CSIRO DIVISION OF RADIOPHYSICS

MEMORANDUM **from** M.M. Komesaroff **Date** 3 October 1985

to Astrophysics Group and others interested

AT/21.3.1.1/006 ✗
<u>Antennas and Feeds Tech Notes and Reports</u>

It would be helpful if you could look this over and let me have your comments, corrections and criticisms at or before the Astrophysics Group meeting next Tuesday, 8/9/85.

Thanks.

Max.

Encl.

— arrived on my desk 13/11/85?

AT/21.3.1.1/006
Antennas and Feeds Tech Notes and Reports 25/9/85

Feed and Receiver Configurations for Parkes - for LBA and for single dish work

1. Requirements of Parkes Feeds

In early 1986 two Australia Telescope dual-channel receivers will be available for Parkes, one for C-band and the other for X-band. However the feeds for the 22-m compact array telescopes will not be suitable for Parkes (see for example AT/22.5/003).

The purpose of this note is to suggest arrangements for coupling feeds into the Parkes receivers, such that the following conditions are satisfied.

1. The feed arrangements should be suitable for either polarimetry or dual beam measurements.
2. When used for polarimetry the option should exist of accepting either two orthogonal linear polarizations or opposite circular polarizations.
3. No switch should be required.
4. Only one waveguide should go into the Dewar containing the receiver.
5. In changing from one polarimetry configuration to the other, or in changing from the polarimetry to the dual-beam configuration, it should not be necessary to open the receiver Dewar.

2. Continuum Measurements

(a) Polarimetry

Figures 1 and 2 illustrate two possible feed configurations suitable for polarimetry. In Fig. 1a circular waveguide passes from a circular horn into the receiver Dewar. Within the Dewar the circular waveguide is terminated, via a matching section, in an "orthogonal mode transducer". This device, of which there is currently one example for X-band with the

Receiver Group, has the property that it resolves an accepted wave into two orthogonal linearly polarized components, the voltages corresponding to which are coupled out through two rectangular waveguides.

In Fig. 1 the voltages, v_1 and v_2, corresponding to the two orthogonal linear polarizations, are amplified by the two independent RF amplifiers, mixers and IF amplifiers. The two mixers have a common local oscillator. The amplified IF signals V_1 and V_2 pass to a "polarimeter back end" similar in principle to the H105-1, IF Polarimeter described by Wilson, Hoesgen and Bestgen (1974).

This device has two input ports, for the two IF voltages V_1 and V_2, and four output ports. Of the voltages from the four output ports, two are proportional to the correlations $<V_1V_2>$ and $<V_1V_2(\pi/2)>$, and the third and fourth are proportional to $<V_1^2>$ and $<V_2^2>$ respectively.

Here the angle brackets denote time averages, $<V_1V_2>$ denotes the "in phase" correlation of V_1 and V_2 and $<V_1V_2(\pi/2)>$ is the "quadrature" correlation, obtained after a relative phase shift of $\pi/2$.

If the gains of the systems 1 and 2 are g_1 and g_2 we may write for the two correlation terms

$$<V_1V_2> = g_1g_2<v_1v_2> \propto g_1g_2\ U$$

$$<V_1V_2(\pi/2)> = g_1g_2<v_1v_2(\pi/2)> \propto g_1g_2\ V \quad .$$

Here Stokes parameter U is the component of linearly polarized flux density measured in a direction which bisects the angle between the two received linear polarizations. Stokes parameter V is the circularly polarized component of flux density.

Taking the sum and the difference of the voltages from the other two output ports we have

$$\begin{aligned}<V_1^2> + <V_2^2> &= g_1^2[<v_{n1}^2>+<v_1^2>] + g_2^2[<v_{n2}^2>+<v_2^2>]\\ &\propto g_1^2[S_{n1}+I/2+Q/2] + g_2^2[S_{n2}+I/2-Q/2]\end{aligned}$$

$$\begin{aligned}<V_1^2> - <V_2^2> &= g_1^2[<v_{n1}^2>+<v_1^2>] - g_2^2[<v_{n2}^2>+<v_2^2>]\\ &\propto g_1^2[S_{n1}+I/2+Q/2] - g_2^2[S_{n2}+I/2-Q/2] \quad .\end{aligned}$$

The voltages v_{n1} and v_{n2} represent the system noise referred to the inputs of the RF stages, and S_{n1} and S_{n2} represent the system noise expressed as flux densities. Stokes parameter I is the total flux density and Q is the component of linearly polarized flux density for which the E-vector has the direction corresponding to v_1.

With the gains of the two channels equalized, i.e. with $g_1 = g_2 = g$

$$<V_1^2> + <V_2^2> \propto g^2 [S_{n1} + S_{n2} + I]$$

$$<V_1^2> - <V_2^2> \propto g^2 [S_{n1} - S_{n2} + Q] \quad .$$

With the best low noise receivers S_{n1} and S_{n2} will be $\gg$I for the majority of continuum sources at frequencies $\gtrsim$1 GHz. Thus for accurate measurement of I very stable receivers will be required. At X-band and higher frequencies, there may be time-variable compounds of S_{n1} and S_{n2} due to clouds, and for these reasons the most accurate measurements of I in the continuum may require a dual beam technique such as that described in Section 3 below. For most continuum sources Q $\ll$ I and thus the relation

$$<V_1^2> - <V_2^2> \propto g^2 [S_{n1} - S_{n2} + Q]$$

will not yield a value of Q of accuracy comparable with that which U can be measured from the correlation

$$<V_1 V_2> \propto g^2 U \quad .$$

In order to measure Q and U with equal accuracy using this configuration it will be necessary to measure the correlation term $< V_1 V_2>$ at two orientations of the feed assembly, separated in position angle by 45°.

Figure 2 is identical with Fig. 1 except that Fig. 2 shows a section of circular waveguide outside the Dewar replaced by a section containing a quarter wave plate, oriented so as to bisect the angle between the two accepted linear polarizations. The accepted polarizations are now the opposite circulars. For equality of gains the four outputs are

$$\langle V_1 V_2 \rangle \propto g^2 \; U$$

$$\langle V_1 V_2(\pi/2) \rangle \propto g^2 \; Q$$

$$\langle V_1^2 \rangle + \langle V_2^2 \rangle \propto g^2 \, [S_{n1} + S_{n2} + I]$$

$$\langle V_1^2 \rangle - \langle V_2^2 \rangle \propto g^2 \, [S_{n1} + S_{n2} + V] \; .$$

This configuration is suitable for those situations in which only the linear polarization and total intensity are required.

(b) Dual-beam operation

At X-band and higher frequencies the most accurate measurements of I are made using a dual beam configuration, in which the response of the system is the difference in the responses of two horns, pointing in two directions having a small angular separation on the sky.

A dual beam system is illustrated in Fig. 3. The circular horn of Fig. 1 has been replaced by another orthogonal mode transducer, with its output ports rotated through 45° with respect to the output ports of the transducer within the Dewar. The two rectangular waveguides are connected to two horns.

If v_a and v_b are the instantaneous voltages from the two horns, and if v_1 and v_2 are the voltages to the two receiver front ends, then apart from a constant phase term ,

$$v_1 = \frac{v_a + v_b}{\sqrt{2}}$$

$$v_2 = \frac{v_a - v_b}{\sqrt{2}} \quad .$$

The output of the "in phase" correlator is then

$$\langle V_1 V_2 \rangle = (g_1 g_2/2)\,[\langle v_a^2 \rangle - \langle v_b^2 \rangle]$$

a result independent of system temperature.

Note: As represented in Fig. 3 the horns accept one sense of circular polarization, since for almost all continuum sources the degree of circular polarization is less than 1%.

3. Spectral Line Observations

For spectral line observations a dual-beam system is not required (see AT/22.5/003) and thus only the "polarimeter" feed configurations need be considered.

For spectral line work there would be ideally, instead of the "polarimeter back end", two digital autocorrelators, to calculate the autocorrelation functions of V_1 and V_2, and one cross correlator of twice as many lags, to calculate the cross correlation of V_1 and V_2. The cross correlation can be resolved into a symmetric and an antisymmetric component. The symmetric and the antisymmetric components, after Fourier transformation, yield terms corresponding to $<V_1 V_2>$ and $<V_1 V_2(\pi/2)>$, respectively, in the continuum case.

4. Relative merits of the two "polarimeter" configurations

Table I lists the advantages and disadvantages of each "polarimeter" configuration. Since there are arguments for both configurations for LBA work (see for example AT/10.1/039), and since changing from one configuration to the other is a relatively small operation, it seems that provision could be made for both.

TABLE I

RELATIVE MERITS OF THE TWO "POLARIMETER" CONFIGURATIONS

CONFIGURATION 1 (Figure 1)		CONFIGURATION 2 (Figure 2)	
Advantages	Disadvantages	Advantages	Disadvantages
Can measure V by correlation	Cannot measure Q and U simultaneously	Can measure Q and U simultaneously	Quarter wave plate may increase losses and restrict bandwidth
Can measure I, Q, U and V but requires feed rotation		IF outputs represent I+Q and I-Q (may be useful in spectral line work)	Cannot measure V by correlation
Minimum loss			λ/4 plate may introduce cross-polarization, between receivers (Cannot be tolerated [illegible] for spectral line work).
No bandwidth restriction due to quarter-wave plate			

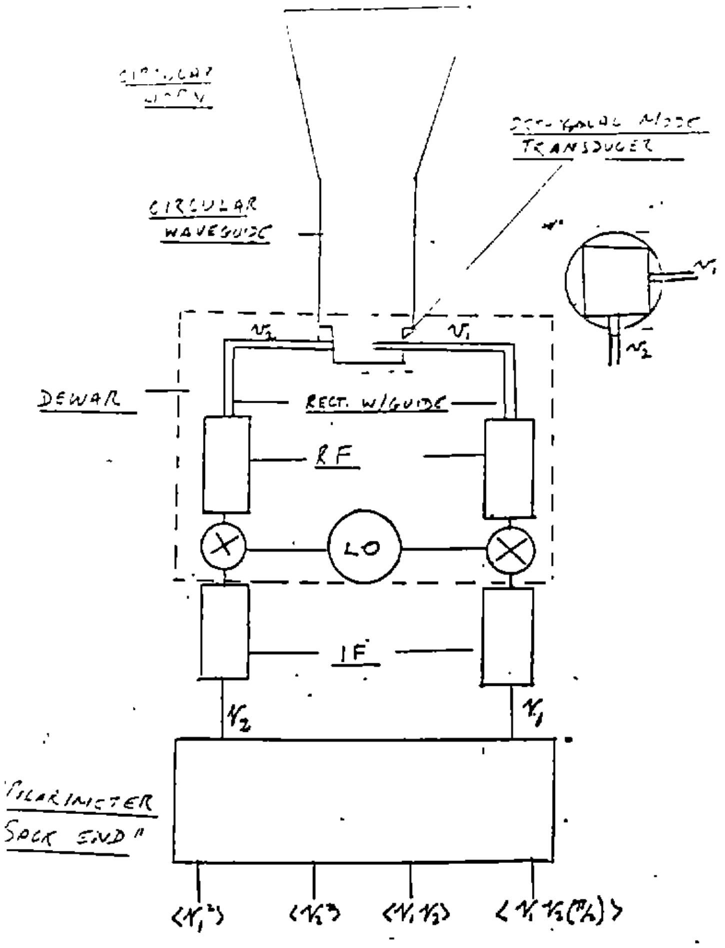

FIG 1

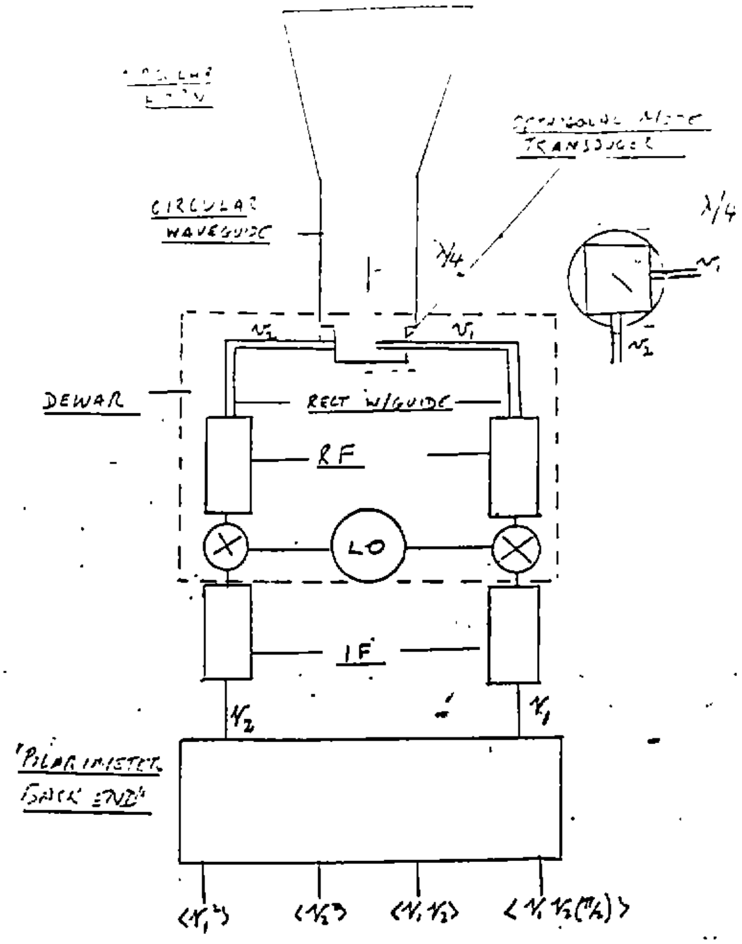

FIG. 2

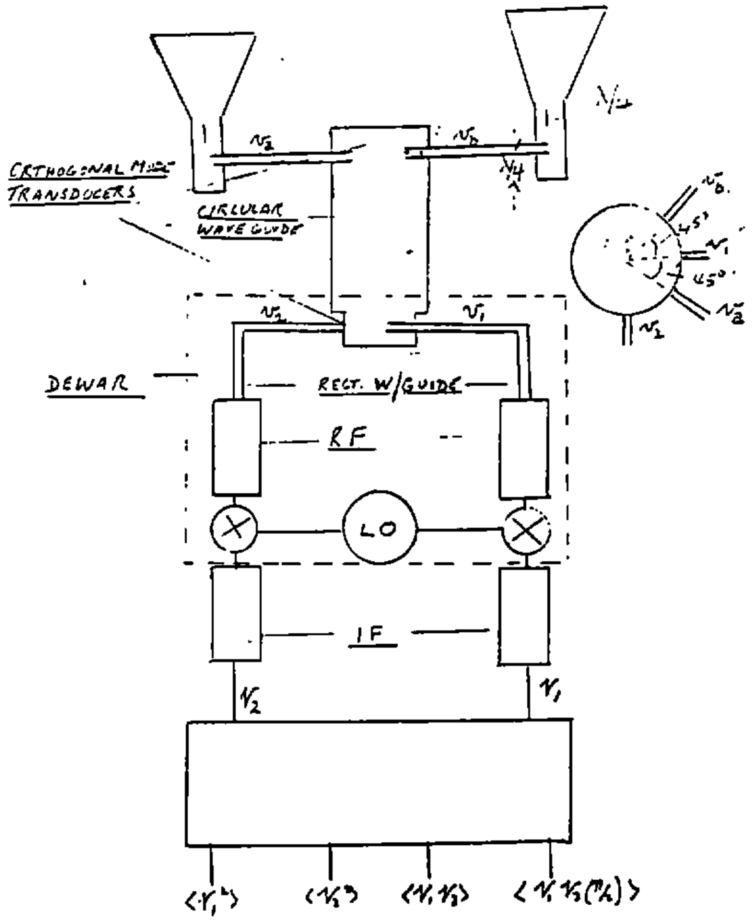

Fig 3