VLA Test Memo # 235

Optimal Settings for the 300 MHz (P) band at the VLA

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ABSTRACT

I review some of the relevant characteristics of the 300 MHz (P) band at the VLA and describe the results of test observations of December 13, 2003 that have probed its current performance.

I suggest some modifications of the P band observational defaults. Clean data can be obtained using two 3-MHz bands: 320.0 — 323.125 MHz and 325.0 — 328.125 MHz with the 4IF spectral mode BW4 with on-line Hanning-smoothing, which yields thirty-one 98-kHz channels per setting and polarization. This option is appropriate for all VLA configurations.

In the more extended configurations (A, B and possibly C) there are four relatively clean options that yield wider bandwidths: 305.0 — 311.25 MHz, 315.0 — 321.25 MHz, 320.0 — 326.25 MHz and 325.0 — 331.25 MHz. Two of these can be used in the 4IF spectral mode BW3 with on-line Hanning-smoothing, which yields fifteen 390-kHz channels per setting and polarization. At least one channel of each of these settings suffers from internally generated interference, some can pick up external interference as well. The last two settings are the cleanest; although there is some overlap in frequency between them that results in a loss of 2 channels (out of 28 clean ones), which seems acceptable.

The mixed-band default settings "LP" and "4P" should be modified as well with the P band tuning changed to 320.0 — 323.125 MHz (narrow-band option) or 320.0 — 326.25 MHz (wide-band option).

New VLBI defaults should be tested. The cleanest wide-band option should be 310.65 — 323.15 MHz which can be used with the 12.5 MHz front-end filter. A second option, 322.6 — 335.1 MHz, requires the use of the 25 MHz front-end filter, which might lead to excessive RFI during daytime observations. The full P band can be used for single-(VLA)-antenna VLBI observations.

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1. Introduction

P band observations at the VLA[2] are normally done in spectral mode, using 2 IF pairs with ~3.125 MHz bandwidth each, centered at 327.5 MHz and 321.5625 MHz (default PP in JObserve), 2 IF pairs with ~6.25 MHz bandwidth each, centered at 328.5 MHz and 321.5625 MHz (default P1 in JObserve) or 2 IF pairs with ~6.25 MHz bandwidth each, centered at 327.5 MHz and 321.5625 MHz (default P2 in JObserve). Some of these bands suffer from out-of-band interference that is aliased into the observed band by the LO chain.

The default setting that is used for VLBI observations with one or more VLA antennas (default VP in JObserve) calls for a 3.125 MHz band centered at 327.0625 MHz, which seems unnecessarily narrow.

2. Background

A review of some of the characteristics of the P band hardware is useful for the discussion below.

The P band feed consists of a pair of orthogonal "half-wavelength" dipoles, located one quarter-wavelength in front of the (secondary) subreflector which acts as a ground plane. Signals from both dipoles are combined in a "quadrature hybrid" to produce right- and left-hand circularly polarized beams on the sky which are slightly off-axis (~8′, Uson and Bagri 1991). The phase center of the feed is located about 2 cm behind the apex of the subreflector which is still 0.4 m in front of the best-fit prime focus, even when the subreflector is pushed back as far as possible. This results in defocusing of the antenna with a resulting loss of ~1.5 dB (Ruze 1966). The aperture efficiency is about 0.4 and the system temperature is as low as 130 K (at 330 MHz) when pointing away from the Galactic plane. The defocusing leads to a somewhat broadened beam (HPBW ~ 155′ at 327 MHz) with no clear nulls.

The right- and left-circular polarization outputs of the quadrature hybrid are fed to a low-noise "room temperature" amplifier that is mounted with the quadrature hybrid device in a temperature-controlled front-end box located near the prime focus. The amplified RF signals are sent via coaxial cables to the vertex room where they are first passed through a bandpass filter (nominally 306 — 340 MHz) which defines the usable band. Subsequently, the signals are upconverted with LO frequencies 689.9 MHz or 710.1 MHz supplied by the

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[2]The Very Large Array of the National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

L6 modules (which normally supply the "2 — 4 GHz" LO signals used to down-convert the Cassegrain bands. The resulting IF signals (nominally 1025 ± 25 MHz) go through one of the "front-end" filters (FE) which have widths of 50 MHz or 25 MHz centered at 1025 MHz or 12.5 MHz centered at 1027 MHz. Given only the two possible values for the "L6" LO, not all of the P band can use the narrower 12.5 MHz FE filter (only frequencies in the range 310.65 — 323.15 MHz as well as those above 330.85 MHz can use this narrowest FE filter). Use of the 25 MHz FE filter with the 710.1 MHz LO covers the range 302.4 — 327.4 MHz, whereas the 689.9 MHz LO covers the range 322.6 — 347.6 MHz; although the first option is limited at ∼ 305 MHz at the low-frequency end whereas the second option is limited at ∼ 340 MHz at the high-frequency end by the aforementioned "bandpass" filter (these cutoffs are soft and vary somewhat between antennas).

The previous considerations are also relevant to VLBI observations that use the VLA, and especially so to those that use the phased-VLA. Because only ifs A and D can be phased-up simultaneously, phased-array P band observations can only use one frequency setting and the only way to cover the full VLA P band with one setting is to use the 50 MHz FE filter with the LO set at 710.1 MHz.

The 1000 — 1050 MHz signals are once again upconverted with offset frequencies of 300 MHz (IF A), 400 MHz (B), 550 MHz (C) and 650 MHz (D) for their transmission through the VLA waveguide system. At the "D-racks" located in the VLA control building, they are mixed with a 1200 MHz (IFs A and B) or a 1800 MHz (C and D) reference signal and finally brought down to baseband through one more mixing with the "fluke" frequencies (100 — 150 MHz for IF A, 200 — 250 MHz for B, (−250) — (−200) MHz for C and (−150) — (−100) MHz for D) followed by a baseband filter and subsequent digitization. For most spectral modes (including those considered in this memo) this results in bandpasses that are fairly rectangular at the lower frequency end and roll-off at the high end (due to the roll-off of the baseband filters). Because of this, unwanted spurious signals can be aliased into the baseband more easily from the lower frequency side than from the upper frequency side (as these are attenuated by the roll-off). Thus, it is advantageous to choose the band edges in a manner that minimizes such aliased signals and it is advisable to keep the lower-frequency edge of the band at a frequency that is a multiple of 5 MHz (see Section 3).

3. Interference environment

Aside from some well-defined, strong, external sources of radio frequency interference (RFI) described below, most potentially harmful RFI in the P band is generated at the VLA antennas themselves. These are harmonic signals of the primary frequencies 100 kHz, 5 MHz and 12.5 MHz, which are generated in the "fringe generators" (L7 modules), the "timing generators" (L8 modules) and the "digital communication systems" (DCS modules). Most of the "100 kHz harmonics" are generated in the DCS modules (although the L7 and L8 modules add a minor contribution). These signals are mostly weak in the P band due to their high harmonic number, and are reasonably uncorrelated between the different antennas because the DCS clocks are deliberately unsynchronized. However, the slow fringe rate that corresponds to observations with the most compact configurations (D array and perhaps even C array) might allow these signals to contribute extra (noise) power to the observed visibilities. This is the reason for the recommendation of narrower band settings for observations with the D array and perhaps C array (see Section 6 below).

The "5 MHz harmonics" are generated in the L8 and DCS modules and the "12.5 MHz harmonics" are generated in the L7 modules. The L7 and L8 modules are mounted in the "B racks" located in the antenna vertex room and fairly well shielded by Faraday cages (the DCS modules are distributed throughout the antennas and are not shielded).

External interference arises at 307.2 MHz from ground to aircraft communication to the Albuquerque airport, which can be very strong at times, especially when the North-South runway is being used. There is little that can be done about this although, on occasion, discrete requests have succeeded in minimizing the use of this channel. A stronger and almost always present RFI signal occurs at 332.9 MHz, which is used by the Glide Slope transmitter at the Albuquerque and perhaps also El Paso airports as part of their Instrument Landing Systems. This channel is a primary frequency for that system that has made our former "best default" setting (330.0 — 333.125 MHz) essentially useless after 1996. Another such signal seems to have appeared after April 2000, as seen in the RFI monitoring plots. This signal has a frequency of 317.7 MHz and seems a bit weaker than the previous ones. I detected it in the test observations described below and found it to be "single-channel," short (less than the 10-second dump time) and quasi-periodic, appearing every 90 seconds to 120 seconds. The power seen in the LL correlations was more than twice that seen on the RR side.

In addition, other sources of RFI seem to originate at the VLA site, possibly due to computer (PC) clocks as even the "L band" PCs often seem to use primary clocks with frequencies in the P band. In the test observations described below, I detected RFI at 306.56 ± 0.3 MHz on short baselines to the antenna located on pad W20 (antenna 14, with some spill over the channels on either side), as well as at 326.56 ± 0.1 MHz (single channel) on baselines to the antennas located on pads W8 (antenna 6) and W12 (antenna 8) as well as an extra component of RFI at 307.2 MHz that affected all visibilities corresponding to the baseline W12 (antenna 8) with N8 (antenna 9). This is distinct from the contribution ascribed to aircraft communication described above, which affected at least two-thirds of all baselines and is generally a short burst (less than 10 seconds) that recurs every few minutes.

Most of these interfering signals are narrow-band and of tolerable strength (i.e., they do not seem to force the receivers into non-linearity), so that for continuum observations that use the spectral observing modes (the best option at P band) it might be sufficient to discard specific channels of the contaminated visibilities. However, even out-of-band RFI can be a problem if it falls within the band allowed by the bandpass and front-end filters, as it can lead to gain-compression in the modems that feed the VLA waveguide transmission system. This can lead to serious problems during daytime observations which should be avoided at P band, or restricted to frequency settings that can use the 12.5 MHz front-end filters.

4. Test Observations

I obtained 3 hours of test observations on 2003 December 13 (Saturday evening). I used four different settings arranged in two pairs with the 4 IF spectral mode BW 3 tuned to cover the frequencies 305.0 — 311.25 MHz (hereafter setting 1) and 315.0 — 321.25 MHz (setting 2) which were observed simultaneously, and 320.0 — 326.25 MHz (setting 3) and 325.0 — 331.25 MHz (setting 4) which were also observed simultaneously. After on-line Hanning smoothing, this resulted in sets of 15 channels of width 390 kHz for each of the frequency intervals.

Each setting was observed twice for 30 minutes of on-source observations of a relatively "blank field" (to the extent that there is such field at P band) at J0230+050. Each observation was bracketed by observations of J0137+331 (3C48) at the corresponding setting with at least 5 minutes on source each time. The 12 MHz front-end filter was used for the second frequency setting, whereas the 25 MHz filter was used for the other three settings.

5. Data Reduction

I reduced the data using the 31DEC04 version of AIPS. After separating the four observational settings, I deleted the "first dump" of each scan as well as some spurious data that were contaminated with values that exceeded the bulk of the values by a factor of about 10^4 (less than 0.1% of the visibilities). Next, I computed the appropriate flux values for 3C48, using SETJY which yielded the values: 44.73 Jy (308.125 MHz), 43.94 Jy (318.125 MHz), 43.55 Jy (323.125 MHz) and 43.17 Jy (328.125 MHz) (these "1999" VLA calibration values are $\sim$ 4% lower than those of the Baars *et al.* 1977) scale (for 3C48). Next, I evaluated the bandpass table using "scan" averages, without normalization by "channel-0" and applied this calibration using 2-point interpolation. This provided the full amplitude, phase and bandpass calibration to the data. The bandpasses corresponding to the first frequency setting were somewhat sloped in amplitude; although less than I expected given the "edge" of the bandpass filter. Figures 1 and 2 show two examples that correspond to one of the central antennas (antenna 18, located at N4). Some antennas showed a slightly larger slope for the first frequency setting although the effect was smaller in a number of them and it was even reversed in some (i.e. a more pronounced slope was seen on the third frequency setting than on the first one). In any case, the effect was small.

The calibrated, spectral visibilities for the target field were cleaned of some spurious data using "UVLIN" with a flagging threshold of 10 Jy, which resulted in the removal of a small fraction of the visibilities (about 6%). This mode of UVLIN retains the full visibility (i.e. no continuum is removed) on those that pass under the noise threshold.

The phases were remarkably stable, possibly because the observations were obtained at nighttime. A first set of the pseudo-continuum images described in section 5.2 below was obtained with only the bandpass calibration described above and used to determine phase corrections through phase-only self-calibration. For each setting (15 channels), I determined one phase correction per antenna and polarization per 1-minute time interval, which was applied to all the channels corresponding to that setting. Finally, I determined both amplitude and phase corrections through self-calibration with a 15 minute time inteval (again one correction for all 15 channels) using the pseudo-continuum images determined after the previous phase-only self-calibration.

5.1. Channel Images

For each frequency setting, I obtained a set of 201 image cubes (15-channels each) that covered a circle of 1-degree radius centered on the nominal pointing position supplemented with a "cube" for each source in the NVSS catalog with an L-band flux density in excess of 0.1 Jy that was located within 10 degrees of the pointing center and detected in this observation. These were found after an initial imaging run that used 581 fields selected with the AIPS task "SETFC" from the NVSS catalog (Condon *et al.* 1998) using the criterion stated above. The images were obtained using the "3-D" imaging option in "IMAGR" with "OVERLAP" = 2 and a robust parameter of 0.7. Using only the 60 fields that contained the strongest sources (43 in-beam fields plus 17 "flanking fields") resulted in noise levels that were $\sim 40\%$ higher than the ones obtained with 201 fields.

I obtained deconvolved cubes for both Stokes V and I, with the noise levels that are shown in figure 3 (these correspond to the I cubes obtained after the phase-only self-calibration. The noise level exceeds the theoretical level by $\sim$ 15 — 25%, mostly due to the sparse (snapshot) coverage of these observations. Indeed, the noise in the V cubes was about 10% smaller for each corresponding channel, close to the somewhat uncertain "theoretical" level.

The figure clearly shows the larger noise that corresponds to the "5-MHz" harmonics discussed above (Section 3). Small bumps correspond to the various sources of local rfi discussed as well. Minor editing of the contaminated (channel) visibilities (with "TVFLG") was sufficient to remove these hicups. The extra noise at 307.2 MHz and 317.7 MHz would have required discarding too large a fraction of the visibilities for these channels and thus eliminating these contaminated data was impractical. The rapid fringe rotation in the B array hides their effect in the images to a large extent; although these visibilites would likely have to be discarded in observations obtained in C array and almost certainly in D array.

Although the channel images obtained with setting 3 (320 — 326.25 MHz) are a bit noisier than those obtained with settings 2 and 4, this could be due to deconvolution errors because the frequency dependency of the primary beam results in different contributions from the sources in the flanking fields at the different settings. On the other hand, setting 3 was the cleanest one in these test observations as it showed no RFI except for the "5-MHz" birdie that affects channel 13 of every setting.

5.2. Continuum Images

Continuum images were obtained with IMAGR using proper gridding of the spectral visibilities, again using 201 fields. The rms noise levels reached were about 1.9 times what would have been expected from the rms noise levels in the channel images; but, as indicated in the previous section, the images were limited by the snapshot coverage. Even though the field was selected to be reasonably "empty," the images contain about 17 Jy (before any correction for the attenuation of the primary beam). The amplitude self-calibration did not have much of an effect on the channel images but improved the continuum images by lowering the noise by factors of about 0.8.

A final "continuum image was obtained from a straight average of the four continuum images without correction for the different response of the primary beam with frequency. This should not introduce too large an error in the central part of the field, and suffices to produce a reasonably deep "final" image (figures 4 and 5). The rms in this final image was

0.55 mJy/beam, about one order of magnitude larger than the value expected from source confusion alone in the B array but as good as could be expected from the four combined images. This shows that all four of the tested settings yield reasonable results.

6. Recommended Defaults

6.1. Defaults for VLA Observations

As discussed above, keeping a "5-MHz" birdie at the lower edge of the band prevents it from getting aliased into it and thus contaminating one or two channels. Other bands that verify this constraint are 310 — 316.25 MHz, which contains the very strong "12.5 MHz harmonic" at 312.5 MHz and the 330 — 336.25 MHz band which contains the external ILS RFI signal at 332.9 MHz. Having failed to get useful results with these bands in the past, I did not attempt to use them. One more band worth considering is the 335 — 341.25 MHz. However, past attempts to use this band showed poor sensitivity and I did not try to use it during these tests. As discussed in Section 5.1, the 320 — 326.25 MHz setting was free of RFI (except for the "5-MHz" birdie at 325 MHz) and should be considered the prime P band default. Only minor (local) RFI was present in the 325 — 331.25 MHz setting which should be our second P band default.

The slow fringe rates in the compact configurations (D and perhaps C) require using the cleanest bands. These remain the two "3-MHz" bands that are used in the present "PP" setting in JObserve. However, I recommend lowering the frequency of the "327 MHz" setting to 325 — 328.125 MHz which would avoid aliasing the 325 MHz birdie into the band. Thus, the "PP" mode should cover 320 — 323.125 MHz and 325 — 328.125 MHz using the "4 IF" mode. The first IF pair can use the 12 MHz front-end filter; although JObserve will return an error message, ostensibly because it believes the filter to be rectangular with a width of 12.2 MHz. The second IF pair requires using the 25 MHz front-end filter (see Table 1 for details). Daytime observations are likely to suffer from higher levels of RFI.

The more extended configurations can get better sensitivity using two of the "6-MHz" bands discussed in this memo, given that the higher fringe rates minimize the effect of the RFI. Although it would seem that using two non-overlapping bands would yield the best sensitivity, and in these tests the non-overlapping settings "2" and "4" yielded the lowest noise, I favor using settings "3" and "4" because they are the cleanest ones. Indeed, the origin of the 317.7 MHz RFI is presently not known. Given that the antennas were pointing southwards during these tests, the weak level of this RFI might indicate that it is once again associated with the Albuquerque airport or some other northernly source and thus might be much stronger in other observations.

Using settings "3" and "4" results in 2 channels of overlap. Given that channel 15 is noisier than the others (except for channel 13) due to the edge effect of the baseband filter, its loss is not too damaging. Shifting the edge of one of the settings in order to avoid the loss of the remaining overlap channel would lead to a contamination of at least one and possibly two channels due to the aliased "5-MHz birdie" which seems counterproductive. Therefore, I recommend that we modify the "P1" default to cover 320 — 326.25 MHz and 325 — 331.25 MHz, both with the 25 MHz front-end filters. Default "P2" is also addressed by these settings and should be dropped from JObserve.

Although good observations are likely using the settings 315 — 321.25 MHz (with the 12 MHz front-end filter) and 325 — 331.25 MHz (with the 25-MHz front-end filter) the 317.7 MHz RFI could be strong at times, so that it might be unwise to list this combination as a "default" in JObserve. Of course, use of the 305 — 311.25 MHz setting perhaps with the 320 — 326.25 MHz setting should also produce good results. Again, given the 307.2 MHz RFI, it would seem unwise to list this combination as a JObserve default.

6.2. VLA Defaults for Mixed-band Observations

The VLA is used on occasion to observe simultaneously at L band and P band, as well as at 4 band (~74 MHz) and P band. Because of the ~8′ pointing offset between the L band pointing and the P band pointing, the LP mode should only be used to observe highly-variable sources when simultaneous data at both frequencies are desirable. In other cases, it is better so intersperse separate observations at L band with those at P band (each with 4 IFs) as the sensitivity should be the same and the problems derived from the relative pointing offsets are avoided.

Observations that need the simultaneous data use the LP or 4P modes. The P band default invoked by these modes should be changed to the cleanest setting discussed above, that is 320.0 — 323.125 MHz with the 12.5 MHz front-end filter (although JObserve will return an error message as discussed in the previous section). An alternative option is to use the 325.0 — 328.125 MHz setting with the 25 MHZ front-end filter. Of course, using the 6.25 MHz bandwidth options 320.0 — 326.25 MHz and 325.0 — 331.25 MHz should work well for nighttime observations in A and B (and perhaps C) configuration.

6.3. Defaults for VLA use with the VLBA

The current default for incorporating VLA antennas into a VLBI observation (VP in JObserve) is unnecessarily narrow as it selects a 3.125 MHz band centered at 327.0625 MHz (325.5 — 328.625 MHz). In addition, it uses the 25 MHz front-end filters transmitting the 322.6 — 340 MHz band through the VLA waveguide which might lead to gain compression in the VLA modems due to excessive RFI pickup during daytime observations.

The P band at the VLBA[3] is defined by the hardware to cover 312 — 342 MHz (nominal band edges); although it seems that the response is quite good between 310 — 346 MHz. In addition to the slight mismatch of the usable P bands on the VLA and VLBA systems, the restrictions imposed by the VLA LO chain (Section 2) have to be taken into account as well. Furthermore, VLBI observations that use the phased-VLA can only use one frequency setting for all four IFs at the VLA because only IFs A and D can be phased-up independently.

As indicated in Section 2, there is only one setting that will cover the full VLA P band. It requires using the 50 MHz front-end filter with the first LO set at 710.1 MHz which allows a 35 MHz (305 — 339.9 MHz) band to be observed. Notice that the low-frequency side is cut off by the bandpass filter. Given that the "50 MHz" baseband filters at the VLA are in practice somewhat narrower, the flukes should be set at 115.1 MHz and 215.1 MHz. Although this will trigger a warning in JObserve as it effectively leads to a mismatch with the 50 MHz front-end filter, it might work well in practice as the mismatched portion is rejecter earlier by the bandpass filter and the setting will use the lower 34.9 MHz of the 50-MHz baseband filter. However, given that the strongest source of RFI is often the 332.9 MHz signal from the ILS system discussed in Section 3 above, it might be best to restrict the band to 305.0 — 330.0 MHz using the 25 MHz baseband filters. The hardware restrictions on the VLBA would limit the band to ~310.0 — 330.0 MHz. Although it is unlikely to be usable in the daytime, this setting might work well for nighttime observations. It should be tested to check that the RFI allowed by the 305 — 340 MHz bandpass filter does not drive the system (especially the VLA modems) into non-linearity.

The P band available to both the VLA and VLBA antennas could be covered as well tuning the first LO to 689.9 MHz, again using the 50 MHz front-end filter. This would yield the band 310.1 — 340 MHz, with the high-frequency edge again restricted by the bandpass filter. However, the 332.9 MHz RFI cannot be rejected with either the 50 MHz or the 25 MHz baseband filters and would require restricting the band with the 12.5 MHz baseband filter,

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[3]The Very Long Baseline Array of the National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

thus making this option unattractive.

Most often, the RFI environment might contribute excessive power over the full P band which could drive the VLA modems into nonlinearity. Using the 25 MHz front-end filter and setting the first LO to 710.1 MHz gives the band 310 — 327.4 MHz (lower cutoff from the VLBA limitation), whereas using a first LO of 689.9 MHz yields the band 322.6 — 340 MHz (upper cutoff from the bandpass filter) which contains the 332.9 MHz RFI from the ILS system discussed in Section 3 above. Even this option might lead to excessive RFI pickup during daytime observations.

Using the 12.5 MHz front-end filter would reject a larger portion of the RFI. The 710.1 MHz LO would yield the band 310.65 — 323.15 MHz which is likely to be the cleanest 12.5 MHz option and should be considered as the VP default in JObserve. Test observations should check the effect of the 317.7 MHz RFI on this setting. Using the 689.9 MHz LO would yield the band 330.85 — 340 MHz (limited at the high end by the bandpass filter) which again would contain the 332.9 MHz RFI from the ILS system discussed in Section 3 above.

If only one VLA antenna is used and therefore no phasing is necessary, the full VLA P band can be covered using the 4-IF mode with 25 MHz FE filters. IFs A and C would observe 302.4 — 327.4 MHz and IFs B and D would cover 322.6 — 347.6 MHz, again cut-off in practice below $\sim$ 305 MHz and above $\sim$ 340 MHz by the bandpass filters. However, given the low-frequency cutoff of the VLBA, it seems better to use the 12.5 MHz front-end filter for the lower-frequency part (as in the VP setting). I have listed this option as setting VP1 in Table 1; although RFI might once again preclude using such a wide band, especially in the daytime.

I thank Durga Bagri for teaching me much of what I know about the P band hardware at the VLA and for being most responsible for making it work, Ken Sowinski and Paul Lillie for answering many questions on the VLA LO chain and electronics and Robert Ridgeway for his help and comments with assessing the present RFI environment at the VLA. I also thank Tracy Clarke for sharing the results of some of her P band tests and Greg Taylor for several useful discussions on VLBA P band observations with the VLA. I am grateful to Eric Greisen for implementing the "3-D" imaging option in AIPS as well as a number of calibration and editing tasks. I have also benefited from valuable discussions with Barry Clark, Jim Condon, Bill Cotton, Ed Fomalont, John Hibbard, Dave Hogg, Frazer Owen and Dick Thompson.

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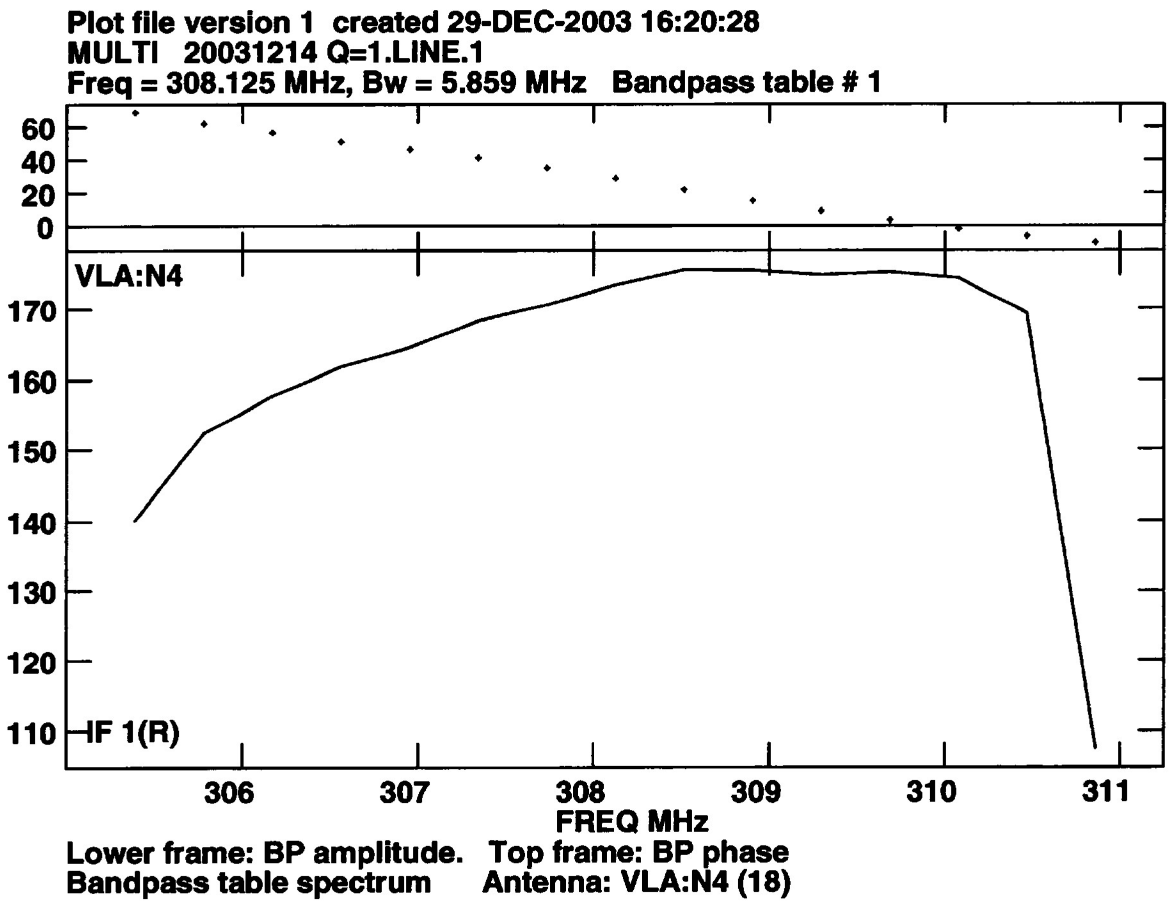

Fig. 1.— Sample bandpass for the lowest frequency setting on a centrally located antenna. Phase is at the top and amplitude at the bottom. Notice that the phases are not near zero and the amplitudes are not near unity as is customary because the bandpass provided full amplitude and phase calibration in the reduction used in these tests.

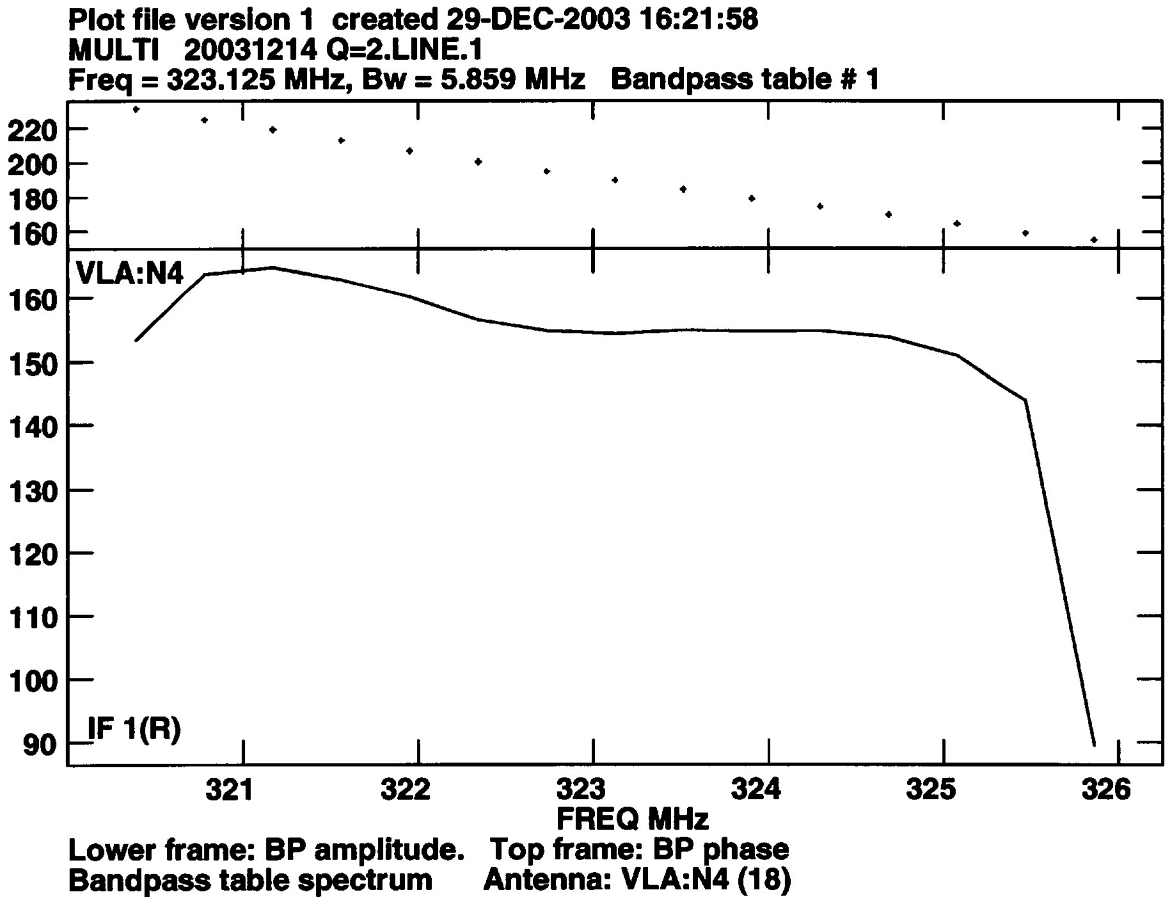

Fig. 2.— Sample bandpass for the third frequency setting on the same antenna used in fig. 1.

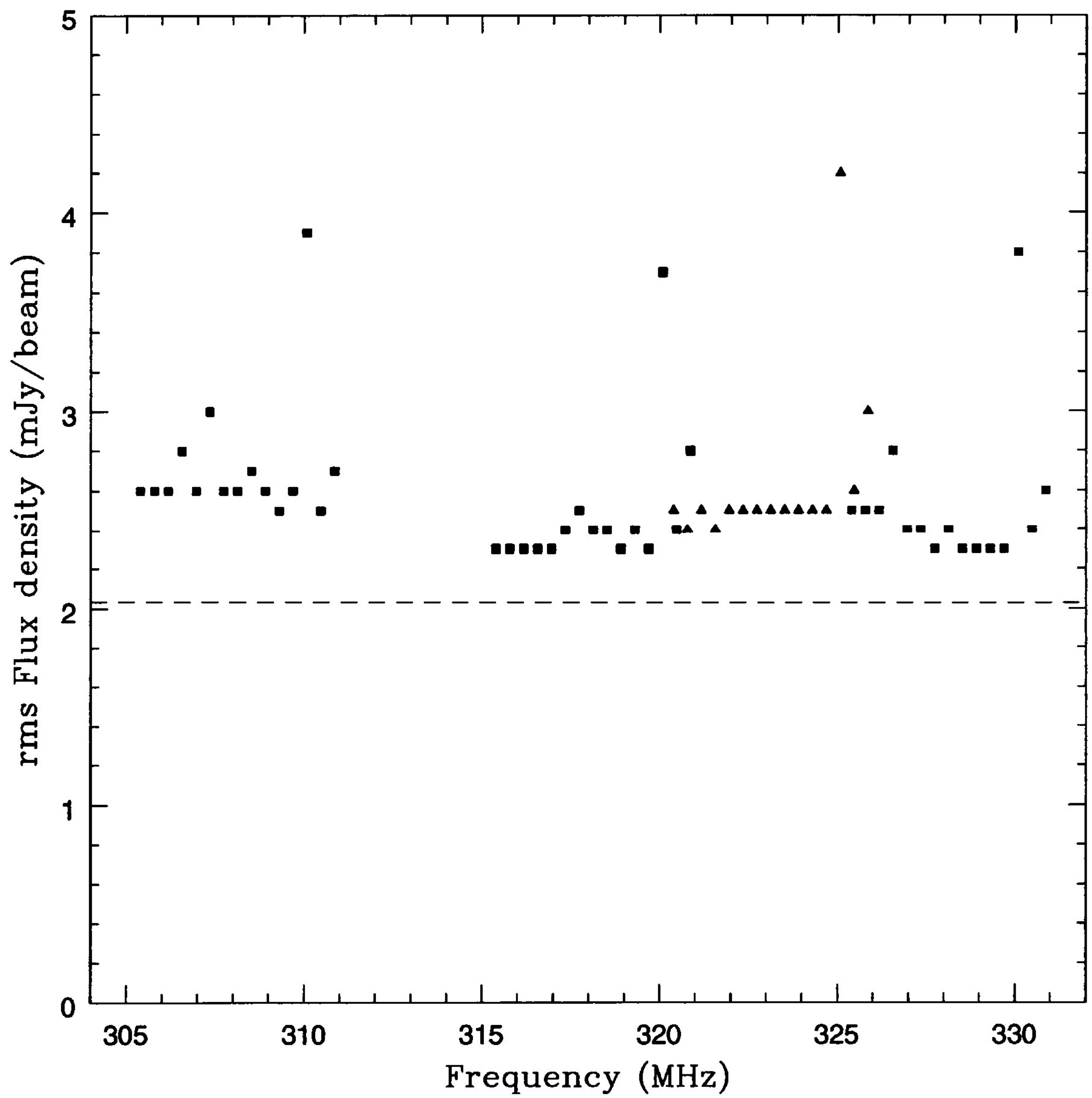

Fig. 3.— Observed rms noise in the Stokes I images as a function of frequency computed from the half-width of the pixel-intensity histograms obtained from the images of the different channels. The horizontal, dashed line corresponds to the theoretical noise. The third setting is shown with triangles for clarity. The images were made after a 60-second, phase-only self-calibration.

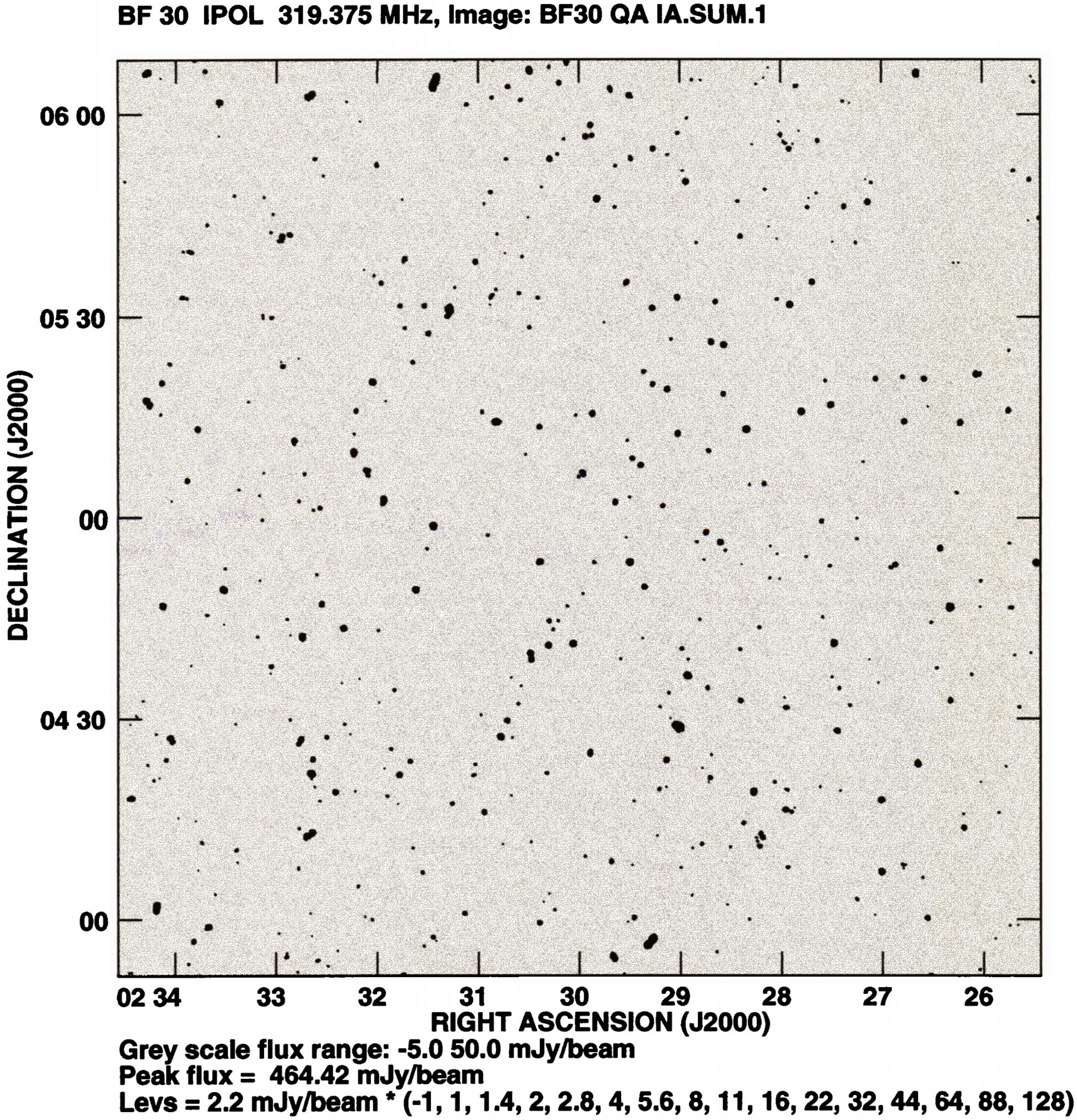

Fig. 4.— Contour and grey scale image of the central portion of the observed "blank" field. The contours are [-1.4 (absent), -1, 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 44, 64, 88, 128] times 2.2 mJy/beam (the 4σ level). The low-level structure which is barely visible is due to deconvolution noise arising from the incomplete coverage of the snapshot observation.

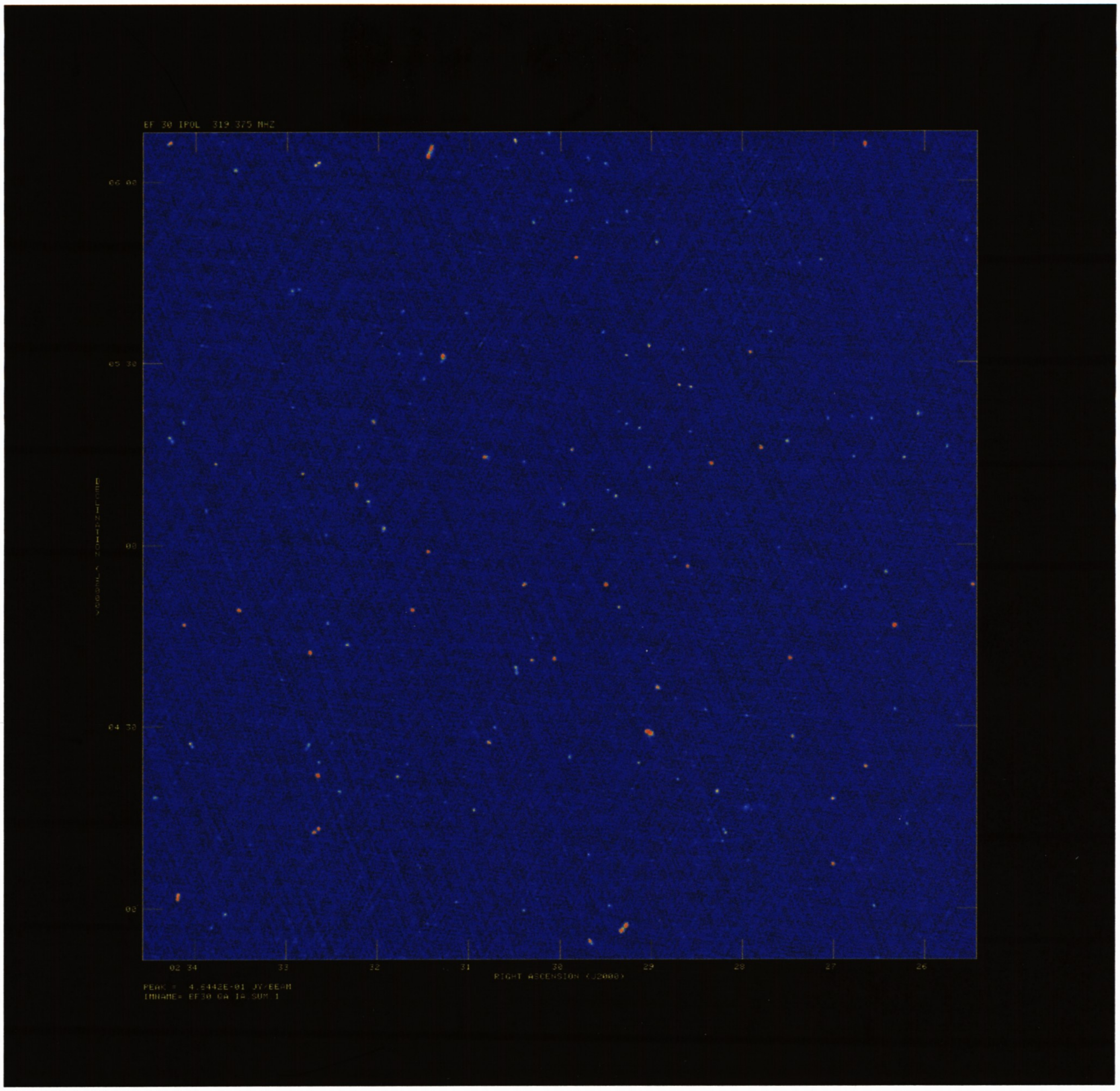

Fig. 5.— Another rendition of the image from the previous figure, using 64-color contouring with linear spacing from −5 mJy/beam to 50 mJy/beam. Again, the low-level structure, which is more clearly visible in this image, is mostly due to the incomplete coverage of the snapshot observation.

Table 1. Proposed P band defaults.

Code	A-C range	B-D range	AC LO	BD LO	AC fluke	BD fluke	FE Filter	BW code
PP	320.0 — 323.125	325.0 — 328.125	−710	−690	130.1	214.9	2121[a]	4444
P1	320.0 — 326.25	325.0 — 331.25	−710	−690	130.1	214.9	1111	3333
LP	1439.9 — 1489.9	320.0 — 323.125	−3.2, 3640	−710	100.0	230.1	0202[b]	0404
LP1	1439.9 — 1489.9	320.0 — 326.25	−3.2, 3640	−710	100.0	230.1	0101	0303
4P	73.02 — 74.58	320.0 — 323.125	−940	−710	112.91875	230.1	0202[bc]	5454
4P1	73.02 — 74.58	320.0 — 326.25	−940	−710	112.91875	230.1	0101[c]	5353
VP	310.65 — 323.15	310.65 — 323.15	−710	−710	120.75	220.75	2222	2222
VP1[d]	310.65 — 323.15	322.6 — 347.6[e]	−710	−690	112.5	212.5	2121	2121

Note. — All frequencies expressed in MHz. The LO frequencies are 689.9 MHz, 710.1 MHz, 939.9 MHz and 3639.9 MHz; but are rounded-off in the table to the values that are used in the observe files.

[a]The nominal edge of the 12 MHz FE filter might attenuate slightly channel 31 of the AC IFs. This should be a reasonable penalty in exchange for narrowing the accepted band for RFI rejection especially during daytime observations. Change to 1111 to use the 25 MHz front-end filter for the AC IFs.

[b]This filter setting might attenuate slightly channel 31 of the BD IFs, again a reasonable penalty in exchange for narrowing the accepted band for RFI rejection especially during daytime observations. Change to 0101 to use the 25 MHz front-end filter for the BD IFs.

[c]The 50 MHz FE filter is selected at 4 band only as a signal path, the 4 band system includes a narrow bandpass filter that minimizes RFI pickup.

[d]This mode can only be used for single-VLA-antenna VLBI.

[e]Restricted to $\sim$ 340 MHz by the bandpass filter.