A DESIGN OF NOVEL ASYMMETRICALLY COUPLED CPW BANDPASS FILTER USING TEM ANALYSIS

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ABSTRACT

The new coplanar waveguide (CPW) bandpass filter with an asymmetric structure is proposed. The proposed filter is designed based on TEM analysis technique. It has quarter wavelength CPW couplers so that the physical dimension and radiation loss can be improved. A compact three-pole bandpass filter is designed and fabricated to prove the validity of the design method. The measured results show good agreement with the simulated characteristics.

INTRODUCTION

Advance in circuit fabrication technology with MMIC and flip-chip makes a growing demand to use the coplanar waveguide structures for practical applications. Several kinds of circuit have been realized with microstrip structure for planar circuit applications with various design and analysis techniques. Recently the rigorous design methods for CPW bandpass filter have been reported with open and short stubs, ribbon-of-brick-wall (RBW), end-gap, and impedance step structure [1 - 4]. However, these kinds of bandpass filters use an end-gap coupling, so the radiation losses are very severe. In this paper, a novel CPW bandpass filter structure is proposed to reduce the radiation loss and its physical dimension. The network analysis method based on TEM mode is applied to analyze the asymmetrically coupled CPW bandpass filter [5], [6]. In order to prove the validity, a three-pole bandpass filter has been designed, simulated with Libra3.1, and fabricated. The measured results and the predicted performances of designed bandpass filter show good agreement.

DESIGN METHOD

Fig.1 shows the layout pattern of the asymmetrically coupled CPW bandpass filter. The basic components of the asymmetrically coupled CPW bandpass filter are quarter wavelength coupled lines with two open ports and impedance steps.

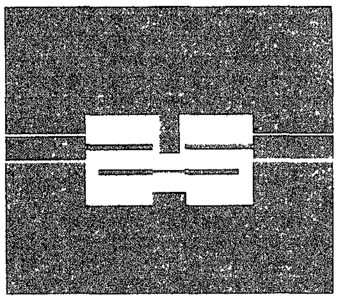

Fig.1 Asymmetrically coupled CPW bandpass filter

Fig.2 shows the general coupled line with two open ports. The equivalent circuits of Fig.2 are shown in Fig.3 [5]. Fig.4 shows the equivalent lumped circuit of discontinuity at the junction between transmission line and coupled line section [3]. Thus, the equivalent circuit of asymmetrically coupled CPW bandpass filter can be expressed as shown in Fig.5. In order to have the bandpass filter characteristic, Fig.5 should

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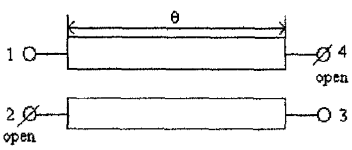
be equivalent to Fig.6. Thus the equivalent circuit of Fig.3 (b) should be expressed as Fig.7. The condition of the equivalence between Fig.3 (b) and Fig.7 can be easily derived by using the transfer matrix as follows.

The transfer matrix of Fig.3 (b) is given by

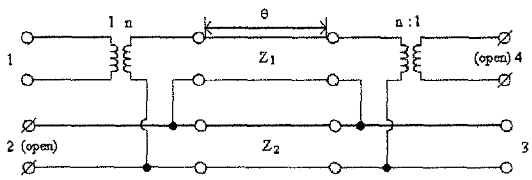
$$\begin{bmatrix} A_o & jB_o \\ jC_o & A_o \end{bmatrix} = \begin{bmatrix} 1 & j\varpi \cdot n \big/ \{Z_1 \cdot (n-1)\} \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos\theta & (jZ_2 \cdot \sin\theta) \big/ n \\ (jn \cdot \sin\theta) \big/ Z_2 & \cos\theta \end{bmatrix} \cdot \begin{bmatrix} 1 & j\varpi \cdot n \big/ (k \cdot Z_1) \\ 0 & 1 \end{bmatrix} \quad (1)$$

The corresponding transfer matrix for Fig.3(b) is

$$\begin{bmatrix} A_o & jB_o \\ jC_o & A_o \end{bmatrix} = \begin{bmatrix} \cos\theta - \varpi \cdot n^2 \sin\theta & j\left\{ (\varpi \cdot n \cdot \cos\theta) \cdot \left(\frac{1}{Z_1 \cdot (n-1)} + \frac{1}{k \cdot Z_1} \right) + \frac{Z_2 \sin\theta}{n} \right\} \\ (jn \cdot \sin\theta) \big/ Z_2 & \cos\theta - \frac{\varpi \cdot n^2 \sin\theta}{Z_1 \cdot Z_2 (n-1)} \end{bmatrix} \quad (2)$$

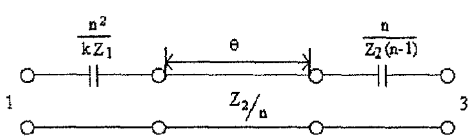


(a)



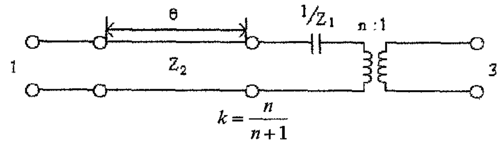
(b)

Fig.2 Coupled line with opened two ports



$$Z_1 = \frac{Z_{oe} + Z_{oo}}{2} \qquad n = \frac{Z_{oe} + Z_{oo}}{Z_{oe} - Z_{oo}} \qquad Z_2 = Z_1(n^2 - 1)$$

(a)



(b)

Fig.3 The equivalent circuit for the coupled line with opened two ports.

The transfer matrix for Fig.7 can be easily expressed as Eq.(3) by using transfer matrix of transmission line. In order that matrices (2) and (3) should be equal, it is sufficient that $A_o = A_o'$ and $B_o = B_o'$, for reciprocal condition, and then it is ensured that $C_o = C_o'$. These equalities result in the two equations

$$\begin{bmatrix} A_o' & jB_o' \\ jC_o' & A_o' \end{bmatrix} = \begin{bmatrix} \cos\theta' & jZ_2' \cdot \sin\theta' \\ j\sin\theta' \big/ Z_2' & \cos\theta' \end{bmatrix} \quad (3)$$

$$\cos\theta - \varpi \cdot n^2 \sin\theta = \cos\theta' \quad (4)$$

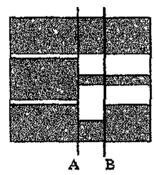
$$\left\{ (\varpi \cdot n \cdot \cos\theta) \cdot \left(\frac{1}{Z_1 \cdot (n-1)} + \frac{1}{k \cdot Z_1} \right) + \frac{Z_2 \sin\theta}{n} \right\} = Z_2' \sin\theta' \quad (5)$$

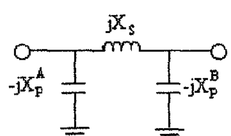
Then the following equations can be used to design the asymmetrically coupled CPW bandpass filter [7].

$$\frac{K_{01}}{Z_o} = \sqrt{\frac{\pi \cdot \varpi}{4 g_0 g_1 \omega_1'}} \qquad \frac{K_{J,J+1}}{Z_o} = \frac{\pi \cdot \varpi}{4\omega_1'} \sqrt{\frac{1}{g_n g_{n+1}}}$$

$$\frac{K_{n,n+1}}{Z_o} = \sqrt{\frac{\pi \cdot \varpi}{4 g_n g_{n+1} \omega_1'}} \quad (6)$$

$$\theta_J = \frac{\pi}{2} + \frac{1}{2}[\phi_{J-1,J} + \phi_{J,J+1}] \ \text{[rad]} \quad (7)$$





(a) (b)

Fig.4 Discontinuity and their equivalent lumped circuit model at the junction between transmission line and coupled line section.

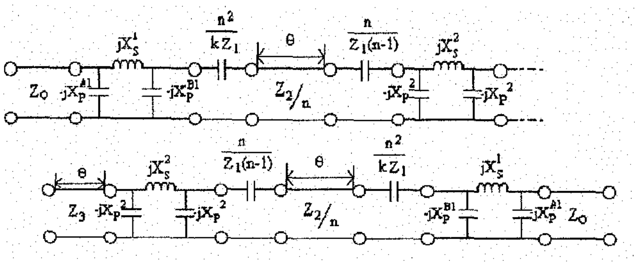


Fig.5 The equivalent circuit of an asymmetrically coupled CPW bandpass filter

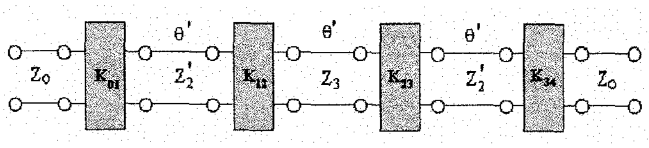


Fig.6 The equivalent circuit of 3-pole bandpass filter with impedance K-inverter.

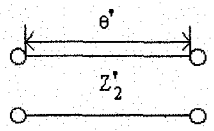


Fig.7 The equivalent circuit of Fig.3.

SIMULATION AND MEASUREMENTS

The proposed three-pole bandpass filter has been designed by present design method at the center frequency 3.17GHz with 20% fractional bandwidth. The total electrical length of the designed bandpass filter is less then 270°. The design result was simulated by Libra v.3.1 with equivalent circuit parameters. The asymmetrically coupled CPW bandpass filter has been fabricated using 25-mil Duroid (ε_r = 10.2) and measured. The measured insertion loss and return loss are less than -1dB and –20dB, respectively. The attenuation characteristics at fo ±1.7GHz are less than –20dB.

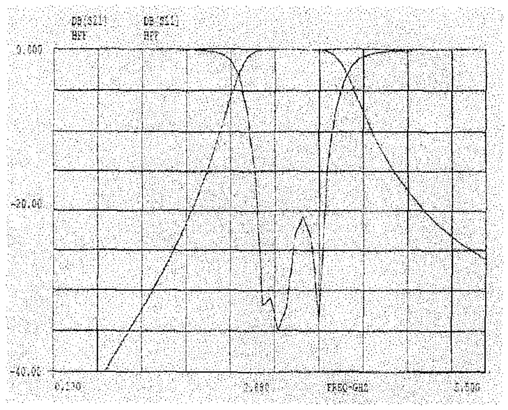


Fig.8 Simulation characteristic with Libra.

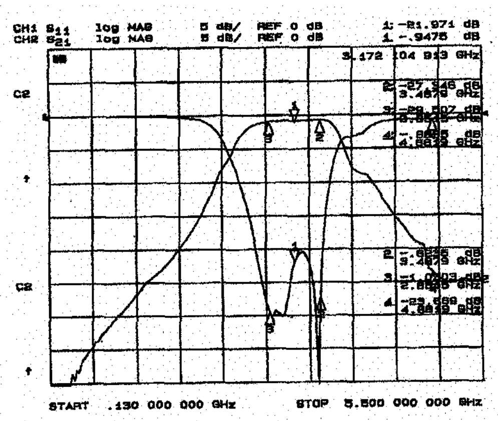


Fig.9 Measurement of the realized asymmetrically coupled CPW bandpass filter

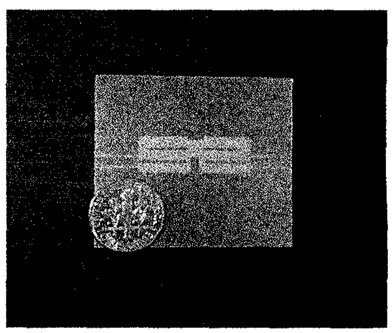


Fig.10 The fabricated asymmetrically coupled CPW bandpass filter

CONCLUSION

An asymmetrically coupled CPW bandpass filter was proposed to improve the loss characteristics and the physical dimension. The suggested bandpass filter has been designed by synthesis method based on TEM analysis and realized to show the validity. Three-resonator bandpass filter is chosen for a design example at 3.17GHz. Employing the quarter wavelength broadside coupled lines without end-gap leads to passband insertion losses of about 1dB and compact size. The measurement on the filter shows validity of the novel structure and design method.

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