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SYMMETRICAL SINGLE BAND FILTERS AND ITS EXPANSION FOR USE AT IEEE STANDARD FREQUENCIES

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Abstract- In this paper a bandpass filter has been proposed according to IEEE standard frequencies. This filter is on the base of the design of the bandpass filter at 2.4 GHz, 3.7 GHz and 5 GHz frequencies and expanding that to dual-band filter of 2.4 GHz, 3.7 GHz and then dual-band filter 2.4 GHz and 5 GHz is discussed. In the proposed filter double coupling technique has been used to increase band width and low impedance piece is surveyed because of the creating double zero and the stop-band profile is improved. These transmission frequencies shows that the intended plan is effective for all plans.

Keywords: Transition Filter, Low Impedance, Additional Coupling.

I. INTRODUCTION

Bandpass filter has great potential in development of modern communication systems which the bandpass filter in multi-band communication systems is used as a key component for selecting the frequency in the specified range. Another type of filter is the Transition Filter that passes through itself a certain range of frequency components and weakens another components of the frequency (Figure 1).

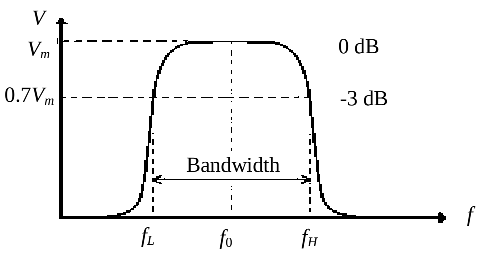

Figure 1. The Transition Filter

In Transition Filter, as the bandpass, passes through itself frequencies of about 0.707 of the maximal rate and deletes the other frequencies. The f_H is the high range of the pass band and f_L is the low range. The range of frequency between f_H and f_L is called bandwidth. This filter is used for retrieving of useful information in a noise signal. In parts which we have the input, output signals and communication buses, what is important in terms of being achievable, are according to physical structure and classification.

Microstrip filters play various roles in communication systems. The dimensions of a microstrip filter compared to other structures that operate in the frequency range are smaller. For most applications, including factors that reduce the size initial matter, the microstrip filters are optimized. Minimal microstrip may be supplied using dielectric constant or compressed elements. But often for the specified substrata, for minimizing filter, it is required to change the dimensions of the filter. Therefore, using this method, many filters are designed and built.

In this paper, the design, and optimization of dual-band microstrip bandpass filter with use of direct engineering according to IEEE standards. There are numerous articles on the technology of the dual-band filter. In [1] a dual-band filter has been proposed using a piece of impedance, frequency range of the filter in pass band which is settling between 2.5 GHz and 3.5 GHz. In this part, three-part microstrip band is designed using passband filter and effect of pairing each of resonators as well as the characteristics of the filter such as bandwidth, will be analyzed [2].

Also, a new design of a dual-band bandpass filter with wide bandwidth and low loss at frequencies of 2.40 GHz and 5.20 GHz center for wireless communication networks is presented [3]. The dual-band filter using stepped impedance is designed in which the second pass-band is flexible while the first pass-band is fixed. The function of this filter is in the working frequency 2.4 GHz and 5.25 GHz has a smaller structure comparing with its previous studies [4].

A new topology is suggested, using impedance Stepped Impedance Resonator (SIR) to improve the response [5-6]. The dual-band filter is also designed with placing the transmission zeros in the pass-band and using the resonator impedance ring [7]. In this paper, three bandpass filters are designed using electromagnetic simulator and simulated with connection between Stepped Impedance Resonator, and then optimized [9]. In [10] the idea of three-part Stepped Impedance Resonator filter is discussed, to improve the performance of the filter in new closed-form models. The step discontinuity shunt capacitance (C_P) and series inductance (L_S) for the microstrip step discontinuity is reported for the substrate $2.3 \leq \varepsilon_r \leq 40.0$ or more.

The step junction have wide range of impedance ratio. The models have average deviation 0.027 for the C_P and 0.015 for L_S against the results of Sonnet.

II. PROCESS OF DESIGN AND SIMULATION

A. Single Band Resonator Proposed Structure

A microstrip filter is a double finish network used to control frequency response at a given point in a microstrip system and this action provides transmission at frequencies within the filter pass band and the filter stop-band is loosed. Central frequency is an equivalent frequency and the resonant frequency is a resonator. Narrow-band filters are used to remove all frequencies except the specific frequencies. The equivalent circuit of two lines of microstrip with different characteristic impedance is shown in Figure 2. Thus the circuit model can be designed as Figure 3.

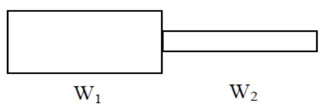

Figure 2. The discontinuity in the microstrip

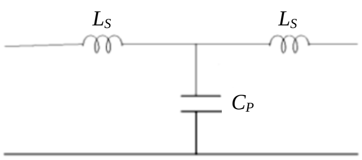

Figure 3. Equivalent circuit of the discontinuity

Shunt capacitance and series inductance step discontinuity model for a wide range of physical parameters are valid. It is supposed that the shunt step discontinuity capacitance (C_P) at the junction of two microstrip lines is created due to the margin capacitance (C_F) in the range width (W_1) with inductance of series (L_S) in the bottom of line. The width of the strip W together with dielectric constant and the thickness of substrate determines the characteristic impedance Z_O of the line. The C_P capacitor is obtained as $C_P = C_F\,(W_1\text{-}W_2)$. So to achieve the ideal circuit with the extent of the positive capacitor C_P, it should be $W_1>W_2$, by adding a filter in the right the filter.

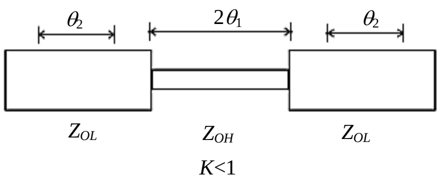

Figure 4. The microstrip SIR resonators

Figure 4 shows the microstrip SIR resonators. The left-side SIR with narrow strip width in center and wide strip widths in two sides has been well exhibited an excellent capacity to increase the stopband width (f_1/f_0). A series inductance is presented between two Impedance Inverters, as a shunt capacitance shown in Figure 5.

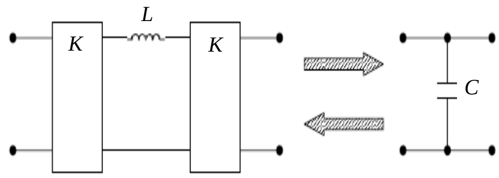

Figure 5. Equivalent circuit of the microstrip SIR resonators

Immittance inverter is used to convert a shunt capacitance into an equivalent circuit with series inductance. In order to quantitatively presentation, the multiple resonant frequencies versus impedance ratio (K) and input admittance Y at one end and the other end of th SIR resonator, can be explicitly derived using the simple transmission line theorem, such as Equation (1).

$$Y = jY_{0L}\cdot\frac{2(K\tan\theta_1+\tan\theta_2).(K-\tan\theta_1.\tan\theta_2)}{K(1-\tan^2\theta_1).(1-\tan^2\theta_2)-2(1+K^2).\tan\theta_1.\tan\theta_2} \quad (1)$$

$$K = Z_{ol}\,/\,Z_{oh} \quad (2)$$

The Equation (1) presents the electrical lengths of half a central section including θ_1 and θ_2 in two identical side sections. At each resonance, Y=0 must be valid so to establish an algebraic equation for solving the multiple roots, i.e., the aspect ratio of resonant frequencies can be explicitly expressed in terms of K such a closed form.

$$f_1\,/\,f_0 = \Pi\,/\,(2\tan^{-1}\sqrt{K}) \quad (3)$$

The Equation (3) shows that the smaller K results in the larger aspect ratio of f_1/f_0 and this criterion is basically valid for all the cases of θ_1 and θ_2. In this context, the strip width in two sides can be readily widened so as to reduce the value of Z_{OL}. In the meantime, Z_{OH} in the central section can be intuitively enlarged by narrowing its strip width. The narrow strip width may only be reduced to the certain extent of a few mils due to limited fabrication tolerance in etching process, and increased conductor loss and parasitic effect of conductor thickness.

B. Design a Single-Band Filter

B.1. Filter Designing in Central Frequency 2.4 GHz

A single-band filter at the central frequency of 2.4 GHz is designed without using of double coupling that the insertion loss (S_{21}) is -0.68 dB and return loss (S_{11}) is -21.25 dB (Figure 6).

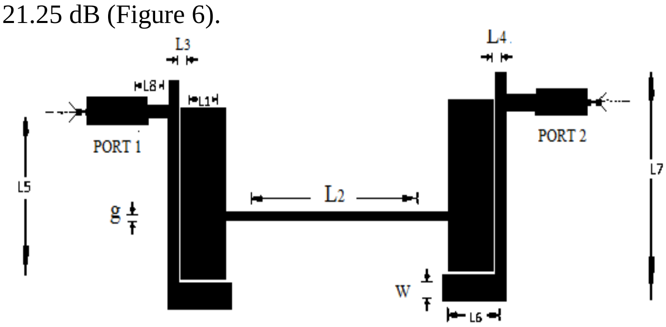

Figure 6. Dimensions of the first single-band filter between the proposed

In this filter the extent of dimensions shown in Figure 6 are as follows: l_1=2.16, l_2=11, l_3=0.1, L_4=0.54, L_5 =7.20, l_6=3.13, L_7=9.64, L_8=0.97, g=0.35, w=1.07 (all dimensions are in mm) and distance of the coupling is 0.12 mm. As seen in simulated filter response in Figure 7, the bandwidth is small and this amount is not optimal and is the disadvantage for the filter. So to increase the pass bandwidth, the technique of double coupling is utilized and a filter according to Figure 8 is used.

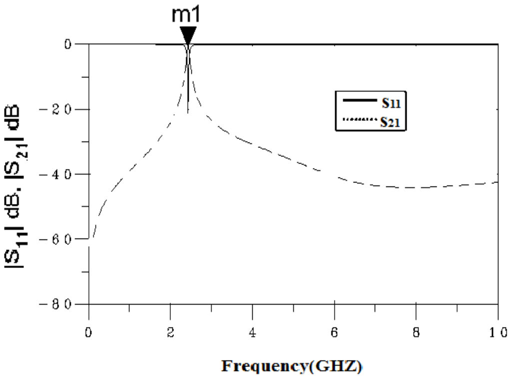

Figure 7. Simulated filter response in Figure 6 without double coupling

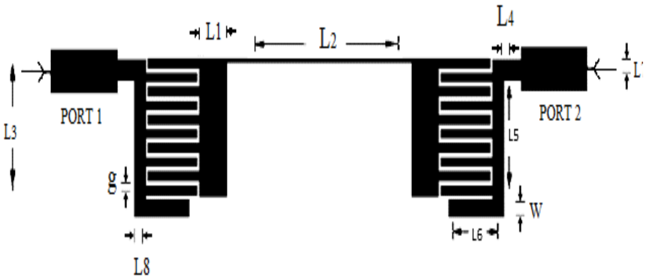

Figure 8. Dimensions of the first dual band proposed filter with double coupling

The designing of bandpass filter will be done at the central frequency of 2.4 GHz. In this filter the extent of the dimensions shown in Figure 8 are as follows: l_1=0.5, l_2=8.40, l_3=4.18, L_4=1.28, L_5=3.18, l_6=2.40, L_7=0.54, L_8=0.51, g=0.24, w=0.45 (all dimensions are in mm) and distance of the coupling is 0.12 mm. The circuit is designed for single-frequency filter at the central frequency of 2.4 GHz to enhance the bandwidth as double coupling.

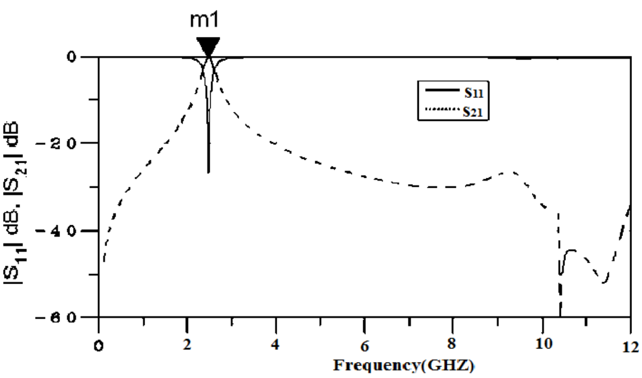

Figure 9. Simulation results of filter in central frequency of 2.4 GHz

As seen from Figure 9 with double coupling, the bandwidth of designed filter is more ever from 0.24 GHz. Therefore, the single-band filter is designed so no longer.

B.2. Filter Designing in Central Frequency 3.7 GHz

We designed a bandpass filter with the data given in Figure 10. In this filter the extent of the dimensions are: l_1=0.35, l_2=6.03, l_3=2.65, L_4=1.03, L_5=3.37, l_6=1.69, L_7=0.51, g=0.13, w=0.42 (all dimensions are in mm). Therefore, by adjusting the impedance ratio of the central frequency to band of 3.7 GHz the bandwidth is reached to 0.35 GHz.

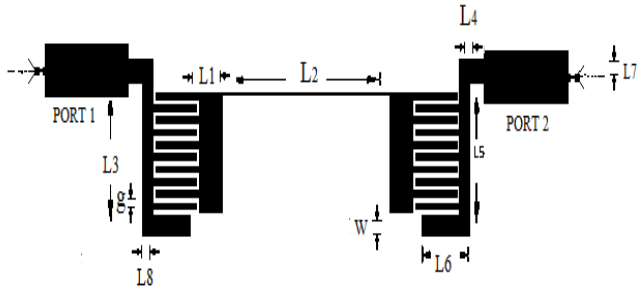

Figure 10. The designed filter in the orbital frequency of 3.7 GHz

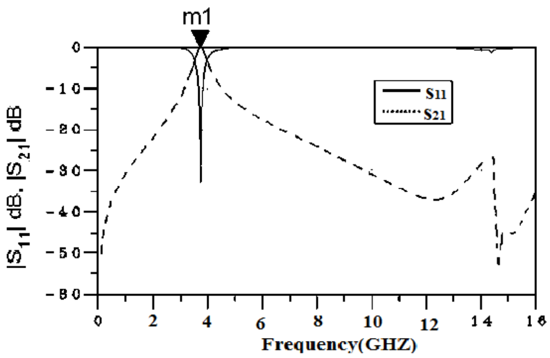

Figure 11. Simulation results of filter in central frequency of 3.7 GHz

B.3. Filter Designing in Central Frequency 5 GHz

The characteristics and dimensions of this filter shown in Figure 12, are as follows: l_1=1.09, l_2=3.82, l_3=2.15, L_4=0.93, L_5=2.29, l_6=1.79, L_7=0.39, L_8=0.37, L_9=1.08, g=0.08, w=0.32 (all dimensions are in mm), and distance of the coupling is 0.12 mm.

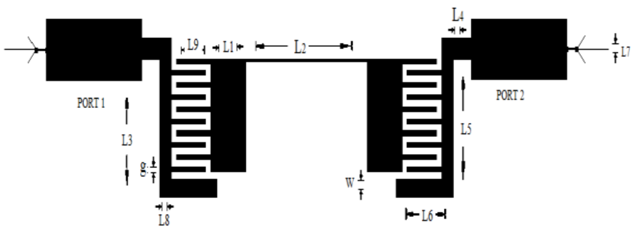

Figure 12. The designed filter in the orbital frequency of 5 GHz

Figure 13 shows the physical structure of single-band filter. It is constructed by two types of the stepped impedance resonators. This process is to reduce the filter size for frequency at the main central frequency of 5 GHz. This filter is designed by the characteristics of dielectric constant (ε_r) 3.38 and the thickness (h) of 20 mm and loss tangent (δ) 0.0021. The simulated and measured results of the filters are shown in Figure 14 that the insertion loss is -0.2 dB and the return loss is -32.5 dB. By setting the impedance and double coupling length, the central frequency 5 GHz and the bandwidth reaches 0.43 GHz.

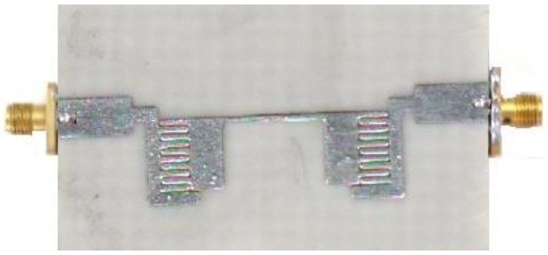

Figure 13. Physical structure of single-band filter

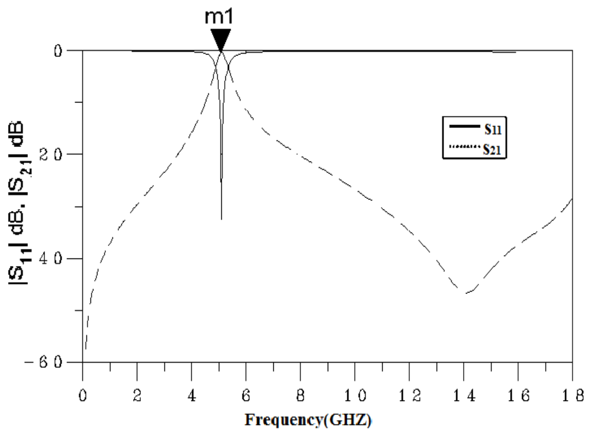

Figure 14. Simulation results of filter in central frequency of 5 GHz

III. STRUCTURE OF DUAL-BAND RESONATOR PROPOSED

Figure 15 shows the basic structure of the Resonator. As shown in this figure, the resonator is composed from the connection of the low impedance piece (Z_1) to two high impedance (Z_2) that have the electrical length θ_1 and θ_2. Figure 16 has a structure in contrary to resonator shown in Figure 15.

Considering the extent of the impedance and balance, this connection brings a different resonant frequency. The resonator can be achieved by the following relations. Resonator filter can be used to realize bandpass of the filters with high performance by suppression of additional harmonics that the resonant frequency can be achieved by adjusting the impedance ratio. It can be seen that by proper choice of impedance, the frequency range can become wide for the stop band.

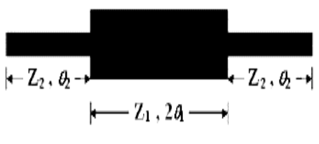

Figure 15. The connection of the low impedance in the middle

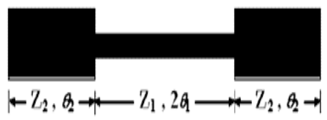

Figure 16. The connection of the low impedance piece with the sides

$$YI = JY_2 \frac{Y_2 \tan\theta_1 \times \tan\theta_2 - y_1}{Y_2 \tan\theta_1 + y_1 \tan\theta_2} \quad (4)$$

$$Y_1 = \frac{1}{Z_1} \quad (5)$$

$$Y_2 = \frac{1}{Z_2} \quad (6)$$

The Impedance ratio is as the follows:

$$R_z = \frac{Y_1}{Y_2} = \frac{Z_2}{Z_1} \quad (7)$$

The resonance analysis is as the follows where $Y_i = 0$

$$R_z = \tan\theta_1 \times \tan\theta_2 \quad (8)$$

$$R_z = -\cot\theta_1 \times \tan\theta_2 \quad (9)$$

$$R_Z = \frac{Z_2}{Z_1} = \tan\theta_1 \times \tan\theta_2 \quad (10)$$

where:

Y: Characteristic admittance

Z: Characteristic impedance

θ: Electrical length

R_Z: Impedance ratio

f: Resonant frequency

Fundamental frequency as f_0 and the first spurious frequencies as f_{SB1} are derived by the Equation (11).

$$\frac{f_{SB1}}{f_0} = \frac{\pi}{2\tan\sqrt{R_Z}} \quad (11)$$

The resonant frequencies associated with the impedance ratio, are designed based on the filters with dual-band bandpass.

$$\begin{cases} \frac{f_2}{f_1} < 2 \Rightarrow R_Z > 1 \\ \frac{f_2}{f_1} = 2 \Rightarrow R_Z = 1 \\ \frac{f_2}{f_1} > 2 \Rightarrow R_Z < 1 \end{cases} \quad (12)$$

where f_1 and f_2 are the resonance frequencies. The filter is designed so that there is $R_Z < 1$.

A. Designing a Single-Band Filter

This designing is a lower one for the cut band to reach the lower of -20dB. The shape of the filter is to extend below two pieces of the low impedance on the previous form, which is surveyed because of creating double zero and in this area it is improved the stop-band profile. Figure 17 shows the dimensions of the first filter using a combination of both resonator.

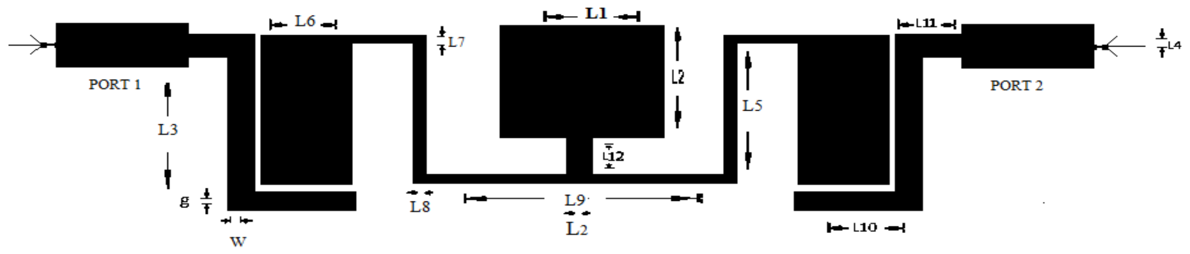

Figure 17. Dimensions of be proposed filter including the first dual-band bandpass

B. Designing a Dual-Band Filter

The dimensions of this filter are designed as in the following: L_1=3.7, L_2=3, l_3=3.59, L_4=0.6, L_5=3.96, l_6=2, L_7=0.61, L_8=0.28, L_9=6.77, L_{10}=0.51, L_{11}=1.49, g=0.51, w=0.59 (all dimensions are in mm). Parametric study yielding a spacing of 0.1 mm, is a low impedance between the input and output to improve the stop band profile takes. The central frequencies of the filter are 2.4 GHz and 3.7 GHz, respectively. The bandwidth of the first and second passes are 0.04 and 0.03 MHz, respectively, and the insertion losses (S_{21}) are -1.2 dB and -1.8 dB, the return losses (S_{11}) are -16.62 dB and -13.1 dB. The distance created is 0.12 mm.

As shown in Figure 18, the simulated filter bandwidth is small, and this amount does not suffer from the disadvantages of the optimal filter in the desired frequency. So, to increase the bandwidth, double coupling technique is utilized in accordance with Figure 19.

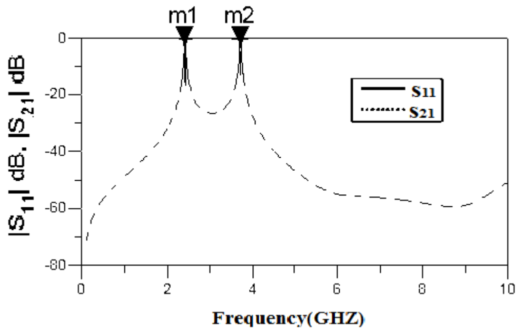

Figure 18. Simulated filter response in Figure 17 without binary coupling

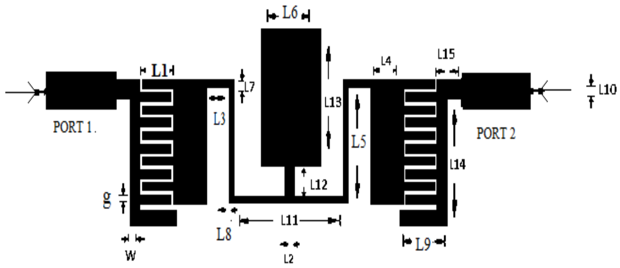

Figure 19. Dimensions of dual-band bandpass filter with double coupling

The filter designing parameters are: l_1=1.35, l_2=0.4, l_3=0.98, L_4=1.43, L_5=3.74, l_6=2.59, L_7=0.22, L_8=0.19, L_9=2.35, L_{11}=4.73, L_{10}=0.55, L_{12}=1.1, L_{13}=4.41, L_{14}=3.73, L_{15}=0.73, g= 0.27, w=0.48 (all dimensions are in mm). Bandwidth of the first and second passes are 0.12 and 0.11 MHz, respectively. The insertion losses are -0.18 and -0.4 dB, respectively and the return losses are -32 dB and -20 dB, respectively (based on simulated results in Figure 20).

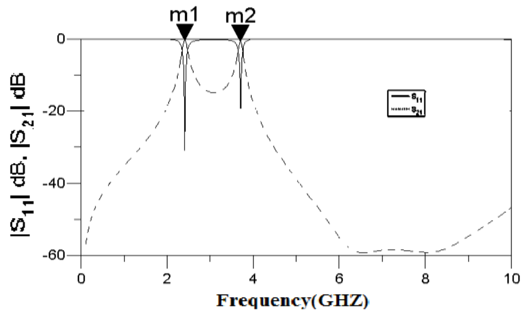

Figure 20. Simulated response of the double coupling

IV. RESULTS AND DISCUSSION

As seen in designing of two band-pass filter, the bandwidth is also enhanced with a double coupling to 0.22 MHz. Therefore, the filters are more efficient than similar filters that are used in the communications industry which have a low impedance device in the filter with the stop-band profile due to a double zero. The final dimensional two-band filter is also designed and is shown in Figure 21.

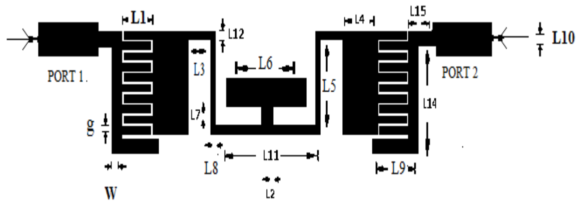

Figure 21. Dimensions of dual-band bandpass filter with double coupling

The filter designing parameters are: l_1=1.48, l_2=0.59, l_3=1.14, L_4=1.79, L_5=3.32, l_6=4, L_7=0.7, L_8=0.23, L_9=2.35, L_{10}=0.55, L_{11}=5.1, L_{12}=0.27, L_{13}=0.99, L_{14}=3.73, L_{15}=0.73, g=0.25, w=0.48 (all dimensions are in mm). The bandwidth through the first and second passes are 0.14 and 0.13 MHz, respectively. The insertion losses are -0.37 dB and -0.67 dB, respectively, and the return losses are -30dB and -22dB, respectively. Therefore, applying this technique as double coupling increases the bandwidth as shown in Figure 22.

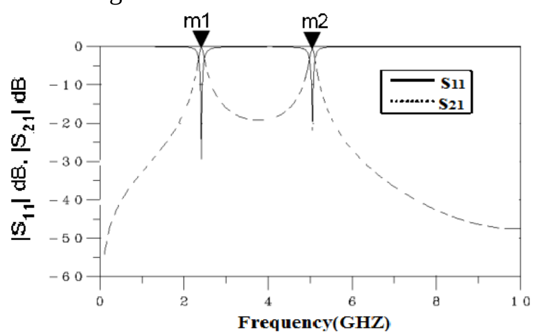

Figure 22. Developed Simulator at working frequency

V. CONCLUSIONS

In this paper the microstrip bandpass filter is designed, simulated, built and tested and the measured and simulation results are compared. The coupling between each resonator is studied to observe its effect in the filter performance. This paper is designed for the microstrip bandpass filters for use at IEEE standard frequencies and the results are fully described. This filter with dielectric constant 3.38 and the thickness of 20 mm is designed. The coupling technique increased the band width and the effect of using the low impedance piece is surveyed. Therefore, creating double zero characteristic improved the stop-band profile which caused to improve the performance of the communications industries. This type of filter can be used in where multiple frequency bands are required.

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BIOGRAPHY

Tayebeh Asiyabi was born in Iran, 1983. She received the B.Sc. degree from Electrical Engineering Department, Shariaty University, Tehran, Iran and M.Sc. degree from Kermanshah Branch, Islamic Azad University, Kermanshah, Iran. Currently, she is a Lecturer of Power Electrical Engineering at Dezful Branch, Islamic Azad University, Dezful, Iran. Her research interests are in the area of power quality, energy management systems, ICT in power engineering and in the areas of microstrip multiband bandpass filters and learning educational systems. She has published several papers and research reports in the mentioned areas.