Measurements of a scale-model ortho-mode transducer

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ABSTRACT

This memo describes measurements made of a scale-model ortho-mode transducer to evaluate its suitability for use at millimeter wavelengths. The device consists of four probes placed in a single cross-sectional plane of a cylindrical waveguide. Each pair of probes is driven in anti-phase with a 180° hybrid. A good 50 Ω match with a return loss of 20 dB and polarization isolation of 40 dB was achieved with a fixed backshort in a 40% bandwidth. An implementation in the 3-mm band is suggested.

1. Introduction

The simultaneous detection of two orthogonal polarizations allows greater sensitivity both in line and continuum radio-astronomical observations. An additional advantage when measuring polarized emission is the higher polarization purity obtainable. At millimeter wavelengths, polarization separation using optical techniques has been the norm, while at lower wavelengths ortho-mode transducers (OMTs) have traditionally been used. OMTs provide a waveguide separation of two orthogonal polarizations. The problem with existing implementations is that they are generally either complex and difficult to manufacture at mm-wavelengths (Bøifot 1991; Skinner & James 1991) or intrinsically narrow-band (e.g. Joglekar & Singh 1979).

Motivated by recent calculations showing that a simple probe in a rectangular waveguide could give a good broadband match (Yassin & Withington 1996; Withington & Yassin 1997), I constructed a model of an OMT design which should be easy to build when scaled to millimeter wavelengths. The design relies on basic symmetry to ensure polarimetric isolation.

2. Measurements

2.1. Description of the scale model

The scale model used for these measurements was built in a 6-inch inside-diameter aluminum tube 30 inches in length. Four probes (Figure 1) were mounted 5.7 inches from one end, which

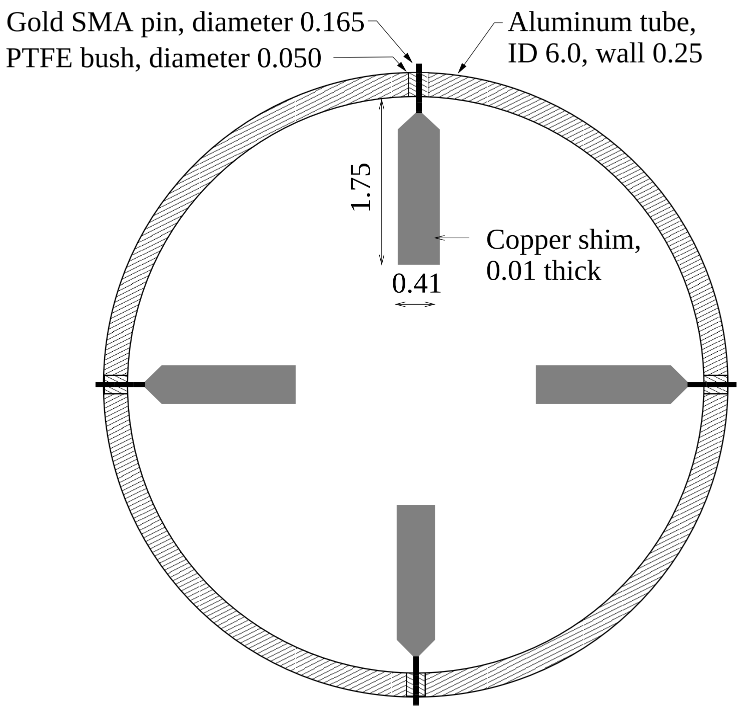

Fig. 1.— Cross-section of the scale model (half actual size, dimensions in inches). An opposite pair of probes were fed with a relative phase of 180°. Isolation measurements were made at a remaining probe.

was terminated by a movable planar backshort. The other end of the tube was electromagnetically terminated by a conical load of diameter 3 in and length 11.5 in.[1]

2.2. Return loss and isolation

To drive the scale model an opposite pair of probes was fed in anti-phase at 50 Ω using a network analyzer through a 180° hybrid.[2] Return loss was measured at the fed probes and the received signal at a passive probe (not connected to a 180° hybrid) was used to determine polarization isolation.

Measurements were made for probes of length 1.55–2.05 in. For each probe the backshort was adjusted to give a good match over a 40% bandwidth. The band-averaged return loss measurements and the corresponding backshort positions are given in table 1. In each case, the peak-to-peak

[1]The load was a Resin Systems CTL-0130 polyiron load, with specified VSWR< 1.05.

[2]The MACOM H-9 used has phase imbalance $< 7°$, amplitude imbalance < 0.5 dB and an isolation > 38 dB over the range considered here.

probe length (in)	return loss (dB)	backshort distance from probes (in)
1.55	8	2.81
1.65	12	2.66
1.75	20	2.22
1.85	16	2.26
1.95	12	2.17
2.05	9	2.12

Table 1: Relationship between probe length and wide-band (1.4–1.9 GHz) return loss

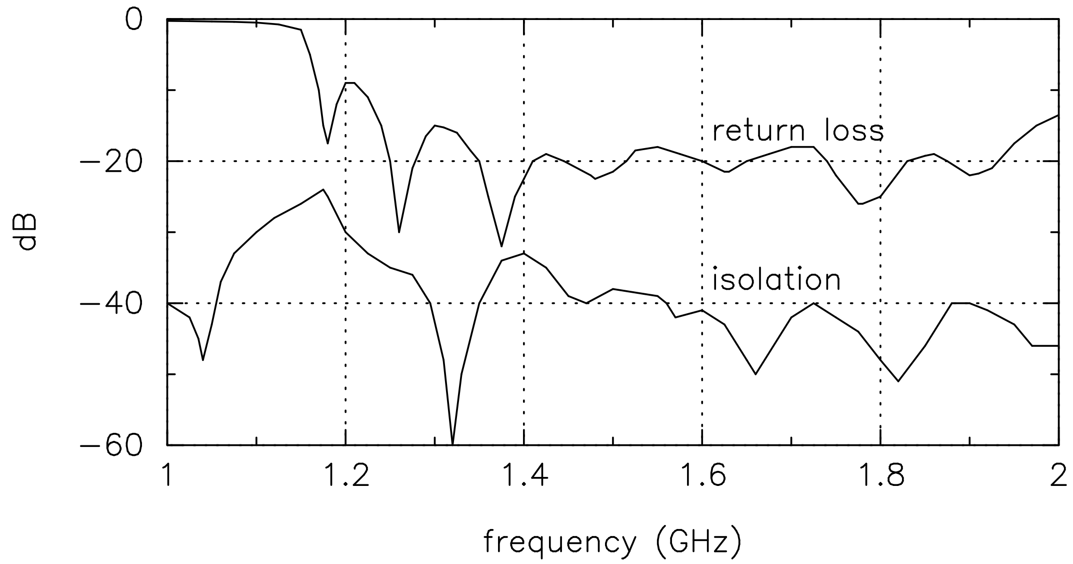

Fig. 2.— Return loss and isolation for 1.75 in probes. Optimum performance is achieved between 1.4 and 1.9 GHz, a 40% bandwidth. The theoretical waveguide cutoff frequency for the lowest order (TE_{11}) mode is 1.15 GHz. The cutoff frequency for the TE_{21} mode is 2.06 GHz.

variation in return loss was about 5 dB. Note that it was possible to obtain a substantially better match (around 10 dB improvement) over a narrower bandwith (typically 10%) with the backshort in an alternate position. The return loss at the optimum probe length is shown as a function of frequency in figure 2.

Polarization isolation was not a strong function of probe length or of backshort position for the cases considered. It remained at approximately 40 dB, as shown in figure 2. Neither polarization isolation nor return loss were significantly affected by probe rotation.

2.3. Other measurements

The experiments conducted used exclusively 50 Ω input signals. However, input impedance measurements were made for a variety of probe lengths. By lengthening the probes it was possible to get reasonably good broadband probes with input impedances up to about 150–200 Ω. By contrast, shorter probes do not appear to couple well to the waveguide, and it may be difficult to obtain input impedances below 50 Ω.

The wide probes discussed above were chosen to facilitate construction of the OMT on smaller scales. However, measurements with thin wire probes were also made. The bandwidth over which a good match was obtained was somewhat narrower.

3. Discussion

The measurements described in this memo indicate that the development of a similar 3-mm OMT might be fruitful. The probe structure lends itself to microstrip fabrication on standard circuit board material. In such an implementation, the mixers (either SIS or MMIC) would be external to the waveguide, probably on the same substrate. The challenging part looks to be the development of a wide-band hybrid or a mixer configurations accepting balanced inputs.

An alternative implementation might be to place mixers within the waveguide, employing filters to allow the IF/LO signals to travel along the same probe. Presumably an RF ground would be made at the waveguide wall. However, the measurements described above do not shed light on the viability of such a design. It seems more difficult to model. As part of this program, a quick test of the of one possible configuration was made. In this test, the waveguide was center-fed by a pair of probes through coaxial lines along paths at 90° to the probes (corresponding to the position of the isolated probes at the other polarization). The best return loss achieved was 9 dB.

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