ALUMINA SANDWICH LINE FILTERS FOR HIGH PERFORMANCE INTEGRATED CIRCUIT APPLICATION*

by

A. F. Hinte, G. Kopcsay, and J. J. Taub
AIL, a division of Cutler-Hammer
Melville, New York 11746

Abstract

Doubly shielded strip line, formed by the sandwiching of two alumina substrates, has been found to yield superior microwave filters than that attainable with microstrip of comparable volume.

General

Microstrip on alumina has had widespread use for a variety of miniature microwave components and subsystems. It has, however, had serious drawbacks for use in microwave filter design. Strip line consisting of a thin-film conductor sandwiched between alumina substrates has been found to be superior for filter applications.

Filters designed in miniature microstrip and other partially shielded lines such as slot line have suffered from limited selectivity and high passband loss due to high conductor losses and radiation from open circuits. Furthermore, residual loss levels in the stopbands are rarely in excess of 30 to 40 dB due to surface wave coupling and box resonances in the structure. The use of fully shielded sandwich line has resulted in measured filter responses with rejections following the theory down to at least 50 dB and lower passband loss because higher Q resonators can be realized in the same volume. Other advantages of sandwich line for filter circuits are: (1) it propagates a pure TEM wave; hence, circuits involving coupled transmission lines can be more exactly designed because odd and even mode phase velocities are the same, and its lack of dispersion is also an asset in many applications; and (2) higher effective dielectric constant resulting in reductions in filter length, the effective dielectric constant is about 9.8, as compared to 6.7 for microstrip on alumina.

One possible disadvantage is that substrates must be camber free to make a tight dielectric sandwich. This requires finish grinding to a flatness of ±1.0 mil. This has added a nominal cost to each substrate, but the construction technique is still economically sound.

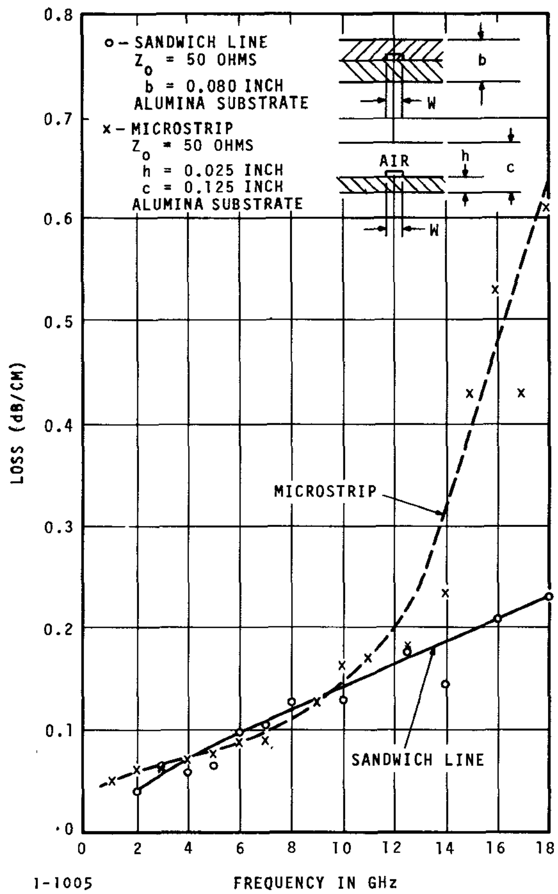

Figure 1. Attenuation as a Function of Frequency for Microstrip and Sandwich Line

Transmission Line Data

Figures 1 and 2 show experimental data on attenuation loss and unloaded Q for microstrip and sandwich line, respectively. Figure 1 compares the attenuation in dB/cm for the two lines and shows that comparable loss per unit length is obtained up to 10 GHz for cross sections of comparable area; the loss then rises rapidly for microstrip in the 10 to 18 GHz range. The loss in dB per wavelength is about 15% lower for sandwich line because of its shorter physical wavelength.

The unloaded Q data of Figure 2 further reflects the lower loss. This was taken on half-wavelength open-circuited resonators. The cross-sectional areas are again comparable. The unloaded Q is substantially higher for sandwich line. Furthermore, the decreasing Q of microstrip in the 7 to 18 GHz range is due to radiation loss caused by the open circuits. Sandwich line opens, however, do not radiate.

Stray coupling between two parallel 50-ohm microstrip lines that were spaced 150 mils apart (six substrate thicknesses) and were 0.5 inch long was measured from 1 to 18 GHz. The lines were decoupled by 50 dB at 1 GHz and became as tight as 22 dB at 18 GHz, indicating strong evidence of surface waves. A similar sandwich line experiment with a spacing of 240 mils (three ground plane spacings) and a 1-inch coupling length gave decoupling values ranging from 70 to 50 dB from 1 to 18 GHz, respectively. Hence, for filters requiring high rejection levels (50 dB or greater), sandwich line is clearly preferable. Sandwich line has been used in the design of several filters which are described in the next section.

Filters

For economy and simplicity, filters requiring open-circuited resonators are the most desirable for sandwich

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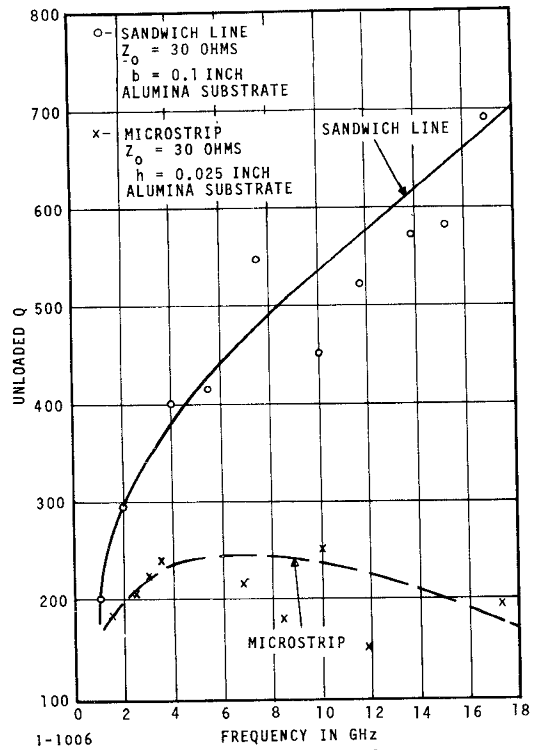

Figure 2. Unloaded Q as a Function of Frequency

line circuits. The hardness of the material and the difficulty of making connections in the middle of a substrate make short-circuited structures costly and difficult to fabricate. Unlike microstrip, balanced stripline will not radiate from an open circuit, so there is no loss in Q.

A typical example of an open-circuited band-pass filter configuration is the quarter-wavelength coupled, half-wavelength open-circuited stub filters.[1] These were designed with the aid of a computer using procedures given in reference 1. Figure 3 gives a typical measured response. Since considerable data exists on strip line discontinuities, the time sharing computer can be used to calculate the required dimensions quite accurately. Accuracies of better than 2% can be achieved on center frequency and bandwidth without adjustments.

The filter shown provides approximately 50 dB of rejection 1 GHz away from the band edges, and less than 1-dB loss in the passband. Moderate to large (30% to an octave) bandwidths are feasible with the stub filter in sandwich line.

As a result of the half-wavelength stub, this filter will have a spurious response at twice the center frequency. In cases where this cannot be tolerated, a low-pass filter[2] of the type shown in Figure 4 can be added in cascade with the stub filter. The filter shown uses alternating high and low impedance lines to simulate the lumped element low-pass circuit. Again, the body of knowledge available on discontinuities has been programmed to permit easy computation of final dimensions. With a suitable number of sections and the proper cutoff frequency, the low-pass filter can maintain the rejection level of the stub filter through its spurious response in a minimal amount of space.

Another filter that is useful in sandwich line is a modified form of the interdigital filter.[3] This filter replaces the short circuit normally required in an interdigital filter with a quarter-wavelength open-circuited stub. At present, only small to moderate bandwidths are feasible. It may be possible to extend the useful range to larger bandwidths with more development effort. The design follows the normal procedure using Getsinger's curves and can provide about a 50-dB rejection. In sandwich line, it is extremely compact and holds considerable promise in future miniature filter work. Figure 3 shows a measured response.

In conclusion, miniature sandwich line filters have been designed that demonstrate their lower loss and superior rejection properties to that of microstrip.

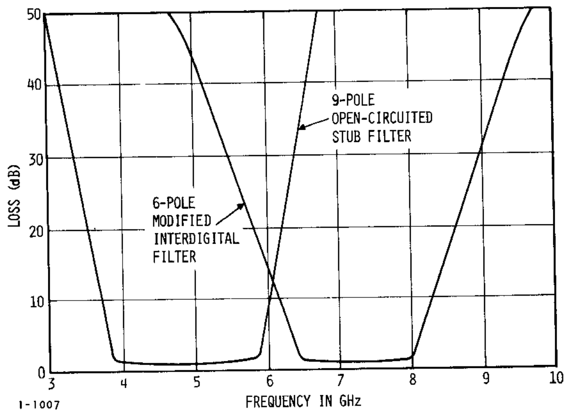

Figure 3. Band-Pass Filter Responses

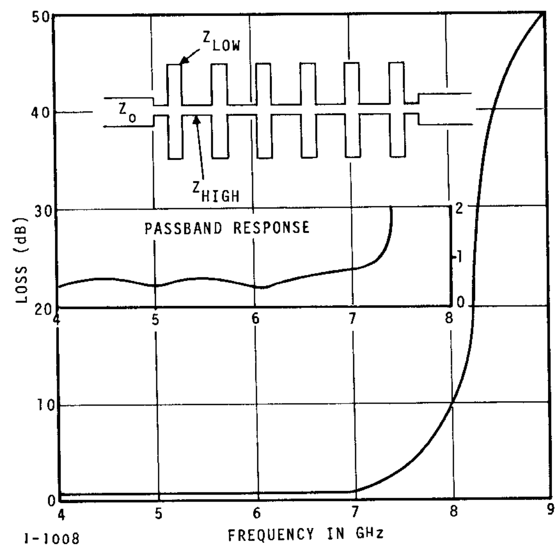

Figure 4. Low-Pass Filter Response and Conductor Pattern

References

1. G. L. Matthaei, L. Young, and E. M. T. Jones, "Microwave Filters, Impedance-Matching Networks and Coupling Structures," McGraw-Hill, New York, 1964, pp. 601-604.

2. Ibid., pp. 361-370.

3. R. M. Davis, "$3\lambda_0/4$ Parallel-Staggered Microwave Filters," Correspondence, IEEE Trans., Vol. MTT-17, July 1969, pp. 404-406.

Notes