Research Article

Design of a Broadband Parallel-Coupled Microstrip Filters without Spurious Resonances

Maher M. Abd-Elrazzak

Faculty of Engineering, Mansoura University, Mansoura, Egypt

Received 5 March 2007; Accepted 21 November 2007

Recommended by Ashok K. Goel

A design of parallel-coupled microstrip bandpass filters without spurious resonance is presented. Two different techniques are used to eliminate this response at twice the passband frequency \(2f_0\). The first one is based on usage of suspended substrate, while the second is carried out by shorting the parallel-coupled lines to the ground plane through two shorting walls. The numerical results show that a broadband filter can be obtained by the suppression of the spurious response. The finite difference time domain (FDTD) with the perfect matched layer (PML) is used in the present analysis. The obtained results are compared with the available published data and good agreements are found.

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1. INTRODUCTION

In microwave and millimeter-wave systems, parallel-coupled microstrip bandpass filters are widely used. The conventional design of these filters suffers from the spurious response at twice the passband frequency \(2f_0\) \([1, 2]\). This is because the inequality of the velocities of the even and odd modes of each coupled sections \([1]\). This problem could greatly limit the filter applications.

Many techniques have been proposed for avoiding the presence of the spurious response. A defected ground plane is effective in suppressing the spurious response \([3]\). Microstrip filters with ground grooves are used for implementation of harmonic suppression in \([4]\). In \([1, 2]\), microstrip-coupled lines with a dielectric overlay or a suspended substrate are used, respectively. Recently, shorting walls are used to get a broadband antenna \([5]\).

In the present work, two different techniques are used to suppress the spurious response of broadband parallel-coupled microstrip filters. These techniques based on usage of either suspended dielectric substrates or shorting the parallel-coupled lines to the ground planes through two shorting walls. The effect of the dielectric permittivity as well as the width of the shorting walls is studied.

2. FORMULATION OF THE PROBLEM

2.1. Time domain finite difference formulation

The microstrip transmission line filter is shown in Figure 1 where the strips and the bottom planes are made of perfectly conducting material. The substrate has a relative dielectric constant \(\varepsilon_r\). The microstrip line is taken as an open structure. For this structure, Maxwell’s equations can be written as

\[
\frac{\partial \mathbf{H}_i}{\partial t} = -\frac{1}{\mu_i} \nabla \times \mathbf{E}_i - \frac{\rho_i}{\mu_i} \mathbf{H}_i, \tag{1}
\]

\[
\frac{\partial \mathbf{E}_i}{\partial t} = \frac{1}{\varepsilon_i} \nabla \times \mathbf{H}_i - \sigma_i \mathbf{E}_i, \tag{2}
\]

where \(\rho\) is the magnetic resistivity of the medium in \((\Omega/m)\); \(\sigma\) is the electric conductivity of the medium in \((S/m)\); and \(i = 1, 2\) represents the substrates and free space, as shown in Figure 1.

To discretize Maxwell’s equations (1) and (2), the centered difference approximation is applied to both time and space first-order partial differentiations. This leads to the discretized Maxwell’s equations for homogeneous regions \([5–7]\).
2 Active and Passive Electronic Components

are related by [8, 9].

tional degree of freedom by splitting the field components
transmitted into PLM region with a negligible reflections to-
the electric conductivity and the magnetic loss
PML ensures that a plane wave incident at any arbitrary angle
anisotropic material properties in the PML region. For
boundary of the open structure computational domain. The
has a 50 Ω at passband frequency when using a suspended sub-
frequency from the free space upon a PML region is totally
this material, the electric conductivity and the magnetic loss
is changed to study its e
With different number of cells is considered.
and centered on the substrate.
the strip widths are 6Δ, and
The time step used is Δt = 0.176 picoseconds. The input
a band-limited cosine pulse of the form

\[
E_y(t) = 1 - \cos\left(2\pi f_{\text{band}} t\right) \quad \text{for } 0 \leq t \leq 1/f_{\text{band}}
\]
\[
= 0 \quad \text{for } t > 1/f_{\text{band}}
\]
\[
f_{\text{band}} = 11.8 \text{ GHz}.
\]

This pulse is fed under the microstrip conductor at the
plane z = 0, and the initial values of the other components
are made zero.

The two proposed structures are shown in Figure 2. In
Figure 2(a), a suspended microstrip filter is given. Four dif-
ferent dielectric substrates (εr = 2.6, 3.5, 4.8, 10) are stud-
ted. Figure 2(b) shows a microstrip filter with shorted cou-
pled lines to the ground plane through shorting walls. Three
different wall widths are considered. The walls shorted the
left- and the right-coupled lines. These lines are shortened
almost pure real of 50 Ω over the passband.

In the second part, the parallel-coupled lines of the fil-
Figure 3 shows a comparison between the results of the
conventional and the suspended case of dielectric constant
(εr2) equals 2.6. The scattering parameters show that the sus-
pared substrate rejects the spurious response at 8 GHz by
more than 20 dB. On the other hand, the input impedance
is almost pure real of 50 Ω over the passband.

In the final case (see Figure 6) a suspended substrate of
εr2 equals 10.0 is used in which the spurious response starts
to appear again at 2f0 (8 GHz) for a sus-
{suspended substrate of εr2 equals 4.8.

In the first part of the present work, a conventional filter
without suspended substrate is analyzed then four different
cases of suspended substrate are considered. In these cases,
the dielectric constant is changed to study its effect on the
rejection level of the spurious response on the upper stopband.

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The configuration of the analyzed microstrip filter is shown
in Figure 1. The space steps are Δx = Δy = Δz = 0.212 mm
and the total mesh dimensions are 80 × 20 × 120 in the x,
y, and z directions, respectively. At the top and side faces, a
PML of width with different number of cells is considered.
The microstrip line parameters are [10] as follows:
(i) width of the microstrip conductor W = 6Δ,
(ii) thickness of the substrate H = 6Δ,
(iii) dielectric constant of the substrate εr = 10.0, and
(iv) length of each transmission line = 60Δ.

The spaces between the strips and the strip widths are 6Δ,

Figure 2(a), a suspended microstrip filter is given. Four dif-

different cases are studied.

Case 1. Shorting wall width = 3Δx.

Case 2. Shorting wall width = 6Δx.

Case 3. Shorting wall width = 10Δx.

The two proposed structures are shown in Figure 2. In
Figure 2(a), a suspended microstrip filter is given. Four dif-
ferent dielectric substrates (εr = 2.6, 3.5, 4.8, 10) are stud-
ted. Figure 2(b) shows a microstrip filter with shorted cou-
pled lines to the ground plane through shorting walls. Three
different wall widths are considered. The walls shorted the
left- and the right-coupled lines. These lines are shortened
a distance equals 30Δ of the plane z = 0.

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cases of suspended substrate are considered. In these cases,
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rejection level of the spurious response on the upper stopband.
Figure 3: Comparison between the frequency response of the conventional and suspended filter with suspended substrate of $\varepsilon_{r2}$ equals 2.6.

Figure 4: Comparison between the frequency response of the conventional and suspended filter with suspended substrate of $\varepsilon_{r2}$ equals 3.5.
Figure 5: Comparison between the frequency response of the conventional and suspended filter with suspended substrate of $\varepsilon_{r_2}$ equals 4.8.

Figure 6: Comparison between the frequency response of the conventional and suspended filter with suspended substrate of $\varepsilon_{r_2}$ equals 10.0.
eliminated especially for Case 1 as the rejection level of more than 20 dB can be obtained.

4. CONCLUSION

A design of broadband filters is presented. This is carried out by suppression of the spurious resonance at twice the passband frequency (2f₀). Suspended substrates and shorting of the coupled microstrip lines are used. The effect of the suspended substrate dielectric constant as well as the shorting wall width is studied. Numerical results show that a rejection level of almost 40 dB at passband frequency can be obtained when using a suspended substrate of ε_r equals 3.5 with input impedance equals 50 Ω. While this level is about 20 dB for a shortened microstrip lines of shorting walls width equals 3Δx. The finite difference time domain (FDTD) with the perfect matched layer (PML) is used in the present analysis. The obtained results are compared with the available published data and good agreements are found.

REFERENCES

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