A STRIPLINE RE-ENTRANT COUPLER NETWORK FOR COFIRED MULTILAYER MICROWAVE CIRCUITS

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ABSTRACT

A stripline coupler network is presented that is suitable for cofired multilayer circuit applications. The network contains a tandem arrangement of two re-entrant coupler structures that can provide tight coupling (3 dB) and is insensitive to conductor registration or misalignments. In addition, circuit modeling and EM simulation for a coupler design using Low Temperature Cofired Ceramic (LTCC) is presented along with experimental results.

INTRODUCTION

Advances in substrate technologies have led to the development of multilayer circuits to achieve higher packaging densities for microwave integrated circuits. The integration of low loss microwave structures, high speed digital circuitry and D.C. power circuits in multitiered cofired assemblies using Low Temperature Cofired Ceramics (LTCC), for example has become common practice for many microwave module applications. A commonly used multilayer circuit structure is the stripline quadrature coupler. This network has many applications including power splitting and combining for high efficiency power amplifiers [1], [2]. In this paper we introduce a stripline re-entrant coupling structure that can be used to obtain tight coupling when used in a tandem configuration, and is suitable for LTCC applications.

DESIGN CONSIDERATION

In LTCC substrate technology, the task of fabricating tight coupling structures (such as 3 dB) in a 50 ohm characteristic impedance using broadside coupling techniques is difficult since the two coupled conductors can not be made closer than one tape thickness. The minimum available thickness from most LTCC tape suppliers is 0.005 inches (green) which fires to about 0.0037 to 0.004 inches. To obtain a representative 3 dB, 50 ohm broadside coupling structure, the typical ground plane spacing is prohibitively large when designing in moderate dielectric constants typically found in LTCC materials. This large ground plane spacing would require a large number of LTCC tape layers that would add to the material and processing costs. An alternate design that would require fewer layers of tape (and a closer ground plane spacing) is the tandem arrangement of two loosely coupled 8.34 dB couplers shown in figure 1. This network however has certain disadvantages. First, since the ground plane spacing must be an integral number of tape thickness, a totally broadside structure may not be possible. Offset conductors [3] would be required with conductor crossovers to allow for the tandem connections of the two couplers. This arrangement is very sensitive to conductor registration and difficult to control in a manufacturing environment. Also, the crossover sections tend to degrade the coupler directivity.

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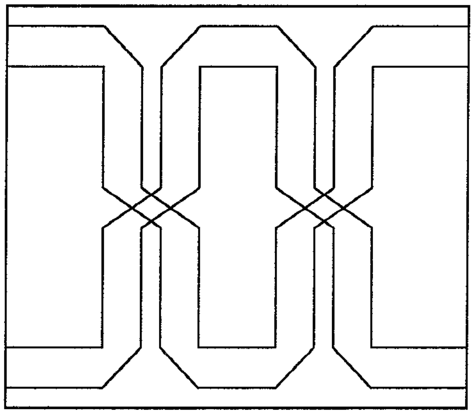

Figure 1

COUPLER DESIGN

The coupler network described in this section makes use of a re-entrant technique to overcome the shortcomings of the coupler networks described above. The re-entry technique was first described by Seymour B. Cohn [4] for coaxial couplers, and later by L. Lavendol [5] for stripline and by A. Pavio [6] for microstrip. The design equations are well documented in those references and will not be repeated here. The re-entrant cross-section for this coupler design is shown in figure 2. It differs from the stripline version described by Lavendal, in which the two stripline conductors are located in the same plane. In this design, the two stripline conductors are located on different planes and are separated by an extra floating conductor. With this arrangement, the coupled and direct outputs may be brought out on the same side of the coupler to allow for tandem connections.

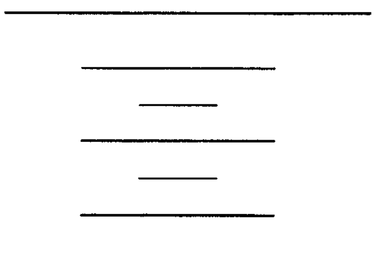

Figure 2

DESIGN IMPLEMENTATION

The substrate selected for the stripline structure is a Low Temperature Cofired Ceramic (LTCC), Ferro type A6. The Ferro A6 LTCC has a relative dielectric constant of 5.9 and a loss tangent of .002. The stripline circuit contains 10 layers, each layer approximately .0039 inches thick resulting in the stripline ground plane spacing of .039 inches. The coupler structure is realized with the coupler circuitry on the fourth and sixth layers and the floating conductors placed on the third, fifth and seventh layers.

CIRCUIT MODELING AND SIMULATION

The initial dimensions for the coupler were computed using circuit modeling (Touchstone version 3.0) [7] and the circuit was modeled on HPs High Frequency Structure Simulator [8] to include all junction effects. A model of the coupler is shown in Figure 3.

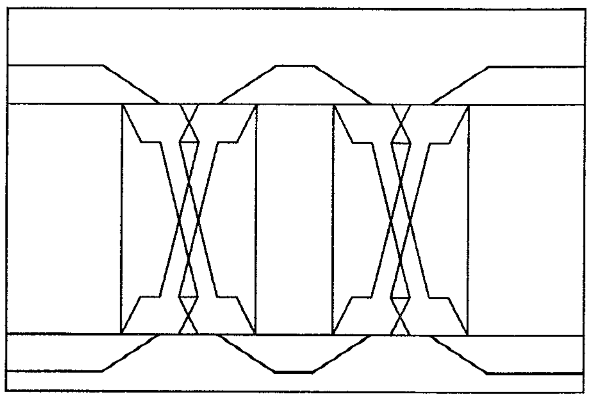

Figure 3

The coupler line widths, overlay offsets and line lengths were varied to optimize the response. The coupler was intentionally overcoupled at the band center to benefit the response at the band edges. The modeled return loss is better than -20 dB over most of the band and rises to -19 dB at the high end of the band. An attractive feature of this coupler design over a typical broadside coupler is that the coupler is relatively insensitive to mis alignments between the coupled tracks. Modeled results with a misalignment of 5 mils between the coupled tracks show relatively small changes in the response of the coupler. These results are shown in Figures 4 and 5.

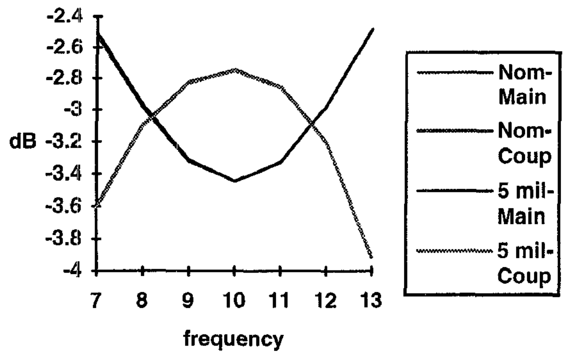

Figure 4

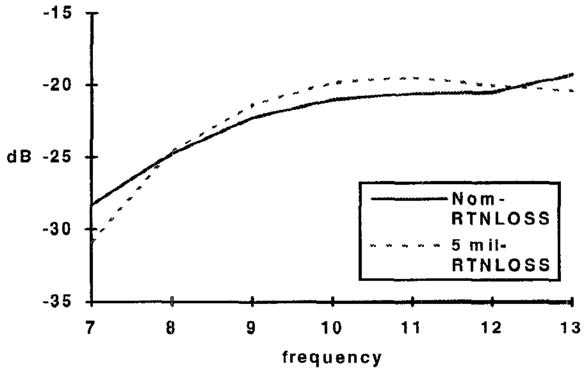

Figure 5

EXPERIMENTAL RESULTS

To validate to modeled design, an experimental circuit was fabricated and measured. The measured performance is shown in Figure 6. The power split is equal to within +/- 0.5 dB over a 3 GHz bandwidth. The measured response is very close to the modeled response.

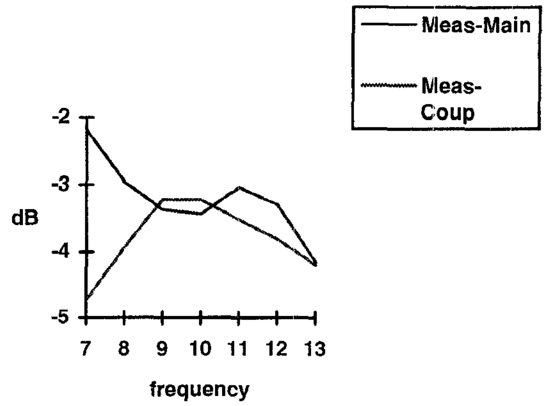

Figure 6

SUMMARY AND CONCLUSIONS

A stripline coupler network that contains a tandem arrangement of two re-entrant coupler structures was demonstrated. Measured performance was presented which closely agrees with the modeled response. The coupler network is suitable for cofired multilayer circuits and is very insensitive to conductor misalignments.

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