Broadband Microstrip to Dielectric Image Line Transitions

Hooman Tehrani, Ming-Yi Li, and Kai Chang, *Fellow, IEEE*

***Abstract*—Novel broadband microstrip to dielectric image line (DIL) transitions have been developed. A conducting strip is flared linearly from the microstrip line to the DIL. The DIL and microstrip substrate are on the same side of their common ground plane. Theoretical simulation results, obtained by using the finite-difference time-domain method, agree well with experimental results. The transitions should have applications in the integration of the dielectric image line with microwave integrated circuits (MICs) and monolithic microwave integrated circuits (MMICs).**

***Index Terms*—Broadband transition, dielectric image line, microstrip to image line transition.**

I. INTRODUCTION

DIELECTRIC image line (DIL) has low losses at microwave and millimeter-wave frequencies since most of the signal travels in the low-loss dielectric region [1]. This structure was recently proposed for feeding the aperture-coupled microstrip patch antenna arrays [2], [3], and overcomes the high conduction loss problem at millimeter-wave frequencies. In addition, novel low-cost beam-streering techniques were designed using the dielectric image line feed [4], [5]. In all these applications, the DIL was connected to a rectangular waveguide by means of a three-section transition [1], which is bulky and not easily fabricated.

Microstrip is a good candidate for coupling power to a DIL because both transmission lines can use a common ground and the transition structure can be made compact. However, a wide band, low reflection, low insertion loss, and direct transition between microstrip and DIL is not easy to design and fabricate. A microstrip-fed Yagi-Uda slot array was used to couple the DIL, yielding about 6% frequency bandwidth at 8.276 GHz [6]. The microstrip and DIL in [6] were on opposite sides of their common ground plane. In this letter, new microstrip to DIL transitions are presented using a conducting strip flared linearly from the microstrip width to the width of the DIL. Finite-Difference Time-Domain (FDTD) method was used for full-wave analysis of the transition structures. Experimental results verify the simulation results well.

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The authors are with the Department of Electrical Engineering, Texas A&M University, College Station, TX 77843-3128 USA (e-mail: chang@ee.tamu.edu).

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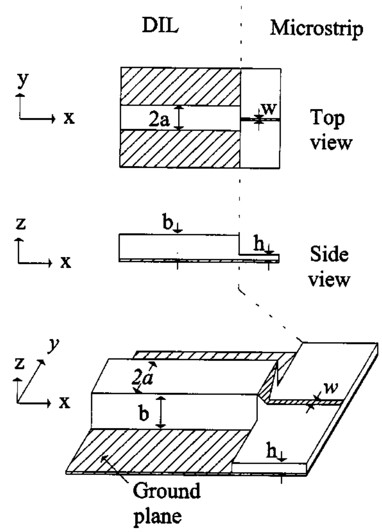

Fig. 1. Perspective and geometry of the compact boadband microstrip to dielectric image line transition.

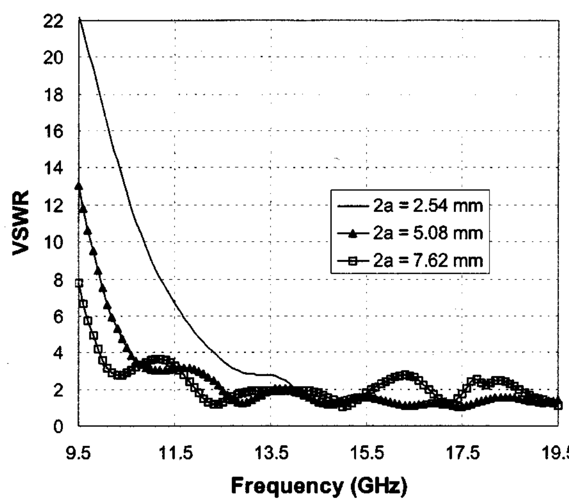

Fig. 2. Simulated effects of changing dielectric image line width for two back-to-back compact transitions of Fig. 1. $b = 2.54$ mm, $w = 1.27$ mm, and $h = 1.27$ mm.

II. DESIGN, SIMULATION, AND EXPERIMENTS

Fig. 1 shows the proposed compact broadband microstrip to DIL transition. Two back-to-back transitions were used to facilitate the measurement and simulation. The DIL and 50-Ω microstrip are on the same side of a common ground plane. A conducting strip is flared from the microstrip to the DIL along a 90-degree transition region, starting from the microstrip width

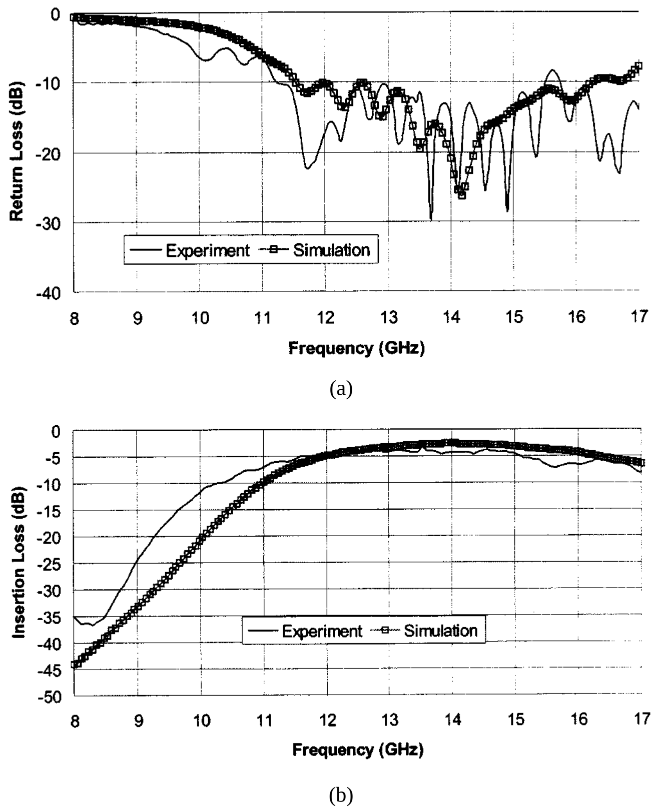

Fig. 3. Experimental and simulation results for two back-to-back transitions of Fig. 1. $2a = 5.842$ mm, $b = 2.54$ mm, $w = 0.635$ mm, and $h = 0.635$ mm: (a) return loss and (b) insertion loss.

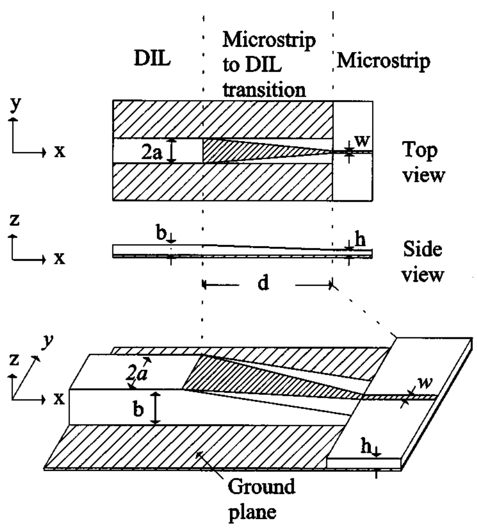

Fig. 4. Perspective and geometry of a broadband microstrip to dielectric image line transition with dielectric tapering.

w ending in width $2a$ of the DIL. RT/Duroid substrate with relative dielectric constant of 10.8 was used to make the microstrip and the DIL. The connection planes of the open end of the microstrip substrate and the DIL transition were made very flat, smooth, and contacted very tightly. The transition structure was simulated using Fidelity [7], a commercially available FDTD electromagnetic simulator.

Fig. 2 shows VSWR data simulated for two back-to-back transitions as DIL width $2a$ was varied. The simulation cube was meshed uniformly with $dx = dy = 0.3175$ mm and $dz = 0.158\,75$ mm. It can be seen from Fig. 2 that as DIL width is increased, the cutoff frequency becomes lower at the expense of reducing usable bandwidth. Fig. 3 shows the experimental results of the compact microstrip-DIL-microstrip structure, fabricated and tested using an HP 8510B vector network analyzer. These results include the connector, DIL, and microstrip line losses. From 11.6 to 15 GHz, results show a better than 5 dB insertion loss and 10 dB return loss for two back-to-back transitions. The estimated insertion loss per transition is less than 2 dB. The quasi-TEM fields in the microstrip circuit and the DIL dominant-mode field components, away from the transition region, are matched because microstrip and DIL are on the same side of the ground plane. At the transition, continuous modes are excited, causing some radiation loss from this open configuration.

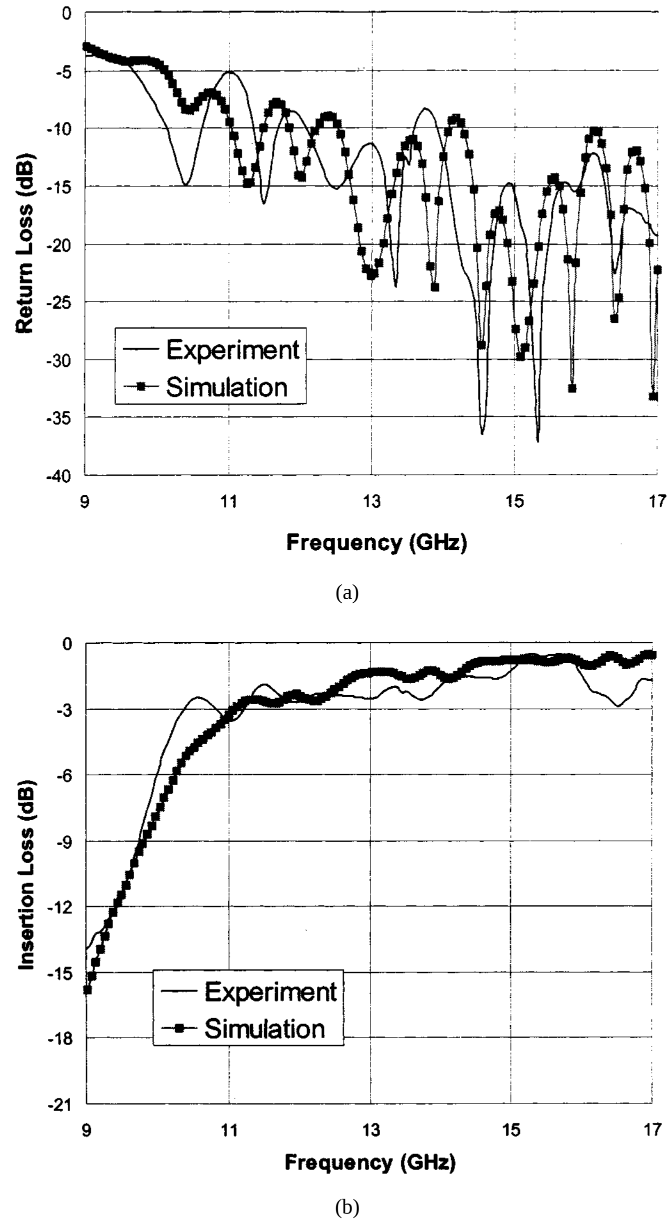

Fig. 5. TRL-calibrated experimental and simulation impedance results for two back-to-back transitions of Fig. 4: $d = 20.32$ mm, $2a = 7.62$ mm, $b = 2.54$ mm, $w = 1.27$ mm and $h = 1.27$ mm: (a) return loss and (b) insertion loss.

From Fig. 2, it can be seen that the compact transition shown in Fig. 1 does not work too well for a wide DIL. Another transition was developed for dielectric image lines with higher image line aspect ratios (a/b) by tapering the dielectric image line, as shown in Fig. 4. The transition length d is adjusted such that the ramp angle is small. Fig. 5 shows experimental and simulation results of a wide band microstrip to DIL transition. FDTD simulation of this structure was performed with nonuniform meshing of the simulation cube, with rate of change between adjacent cells less than 1.35. The microstrip to DIL transition region had the smallest mesh size of the entire grid, $dx = dy = dz = 0.158\,75$ mm, to improve the accuracy of the simulation. Largest cell size of 0.79 mm was used in the simulation space. Through-Reflect-Line (TRL) calibration method was used in this experiment to remove the effects of connectors and the microstrip lines by shifting the reference plane to the edge of the transition region. The experimental and simulated results for two back-to-back (microstrip to DIL to microstrip) transitions are shown in Fig. 5. The results indicate an insertion loss of less than 1.5 dB (half of that shown in Fig. 5) and return loss of better than 10 dB per transition from 11.5 to 17 GHz. Ripples in the return loss are mainly due to the 4.5-cm length of the dielectric image line. This transition is harder to realize than the compact transition of Fig. 1.

III. CONCLUSION

Broadband microstrip to dielectric image line transitions have been presented with relatively low insertion loss and reflection. Finite-difference time-domain method with small meshing was used effectively to simulate the transition structures. The transitions should be useful for integrating microstrip-based microwave integrated circuits (MICs) or monolithic microwave integrated circuits (MMICs) with dielectric image lines for system applications.

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