VLB ARRAY MEMO No. 320

Use of Linear Polarization for the VLBA

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February 14, 1984

We have considered only circularly polarized feeds for the VLBA, primarily for historical reasons. Since the bandwidth, and in some cases the system temperature, of the receivers is compromised by the circular polarizer, we should at least think about using linear polarization.

The primary reason that past VLB work has emphasized the use of circular polarizations is that a reasonable approximation to the Stokes parameter I is to be had by simply taking the output of a single correlator, because source circular polarizations are very small. A secondary reason is that the line maser sources are frequently naturally circularly or nearly circularly polarized, so that it is convenient, again, to look at a single correlator to see a spectrum in circular polarization.

In normal astronomical observing, it seems to me that there are strong reasons to observe with matching bandpasses in two orthogonal polarizations as a standard mode. Observations in a single polarization would only be done in special cases when dictated by special considerations. The four correlators of a full polarization processor give

$$I\cos(\chi_1-\chi_2) + Q\cos(\chi_1+\chi_2) + iU\sin(\chi_1+\chi_2) + iV\sin(\chi_1-\chi_2)$$
$$I\sin(\chi_1-\chi_2) + Q\sin(\chi_1+\chi_2) - iU\sin(\chi_1+\chi_2) - iV\cos(\chi_1-\chi_2)$$
$$-I\sin(\chi_1-\chi_2) + Q\sin(\chi_1+\chi_2) - iU\sin(\chi_1+\chi_2) + iV\cos(\chi_1-\chi_2)$$
$$I\cos(\chi_1-\chi_2) - Q\cos(\chi_1+\chi_2) - iU\sin(\chi_1+\chi_2) + iV\sin(\chi_1-\chi_2)$$

where χ is the paralactic angle at the subscripted station.
The above expressions are for the case of perfect feeds . There is an obvious but messy extension to the case of an imperfect feed. These are, in principle, no more difficult to work with than for circular polarizations. In fact, a simple combination

$$(VV+HH)*\cos(\chi_1-\chi_2) + (VH-HV)*\sin(\chi_1-\chi_2)$$

is a reasonable approximation to I (where VV etc denote the four correlators operating on the vertical and horizontal polarizations).

There is some traditional hesitancy about using linear polarizations for interferometers because the derivations of Q and U usually involve differences of much larger numbers. However, experience at Westerbork, etc, indicates that these differences are much better behaved than the raw amplitudes themselves. There is currently no evidence that the use of linearly polarized feeds would degrade the accuracy of VLBA linear polarization measurements, and they would surely not be worse than circularly polarized feeds for circular polarization measurements.

For some experiments the use of linear polarization is not suitable, either because one wishes to conserve the number of IF channels recorded, as in the case of synthesized bandwidth delay determination, or because

one wishes to use a simple correlator rather than a polarization processor, to maximize channels in a line observation. I do not know of such a case that requires very high purity of circular polarization. It probably suffices for these cases to provide a switchable hybrid, with a computer controlled phase shifter in one arm, in the 500 MHz bandwidth IFs, to synthesize circular polarization at this point.

In summary, although circularly polarized feeds have major advantages in simplicity of concept and usage, if the circular polarizers contribute to major physical or cost constraints, the option of using linearly polarized feeds is not entirely closed to us.

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