DESIGN, ANALYSIS AND SCALE MODEL TESTING OF FIXED-TUNED BROADBAND WAVEGUIDE TO MICROSTRIP TRANSITIONS

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Abstract

We have designed and tested broadband fixed-tuned waveguide to microstrip transitions in which the probe is extended across the waveguide. We have performed scale-model testing of several configurations of waveguide to microstrip transitions, and have measured a fixed-tuned bandwidth of 32%. Simulations of these structures were performed using Hewlett Packard's High Frequency Structure Simulator (HFSS). The sensitivity of the transition bandwidth to changes in geometry and microstrip circuit layout are discussed.

Introduction

Many mixers and multipliers use waveguide at their input because of the availability of waveguide flanges and horns, which allow for efficient coupling of power into the waveguide over a broad bandwidth. Once inside the waveguide, it is often convenient to transition into a shielded microstrip channel in order to simplify the integration of filters and nonlinear devices into the mixer or multiplier. One method to make a broadband transition is to use a probe inserted partially across the waveguide, which can be designed to provide excellent coupling across an entire waveguide band [1]. However, in certain circumstances it is desirable to extend the probe across the input waveguide, thus allowing for the possibility of a current path thru to a channel on the other side of the waveguide. This paper describes the design and scale-model testing of a broadband fixed-tuned waveguide to microstrip transition in which the probe is extended across the waveguide. In addition, several geometries of waveguide to microstrip transitions are examined, and their bandwidths are compared for different tuning configurations.

Summary of Modeling Results for Different Geometries

A schematic of the basic probe design is shown in Fig. 1, where tuning is provided by a waveguide backshort and a termination in one of the microstrip channels. For this modeling it was assumed that the microstrip channel was terminated by either an ideal open or short circuit at some length down the channel. For transitions which are designed solely to provide an IF or DC signal ground, it is possible to provide a microstrip short circuit termination. However, for structures in which it is desirable to continue the line through there will be a filter terminating the channel.

There were two main transition geometries modeled during this study. Fig. 1(a) shows a transition in which the quartz circuit is oriented parallel with the E-plane of the waveguide. In the geometry shown in Fig. 1(b), the quartz is mounted perpendicular to the waveguide E-plane. The waveguide height for both geometries was chosen to be 1/3 height. Reducing the height was found to be necessary to achieve broadband operation with this transition. Simulations of these transitions were performed using Hewlett Packard's High Frequency Structure Simulator

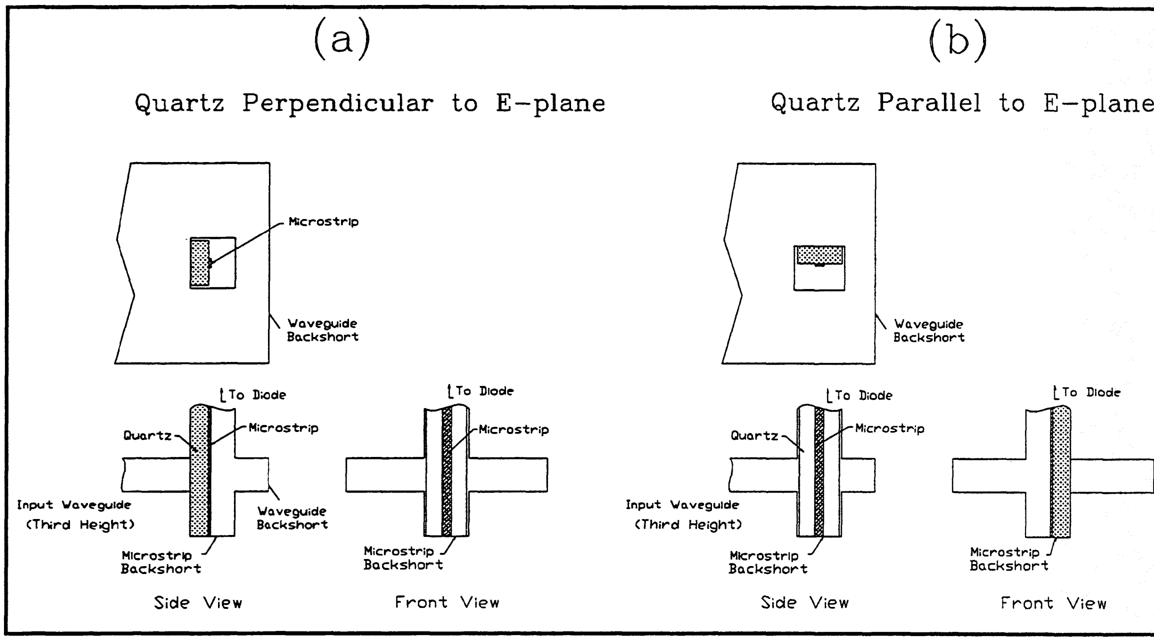

Fig. 1. Schematic of the basic waveguide to microstrip transition design with (a) quartz substrate perpendicular to waveguide E-plane and (b) substrate parallel to E-plane.

(HFSS). The structure was solved with two waveguide and two microstrip ports, and the effect of the waveguide and microstrip tuning lines was taken into account using the linear S-parameter simulator of Hewlett Packard's Microwave Design System (MDS).

Fig. 2 shows the maximum thru coupling from the waveguide to the microstrip line at a single frequency as a function of the microstrip line length before the termination, where at each channel length the waveguide backshort position has been optimized for peak coupling. A microstrip line impedance of 81 Ω was used for the transition of Fig. 2. Both the open and short circuit terminations have two positions within the first 180 degrees of microstrip line electrical length which allow for unity thru coupling, as marked in Fig. 2 by SC1, SC2, OC1, and OC2. Fig. 3 shows the fixed tuned variation of the return loss versus frequency across the band for each of these points of unity coupling. As shown in Fig. 3, a transition with an open circuit termination just inside the microstrip channel was predicted to provide the best bandwidth performance. Neither of the short circuit positions were predicted to provide as broad a bandwidth as the open circuit.

One key design parameter is the microstrip line impedance. Fig. 4 shows the variation of the transition bandwidth versus line impedance, where the bandwidth has been defined as the range over which the return loss is greater than 20 dB. For the remaining simulations, a microstrip impedance of 81 Ω was used so that the transition would be relatively broad band while not incurring excessive conductor loss.

Table 1 summarizes the simulation results for a number of transition geometries. There are several things to note in Table 1:

- For the transition with the quartz perpendicular to the waveguide E-plane, the microstrip circuit can be placed with the metallization facing either the waveguide backshort or the input waveguide. In all cases the bandwidth was found to be larger when the microstrip metallization faced the waveguide backshort.

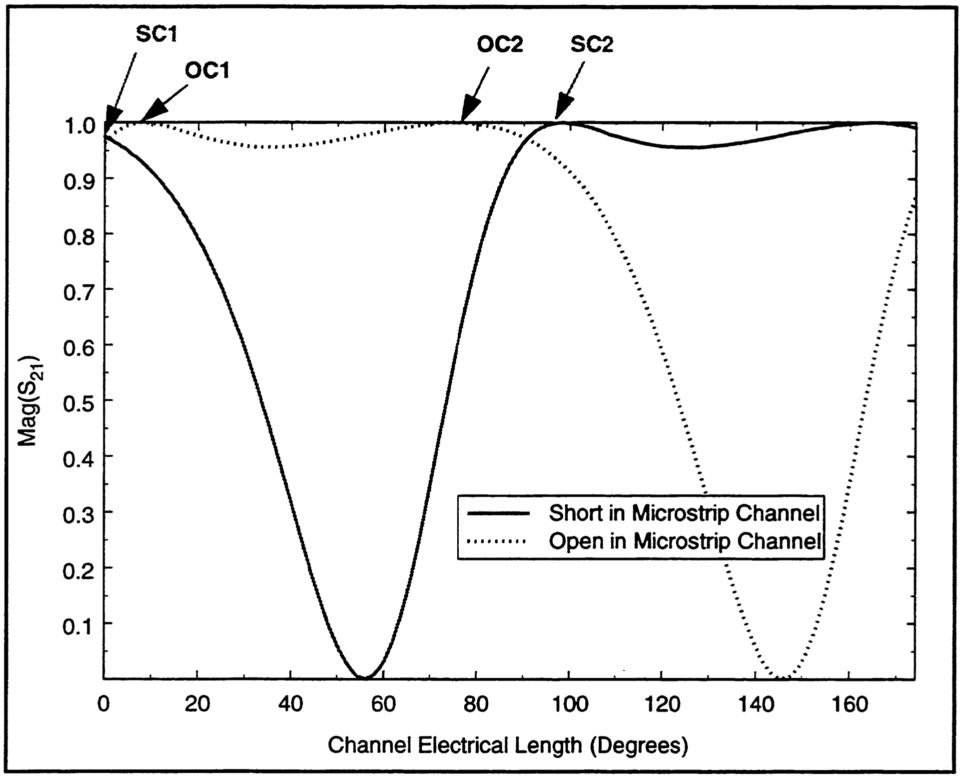

Fig. 2. Maximum thru coupling versus microstrip channel length with open and short circuit terminations in microstrip channel. For each channel length, the waveguide backshort was optimized for peak thru coupling.

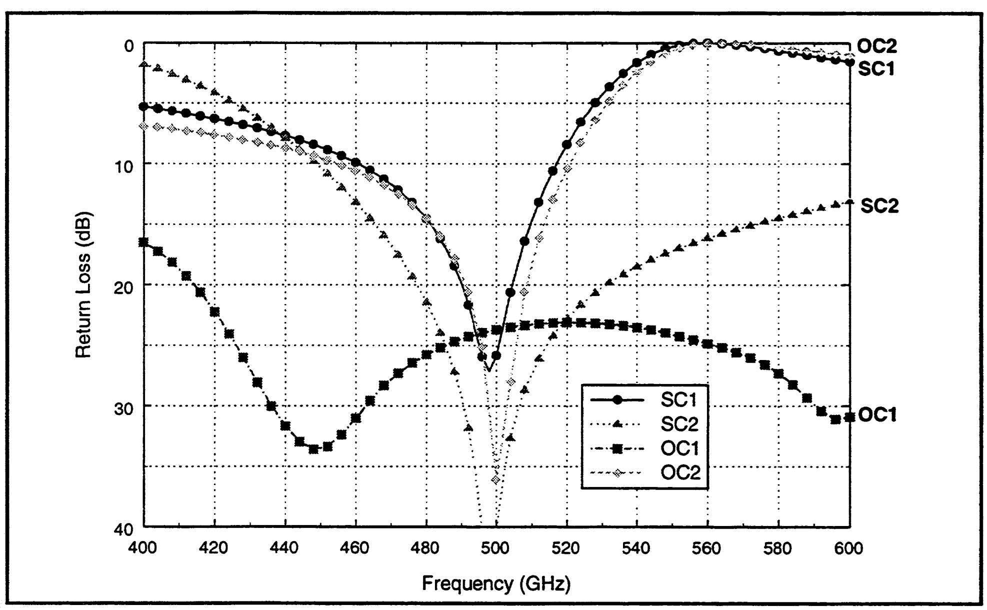

Fig. 3. Fixed tuned variation of the return loss versus frequency across the band for each of the points of unity coupling shown in Fig. 2. These curves are for a transition centered at 500 GHz.

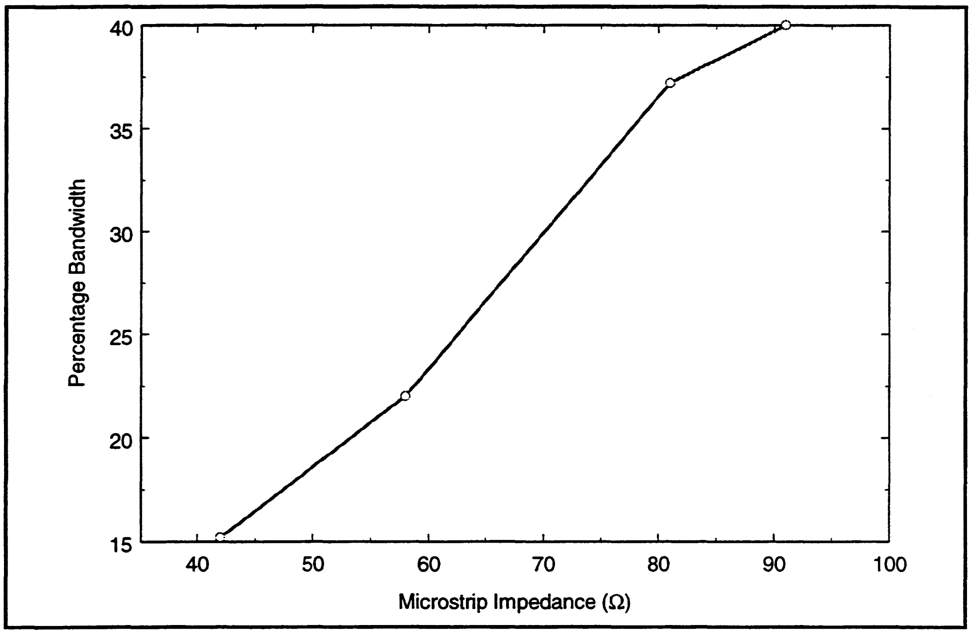

Fig. 4. Variation of the transition bandwidth versus line impedance for the transition of Fig. 1(a). The bandwidth has been defined as the range over which the return loss is greater than 20 dB.

Table 1: Summary of simulation results for waveguide to microstrip transitions.

Quartz ∥ or ⊥ to E-plane	Microstrip Metallization Facing	Microstrip Impedance (Ω)	In Waveguide	In Microstrip Channel	BW (%)
⊥	backshort	42	thru line	short open	2.6 15.2
⊥	backshort backshort input input	81	thru line	short open short open	10.8 37.2 2.6 12.6
⊥	backshort backshort input input	81	cross (1.2x12.4 mm)	short open short open	33.2 34.8 9.4 15
⊥	backshort	81	cross (6.2x12.4 mm)	short open	16 22.4
⊥	backshort	81	cross (0.6x12.4 mm)	short open	29.6 31.4
⊥	backshort	91	thru line	short open	15.2 40
∥	-	85	thru line	short open	9.6 21.2
∥	-	85	cross (2.5x11.4 mm)	short open	15.2 23.2
∥	-	85	cross (7.6x11.4 mm)	short open	11.2 16.8

- The transition with the quartz perpendicular to the waveguide E-plane was found to have larger bandwidth than a similar transition with the quartz parallel to the E-plane.
- In an attempt to increase the transition bandwidth, simulations were performed for a transition in which a cross shape is added to the microstrip metallization in the waveguide, as shown in Fig. 5. For a transition with a short circuit termination in the microstrip channel, the cross was found to increase the bandwidth from about 10.8% to 33.2%. The cross has a less significant effect for the transition with an open circuit termination in the microstrip channel. The effect of the cross width on the transition bandwidth is shown in Fig. 6.
- Placing a cross in the microstrip metallization has little effect when the quartz is parallel to the waveguide E-plane.

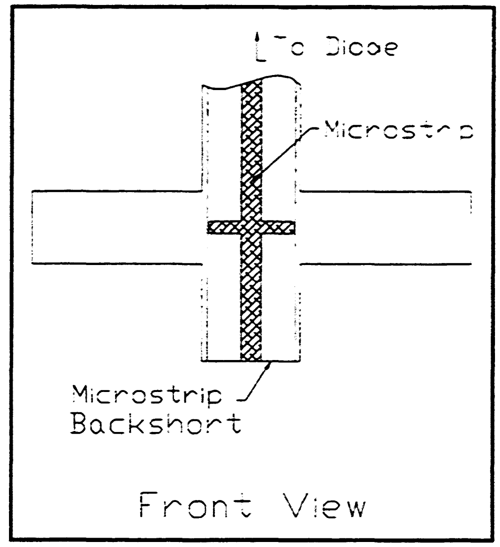

Fig. 5. Schematic showing cross in the microstrip metallization in the waveguide.

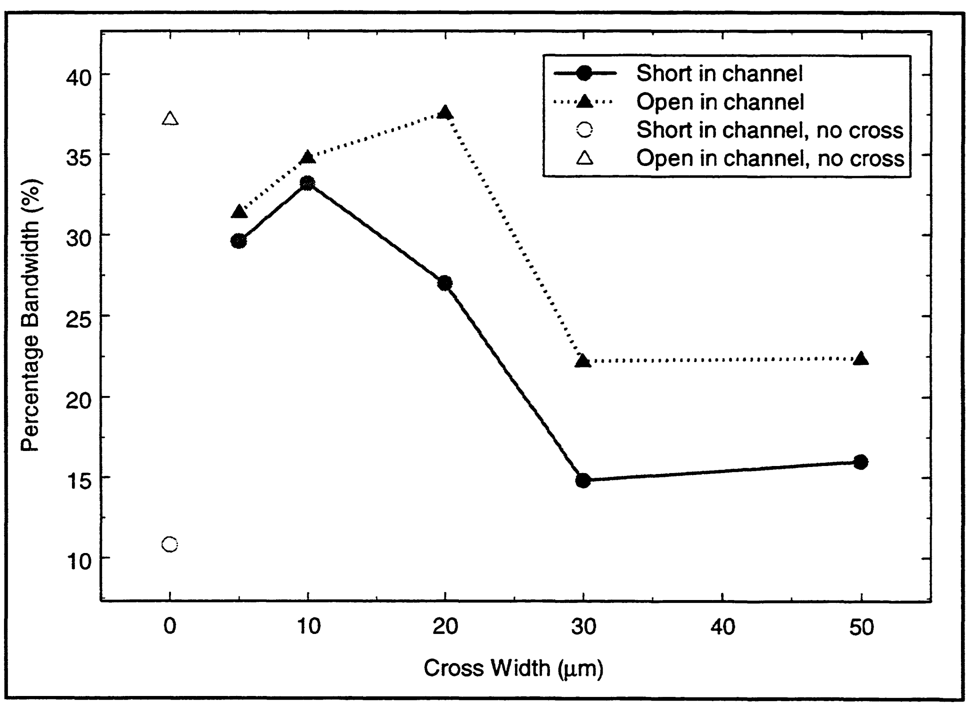

Fig. 6. Effect of the cross width on the transition bandwidth. The bandwidth has been defined as the range over which the return loss is greater than 20 dB.

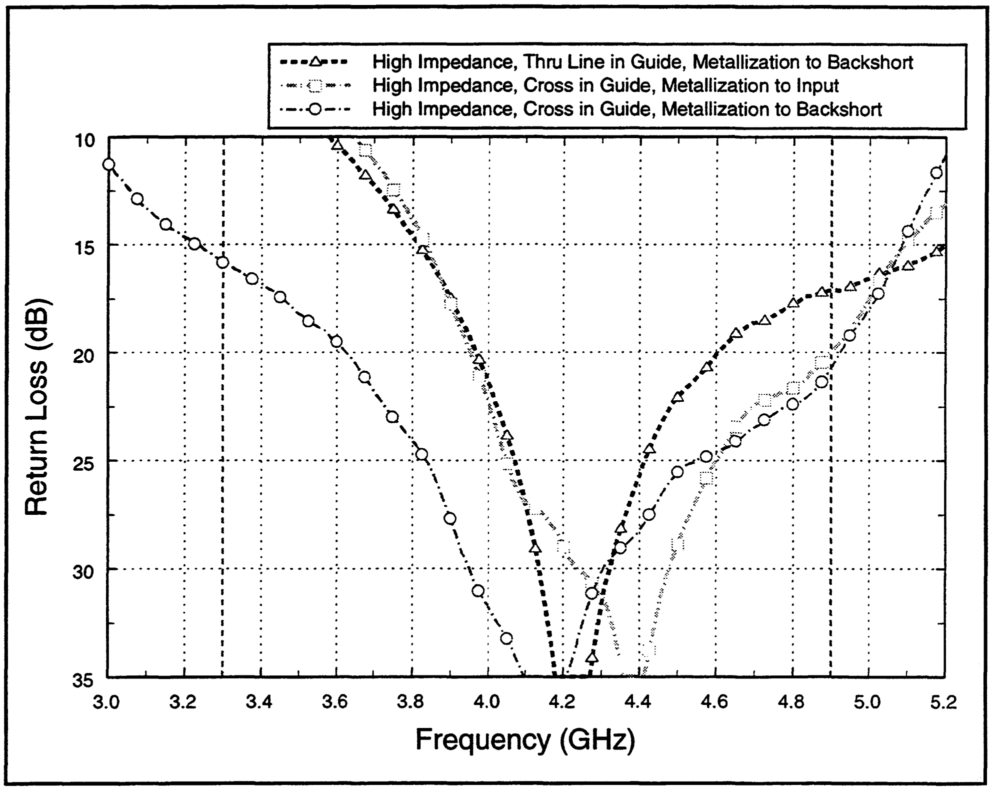

Fig. 7. Measured results using a 3.3-4.9 GHz scale model (the vertical dashed lines mark the edges of the waveguide band). The waveguide and microstrip backshorts were fixed across the waveguide band.

Measured Results

Measurements were made on a scale model waveguide with a frequency band from 3.3 to 4.9 GHz. The reduced height waveguide dimensions for the scale model were 10.0x58.0 mm. The microstrip channel dimensions were 14.7 mm wide by 12.2 mm high, with a quartz substrate thickness of 4.4 mm. For the scale modeling, the quartz was modeled using C-Stock AK-4 plastic stock with adjusted dielectric constant [2] with a relative dielectric constant of 4.0.

Fig. 7 shows measured plots of return loss versus frequency for several waveguide to microstrip transitions. For all of these plots the waveguide and microstrip backshorts were held fixed across the band. The bandwidth for the transition using the high impedance microstrip line with a short circuit termination increased by more than a factor of two when the cross-bar was introduced. The scale model measurements also showed the decrease in bandwidth performance when the microstrip metallization faces toward the input waveguide.

Conclusions

This paper discusses a fixed tuned waveguide to microstrip transition in which the probe is extended across the waveguide. By the introduction of the cross-bar, the fixed-tuned bandwidth of the thru microstrip transition with a built in signal ground was more than doubled. The transition was found to be relatively insensitive to misalignment of the cross-bar from the center of the guide. Also, the design of the cross-bar is insensitive to changes in cross-bar length and width, although it is believed that additional bandwidth can be gained by fine-tuning of these parameters. Using these results, a broadband transition can be designed which allows for the possibility of continuing the IF or DC lines across the waveguide, which can be advantageous for certain mixer or multiplier configurations.

Bibliography

1. J.L. Hesler, W.R. Hall, T.W. Crowe, R.M. Weikle, II, B.S. Deaver, Jr., R.F. Bradley, and S.-K. Pan, "Fixed-Tuned Submillimeter Wavelength Waveguide Mixers Using Planar Schottky Barrier Diodes," to be published in the *IEEE Trans. Microwave Theory Tech.*, May 1997.

2. C-Stock AK-4, Cuming Corp., 230 Bodwell St., Avon, MA 02322.