MILLIMETER-WAVE DIPLEXERS WITH PRINTED CIRCUIT ELEMENTS

Y. C. Shih*, L.Q. Bui*, and T. Itoh**

*Hughes Aircraft Company
Microwave Products Division
Torrance, CA 90509

**Department of Electrical Engineering
The University of Texas at Austin
Austin, TX 78712

ABSTRACT

A novel design of W-band (75-110 GHz) non-contiguous diplexers is described. The common port of the diplexer is fed by suspended probe transitions which are suitable for wide-band applications. The circuit is printed on a single substrate and easily assembled in a split-block housing. The insertion loss at the passbands is about 1 dB.

INTRODUCTION

Recent advances in the design of millimeter-wave (MMW) channeled receivers create a need for small, integrated, high performance diplexers and multiplexers(1,2,3). However, the design information on these components is very limited. In this paper, we will describe a novel design of a MMW non-contiguous diplexer that is capable of wide-band applications. Channel bandwidths as wide as 10 GHz can now be achieved with an insertion loss of about 1 dB at W-band.

DIPLEXER DESIGN

Figure 1 shows a typical layout of the diplexer. It consists of two band-select filters and two waveguide-to-suspended-stripline probe transitions. The filters are E-plane filters(5,6,7) which can be bilateral, unilateral, or a combination of both. The complete circuit is fabricated on a single substrate, which is then cut to size and placed in a split-block housing.

The use of waveguide-to-suspended-stripline transitions at the common port of the diplexer makes it possible for wide-band applications. The idea stems from our experience in the design of suspended-stripline circuits at millimeter-wave frequencies, where a good transition has been designed to cover the full W-band (75-110 GHz). The design is a refinement of the work done by the other designers in this field(4).

There are two probe transitions, the input-port probe and the common-port probe. The input-port probe transition is very similar to the conventional coaxial-to-waveguide adaptor. One end of the suspended-strip probe is inserted into the broadside of the waveguide about one quarter wavelength deep and a waveguide backshort is located behind the probe to optimize the coupling. The other end of the probe is the common-port input to the diplexer and works in a similar way; however, this coupling structure is

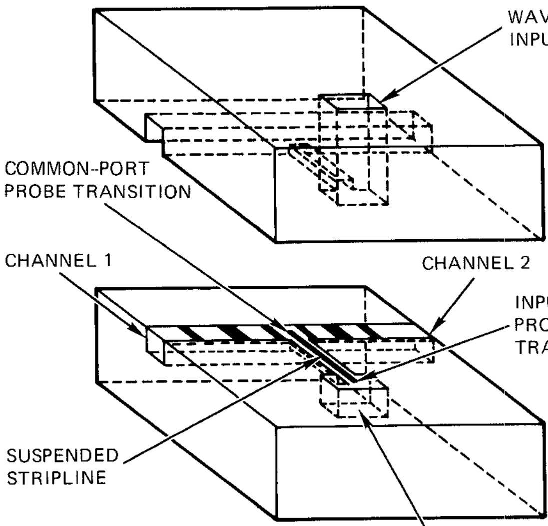

Fig. 1. Physical Configuration of a Diplexer

quite different. There are not waveguide back-shorts but the bandpass filters. The transition works because at the passband of one channel, the other filter will reflect almost all the energy, and thus serves as a good short circuit. In this case, the loading effects of each filter at the short-circuit reference planes are required for the design of the transition and must be included in the net design of the diplexer to ensure good response. This requirement makes the E-plane filters an ideal candidate because of the existing accurate analytical modeling. High performance E-plane filters have been designed up to 160 GHz using our modeling technique, and have found excellent correlation betweeen theory and measured data(7).

The filters may have any E-plane configuration, as defined earlier; however, because of the suspended-strip transition, we found it more convenient to make the filters and transitions on a single substrate. Furthermore, we have found that, for the same filter specifications, the bilateral structure offers a loss performance comparable with, and sometimes superior to, that of the metal-insert structure. Note that the diplexer contains three parts, the upper and

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lower halves of the split block and the printed circuit; it is a very low cost structure.

RESULTS

The waveguide-to-suspended-strip transition is essential for the diplexer design. Therefore, we have tested numerous W-band transition circuits to find a good combination. Figure 2 depicts the geometry and the dimensions of an operating W-band transition. The circuit is designed on an RT-5890 Duroid substrate whose dielectric constant is 2.0. With two such transitions connected back to back by one-inch long suspended stripline, we have measured the performance shown in Figure 3. The return loss is better than 15 dB, and the insertion loss is better than 0.7 dB (not shown) over the W-band frequencies.

The E-plane filters are designed using the procedures described in (5,6,7). We then analyze the filters to obtain the short-circuit reference location at the passband of the other filter. This information is required in the transition and diplexer designs. The typical performances are shown in Figure 4 for two 3-cavity bilateral E-plan filters. They are designed to have 5 GHz bandwidths centered at 87.5 and 102.5 GHz, with passband ripple of 0.2 and 0.1 dB, respectively. The dielectric substrate is 5-mils thick. The

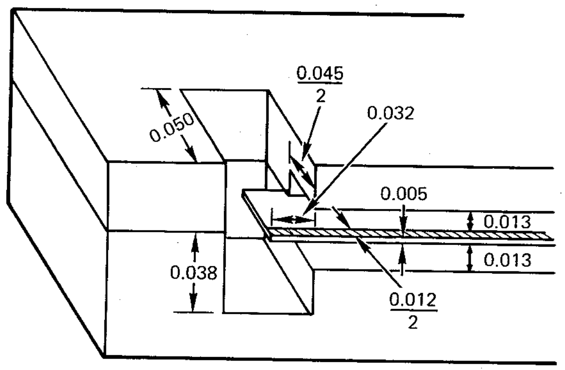

Fig. 2. Cross-section View of a W-band Waveguide-to-Suspended-Strip Transition in WR-10 Waveguide

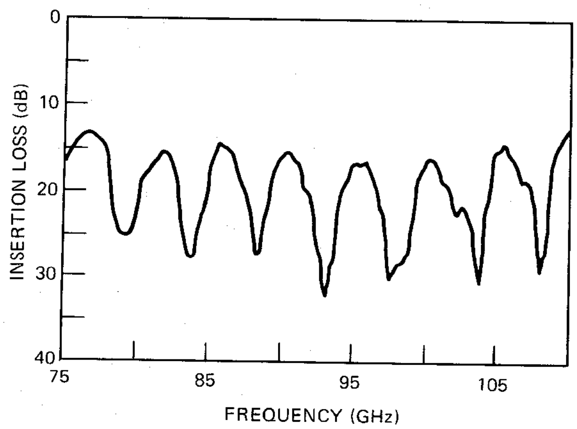

Fig. 3. Measured Return Loss of the Probe Transition at W-band

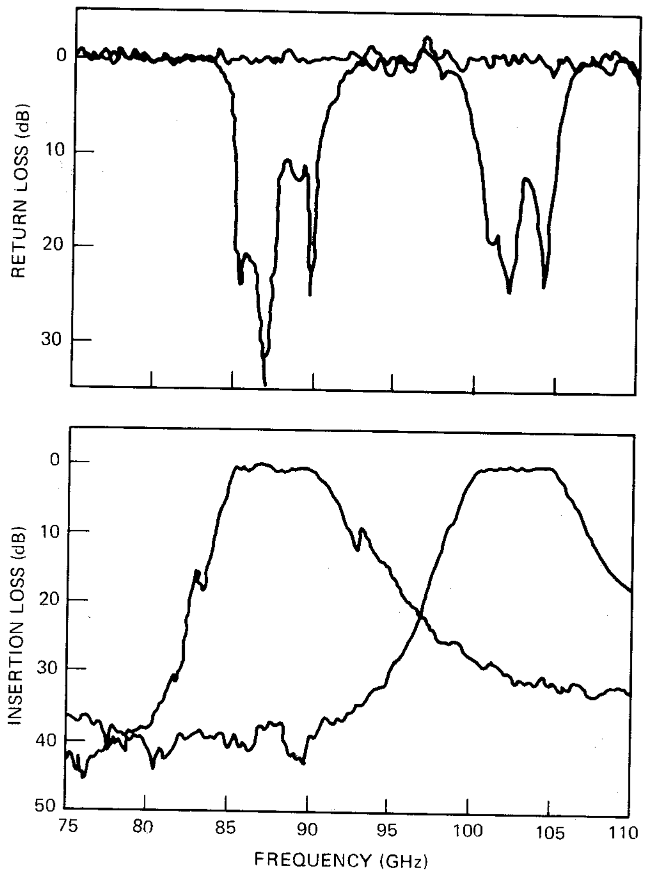

Fig. 4. (a) Insertion Loss and (b) Return Loss of E-Plane Filters

measured insertion loss is less than 1 dB in the passband of both filters.

Figure 5 is the picture of a complete diplexer. The E-plane filters and the transitions are fabricated on a single 5-mil substrate using chemical etching. The circuit is then cut and placed in the split-block housing. The diplexer was evaluated over the frequencies of interest and performance is shown in Figure 6. In the passband of the channels, the

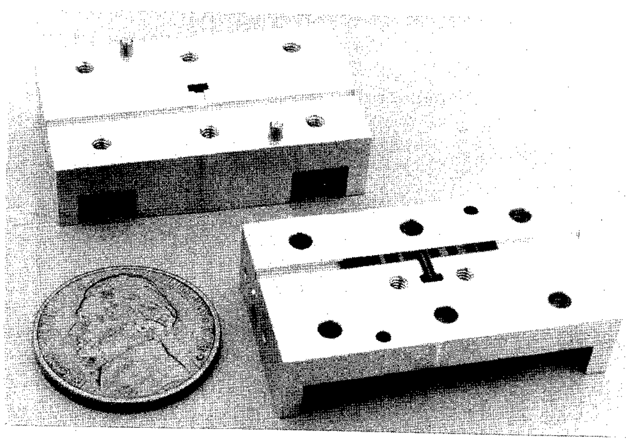

Fig. 5. Photograph of a completed W-band diplexer

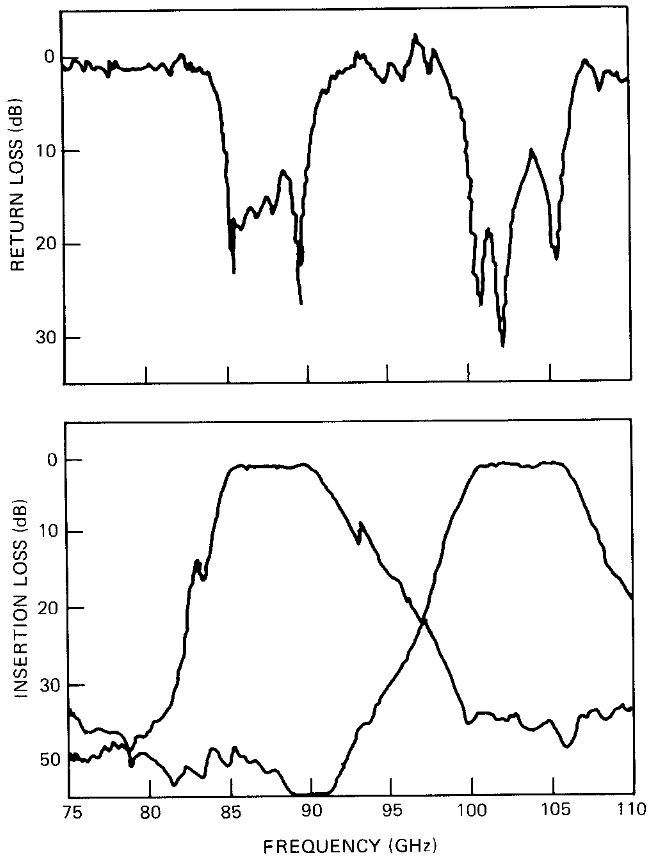

Fig. 6. Measured insertion loss and return loss of a diplexer shown in Figure 4

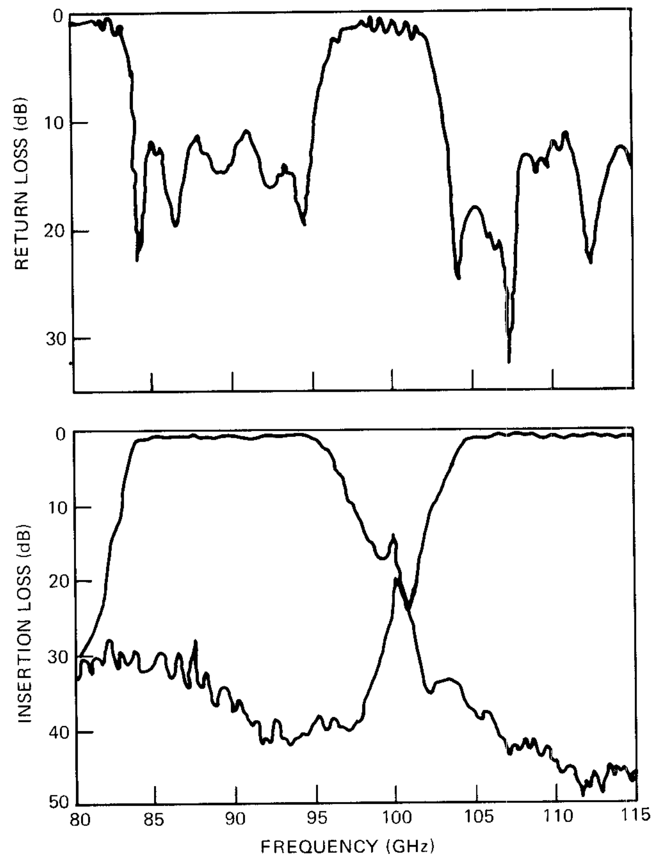

Fig. 7. Measured Insertion Loss and Return Loss of a Diplexer with 10 GHz Channel Bandwidths

return loss is more than 10 dB, and more typically 15 dB. The insertion loss is tyically 1 dB. Notice that each channel very much preserves the characteristics of the corresponding filter, except that the upper-end rejection of the lower channel has a slight improvement.

Diplexers having wider channel passbands can also be built in a similar manner. For example, Figure 7 shows the performance of a diplexer having 10 GHz passband for both channels. A 10 GHz guard band is placed between the two channels. The input return loss in the passband of the channels is more than 12 dB, and the insertion loss is approximately 1 dB.

CONCLUSION

The combination of the E-plane filters and a unique suspended probe transition imbedded a the common port has resulted in the design of high performance and low cost diplexers with wide channel bandwidths. The complete circuit is printed on a single substrate and is easily assembled in a split-block housing. This makes it highly reproducible using photolithographic techniques. Typical W-band diplexers exhibit about 1 dB insertion loss over the channel passbands.

ACKNOWLEDGEMENT

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