THE DESIGN OF PARALLEL COUPLED LINE FILTER WITH ARBITRARY IMAGE IMPEDANCE

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Abstracts

In this paper, new design equations are presented to make a parallel-coupled line filter with arbitrary image impedance. These equations are more accurate than the conventional design method. They have an advantage that the designer can control the coupled line width and gap. So, they are applicable to design parallel-coupled line BPF using high dielectric material. Also, they can be applied to fin-line wave-guide filter and hairpin line filter.

Introduction

Parallel-coupled line filter design methods are developed by many authors[1][2][3]. They are, basically, analyzed by the concept that the image impedance of parallel-coupled line is equal to the in/out termination impedance. In case of the parallel-coupled line filter design by using high(low) dielectric material, it is difficult to get the realizable line width(line gap). So, we have derived the new design equations of parallel coupled line filters have the realizable coupled line width and gap.

Design Theory

The design theory of coupled line filters as printed circuits based on two parallel transmission lines with image arbitrary admittance Y_1. Fig.1(a) shows the electrical parameters of single coupled line expressed by even and odd mode impedance, Z_{oe} , Z_{oo} and coupling angle θ. These parameters can be represented by equivalent circuit of admittance inverter J and two single lines with electrical length θ and admittance Y_1 , as shown in Fig. 1(b)[2][3].

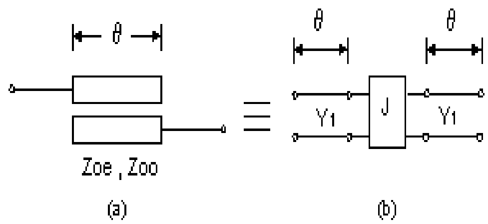

Fig. 1 Parallel coupled line and equivalent circuit

If they are satisfied by θ=90°, the two circuits in Fig. 1 are equivalent circuits. Z_{oe} and Z_{oo} can be derived from fig. 1.

$$Z_{oe} = Z_1\left[1 + JZ_1 + (JZ_1)^2\right]$$
$$Z_{oo} = Z_1\left[1 - JZ_1 + (JZ_1)^2\right] \tag{1}$$

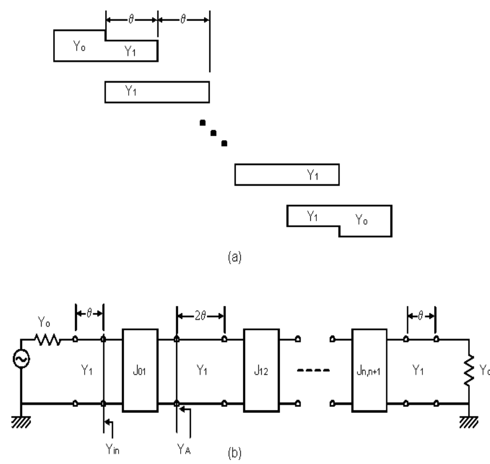

Fig. 2 The coupled line filter with arbitrary image Admittance Y_1 and the equivalent circuit.

In fig. 2, there is the band-pass filter which has N+1 coupled lines and the equivalent circuit which has J-inverters. With reference to Fig. 2(b), the admittance Y_{in} seen looking toward the input admittance is

$$
\begin{aligned}
Y_{in} &= Y_1 \frac{Y_0 + jY_1 \tan \beta l}{Y_1 + jY_0 \tan \beta l} \\
&= Y_1 \left. \frac{\frac{Y_1}{Y_0} + j\frac{\pi}{2}\frac{\omega-\omega_0}{\omega_0}}{1 + j\frac{Y_1}{Y_0}\frac{\pi}{2}\frac{\omega-\omega_0}{\omega_0}} \right|_{\omega \text{ near } \omega_0} \\
&= \frac{Y_1^2}{Y_0} + jY_1 X(1-A^2)
\end{aligned}
\qquad (2)
$$

where

$$A = \frac{Y_1}{Y_0}, \quad X = \frac{\pi}{2}\frac{\omega-\omega_0}{\omega_0}$$

In Fig. 2(b), the admittance Y_A seen looking toward the J_{01}-inverter is

$$
\begin{aligned}
Y_A &= \frac{J_{01}^2}{Y_1 A + jY_1 X(1-A^2)} \\
&= \frac{J_{01}^2}{Y_1 A}\left[1 + jX\left(A - \frac{1}{A}\right)\right] \\
&= \frac{J_{01}^2}{Y_1 A} + jB_A(\omega)
\end{aligned}
\qquad (3)
$$

We can obtain the circuit of Fig. 3 from eq. (3)

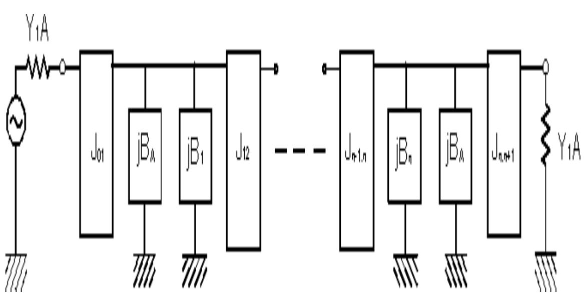

Fig. 3 Equivalent circuit of Fig. 2 (b)

Because of $jB_A(\omega)$, the slope parameter of first resonator $jB_{r1}(\omega)$ is changed as following

$$
\begin{aligned}
B_{r1}(\omega) &= B_A(\omega) + B_1(\omega) \\
&= \frac{J_{01}^2}{Y_1} X\left(1 - \frac{1}{A^2}\right) + Y_1 2X
\end{aligned}
\qquad (4)
$$

$$
\begin{aligned}
b_1 &= \frac{\omega_0}{2} \left. \frac{dB_{r1}(\omega)}{d\omega} \right|_{\omega=\omega_0} \\
&= \frac{\pi}{4} Y_1 \left[\frac{J_{01}^2}{Y_1^2}\left(1 - \frac{1}{A^2}\right) + 2\right]
\end{aligned}
\qquad (5)
$$

In Fig. 3, the transmission of the length $2\theta = \lambda/2$ except the first and last lines can be derived as following:

$$
\begin{aligned}
Z_{in} &= Z_1 \frac{Z_L + jZ_1 \tan \beta l}{Z_1 + jZ_L \tan \beta l} \\
&= Z_1 \left. \frac{Z_L + jZ_1 \pi \frac{\omega-\omega_0}{\omega}}{Z_1 + jZ_L \pi \frac{\omega-\omega_0}{\omega}} \right|_{\omega=\omega_0 \text{ near}} \\
&= \left. \frac{1}{jY_1 \pi \frac{\omega-\omega_0}{\omega}} \right|_{\omega=\omega_0 \text{ near}, Z_L >> Z_1}
\end{aligned}
\qquad (6)
$$

Eq. (6) can be described as shown in Fig. 4 (b). Thus, we can find that it is identical with parallel resonator

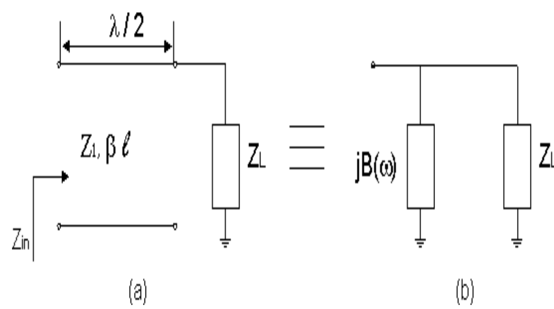

Fig. 4 The transmission line of length λ/2 and the equivalent circuit.

The susceptance of this resonator is expressed by

$$B(\omega) = Y_1 \pi \frac{\omega-\omega_0}{\omega_0} \qquad (7)$$

Also, we can obtain admittance slope parameter as eq. (8)

$$b = \frac{\pi}{2} Y_1 \qquad (8)$$

As the slope parameter of parallel resonator changes, also J-inverters are changed as following.

$$\frac{J_{01}}{Y_1} = \frac{J_{n,n+1}}{Y_1} = \sqrt{\frac{\frac{\pi}{2}AW}{\omega_1' g_0 g_1 - \frac{\pi}{4}AW\left(1-\frac{1}{A^2}\right)}}$$

$$\frac{J_{12}}{Y_1} = \frac{J_{n-1,n}}{Y_1} = \frac{\pi W}{2\omega_1'}\sqrt{\frac{\frac{1}{2}\left[\frac{J_{01}^2}{Y_1^2}\left(1-\frac{1}{A^2}\right)+2\right]}{g_1 g_2}}$$

$$\frac{J_{j,j+1}}{Y_1} = \frac{\pi}{2}\frac{W}{\omega_1'}\sqrt{\frac{1}{g_j g_{j+1}}}$$

$$j = 2,\cdots,n-2$$

where

$$\frac{\omega'}{\omega_1'} = \frac{1}{W}\frac{\omega-\omega_0}{\omega_0}, \quad \omega_0 = \frac{\omega_1+\omega_2}{2}$$

$$W = \frac{\omega_2-\omega_1}{\omega_0}, \quad \mathrm{A} = \frac{\mathrm{Y}_1}{\mathrm{Y}_0}$$

Simulation

On the basis of the derived formulae in this paper, parallel-coupled line band-pass filters are simulated using the following parameters:

Center frequency f_0 = 1.85GHz
The number of resonators N = 5
Pass-band ripple 0.01dB (Chebyshev)
In/out impedance 50Ω

In fig. 4 and 5, image impedances of parallel-coupled lines are equal to the termination impedance 50Ω. In fig. 6 and 7, image impedances of parallel coupled lines are 10Ω that different the termination impedance 50Ω. In fig. 8 and 9, image impedances of parallel coupled lines are 100Ω. We have compared the performance of conventional and new design method. The results simulated by new design method show that their return losses are about –26.4dB for 0.01dB Chebyshev ripple and their bandwidths are 100MHz. It proves that the presented design method is valid.

Conclusion

New band-pass filter design equations are presented by using arbitrary image impedance of the coupled line different the termination impedance. In order to prove the usefulness presented design formulae, we have simulated 5-pole coupled line band pass filters which have the same pass-band of 1.8• 1.9GHz for 0.01dB chebyshev ripple and have 50Ω, 10Ω and 100Ω image impedance. Simulated results of new design method show the exact return loss and bandwidth. The important features of this method are that it allows a greater geometrical tolerance for the formation and use of thinner dielectric substrate as compared to the conventional method.

Reference

1. M. Makimoto, S. Yamashita, "Strip-line resonator filters having multi-coupled sections", IEEE MTT-S International Microwave Symposium Digest, pp. 92-94, 1983
2. S. B. Cohn, "Parallel coupled transmission-line-resonator filter", IEE Trans. Microwave Theory Tech., vol. MTT-6, pp.223 - 231, Apr. 1958.
3. George L. Matthaei, Leo Young, E. M. T. Johns, "Microwave Filters, Impedance Matching Networks, and Coupling Structures", Artech House, 472-478, 1980

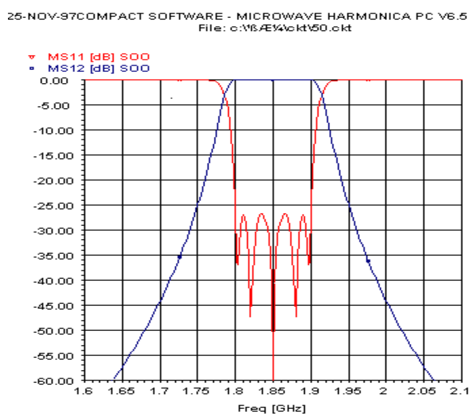

Fig. 5 The frequency characteristic of coupled line BPF with 50Ω image impedance using the conventional method

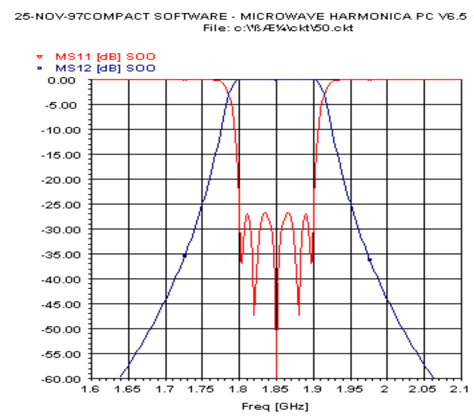

Fig. 6 The frequency characteristic of coupled line BPF with 50Ω image impedance using the new method

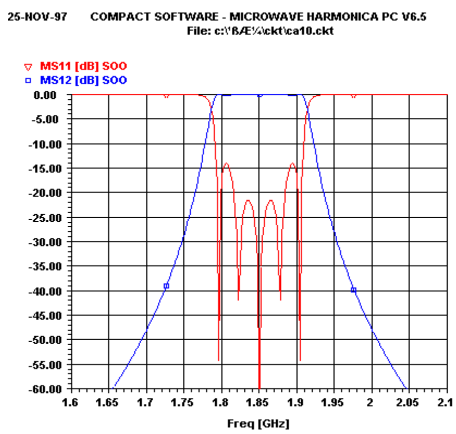

Fig. 7 The frequency characteristic of coupled line BPF with 10Ω image impedance using the conventional method

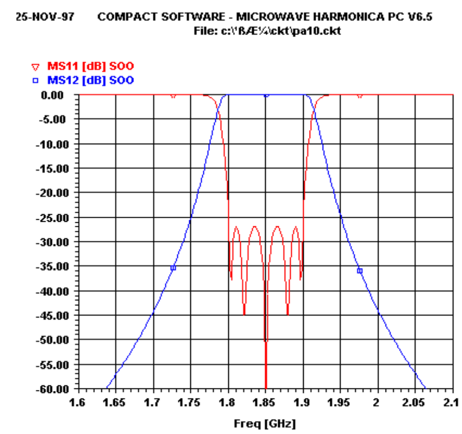

Fig. 8 The frequency characteristic of coupled line BPF with 10Ω image impedance using the new method

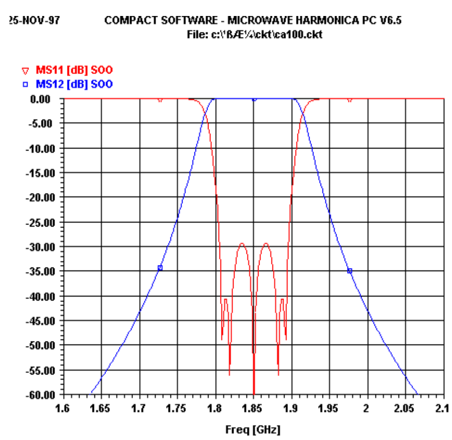

Fig. 9 The frequency characteristic of coupled line BPF with 100Ω image impedance using the conventional method

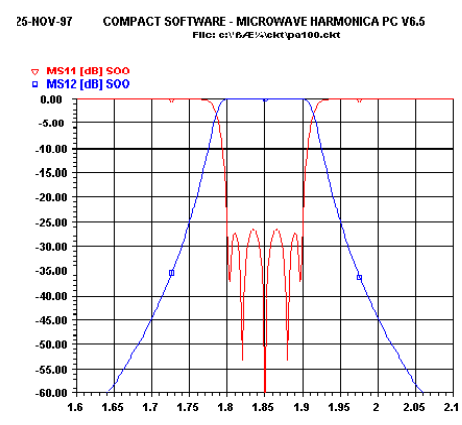

Fig. 10 The frequency characteristic of coupled line BPF with 100Ω image impedance using the new method