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Rejection of Undesired Frequency Bands in UWB

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Abstract: In recent era, Ultra wideband (UWB) technology has greater demand. It has attracted interest of researcher to work in this field. UWB covers wide bandwidth of more than 500 MHz and fractional bandwidth greater than 20%. Resonant frequencies of WLAN are 2.5GHz, 5.8GHz and resonant frequency of Wi-MAX is 3.5GHz which are included in UWB range. Multiple interfering bands can be notched by the help of stepped impedance resonator and split ring resonator. In this article, we design and evaluate the performance of circular monopole UWB antenna with the help of stepped impedance resonator and split ring resonator along feed line to notch triple narrow band frequencies

Keywords: Stepped Impedance Resonator (SIR), Ultra wideband (UWB), Split Ring Resonator(SRR), Wireless local Area Networks (WLAN), Worldwide Interoperation for Microwave Access (Wi-MAX).

I. INTRODUCTION

UWB technology is widely used because of its less power consumption for a large signal. Other than this, it is a wide band signal having large channel capacity, high speed transmission etc. These are advantages of UWB technology but there is a flaw in UWB technology is that some other narrow band standard such as Wireless local Area Networks (WLAN), Worldwide Interoperation for Microwave Access (Wi-MAX) provides interference in UWB during transmission and reception. So notching of these undesired bands from ultra wideband (UWB) systems is an interesting topic of research.

There are many technologies by which notching of interfering bands in UWB can be done. Etching of slots[1-3], Electromagnetic band gap (EBG) structure[4-5], open loop resonator [6], split ring resonator[7], are the technologies used for notching. SIR and SRR in integrated form used to notch tri band and other resonator does not notch more than two bands.

In this paper, a UWB antenna has been designed on CST microwave studio operating at 1.75-10GHz. 2.4, 3.5 and 5.8GHZ are undesired frequencies which are notched by resonators.

II. THEORY OF DIFFERENT RESONATOR

A. Stepped Impedance Resonator

It is non uniform transmission line i.e. as transmission line is in step form having different electrical length and different impedance. Wave cancellation theory [8] states that when two signal having same properties but phase shift of 1800 at defined frequency then they cancel out each other at that defined frequency.

In this designing, a SIR is connected along the transmission line of UWB monopole antenna. SIR is not manually connected to transmission line but there is mutual coupling between them. There are two frequencies at which resonance condition take place. One frequency is named as fundamental frequency and other spurious frequency. At these frequencies current does not reach at antenna. In this way it will notch these frequencies.

According to transmission line theory [9] the admittance Yi from open side of SIR is given as

$$Y_i = j\, Y_2 \frac{Y_2 \tan\Theta_1 . \tan\Theta_2 - Y_1}{Y_2 \tan\Theta_1 + Y_1 \tan\Theta_2} \qquad (1)$$

Where, Y_1 and Y_2 are admittance of two different transmission lines which are connected to each other.
Resonance condition can be obtain when Yi = 0, then

$$\tan\Theta_1 . \tan\Theta_2 = R_Z \qquad (2)$$

Here Rz is impedance ratio
$R_Z = Y_1/Y_2 = Z_2/Z_1$
Θ_1 and Θ_2 are electrical length of two transmission line in SIR.
Relation between fundamental and spurious frequency

$$\frac{f_S}{f_f} = \frac{\pi}{\tan^{-1}(\sqrt{R_Z})} - 1 \qquad (3)$$

Where fs is spurious frequency and f_f fundamental frequency.

B. Split Ring Resonator

In this paper a circular split ring resonator is used for notching the interfering frequency. It is one type of metamaterial. Metamaterial having left handed property that means it has negative reflection and backward wave radiation.

A SRR is on the upper side of the substrate and vicinity of the feed line. A negative permittivity is not a challenge as it is found in metal. But negative permeability is defined by series gap in conductor strip. In this way it opposes the Snell's law [10].

By equivalent circuit analysis it is easy to determine the resonant frequency. Here gap between the conductors will form capacitance and conductor itself acts as inductor. A LC equivalent circuit is formed whose resonant frequency is defined [11] as

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$$\omega_{LC}=\frac{1}{2\pi(\sqrt{LCs})} \quad (4)$$

Where ω_{LC} is resonant frequency,
C_s is the equivalent capacitance and
L is the effective inductance.
Now L is expressed as

$$L=\frac{4.86\ \mu0}{2}(a-w-d)[\ln\left(\frac{0.98}{\rho}\right)+1.84\rho] \quad (5)$$

Here, a is radius of conductor,
w is the thickness of conductor,
d is gap between conductor and
ρ is the filling factor of the inductance and is given as

$$\rho=\frac{w+d}{a-w-d} \quad (6)$$

The effective capacitance is given by

$$Cs = [a-\frac{3}{2}(w+d)]C_{pul} \quad (7)$$

Where, C_{pul} is the per-unit-length capacitance between the rings which is given by

$$C_{pul} = \varepsilon_0\varepsilon_{eff}\frac{K(\sqrt{1-k^2})}{K(k)} \quad (8)$$

Here, ε_{eff} is the effective dielectric constant which is defined as

$$\varepsilon eff =\frac{\varepsilon r+1}{2} \quad (9)$$

K(k) the complete elliptical integral of the first kind with k given as

$$k=\frac{d}{d+2w} \quad (10)$$

III. ULTRAWIDE BAND (UWB) ANTENNA DESIGN

A monopole circular UWB antenna is created on substrate having ,

Relative dielectric constant =3.48,
Loss tangent= 0 .004,
Thickness =1mm,
Length =52mm,
Width =43mm

This same antenna is integrated with a notch band filter along its feed line to notch triple bands. This filter is a combination of SIR, SRR. Tapering is done for impedance matching between antenna and filter. Dimension of whole antenna is listed in Table 1. This novel antenna with band rejection filter is shown in Fig. 1.

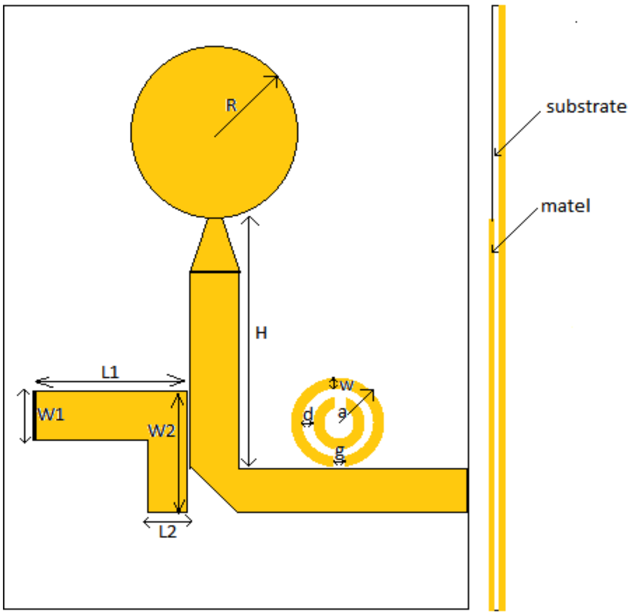

Fig. 1 A UWB antenna with resonators

IV. SIMULATIONS AND RESULTS

The proposed UWB antenna is shown on Fig. 2.

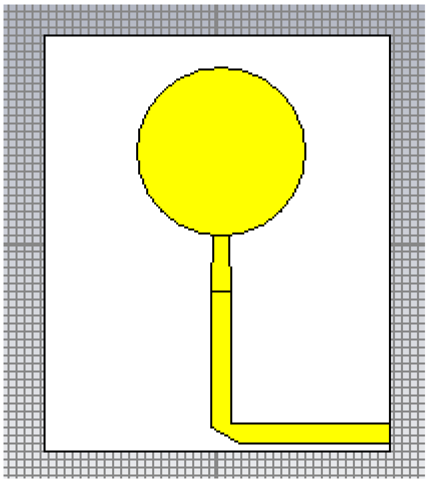

Fig. 2 A UWB circular monopole antenna

This UWB antenna's operating frequency range is 1.75 – 10GHz, as frequency range is too high so it is known as ultra wide band.
Return loss curve of UWB antenna is shown in Fig.3.

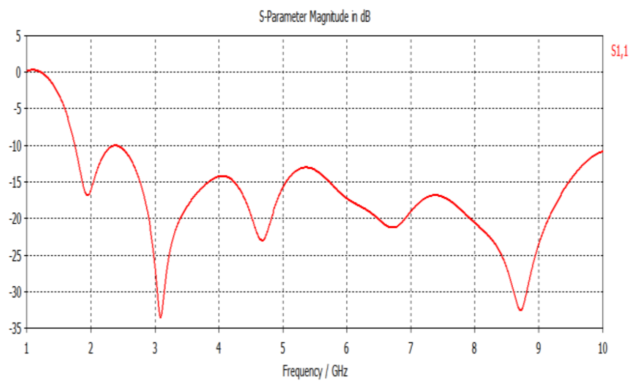

Fig. 3 Return loss curve of UWB circular monopole antenna

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From fig. 3 it is observed that from 1.75GHz to 10GHz S1,1 value is below -10dB. That means that from 1.75GHz to 10GHz all the frequencies are passed. Here we can see that 2.4 GHz, 3.5GHz, 5.8GHz are passed which are interfering frequencies.

To reject 2.4GHz, 5.8GHz a stepped impedance resonator is implemented on UWB antenna. 2.4GHz is a fundamental frequency and 5.8 is a spurious frequency. From above equations (1,2,3) impedance ratio and other parameter are calculated as listed in Table 1. A short circuit is provided by conducting split at one end and other end remains open. There is a mutual coupling between antenna and SIR.A UWB antenna with SIR is shown in Fig. 4.

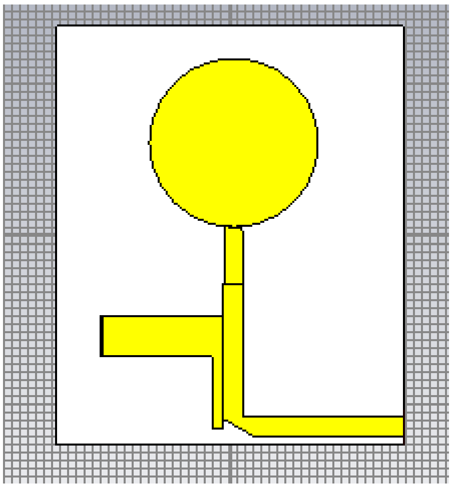

Fig. 4 UWB circular monopole antenna with SIR

The return loss curve when SIR is placed on left side of UWB antenna is shown in Fig. 5.

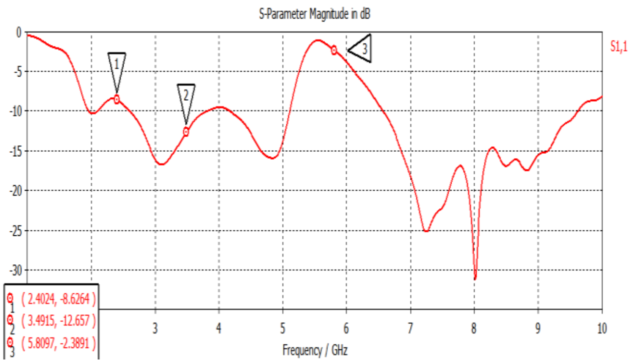

Fig. 5 Return loss curve of UWB circular monopole antenna with SIR

From fig. 5 it is observed that at 2.4GHz and 5.8GHz S1,1 value are above -10GHz i.e. these frequencies are stopped rest all are passed.

Rejection of 3.5GHz can be done by the help of circular split ring resonator. It resonant frequency is calculated by (4) where L and C is observed form LC equivalent circuit. SRR is placed in right side of UWB antenna along the feed line as shown in Fig. 6.

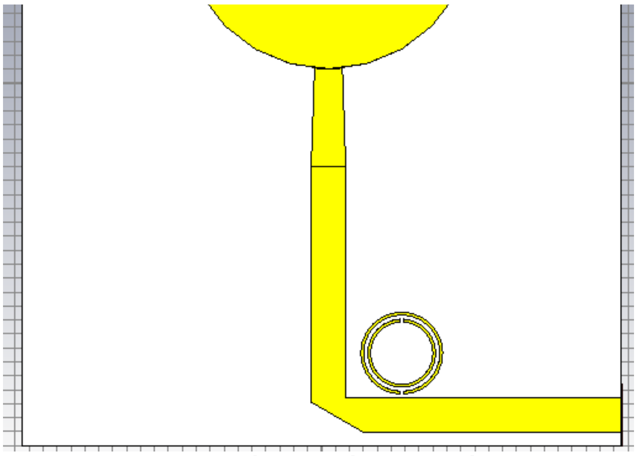

Fig. 6 UWB circular monopole antenna with SRR

The return loss curve when SRR is on the right side of UWB antenna is shown in Fig. 7.

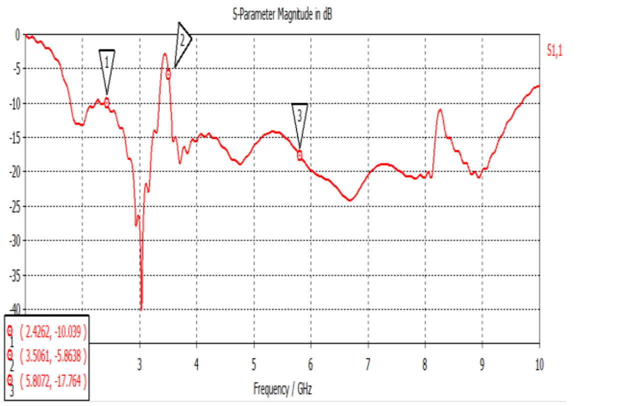

Fig. 7 Return loss curve of UWB circular monopole antenna with SRR

It is observed from Fig. 7 that at 3.5GHz frequency S1,1 value is above -10dB. So it is stopped rest all frequencies are passed.

Both SIR and SRR are integrated to form filter and connected to UWB antenna as shown in Fig. 8.

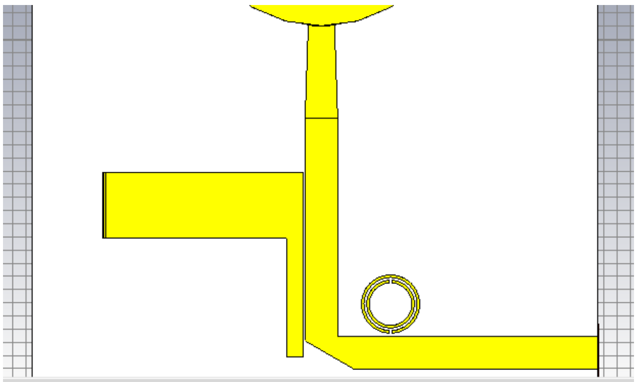

Fig. 8 UWB circular monopole antenna with SIR and SRR

The return loss curve when both SIR and SRR are connected to UWB antenna is shown in Fig. 9.

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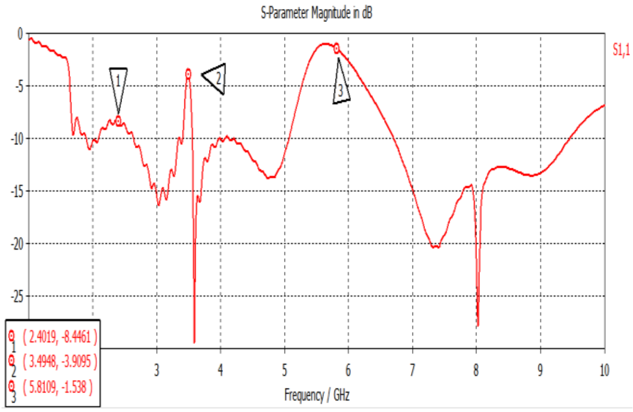

Fig. 9 Return loss curve of UWB circular monopole antenna with SIR and SRR

From curve it is concluded that at 2.4GHz,3.5GHz and 5.8GHz S1,1 value is above -10dB. So these frequencies are notched rest all are passed.
VSWR curve is shown in Fig. 10 when SIR and SRR is connected to UWB antenna.

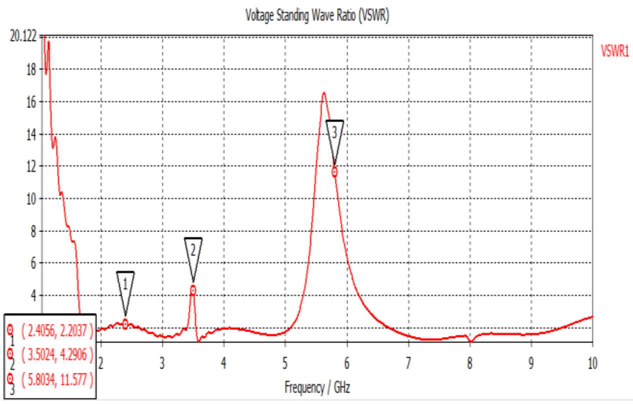

Fig. 10 VSWR curve when SIR and SRR is connected to UWB circular monopole antenna

From VSWR curve it is observed that at 2.4, 3.5, and 5.8GHz VSWR value is greater than 2.

Current Distribution at different frequencies when resonators are connected to UWB antenna

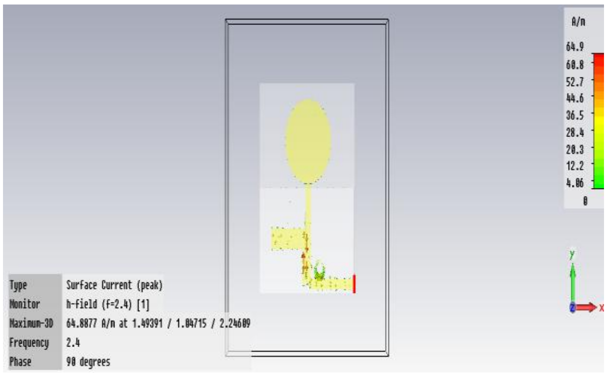

Fig. 11 current distribution at 2.4GHz

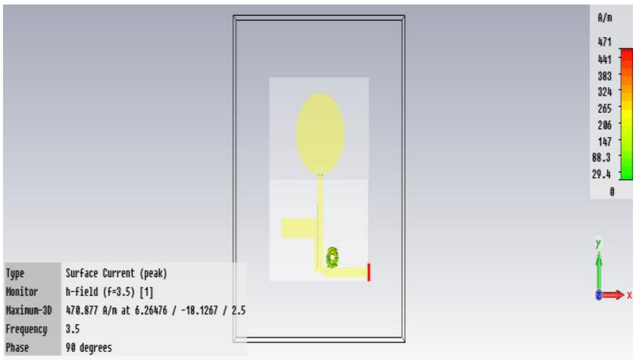

Fig. 12 current distribution at 3.5GHz

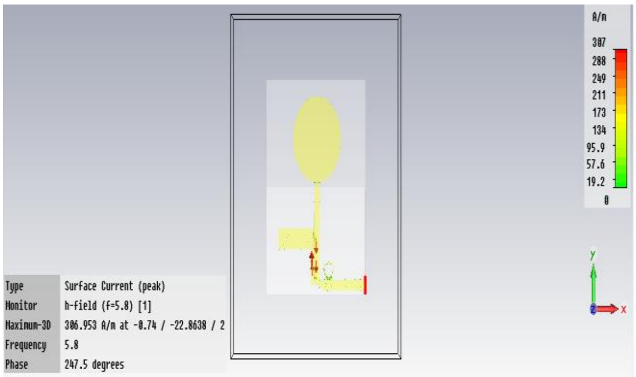

Fig. 13 current distribution at 5.8GHz

From current distribution figures we concluded that SIR does not allow current to reach at antenna at frequencies 2.4GHz and 5.8GHz, SRR to stop current to reach at antenna at frequency 3.5GHz.

TABLE 1
Parameters and its value

Parameter	R	H	L1	L2	W1
Value(mm)	10.5	26	15.13	1.25	5
Parameter	W2	a	d	G	w
Value(mm)	14	2.22	.2	.2	.2

TABLE 2
Comparison of various notch frequencies with different resonators on UWB monopole antenna

Notch Frequencies (in GHz)	**SIR on the left side of the feed line (in dB)**	**SRR on the right side of the feed line (in dB)**	**SIR and SRR on feed line (in dB)**
2.4	-8.6162885	-9.89584	-8.4181177
3.5	-12.546945	-5.311348	-4.0530884
5.8	-2.327438	-17.657486	-1.4891203

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V. CONCLUSION

SIR and SRR has been worked as filter to reject undesired frequencies such as 2.4GHz, 3.5GHz and 5.8GHz from UWB as shown in simulations. These frequencies are creating interference in UWB. Current distribution is also shown at various frequencies and concluded that at these frequencies current does not reach at antenna because they will resonate at these interfering frequencies.
The proposed antenna will be fabricated using PCB technology and results will be verify on Vector Network Analyzer.

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