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International
Journal
Of Modern Engineering Research (IJMER)

Ultra-Wide Bandpass filter using isosceles triangular microstrip patch resonator

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Abstract: *In this paper, Ultra-Wide bandpass filter using isosceles triangular patch resonator (ITPR) is proposed. The reported design has wide bandwidth, low insertion loss, high return loss and flat group delay properties. The filter characteristics, which are influenced by the height of the triangular structure, are studied. The proposed design has been prepared in two steps: First, cutting the corners of the triangular structure to make filter size more compact and avoid line coupling losses, Second, Etching slits to improve filter performance. Simulation of proposed filter has been carried out with Agilent Advanced` Design System (ADS) and it shows good agreement with theoretical results.*

Keywords: *microstrip filters, s-parameters, bandpass filter, microstrip patch resonators*

I. INTRODUCTION

Ultra-Wide Band (UWB) technology has found many applications in high speed wireless communication. UWB radio systems are very promising, because data transmission rates greater than those of other wireless LAN systems can be obtained with low power dissipation. In this area, various studies are under progress [1–6]. Ultra-Wide bandpass filters are characterized by wide bandwidth, low insertion loss, good band rejection and flat group delay properties. The filter is designed using microstrip planar technology due to its high power handling capability, low insertion loss, low cost and easy fabrication. The patch resonators are an obvious choice for bandpass filter applications where low insertion loss and high power handling are primary concern [7–10]. Microstrip circuits suffer from radiation losses, dispersion, unwanted coupling and discontinuity effects. These problems can be greatly reduced by using thinner substrate which allows operation at millimeter-waves with reduced dispersion and radiation losses [11].

Many kind of microstrip patch resonator filter configurations such as square patch [12], circular patch [13-14], trapezoidal patch [15] and ring patches have been reported, but they suffer from high conductor losses and low power handling capability. Triangular resonator was first studied by Ogasawara and Noguchi [16] in 1974, later Helszajn and James in 1978 [17] studied the microstrip one and confirmed that two orthogonal split modes could be excited. Moreover, they also demonstrated that the radiation loss was lower than that of a disk-shaped microstrip resonator. In 2004 Hong and Li [11] reported dual mode microstrip filters using equilateral triangular patch resonator. With the rapid development of modern communication systems, more and more miniature planar filters [18-22] with excellent performances are required.

In this paper, we propose an ultra-wide bandpass filter using isosceles triangular microstrip patch resonator. The filter is designed on a 1.27mm thick dielectric substrate with relative dielectric constant 10.8 and loss tangent of 0.002. A 10 µm thick copper patch is used with corners cut and etched slits. The simulated results show that it has insertion loss of 0.224 dB, return loss of more than 58 dB at central frequency 8.47 GHz, multiple transmission zeroes, passband in C-X band, wider bandwidth and it can be fabricated on 8 mm x 12 mm board.

II. THEORETICAL FORMULATIONS

Helszajn and James [16] reported a theoretical and experimental investigation for the resonant frequency of electromagnetic filed patterns of TM modes of an equilateral triangular microstrip planar resonator. The electromagnetic field pattern has no variation along the thickness of resonator and the wave equation can be written as:

$$E_z(x,y) = A_{m,n,i}\left\{\begin{array}{l}\cos\left[\left(\frac{2\pi x}{\sqrt{3}b}+\frac{2\pi}{3}\right)i\right]\cos\left[\frac{2\pi(m-n)y}{3b}\right]\\ +\cos\left[\left(\frac{2\pi x}{\sqrt{3}b}+\frac{2\pi}{3}\right)m\right]\cos\left[\frac{2\pi(n-i)y}{3b}\right]\\ +\cos\left[\left(\frac{2\pi x}{\sqrt{3}b}+\frac{2\pi}{3}\right)n\right]\cos\left[\frac{2\pi(i-m)y}{3b}\right]\end{array}\right\} \tag{1}$$

$$H_x = \frac{j}{\omega\mu_0\mu_r}\frac{\partial E_z}{\partial y} \tag{2}$$

$$H_y = \frac{-j}{\omega\mu_0\mu_r}\frac{\partial E_z}{\partial x} \tag{3}$$

$$H_z = E_x = E_y = 0 \tag{4}$$

Where $A_{m,n,i}$ is a constant representing the mode amplitude, b is the effective length of the triangle, Ω is the angular frequency and m, n and i are indexes under condition $m+n+i=0$, which determine the resonant mode of the triangular resonator and must satisfy the wave equation below:

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+k^2_{m,n,i}\right)E_z = 0 \tag{5}$$

Where $k_{m,n,i}$ is the resonance wave-number, it can be written as:

$$k_{m,n,i} = \left(\frac{4\pi}{b}\right)\left(\sqrt{m^2+mn+n^2}\right) \tag{6}$$

Resonance frequency corresponding to different modes can be written as:

$$f_{r(m,n,i)} = \frac{ck_{m,n,i}}{2\pi\sqrt{\varepsilon_r}} = \left(\frac{2c}{3b\sqrt{\varepsilon_r}}\right)\left(\sqrt{m^2+mn+n^2}\right)$$

(7)

Where c is the velocity of light in free space and ϵ_r is the relative dielectric constant of the substrate. According to equation (7) there are an infinite number of resonant frequencies corresponding to different modes.

III. CHARACTERIZATION OF PROPOSED FILTER

The dimensions of proposed filter are shown in Figure 1, the design is developed using 10µm thick copper patch on a 1.27 mm thick RT Duroid dielectric with a relative dielectric constant of 10.8 and loss tangent 0.002.

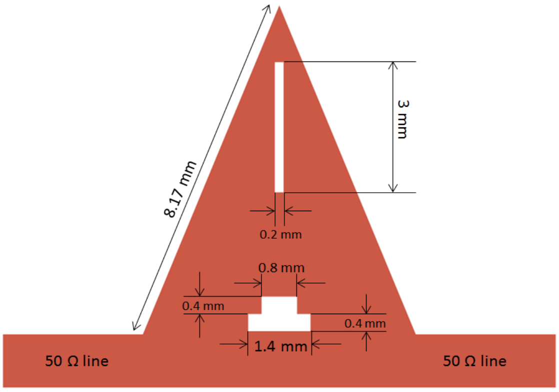

Fig.1 dimensions of the proposed filter

I/O feed lines have characteristic impedance of 50Ω so that maximum power transfer from source to resonator can be ensured. Cutting the corners of the triangular structure will result in reduction of the filter size and improve its performances in terms of the frequency response. Using Eq. (7), the central frequency is 8.47 GHz, corresponding to the $TM_{1,0,-1}$ mode. Central frequency of 8.47 GHZ, insertion loss S_{21} of 0.224 dB, 3-dB bandwidth BW of 78.16% and return loss S_{11} of 58.69 dB were observed in simulated results, as shown in Figure 2. Moreover, the three transmission zeroes are located near the passband edge in order to show quasi-elliptic function response, as 34.72 dB at 7.42 GHz, 58.69 dB at 8.47 GHz, and 26.74 dB at 10.40 GHz. The simulation was completed using the Agilent Advanced Design System (ADS) simulator, which uses Method of Moments (MoM) to process the results.

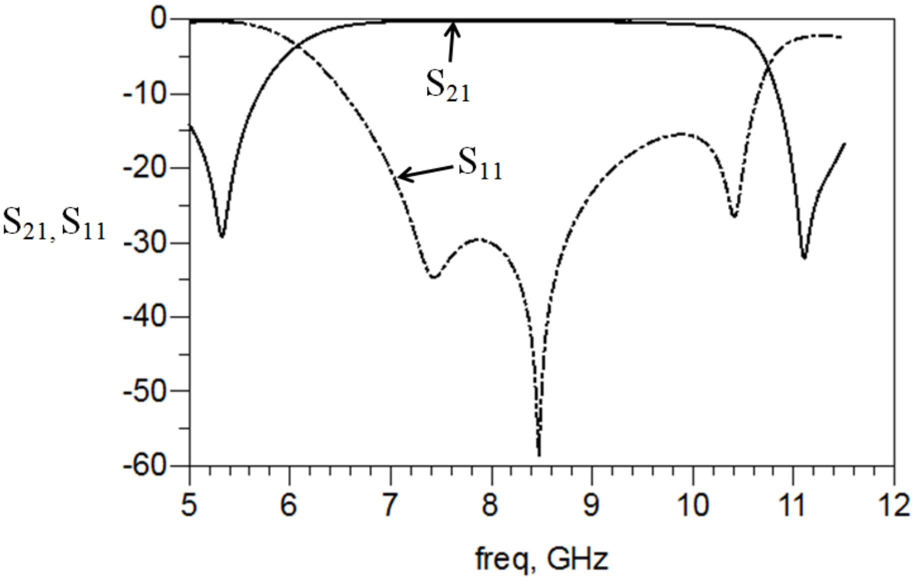

Fig.2 frequency response of proposed filter

Figure 3 shows the current distribution at the central frequency i.e., 8.47 GHz, the accumulation of the energy is near the lower slit and along the Input-Output lines. There is moderate level of current density near the upper slit.

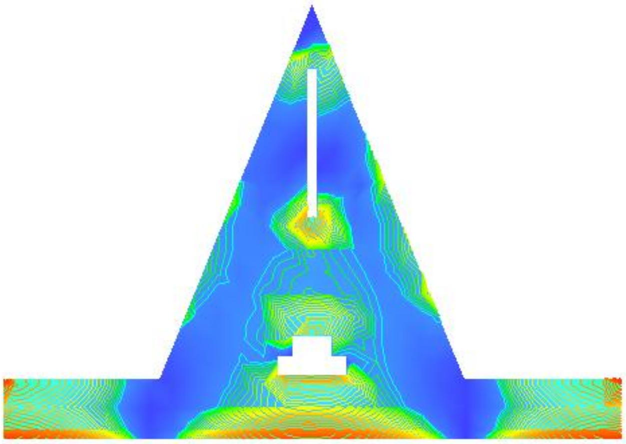

Fig.3 current distribution in proposed filter

The width 'w' as shown in Figure 4 was varied and results has been plotted in Figure 5 and it was observed that the bandwidth will decrease with increase in width of the lower slit. Also, a drop in band rejection at upper frequency was observed.

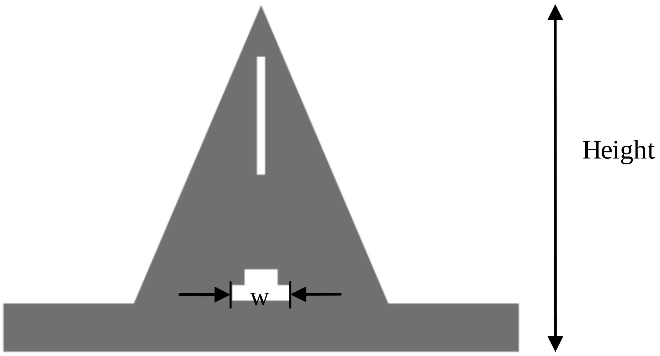

Fig.4 representation of ‘w’ and ‘height’ in geometrical structure of filter

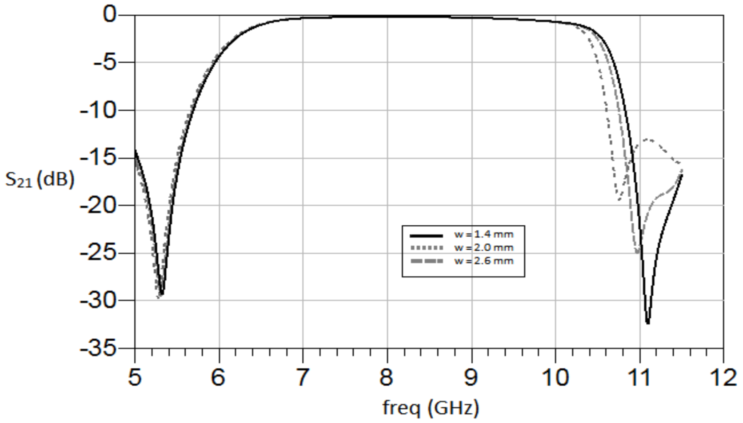

Fig.5 relationship between frequency response and width ‘w’ of the lower slit

When height of the triangular structure was varied and it was observed that the passband shifted towards the lower frequency region of the response with increase in height.

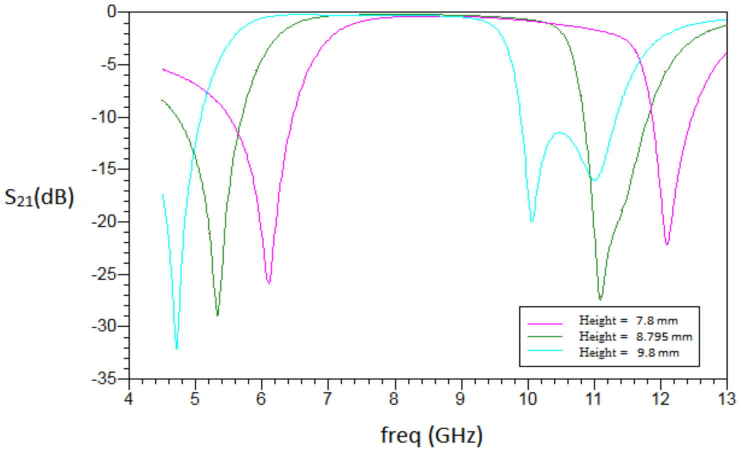

Fig.6 relationship between frequency response and ‘height’ of the filter

IV. CONCLUSION

The presented Ultra-Wide bandpass filter using isosceles triangular microstrip patch resonator possess multiple transmission zeros and wide passband. The designed filter has outstanding advantages such as simple structure, compact size without coupling gaps, low cost, low insertion loss, high power handling capability, compatibility with MMICs, ease of on chip integration and compatibility with various fabrication processes.

Also, it can be realized on variety of substrates depending on the specific need. The proposed filter can be easily integrated in UWB wireless communication systems. It may also find applications in RFID, vehicular RADARs, military RADARs, indoor and handheld devices.

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