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VLA TEST MEMO. 197

SYSTEM GENERATED RFI AT HIGH FREQUENCY BANDS AND SPURIOUS SIGNALS DUE TO INTERMODULATIONS

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Test observations at high frequency bands (C-band to k-band frequency range) looking at celestial North Pole show birdies due to radio frequency interference (rfi) caused by:

1) IF at 4800 MHz:

The rfi at 4800 MHz at the X-band and higher frequency bands is caused due to the leakage of 4800 MHz along with the F12/F3 local oscillator signals (e.g. Fig. 1a). The leakage of the 4800 MHz signal is caused by back feeding of the harmonics of the 600 MHz from the harmonic mixer in the PLL of the system phase-locking the oscillator signal. The rfi is reduced if a bandpass filter is introdued in the LO path before the mixers (see Fig. 1b). Also, if the first LO is phase switched (using phase switching on the 200 MHz offset signal), then the effect of the 4800 MHz leakage is considerably reduced (see Figs. 2a and 2b).

The 4800 MHz rfi at the C-band is caused by radiation of 4800 MHz signal from the B-rack as well as from radiation of 600 MHz harmonics from F-rack and A-rack. When 600 MHz signals going from B-rack to A and F racks are removed (terminated at the outputs of B-rack) in Ant. 8, strong rfi at 4800 MHz is still seen on baselines with this antenna (see Fig. 3). It means RFI shielding of the B-rack seems to have helped little to reduce 4800 MHz rfi radiated from the B-rack. Also radiation from the A-rack and F-rack contribute to the 4800 MHz rfi in the C-band (see Figs. 4a and 4b).

2) Harmonics of 600 MHz in the RF passband:

At X-band the rfi (see Fig. 5a) is predominantly due to radiation of harmonics of the 600 MHz from the F3 module in the A-rack. The radiation is picked up by the RF system (probably feed). Terminating the 600 MHz at the output of the B-rack (which normally goes to A-rack to lock F3 LO) in antenna 8 reduces the 8400 MHz rfi considerably as seen in the X-band observations in Fig. 5b (also compare it with Fig. 5a).

At higher frequency bands (u and k bands; see Fig. 6) the problem is due to radiation of the 600 MHz harmonics from the F3 module getting pickedup by the bias lines of the first mixer at that band. RFI shielding of the mixer bias line and the harmonic mixer in antenna 8 seems to reduce the rfi in the total power spectra for

the antenna (see Fig. 7), and also in the cross power spectra for the baselines with the antenna (see Fig. 8); though results in the cross power spectra are somewhat confusing due to large rfi and high noise.

3) Harmonics of 600 MHz in the image passband:

The problem at X-band is much less severe than at u and k bands. It is caused by same mechanism as the harmonics of 600 MHz in the RF (e.g. Fig 9).

4) Intermodulation Products:

Spurious signals are also observed due to non-linearities in the IF transmission system (e.g. Fig. 10a and 10b). The spurious signals are generated due to compression in the IF system producing intermodulation components.

With a careful selection of the hardware setup (F3 and F12 frequency selection) it is generally possible to avoid strong birdies, except those due to the harmonics of 600 MHz in the RF. Use of suitable frequency setup combined with non zero fringe rate at these frequencies make rfi due to these sources unimportant for most continuum observations except in X-band. For 8400 MHz observations with 50 MHz bandwidth rfi has been noticed on some baselines occasionally. However it may be desirable to use suitable observing frequency and proper setup (F3/F12 frequency) to avoid above sources of strong rfi. It should be noted that weak rfi is also observed at almost all harmonics of 100 MHz (e.g. Figs. 11a and 11b), but these should not be important for most continuum observations.

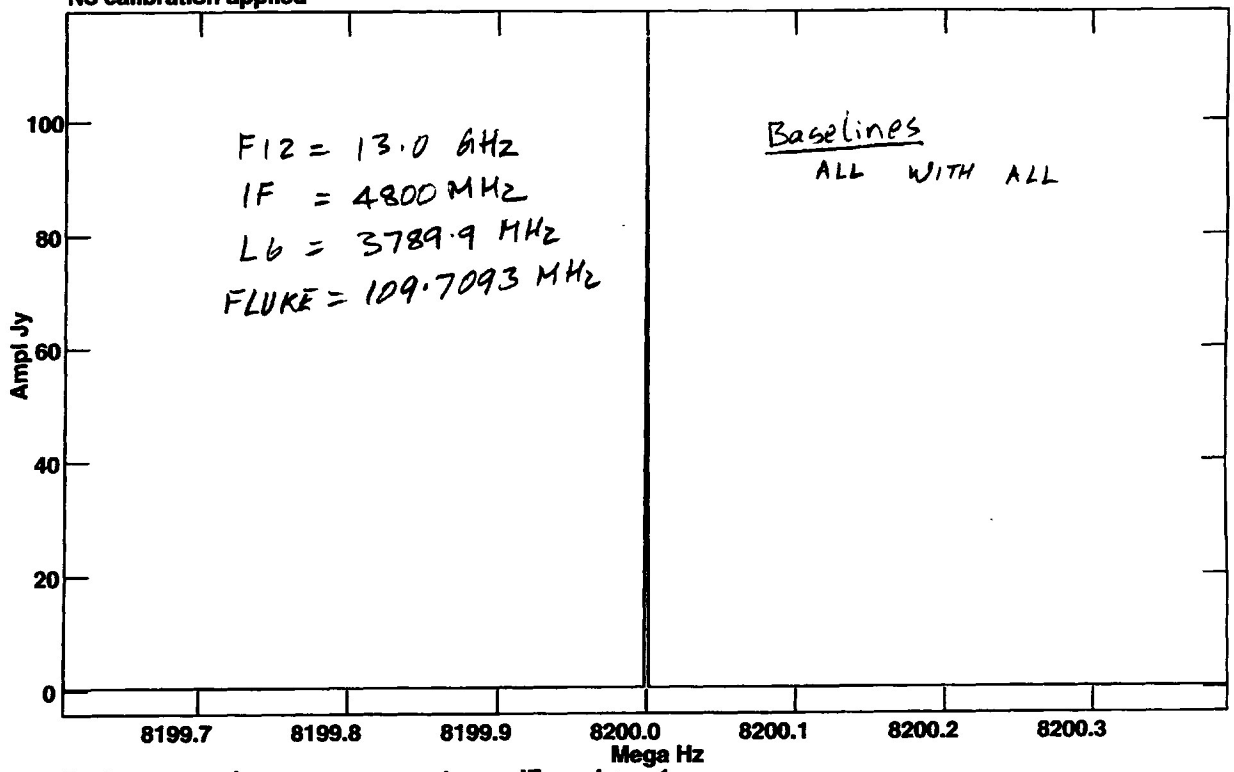
The intermodulation products, generated due to rfi from the local oscillator system, are generally weak and are likely to affect only spectral line observations. To minimize spurious signals due to intermodulations in the IF system it is suggested to remove all unwanted IFs using frontend filter bandwidth code =4 (which disconnects the IF signal in the F7 Module). This helps in two ways. First it reduces the total power in the IF transmission system and therefore reduces generation of spurious signals due to intermodulations. Secondly, offset frequencies for various IFs are such that spurious signals at some IF due to signals in another IF are generated by mixing with sum of 1.2 and 1.8 GHz signals (e.g. 1200+1800-IF D⇒IF A) or combination of two IFs beating with either 1.2 or 1.8 GHz signals. It means, for example, if B and D IFs are disconnected, then chances of any strong signals in these IFs beating with 1.2 and/or 1.8 GHz local oscillator signals and producing spurious signals in the passbands of A and C IFs are also eliminated.

These are some of the known sources of rfi in the VLA electronics. Many of these sources were not known till very recently. There may be other sources of rfi of which we are not aware. In the past observers have been caught unaware of internal (system generated) rfi affecting their observations. As there are a large number of rfi sources (including intermodulation products) , therefore for sensitive observations it is suggested to make a short observation looking at the North Pole (or preferably point the antennas at your target source and use the observing mode NP i.e. force

the L7 fringe rate to zero) with actual observing setup to recognize/detect any rfi which may affect the observations. This will also help in detecting any local source of strong rfi even if that is not part of the VLA electronics. To save extra observing time required for this testing it may be desirable to do this testing every time during slewing from target source to calibrator or other way, but that may require some changes in the online software. Infact if the online system allows to collect data using this mode during slewing/source change, it will be desirable to do this testing all the times while going from one source to another to keep a watch on local source(s) of strong rfi.

These tests were made with the help of Paul Lilie and Larry May, and provide some useful lessons to remember while planning/building the VLA Upgrade electronics to minimize the problems of system generated rfi. The tests suggest that (1) local oscillator modules in the antennas should be rfi shielded, and (2) phase switching should be moved to the front of the system as far as possible.

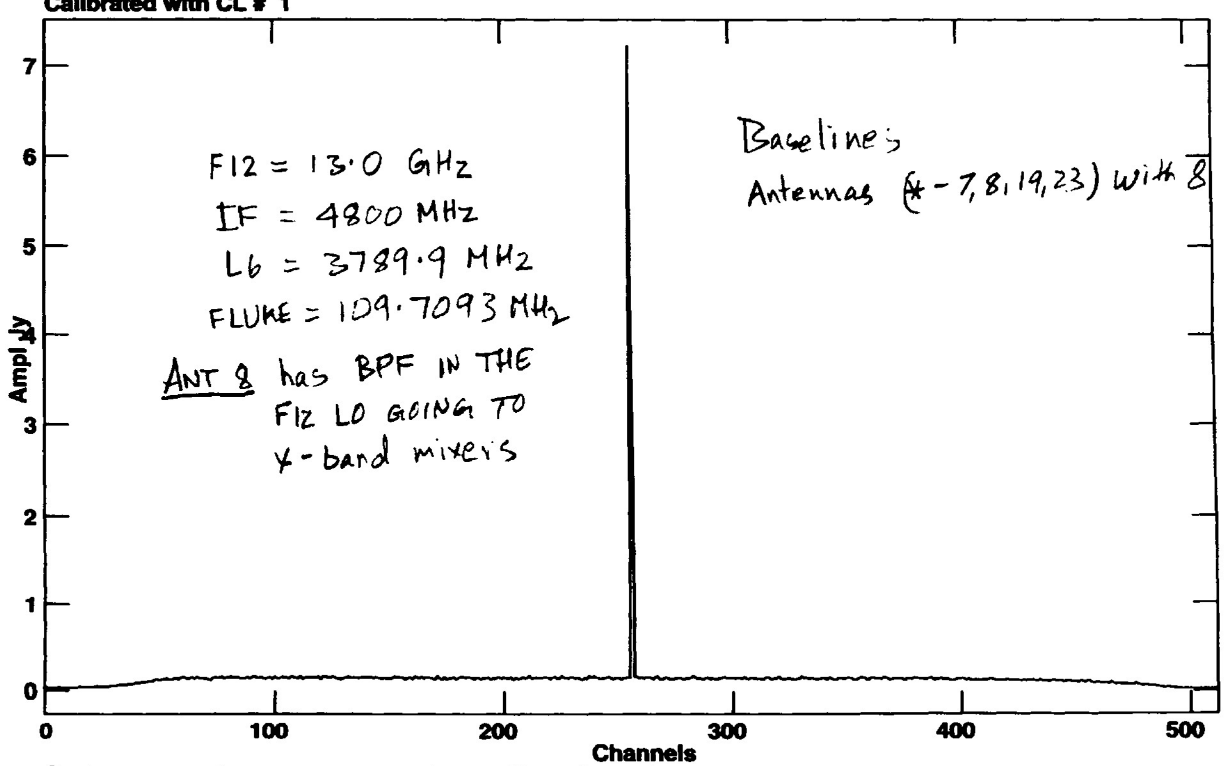
Plot file version 5 created 18-OCT-1995 10:59:43
NPOLE VLA951017-4.LINE.2
Freq = 8.2000 GHz, Bw = 0.781 MHz
No calibration applied



Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/22:20:20 to 00/22:36:00
Baseline: Several averaged Stokes: RR

FIG. 1a

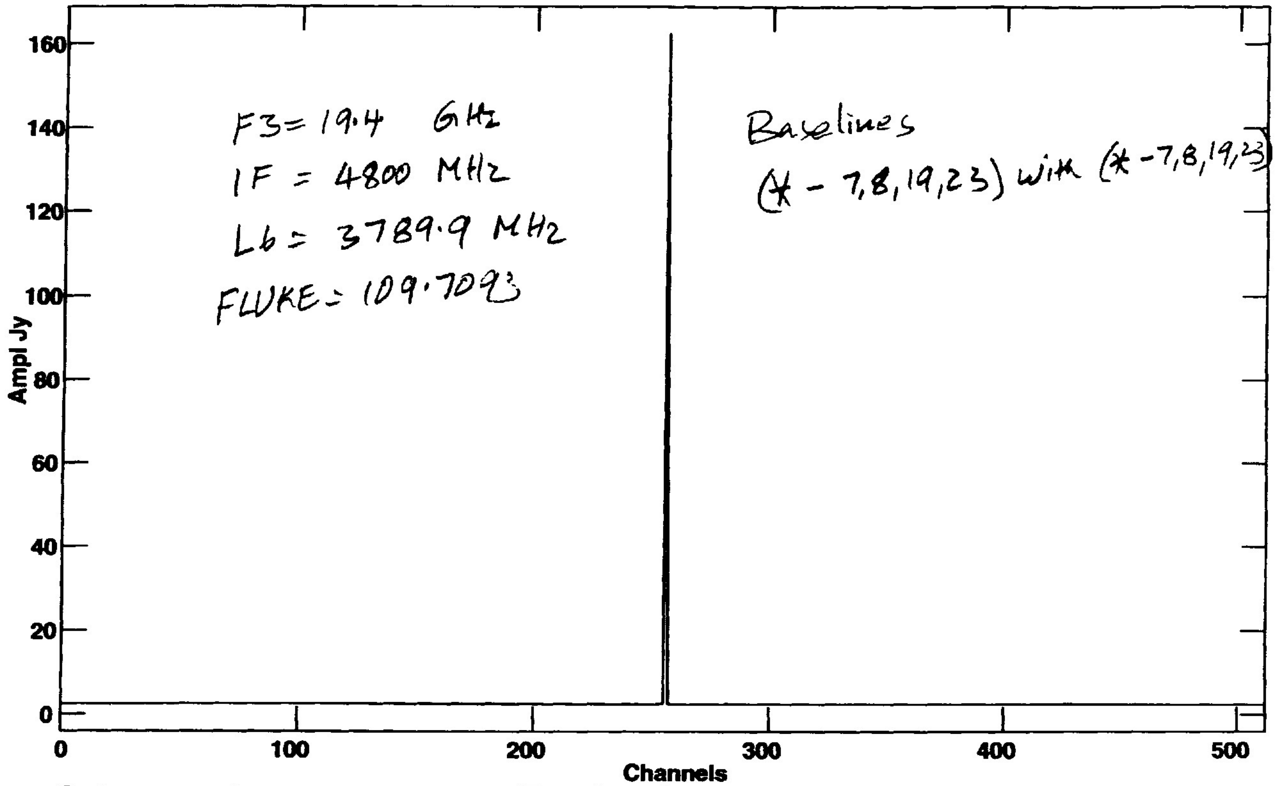
Plot file version 11 created 31-OCT-1995 14:11:03
NPOLE VLA951017-4.LINE.2
Freq = 8.2000 GHz, Bw = 0.781 MHz
Calibrated with CL # 1



Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/22:20:20 to 00/22:31:40
Baseline: Several averaged Stokes: RR

FIG. 1b

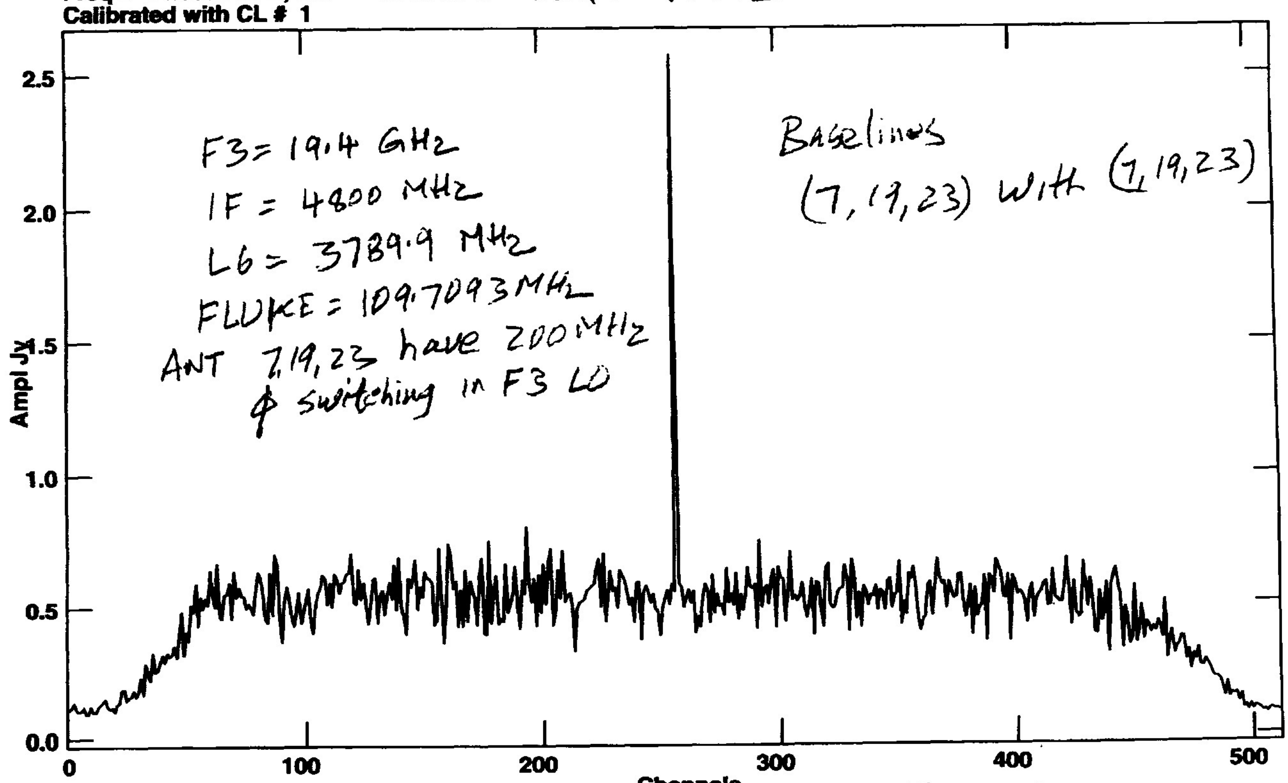
Plot file version 11 created 31-OCT-1995 14:24:55
NPOLE VLA950820.LINE.2
Freq = ~~14.8000~~ GHz, Bw = 0.781 MHz Freq = 14.600 GHz
Calibrated with CL # 1



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

FIG. 2a

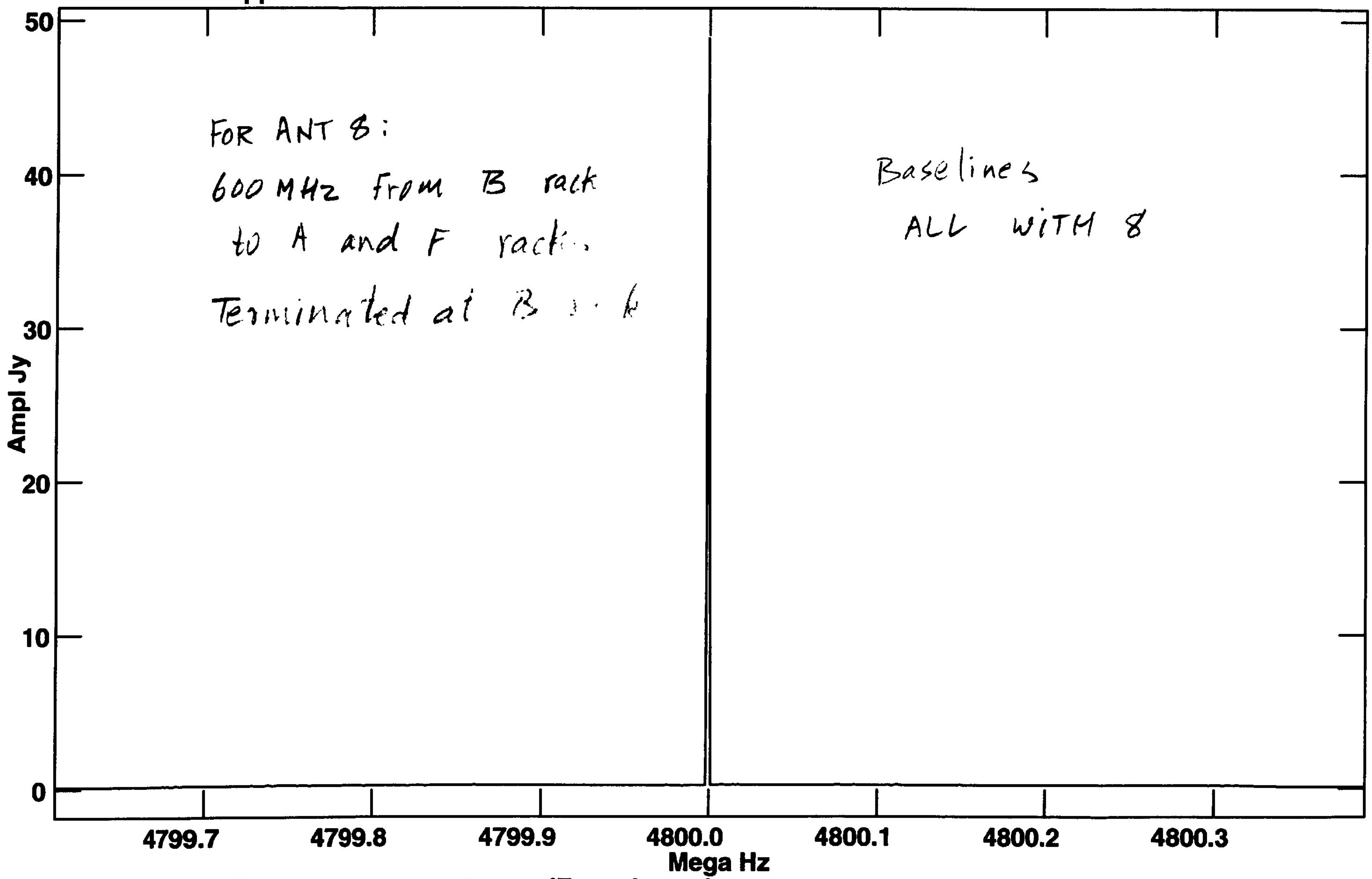
Plot file version 10 created 31-OCT-1995 14:21:44
NPOLE VLA950820.LINE.2
Freq = ~~14.8000~~ GHz, Bw = 0.781 MHz FREQ = 14.6 GHz
Calibrated with CL # 1



Scalar averaged cross-power spectrum IF number: 1

FIG. 2b

Plot file version 1 created 18-OCT-1995 08:43:17
NPOLE VLA951017-1.LINE.2
Freq = 4.8000 GHz, Bw = 0.781 MHz
No calibration applied



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

FIG. 3

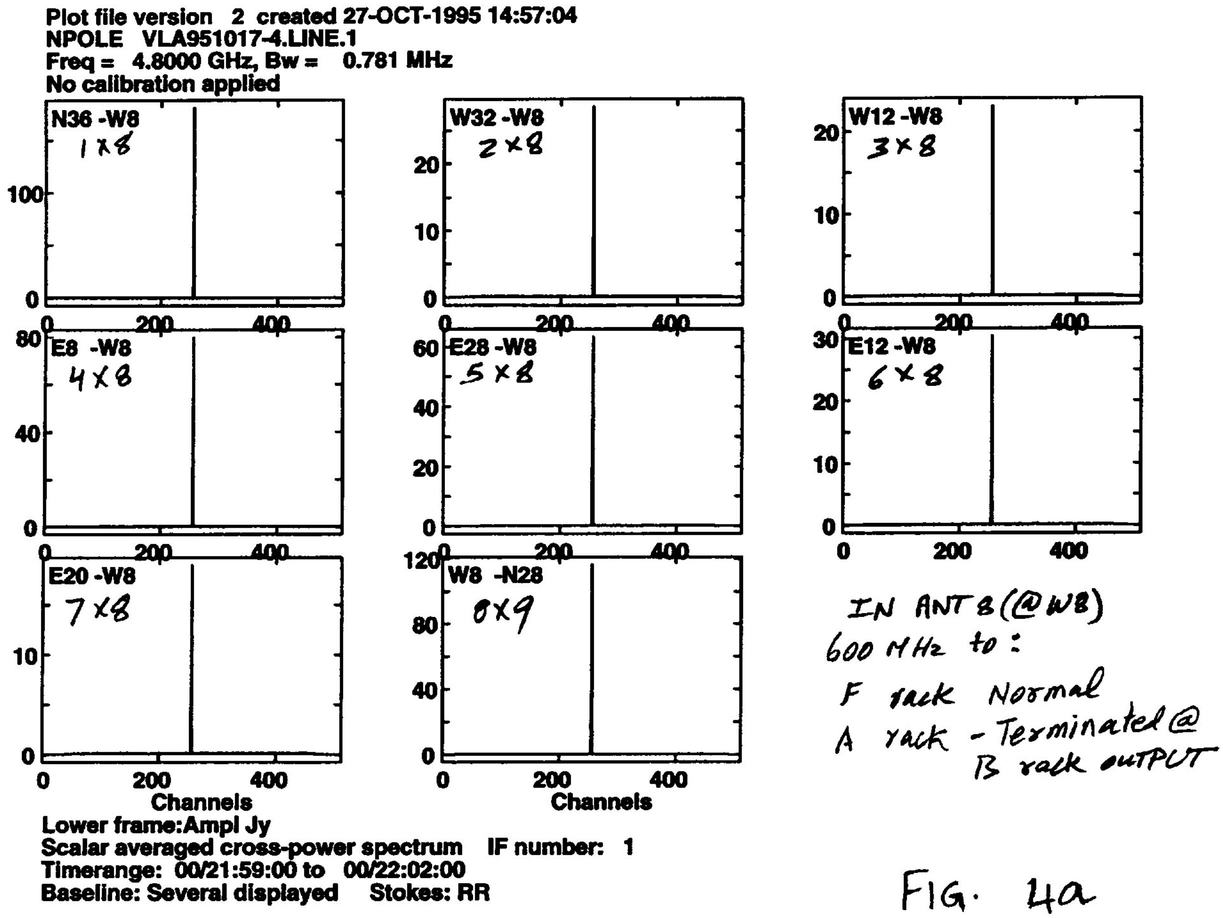

Plot file version 2 created 27-OCT-1995 14:57:04
NPOLE VLA951017-4.LINE.1
Freq = 4.8000 GHz, Bw = 0.781 MHz
No calibration applied
N36 -W8
1×8
W32 -W8
2×8
W12 -W8
3×8
E8 -W8
4×8
E28 -W8
5×8
E12 -W8
6×8
E20 -W8
7×8
W8 -N28
8×9
Channels
Lower frame:Ampl Jy
Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:59:00 to 00/22:02:00
Baseline: Several displayed Stokes: RR
IN ANT 8 (@W8)
600 MHz to:
F rack Normal
A rack - Terminated @
B rack output

FIG. 4a

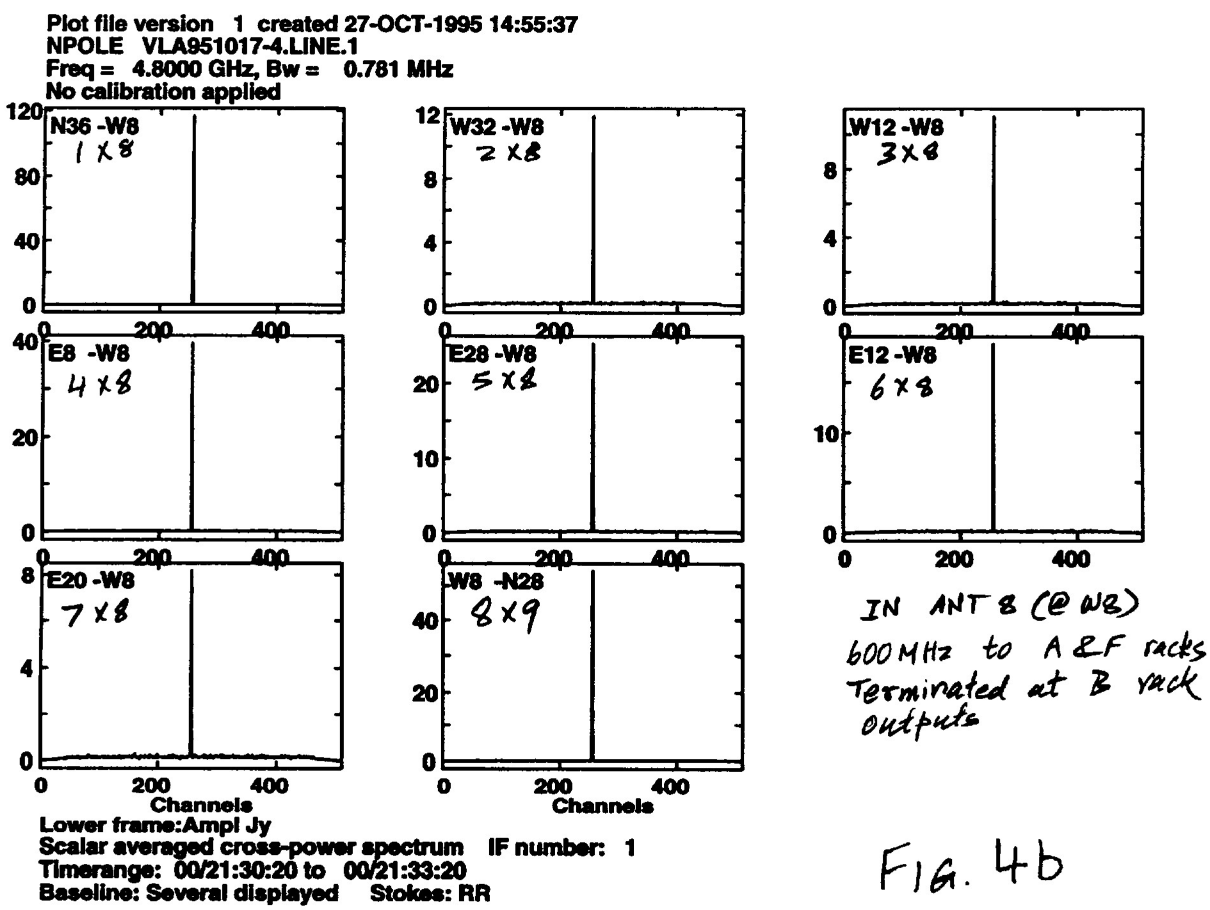

Plot file version 1 created 27-OCT-1995 14:55:37
NPOLE VLA951017-4.LINE.1
Freq = 4.8000 GHz, Bw = 0.781 MHz
No calibration applied
N36 -W8
1×8
W32 -W8
2×8
W12 -W8
3×8
E8 -W8
4×8
E28 -W8
5×8
E12 -W8
6×8
E20 -W8
7×8
W8 -N28
8×9
Channels
Lower frame:Ampl Jy
Scalar averaged cross-power spectrum IF number: 1
Timerange: 00/21:30:20 to 00/21:33:20
Baseline: Several displayed Stokes: RR
IN ANT 8 (@W8)
600 MHz to A & F racks
Terminated at B rack
outputs

FIG. 4b

8400; F12 = 13.0, L6 = 3590
BASELINES : (*-8) with 9

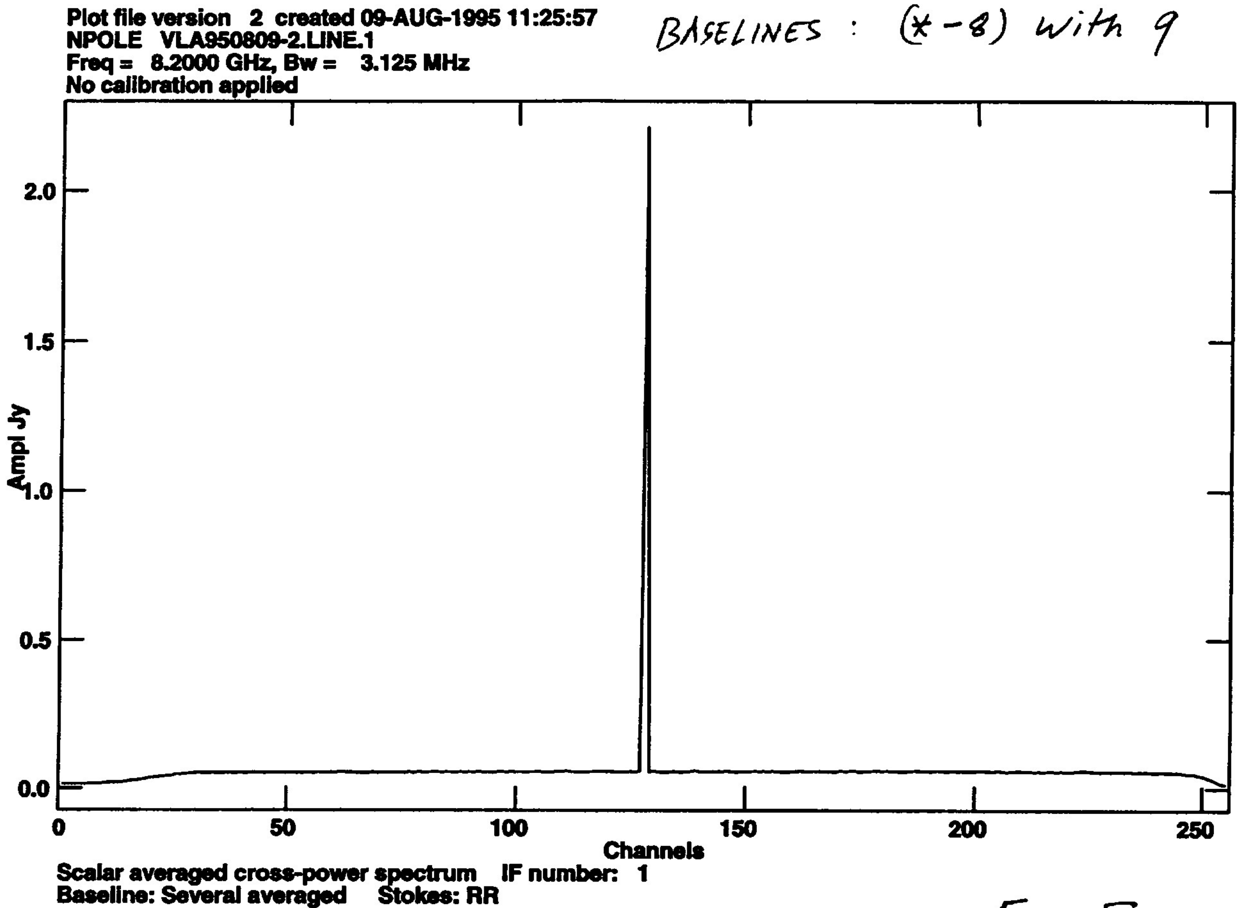


FIG. 5a

8400; F12=13.0, L6=3590
BASELINES : (*-8) with 8

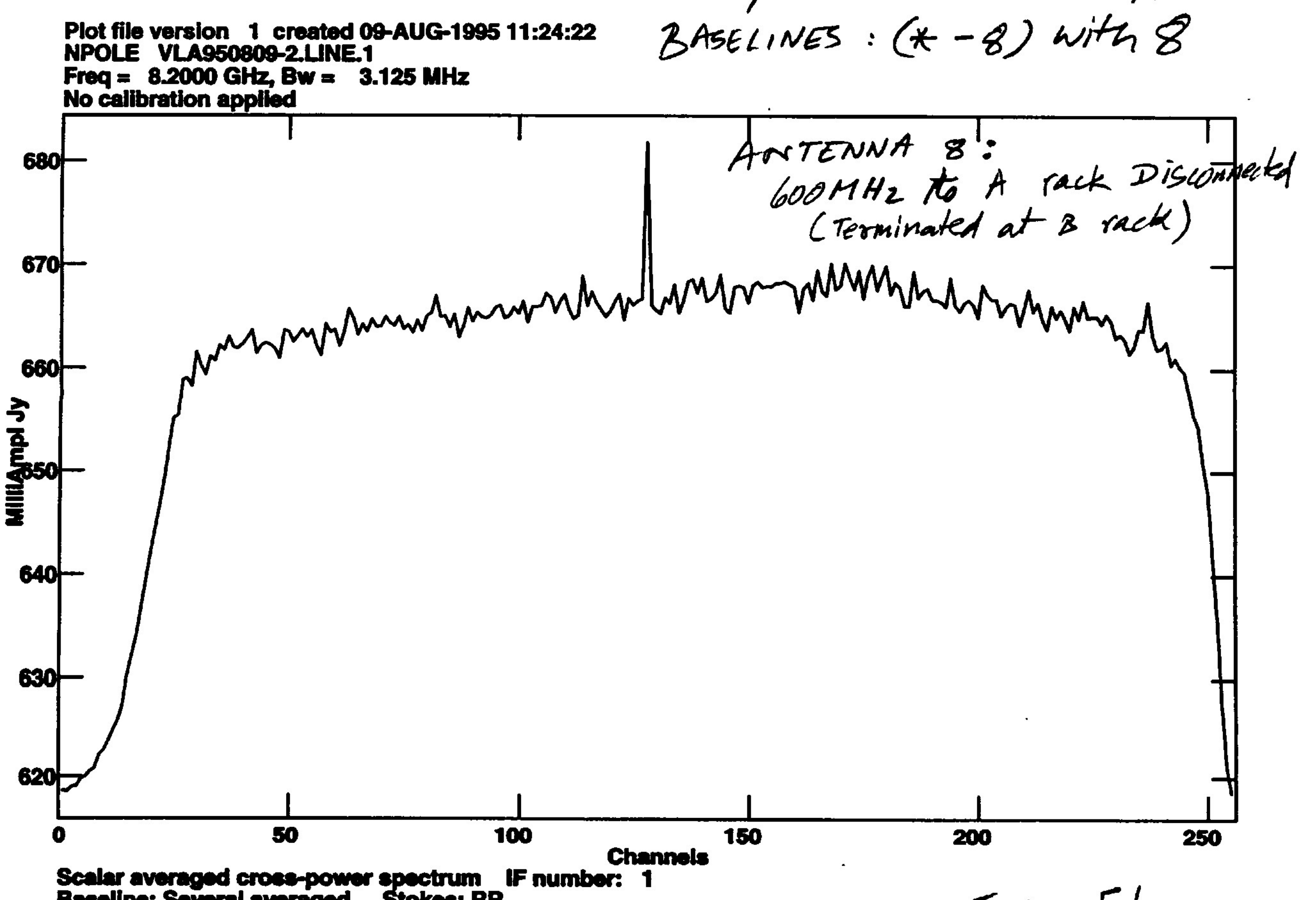
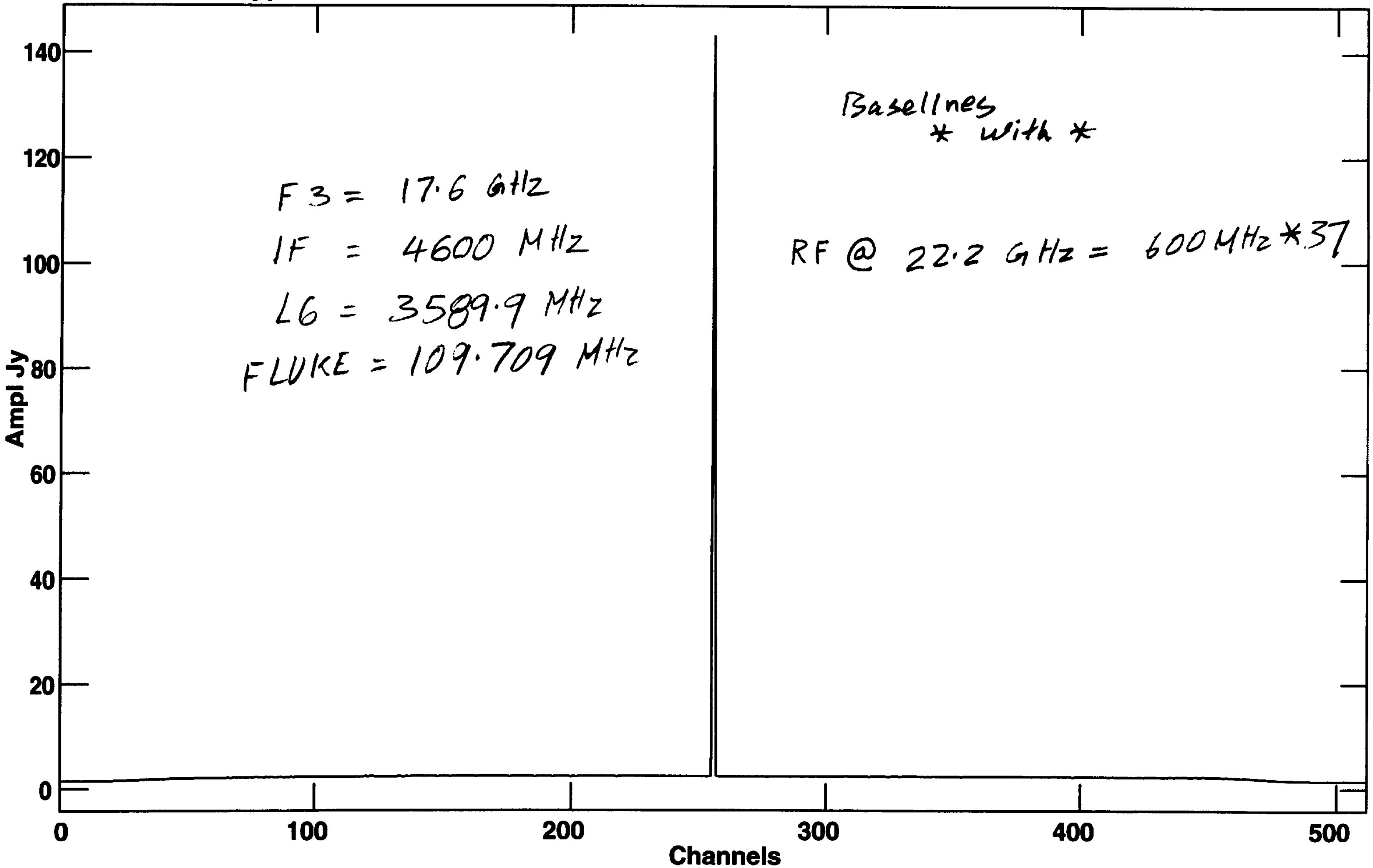


FIG. 5b

Plot file version 34 created 16-OCT-1995 08:30:38
NPOLE VLA950820.LINE.4
Freq = ~~22.0000~~ GHz, Bw = 0.781 MHz   Freq = 22.2000 GHz
No calibration applied



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

FIG. 6

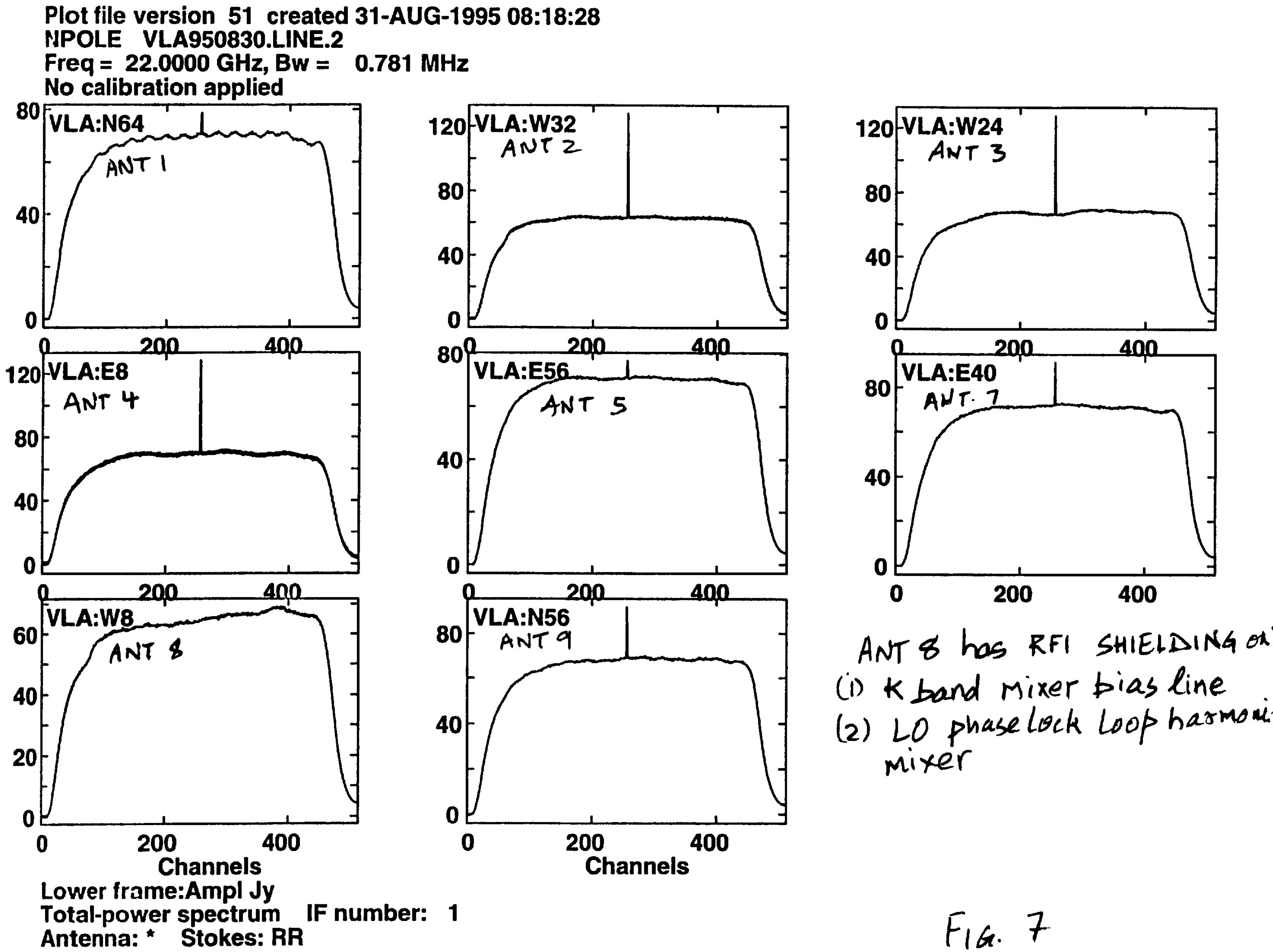
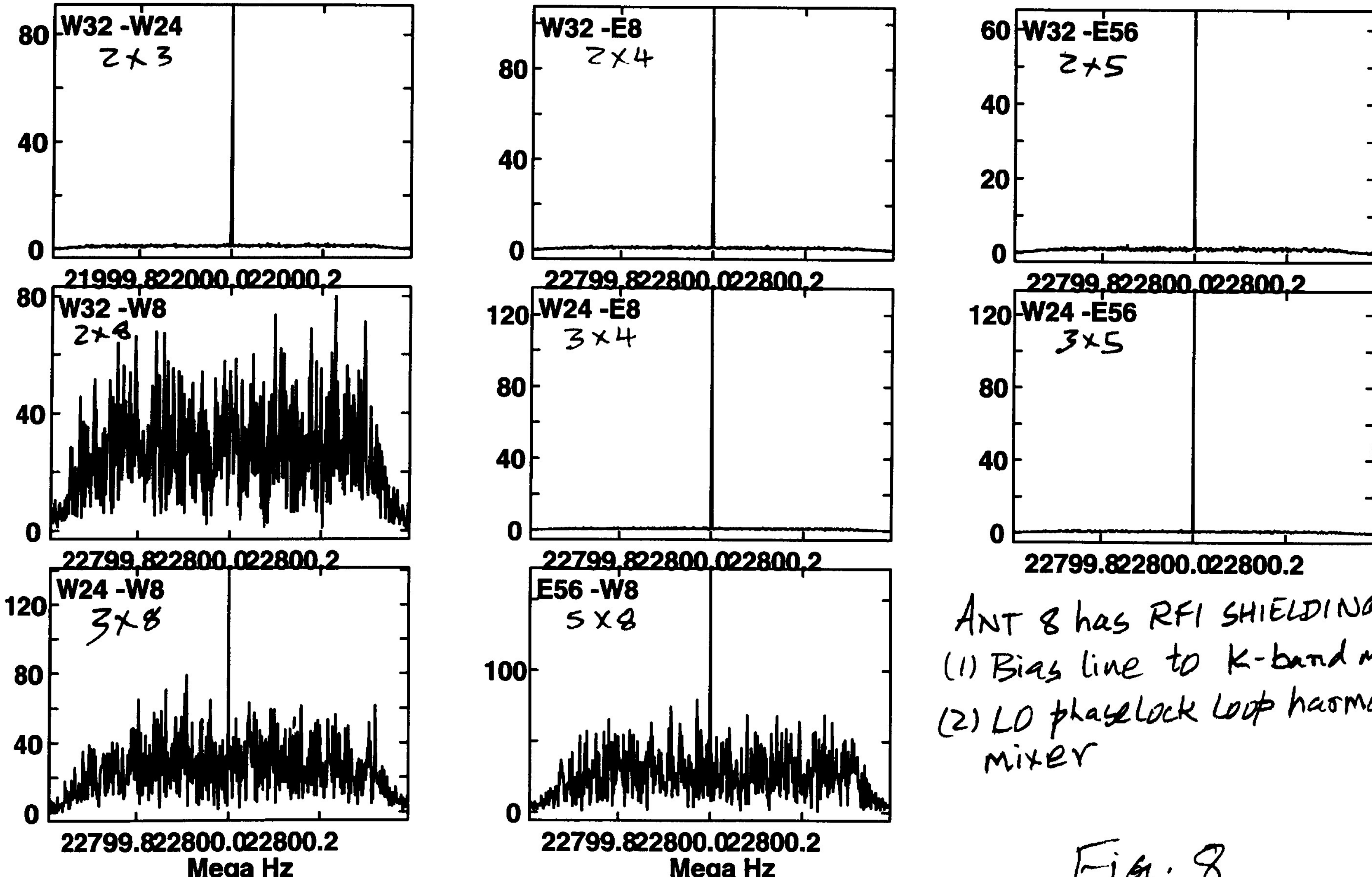

Plot file version 51 created 31-AUG-1995 08:18:28
NPOLE VLA950830.LINE.2
Freq = 22.0000 GHz, Bw = 0.781 MHz
No calibration applied
VLA:N64
ANT 1
VLA:W32
ANT 2
VLA:W24
ANT 3
VLA:E8
ANT 4
VLA:E56
ANT 5
VLA:E40
ANT 7
VLA:W8
ANT 8
VLA:N56
ANT 9
Channels
Lower frame:Ampl Jy
Total-power spectrum IF number: 1
Antenna: * Stokes: RR
ANT 8 has RFI SHIELDING on:
(1) K band mixer bias line
(2) LO phaselock Loop harmonic mixer

FIG. 7

Plot file version 61 created 31-AUG-1995 10:53:41
NPOLE VLA950830.LINE.2
Freq = 22.0000 GHz, Bw = 0.781 MHz
No calibration applied

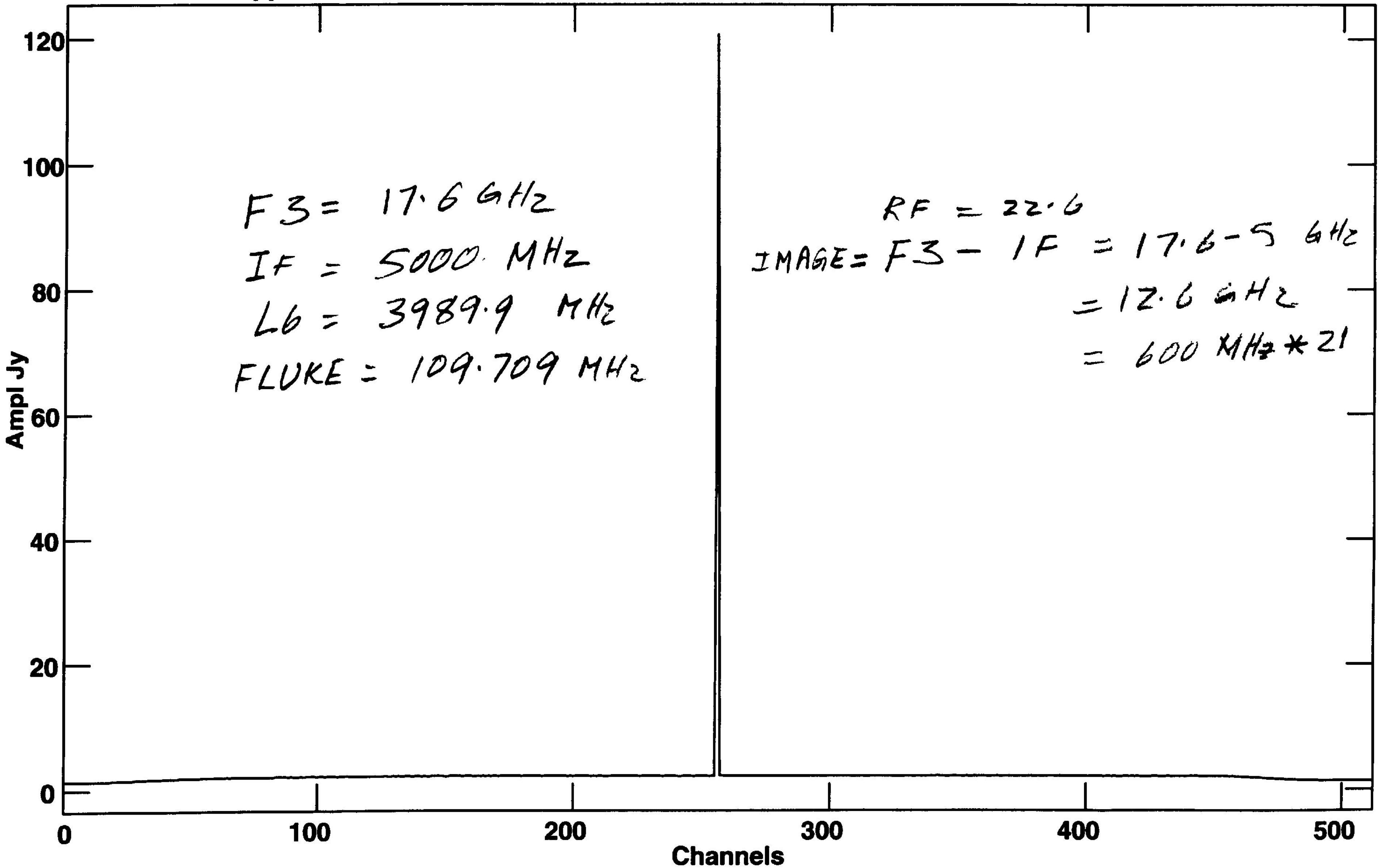


Lower frame:Ampl Jy
Scalar averaged cross-power spectrum IF number: 1
Baseline: Several displayed Stokes: RR

ANT 8 has RFI SHIELDING ON
(1) Bias line to K-band mixer
(2) LO phaselock loop harmonic mixer

Fig. 8

Plot file version 35 created 16-OCT-1995 08:31:56
NPOLE VLA950820.LINE.4
Freq = ~~22.0000~~ GHz, Bw = 0.781 MHz Freq= 22·0000 GHz
No calibration applied



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

FIG. 9

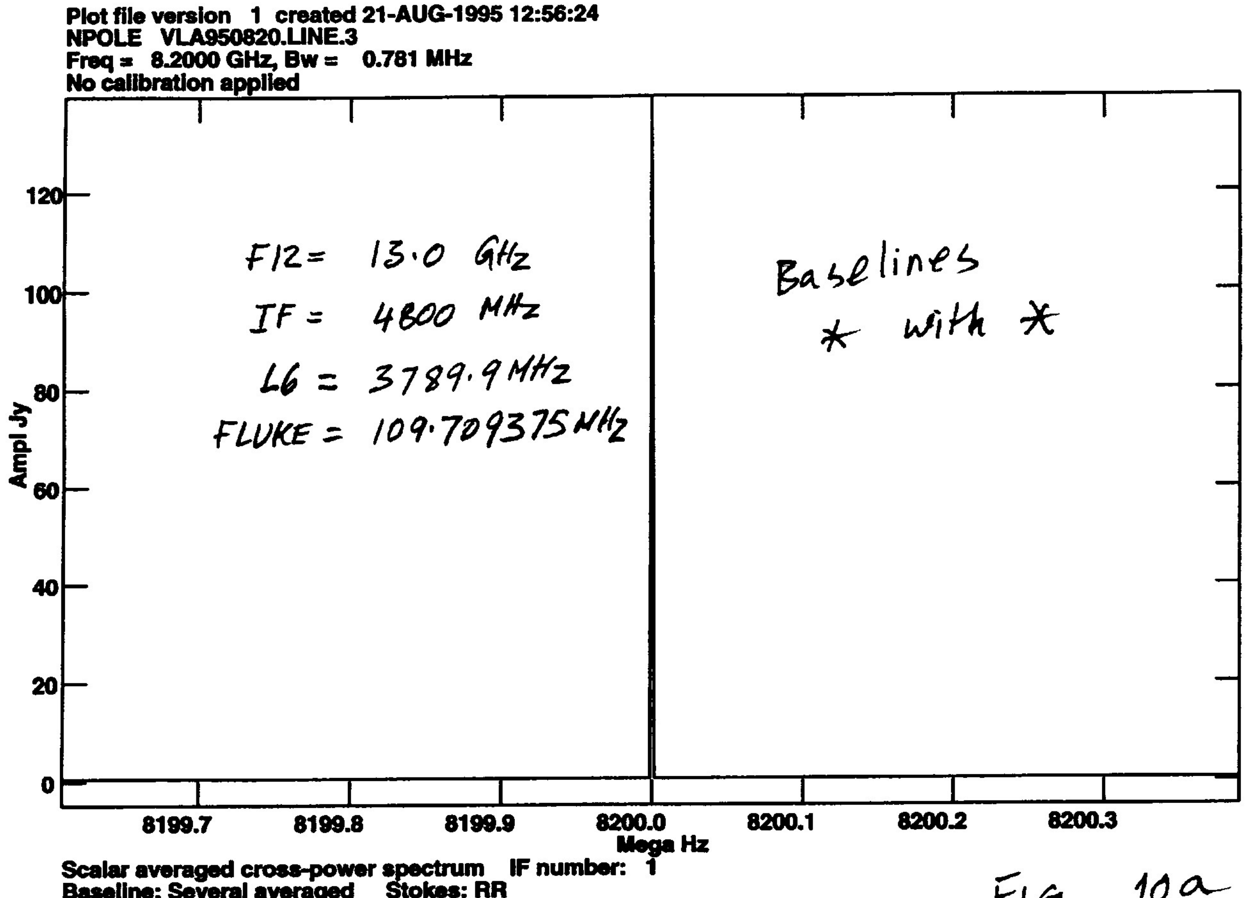


FIG. 10a

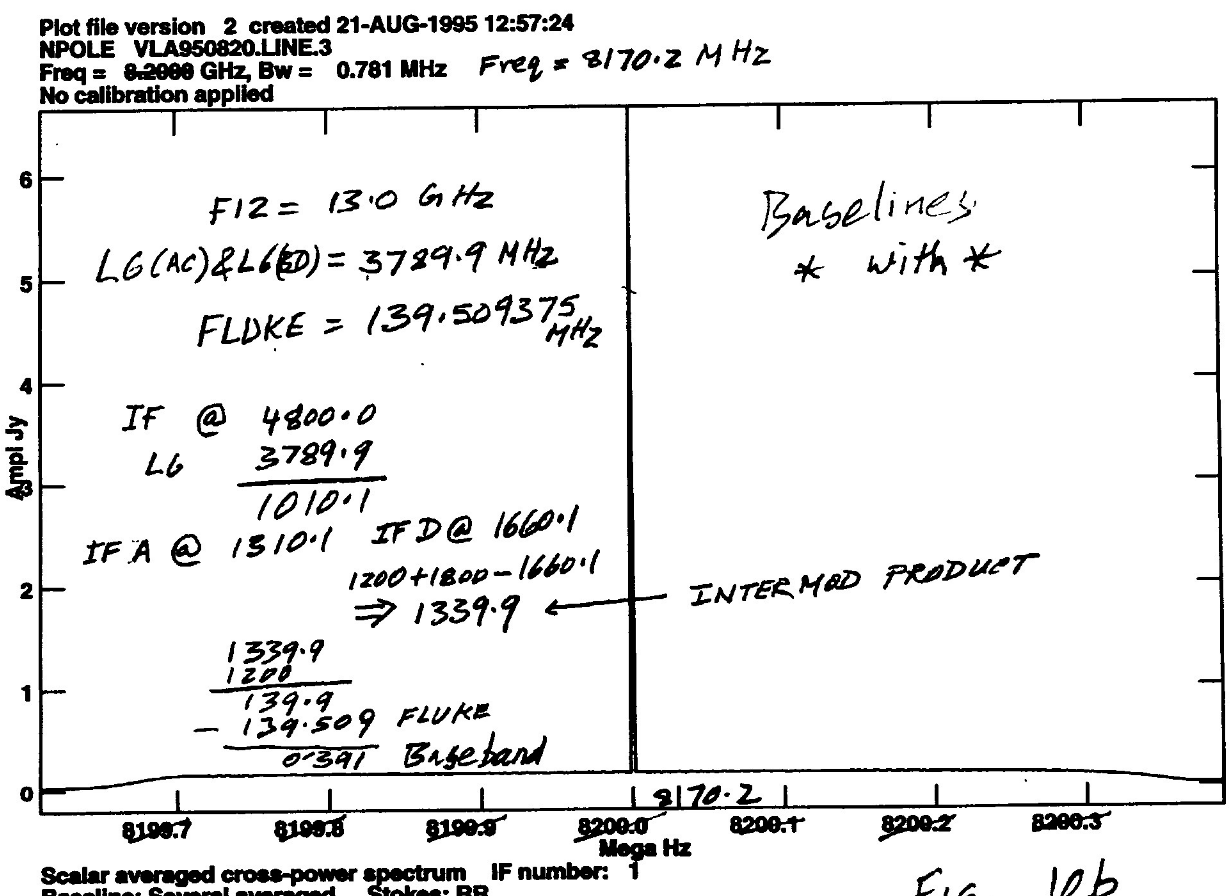
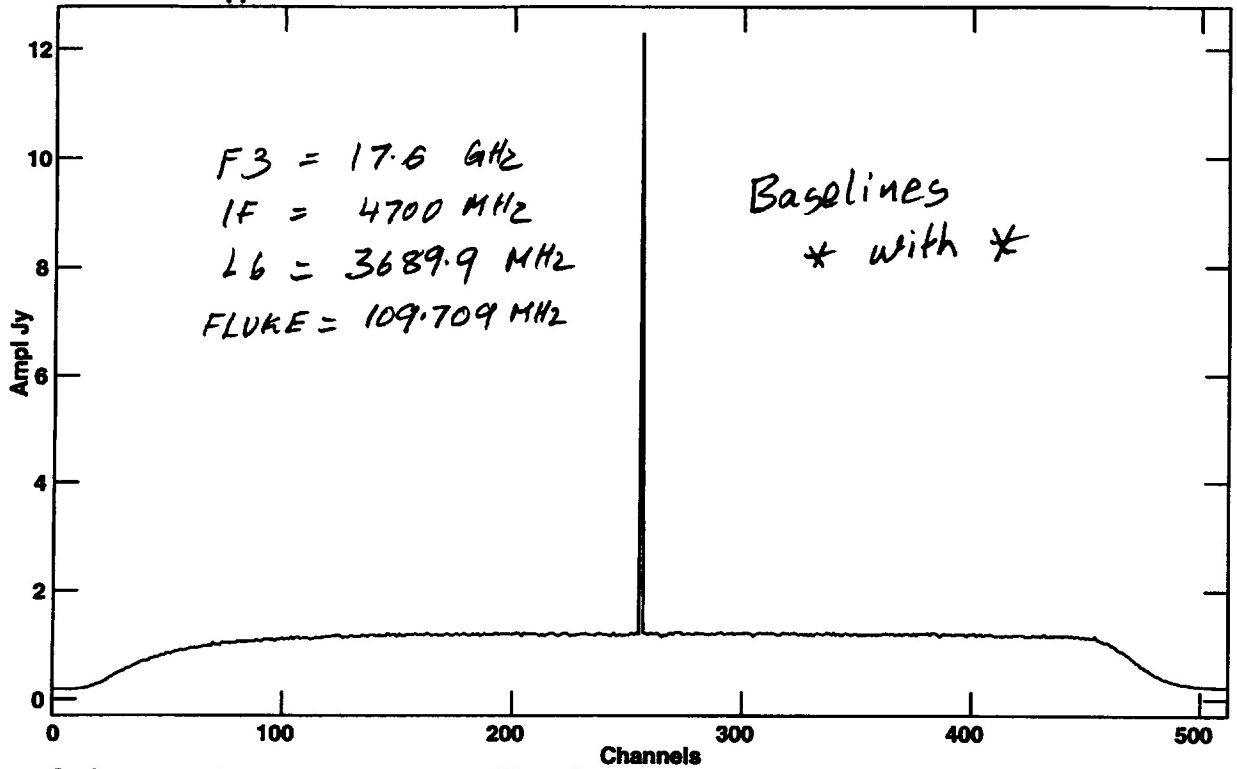


FIG. 10b

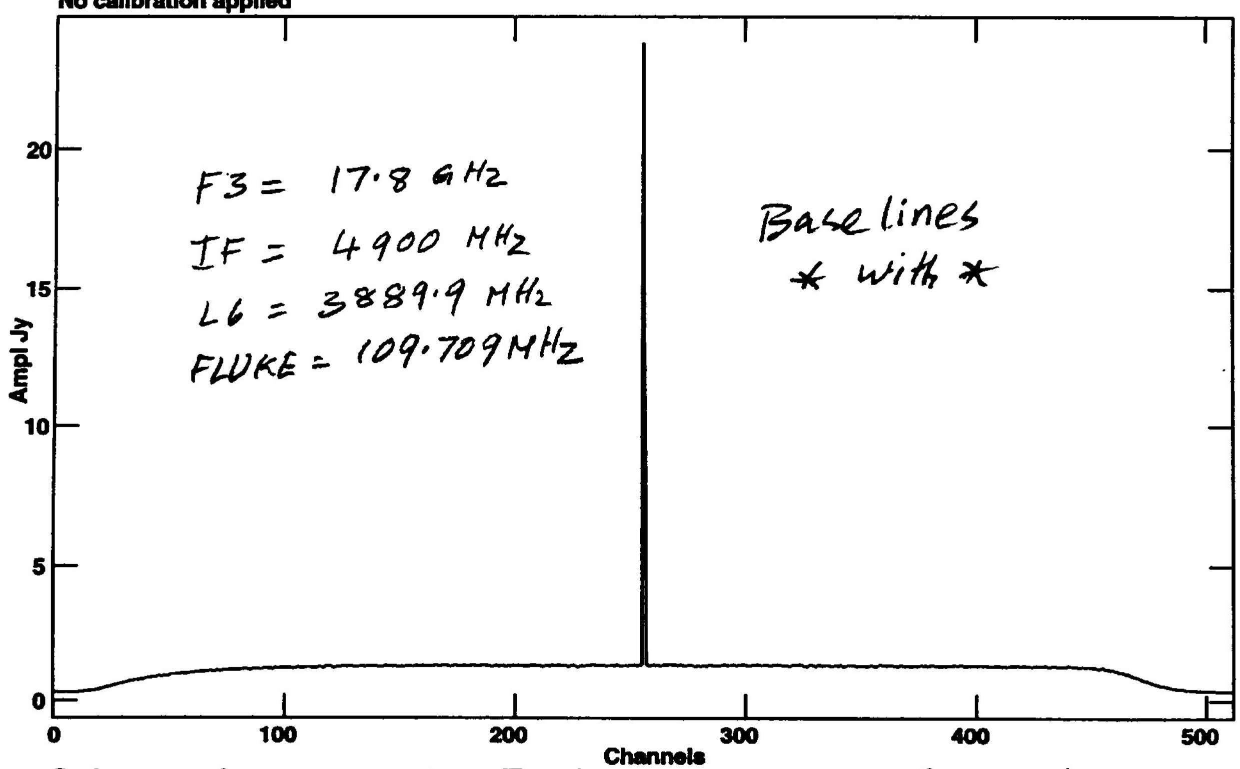
Plot file version 89 created 16-OCT-1995 08:36:48
NPOLE VLA950911.LINE.3
Freq = ~~22.0000 GHz~~, Bw = 0.781 MHz Freq = 22.3000 GHz
No calibration applied



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

FIG. 11a

Plot file version 90 created 16-OCT-1995 08:37:47
NPOLE VLA950911.LINE.3
Freq = ~~22.0000~~ GHz, Bw = 0.781 MHz Freq = 22.7000 GHz
No calibration applied



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

FIG. 11b