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WAVEGUIDE-TO-MICROSTRIP TRANSITIONS FOR MILLIMETER-WAVE APPLICATIONS

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ABSTRACT

Design data are presented for waveguide-to-microstrip probe transitions that cover millimeter-wave frequencies from 26 to 110 GHz. Experimental results show that the transitions have full waveguide-band performance with low insertion loss. They are useful for the device and circuit characterization of millimeter-wave MICs and MMICs.

INTRODUCTION

Recently, there has been increasing demand to use millimeter-wave hybrid and monolithic integrated circuits (MICs and MMICs) for applications in smart munitions, missile seekers, and phased-array radars. To date, most of the integrated circuits have been built on microstrip transmission lines. In the course of development for MICs and MMICs, the characterization of devices and circuits requires a transition to the waveguide measurement systems. In the final system integration, transitions may also be required to combine the integrated circuits with the waveguide components.

A simple waveguide-to-microstrip transition can be designed using a waveguide-microstrip cross junction. This type of transition has been designed for suspended stripline (1,2,3,4); however, the microstrip probe transition design has been limited to about 20-percent bandwidth. This paper presents the design and test results for waveguide-to-microstrip probe transitions covering 26 to 110 GHz. The broadband design provides a good transition for full waveguide bandwidth (40 percent). Because of the compact structure, the measured insertion loss contributed by the transition is less than 0.1 dB in Ka-band, less than 0.2 dB in Q- and V-band, and less than 0.35 dB in W-band.

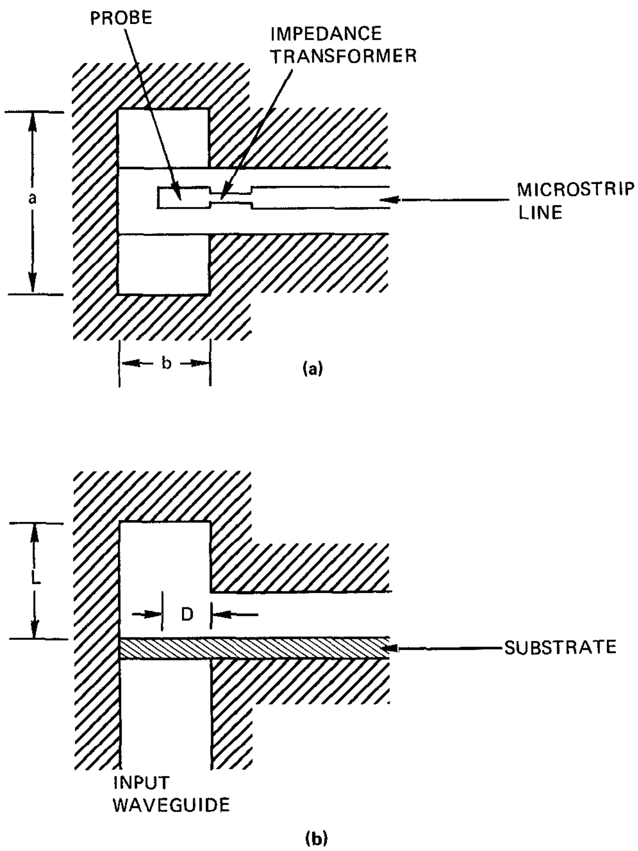

Figure 1. Cross-sectional view of waveguide-to-microstrip.

DESIGN

As depicted in Fig. 1, the transition consists of a printed microstrip circuit, a portion of which extends into the waveguide through an aperture in the broad wall. The substrate is designed to fit the full height of the waveguide for easy and precise alignment during assembly. The aperture size is kept as small as possible to minimize its effect on the field distribution in the waveguide. A metal strip supported by the substrate serves as a probe to couple the energy from the waveguide. At the microstrip feed point, a quarter-wave impedance transformer is used to match the probe input impedance to a 50-ohm line.

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In a previous study, the input impedance was calculated as a function of frequency for varying strip probe dimensions. The change in strip width was found to have little effect on the input impedance. Therefore, the strip width is chosen to meet the narrow strip assumption in the analysis, but not narrow enough to cause excessive conductor loss. For broadband applications, the probe length (D) and backshort location (L) are determined so that, in the frequency of interest, the input resistance maintains fairly constant and the reactance remains small. At Ka-band, the dimensions of D and L were optimized numerically and later refined by experiments to be D=80 mils and L=80 mils. The results are obtained using a 10-mil RT-5880/Duroid (ϵr=2.2) substrate. Since the input resistance is on the order of 75 ohms, the transition can be used in a typical 50-ohm microstrip system via a simple quarter-wave impedance transformer.

The critical dimensions of the transitions are summarized in Table 1. Four full waveguide-band designs for Ka-, Q-, V-, and W-bands are required to cover the 26- to 110-GHz range. Notice that at Ka- and Q-bands, 10-mil Duroid substrates are used.

MEASUREMENTS

The transitions have been fabricated and tested in test fixtures designed for different waveguide sizes. A photograph of the Ka-band version is shown in Fig. 2. For convenient measurement, two transitions are connected back-to-back with a 600-mil long microstrip line. The measured frequency responses for the Ka-band transition are shown in Fig. 3. The insertion loss is about 0.4 dB, including the losses in the microstrip line and the input/output waveguides. The return loss is better than 15 dB over the full Ka-band. Taking into account the theoretical microstrip losses (~0.25 dB) and waveguide losses (~0.03 dB) and assuming a symmetrical structure, the performance of a single transition can be approximated. Over the Ka-band frequencies, the insertion loss is about 0.06 dB and the return loss greater than 21 dB.

The Q-band test fixture integrates two transitions with a 600-mil long microstrip line on the 10-mil Duroid substrate. The measured frequency response is shown in Fig. 4. The insertion loss is about 0.6 dB between 40 and 50 GHz. Removing the theoretical microstrip and waveguide losses, the loss of a single transition is approximately 0.15 dB at 44 GHz.

TABLE 1

CRITICAL DIMENSIONS FOR WAVEGUIDE-TO-MICROSTRIP TRANSITIONS

Waveguide Band	t(mils)	D(mils)	L(mils)
Ka	10	80	80
Q	10	60	60
V	5	45	50
W	5	28	30

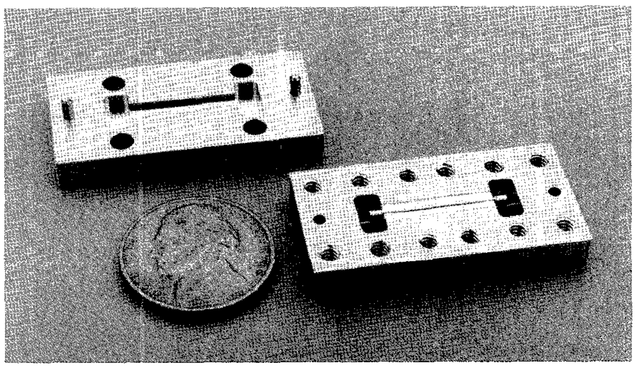

Figure 2. Ka-band test fixture for measurements of two transitions separated by a 600-mil long microstrip line.

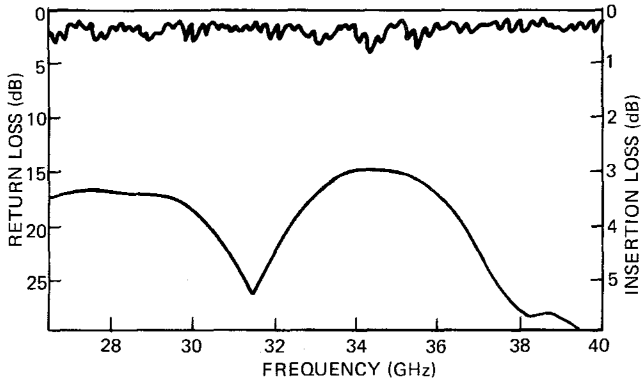

Figure 3. Insertion loss and return loss for two Ka-band transitions separated by a 600-mil long microstrip line.

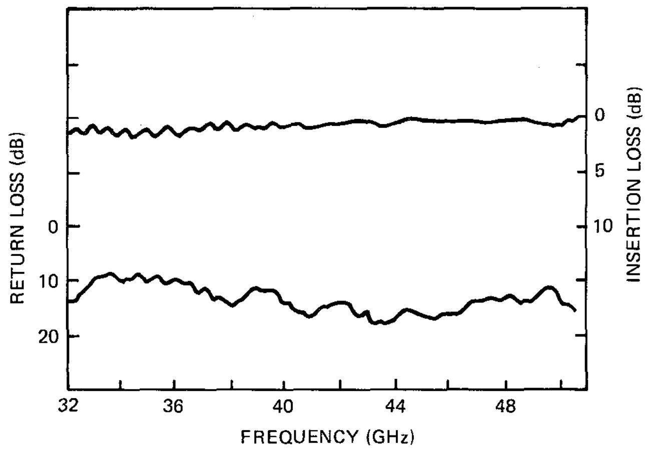

Figure 4. Insertion loss and return loss for two Q-band transitions separated by a 600-mil long microstrip line.

The V-band test fixture integrates two transitions with a 680-mil long microstrip line on 5-mil Duroid substrate. The measured frequency response is shown in Fig. 5. The insertion loss is about 1 dB up to 70 GHz, with a return loss of better than 12 dB. The sharp drop in insertion loss at the high end is due to the resonance of the channel containing the microstrip line. Removing the theoretical microstrip and waveguide losses, the loss of a single transition is approximately 0.15 dB at 60 GHz.

The W-band test fixture integrates two transitions with a 450-mil long microstrip line on 5-mil Duroid substrate. The measured frequency response is shown in Fig. 6. The insertion loss is about 1 dB at 75 GHz, and it almost linearly increases to about 2 dB at 110 GHz. The return loss is better than 15 dB across the full waveguide band. Removing the theoretical microstrip and waveguide losses, the loss of a single transition is approximately 0.2 dB at 75 GHz and 0.35 dB at 110 GHz.

CONCLUSION

Design data are presented for waveguide-to-microstrip probe transitions that cover millimeter-wave frequencies from 26 to 110 GHz. The transitions have broadband performance with low insertion loss. They will find their use in the device and circuit characterization in the development of MICs and MMICs.

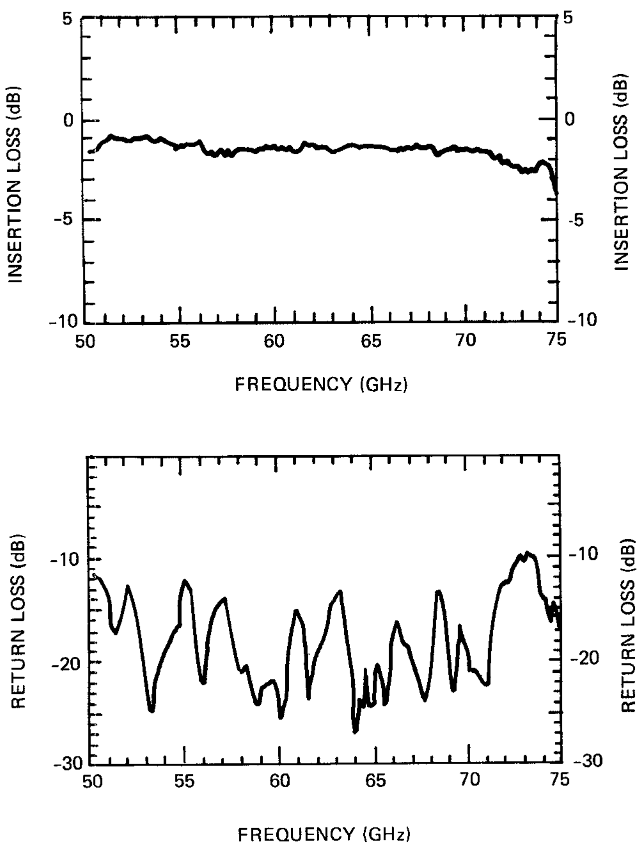

Figure 5. Insertion loss and return loss for two V-band transitions separated by a 680-mil long microstrip line.

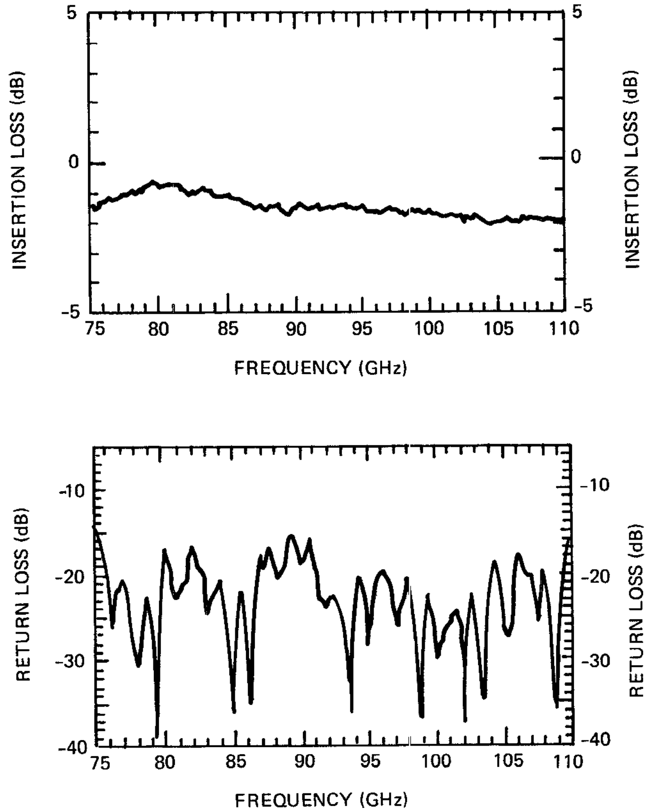

Figure 6. Insertion loss and return loss for two W-band transitions separated by a 450-mil long microstrip line.

REFERENCES

(1) B. Glance and R. Trumbarulo, "A Waveguide to Suspended Stripline Transition," IEEE Trans. Microwave Theory Tech., Vol. MTT-21, pp 117-118, Feb. 1973.

(2) E. A. Oxley, "Hybrid Microwave Integrated Circuits for MM Wave-Length," 1972, IEEE-GMTT Intl. Microwave Symp. Digest, pp 224-226.

(3) R. H. Knerr, "A New Type of Waveguide-to-Stripline Transition," IEEE Trans. Microwave Theory Tech., Vol. MTT-16, pp 192-194, Mar. 1968.

(4) Y. C. Shih, L. Q. Bui, and T. Itoh, "Millimeter-Wave Diplexers With Printed Circuit Elements," IEEE Trans. Microwave Theory Tech., Vol. MTT-33, pp 1465-1469, Dec. 1985.