New Concept for Designing of Compact Parallel Coupled Bandpass Filter

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ABSTRACT

This paper presents the design procedure of a bandpass filter based on parallel coupled half wave length resonator concept with full length coupling. For the purpose of miniaturization and to get high coupling the new model of parallel coupled bandpass filter has been introduced. Here, the third resonator is placed just beneath the first one & fifth beneath the third one. Similar condition is for even order resonators. Here, area of the microstrip filter is very less, i.e., it is a compact structure. Finally a bandpass filter having Fractional bandwidth of 20% is obtained. The proposed BPF filter has been fabricated and measured with an Agilent make vector network analyzer of model N5230A and also good agreement between simulated and measurement results have been obtained.

Keywords

Compact filter, parallel coupled bandpass filter, resonator, miniaturization.

1. INTRODUCTION

The advancement of telecommunication technology arising hand in hand with the market demands and governmental regulations push the invention of new applications in wireless communication[1-2]. In order to provide additional transmission capacity, a strategy would be to open certain frequency regions for new applications or systems. So, we need a complete new transmitter and receiver. A bandpass filter is an important component must be found in the transmitter or receiver[1]. Bandpass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals. The miniaturization or the compactness of bandpass filter also realised previously using spiral-shaped resonators [3] and also, Parallel-Coupled Wideband Bandpass filters was made of Image Parameter Method[4]. Here, the parallel coupled bandpass filters are designed and also improvement of the design are introduced. Using the novel concept of resonating properties of the microstrip lines of a bandpass filter, the modification occurs which in terms minimizes the structures of the filter. The measured result shows much higher FBW ,wider bandwidth and comparatively low loss for the new compact model of parallel coupled bandpass filter than the conventional one.

2. DESIGN METHODOLOGY OF COMPACT BANDPASS FILTER

In designing of microstrip filters, the first step is to carry out an approximated calculation based on concentrated components like inductors and capacitors[1]. This filter type is known as parallel-coupled filter. The strips are arranged parallel close to each other, so that they are coupled with certain coupling factors. A structure of parallel coupled-line microstrip bandpass filter that uses half wavelength line resonators, they are positioned so that adjacent resonators are parallel to each other along the full of their length as shown in Fig.1. This parallel arrangement gives relatively large coupling for a given spacing between resonators, also for compactness and to get high coupling this new model of parallel coupled bandpass filter has been introduced as shown in Fig 1. To maintain the resonating effect of the coupled microstrip line like the normal parallel coupled structure, here in this model also have the same concept but the only difference is that, here we connect the microstrip line of width W_3 and length l_3 in the opposite site of the microstrip line of width W_2 and length l_2 in comparison to conventional one. So, we found here the third resonator just beneath the first one and fifth beneath the third one. Similar condition is satisfied for second, fourth and sixth resonator also. Thus instead of using long length for the total filter design, shorter length is used. Thus, this filter structure is particularly convenient for constructing filters having a wider bandwidth as compared to the other structures.

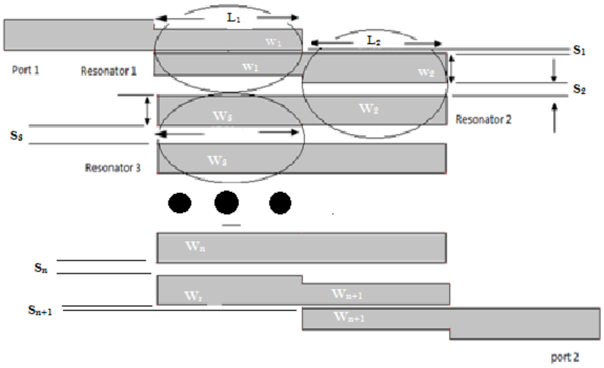

Fig 1: New configuration of end-coupled microstrip bandpass filter

Considering, g_0, g_1 . . . g_n are the element of a ladder-type lowpass prototype with a normalized cutoff $\Omega_c = 1$, and FBW is the fractional bandwidth of band pass filter . The $J_{j,j+1}$ are the characteristic admittances of J- inverters and Y_0 is the characteristic admittance of the microstrip line. We use the following equations for designing the parallel-coupled filter

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2}\frac{FBW}{g_n g_{n+1}}} \qquad (1a)$$

$$\frac{J_{j\,j+1}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_j g_{j+1}}} \qquad j = 1 \text{ to } n-1 \qquad (1b)$$

$$\frac{J_{j\,j+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2\ g_n\ g_{n+1}}} \qquad (1c)$$

To realize the *J*-inverters obtained above, the even- and odd-mode characteristic impedances of the coupled microstrip line resonators are determined by[5]-

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad j = 0 \text{ to } n \qquad (2.a)$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad j = 0 \text{ to } n \qquad (2b)$$

3. A FIVE POLE COMPACT PARALLEL COUPLED FILTER DESIGN

Microstrip parallel-coupled bandpass filter is designed to have a fractional bandwidth FBW = 0.12 or 12% at the midband frequency f_0 = 2.4 GHz. A five-pole (n = 5) Chebyshev lowpass prototype with 0.1 dB passband ripple is chosen, whose element values are $g_0 = g_6 = 1.0$, $g_1 = g5 = 1.1468$, $g_2 = g_4 = 1.3712$, and $g_3 = 1.9750$. From (1) we have

$$J_{0,1} = J_{5,6} = 0.02 \times \sqrt{\frac{\pi}{2} \times \frac{0.12}{1 \times 1.1468}} = 8.103 \times 10^{-3}$$

$$J_{1,2} = J_{4,5} = \frac{\pi \times 0.12}{2} \frac{1}{\sqrt{1.3712 \times 1.1468}} \times 0.02 = 3.006 \times 10^{-3}$$

the even- and odd-mode characteristic impedances of the coupled microstrip line resonators are determined by

$$(Z_{0e})_{0,1} = (Z_{0e})_{5,6} = 50[1 + (50 \times 8.103 \times 10^{-3}) + (50 \times 8.103 \times 10^{-3})^2] = 78.464\ \Omega$$

$$(Z_{0o})_{0,1} = (Z_{0o})_{5,6} = 50[1 - (50 \times 8.103 \times 10^{-3}) + (50 \times 8.103 \times 10^{-3})^2] = 37.95\ \Omega$$

Similarly, $(Z_{0e})_{1,2} = (Z_{0e})_{4,5} = 58.6445\ \Omega$

$$(Z_{0o})_{1,2} = (Z_{0o})_{4,5} = 43.615\ \Omega$$

$$(Z_{0e})_{2,3} = (Z_{0e})_{3,4} = 56.38\ \Omega$$

$$(Z_{0o})_{2,3} = (Z_{0o})_{3,4} = 44.1.92\ \Omega$$

With the procedure explained in the previously, we can determine the width of parallel-coupled microstrip lines "W" and the distance between them "s". A pair of parallel-coupled microstrip lines with certain width and separation distance will deliver a pair of characteristic impedances, the even mode and the odd mode ones. We have used here the FR4 material of permittivity of 4.4 and thickness 1.59 mm. We can see, if the separation is small, the even mode impedance is high and the odd mode impedance is small. In order to achieve the $(Z_{0e})_{0,1} = 78.464\ \Omega$ and $(Z_{0o})_{0,1} = 37.95\Omega$, we get W_1=2.11 mm, S_1=0.26 mm and the length of the resonator required is l_1=17.72 mm, The same data will be also used for the sixth resonator. Similarly for the second and fifth resonator we must find the value for W_2 and S_2 as 2.88mm and 1.28mm respectively. Also for third and fourth resonator W_3=2.95mm and S_3=1.74mm. Fig-2 shows the schematic of the bandpass filter.

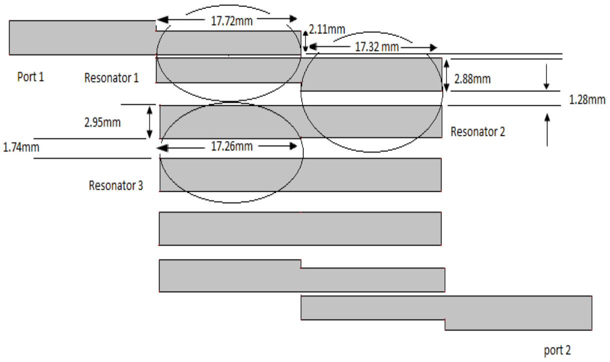

Fig 2 Schematic of the proposed bandpass filter

4. RESULTS & DISCUSSION

The new bandpass filter with the data given in Figure 2, which has been simulated using MoM based IE3D software and the simulated S-parameters are shown in Fig. 4. The center frequency at 2.2837 GHz and 3dB bandwidth of 277.4 MHz with insertion loss of -1.74dB is observed. Also the Selectivity 117.24 dB/GHz for rising edge and 251.479dB/GHz for falling edge is observed.

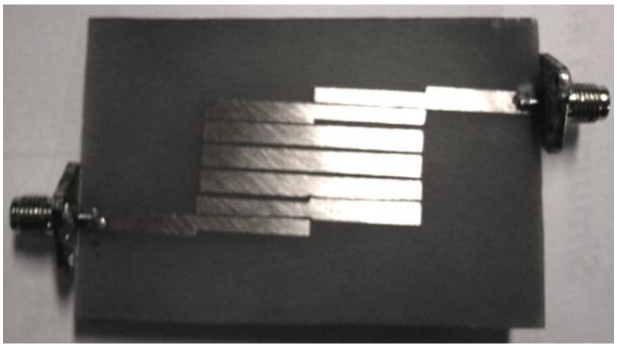

Fig 3 Photograph of the miniaturized model of parallel coupled bandpass filter

A prototype filter has also been fabricated for on FR-4 substrate with dielectric constant of 4.4 and thickness of 1.59mm as shown in Fig.3. The fabricated unit has been measured using Agilent make vector network analyzer (model N5230A).

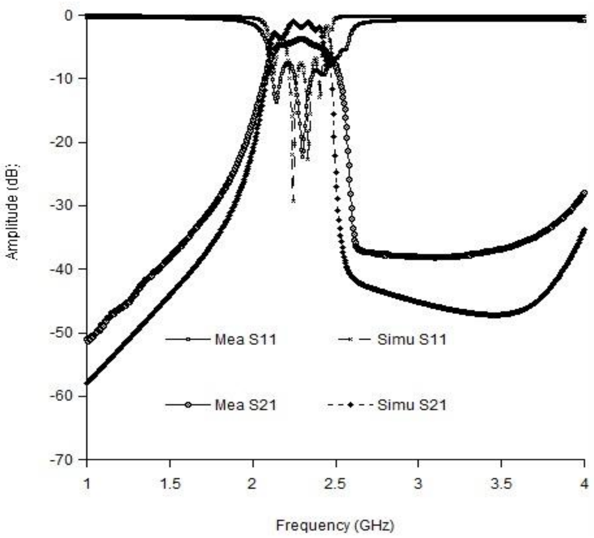

Fig. 4 Comparative study between measured & simulated s-parameters of the bandpass filter

The measured results in Fig.4 shows center frequency at 2.3GHz with fractional bandwidth of 20 % for the 3 dB bandwidth of 360 MHz with insertion loss of -3.74dB in comparison to the simulated results obtained as center frequency at 2.2837 GHz and 3dB bandwidth of 277.4 MHz with insertion loss of -1.74dB. Also the Selectivity 100 dB/GHz for rising edge and 250 dB/GHz for falling edge is observed. The EM-simulated and experimentally measured results are compared & found a good agreement between these two.

5. CONCLUSION

Using the novel concept of resonating properties of the microstrip lines of a bandpass filter, the modification occurs which in terms minimizes the structures of the filter. As the full length coupling introduces the total structure becomes more compact than ever. The measured result shows much higher FBW, wider bandwidth and comparatively low loss for this compact model of parallel coupled bandpass filter than the conventional one. This type of bandpass filter may be applicable in many wireless applications.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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