CSIRO DIVISION OF RADIOPHYSICS

THE AUSTRALIA TELESCOPE

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Tech Notes
Systems & Performance

# DIFFERENTIAL DELAYS IN POLARIZERS

Concern has been expressed that the non symmetrical design of the L/S and C/X polarizers may result in significant differential delays between polarization channels. Certainly there is a geometrical path difference which should be equalized to a first order in coax or waveguide. It is however the variation of the differential delay with frequency (non linear differential phase slope) which may cause problems. This will require that the fine delay (sampler phase) - (a) be different for the two polarizations, and (b) the difference be a function of frequency. Clearly the relationship involved needs at least to be stored in a look-up table for use when first setting up for an observation. It is however important that in addition (or instead) we have a procedure for actually measuring and equalizing the delays in the two polarizations. This procedure would be part of a set of calibrations to be carried out at the beginning of an observation. (It may also be repeated during observations if necessary). For equalizing the delays between antennas the proceedure involves detecting a phase slope across the bandwidth in the output channels of the correlator. For the differential delay between polarization channels a similar procedure cannot be followed unless we provide a range of delays in the switched correlators. These correlators were originally designed to measure the phase difference between polarization channels.

If the phase error is actually measured by accumulating 3 (or more) lagged products then the delay error will also be measured as a by-product. For example if 3 products (r(1), r(0), r(-1)) are accumulated, the bandpass is rectangular and the phase difference between polarization channels is small then the differential phase and delay are given by:-

$$\tan \Delta\phi = \frac{\pi}{4} \; \frac{r(1)-r(-1)}{r(0)}$$

$$\Delta\tau = \frac{\tau}{4} \; \frac{r(1)+r(-1)}{r(0)}$$

where $\tau$ is the sample interval.

If $\Delta\tau$ is to be measured with a precision better than $\frac{1}{32}$ of a sample interval then the error in measuring $\frac{r(1)+r(-1)}{r(0)}$ should be $< \frac{4}{32} = \frac{1}{8}$. For r(1) and r(-1)<r(0) this is equivalent to an error in measuring r(0), r(1) and r(-1) of $\Delta\tau \cong \frac{r(0)}{8\sqrt{2}} = 0.09\ r(0)$.

In fact (AT/20.1.1/020) the error in measuring correlations in the switched correlator is

$$\frac{\Delta r}{r(0)} = \frac{\sqrt{2}\ \frac{T_s}{T_N}}{\sqrt{Bt}}$$

For $\frac{T_N}{T_s}$ = 5%, B = 0.5 MHz and an integration time t = 10 sec.

$$\frac{\Delta r}{r(0)} = 0.013.$$

Thus the differential delay between polarization channels can be measured with the switched correlators with a precision well in excess of that required.

The actual situation is more complicated than that described above. For the AT the phases between polarization channels will be maintained at 90° rather than zero, the bandpass will not be rectangular and possibly more than three lagged products will be accumulated in the switched correlators. The above example however illustrates the adequacy of the switched noise system to perform the required delay measurements.

The above discussion indicates how frequency dependent delay differences between polarization channels can be measured and removed by appropriately offsetting the phases of the sampler clocked. It does not address the problem of decorrelation in polarization measurements due to differential delays which vary with frequency within a passband. The effect of this is that the gains associated with XY and YX products will be less than those associated with XX and YY products. If as expected the effect is stable it should calibrate out. In addition preliminary worst case calculations by Graeme James suggest that the effect is negligible. For a 128 MHz bandwidth at the lower end of L band the differential phase delay between polarizations is expected to deviate from a straight line (constant delay difference) by less than 1°.

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