National Radio Astronomy Observatory

Socorro, New Mexico

Very Large Array Program

VLA Test Memorandum Nr. 162

Suppressing Interference at 1351 and 1361 MHz or How to get Rid of the Forest Service Birdies

Elias Brinks and Patrick Crane

May 1992

Introduction

It has been known since 1980, when the Forest Service planned its microwave system in consultation with the NRAO, that transmissions from the relay station on South Baldy could cause interference within L-band at the VLA. Because of the wide frequency responses of the cryoFET RF amplifiers, an out-of-band signal at frequency ν can reach the mixer and mix with the second harmonic of the first local oscillator frequency (3200 MHz) to produce an unwanted response at $(3200 - \nu)$ MHz reduced by 20–30 dB. In 1982 bandstop filters rejecting 1768–1804 MHz were installed on all antennas to eliminate the 1404 MHz spurious signal produced by transmissions at 1796 MHz.

The bandstop filters did not eliminate the spurious signals at 1351 and 1361 MHz corresponding to transmissions at 1839 and 1849 MHz. Installation of additional bandpass filters to eliminate these spurious signals was completed by 8 April 1992. The combination of bandstop and bandpass filters provides more than 60 dB of attenuation at frequencies above 1765 MHz. Figure 1a shows a composite spectrum of the band 1215–1755 MHz before (16 December 1991) and Figure 1b, after (8 April 1992) the installation of the filters; the spurious signals have been reduced by at least 20 dB.

In order to assess the effectiveness of the suppression filters in a more quantitative way, two test runs were made. The first run was used to test the performance of the filters after only three telescopes were equipped with them in September 1991. On 19 April 1992 a final check was made after all antennae had been outfitted. We report on both these runs in this test memo.

Test Observations

The first set of observations were performed on 25 September 1991. The VLA was in the AnB configuration (move time). Antenna 8 was used in Subarray 2 for a VLBI run. We used spectral line mode 1A, a total bandwidth of 6.25 MHz and Hanning smoothing, which gave 64 channels at 97kHz resolution. The integration time used was 20 sec.

We chose three central frequencies, 1351.5 MHz, 1356 MHz and 1361.5 MHz in order to scan the entire region where interference was anticipated, the central setting of 1356 MHz serving as reference for the other two settings. Pointing was at the North Celestial Pole. Although not essential for this test, some time was spent on calibrators. In total, 30 minutes were spent per frequency setting on the NCP. Antennae 3, 23 and 26 were equipped with the L-band interference rejection filters.

The second run took place on 19 April 1992. Antenna 2 was stowed because of servo problems. We used the same set-up as for the September run. As less time was scheduled only 15 minutes were spent per frequency setting. The data, although not strictly necessary, were flux and bandpass calibrated, using 0542+498 (3C147).

Results

It is illustrative to look at some of the autocorrelations which are presented in Figures 2a–f. Those antennae without filters show strong interference, the ones with filters are featureless. For reasons which are not understood, two antennae which weren't outfitted with filters didn't show any interference either. These are antennae 2 and 11.

More meaningful are plots of crosscorrelations between antennae, Figures 3a–d. We present here crosscorrelations at a central frequency of 1351.5 MHz between two antennae outfitted with filters (3a, scalar averaged and 3b, vector averaged), two antennae without filters (3c, scalar) and a combination where only one antenna is outfitted (3d, scalar). Many more spectra were inspected than the typical examples presented here. The rms noise in vector averaged spectra is about 30mJy and agrees with the thermal noise level.

When comparing figure 3d with 3a and c it is clear that the rejection filters work very well. Suppressing the Forest Service birdie in one of the elements of an interferometer reduces the level of interference to close to the noise level. Inspection of a whole range of baselines shows that some correlated signal gets through at a level of about 200:1, indicating that the rejection, although quite good, is not perfect. Given a typical "leakage" at the level of 200:1 this implies roughly an interference rejection per antenna of order 10000:1 or 40 db.

The results of the 19 April run can be summarized by figures 4a–c. These are scalar averaged crosscorrelations averaging over all baselines. No trace of any interference at 1351 or 1361 MHz is seen. The spike at 1350 MHz is one of the internally generated 50 MHz spikes of which a more pronounced example is located at 1400 MHz.

Summary

It is found that the 20-cm filters reject the Forest Service interference by about 40 db. This is sufficient to enable L-band observations in the immediate neighbourhood of the 1351 and 1361 MHz interference spikes. Maps made of the 19 April 1992 data reach typically 2.5 mJy beam^{-1} and show no sign of interference. Some low level interference might be hiding altough this is expected not to pose any restrictions to observing programs at or near these frequencies, especially since phase winding will distribute any remaining power.

Figure Captions

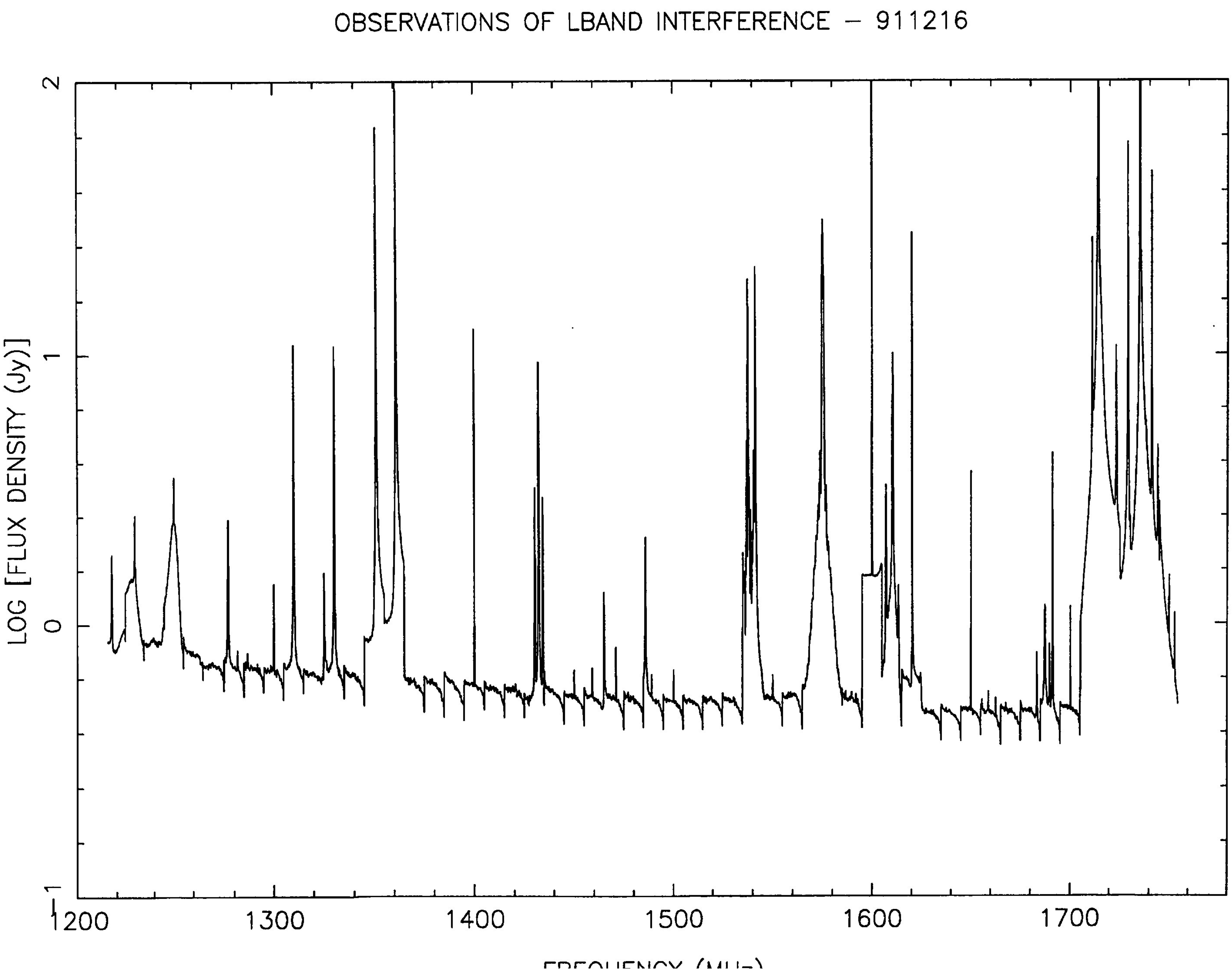
Figure 1a: Complete spectrum of the band 1215–1755 MHz made on 16 December 1991, i.e. before the bandstop filters were installed. Note that the flux density scale is in logarithmic units.

Figure 1b: Same as Fig. 1a but made on 8 April 1992, i.e. after installation of the bandstop filters.

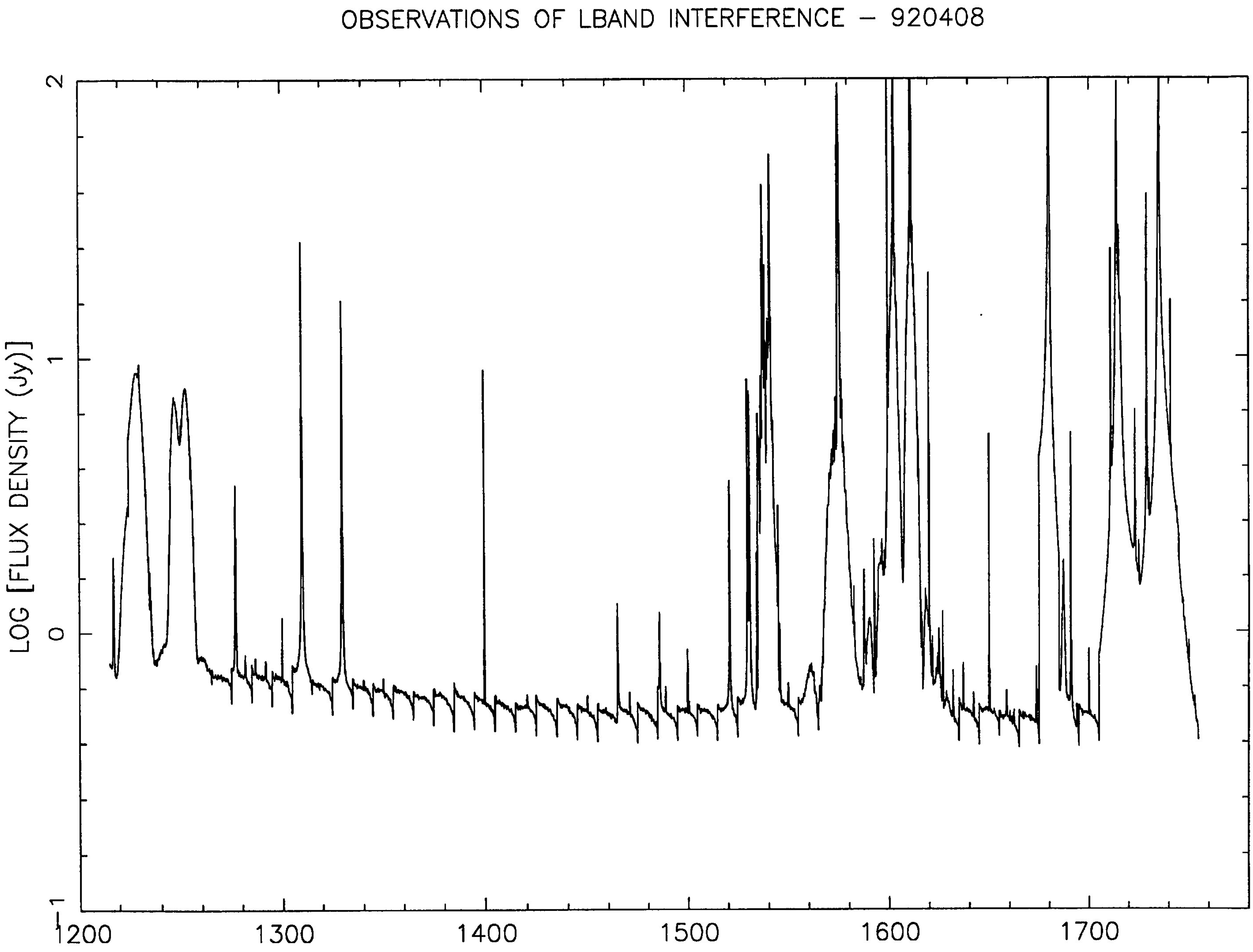
Figure 2a–f: Autocorrelation spectra of antennae 25 and 26 taken on 25 September 1991. At that time antenna 26 was equipped with a bandstop filter, antenna 25 was without one. Spectra are shown at each of the three central frequency settings, 1351.5, 1356.0, and 1361.5 MHz (marked by hand on each plot).

Figure 3a–d: Scalar averaged crosscorrelated power based on the 25 September 1991 observations at 1351.5 MHz for a set of baselines with both antennae equipped with rejection filters (3a; 3b is a vector averaged version of 3a), none equipped with filters (3c) and with only one outfitted (3d). Note the difference in amplitude scale.

Figure 4a–c: Scalar averaged crosscorrelation spectra based on the 19 April 1992 data, all baselines averaged at each of the three central frequencies. No Forest Service birdies are seen at the sensitivity limit of these observations of 2.5 mJy beam^{-1}. The spike at 1350 MHz is one of the regular 50 MHz internally generated interference spikes.



OBSERVATIONS OF LBAND INTERFERENCE – 911216
LOG [FLUX DENSITY (Jy)]
2
1
0
-1
1200
1300
1400
1500
1600
1700



OBSERVATIONS OF LBAND INTERFERENCE – 920408
LOG [FLUX DENSITY (Jy)]
FREQUENCY (MHz)
2
1
0
-1
1200
1300
1400
1500
1600
1700

FIG. 1 B

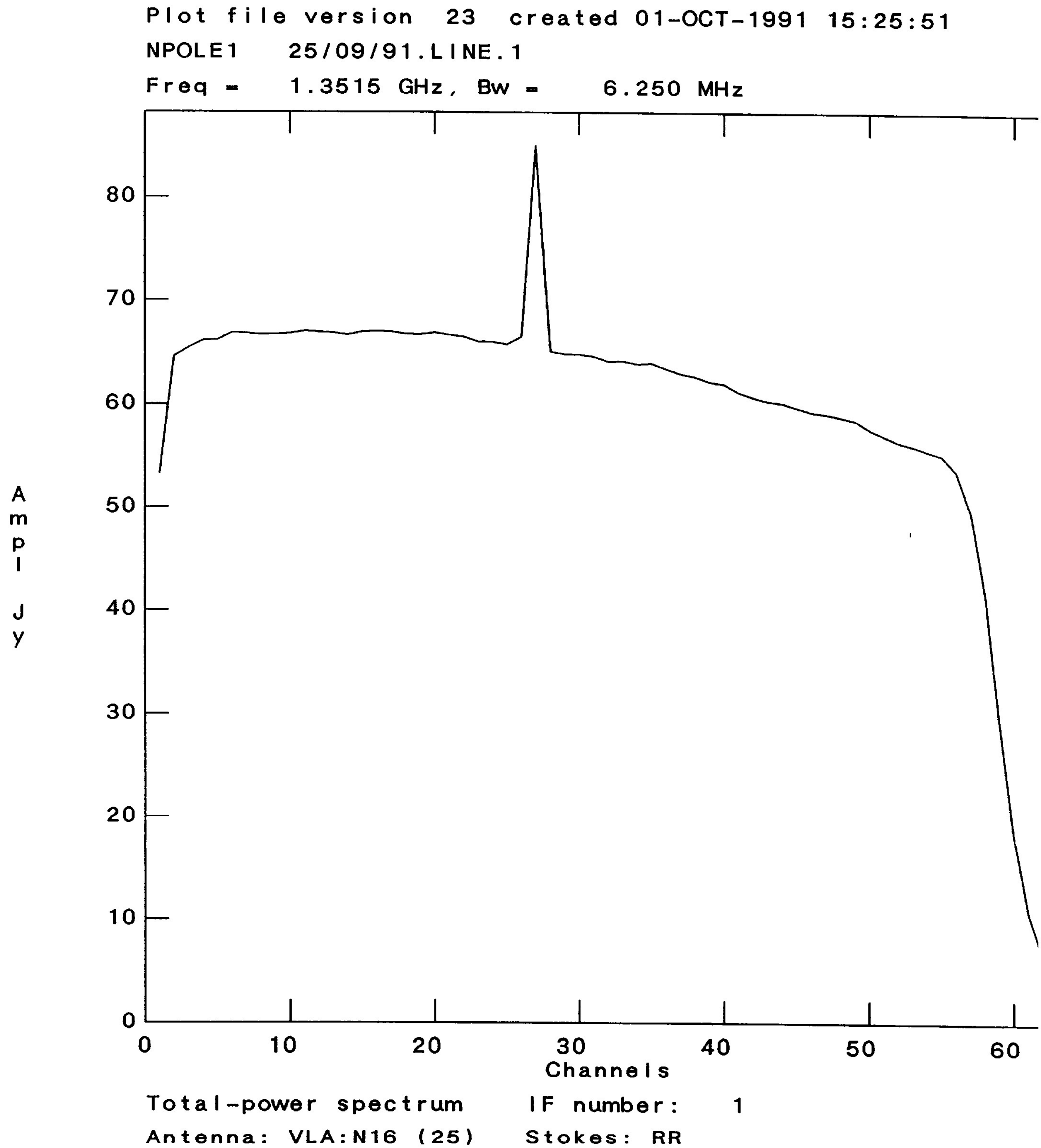
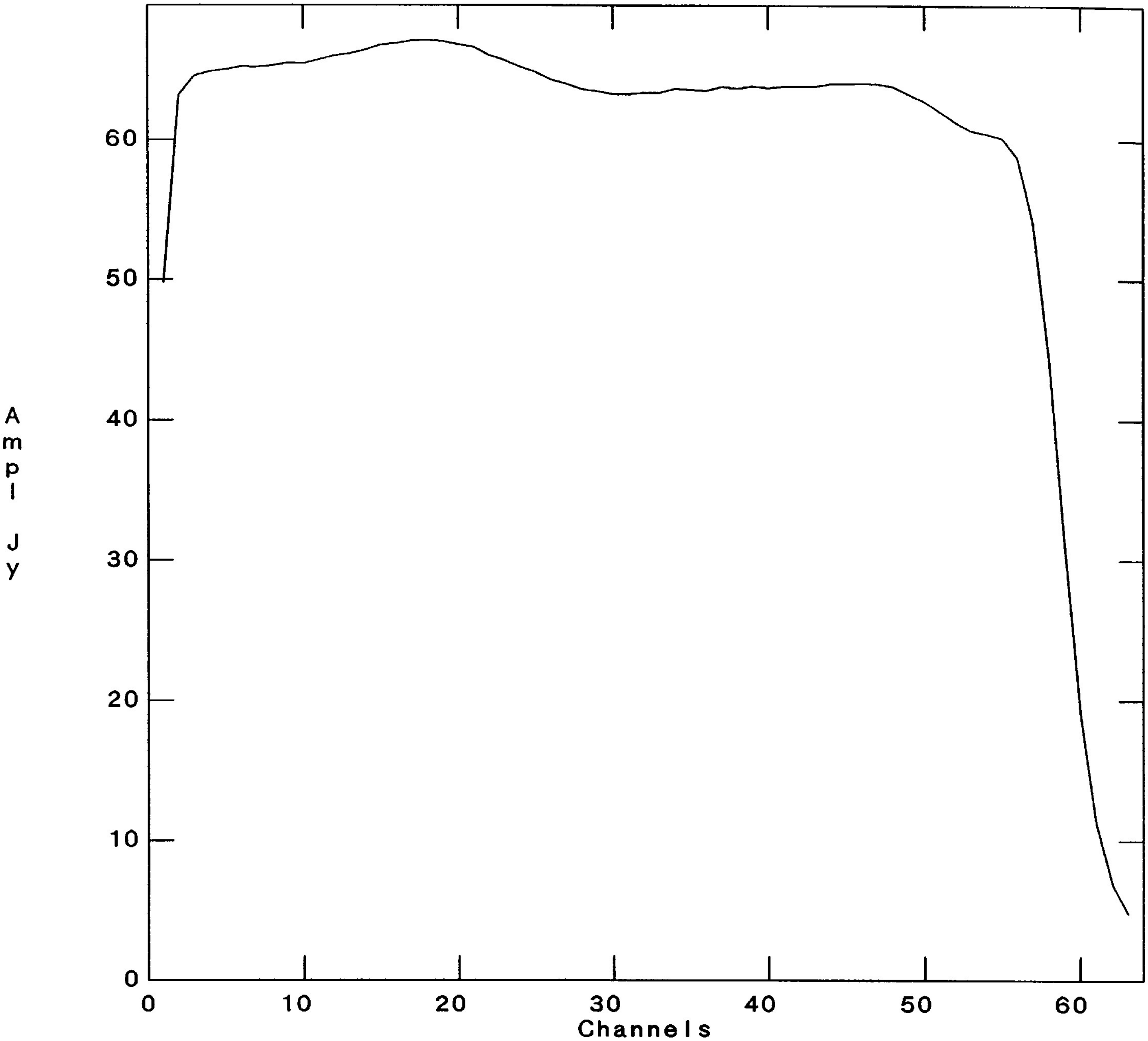


FIG. 2A 1351.5 MHz

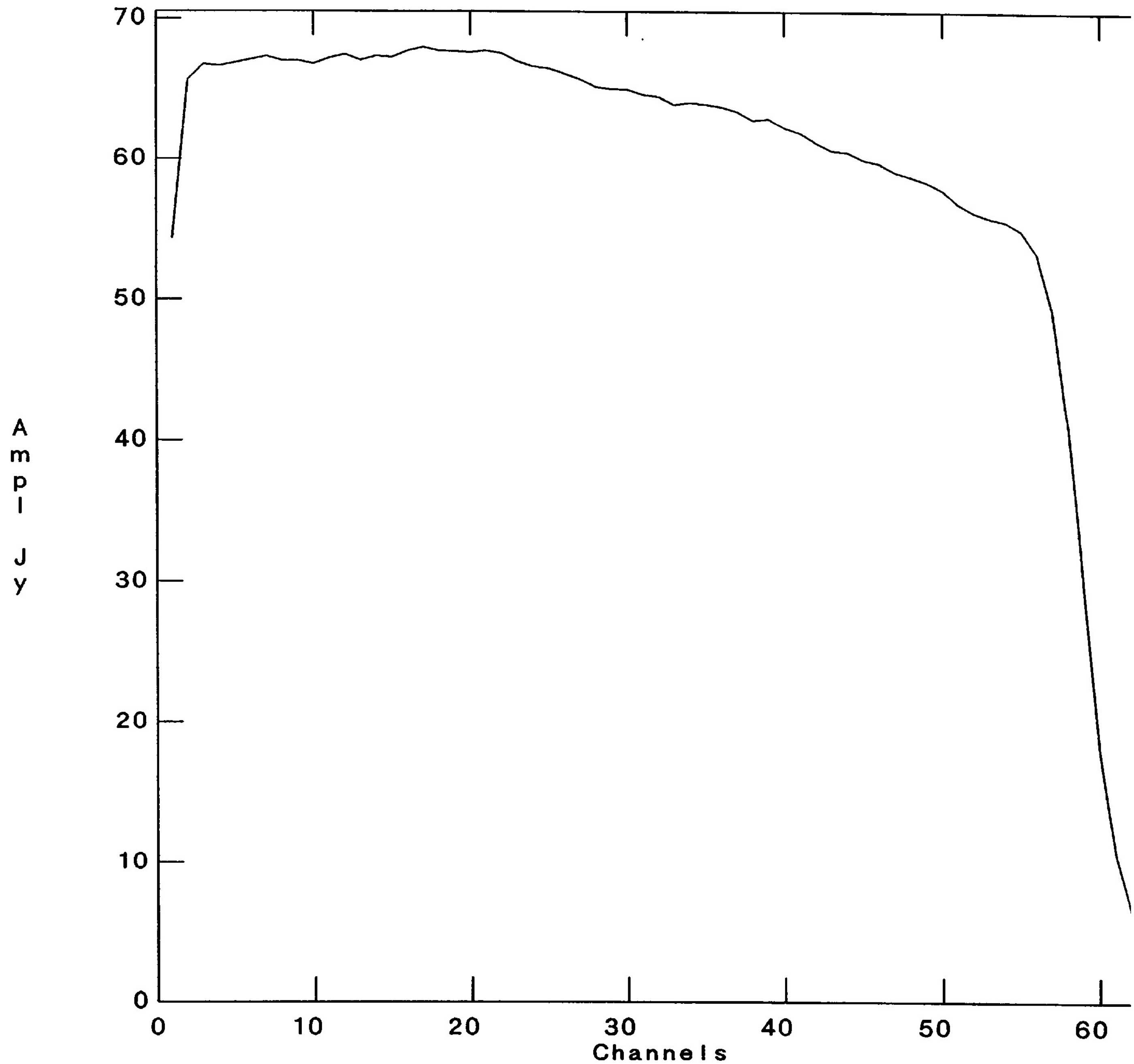
Plot file version 24 created 01-OCT-1991 15:26:11
NPOLE1 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz



Total-power spectrum IF number: 1
Antenna: VLA:N32 (26) Stokes: RR

FIG. 2B 1351.5 MHz

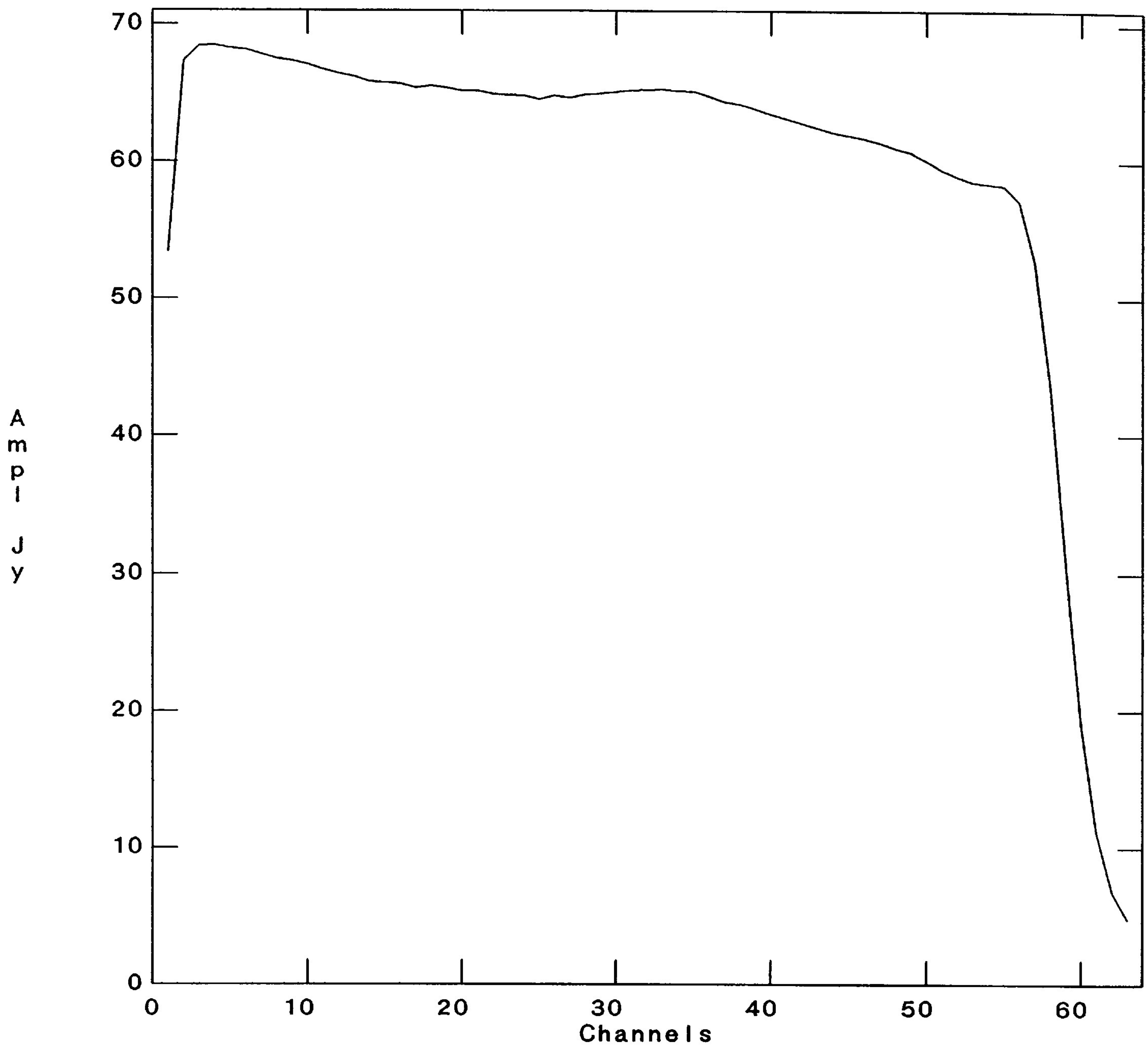
Plot file version 49 created 01-OCT-1991 17:15:14
NPOLE2 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz



Total-power spectrum IF number: 1
Antenna: VLA:N16 (25) Stokes: RR

FIG. 2C 1356.0 MHz

Plot file version 50 created 01-OCT-1991 17:15:27
NPOLE2 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz



Total-power spectrum IF number: 1
Antenna: VLA:N32 (26) Stokes: RR

FIG. 2D 1356.0 MHz

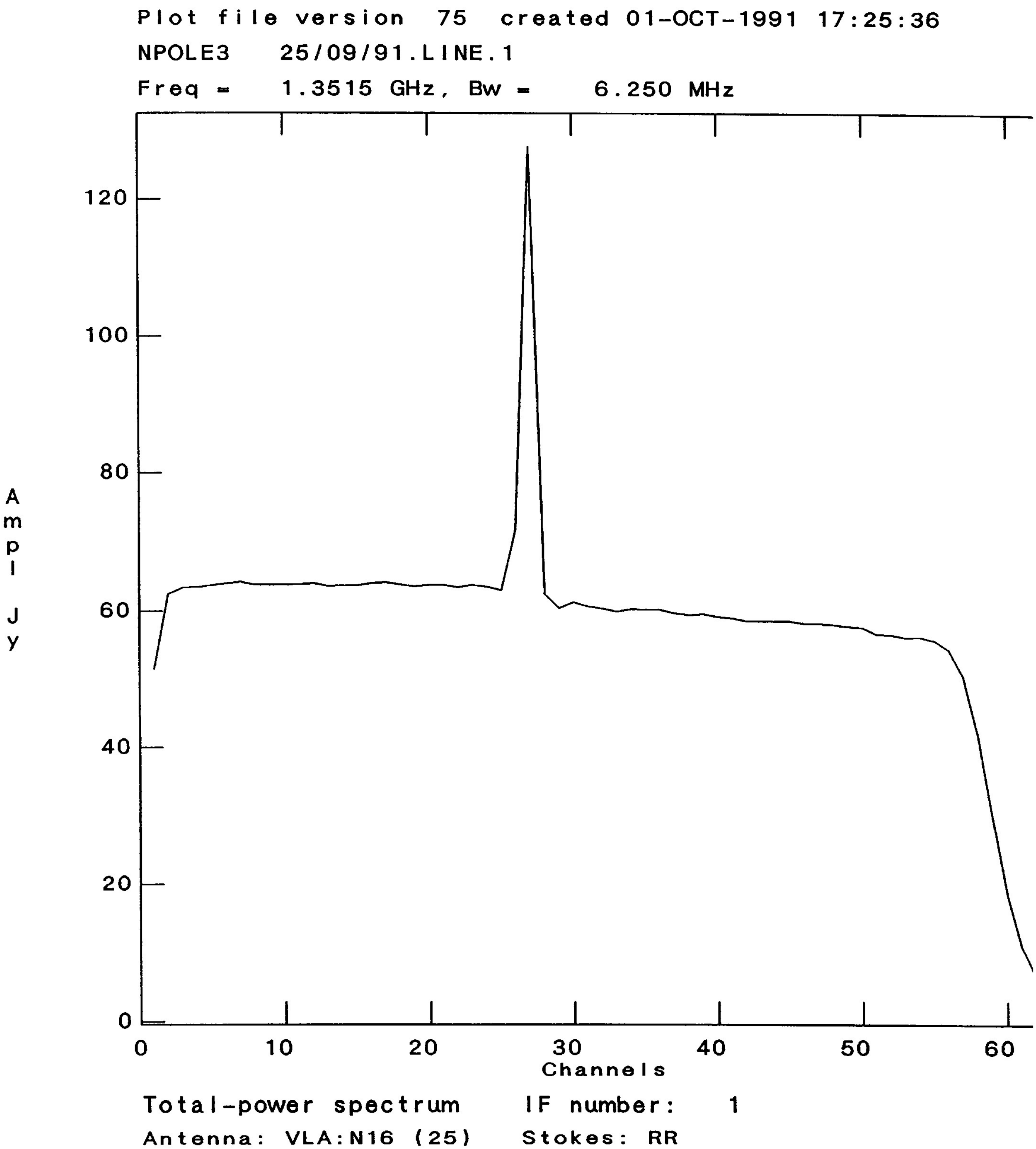
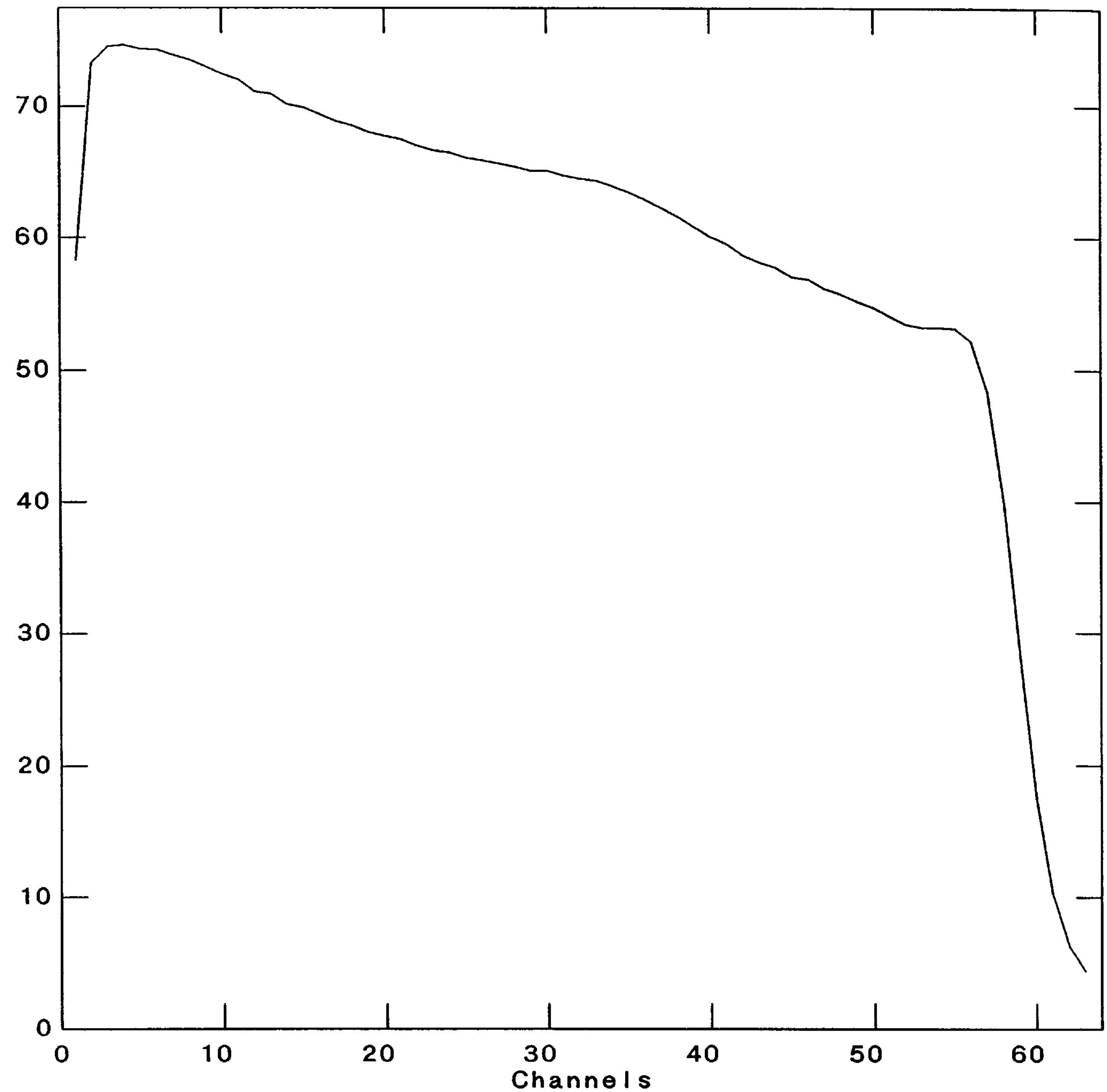


FIG. 2E 1361.5 MHz

Plot file version 76 created 01-OCT-1991 17:25:47
NPOLE3 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz



Total-power spectrum IF number: 1
Antenna: VLA:N32 (26) Stokes: RR

FIG. 2F 1361.5 MHz

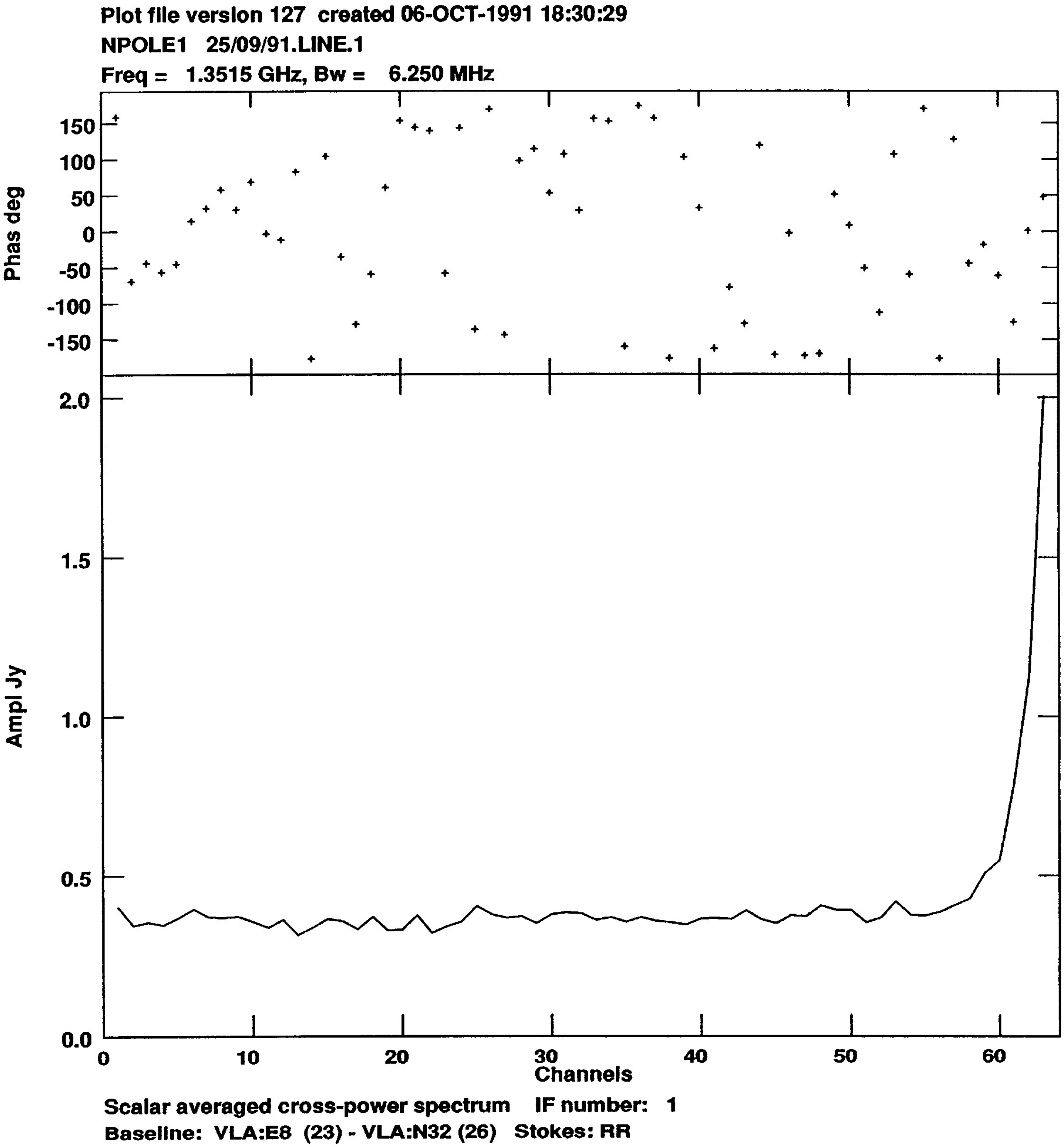
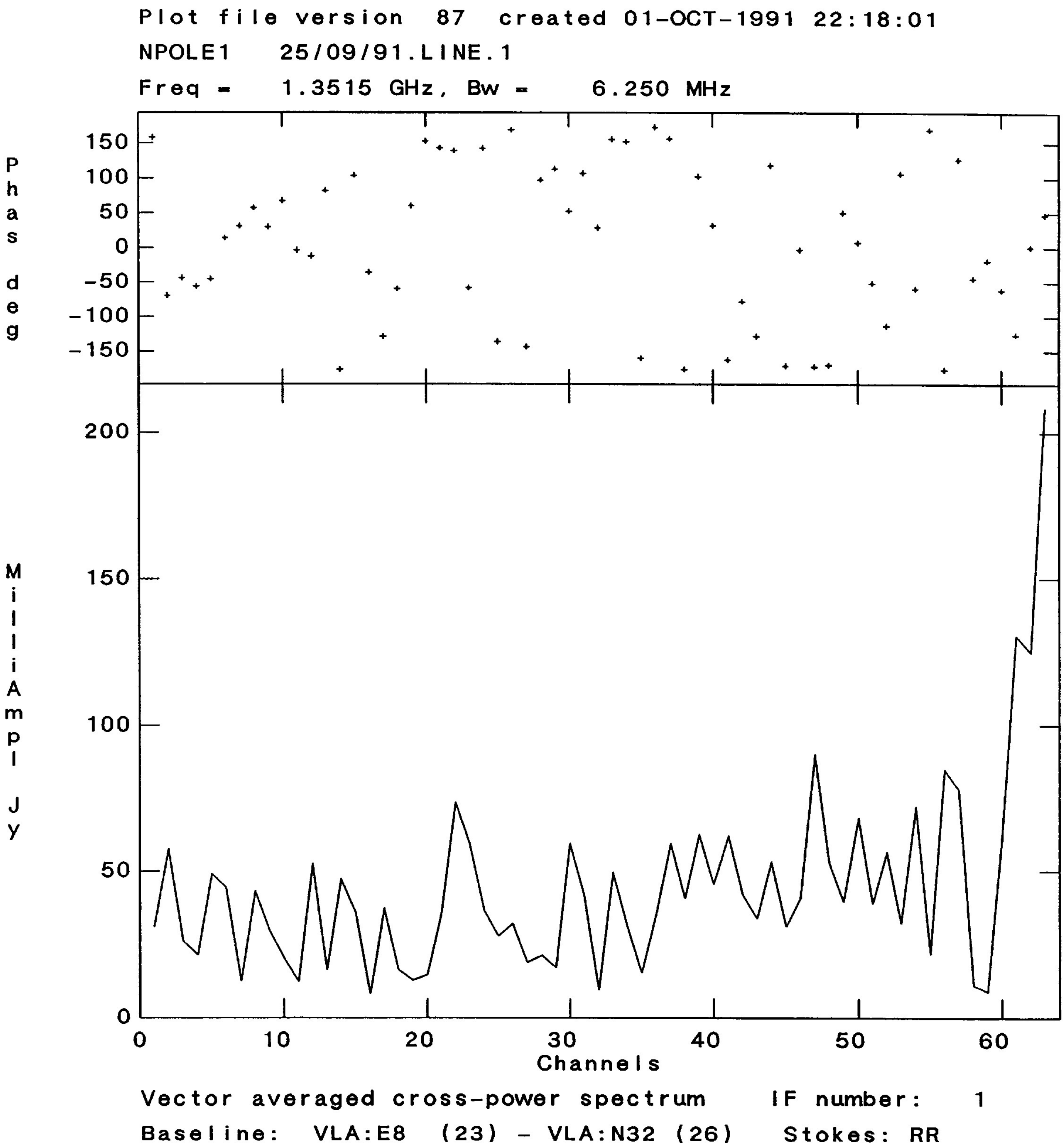

Plot file version 127 created 06-OCT-1991 18:30:29
NPOLE1 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz
Phas deg
150
100
50
0
-50
-100
-150
Ampl Jy
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
Channels
Scalar averaged cross-power spectrum IF number: 1
Baseline: VLA:E8 (23) - VLA:N32 (26) Stokes: RR

FIG. 3A



Plot file version 87 created 01-OCT-1991 22:18:01
NPOLE1 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz
Phas deg
150
100
50
0
-50
-100
-150
MilliAmpl Jy
200
150
100
50
0
0
10
20
30
40
50
60
Channels
Vector averaged cross-power spectrum IF number: 1
Baseline: VLA:E8 (23) - VLA:N32 (26) Stokes: RR

FIG. 3B

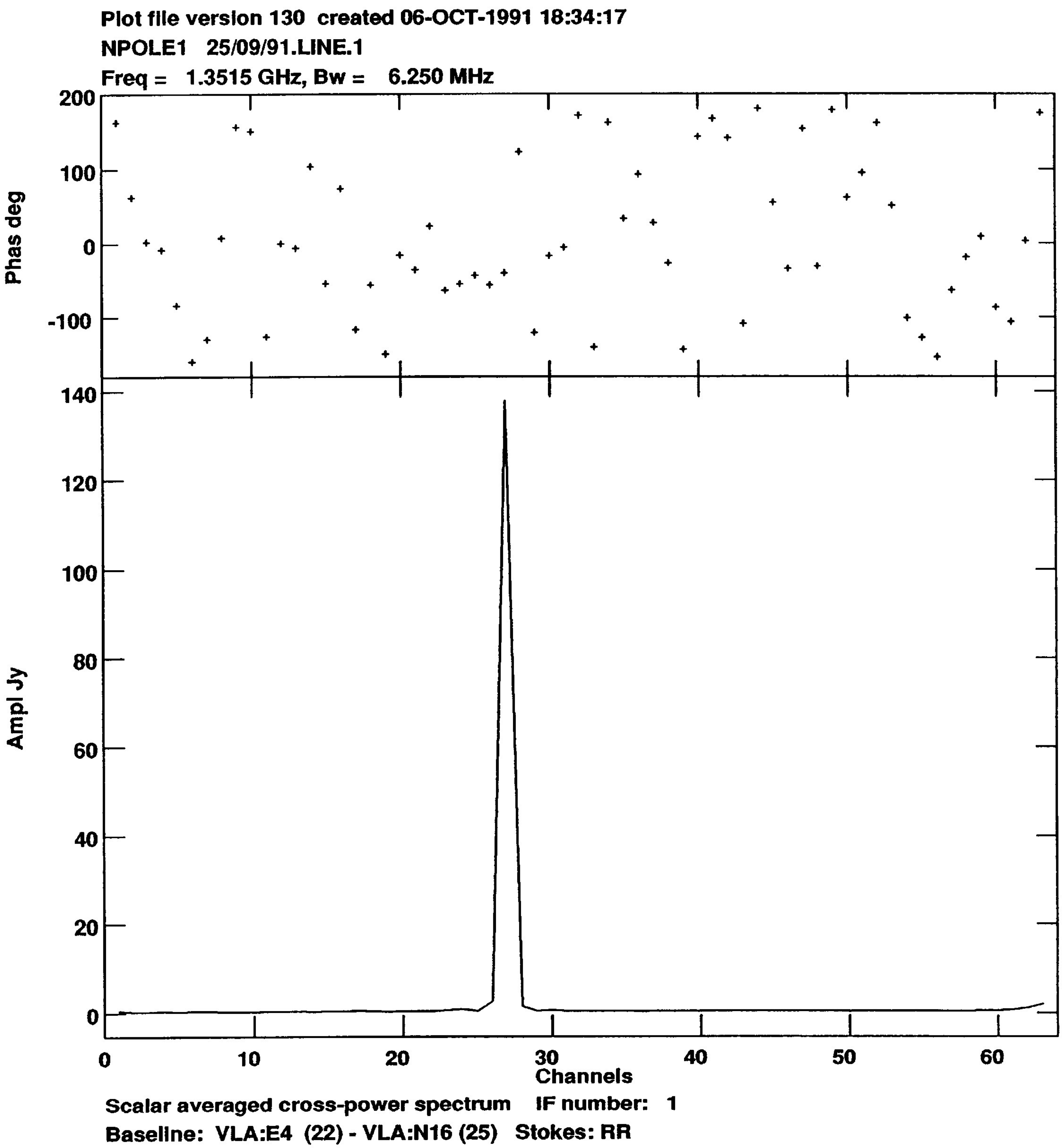

Plot file version 130 created 06-OCT-1991 18:34:17
NPOLE1 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz
Phas deg
200
100
0
-100
Ampl Jy
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
Channels
Scalar averaged cross-power spectrum IF number: 1
Baseline: VLA:E4 (22) - VLA:N16 (25) Stokes: RR

FIG. 3C

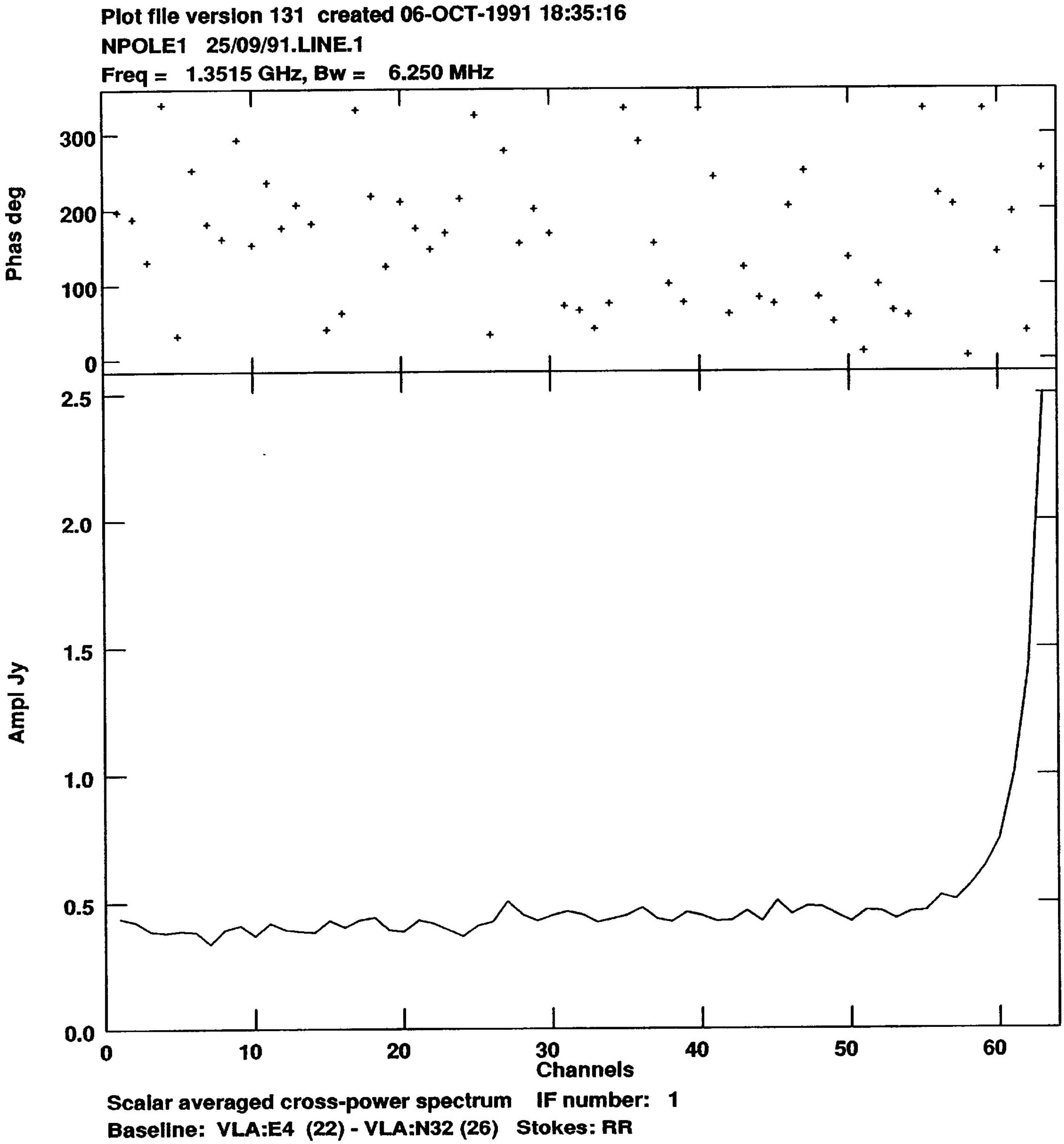

Plot file version 131 created 06-OCT-1991 18:35:16
NPOLE1 25/09/91.LINE.1
Freq = 1.3515 GHz, Bw = 6.250 MHz
Phas deg
300
200
100
0
2.5
2.0
1.5
1.0
0.5
0.0
Ampl Jy
0
10
20
30
40
50
60
Channels
Scalar averaged cross-power spectrum IF number: 1
Baseline: VLA:E4 (22) - VLA:N32 (26) Stokes: RR

FIG. 3D

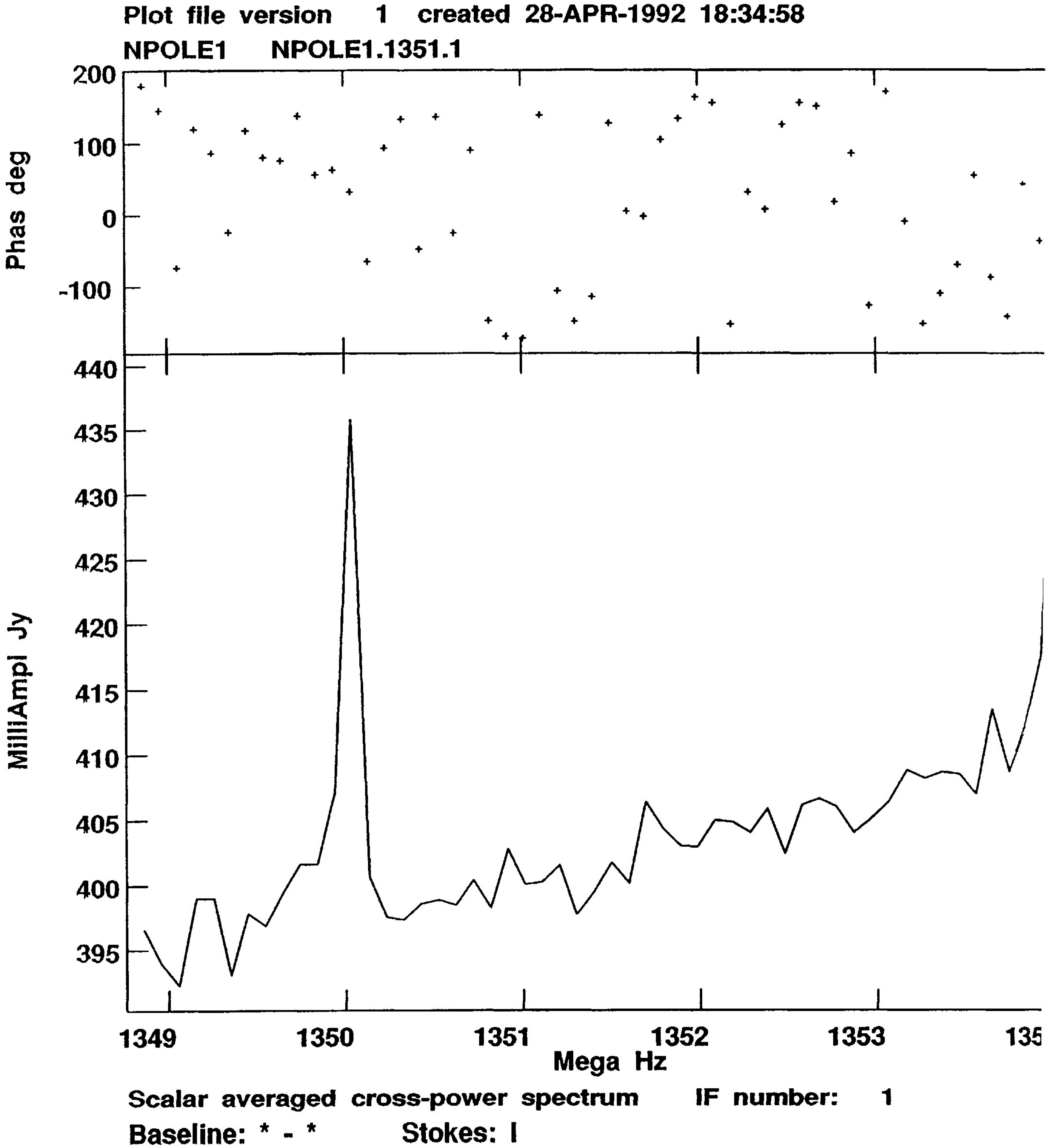
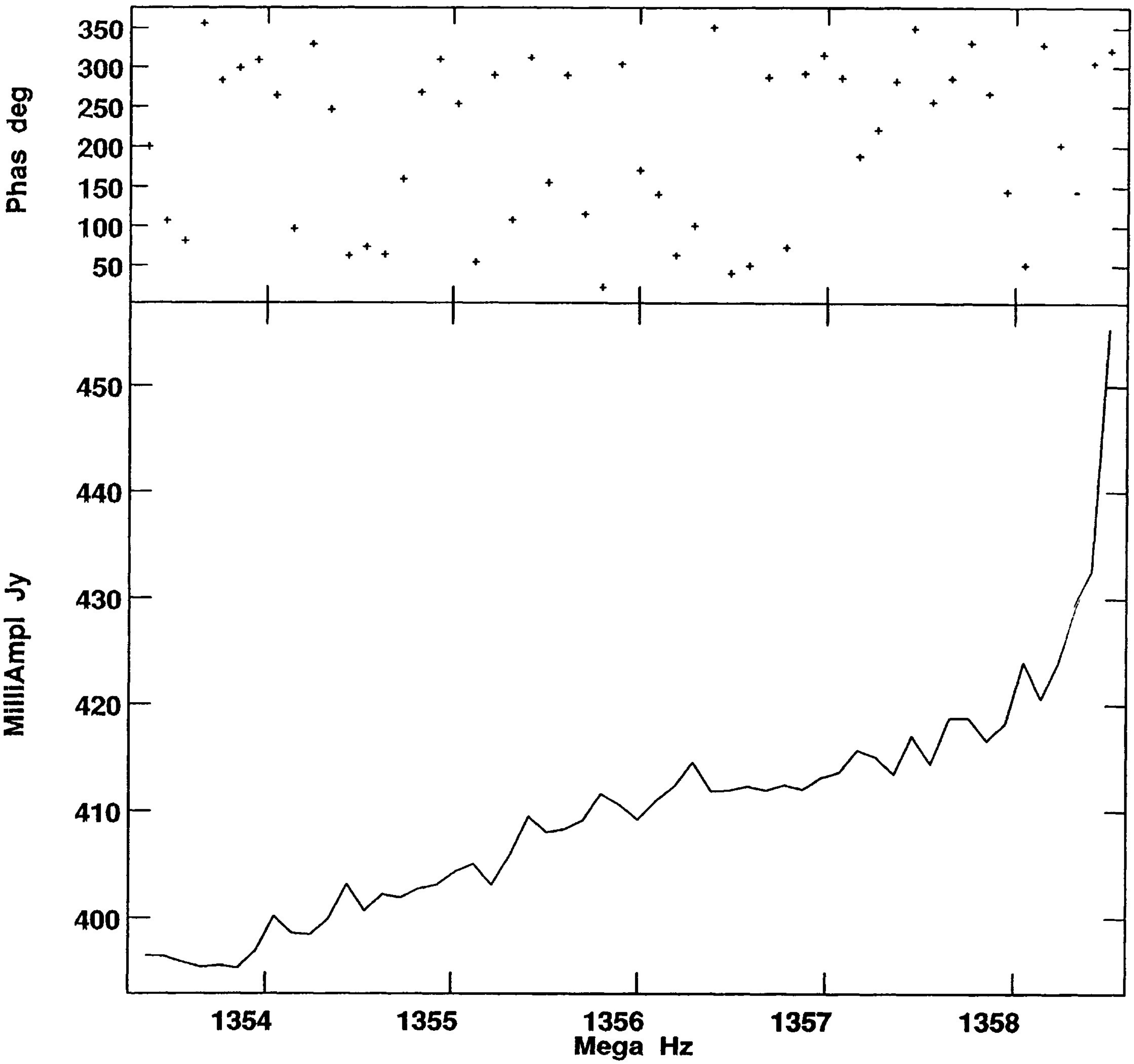


FIG. 4A 1351.5 MHz

Plot file version 1 created 28-APR-1992 18:35:53
NPOLE2 NPOLE2.1356.1

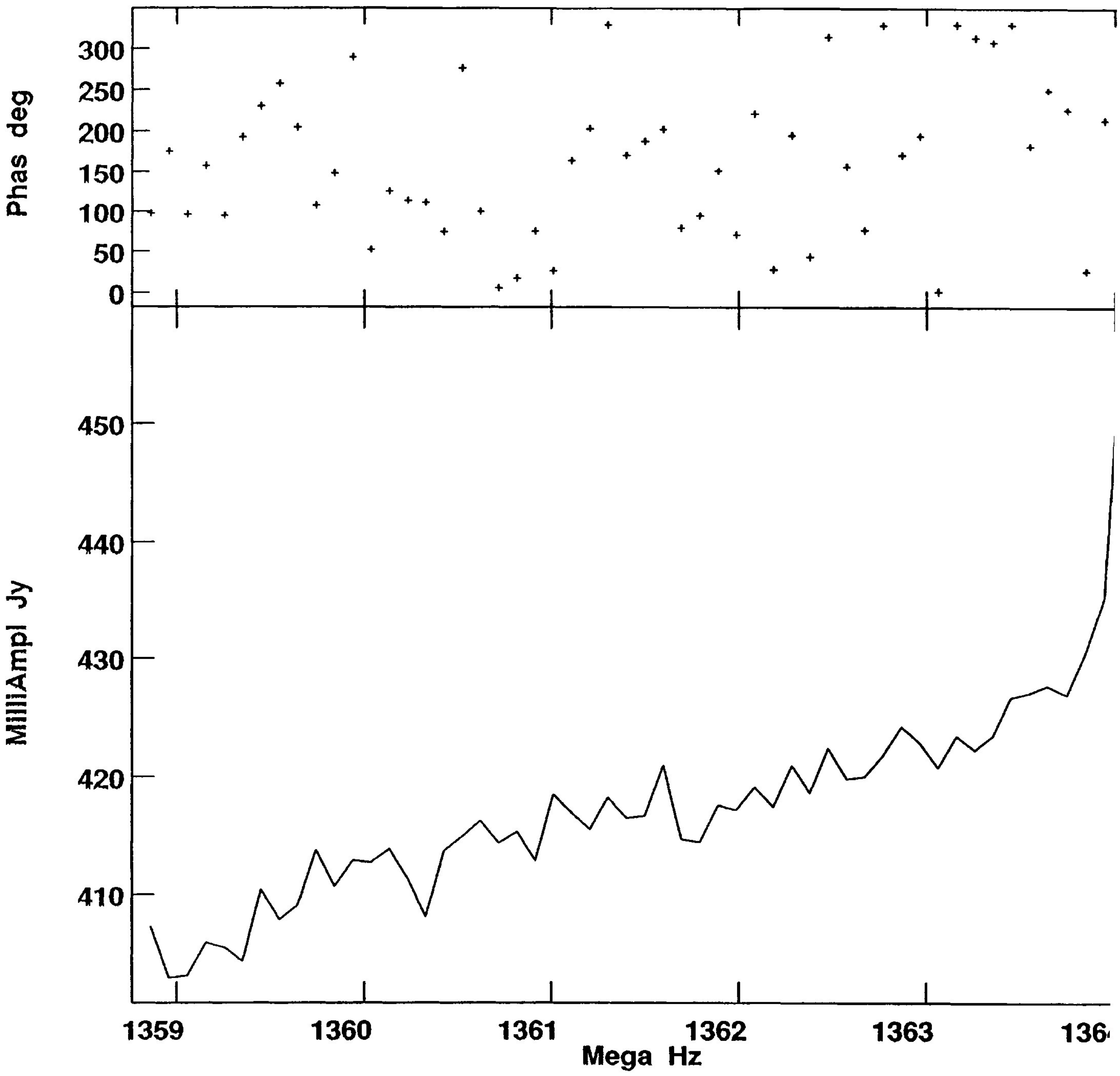


Scalar averaged cross-power spectrum IF number: 1
Baseline: * - * Stokes: I

FIG. 4B 1356.0 MHz

Plot file version 1 created 28-APR-1992 18:37:11

NPOLE3 NPOLE3.1361.1



Scalar averaged cross-power spectrum IF number: 1

Baseline: * - * Stokes: I

FIG. 4C 1361.5 MHz