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Design and Analysis of Reconfigurable UWB Antenna for Cognitive Radio Applications

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ABSTRACT: Cognitive radio is rapidly shaping the future of wireless communications. Research on antenna design is very critical for the implementation of cognitive radio. A special antenna is required in cognitive radio for sensing and communicating. For the purpose of spectrum sensing, an Ultra-wideband (UWB) antenna is being considered as a potential candidate by many experts. In this paper, a novel design of a compact planar reconfigurable ultra wide band (UWB) antenna with double band notched characteristics has been presented. The antenna has a unique shape and has been fed through a 50 Ω micro-strip feed-line. The strength of the antenna lies in dual band notched properties for Wi-Max system at 3.3 - 3.7 GHz, and WLAN IEEE 802.11a at 5.15 - 5.85 GHz. By etching two identical circular split ring resonators (CSRRs) in the radiation patch, dual band rejections in the Wi-MAX and WLAN bands are achieved. Owing to its band notch property and simple structure, the proposed antenna can be used in UWB communications applications to suppress the radio-frequency interference. In order to realize impedance matching over the ultra-wideband, two staircase cuts are made symmetrically at the junction of feed-line and radiation patch. The simulated and measured results, including return loss, radiation pattern and peak gains are in good agreement with theory analysis which validates our design concept. The proposed antenna, with the size of 19×32mm^2, can operate over the frequency band between 2.9-26.05 GHz for VSWR < 2 with dual band notches of 3.3-3.74 GHz and 5.1-5.8 GHz. Besides, in the working bands, the simulated VSWR and radiation pattern of proposed antenna prove that the proposed antenna is a good candidate for various UWB and cognitive radio applications.

KEYWORDS: Cognitive Radio, Ultra Wide Band (UWB), Reconfigurable, Circular Split Ring Resonator (CSRR).

I.INTRODUCTION

Ultra-wideband (UWB) systems have drawn lots of interests since the Federal Communications Commission (FCC) released the unlicensed frequency band of 3.1-10.6 GHz for commercial UWB applications [1]. Also for their high data rates, great capacity, low complexity and low operating power level, UWB system becomes a hot topic which will bring us great potential interests [2]. The UWB systems are usually used in home networking as a convenient way for personal wireless communications. As one of the most essential parts of the UWB systems, UWB antennas have drawn more and more researching interests. Besides the advantages that UWB system brings to us, it also carries troubles. One of the troubles is the interference between UWB system and other communication system, such as local area network (WLAN, 5.15-5.825 GHz), worldwide interoperability for microwave access (Wi-MAX, 3.3-3.7 GHz) IEEE802.11a in the United States (5.15-5.35 GHz, 5.725-5.825 GHz) and HIPERLAN/2 in Europe (5.15-5.35 GHz, 5.47-5.725 GHz) [3].

The traditional way to solve problem like this is insert a filter in the receive terminal, but this will make the UWB system more complex, especially for portable devices. UWB antenna as the key component of UWB system, and also based on the antenna theory, researchers found the best way to eliminate this trouble is design the filter and the UWB antenna together, which is called band-notched UWB antenna. In recent researches, many UWB antennas with band-notched characteristics have been proposed and studied. The conventional and effective way to achieve the notch-band is inserting a slot on the patch or on the ground plane [4-7]. While there are also many other ways to create band-notched characteristics on a UWB antenna, such as using parasitic structures [8-12], embedding a slit in the feed-line [13, 14], or adding split ring resonator (SRR) coupled to the feed-line [15-17]. These slots, stubs or branches are in different shapes, but the common point they all share is the same that is introducing a perturbation into the UWB antenna and they all are near $\lambda/2$ or $\lambda/4$ resonant lengths corresponding their notched frequencies. So in a band-notched antenna designing procedure, perturbation structures with proper resonant length is the key point of the antenna design.

Cognitive radio (CR) technology is key enabling technology which provides the capability to share the wireless channel with the licensed users in an opportunistic way. CRs are foreseen to be able to provide the high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. In order to share the spectrum with licensed users without interfering with them, and meet. The diverse quality of service requirements of applications, each CR user in a CR network must:

-Determine the portion of spectrum that is available,– which is known as Spectrum sensing.
-Select the best available channel, which is called– Spectrum decision.
-Coordinate access to this channel with other is known as Spectrum sharing.
-Vacate the channel when a licensed user is– detected, which is referred as Spectrum mobility.

To fulfil these functions of spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility, a CR has to be cognitive, reconfigurable and self-organized. An example of the cognitive capability is the CR’s ability to sense the spectrum and detect spectrum holes (also called white spaces), which are those frequency bands not used by the licensed users. Choose the suitable operating frequency (frequency agility), and the ability to adapt the modulation/coding schemes and transmit power as needed. The self-organized capability has to do with the possession of a good spectrum management scheme, a good mobility and connection management, and the ability to support security functions in dynamic environments.

Cognitive radio (CR) technology works in two modes-

-underlay mode
-overlay mode

The difference between the two modes is the amount of transmitted power. In the underlay mode, UWB has a considerably restricted power, which is spread over a wide frequency band. When a UWB system is operating in the underlay mode, it is quite unlikely that any coexisting licensed system is affected from it. On top of this, underlay UWB can employ various narrowband interference avoidance methods.

In the overlay mode, however, the transmitted power can be much higher. It actually can be increased to a level that is comparable to the power of licensed systems. But this mode is only applicable if two conditions are met:

1) If the UWB transmitter ensures that the targeted spectrum is completely free of signals of other systems, and
2) If the regulations are revised to allow this mode of operation.

UWB can also operate in both underlay and overlay modes simultaneously. This can happen by shaping the transmitted signal so as to make part of the spectrum occupied in an underlay mode and some other parts occupied in an overlay mode. Apparently, in any mode of operation, UWB causes negligible interference to other communication systems. This special feature of UWB makes it very tempting for the realization of cognitive radio.

In this paper, a simple and compact reconfigurable UWB antenna with dual band notches for Wi-MAX 3.5 GHz and WLAN 5.2/5.8 GHz is proposed. The antenna consists of a micro-strip feed-line, a ground plane and a dustpan-shaped radiation patch with two identical circular split ring resonators (CSRRs) which realize the dual band stop-band function etched in it. Since both the lower and higher resonant modes of the CSRRs has been fully used to generate the notched bands, the designed antenna can realize the dual band rejection conveniently by etching the CSRRs in the radiation patch.

II. ANTENNA DESIGN AND CONFIGURATION

The proposed antenna is designed on an FR4 substrate, with dimensions of 19mm × 32mm, with the relative permittivity $\varepsilon_r = 4.4$, a loss tangent tan $\delta = 0.02$ and a thickness $h = 1$ mm. It is composed of a 50Ω micro-strip feed line with the width of W_f and length of L_f to couple the input signal to the radiating patch. Figure 1(a) demonstrates the top view & Figure 1(b) depicts bottom view of proposed reconfigurable band notched antenna structure with slots inserted at the partial ground plane.

The antenna consists of a dust-pan shaped radiating patch with two circular ring resonator etched in the patch. In this structure, two rectangular slots on the ground plane are embedded for better impedance matching. To achieve the desired frequency band notch re-configurability, two ideal SW is placed between the two ring resonator elements on the radiator plane. Several aspects were considered to optimize the final design like the overall impedance bandwidth of the antenna, bandwidth of the notched bands and the level of band rejection at notched frequency.

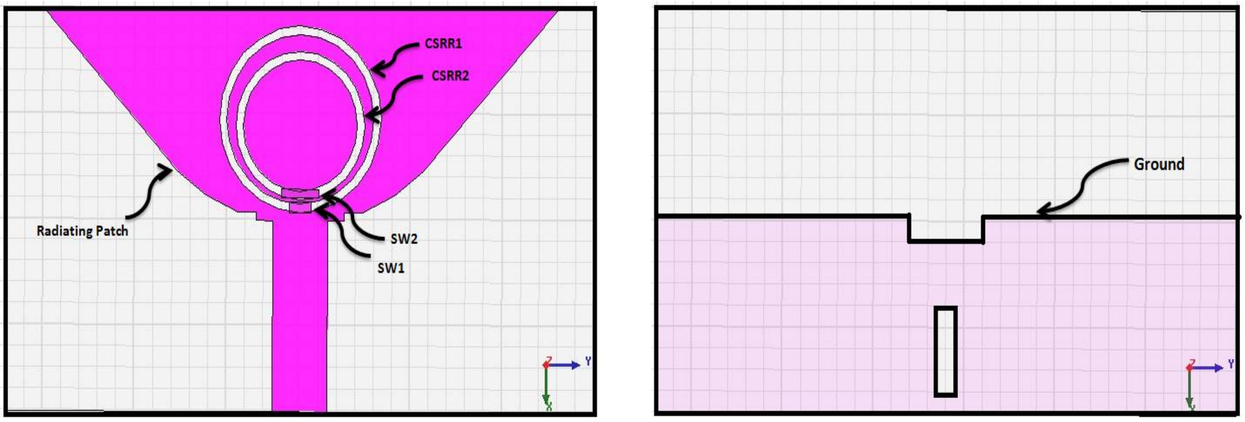


Figure: 1 – Top & Bottom view of proposed antenna

Proper impedance matching produces the best return loss at the wanted frequency. In the micro-strip feed line, the impedance of the micro-strip line is given by –

$$Zc = \frac{120\,\Pi}{\sqrt{\varepsilon reff}}\left\{\frac{1}{\frac{Wf}{h} + 1.393 + 0.667\ln\left(\frac{Wf}{h} + 1.444\right)}\right\} \qquad (1)$$

The optimal antenna parameters are tabulated in Table 1.

TABLE 1 Summary of Design Parameters of proposed UWB antenna

Parameter	Dimension(in mm)	Parameter	Dimension(in mm)
W_{sub}	32	Wg1	4
L_{sub}	19	Wg2	1
W_f	3	W_{SLOT}	0.3
L_f	9.016	W1	0.9
H	1	W2	1
Lg	9.3	Wp	28
Lg1	5	R1	4.3
Lg2	4	R2	3.1
Lg3	1.2		

The analysis of the proposed antenna structure is based on transmission line modal analysis. Figure 2 shows the geometry of proposed antenna structure used for simulation in next section. Larger CSRR is etched out to obtain a single band-notched antenna structure.

To get this first band-notch at 3.5 GHz within the Wi-MAX band (3.3–3.7 GHz), we choose R1= 3.6 mm and centre of the resonating structure at (-4.3, 0, 1). Another smaller CSRR element with R2= 4.5 mm and centred at (-4, 0, 1); is etched out to obtain second notch band at 5.5 GHz within the WLAN band (5.15–5.85 GHz).

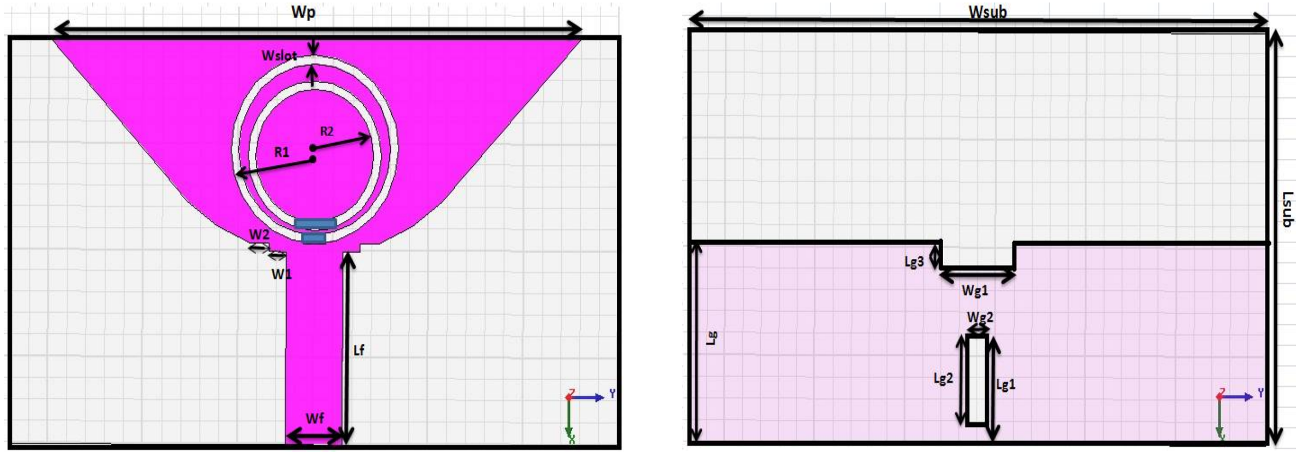


Figure: 2- Geometry of (a) Radiating patch & CSRR (b) Ground & Substrate

III. RESULTS AND DISCUSSIONS

The analysis of proposed antenna is done using the simulation performed on Ansys HFSS EM simulator for the frequency range of 1 to 28 GHz. During the simulation and measurement, the presence of a metal bridge represents ON state and the absence of a metal bridge represents OFF state.

The various switch configurations are tabulated in table no. 2.

Table 2: Switches and their respective frequency tuning

Switch Configuration			Function
Configuration	S1	S2	
Configuration I	OFF	OFF	Wide-band antenna
Configuration II	ON	OFF	Single band notch wideband antenna
Configuration III	ON	ON	Double band notch wideband antenna

- **VSWR Vs frequency results**

1. **Graph of VSWR Vs frequency (Switch Configuration I):**
   Figure 3 shows the simulated VSWR of proposed wide-band antenna structure in switch configuration I. From the plot of simulated VSWR Vs frequency of proposed antenna structure, it is seen that antenna covers wide bandwidth i.e. 2.9-26.05 GHz for VSWR < 2 dB for the switch configuration I.

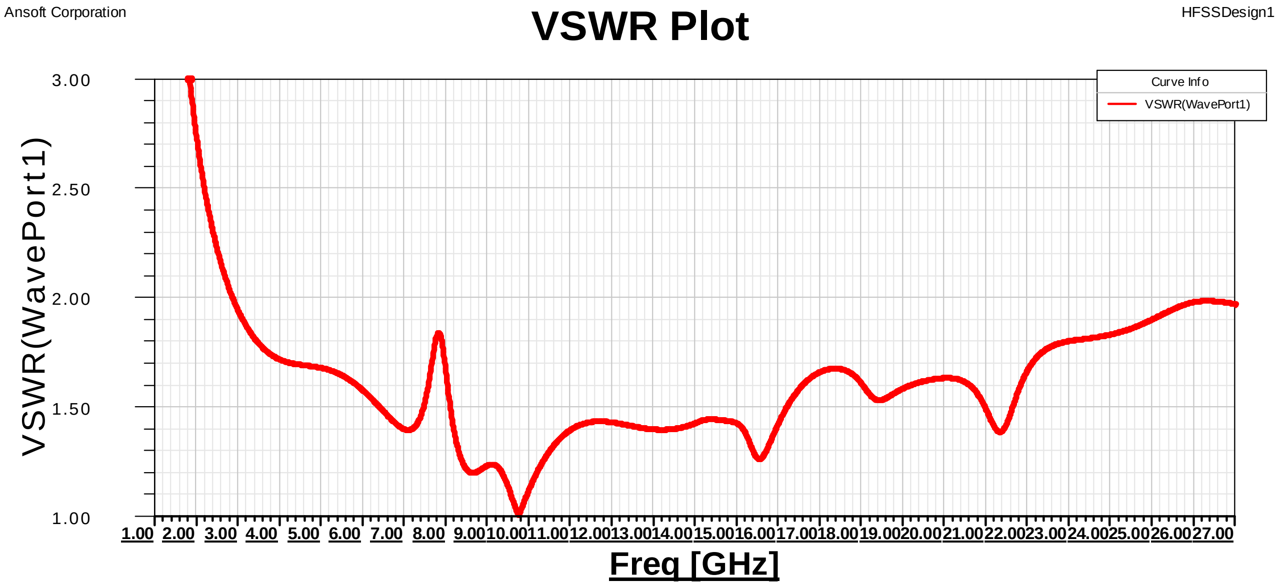


Figure: 3 graph of VSWR Vs frequency in switch configuration I.

2. **Graph of VSWR Vs Frequency (Switch Configuration II):**
   The VSWR Vs frequency curve for the proposed antenna with optimized parameters in switch configuration II is depicted below.

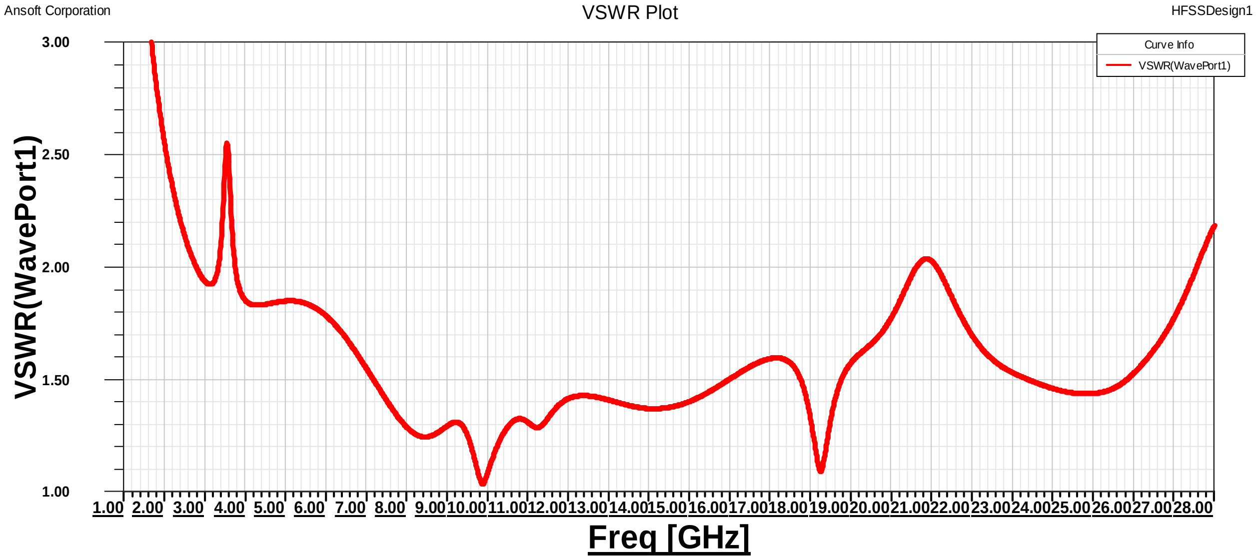


Figure: 4 graph of VSWR Vs frequency in switch configuration II.

It can be seen that the proposed antenna ;in switch configuration II (SW1-ON); is a single band notched UWB antenna, which has a bandwidth ranging from 2.7 GHz to 27.34 GHz with the VSWR less than 2 except a notch band 3.3 to 3.74 GHz.

3. Graph of VSWR Vs Frequency (Switch Configuration III)

The simulated VSWR of wide-band antenna structure in switch configuration III is depicted below-.

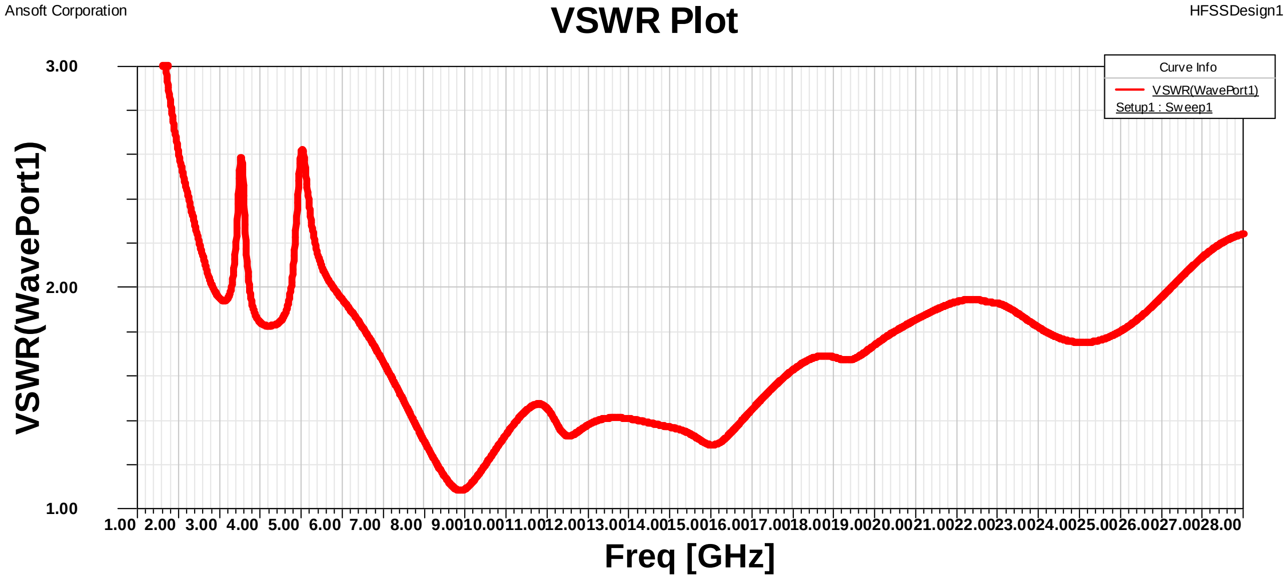
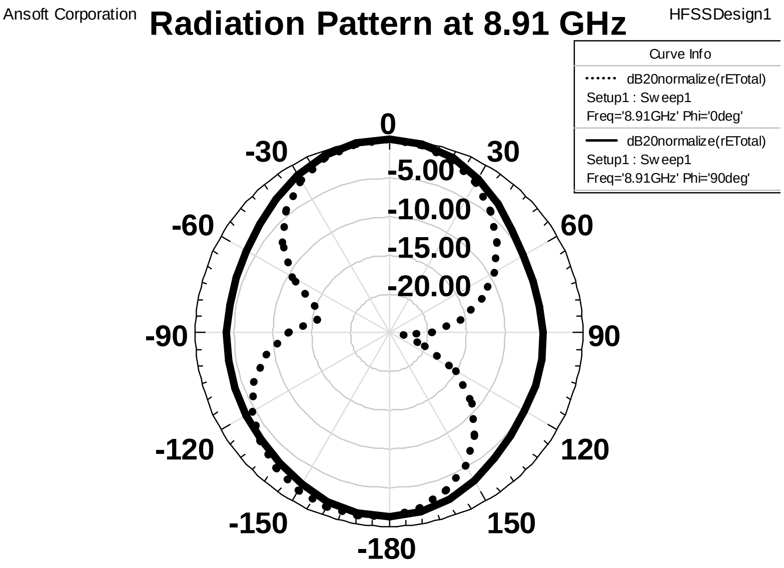


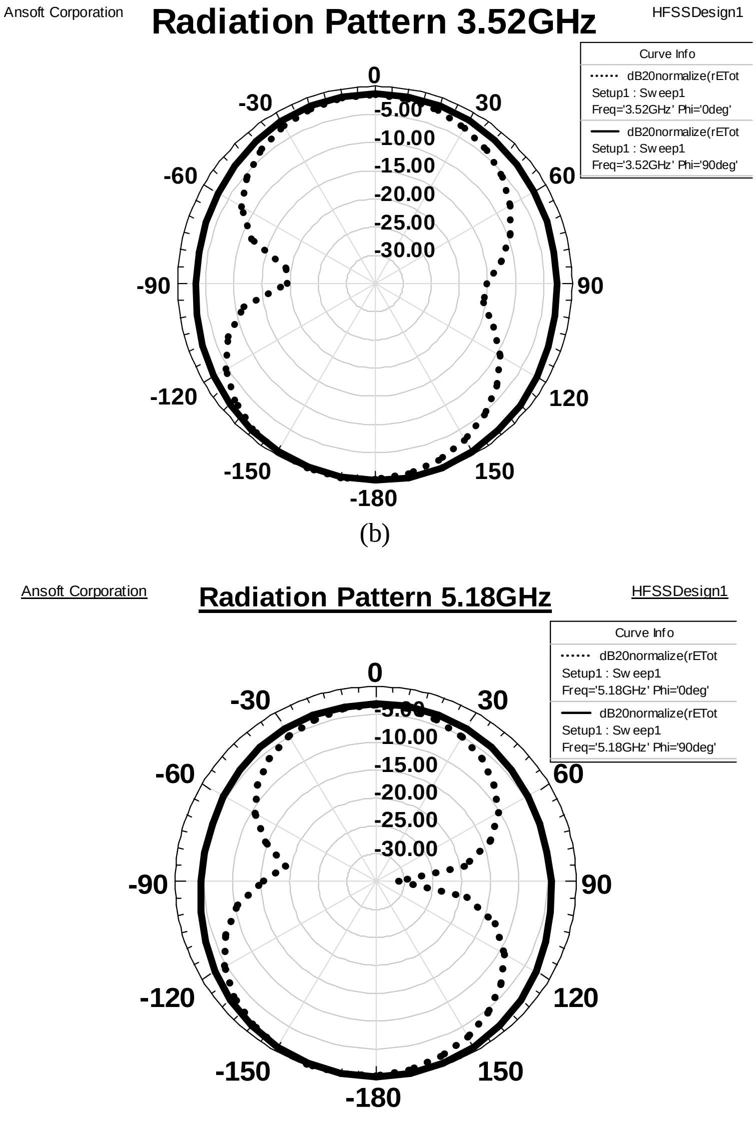
Figure: 5 graph of VSWR Vs frequency in switch configuration III.

It can be seen that when both switches are in ON state, antenna structure has two CSRR etched in the radiating patch, it can give two notch bands at 3.5 GHz and 5.2 GHz to filter out the potential interferences from Wi-MAX and WLAN communication systems.

- **Radiation pattern results:**
  Below show the 2D radiation pattern of the antenna at the designed frequency for Φ=0 and Φ=90 degrees. The measured radiation patterns in various switch configurations are plotted in Figure 6.



(a)



(b)

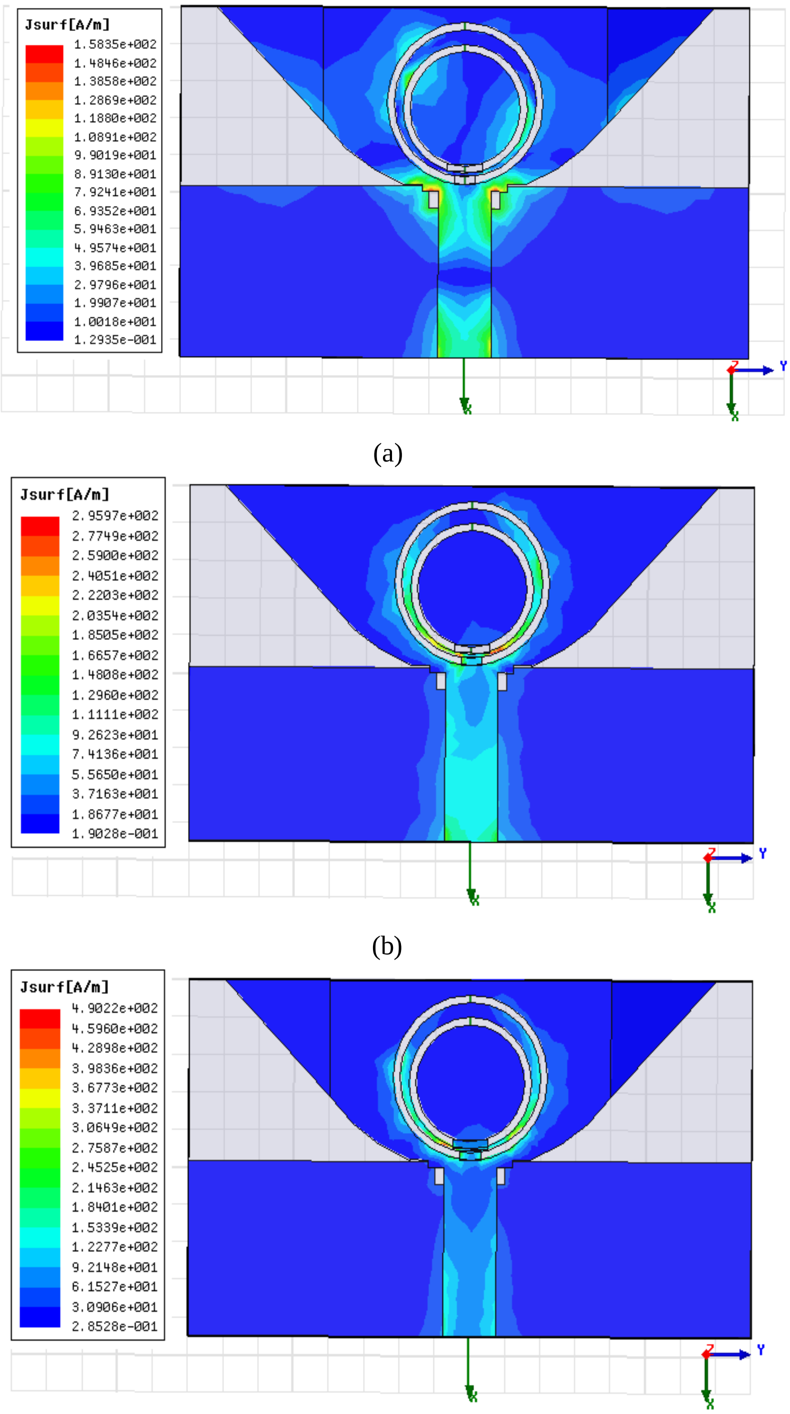
(c)

Figure.6: Simulated radiation pattern of the proposed antenna for Φ=0 and Φ= 90 degrees in (a) switch configuration I at 8.91 GHz[pass-band frequency] (b)switch configuration II at 3.52 GHz [notch frequency] (c) switch configuration III at 5.18 GHz [notch frequency]

It can be seen that the proposed antenna has a nearly Omni-directional radiation pattern in the H-plane and a dipole-like radiation pattern in the E-plane.

- **Surface Current distribution**

The simulated surface current distributions of the proposed antenna in three switch configurations are shown in Figure 7. Figure 7 (a) depicts the surface current distribution when both switches are in OFF state. As shown in Figure 7 (b), the current at 3.4 GHz is mainly distributed around outer CSRR. The current distribution at 5.5 GHz is mainly concentrated around the inner CSRR element as shown in Figure 7(c).



(a)

(b)

(c)

Figure 7: Simulated current distributions for proposed antenna structure in (a) switch configuration I at 8.18 GHz (b) switch configuration II at 3.4 GHz (c) switch configuration III at 5.5 GHz

It can be observe that the surface current is concentrated mainly on the notched that are responsible for band rejection at that frequency.

IV.CONCLUSION

A reconfigurable band-notched UWB antenna has been introduced. The antenna is designed to operate at frequency band from 3.1GHz to 12GHz. The antenna has double band-notch property, which has been achieved using split ring resonator inserted in the radiating patch. These resonators are used to decrease the interference with Wi-MAX and WLAN applications. The switching reconfiguration of the proposed antenna has been achieved using two ideal switches. The Proposed antenna has a VSWR < 2 except for the two notch bands. The antenna has been designed, fabricated, and tested. A good agreement has been achieved between the simulated and the measured results.

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