 10:20:11
NPOLE VLA950627.LINE.1
Freq = 1.4000 GHz, Bw = 12.500 MHz
No calibration applied and no bandpass applied
BASELINES
(*-7,19,23) w (*-7,19,23)
MilliAmpl Jy
0
100
200
300
400
500
600
1394
1396
1398
1400
1402
1404
1406
Mega Hz
Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:03:00 to 00/21:21:14
Baseline: Several averaged Stokes: RR

FIG. 2b


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
BASELINES
(*-7,19,23) w (7,19,23)
(1) ANTENNAS 7, 19, 23 HAVE YZ PHASE SWITCHING IN 200 MHz GOING TO F2
(2) 200 MHz FROM B RACK TO F12 (F-RACK) TERMINATED AT THE OUTPUT OF B-RACK FOR ANTENNAS 7, 19, 23.
MilliAmpl Jy
0
5
10
15
20
25
30
35
40
1394
1396
1398
1400
1402
1404
1406
Mega Hz
Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:03:00 to 00/21:21:14
Baseline: Several averaged Stokes: RR

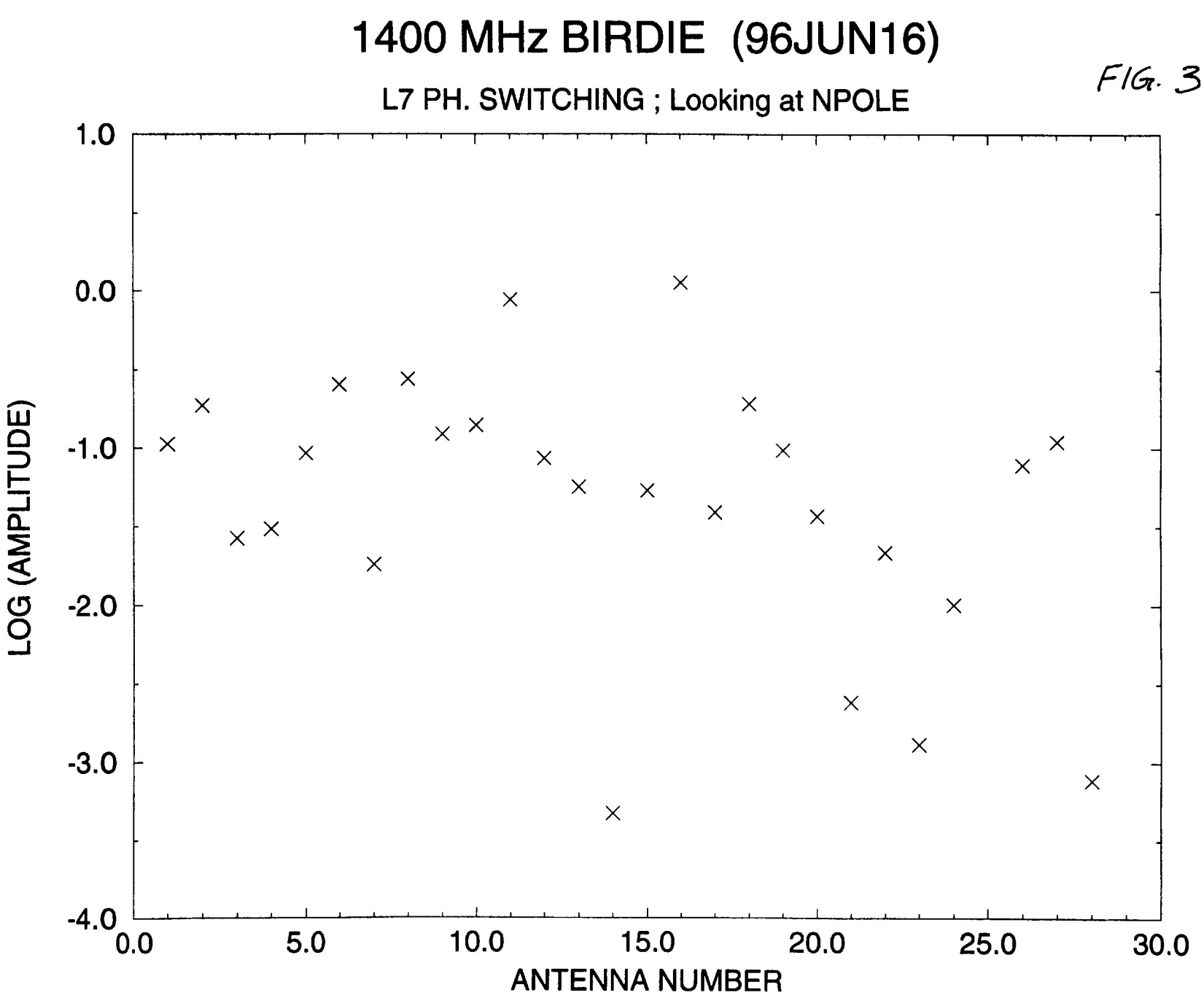
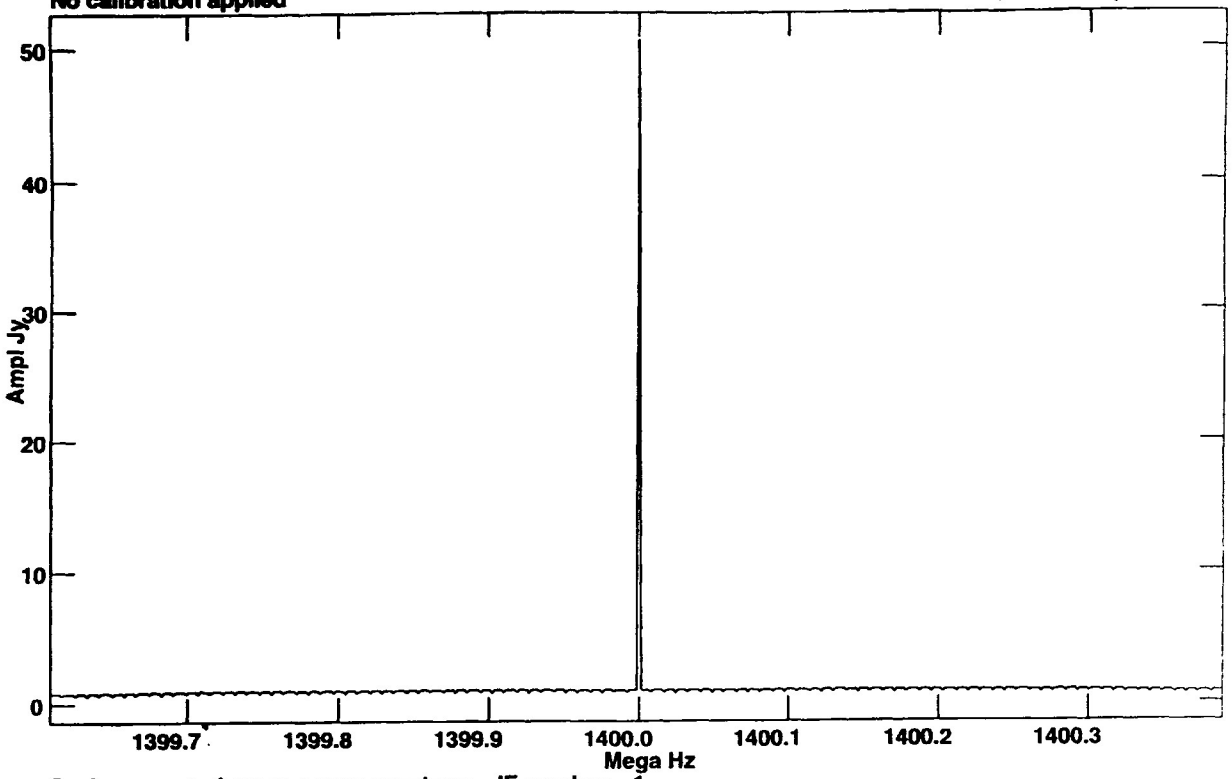

1400 MHz BIRDIE (96JUN16)
L7 PH. SWITCHING ; Looking at NPOLE
1.0
0.0
-1.0
-2.0
-3.0
-4.0
LOG (AMPLITUDE)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
ANTENNA NUMBER

FIG. 3

1400.0 MHz

Plot file version 1 created 06-SEP-1995 13:39:24
NPOLE VLA950906.LINE.3
Freq = 1.4000 GHz, Bw = 0.781 MHz / 512 ch.
No calibration applied

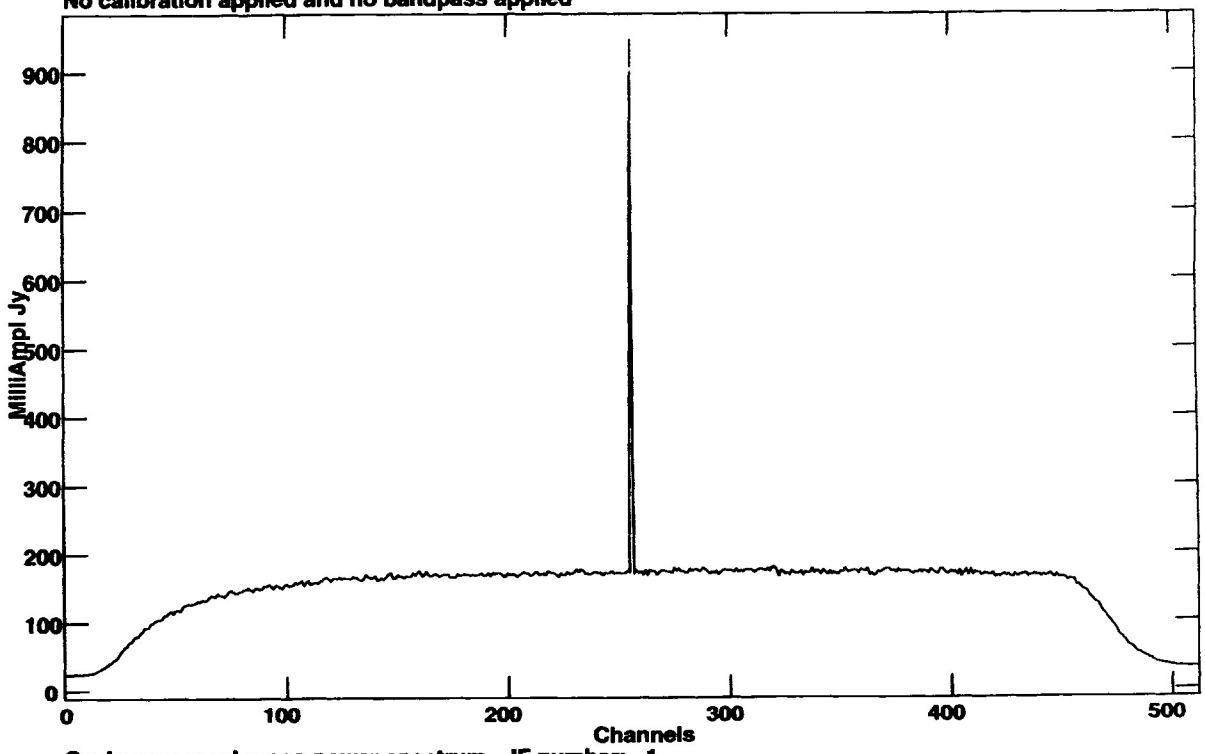
FIG. 4a



Scalar averaged cross-power spectrum IF number: 1
Baseline: Several averaged Stokes: RR

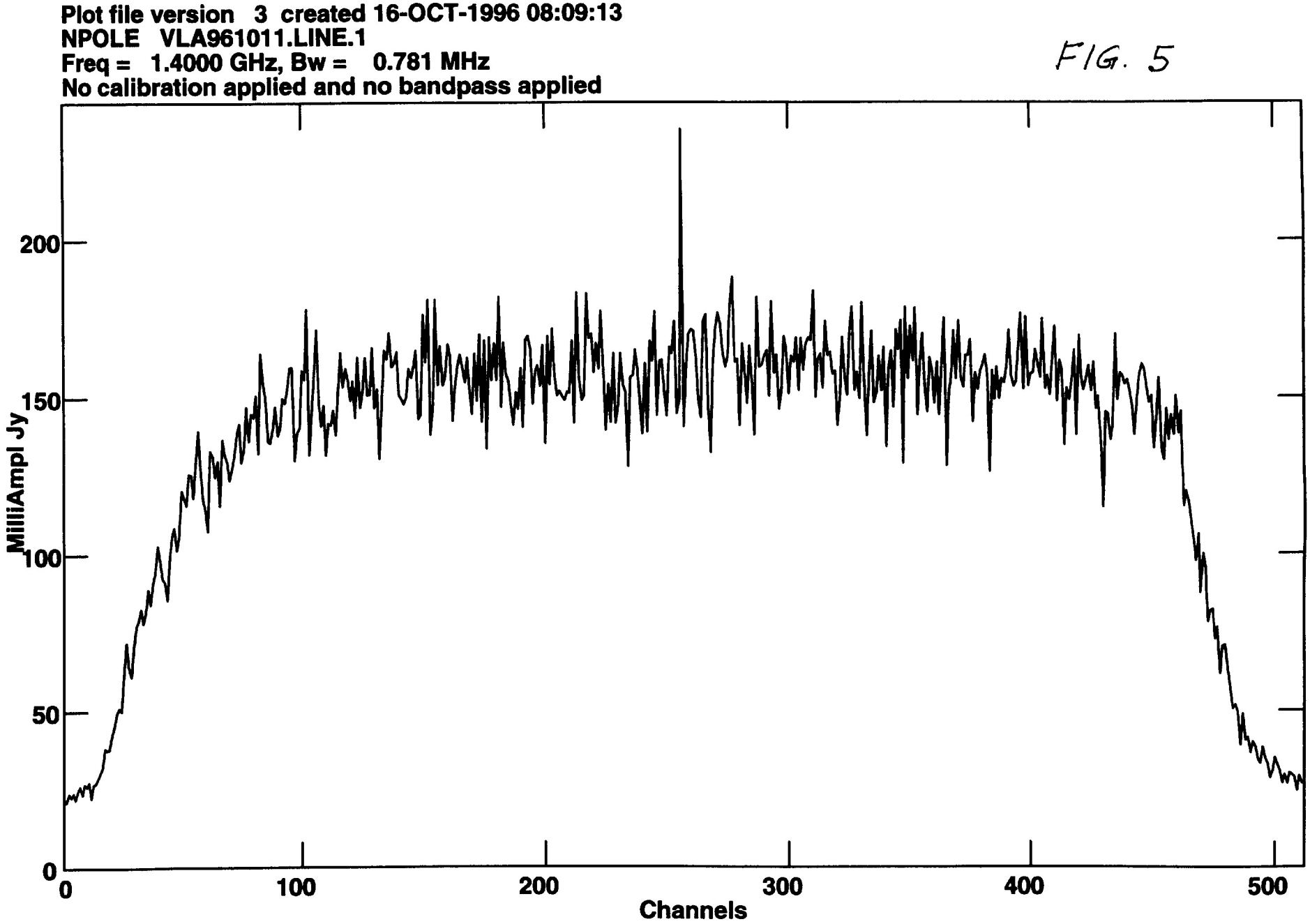
Plot file version 4 created 18-OCT-1996 08:52:13
NPOLE VLA961011.LINE.1
Freq = 1.4000 GHz, Bw = 0.781 MHz
No calibration applied and no bandpass applied

FIG. 4b



Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/15:26:00 to 00/15:29:00
Baseline: Several averaged Stokes: RR

FIG. 5


Plot file version 3 created 16-OCT-1996 08:09:13
NPOLE VLA961011.LINE.1
Freq = 1.4000 GHz, Bw = 0.781 MHz
No calibration applied and no bandpass applied
MilliAmpl Jy
0
50
100
150
200
0
100
200
300
400
500
Channels
Scalar averaged cross-power spectrum IF number: 1
Baseline: Several averaged Stokes: RR