MINIATURIZED STRIPLINE CIRCUITRY UTILIZING LOW TEMPERATURE COFIRED CERAMIC (LTCC) TECHNOLOGY

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ABSTRACT

LTCC substrate material has been successfully used to fabricate a 4 GHz 20-dB stripline coupler with 20 dB directivity and a low second harmonic 4 GHz stripline edge coupled filter. These circuits provide mechanical, size, performance, and cost advantages, when compared to stripline assemblies made from softboard or non-homogeneous materials.

INTRODUCTION

The wide variety of coupling configurations available to designers in stripline make it a very useful and versatile design medium for passive components. Stripline is especially well suited to realize high directivity broad-band couplers and low second harmonic edge-coupled filters due to the equivalence of its even- and odd-mode phase velocities. These circuits are usually realized by placing two patterned softboards between two metal plates that are screwed together. Unfortunately, this leads to circuits that are much larger and heavier than their microstrip counterparts. These circuits also can not be directly integrated with microstrip hybrids because of the difficulty of bonding directly between softboard and ceramic material.

Stripline circuits created with softboard assemblies can also have air gaps between the coupled lines, which will cause small differences between the even- and odd-mode phase velocities. These phase velocity differences will also be present for ceramic stripline assemblies that are attached with sealing glass that does not have a dielectric constant matched to the ceramics. This leads to inconsistent and degraded directivity for directional couplers and increased second harmonics for edge coupled filters.

LTTC's can be used to obtain all of the circuit design advantages of stripline without the need for any mechanical mechanism to hold the circuit together. These circuits can then be directly wire bonded to ceramic based hybrids. The use of LTCC's also eliminates air gaps or other discontinuities present in stripline assemblies, which will enhance the repeatability and performance of these circuits. All of these factors combined can greatly reduce the size, weight, cost, and mechanical complexity of systems that require stripline design advantages. Little information exists, however, on the performance and design considerations involved with LTCC circuits at microwave frequencies. This paper describes the fabrication and design of both a high directivity stripline coupler and a reduced second harmonic stripline edge-coupled filter fabricated on DuPont Green Tape‡. Measured results for both circuits are also presented and design recommendations are discussed.

STRIPLINE EDGE COUPLED FILTER

The stripline filter was designed to realize a 4^{th} order Tchebyscheff prototype response from 3.4–4.6 GHz with .05 dB ripple. The filter is comprised of 5 stripline edge coupled sections, which are then connected to 50Ω striplines. These 50Ω striplines are then directly connected to microstrip 50Ω lines. The even- and odd-mode impedance values for each section were converted into physical dimensions by the use of closed form expressions.[1,2] The width, gap, and length for the coupled sections are summarized in Table 1.

This component was fabricated using Dupont Type 851A3 material, and each sheet of this LTCC has a

‡Green Tape is a trademark of DuPont Corporation.

QQ

Section	W	G	L
1	.0096"	.0074"	.2522"
2	.0200"	.0140"	.2497"
3	.0240"	.0199"	.2489"
4	.0200"	.0140"	.2497"
5	.0096"	.0074"	.2522"

Table 1: Coupled Section Dimensions for the LTCC Stripline Edge Coupled Filter

postfire thickness of .0065" and a dielectric constant of k=7.9. Circuits can use anywhere from 4–20 sheets of this material, which allows a great deal of design flexibility. Line widths and spaces must be a minimum of .005" for LTCC designs due to stencil and screen limitations. For this reason the substrate thickness was chosen to be the maximum of 20 sheets (.130") so that the required coupled line gaps would be as large as possible. The stripline and microstrip conductors were patterned with a 400 mesh thick film screen using cofired ink. The top and bottom ground planes were then connected on all edges, except the area around the microstrip transitions, by painting wrap-around grounds with post fired ink.

A photograph of the completed circuit is shown in Figure 1, and measured data is shown in Figure 2.

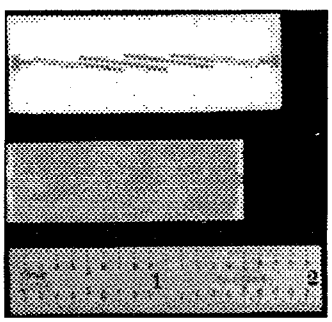

Figure 1: Photograph of the LTCC Stripline Edge Coupled Filter

In the photograph the substrate with the exposed pattern is larger than the finished circuit at the top because it has not been fired.

The measured mid-band insertion loss was –1.5 dB, and the filter achieved approximately 50 dB of

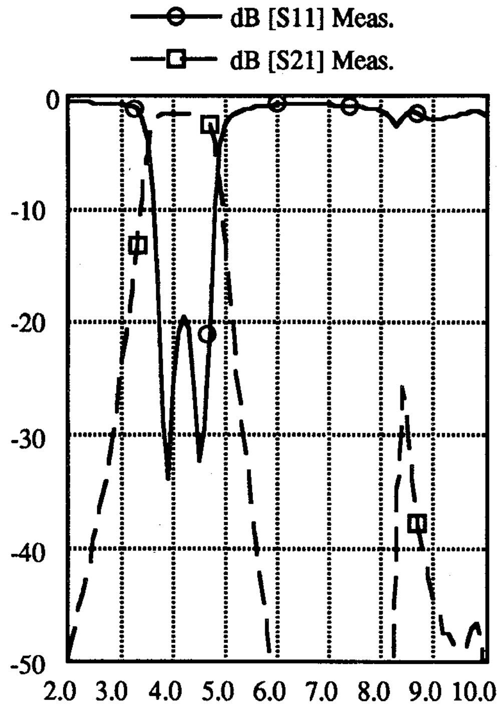

Figure 2: Measured Data of the LTCC Stripline Edge Coupled Filter

ultimate rejection. Testing of the filter was difficult due to "hot" grounds at the microstrip to stripline transition, and the insertion loss comeback at 8.5 GHz is attributable to a grounding problem and not the unequal phase velocities of the even- and odd-mode. It was difficult to achieve a continuous microwave ground at the transition because of the large thickness of the substrate, which was selected to provide larger coupled line gaps. To solve this problem broadside coupled sections could be used for the input and output sections of the filter. This would permit a much thinner substrate to be used, which would shorten the electrical distance from the bottom to the top ground plane.

STRIPLINE 20-DB COUPLER

A 20-dB single section 4 GHz directional stripline coupler was designed to further investigate the electrical characteristics of LTCC materials at high frequencies and the grounding problems associated with the filter. This coupler consists of a section of coupled striplines that are connected to 50Ω striplines. These

50Ω striplines are then directly connected to 50Ω microstrips. The physical dimensions of the lines were determined from the same equations as the stripline filter. The coupled lines were .0084" wide and spaced .0117" apart.

This circuit was fabricated using DuPont Type 848A4 material, and each sheet of this material has a postfire thickness of .0042" and a dielectric constant of k=4.8. The coupler was fabricated with 6 sheets of material to keep the wrap around ground distance from the bottom to the top plate to a minimum. This reduced the length of the wraparound ground by .105" as compared to the filter. A photograph of the completed circuit is shown in Figure 3, and measured data is shown in Figures 4 and 5.

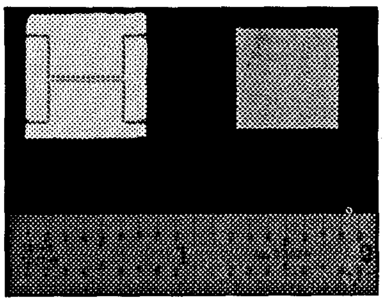

Figure 3: Photograph of the LTCC Stripline 20-dB Coupler

The coupler exhibited .62 ± .12 dB insertion loss, –25 dB minimum return loss, –23.1 ± .3 dB of coupling, –42 dB minimum isolation, and 20 dB minimum directivity from 3–5 GHz. Several important conclusions can be drawn from this data. Since the directivity of the coupler was so high, it can safely be assumed that the dielectric around the coupled lines is homogeneous and that no air gap was present between the lines. The return loss of the coupler and hence the microstrip to stripline transition was also excellent, which means that a thin substrate is necessary to provide a continuous ground from the top to the bottom plate. Both of these facts support the conclusion that the insertion loss comeback of the edge coupled filter was due to the thickness of the substrate rather than a difference between the even- and odd-mode impedances.

This data was obtained without de-embedding the coaxial to microstrip launchers used to make the measurement. Two of these connectors back to back exhibit .25 dB of insertion loss at 4 GHz. The circuit also includes .300" of 50Ω stripline on all ports in addition to the .337" long coupled line section to enable four connectors to be attached at the same time. This means that the actual loss of greentape stripline is around .35 dB/inch. This loss is suitable for most microwave circuit applications except for circuits such as very narrowband filters that require very high Q's. An optimum maximum substrate thickness should be de-

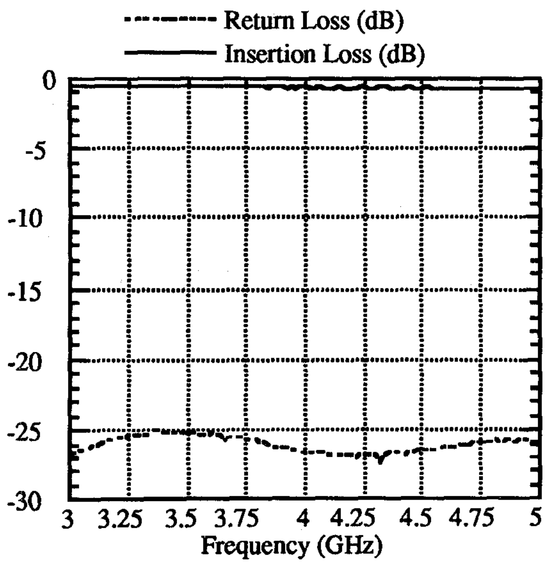

Figure 4: Measured Insertion Loss and Return Loss of the LTCC Stripline 20-dB Coupler

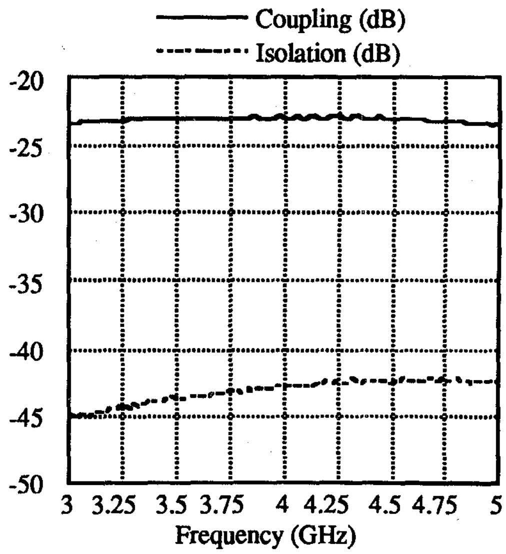

Figure 5: Measured Coupling and Isolation of the LTCC Stripline Coupler

termined that would provide the highest Q possible without degrading the microstrip to stripline transition for circuits that require lower loss.

CONCLUSIONS

LTCC material can be used to fabricate high performance passive microwave stripline circuits with integrated microstrip transitions because of its homogeneous dielectric and low loss. To achieve optimum performance the substrate height should be minimized in order to ensure that the top and bottom ground planes are at the same potential. These circuits are also much lighter, smaller, and less expensive than soft board assemblies that require mechanical assemblies to hold the boards together, and they can easily be integrated with microstrip ceramic circuits.

ACKNOWLEDGEMENT

The author wishes to thank Mike Lambros for providing the test data.

REFERENCES

[1] Cohn, S. B., "Shielded Coupled-Strip Transmission Line," IRE Trans. Microwave Theory Tech., Oct. 1955, pp. 29-38.
[2] Cohn, S. B., "Direct-Coupled-Resonator Filters," IRE Trans. Microwave Theory Tech., Feb. 1957, pp. 187-196.