New Wide-Band DC-Block Cymbal Bandpass Filter

B. Strassner and K. Chang

***Abstract*—A new low-loss dc-blocking parallel-cascaded bandpass filter is presented. The filter is much easier to use and fabricate, more compact, and simpler to design than the conventional end- or parallel-coupled line filters. The filter has a wide passband with a 2 : 1 voltage standing-wave ratio bandwidth of around 10% and an insertion loss of 0.5 dB at 10 GHz. Simulated results agree very well with experimental results.**

***Index Terms*—Bandpass filter, dc block, parallel cascaded.**

I. Introduction

Most bandpass filters use end- or parallel-coupled lines [1]. These filters usually require several sections to have a return loss of better than 20 dB [2]. Each of the resonant sections is separated by a gap. Reducing this number of gaps would result in lower loss, as well as lessen the chance of error in the design or etching of the filter. Such errors can greatly affect the operating frequency and return loss of bandpass filters. The smallest width and gap of the proposed filter are much greater than the etching tolerances. This new filter utilizes two coupled triangular-shaped microstrip patch resonators [3], [4] in a parallel-cascaded geometry [5], [6]. The microstrip patches have lower conductor loss than the end- and parallel-coupled designs allowing for greater power handling at the expense of being slightly larger in size.

A series of equations were derived from electromagnetic (EM) simulation curves to facilitate the design and govern the filter's behavior. These equations can be used as the design guidelines.

II. Design Equations

The filter design was done using the full-wave EM simulator IE3D.[1] Every dimension of the filter shown in Fig. 1 was varied in order to formulate design equations that predict the filter's center frequency and to determine the minimum return loss. Fig. 2 illustrates the effects of different W and L on the resonant frequency. Based on these curves, W determines the center frequency by

$$f \cong 1.27 \frac{c}{W\sqrt{\varepsilon_r}} \tag{1}$$

where W is in meters, c is the speed of light (3×10^8 m/s), ε_r is the substrate dielectric constant, and the center frequency f is in hertz. The dimension L in meters is chosen to provide the lowest return loss by the following equation:

$$L \cong \frac{c}{5f\sqrt{\varepsilon_r}} \cong \frac{W}{6.35} \tag{2}$$

where the center frequency f is in hertz, c is the speed of light in meters per second and L and W are in meters.

The following ratio is used to yield G for the L determined in (2):

$$\frac{L}{G} \cong 5. \tag{3}$$

Manuscript received January 3, 2000; revised September 21, 2001. This work was supported in part by the State of Texas Higher Education Coordinating Board's Advanced Technology Program.

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

Publisher Item Identifier S 0018-9480(02)04047-4.

[1]IE3D, version 4.0, Zeland Software Inc., Fremont, CA, 1993.

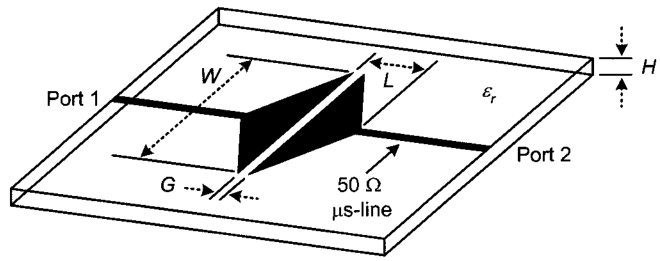

Fig. 1. Bandpass-filter schematic and its test fixture.

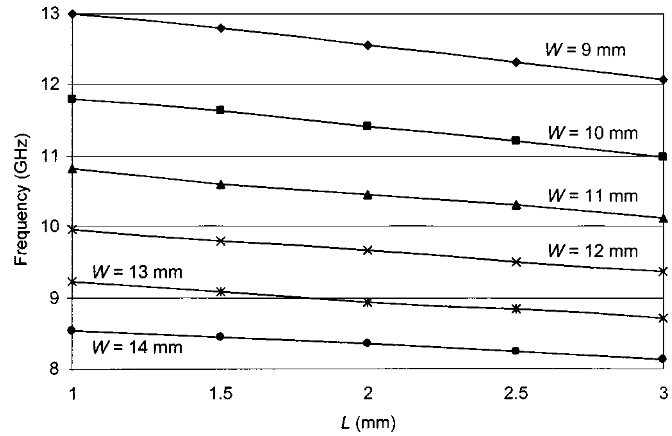

Fig. 2. IE3D simulated resonant frequency versus L for various W when $\varepsilon_r = 10.8$ and $H = 0.635$ mm.

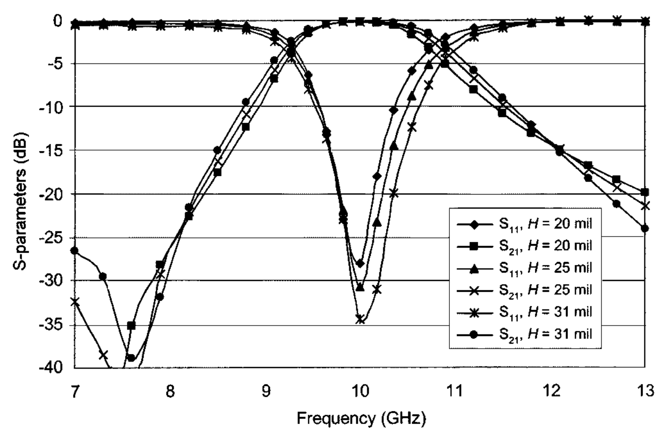

Fig. 3. IE3D simulated S-parameters for different substrate thickness H. $W = 11.6$ mm, $L = 1.83$ mm, $G = 0.37$ mm, and $\varepsilon_r = 10.8$.

This ratio provides the gap needed to achieve the best return loss characteristics. Equations (1)–(3) determine all of the filter's dimensions. These dimensions should produce a filter with an insertion loss around 0.5 dB and a return loss better than 20 dB at the desired center frequency.

The thickness of the substrate H has little effect on the filter's resonant frequency, but does play a role in determining the filter's bandwidth, as illustrated by Fig. 3. This figure shows the simulated S-parameters for a filter with $W = 11.6$ mm, $L = 1.83$ mm, $G = 0.37$ mm, and $\varepsilon_r = 10.8$, as determined by (1)–(3). As H increases, so does the filter's bandwidth. The optimal bandwidth of the filter at 10 GHz is around 10%.

Unlike the substrate's thickness, changes in its dielectric constant greatly affect the operating frequency. The design equations take into

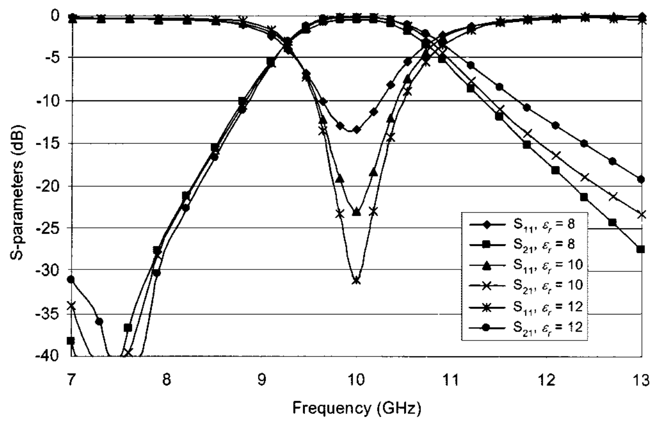

Fig. 4. IE3D simulated S-parameters for different substrate dielectric constants when $H = 25$ mil; when $\varepsilon_r = 8$, $W = 13.5$ mm, $L = 2.12$ mm, and $G = 0.42$ mm; when $\varepsilon_r = 10$, $W = 12.1$ mm, $L = 1.9$ mm, and $G = 0.38$ mm; when $\varepsilon_r = 12$, $W = 11$ mm, $L = 1.73$ mm, and $G = 0.35$ mm.

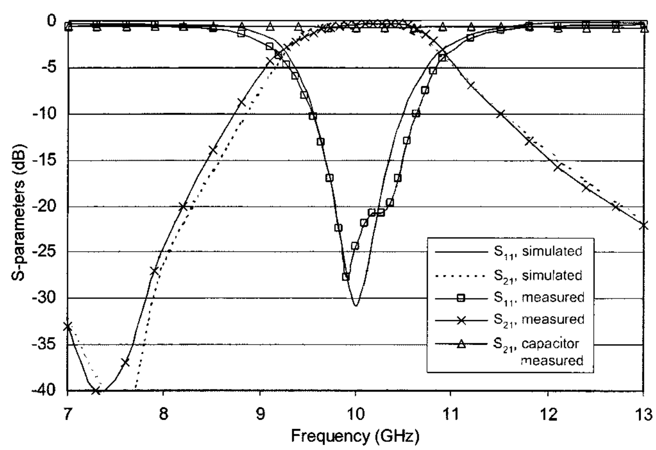

Fig. 5. Measured and simulated S-parameter curves for $W = 11.6$ mm, $L = 1.83$ mm, $G = 0.37$ mm, $H = 0.635$ mm, and $\varepsilon_r = 10.8$. A curve representing the measured insertion loss of a chip capacitor is also shown.

account different dielectric constants. Fig. 4 shows the simulated S-parameter curves for three different filters on different substrates. Since changing the dielectric constant changes the resonant frequency, different W's, determined by (1)–(3), are used for each filter in order for all of the filters to resonate at 10 GHz. The EM simulator IE3D shows all of the filters to be resonant at 10 GHz, proving the validity of the design equations for changes in the dielectric constant. Similar IE3D analysis for changes in the filter's dimensions and substrate dielectric constant was carried out at both 5 and 15 GHz. IE3D proved the effectiveness of the design equations at both these frequencies.

III. Filter Performance

Fig. 5 shows measured and simulated S-parameter curves for a filter with $W = 11.6$ mm, $L = 1.83$ mm, $G = 0.37$ mm, $H = 0.635$ mm, and $\varepsilon_r = 10.8$. Note that $W/L = 6.35$ and $L/G = 5$ were used as specified by the design guidelines in (2) and (3). Using our design, i.e., (1), these dimensions compute a resonant frequency of 10 GHz. The IE3D EM simulation accurately predicts the filter's behavior. Using an HP 8510B measurement system, the filter's insertion loss is measured to be 0.5 dB, and the return loss is measured at around 25 dB at 10 GHz. The filter's return-loss curve clearly shows the two poles of the filter's coupled resonators. The filter's measured results yield a 2 : 1 voltage standing-wave ratio (VSWR) bandwidth of around 10%. Also shown in Fig. 5 is the 0.6-dB insertion loss of a C08BLBB1X5UX dc-block chip capacitor manufactured by Dielectric Laboratories, Cazenovia, NY. The insertion loss of the filter is slightly lower than that of the lumped capacitor, and has the advantages of having bandpass characteristics and being easily analyzed with other microwave components in a circuit simulator.

IV. Conclusion

A new dc-blocking bandpass filter has been developed with low loss and easy fabrication. The wide-band characteristics also provide a useful margin when utilizing this filter in microwave circuit applications. The curve-fitting design equations provide a quick and accurate way to design this type of filter.

Acknowledgment

The authors would like to thank M. Li, Texas A&M University, College Station and C. Wang, Texas A&M University, for fabricating the microstrip circuits.

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