National Radio Astronomy Observatory
Socorro, NM

VLA ELECTRONICS MEMO. 222

Spurious signals and how to minimize them

D. S. Bagri
April 7, 1993

ABSTRACT

In the VLA electronics RF signals are first converted into IF signals at a frequency around 1025 MHz. If there are strog RFI signals present, then spurious signals are produced at the IF due to intermodulations caused in the mixers etc. Strong RFI signals, even if they are in other bands, may cause spurious signals due to finite isolation of switches etc. In certain cases spurious signals are produced due to some of the signals in the system itself. This memo points out how some of the spurious signals are produced due to out of band RFI. These signals may not be strong but still may be large enough to cause problems in spectral line or short integration snap shot observations like those for the L-band Sky Survey planned with the VLA. We suggest how some of these spurious signals can be minimized.

INTRODUCTION

Block diagram in Fig. 1 shows schemetic of how the RF signals from various bands are converted into the IF signals in the frequency range of 1025±25 MHz. The 74 MHz and 327 MHz band signals from the two frontends are first combined in a four way power adder, amplified by about 15 dB, and are then mixed with the LO signal from the low frequency ($\lesssim$ 1 GHz) output of the L6 Synthesizer module in mixer (M1) in the F11 (10-1000 MHz Receiver) module to produce IF signal at 1025 MHz. The frequency of the LO signal is (50*N±10.1) MHz, where N is an integer. RF signal at a higher frequency band (L-band and higher frequencies) from F9 (RF Splitter) module, already converted to 4.5-5 GHz, is mixed in (mixer) M2 in a F4 (IF Receiver) module. The LO signal for this is from the L6 Synthesizer module at a frequency of (50*N+f_r±10.1) MHz, where f_r is 3000 or 2400 (normally 3000 is used). The output of the mixer gives IF signal at 1025 MHz. The single pole double throw (SPDT) coaxial switch (S1), in the F4 module, selects one of these two 1025 MHz IF signals before the (S1 output) signal is further processed. The coaxial switch (S1) has a typical value of isolation between its two inputs of about 50-60 dB.

The Synthesizer (L6) module works in the following way (see Fig. 1). Output of a 2-4 GHz YIG oscillator (normally in the frequency range 3.49 to 3.99 GHz for observations above 1 GHz) is mixed in mixer M3 with a signal from the antenna LO system at 3000 or 2400 MHz (normally 3000 MHz is used) to give a signal of frequency $\lesssim$ 1 GHz. The mixer output is amplified to about +8 dBm in amplifier A1 (gain ≈ 28 dB) and is given to mixer M4, whose other input is a 50 MHz comb signal. Output of the mixer M4 is phase detected with a 10.1 MHz signal from Fringe Generator (L7) module to provide phase lock signal for (fine tunning coil of) the YIG oscillator (whose coarse tunning coil voltage is set to a value corresponding to the desired frequency of the YIG oscillator). The output of the YIG oscillator provides LO signal for F4 modules, and is normally in the range of 3.49 to 3.99 GHz. The low frequency output of the amplifier A1 provides LO signal for the F11 module, and its frequency is normally below 1 GHz.

The LO signals for all the F4s and the F11 modules are always present. Mixers M1 to M4 are double balanced mixers, use LO signal power of about +7 dBm, and have a conversion loss of about 6-8 dB. Nominal values of various signal levels are marked in the block diagram (Fig. 1).

Normally all the time all amplifiers are powered on and all the LO signals are connected to different mixers. A strong RFI signal may therefore produce higher order mixing components which may fall within the IF passband. These spurious components may get pickedup in the output due to finite isolation of the switches, even if the spurious signals are caused by RFI in some other band than the one being used at that time. Below we give some examples of spurious signals produced by RFI in other bands, LO signals, etc., and suggest how some of these can be minimized.

SPURIOUS SIGNALS IN THE HIGHER FREQUENCY BANDS DUE TO RFI IN 74/327 MHz BANDS

Signal at port 1 of the coaxial switch S1 contains components at frequencies $(mf_i \pm nf_l)$, where input signal to the mixer M1 are at frequencies f_i, LO signal to the mixer is at frequency f_l, and m and n are integers. Moderate level of RFI in 74 and 327 MHz bands may cause fairly strong signals at the input of the mixer M1, as there is about 55-60 dB of gain before it. Therefore we may have fairly strong undesired signals at port 1 of the switch S1 due to strong RFI signals beating with various harmonics of the LO signal to M1(i.e. 2*660.1-307.2=1013 will appear as RFI at 1473.1 MHz, and we see a signal at abou this frequency in the VLA L-band RFI plot in Fig. 2; there is a strong FAA signal at about 307.2 MHz from Albuquerque air traffic control).

During the observations at 327 MHz band we may see some spurious signals due to RFI in the 74 MHz band (i.e. 2*689.9-5*71.75=1021.05 MHz, and this will appear as spurious signal at 331.15 MHz; the RFI at 71.75 MHz is due to the TV channel 4 sound frequency). Also we may see strong RFI in 327 MHz band causing spurious signals in the 74 MHz band (i.e. 689.9+2*162.025=1013.95, and this will appear as spurious at 1013.05-939.9=74.05 MHz; 162.025 MHz is the frequency of the local transmitter and receiver system used at the site).

SPURIOUS SIGNALS DUE TO LO SIGNALS

For some of the frequency settings of the L6 Synthesizer the LO to M1 itself may produce interference at its harmonics (i.e. L6 frequency setting of 3510.1 MHz will have LO input to M1 at 510.1 MHz, which will produce 510.1*2=1020.2 MHz in the IF, and will appear as RFI at 1330.3 MHz during the L-band observations, and we do see a signal around this frquency in the L-band RFI plot in Fig. 2).

There may also be 50 MHz comb leaking with the LO signal to the mixer M1 (though it may be only around -60 dBm), which will mix with the signals at the input of M1 to produce spurious signal in frequency range 1025±25 MHz at port 1 of the switch S1. Even though these signals may not be very strong, and also there is further isolation of the switch S1 between ports 1 and 2, but any signal of the order of even -100 dBm leaking into port 3 of S1 will be strong enough to cause spurious response during observations at higher frequency bands, especially for spectral line work or short integration snap shots.

SPURIOUS SIGNALS DUE TO RFI IN OTHER HIGH FREQUENCY BANDS

If there are strong RFI signals (as in L-band), then depending on the F9 bandswitch setting and frequency of the LO signal to a F4 it may produce spurious signal in IF passband range at port 1 of the switch S1 (i.e. RFI at 1544+3200=4744 beating with LO of 3710.1 producing 1033.9 MHz in IF, which will appear as spurious at 1033.9-710.1=323.8MHz in 90 cm band). Depending on the isolation of the switch S1 this will leak to output (port 3) of the switch S1.

Further, depending on the isolation (about 60 dB) of the bandswitch in F9 module this may also cause spurious signal for other higher frequency bands.

SPURIOUS SIGNALS DUE TO INTERMODULATIONS IN THE IF TRANSMISSION SYSTEM

If one of the IF signals (i.e. either of IFs A, B, C, or D) contains strong RFI signal, then nonlinearity of the IF transmission path (particularly Modem transmitting the IF/LO signals) may cause this RFI signal to appear in another IF due to third order intermodulation components generated by beating it with the 1200 and 1800 MHz LO signals (i.e. 1200+1800-IF A giving response in IF D, etc.). Modems in some of the antennas have operating power level which is close to 1 dB compression power level or exceeds it. This may generate about 20 dB lower intermodulation components. Even for narrower frontend filter bandwidths (i.e. 25 and 12.5 MHz) we use the same operating power level, and therefore intermodulation affects will be similar to those for the full bandwidth of 50 MHz.

HOW TO MINIMIZE THE SPURIOUS SIGNALS

In some cases introducing extra attenuation when that side of the system is not used may help to reduce the spurious signals in the output. In general turning off the LO signals to those mixers which are not used will reduce the spurious signals. Specifically following may help minimize the spurious signals:

(1) While observing at 74/327 MHz bands use 2400 MHz reference for L6 Synthesizer instead of 3000 MHz. This will produce L6 outputs to F4 modules at frequencies $\leq$3340 MHz, which will be attenuated before reaching the mixers in F4 modules by bandpass filters (3750$\pm$315 MHz) in the LO path to the mixers.

(2) The spurious signals at the higher frequency bands due to RFI in 74/327 MHz bands can be minimised by introducing a switch in the path of the LO signal to mixer M1, and cutting off the LO to it while observing at the higher frequency bands (L-band and higher frequencies).

(3)For observations in the 327 MHz band the spurious signals due to the 74 MHz (RFI) signals can be eliminated by putting a switch in the path of the 74 MHz band signal before the input of the power adder in the F11 module. The switch can also be located at the input of the 74 MHz amplifiers in the frontend to minimize damage to the amplifiers due to the lightning (when this band is not in use). The switches can be located anywhere between dipole ouputs and the 4-way adders in the F11 module based on practical considerations.

(4) The intermodulation affect due to the IF transmission nonlinearities can be minimized for atleast some of the spectral line observations where all the four IFs are not used. In those cases, IFs not used can be switched-off/disconnected by choosing no-filter position for the frontend filters in the antenna.

It will need a total of 4 coaxial SPDT switches per antenna (one each for rcp and lcp signals at 74 MHz, and one each for AC and BD LOs in the F11 module). This may cost about $700/antenna plus labor. In addition this will require online computer control of these switches.

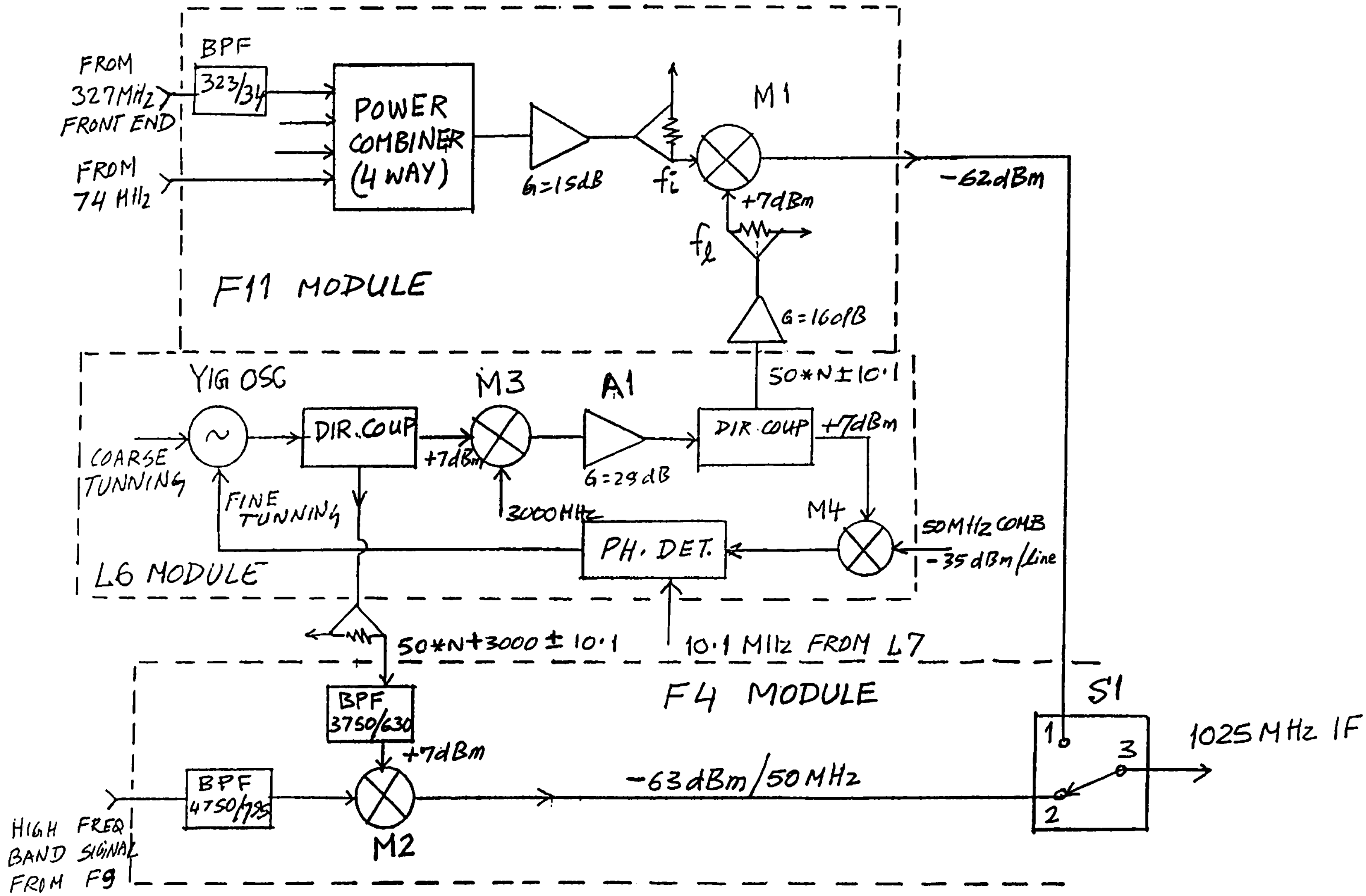

FIG 1 - BLOCK DIAGRAM SHOWING HOW VARIOUS SIGNALS ARE CONVERTED TO 1025 MHz IF SIGNAL.

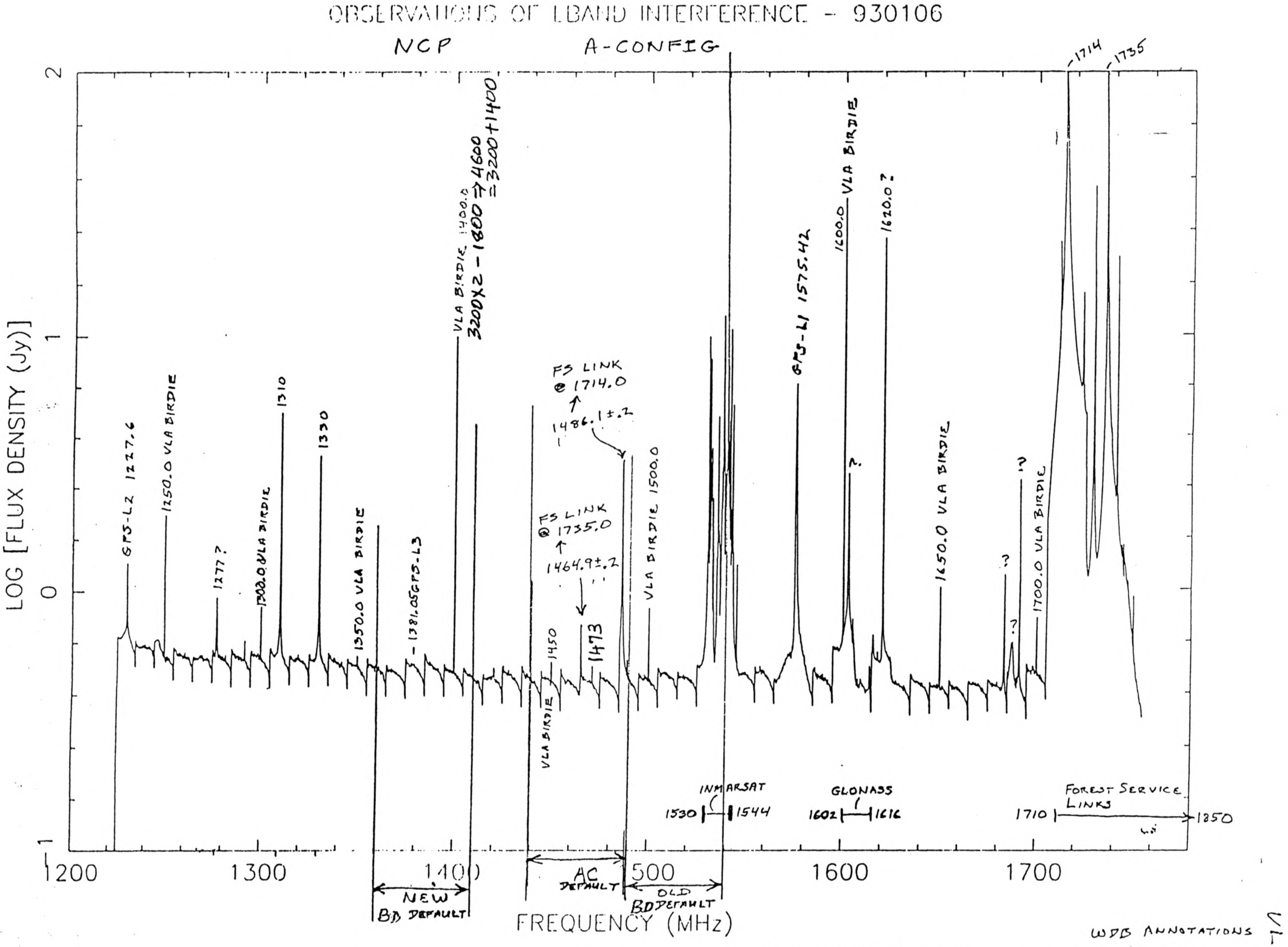

FIG 2 - VLA L-BAND RFI SURVEY LOOKING TOWARDS THE NORTH CELESTIAL POLE