Enhanced Microstrip Filter Design With a Uniform Dielectric Overlay for Suppressing the Second Harmonic Response

Jen-Tsai Kuo, *Senior Member, IEEE,* and Meshon Jiang

***Abstract*—Parallel-coupled microstrip filters are designed to suppress spurious response at twice the passband frequency $(2f_o)$ with a uniform dielectric overlay. The overlay dielectric is used to equalize the modal phase velocities of each coupled stage. Based on the method, we have a large degree of freedom in choosing thickness and permittivity of the overlay dielectric. The image impedances of all the coupled stages in such a filter need adjusting to complete the filter synthesis. Two filters are fabricated and measured results show a good agreement with the simulation. A suppression of at least 40 dB to the spurious responses at $2f_o$ is achieved.**

***Index Terms*—Microstrip filter, overlay dielectric, phase velocity equalization, spurious response.**

I. Introduction

High-performance bandpass filters are usually required in the RF front end of a wireless communication system. One of the most common methods for implementing a planar filter is to use parallel-coupled microstrip filters [1], [2]. The traditional design of parallel-coupled line filters, however, suffers from the spurious response at twice the design frequency $(2f_o)$ [2]–[6], which not only degrades passband symmetry but also deteriorates rejection levels in upper stopband. It is due to that phase constants of the even (β_e) and odd (β_o) modes of each coupled stage are not identical.

It has been shown that a microstrip coupler with $\beta_e = \beta_o$ will have more bandwidth and better isolation characteristic. The equalization of β_e and β_o can be achieved by using capacitor compensation [3], suspended substrates [4], corrugated coupled lines [5] and an overlay dielectric [6].

In this letter, we design a bandpass filter with suppression of spurious responses at $2f_o$ by using a flat dielectric overlay. For a single-stage coupler with an overlay, the thickness of the overlay dielectric can be easily determined by a full-wave transmission line program, e.g., the spectral domain approach [7]. The thickness of the overlay dielectric, however, generally depends on material constants and geometric dimensions of the coupled microstrips. A multiorder filter consists of a cascade of several coupled stages. If the overlay dielectrics for these stages have different dimensions, fabrication of the whole filter will be tedious and difficult. Our objective is thus to design a filter with a uniform overlay dielectric, so that each stage has $\beta_e = \beta_o$, for suppressing the spurious responses.

In the following, Section II describes the design procedure, Section III compares the responses of two fabricated bandpass filters with those obtained by traditional design, and Section IV draws the conclusion.

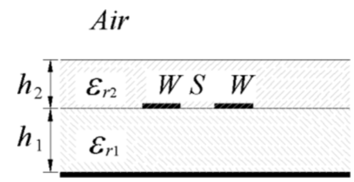

Fig. 1. Coupled microstrips with an overlay dielectric.

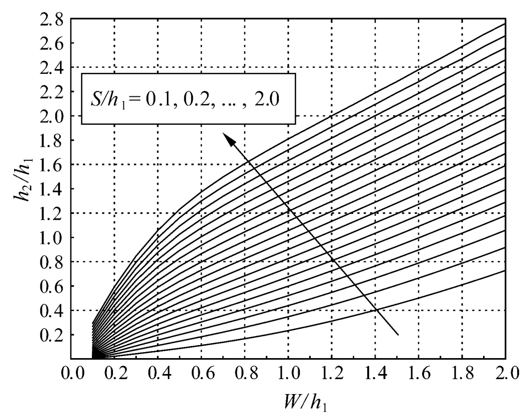

Fig. 2. Required h_2/h_1 ratios for making $\beta_e = \beta_o$ at $2f_o = 4.9$ GHz. $\varepsilon_{r_1} = \varepsilon_{r_2} = 10.2$, $h_1 = 1.27$ mm.

II. Enhanced Design

The design procedure is similar to that in [4] where a parallel-coupled line filter is designed on a suspended substrate with a uniform suspension height. Suppose we are designing a filter with $f_o = 2.45$ GHz. First, referring to the multilayered coupled lines in Fig. 1, use a full-wave program to find a proper h_2/h_1 ratio for given values of W/h_1 and S/h_1 to have $\beta_e = \beta_o$ at $2f_o = 4.9$ GHz. Our numerical experiences show that ε_{r_2} must be no less than ε_{r_1} for the equalization of β_e and β_o. For convenience, choose $\varepsilon_{r_2} = \varepsilon_{r_1}$ herein. Fig. 2 plots the required

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The authors are with the Department of Communication Engineering, National Chiaotung University, Hsinchu 300, Taiwan, R.O.C. (e-mail: jtkuo@cc.nctu.edu.tw).

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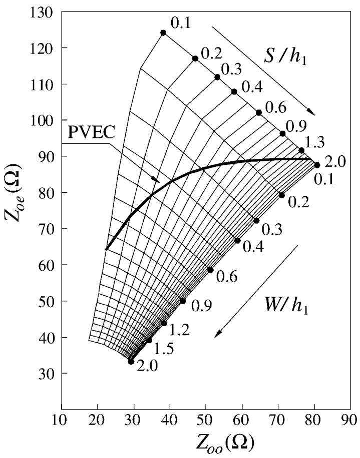


Fig. 3. Even- and odd-mode characteristic impedance design data for coupled microstrips with an overlay dielectric. $\varepsilon_{r_1} = \varepsilon_{r_2} = 10.2$, $h_1 = 1.27$ mm. PVEC represents the phase velocity equalization curve with $h_2/h_1 = 0.2$.

h_2/h_1 for coupled microstrips in such a structure. It can be seen that h_2/h_1 is increased when W/h_1 or S/h_1 is increased. These curves indicate possible choices of geometric dimensions of the coupled lines in the design. For example, if $h_2/h_1 = 0.4$ is used, the range of W/h_1 is from 0.15 to 1.4 when $0.1 \leq S/h_1 \leq 2.0$. It is worth mentioning that when ε_{r_2} is changed, the required thickness ratio h_2/h_1 must be calculated again.

Then, we can choose a suitable h_2 value, e.g., $h_2/h_1 = 0.2$, for circuit realization. The even- and odd-mode characteristic impedance design data at 2.45 GHz for the multi-layer structure can be established as in Fig. 3. In addition, a phase velocity equalization curve (PVEC) can be plotted together with the design data. The curve connects all intersection points of a horizontal line $h_2/h_1 = 0.2$ and the curves in Fig. 2. On the PVEC, all the coupled lines have the same dielectric overlay, and their respective β_e and β_o are identical. Note that the even- and odd-mode characteristic impedances of the coupled microstrips for each point on the PVEC should be calculated at 2.45 GHz.

Finally, apply the synthesis method for parallel-coupled line filters developed in [4] to determine the image impedance of each stage. The method requires three to five iterations to obtain the final results for a fifth-order filter. The reference port impedance can also be a variable in the iteration. When it is not 50 Ω, tapped input/output couplings [8] can be employed to avoid the use of impedance transformers.

III. Measured Results

We use the full-wave ANSOFT HFSS finite element software for simulation before the circuits are fabricated. Fig. 4 plots the simulation and measured $|S_{11}|$ and $|S_{21}|$ responses for a third-order Chebyshev filter with a fractional bandwidth $\Delta = 10\%$. It has four coupled stages, and two pairs of variables $(W/h_1, S/h_1)$ on the PVEC have to be determined by the iteration. The results are (0.501, 0.299) and (0.135, 1.254) for the first and the second stages, respectively. The total length of the filter is 4.09 cm. The measured results agree with the simulation quite well. The responses for a parallel-coupled line filter, based on the traditional design [1], on a substrate with $\varepsilon_r = 10.2$ are also plotted for comparison. The measured data show that the insertion loss at the design frequency is less than 0.7 dB, and that a suppression of more than 40 dB to the spurious response at $2f_o$ is obtained.

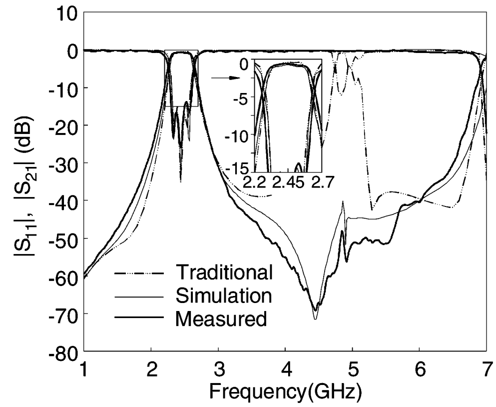
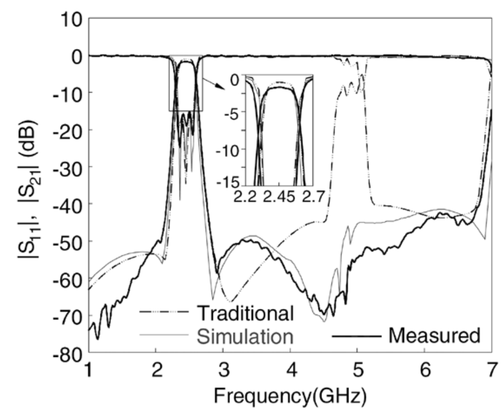
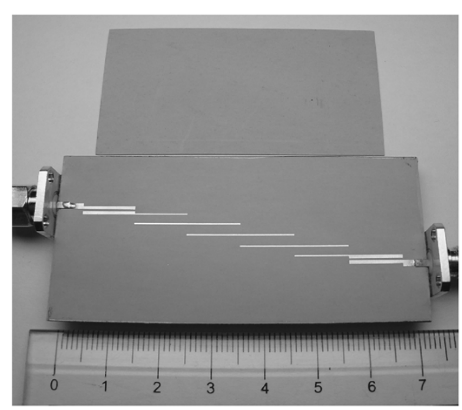


Fig. 4. Simulated and measured $|S_{11}|$ and $|S_{21}|$ responses of a third-order Chebyshev filter. The center frequency $f_o = 2.45$ GHz. Material constants see Fig. 3.



(a)



(b)

Fig. 5. Simulated and measured responses of a fifth-order Chebyshev filter. The center frequency $f_o = 2.45$ GHz. (a) $|S_{11}|$ and $|S_{21}|$ responses. (b) Photo of the circuit. Above the filter is the overlay dielectric.

Fig. 5(a) shows the results of a fifth-order Chebyshev filter with $\Delta = 10\%$ built on the same structure as that in Fig. 4. The first coupled stage has $(W/h_1, S/h_1) = (0.486, 0.315)$, the second (0.124, 1.351), and the third (0.103, 1.573). In measured results, the insertion loss at 2.45 GHz is 1.7 dB and the return loss is better than 15 dB. Both the simulation and measured $|S_{21}|$ responses have a dip at around $2f_o$. This indicates that the even- and odd-mode phase velocities of each coupled stages coincide very well. Again, comparing with the traditional design, we achieve a suppression of at least 40 dB to the spurious response at $2f_o$. Fig. 5(b) is the photo of the circuit.

IV. Conclusion

Parallel-coupled microstrip filters are design with a uniform layer of dielectric overlay to suppress the spurious response at twice the design frequency. Based on our method, the thickness and ε_r of the dielectric overlay can have a large degree of freedom to choose. The results of the third- and fifth-order filters show that a suppression of more than 40 dB is obtained.

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