Aperture Coupling Between Adjacent Layers Using a New Stripline Geometry[1]

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Abstract—**The excitation of the parallel plate mode in stripline configurations is a serious concern in the design of multilayer feeding networks. Using either probes or slots as means of power transfer between adjacent layers, the parallel-plate is always excited, and to insure its suppression a considerable effort has to be made. This letter presents a new method to solve this problem by using striplines with two different dielectric substrates on the two sides of its center strip. By inserting a *dielectric plug* of a high dielectric constant, only in the vicinity of the source, the excitation of the parallel-plate mode is significantly suppressed. A microstrip-to-stripline-to-microstrip coupler was designed with the new *plug configuration* and tested to demonstrate this concept.**

I. Theory

THE PARALLEL plate mode can be excited in a symmetric stripline (both substrates have the same thickness and relative permittivity) either by an electrical current distribution perpendicular to the substrate or by a magnetic current distribution parallel to the substrate. Theoretically, the symmetric stripline itself does not excite this parasitic mode. However, any asymmetry in the fabrication, or discontinuity in the end-launch excitation, does excite this parasitic mode to a level of concern.

Any multilayer feed network would involve stripline configurations and discontinuities that definitely will excite the parallel plate mode. This mode is usually suppressed by shorting posts. Beyond the fabrication complexity involved, these posts can create imperfect waveguides, and resonant cavities that might considerably affect the predictability of the circuit performance. One way to avoid the posts would be by using asymmetric striplines (the two substrates are of different dielectric constants). This solution is acceptable as long as coupling to both sides of the stripline is not necessary. However, in multilayer configurations the coupling to both sides is often needed [1]–[3], and the side having the lower dielectric constant will have a lower coupling level.

The new solution proposed in this paper involves the use of an asymmetric stripline *only in the vicinity of the microstrip-to-stripline coupling slot*. In this case, since the main source for the excitation of the TEM mode is the slot, a small area surrounding the slot is designed to have a higher dielectric constant than the rest of the circuit. Thus, the area surrounding the slot would appear to be closer to a microstrip line rather than a stripline, and the excitation of the parallel mode would be considerably reduced. The discontinuity between the area surrounding the slot and the rest of the circuit excites the TEM parallel plate mode, but at a considerably lower level.

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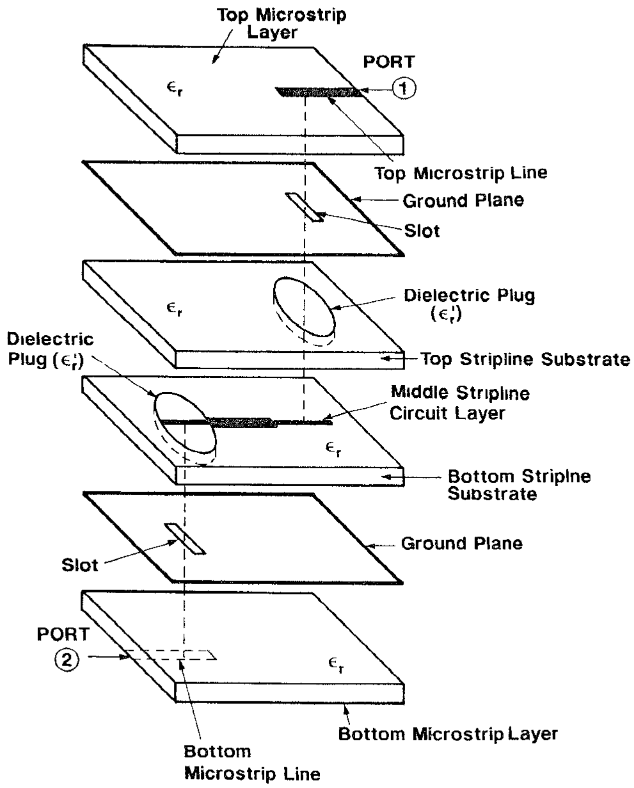

Fig. 1. The geometry of the nonhomogeneous coupler. All substrates are Polyflon Cuflon, 30 mil thick. All lines are 50 Ω. Plugs are cylindrical (ϕ = 3 cm) and made of Duroid 6010.

II. Measurements

To demonstrate this idea, a two-port multilayer coupler was built and tested. This coupler is a microstrip-to-stripline-to-microstrip coupler (Fig. 1) in which the power transfer between adjacent layers is achieved using this new technology. All lines are 50 Ω and the substrates are 31-mils Polyflon Cuflon ($\varepsilon_r = 2.1$). The coupling slots are 2.4 by 0.1 cm. The stripline stubs are 1.5 cm long and the microstrip stubs are 2.4 cm long. The plug insert is 3 cm in diameter and 25 mils in height. The remaining gap between the plug and the

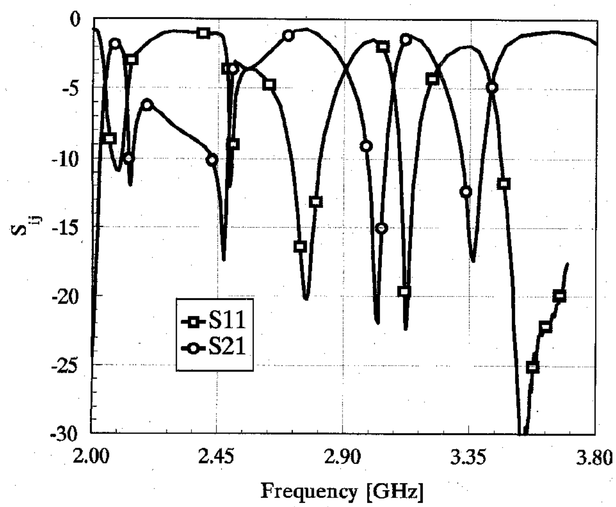

Fig. 2. The measured scattering parameters of the nonhomogeneous microstrip-to-stripline-to-microstrip coupler.

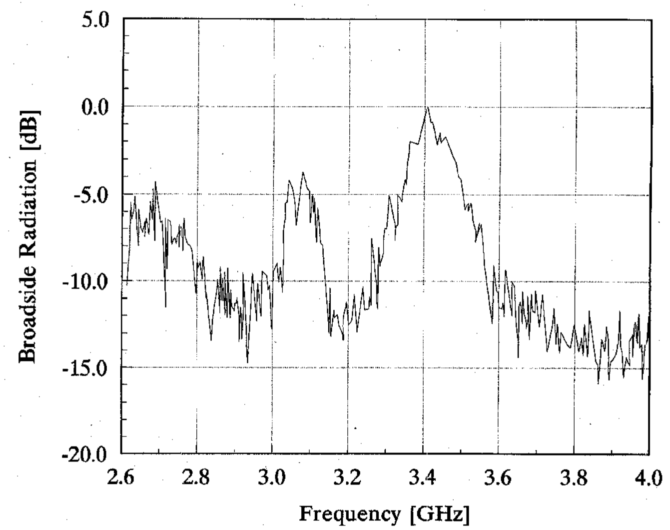

Fig. 3. The swept broadside (with respect to the slot) radiation of the nonhomogeneous microstrip-to-stripline-to-microstrip coupler.

groundplane (6 mils) was filled with bonding film ($\varepsilon_r = 2.5$). Fig. 2 shows the measured insertion loss and return loss of the coupler. Considering a total loss of 0.7 dB being acceptable, the insertion loss results obtained are encouraging for this first prototype. Since the plug resonance frequency is estimated to be about 7.8 GHz, it seems that the plug does not affect the frequency response in the working bandwidth. In previous aperture coupling devices studied [4], [5], the slot is used at frequencies below its own resonance. This is to avoid losses due to the slot radiation. The resonance of the slot used here is about 3.4 GHz. The radiation characteristics of this device were checked and the measured frequency swept broadside (with respect to the coupler) radiation is shown in Fig. 3. As expected, this measurement indicates a certain slot radiation around 3.4 GHz. However, the three peaks in the insertion loss (below the slot resonance frequency at 2.10 and 2.77 GHz, and beyond the slot resonance frequency at 3.7 GHz) are similar ($\approx$ 0.8 dB). Moreover, as pointed out in [4], the loss due to the slot radiation is very small because of the strong difference between the dielectric constants on both sides of the slot (10.2 versus 2.1). In the aperture-coupled patches case, the front-to-back ratio was found to be significantly higher when the patch was printed on a substrate with a permittivity much higher than the one on which the feeding line was printed.

This design was done to demonstrate the feasibility of such a configuration and was not yet optimized. The optimization could not be done without this intermediate stage that is meant to establish the impact of the plug diameter and that of the slot radiation. The development of analytical tools will allow a better design of the microstrip-to-stripline transition so that the slot radiation is minimized. As shown in the past, [1]–[4] the power sharing between the slot radiation and the coupled stripline mode can be controlled by the shape and size of the coupling aperture and by the permitivity of the substrates.

The symmetric stripline-to-microstrip junction was studied in [2]. For such a junction (with similar slot dimensions as the coupler of Fig. 1) the analysis predicts a loss of about 3 dB due to the TEM mode. A total loss of about 5 dB thus was reduced to less than 0.8 dB by the use of the high dielectric plugs, which indicates a significant suppression of the TEM parasitic mode over the operation bandwidth.

III. Conclusion

A new method of avoiding the excitation of the TEM parallel plate mode in stripline configurations was presented. The use of the new *dielectric plug* configuration has clearly reduced the loss to the parallel plate mode. The results are promising in the sense that they eliminate the need for the shorting pins used to suppress this parasitic mode. This method also facilitates the use of slots as means of power transfer between adjacent layers.

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