VLB ARRAY MEMO No. 151

Nov. 30,1982

To: VLBA Project

From: R. C. Walker

Subject: Number of IF bands.

There is still considerable debate over the number of IF bands that the VLBA should have. Two options are 4 channels with frequency switching, as described in the proposal, and a large number of narrow bands following the style of the Mark III system. The later option is clearly more expensive but may be favored for certain kinds of experiments (see Shaffer, VLBA Memo 148). This memo attempts to explain my feeling that we should not sacrafice the ability to use wide-band channels. I have no objection, other than cost, to having the option of using many bands simultaneously. However I would like to have a maximum bandwidth something like that in the proposal, if not the full 50 MHz.

The choice of the number of IF bands and the maximum bandwidth per band will have a large impact on the design of the IF system and the correlator so it should be made soon. However, it should not influence the design of the record system, a point that is either not understood or not argeed upon by everyone (see Memo 148). The record system should be transparent to the rest of the system so that we can easly switch technologies if and when better options than those we now have become available. We should be able to spread as many IF bands as we need across as many recording channels as the system has; only the total number of bits per second is constrained. Concerning the options that we are now considering, the cassette system may seem complicated but the Mark III system, without the bit density increase that has not yet been demonstrated, would break the array's operating budget.

First I would like to respond to some points made in Memo 148.

1. The limits to the accuracy of delay measurements described by Shaffer assume that no attempt is made to compensate for the slight time shift of the different switch cycles by using the fitted residual fringe rate or by picking appropriate integration intervals. The problem is barely significant when no corrections are made so it should not be a problem if some attempt at correction is made.

2. My experience with frequency switched observations (water masers) shows that keeping track of the switching is not a serious problem, even with a system that is primitive compared to the VLBA. The complexity of the bookkeeping later is purely a function of the number of separate bands, regardless of whether they were simultaneous or switched. With a system that has only narrow bands, the observers would be forever condemned to many bands even though the vast majority of experiments could be done at least as well with a small number of wide bands.

3. The correlator dump time must be short to support frequency

switching. It must also be short to support observations of sources in large fields (many water masers), to support phase slope corrections for the fractional bit shift (if all baselines are done the same way and we have short baselines with slow update rates, phase slope corrections seem to be better than statistical methods), or if we use a recirculating design. Therefore the fast dump rate needed for switching may be there in any case.

The factors that make me favor retaining a wide-band capability are outlined below. Some of them are clearly arguments for the wide-band system. Others are concerns that should be addressed by the engineers but that I suspect are more easily handled with a wide-band system.

1. Strong maser sources can significantly affect, or even dominate, the system temperature. A major problem in calibrating multiple-band maser observations is calibrating the relative gains of the various bands. With a single band, a reference feature can be used for calibration (an especially powerful form of self-cal), but with multiple-bands, the amplitude fluctuations due to atmospheric effects will depend on the strength of the maser signal in the band and will not be well correlated from band to band (eg. if the attenuation goes up, the system temperature may go up in channels with little signal and down in channels with lots of signal). Use of a wide band channel to cover the entire (12 MHz or more) spectrum avoids this problem.

2. Some spectral line observations made with the VLBA may be limited by the ability to determine the bandpass shape over wide frequency ranges (> 4 MHz). These will generally be observations of weak lines on top of strong continuum sources such as absorbtion lines in galaxies, including our own, and observation of stimulated recombination lines. The recombination line observations, for example, require determinations of the bandpass to better than one percent over several MHz. I imagine it is much easier to calibrate the bandpass if it is determined by one wide filter that if it consists of several adjacent, separate bands.

3. Current continuum VLBI observations are probably limited in dynamic range by closure errors that have not been calibrated (cf. Wilkinson, 1982). Closure errors are an area that should receive very close attention from all concerned with the VLBA design because they are likely to be a major limiting factor in determining how well the VLBA can meet its primary design goal - to make high dynamic range maps of continuum sources. Thompson and D'Addario (1982) present an analysis of sources of such errors. We should try to keep them well under 1% in gain effect. With the small number of baselines in the VLBA relative to the VLA, the effects of baseline-dependent errors will be much worse for the VLBA. Note that errors on timescales of hours to months will be the most serious because they will be difficult to calibrate carefully and they will not integrate out. I suspect that it will be easier to avoid closure problems with a

wide-band system but this is just a guess. We should obtain an analysis from the engineers of the relative merits of the various systems in this regard. The analysis should include the effects of partial failures such as loss of an IF or of a recording medium track.

4. If a multiple-band system is used, it should be possible to place the bands as close together in frequency as possible without obtaining redundant information. This is to avoid limiting the field of view as determined by the delay beam. Note that the first null of the delay beam (well beyond the region of good performance) for the longest baselines of the VLBA is 150 milli-seconds of arc from the phase center for a 50 MHz bandwidth. This may prove to be a problem, especially at the lower frequencies. A single, wide band would provide the narrowest total bandwidth for a given summed received bandwidth.

5. I suspect that both fringe fitting and calibration will be easier with a wide-band system. All the concerns over the relative performance of the various separate bands are avoided. The fringe fitting and searching is simplified because clock errors (phase slope with zero at each band edge) and geometric offsets (global phase slope) are not separate parameters (use multiple-bands or frequency switching when this is desirable). Fringe fitting is projected to be one of the major computing loads for the VLBA, even assuming dramatic increases in speed over current Mark III algorithms. Anything to speed it up will be valuable.

Let's not forget that the VLBA is intended as a mapping instrument. Even water maser spectral line observations will probably be considerably more frequent than bandwidth synthesis astrometry-geodesy observations. Relative position astrometry and phase calibration using a reference source will be more frequent and will require much of the precise work of geodetic observations, but they probably will use phase connection and the same observing mode as normal mapping experiments. We must not preclude bandwidth systhesis, but when a choice of equipment depends on convenience for various kinds of observations, mapping should take precidence.

References:

Thompson, A. R., and D'Addario, L. R. (1982), Radio Science, 17, 357.

Wilkinson, P. N. (1982) Preprint No. 693 from Jodrell Bank ( To be published in the proceedings of the International Conference on VLBI Techniques held in Toulouse, France, August/September 1982, under the auspices on the CNES).