CAPACITIVELY COMPENSATED HIGH PERFORMANCE PARALLEL COUPLED MICROSTRIP FILTERS

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ABSTRACT

A capacitive compensation technique is described for the design of microstrip parallel coupled filters with improved passband symmetry and very low spurious response up to 2.5 times the center frequency. The technique is useful for the design of filters on alumina as well as GaAs substrates.

INTRODUCTION

Parallel coupled microstrip filters are extensively used as bandpass filters in microwave systems because they are compact in size and easy to fabricate. These filters can be designed with reasonable accuracy using the design information given in the literature [1-4]. Since microstrip is a non- homogeneous medium, the even- and odd-mode phase velocities for a coupled pair of microstrip lines are unequal. The difference in the phase velocities results in filter's asymmetric passband response, deteriorates the upper stopband performance and moves the second passband (which is at about twice the center frequency) towards the center frequency [5,6]. Often this poor stopband rejection forces the microwave designer to employ a low-pass filter preceding the bandpass filter. The second passband of a bandpass filter at twice the center frequency also results in poor second harmonic suppression when used as output filters in oscillators and amplifiers. To overcome this problem bandpass filters using parallel coupled stepped impedance resonators have been implemented [7].

This paper describes a capacitively compensated parallel coupled microstrip filter with symmetric passband and second passband well above twice the filter's center frequency. The compensated structure does not require any extra CAD tools for design and is compatible with monolithic microwave integrated circuit technology.

FILTER DESIGN AND RESULTS

The stopband performance of a parallel coupled microstrip bandpass filter is improved if the phase velocities of the even and odd modes are equalized. There are several ways to equalize the phase velocities: using a proper shielding cover [8], using a suspended microstrip configuration, using dielectric overlay [9], using capacitors at the ends of the coupled section [10,11] and overcoupled resonators [6]. Of these equalization techniques, the simplest is capacitive compensation, which is the subject of this paper, and has been previously reported to improve the directivity of directional couplers [10,11].

Capacitive compensation of phase velocity difference in parallel coupled microstrip lines is illustrated in Figure 1. Microstrip even mode phase velocity is lower than odd mode; the odd-mode electrical length must be extended. In the even mode, the capacitors ,C, are nearly invisible; however, they effectively reduce the odd-mode phase

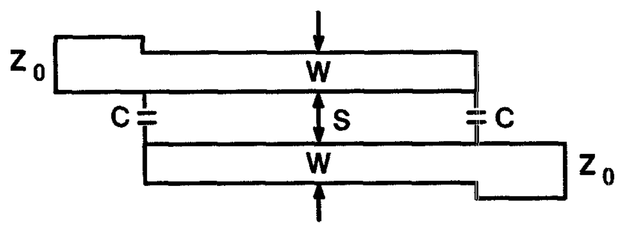

Figure 1 Capacitive compensation of phase velocity difference in parallel coupled microstrip lines.

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velocity, increasing the odd-mode electrical length. The physical length of the filter sections are quarter of the even-mode wavelength at the design center frequency f_0. The capacitor values may be calculated from [10]:

$$C \simeq \Delta\theta_o / (\pi f_0 Z_{0o})$$

where Z_{0o} is the odd-mode impedance and $\Delta\theta_o$ is the effective increase in the odd-mode phase angle.

To illustrate the design procedure for a capacitively compensated high performance parallel coupled microstrip filter, two design examples have been chosen.

Example 1:

Center frequency f_0 = 4 GHz
Response = Chebyshev with 0.2 dB ripple
Bandwidth = 0.4 GHz
40-dB attenuation points = 4 ± 0.6 GHz
GaAs substrate, ε_r = 12.9 and
h = 0.2 mm
Conductor thickness = 5 μm

The number of λ/2 resonators required is 4, whereas coupled λ/4 sections are 5. The various parameters for the filter (Fig. 2) are listed in Table 1, where ε_e^e and ε_e^o are the even mode and odd mode effective dielectric constants, respectively.

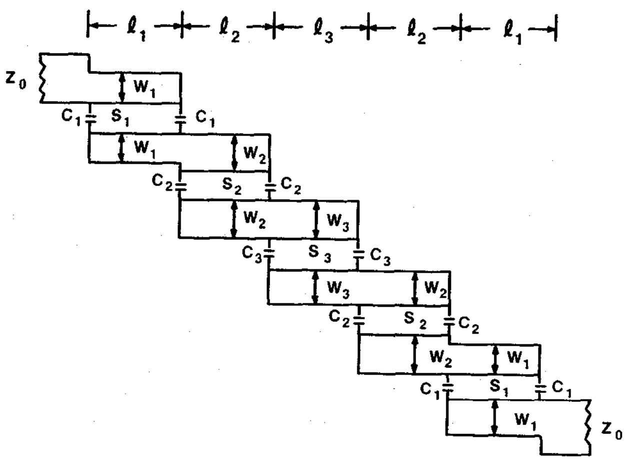

Figure 2 Capacitively compensated four λ/2 resonator microstrip parallel coupled filter configuration.

The insertion loss and return loss of 4-section filter (with and without the capacitive compensation) are shown in Figures 3 and 4, respectively. The filter structure has been assumed lossless. It may be noted from Figure 3 that for the compensated case the second passband level is below 40 dB the fundamental passband response level at least up to 2.5 times the center frequency. The slight shift in the passband towards the lower frequency in the capacitive compensated case is due to the fact that the resonator length is approximately given

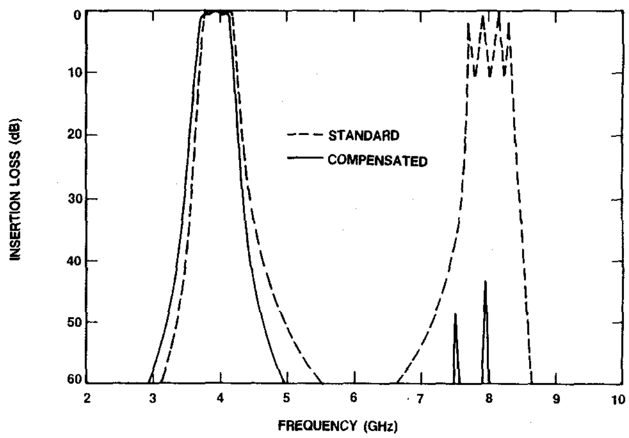

Figure 3 Simulated insertion loss of standard and compensated 4-section parallel coupled filter on a GaAs substrate.

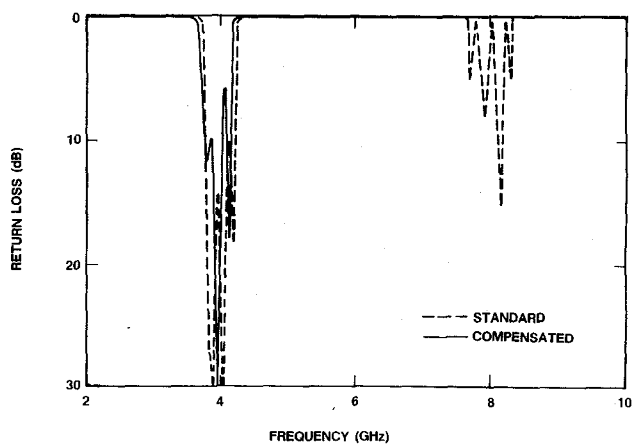

Figure 4 Simulated return loss of standard and compensated 4-section parallel coupled filter on a GaAs substrate.

by $\lambda_0/4\sqrt{\varepsilon_e^e}$ not by $\lambda_0/2\ (\sqrt{\varepsilon_e^e} + \sqrt{\varepsilon_e^o})$ as calculated for uncompensated case. Here no attempt was made to fully optimize the circuit.

Example 2:

Center frequency f_0 = 4 GHz
Response = Chebyshev with 0.2 dB ripple
Bandwidth = 0.4 GHz
Number of Sections = 6
Quartz substrate, ε_r = 3.8 and h = 0.5 mm
Conductor thickness = 5 μm

The various parameters for the filter are listed in Table 2.

The insertion loss and return loss of 6-section Chebyshev filter (with and without the capacitive compensation) are shown in Figures 5 and 6, respectively. It may be noted here also that the second passband level is below 40 dB the fundamental passband response level at least up to 2.5 times the center frequency. Here also no attempt was made to fully optimize the circuit.

CONCLUSIONS

In summary, a capacitive compensated parallel coupled microstrip filter structure has been presented which features improved passband symmetry and spurious free response up to at least 2.5 times the center frequency.

Table 1 Parameters of a 4-Section Filter on a GaAs Substrate

n	Z_{0e} (Ω)	Z_{0o} (Ω)	ε_e^e	ε_e^o	W_n (mm)	S_n (mm)	ℓ_n (mm)	C_n (pF)
1,5	73.4	38.7	8.712	7.109	0.098	0.073	6.67	0.055
2,4	56.8	44.7	8.953	7.442	0.132	0.232	6.56	0.033
3	55.4	45.6	8.939	7.514	0.134	0.274	6.54	0.002

Table 2 Parameters of a 6-Section Filter on a Quartz Substrate

n	Z_{0e} (Ω)	Z_{0o} (Ω)	ε_e^e	ε_e^o	W_n (mm)	S_n (mm)	ℓ_n (mm)	C_n (pF)
1,7	72.8	38.8	3.067	2.530	0.805	0.110	11.22	0.039
2,6	56.4	44.9	3.128	2.697	1.023	0.545	10.99	0.031
3,5	54.9	45.9	3.123	2.722	1.035	0.695	10.97	0.029
4	54.7	46.0	3.122	2.725	1.037	0.715	10.97	0.016

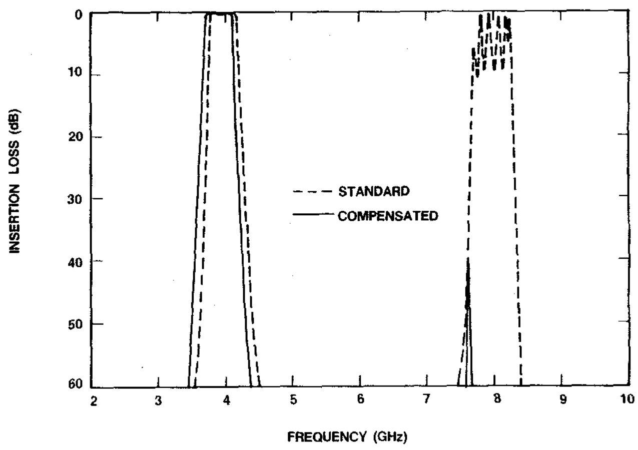

Figure 5 Simulated insertion loss of standard and compensated 6-section parallel coupled filter on a quartz substrate.

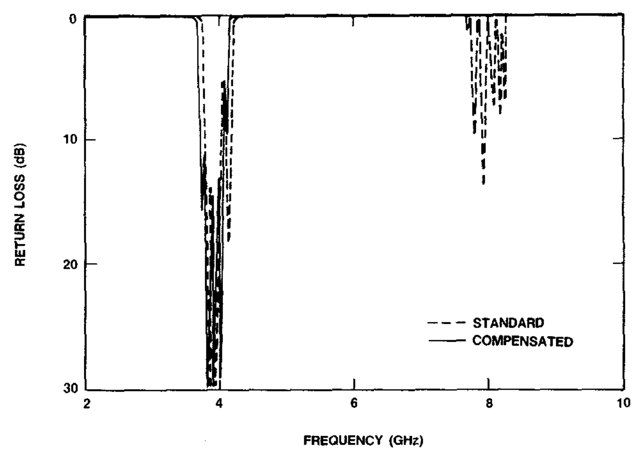

Figure 6 Simulated return loss of standard and compensated 6-section parallel coupled filter on a quartz substrate.

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