Finline Ortho-Mode Transducer for Millimeter Waves

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***Abstract*—We evaluate the possibility of using a finline ortho-mode transducer (OMT) at millimeter wavelengths. A finline OMT has low loss, low cross-polarization, and good return loss over a full waveguide band. We propose a novel finline OMT structure for millimeter-wavelengths and present results at X-band.**

***Index Terms*— Finline, millimeter waves, ortho-mode transducer (OMT).**

I. Introduction

AT MILLIMETER wavelengths, waveguide receivers with cryogenically cooled superconductor insulator superconductor (SIS) devices as mixing element are the most sensitive receivers available today. For higher sensitivity, millimeter-wave receivers require dual-polarization operation. One of the major components for a dual-polarization receiver is an ortho-mode transducer (OMT), which separates orthogonal polarizations within the same frequency band. The OMT's for millimeter-wave bands need to be broadband to match the capabilities of available high-performance dual-polarized broad-band corrugated feed horns. Also, for dual-polarization operation, it is desirable that the cross-polarization introduced by the OMT be less than that introduced by the horn and the related optics. For radio astronomy purposes, the OMT needs to have certain performance criteria and we have adopted the following specification for a millimeter-wave OMT:

- return loss $\sim$ 20 dB or better over a full waveguide band ($\sim$40% bandwidth);
- isolation better than 40 dB.

Symmetry is of considerable importance for broad-band operation of a waveguide device. Any discontinuity in a waveguide produces higher order modes, though most of them are evanescent modes and do not propagate. Higher order modes store reactive energy and prevent broad-band operation of the device. While designing a broad-band device, it is almost impossible to avoid some form of discontinuity in the waveguide, but one can adopt a few simple guidelines to minimize that. The bends and curves in the waveguide should possibly be in the E-plane, because an E-plane bend generates only the even order modes, and hence, is easier to compensate.

In view of the above symmetry considerations, the obvious choice for a broad-band OMT would be "*class three*" OMT described by Bøifot *et al.* [1]. This OMT can be thought of as a turnstile junction [2] where two ports have been folded parallel to the common port. The problem to adopt this design for millimeter waves is the difficulty in fabricating such a device. As we go higher in frequency, the waveguide dimensions become too small and the tolerances become extremely critical. Wollack [3] reported a *Bøifot* OMT for K-band which works very well for the full waveguide band (18–27 GHz) but clearly indicates the machining challenge it poses to fabricate such a device at higher frequencies. It is possible to fabricate Bøifot OMT at frequencies up to W-band, but for frequencies beyond that it does not appear to be a viable option. One could build a septum OMT, described by Chattopadhyay *et al.* [4], at frequencies beyond 100 GHz, but it has about 20% bandwidth, which falls short of our requirement as listed above. We investigated a finline OMT, which uses a finline guide to separate one polarization, as a possible candidate at millimeter wavelengths.

II. Finline OMT

The basic concept of a finline OMT was discussed by Robertson [5] in 1956. Skinner *et al.* [6] looked into it in more detail for use on radio telescopes. A finline OMT consists of a square or circular waveguide fitted with diametrically opposite thin tapered metallic fins. The dominant mode electric field parallel to the fins is gradually transformed to a finline mode whose energy is essentially confined to the narrow gap between the fins in the center of the waveguide. This energy then can be removed from the waveguide by curving the finline and bringing it out through the side wall of the guide. The mode polarized orthogonal to the fins passes through the guide virtually unperturbed when the fins are sufficiently thin.

We designed a new finline OMT, as shown in Fig. 1, which we believe could be fabricated at frequencies beyond W-band and may be a viable option at millimeter wavelengths. The main arm of the OMT is a square waveguide and is assumed to be excited by two orthogonal polarizations $E1$ and $E2$. Polarization $E1$ is gradually transformed to a finline mode within a very small fin gap. This mode is then taken through a 45° bend and out through a narrow hole in the side wall of the guide. A further transition from a finline to standard waveguide allows the $E1$ polarization to be extracted from

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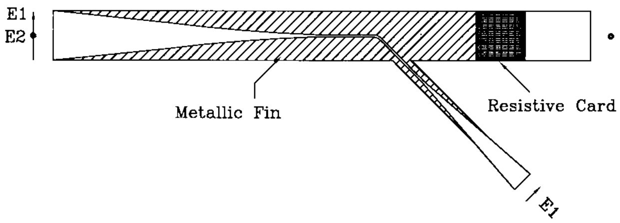

Fig. 1. Sketch of the finline OMT showing the cross-sectional view. For the X-band design, we used 22.86 mm × 22.86 mm square waveguide for the input and 22.86 mm × 10.16 mm standard X-band rectangular waveguides for the outputs.

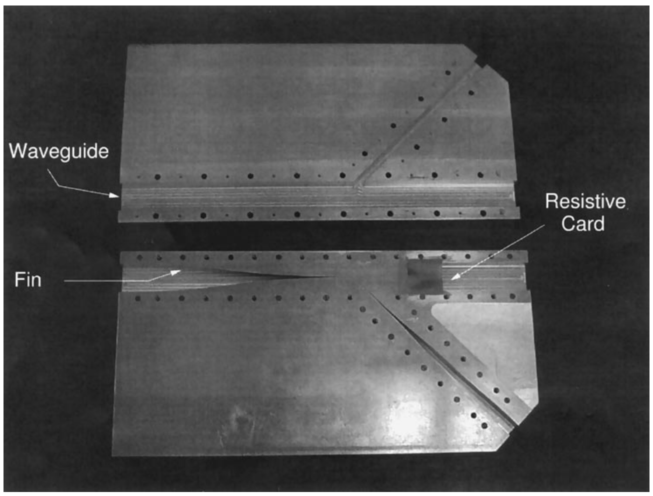

Fig. 2. A picture of the X-band finline OMT.

the system. The orthogonal polarization $E2$ comes out from the other port through a square to rectangular transition. The resistive card is necessary, as in [5], to suppress the excitation of unwanted modes at the termination of the fin. In our design, the finline bend was chosen at 45° instead of 90° to improve cross-polarization performance. However, due to the 45° bend, the opening on the side wall is larger and will have undesirable effect for $E2$ polarization. To overcome this we used reduced height guide for the side arm to reduce the opening on the side wall. Although the waveguide bend for the $E1$ polarization is in the E-plane, and will produce only the even order modes, the higher order modes will be generated at the finline bend and will degrade the cross-polarization performance. The usefulness of the 45° bend with a reduced height guide for the side arm toward improvement in the cross polarization and isolation performance was supported by the simulations performed using Hewlett Packard's High Frequency Structure Simulator (HFSS) [7]. The side arm has a reduced height to full height transition so that it can mate with a standard waveguide.

To evaluate the performance of our OMT, we fabricated an X-band OMT, whose picture is shown in Fig. 2, with 0.76-mm-thick metal plate fin with 0.25-mm fin gap at the center. The reduced height guide was 6.35 mm in height at 45° angle. The profile of the tapered fins, both for the square waveguide and the reduced height guide, was designed using the equations given in [8] and [9] and was verified with HFSS simulation. The return loss measured for the two polarizations $E1$ and

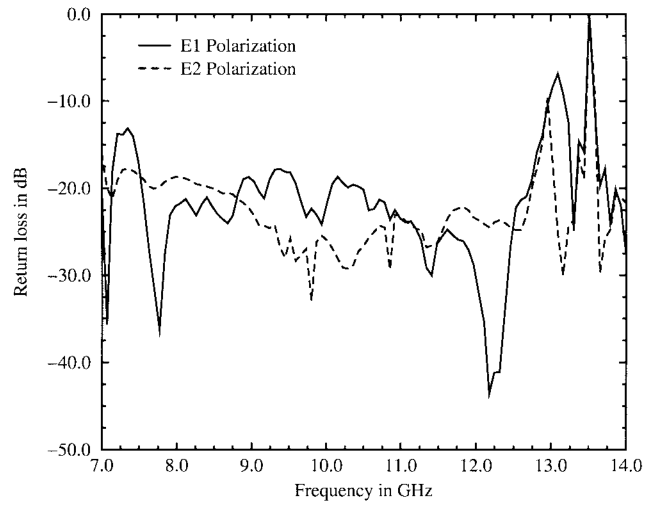

Fig. 3. Measured return loss of the finline OMT.

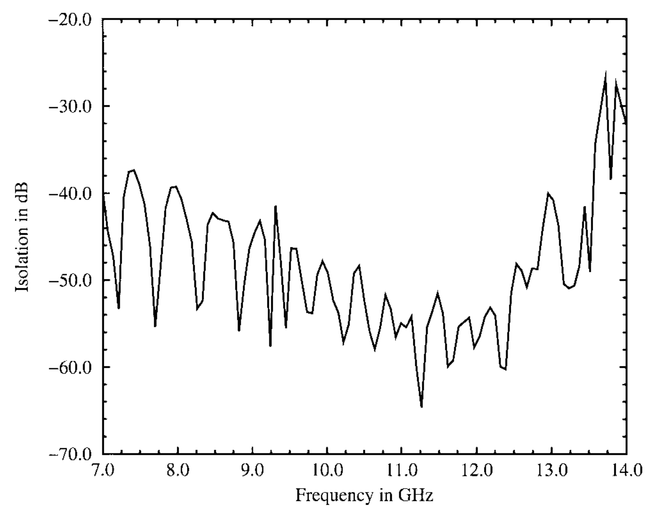

Fig. 4. Measured isolation between the ports of the finline OMT.

$E2$ was found to be 20 dB or better for the entire waveguide band (Fig. 3). Isolation between the two ports of the finline OMT was in excess of 40 dB over the band, as can be seen from Fig. 4. Fig. 5 shows the cross-polarization performance. The bend of the fin gap in the waveguide generates unwanted higher order modes, and that is mainly responsible for most of the cross polarization. Though the cross-polar performance is not as good as desired, it is better than 20 dB for the entire band. The insertion loss was found to be less than 0.3 dB for both the polarizations. In the envisioned application, the OMT will be operated at cryogenic temperatures at millimeter wavelengths, and thus, the ohmic loss in the OMT is not a great limitation.

This finline OMT could be fabricated at millimeter wavelengths from electroformed copper with split block along the fin plane. The critical part would be the fin and the resistive card. The fin could be fabricated using metal etching technique used by Vahldiec *et al.* [10]. The resistive card could be realized by masking the fin and evaporating a thin ohmic film on the necessary area.

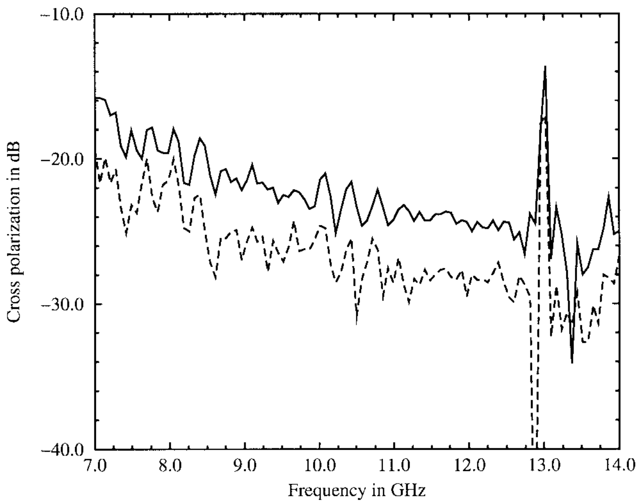

Fig. 5. Measured cross-polarization of the finline OMT. The solid line is for $E1$ input polarization when the output is measured at $E2$, and the dotted line is for $E2$ input polarization when the output is measured at $E1$.

III. Conclusion

We evaluated the possibility of using a finline OMT at millimeter wavelengths and proposed a new OMT structure. The X-band measurement results show good performance over a full waveguide band. The 45° bend in the finline, instead of the 90° bend, has improved the cross-polarization and return loss performance of the OMT. We think that the fabrication of such a device for frequencies up to 250–300 GHz is possible using the techniques we described. For frequencies beyond 300 GHz a dual-polarized mixer [11] is much more practical because the fin gap for the finline OMT becomes very narrow and will be difficult to realize.

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