~~Rick~~, ~~It [illegible] [illegible] [illegible] [illegible] such a file!!! Val~~

C.S.I.R.O.—DIVISION OF RADIOPHYSICS

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MEMORANDUM from Rick Forster Date 27/11/84

to Val Petro

AT/20.1.1/006

Val -

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off on your good printer, give it an AT number (Systems & Performance), and distribute it to: Section Heads, ATSOC and ATAC members please Val?

Thanks, Rick.

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Observational Consequences of Linearly Polarized Feeds for the AT

JRF - 27/11/84

AT/20.1.1/006

INTRODUCTION

Linearly polarized feeds for the AT antennas have been recommended by ATSOC (AT/16.3/007) and the AT Advisory Committee (AT/16.2/008), and is generally accepted by the project designers. The recommendation is based mainly on the difficulty of making a broadband circular polarization splitter and the desire to maintain good polarization characteristics over a broad RF band. It is felt that the increased complexity of the calibration proceedure, and the necessity of accounting for parallactic angle affects, is outweighted by the improved bandwidth and purity of linearly polarized feeds.

ALT-AZ mounts are used on all of the AT antennas, so the feed position angle varies as the parallactic angle. This variation in position angle means that for a point source, a linearly polarized component causes the visibility amplitude measured in a single parallel hand correlation to change with time. This variation results in artificial structure in the map unless the polarization is accounted for. The magnitude of the artifact is roughly the magnitude of the linearly polarized component; often 10% or more of the total intensity. With circularly polarized feeds, no parallactic angle dependence appears in either of the two parallel hand (RR and LL) correlations. This, and the fact that for most sources the linearly polarized component is likely to be much stronger than the circularly polarized component, is why circular feeds are preferred when only one correlation product is available.

In this note the observational consequences of using linear feeds are investigated. We will assume that the calibration of the two linear polarization channels is perfect in order to simplify the discussion. We restrict our attention to cases where an accurate brightness distribution is desired, and not full polarization. If full polarization mapping is desired, it makes no difference in principle whether linear or circular feeds are used.

COMPACT ARRAY

In the present design, the Compact Array antennas have four independent IF channels available as output. If only two frequencies are used, then both horizontal (X) and vertical (Y) polarizations can be output for each frequency. In this case the true total intensity (I) distribution can be derived in the presense of linear polarization, provided that at least the two parallel hand (XX and YY) products are developed in the correlator. If more than two frequencies are used, both polarizations cannot be received for all frequencies. In the presence of linear polarization then, ONLY TWO FREQUENCIES MAY BE OBSERVED SIMULTANEOUSLY in order to properly map I.

A corollary is that at least TWO CORRELATIONS MUST BE PRODUCED at each frequency in order to derive I. This means that even if only I is desired, two correlation products must be developed in the correlator. This does not mean that two maps must be made from the correlations; if only I is desired, the visibilities may be added and only the sum mapped. If circular feeds were available, only half the number of correlator channels would be required to map I assuming there is no circular polarization.

On the bright side, there is an improvement of root 2 in signal to noise ratio in an I map generated from the sum of two parallel hand correlations compared to a map generated from only one. This increased sensitivity means that one could share his observing time between two sets of dual frequency observations, each of which uses two correlation products per frequency, and get the same S/N as a simultaneous four frequency observation. The correlator requirements are also the same in both cases.

There are three kinds of observations that I can think of which may be affected by the above requirements. The first is simultaneous observation of the four OH maser transitions. OH masers have very substantial amounts of linear (and circular) polarization. Although at 5 arcsec resolution the compact array will not resolve many OH maser clusters, accurate I and P (linear polarization) distributions for complicated regions would certainly be desirable. The nice thing about simultaneous observation of these transitions is that the instrumental and atmospheric effects are likely to be very similar, and accurate relative positions may be expected. Fairly rapid frequency switching (timesharing) between 2 pairs of OH transitions could provide similar accuracy, however. In view of the large amounts of circular polarization from OH masers, it is not clear that the situation would be any better if circular feeds were available.

The second type of observation likely to be affected is bandwidth synthesis. In order to cover a large range of frequencies in the least amount of time, an observer may wish to divide his four IF channels into four well separated bands, for example, the top and bottom ends of L and S bands. Except for HII regions, most astrophysically interesting continuum sources have some amount of linear polarization. One is therefore restricted to observing only two different frequencies simultaneously. However, coverage of all four frequencies could still be accomplished in timeshared groups of two frequencies as suggested above.

The third kind is observations which are correlator channel limited. These are generally line observations for which there are not enough correlator channels to give the frequency resolution desired. The usual solution is to give up one of the correlation products (if more than one have been provided for) and use the released correlator channels to improve the resolution. If two correlation products are required because of polarization considerations, this limits the maximum frequency resolution available from the correlator. However, most of the channel limited line cases are not masers, and are therefore not likely to have linear polarization. There are no channel limited cases in the continuum; there are just enough correlator channels to process two correlation products at L band and still avoid bandwidth smearing for a 160 MHz bandwidth. If the maximum continuum bandwidth were to be increased, however, this would become a channel limited case.

LBA

For the LBA the same conditions on mapping linearly polarized sources apply. The current plan for the AT LBA antennas is for two linearly polarized IF channels to be recorded on tape for later correlation. For the Culgoora, Parkes and Siding Spring antennas, which all have linear feeds on ALT-AZ mounts, both IF channels must be at the same frequency in order to obtain an accurate I map in the presence of linear polarization. THIS PRECLUDES LBA OBSERVATIONS AT TWO FREQUENCIES SIMULTANEOUSLY for this kind of observation. Timesharing of two frequencies would ease this limitation, if it could be accomplished for the LBA. Whether this would seriously compromise geodesic and astrometric measurements probably depends on the rate at which the frequencies could be switched. For other kinds of measurements, particularly of transient phenomena, true simultaneous dual frequency capability would be valuable regardless of the polarization.

Another complication arises because of the possibility that some of the non AT antennas (Tidbinbilla, Hobart etc.) might be equipped with circular feeds. In the event that two linear outputs must be correlated against two circular outputs, again at least two correlation products are required to properly map I in the presence of linear polarization. The disadvantage of extracting an I map from mixtures of linear and circular polarization is that, in general, more data processing is required, and twice as many correlation products must be developed in order to achieve the maximum sensitivity in an I map. If all Stokes parameters are desired, there is no apparent disadvantage in mixing linear and circular feeds.

VLBI

The current convention in VLBI experiments is to record a single sense of circular polarization from each participating telescope. If only linear outputs are available from AT antennas, both linear channels must be recorded in order to maintain maximum sensitivity. This requires twice as much magnetic tape and twice as much processing as would be required if circular outputs were available. However, it is expected that as VLBI reaches maturity, both senses of polarization will be recorded. In this case the only disadvantage is that four correlation products must be formed and combined to get the same sensitivity in an I map as combining two parallel hand circular correlation products. Of course, if all four Stokes parameters are desired, four products must be developed in any case.

LINEAR-TO-CIRCULAR CONVERSION

Along with the recommendation for linear feeds on the AT antennas, both ATSOC and the AT Advisory Committee suggested the inclusion of systems to convert the linear outputs to circular for those observations where circular outputs are required. The conversion may be done either at RF or IF. If it is done at RF, the restriction on the number of simultaneous frequencies disappears since the circular outputs are available before mixing and switching to the output IF channels. If it is done at IF, two IF channels are required at each frequency to form the circular outputs, so the restrictions still apply.

In the case of the Compact Array, there appears to be little to be gained from circular outputs over linear outputs. For the LBA the case for circular outputs is stronger. For the Culgoora tied array, conversion at IF is more efficient since only the added output needs to be converted. For the Parkes and Siding Spring antennas conversion at RF appears necessary if simultaneous dual frequency operation of the LBA is to be maintained. Note that dual frequency operation of the LBA will require that two IF linear to circular conversion systems be built for the tied array, one for each frequency.

SUMMARY AND RECOMMENDATIONS

Given that the AT is to use linearly polarized feeds, it is advisable to combine the XX and YY correlation products in all cases where the presence of linearly polarized radiation is suspected. This requirement has consequences on the use of more than two frequencies simultaneously, and on the number of correlator channels required for some observations with the AT Compact Array. The main disadvantage of requiring both XX and YY correlations occurs in channel limited observations.

The restriction to two simultaneous frequencies can be largely overcome by switching between sets of two frequencies, although this results in only near-simultaneous observations. Timesharing would not require any more correlator channels nor result in a loss in sensitivity over the equivalent four simultaneous frequency observation. The feasibility of a timesharing system for the AT should be investigated. The switching time would be on the order of an integration time, typically 10 seconds.

In view of the restriction to two simultaneous frequencies with the Compact Array, the need for four independent local oscillators should be reexamined. Although four LO's could be useful for sources with no linear polarization, there appears to be no significant advantage to a four LO system over timesharing frequency pairs. The restriction to two frequencies also has implications on the number of correlator configurations which need to be accommodated.

Because of the potential use of the LBA antennas in VLBI experiments, circularly polarized outputs are desirable for the Culgoora tied array, Parkes and Siding Spring telescopes. This is most efficiently accomplished for the tied array at IF, after the linearly polarized outputs from the Compact Array antennas have been added. In order to maintian dual frequency capability for the LBA, RF conversion systems are required for the Parkes and Siding Spring telescopes. Alternatively, the conversion could be done at IF and timesharing used to produce near-simultaneous observations when required.