Improve BPF Performance With Wiggly Coupled Lines

The use of wiggly coupled-line resonators can improve the second- and third-harmonic rejection of miniature microstrip bandpass filters.

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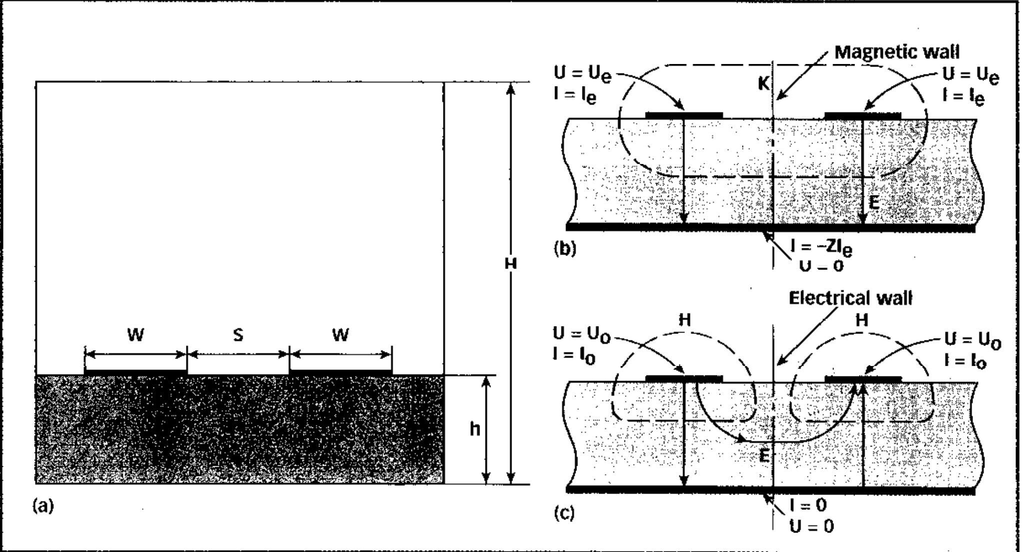
Microstrip coupled-line bandpass filters (BPFs) are used in many applications. They feature the high selectivity needed to reject unwanted signals and interference.[1,2] Unfortunately, conventional microstrip coupled-line BPFs suffer parasitic passbands at twice the center frequency, due to the unequal even- and odd-mode phase velocities in microstrip coupled lines. A novel microstrip filter design using wiggly coupled-line resonators can achieve second- and third-harmonic attenuation that is superior to conventional microstrip coupled-line BPFs, and at a fraction of the size.

For traditional microstrip coupled lines **(Fig. 1)**, the dielectric medium is inhomogeneous. The dielectric substrate fills the cross section of the transmission lines only partially and, because the dielectric constant, ε, is greater than unity, the EM field is more concentrated in the substrate than in the air.



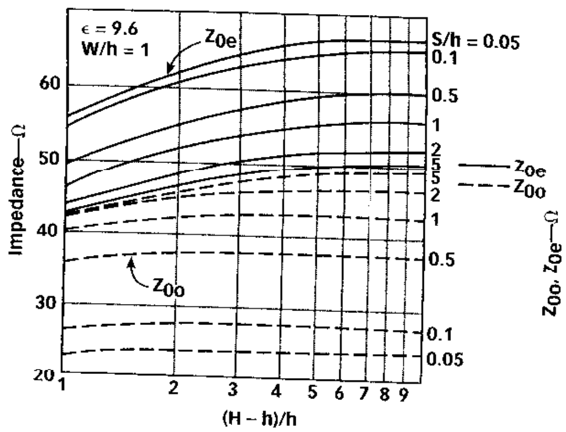
1. The basic configuration of microstrip coupled lines is shown inside a housing (a), with even- (b) and odd-mode (c) electromagnetic (EM) fields.

The large imbalance between the effective dielectric constants and the related phase velocities for the even and odd modes can lead to some limitations in the application of microstrip coupled lines. Extensive calculations have been performed to obtain practical design information.[1-5]

When coupled microstrip lines are enclosed in a real metallic housing (Fig. 1a), the configuration of the electric field lines changes. In this case, the capacitances will increase, and the effective dielectric constants and impedances will decrease **(Fig. 2)**.

Table 1: Harmonic attenuation for the wiggly two-pole BPF

	INSERTION LOSS (dB)				
Relative open stab length (1/Λ)	f_o=4590 MHz	$f_o/2$=2295 MHz	$2f_o$=9180 MHz	3 f_o=13770 MHz	4 f_o=18360 MHz
0.125	1.98	27.0	47.0	39.0	13.0
0.1	2.01	26.8	42.0	39.0	13.2
0.083	2.00	31.4	37.5	7.45	18.3
0.071	1.98	31.3	34.6	12.3	27.0
0.062	1.98	31.1	33.0	13.8	18.4
0.048	1.99	30.9	29.2	7.13	31.8
0	2.03	30.6	9.6	13.8	18.4



2. The relationship between microstrip coupled-line impedance and housing height is shown here.

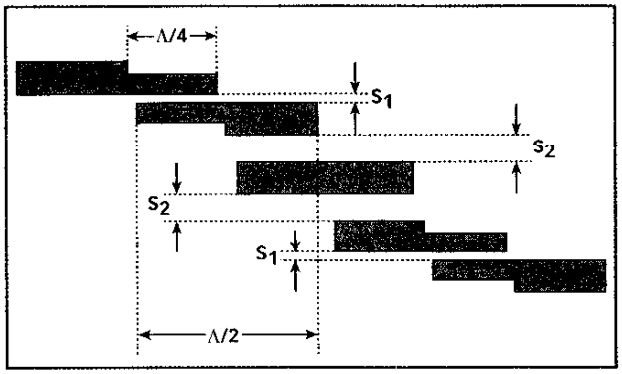
The upper metal cover can be neglected provided that its distance from the substrate H-h is greater than 6 to 8 h. Otherwise, the cover will affect the even-mode characteristic impedance (Z_{0e}), the odd-mode characteristic impedance (Z_{0o}), and the effective dielectric constant (ϵ_{eff}).

The typical planar bandpass filter **(Fig. 3)** consists of a cascade of parallel-coupled half-wavelength-long printed resonators that are open circuited at both ends. The resonators are positioned parallel to each other, so that adjacent resonators are coupled along a length equal to the quarter-wavelength of the center frequency of the filter. There are some problems associated with the coupled-line BPF design. One is that the open end of a strip conductor emits some radiation that can be seen as either adding to capacitance or increasing the effective length of the resonator. The open-end effect on both ends of each resonator increases the electrical length of the resonator and decreases the operating frequency of the filter. The parasitic reactances of the open resonators can be compensated by shortening the resonator lengths.

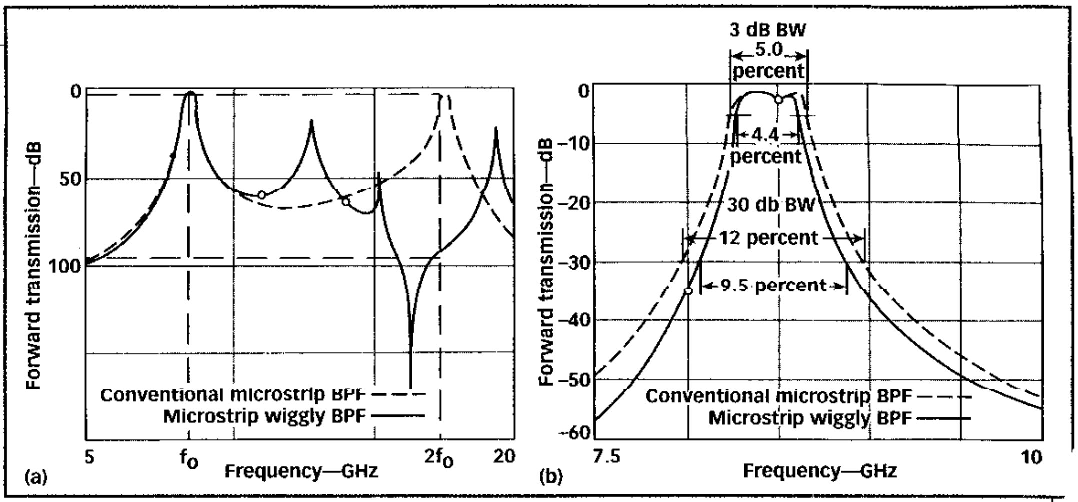
Theoretically, the first spurious response of a coupled-line BPF occurs at three times the center frequency, which is true of pure transverse-EM (TEM)-mode media such as stripline filters. In a practical microstrip parallel-coupled BPF, a spurious mode occurs at approximately twice the passband frequency due to the different even- and odd-mode propagation velocities of the coupled resonators.

Table 2: Simulation results for the wiggly coupled-line BPF

	STUB LENGTH	
PARAMETERS	$l=0$	$l = \lambda/8$
Insertion loss (dB)	2.1	1.98
3-dB bandwidth (%)	4.2	5.3
15-dB bandwidth (%)	22.9	25.9
15-dB bandwidth (%) / 3-dB bandwidth (%)	5.45	4.89



3. This configuration shows a traditional parallel coupled-line BPF.



5. These simulation results compare the second-harmonic attenuation (a) and bandpass responses (b) of conventional and microstrip wiggly coupled-line BPFs.

Z = the normalized impedance of line,

$\Phi_l = 2\pi l_l/\Lambda$ = the electrical length of the line, and

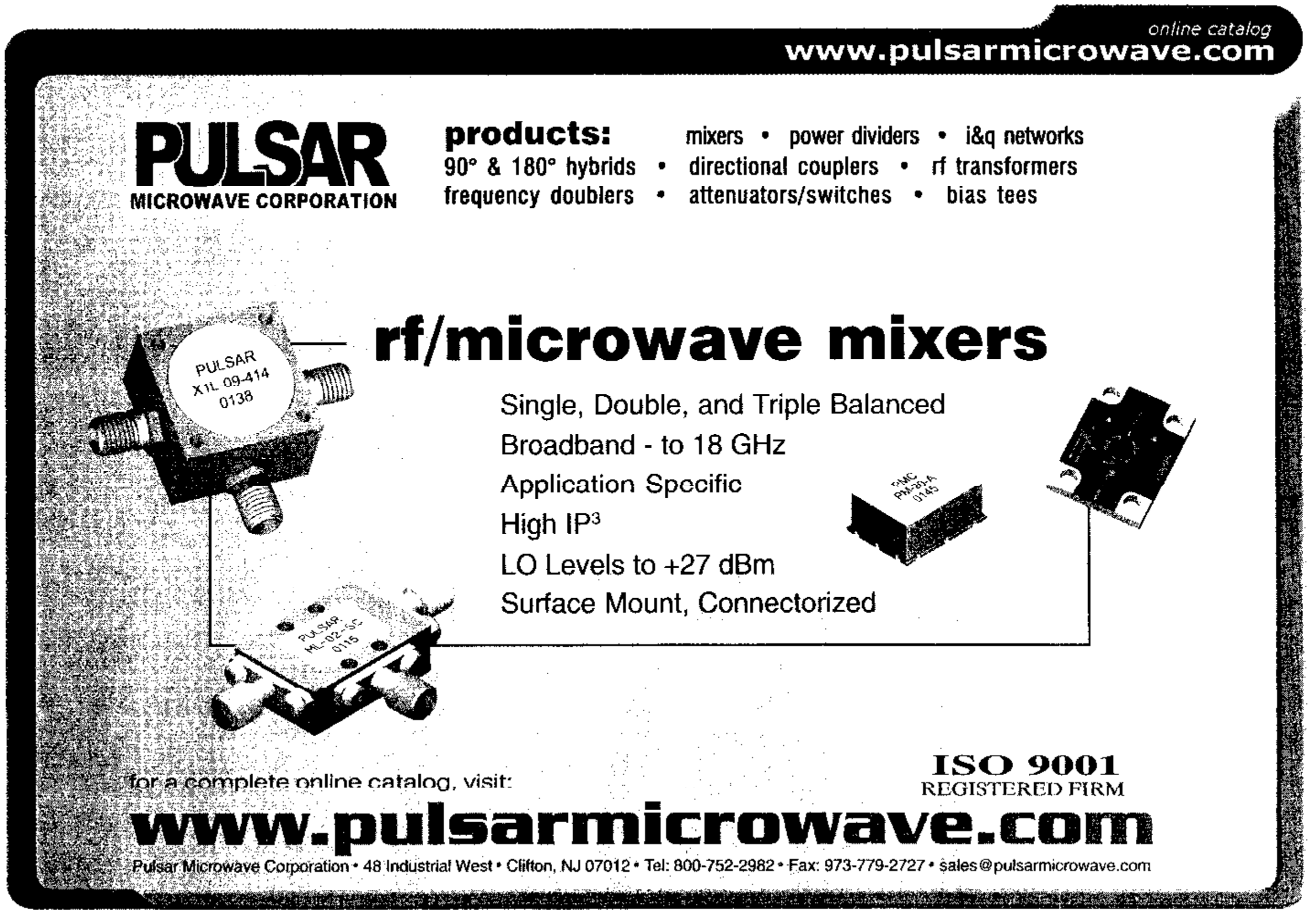
l_l = the physical length of the line.

Parameter Φ_l for the quarter-wavelength input line *cd* is equal to $\pi/2$, therefore making $\phi_l = \phi_{lrad} = -\pi/2$. For the line *fb*, the electrical phase, ϕ_2 of the signal in the open end is $\phi_2 = \phi_l = -\Lambda/2$.

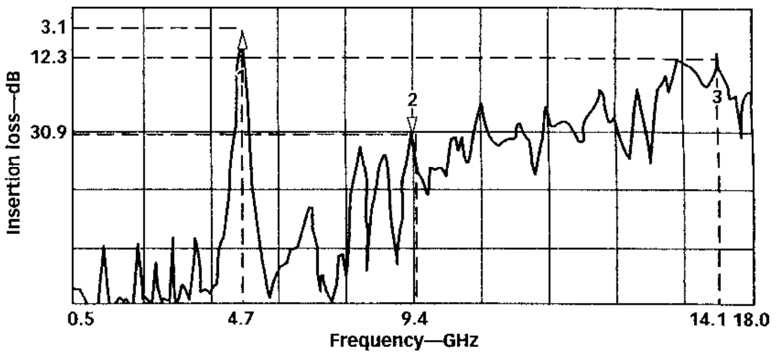
However, the phase of radiation signal is equal to $\phi_{2rad} = -\phi_2 = -\phi_{lrad}$. Therefore, resonators that contain open-circuited lines reduce free-space radiation due to the phase cancellation of fields at the ends *d* and *f*.

The total physical length of the microstrip wiggly coupled-line filter (Fig. 4) is approximately 20 percent less than a conventional coupled-line filter because the half-wavelength resonators which contain open-circuited lines are banded. As discussed earlier, the reduction in length depends on the banding angle, α.

Figures 5a and b illustrate simulated frequency responses of the microstrip wiggly coupled-line four-pole bandpass filter of Fig. 4 compared to a conventional microstrip four-pole BPF. The simulated data for the microstrip wiggly filter is signified with a solid line, while the conventional filter data is identified with a dashed line. As illustrated in Fig.5a, the microstrip wiggly



coupled-line BPF provides significantly improved second-harmonic attenuation of 95 dB, while the conventional BPF provides second-harmonic attenuation of only 3.9 dB. Bandpass losses for the microstrip wiggly BPF are less than 2 dB (Fig. 5b). The 30-dB attenuation level of the microstrip wiggly BPF is 9.5 percent, as compared to 12 percent in the conventional filter. The 3-dB level is 4.4 percent using the wiggly filter, compared to 5 percent for the conventional BPF.



6. These measurements show the response of a wiggly coupled-line BPF.

Performance measurements of the microstrip filter indicated that attenuation at the second and the third harmonics was 31 and 13 dB, respectively **(Fig. 6). Table 1** illustrates harmonic attenuation for the experimental two-pole wiggly coupled-line BPF with different relative length of the opened stub, l/Λ, where Λ is the guide wavelength.

The substrate material for the filters in these experiments was TLE 95 from Taconic Plastics (Petersburg, NY), with thickness of 0.010 in. (0.254 cm) and dielectric constant of 2.95. Measurements of filter performance indicate that attenuation levels at the second and third harmonics were greater than 40 and 39 dB, respectively. **Table 2** illustrates simulation results for the parameters of the wiggly coupled-line BPF with zero and eighth-wavelength opened stubs. MRF

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