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EISCAT SCIENTIFIC ASSOCIATION

**EISCAT
TECHNICAL
NOTES**

TRANSMITTER POLARIZATION CONTROL IN THE EISCAT UHF SYSTEM

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TRANSMITTER POLARIZATION CONTROL IN THE EISCAT UHF SYSTEM.

INTRODUCTION

In the initial system configuration, see Figure 1, an arbitrary polarization of the transmitted wave may be achieved by adjusting the two mechanical phase shifters $\phi 1$ and $\phi 2$. By proper choice of the polarization it is possible to optimize the power scattered to either Kiruna or Sodankylä and to achieve some compromise between the two. In general, particularly at low heights, the best choice is linear polarization.

For reception in Tromsö this choice is awkward, because the linearly polarized wave is experiencing Faraday rotation and the received signal will occur at both receiver ports. The two received signals may be combined for optimum reception, but the combination algorithm must be varied with range. It would, therefore, be an advantage if the monostatic radar could retain circular polarization and the bistatic radars their optimum linear polarization at the same time. In practically all the experiments deviced the wave forms designed for the monostatic and the bistatic situations are different, and they are transmitted at different frequencies to allow them to be separated. One might, therefore, imagine that the two types of waveforms are transmitted with different polarization circular for the monostatic waveform and linear for the tristatic waveform. This would require a polarization switching on a microsecond timescale and would clearly be impossible with the mechanical phase shifters.

In the design of the transmitter certain provisions have been made in the construction to permit a doubling of the power by adding an extra klystron. In the next section it will be shown that, if done in the right way, the addition of another klystron to the UHF tranmitter may allow the rapid polarization flipping to be achieved.

PRESENT POLARIZATION SCHEME

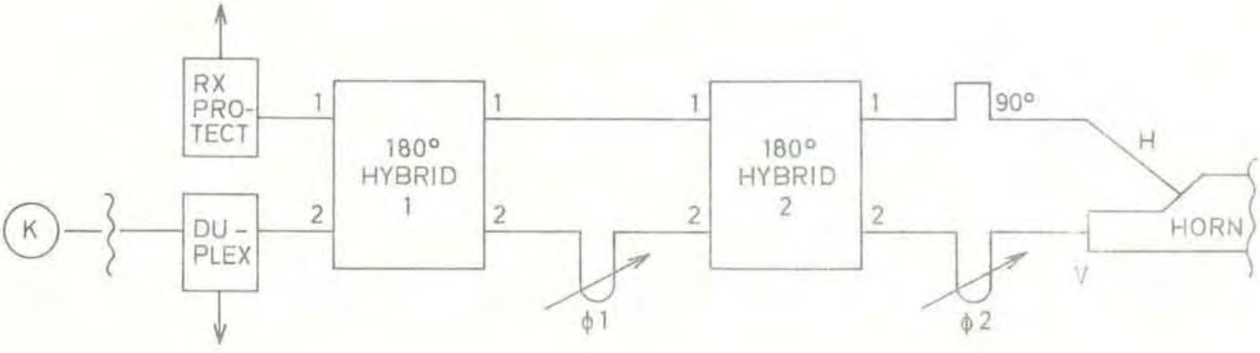

Fig. 1 Present polarization arrangement.

In the present polarization arrangement the horizontal (H) and vertical (V) parts of the feeder horn are fed from a network including two 180° hybrids and two mechanical phase changer. The power from the klystron K is split in two equal parts in the first hybrid. The power ratio between the two output signals from hybrid 2 can be varied at will by changing the phase in phase changer $\phi 1$. The relative phase of the two inputs to the feeder horn can be controlled by $\phi 2$. When the two inputs are set equal by adjusting $\phi 1$ and the phase difference is set to $\pm 90^{\circ}$ by $\phi 2$ either right or left circular polarization results. When $\phi 2$ is set for 0 or 180° phase difference linear polarization results and the plane of polarizatic is changed by varying the relative power to ports H and V by changing $\phi 1$.

Mathematically the action of the 180° hybrid can be represented by the matrix:

$$M = \begin{pmatrix} \frac{1}{\sqrt{2}} , & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} , & -\frac{1}{\sqrt{2}} \end{pmatrix}$$

If the input is $\vec{e}$ defined by

$$\vec{e} = \begin{pmatrix} e_1 \\ e_2 \end{pmatrix}$$

and the output by $\vec{f}$:

$$\vec{f} = \begin{pmatrix} f_1 \\ f_2 \end{pmatrix}$$

then

$$\vec{f} = M\vec{e}$$

Similarly the action of the phase shifter/fixed section can be represented by:

$$N = \begin{pmatrix} 1 & 0 \\ 0 & e^{+i\phi} \end{pmatrix}$$

where ϕ is the phase difference between the phase shifter section and the fixed section.

The action of the total polarization device is:

$$P = N_2MN_1M$$

where the indices refer to the sections containing the phase shifters $\phi 1$ and $\phi 2$.

Explicity we obtain with

$$\vec{e}_{in} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$e_H = \frac{1}{2}(1 - e^{i\phi_1})$$

$$e_V = \frac{1}{2}(1 + e^{i\phi_1}) \cdot e^{i\phi_2'}$$

where $\phi_2' = \phi_2 - 90^\circ$

Circular polarizations can be seen to result when

$$\phi_1 = \pm 90^\circ$$

and when

$\phi_2' = 0, 180^\circ$ or $\phi_2 = \pm 90^\circ$

Linear polarization is obtained by setting

$\phi_2' = \pm 90^\circ$ or $\phi_2 = 0, 180^\circ$

The ratio of the inputs to the feeder horn then becomes:

$$\frac{e_H}{e_V} = \mp \tan\frac{\phi_1}{2}$$

The rotation angle α with respect to vertical polarization is, therefore:

$$\alpha = \frac{\phi_1}{2}$$

PROPOSED NEW ARRANGEMENT

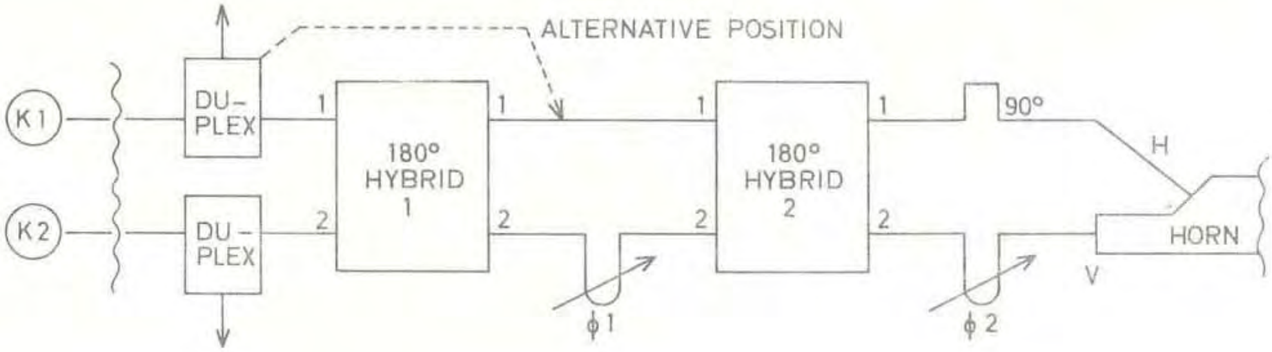

Fig. 2. Proposed future polarization arrangement.

Suppose we connect the present polarizer to the two klystrons K1 and K2 by completely separate and independent waveguide runs. This i not necessary to achieve double power, but it is required to achiev the capability for rapid polarization switching when the power is increased. The price to be paid to accomplish polarization switching flexibility when the second klystron is installed hence equals the price of the waveguide run between transmitter and polarizer. This price must include the cost of two rotary joints and a new duplexer.

The transformation matrix is the same as before and the explicit expressions for e_V and e_H become:

$$e_H = \frac{e_1}{2}\,(1+e^{i\phi_1}) + \frac{e_2}{2}\,(1-e^{i\phi_1})$$

$$e_V = \frac{e_1}{2}\,(1-e^{i\phi_1})\,e^{i\phi_2'} + \frac{e_2}{2}\,(1+e^{i\phi_1})\,e^{i\phi_2}$$

(note that $\phi_2' = \phi_2 - 90^\circ$!)

We shall assume that K1 and K2 are operating at identical power levels (unit amplitude) and that the only free parameter is their relative phase, hence:

$$e_1 = 1$$

$$e_2 = e^{i\phi}$$

When $\phi = \begin{cases} 0^\circ \\ 180^\circ \end{cases}$ and $\phi_2 = 90^\circ$ we obtain

$$e_H = \begin{cases} 1 \\ e^{i\phi_1} \end{cases} \qquad \begin{cases} 0^\circ \\ 180^\circ \end{cases}$$

$$e_V = \begin{cases} i \\ -ie^{i\varphi_1} \end{cases} \qquad \begin{cases} 0^\circ \\ 180^\circ \end{cases}$$

Hence, where $\phi_2' = 90^\circ$ (or -90°) the two circular polarizations can be chosen by setting ϕ either to zero or 180° irrespective of the value of ϕ_1.

Suppose next that $\phi_2^1 = 90^\circ$ is retained but that the relative phase ϕ is set to 90°. It is then obtained:

$$e_H = \sqrt{2}\; e^{i\frac{\phi_1}{2}} \cos\left(\frac{\phi_1}{2} - \frac{\pi}{4}\right)$$

$$e_V = -\sqrt{2}\; e^{i\frac{\phi_1}{2}} \sin\left(\frac{\phi_1}{2} - \frac{\pi}{4}\right)$$

so that:

$$\frac{e_V}{e_H} = -\tan\left(\frac{\phi_1}{2} - \frac{\pi}{4}\right)$$

Hence we have achieved linear polarization with the plane of polarization rotated through an angle α with respect to the vertical

$$\alpha = \frac{\phi_1}{2} + \frac{\pi}{4}$$

Since circular polarizations are independent of ϕ_1 we can switch between circulars and an arbitrary linear polarization through the scheme:

$\phi = 0$	right circular
$\phi = 90^\circ$	linear, plane set by $\phi 1$
$\phi = 180^\circ$	left circular

CONCLUSION

The present note has shown how, in the event EISCAT at some future date chooses to double the UHF power, a very advantageous polarization flipping scheme can be implemented. The scheme will present considerable advantages in the interpretation of the monostatic radar data at a cost which must be carefully weighed against the advantages.

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