A Planar Orthomode Transducer

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***Abstract*—The planar orthomode transducer (OMT) described in this paper couples two microstrip inputs to two orthogonal modes in a square waveguide. One microstripline feeds a 180° hybrid that in turn excites two waveguide probes. A second microstrip directly feeds a third waveguide probe. Mode symmetry provides isolation between the two feeds. All circuitry and probes are fabricated on a single substrate to minimize fabrication cost. An experimental prototype has 30 to 40 dB isolation at millimeter wave frequencies. The low cost and small size of this structure make it appropriate for use in commercial communications applications.**

***Index Terms*—Orthomode transducer (OMT).**

I. Introduction

An orthomode transducer (OMT) combines signals from two single mode ports into two orthogonal modes in a square or cylindrical waveguide. OMTs are often used in transceivers with a single antenna in order to isolate the transmitter output from the receiver input. Standard OMTs are built with single mode waveguide feeds that are offset along the axis of the dual mode output waveguide [1], [2]. Because of this offset, they require expensive machining, are bulky, and are not directly compatible with printed circuit feeds.

This paper describes a planar OMT that directly interfaces microstrip input ports to a square waveguide. It is planar in that the microstrip feeds are fabricated on one substrate oriented orthogonally to the output waveguide axis. Fig. 1 is a photo of the prototype planar OMT structure with its cover/backshort removed. The inset to Fig. 2 shows an illustration. The OMT consists of three microstrip probes and a 180° hybrid all fabricated on a single substrate. The ground plane is removed over (and in a strip around) a square waveguide aperture in the baseplate that supports the substrate. The substrate dielectric was also removed in the same area except where it supports the probes. When the cover is in place, the probes pass through channels milled into the cover side walls and launch energy into the waveguide (into the page). The microstrip port labeled 1 feeds a rat race coupler that in turn feeds the two opposing probes with 180° relative phase. This excites the polarization labeled 3 in the illustration, but creates a zero field along the centerline of the waveguide where the probe that connects to port 2 is located. Thus ports 1 and 2 are isolated. Port 2 feeds polarization 4 directly. A small amount of energy from port 2 excites the port 1 probes in phase and is isolated from port 1 by the hybrid. This energy is reflected from the stub-terminated port of the hybrid and returns to the probes where it has a tuning effect on port 2 and reduces the bandwidth of the port 2 match. Bandwidth could be improved by replacing the stub termination with a matched load; however, this increases the transmission loss between port 2 and port 4 (polarization 4).

In an unpublished technical note [3], D. Bock proposed a similar structure for feeding a cylindrical waveguide at L-band using four probes and two packaged hybrids. The additional probe and hybrid eliminate the coupling between orthogonal probe sets and broadens the bandwidth. However, because packaged hybrids were used, Bock's solution is more bulky and expensive than the approach taken in this paper. Adding a fourth probe and a second hybrid to the configuration in Fig. 1 would complicate the design by requiring one feed to overpass another. The crossing lines would break the feed symmetry and couple at the overpass.

II. Design

The design of the OMT is as follows. The basic probe design is determined according to Leong's procedure [4] assuming a rectangular waveguide with a width equal to the inner dimension of the square waveguide and a height of half the width. For a given frequency, substrate thickness, and substrate dielectric constant, Leong's procedure will determine the probe width and length as well as the backshort location(cover height).

In the channel, where the feed lines penetrate the cover sidewalls, a narrow, inductive microstrip line is used to resonate the probe reactance [4]. The finite element simulator HFSS[1] and a circuit simulator are used to determine the length of this line. The HFSS computational volume is bounded by the waveguide walls, the backshort, the waveguide output aperture, and also extends into the three microstrip channels in the cover. A microstrip "port" is located in each channel and two waveguide ports are located some distance below the baseplate aperture, one for each polarization. The resulting five-port S parameters are loaded into a circuit simulator and the quantity $(S_{1a1a} - S_{1a1b})$ is computed (the subscript "1a" refers to one of the probe ports associated with port 1 and "1b" refers to the other). This quantity is matched to 50 Ω by adding or subtracting lengths of the inductive line.

In order to design the match to port 2, a circuit analysis package is used to simulate the assembly of; the five-port block of HFSS results, the port 1 matching circuits, the rat race coupler, and the 50 Ω microstrip interconnects. Port 2 is matched to 50 Ω by adjusting the length of the channel inductive line, the interconnect between the hybrid and the probes, and the stub on the hybrid. The tuning effect of the

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[1]HFSS is a product of Ansoft Corp., Pittsburgh, PA.

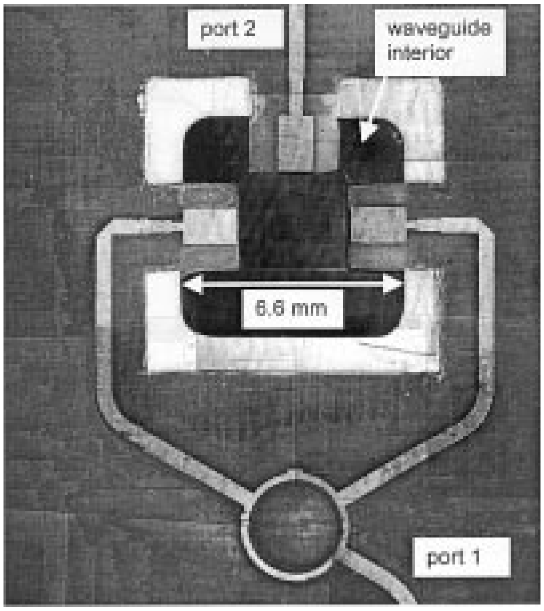

Fig. 1. Prototype 30 GHz orthomode transducer.

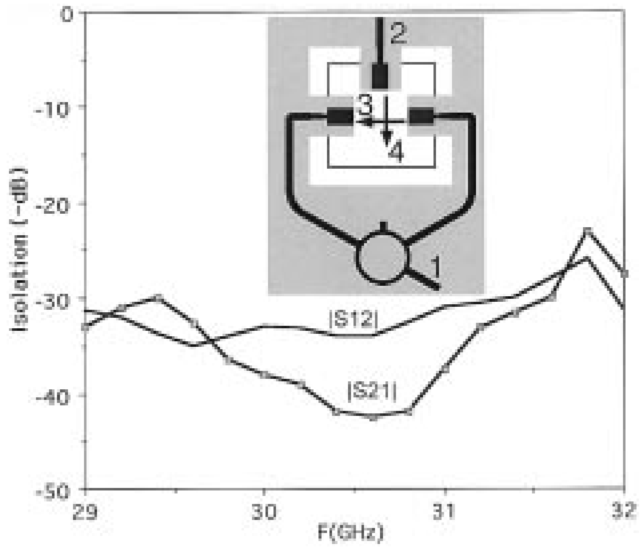

Fig. 2. Measured isolation between ports 1 and 2 of OMT.

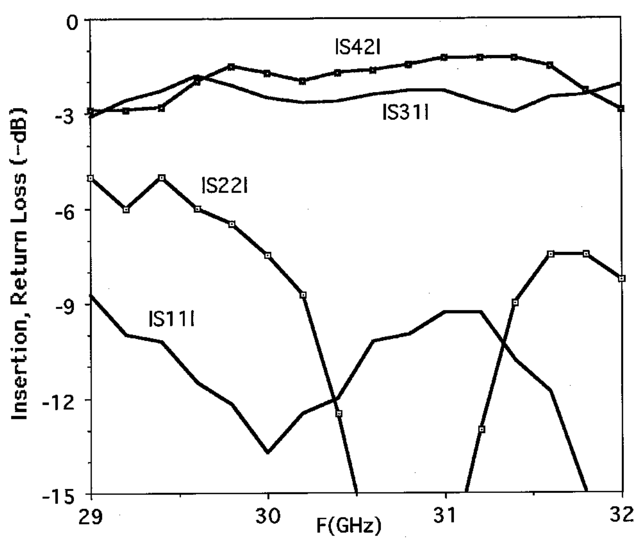

Fig. 3. Measured insertion and return loss.

last two elements was mentioned in the previous section. The model shows a good match can be achieved at port 2 over a 6.7% bandwidth (-15 dB).

III. Experimental Results

The details of the prototype in Fig. 1 are as follows. The figure shows a top view of the prototype OMT with the backshort removed. The square waveguide has interior dimensions of 6.6 $\times$ 6.6 mm. The substrate that supports the probes and hybrid is Rogers 4003 with 0.2 mm thickness and $\varepsilon_r = 3.52$. The width and length of the probes are 1.1 $\times$ 1.6 mm. The substrate has been cut away everywhere within the waveguide aperture, except for a ring 2.6 mm wide around the aperture and strips 1.5 mm wide centered on the probe axes. Installing the cover creates a backshort 2.4 mm above the baseplate. Channels 1.1 $\times$ 2.6 $\times$ 0.54 mm are cut into the cover to pass the probe feeds.

Measured results are shown in Figs. 2 and 3. These measurements were made in a waveguide system so they included waveguide to microstrip transitions (not shown) to connect to the two microstrip feeds. In addition, the square waveguide was terminated with a square to rectangular waveguide adapter followed by a matched detector. Thus, only one polarization at a time could be terminated in a match. Fig. 2 shows isolations of 30 to 40 dB. The traces show different isolations depending on whether port 1 or port 2 was excited. This is because when port 1 was excited, the port 3 polarization is terminated in a matched load, but not the port 4 polarization. When port 2 was excited, the waveguide adapter was rotated so that the port 4 polarization was properly terminated. Because of this measurement difficulty, when port 2 is excited, energy leaking into polarization 3 is completely reflected from the termination, and combines at port 1 with energy that directly leaks from port 1 to port 2.

Fig. 3 shows the measured insertion loss from port 1 to port 3 is 2.2 to 3.0 dB while the insertion loss from port 2 to port 4 is 1.2 to 2 dB. In both cases, about 1.0 dB of the loss is due to the external waveguide to microstrip transition and a 25 mm length of microstrip fed. The port 1 insertion loss includes about 0.3 dB due to loss in the hybrid and 0.5 dB of loss due to mismatch at the probes (see Fig. 3).

Measured return loss is shown in Fig. 3 and includes reflections from all the transitions mentioned above. The return loss seen at port 1 is 8 to 14 dB. This mediocre match results from errors in the prototype design made before the previously described design procedure was developed. As discussed, the match at port 2 is narrow band due to the tuning effect caused by coupling to an even mode excitation of the port 1 probes. Since the probes themselves are very broad band, and the rat race coupler has a 15% bandwidth, the tuning effect resulting from the port 2 to port 1 coupling is the feature limiting the OMTs bandwidth to 30–32 GHz.

IV. Conclusion

A planar orthomode transducer configuration has been presented. It is compact and directly interfaces with microstrip components. Measurements of a prototype show 30 to 40 dB of isolation between ports. Insertion losses are 0.2 to 1 dB for the port which is directly fed and one dB more for the other port. This difference is mostly due to small errors in the matching circuit, but also due to extra loss introduced by the rat race hybrid.

A number of improvements could be made to this design. The matching circuit should obviously be corrected. Also, the surplus dielectric on either side of the probes should be removed. It likely increases the capacitive coupling between the port 2 and port 1 probes, and this increases the tuning effect that the port 1 circuitry has on the port 2 match. Lastly, we note that there are methods other than the rat race hybrid for producing the balance output, and these may have better bandwidth and be more compact [5].

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