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An Equivalent Circuit of UWB Patch Antenna with Band Notched Characteristics

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ABSTRACT

In this paper, aband notched ultra-wideband (UWB) patch antenna is presented with its circuit modeling. The rectangular patch antenna isdesigned ondielectric substrate and fed with 50 Ω microstrip by optimizing the widthof partial ground, the width of the feed line to operate in UWB. Thisantenna consists of a radiating element with a strip, and a partial ground plane and feeding line has been demonstrated. With the design, the return loss is lower than 10 dB in 3.1-10.6 GHz frequency range and show the band-notch characteristic in the UWB band to avoid interferences, which is caused by WLAN (5.15–5.825 GHz) and WiMax (5.25–5.85 GHz) systems. In addition, band-notched filtering properties in the 5.15- 5.85 GHz are achieved by cutting a circular slot on the radiating patch. The antenna design is simulated on electromagnetic (EM) simulation software using FR-4 substrate with dielectric constant of 4.4 and thickness of 1.6 mm.The proposed antenna has a compact structure and the total size is 15×14.5 mm^2.Simplified lumped element circuit model of band notched UWB patch antenna had been derived. The circuit model had been simulated in serenade simulator and the S- parameters is compared with the obtained scattering parameter from simulating in EM simulator.

Keywords: *Band notched,partial ground plane,patch antenna,and UWBantenna*

1. INTRODUCTION

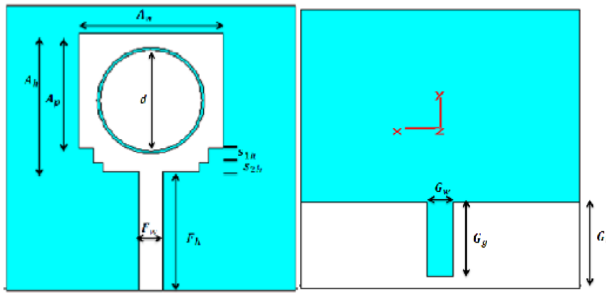
With the development of modern wireless and mobile communication, ultra-wideband (UWB) systems have recently attracted attention owing to several advantages, including high-speed data rate, small size, and low power consumption[1]. According to the Federal Communications Commission (FCC) document, the frequency band of the UWB (category of communications and measurement systems) should be between3.1 and 10.6 GHz in 2002 for the use of indoor and hand-held systems[2]. UWB antennas have enormous attention in both academia and industry for applications in wireless transmission systems [3]. Impulse-Ultra wideband (I-UWB) is a carrier less short range communications technology in which its transmission occupies a bandwidth of more than 20% of its center frequency (>500 MHz) [4].Wireless communication systems have developed rapidly in recent years, an antenna as a front component is required to have a wide band, good radiation performances and sometimes switchable ability [5-6]. To obtain the switchable ability of the antenna, the concept of a reconfigurable antenna was proposed a few years ago [7-10]. To undertake the effect caused by the frequency interference from WLAN (5.15–5.825 GHz) and WiMax (5.25–5.85 GHz) systems, some UWB antennas with band-notched feature have been designed[11-13]like w-shaped slots on the radiating patch [14]. Equivalent circuit of the patch antenna had been also derived by using lumped elements [15-16].

In this paper, an UWB patch antenna is presented. The planar UWB patch antenna is designed with circular slot of desired operating frequency range with band-notch characteristic. The antenna consists of a rectangular patch, a circular slot, a partial ground plane and feeding line. This antenna is easy to integrate with microwave circuitry for low manufacturing cost. Optimum dimension of the antenna is obtained by simulating the design. In the Section II of this paper describes the antenna design. The computer simulation and circuit modeling of UWB antenna results are presented in sectionIII. Finally, the paper is concluded in Section IV.

2. ANTENNA DESCRIPTION

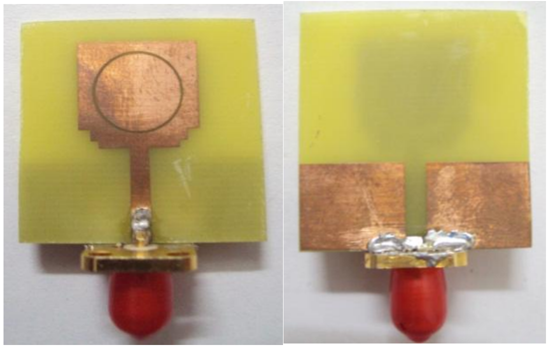
The proposed design of UWB antenna is simple and compact. This planar UWB antenna has the capability to notch frequencies within the 5.15–5.85 GHz band. Fig. 1 illustrated the configuration of the proposed antenna, which consists of a rectangular patch with two steps, a circular slot, a partial ground plane, and a feed-line. The antenna structure was designed on FR-4 substrate having dielectric constant of 4.4 and thickness of 1.6 mm. The design was simulated using EM Simulation software. The substrate dimension is 30×30mm^2. The design antenna has the following optimized parameters: A_w= 15mm, A_p= 12mm, A_h =14.5mm, S_{1h}=1.5mm, S_{2h}=

1mm,d=1mm,G_h=10.8mm, G_g=9.4mm, G_w=2.8mm, F_w=2.4mm, F_h=12.5mm that is shown in Fig. 1. The antenna is fed using a 50Ω microstrip line whose width is calculated using the well-known microstrip line design equations. The circular slot placed at the center of the patch can be devoted to generating desirable resonance for the stop band operation. The rectangular radiating patch antenna with steps, a partial ground plane, feed line and circular slot parameters was optimized to get desired response. Therefore, the geometric parameters of the proposed structure can be adjusted to tune the return loss and bandwidth over wide range of frequency. Fig.2. shows the fabricated structure of the antenna.



(a) (b)

Fig.1. Antenna configuration (a) front (b) back view



(a) (b)

Fig.2. Fabricated structure of the antenna (a) front (b) back view

3. RESULTS AND DISCUSSION

The proposed antenna is optimized by using electromagnetic (EM) simulator software. A planar antenna was designed and the return loss was measured. Fig. 3 shows the simulated results for return loss of this antenna with and without circular slot. The overall goal of the proposed antenna design is to achieve good performance in the return loss below -10dB. Suitable antenna geometry is needed for this reason. The proposed UWB antenna shows the simulated operating frequency band 2.99-12GHz. The circular slot rejects the frequency band of about 5.07–5.89GHz, so the effects due to the frequency interference can be avoided well. The measured impedance bandwidth with 10 dB return loss for the proposed antenna is from 4.05-16.92 GHz, rejecting the frequency band of about 4.99-6.28 GHz.Fig.4 shows simulated and measured return loss of the antenna with notched band behavior.

Fig. 5shows the simulated result of VSWR against frequency (GHz). The VSWR of the antenna is closely related to the return loss. VSWR values from 1 to 2 throughout the frequency region except from 5.07GHz to 5.89GHz. Since UWB characteristic requires the VSWR to range from 1 to 2, the frequency region from 5.07GHz to 5.89GHz for the measured result does not agree with the UWB characteristic. Based on the simulated results, the proposed antenna exhibits good UWB characteristics and operates from 2.99-12GHz. It complies with the VSWR range from 1 to 2 throughout the impedance bandwidth.

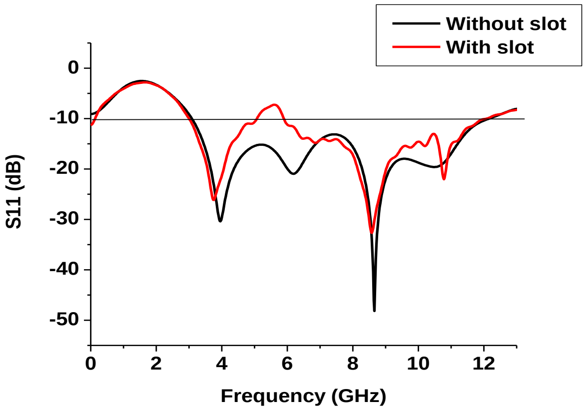


Fig.3. Simulatedreturn loss of the antenna with notched band behavior

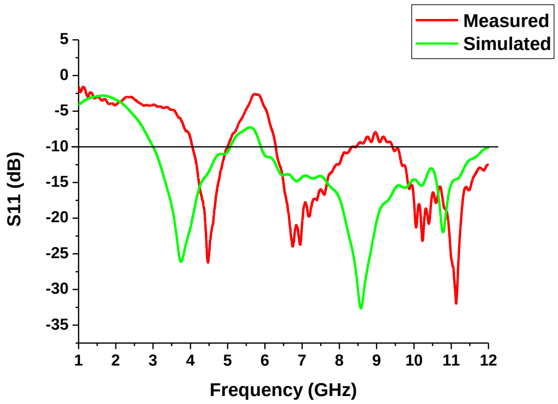


Fig.4. Simulated and measured return loss of the antenna with notched band behavior

Fig. 6 shows the total gain of the proposed antenna. This figure shows that the proposed antenna’s gain variates between 1 dBi and 7 dBi within the operating frequency band of the antenna. At the pass band, the antenna gain stably varies from 1 dBi and 7 dBi. Better antenna performance for practical applications can be attained as a low-loss substrate is used for fabricating the antenna.

Lower performance for gain has been expected and received over the stopband. Therefore, the gain is successfully suppressed at 5.48 GHz.

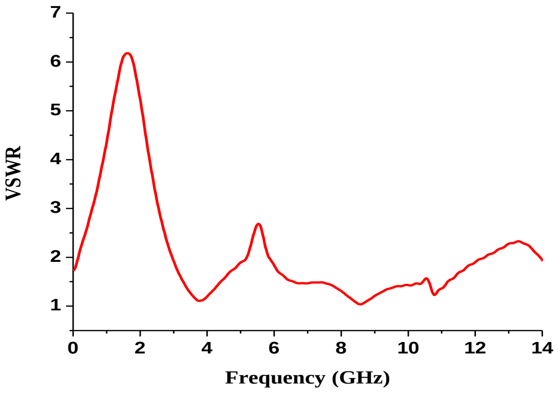


Fig.5. Simulated VSWR of the antenna with band notched behavior

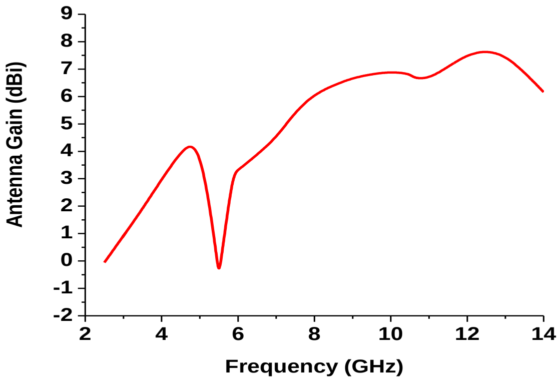


Fig.6. Simulated antenna gain of the proposed antenna

Simplified lumped element circuit model of the UWB patch antenna had been derived. This model was obtained by studying the scattering parameter (S11) of the antenna structure by simulating the antenna in EM simulator. By obtaining this S-parameter the overall structure of the circuit model had been transformed to imply the characteristics of the antenna.

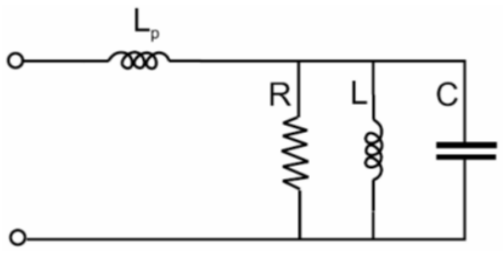


Fig.7. Equivalent circuit of patch antenna

The equivalent circuit of patch antenna is shown in fig. 7 where patch cavity is modelled as a parallel RLC circuit, while the probe inductance is modelled as a series inductor. Fig. 8shows the structure of step discontinuity.

The equivalent circuit of step discontinuity is modelled as in fig. 9.

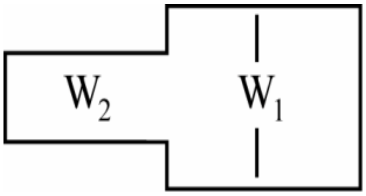


Fig.8. Structure of step discontinuity

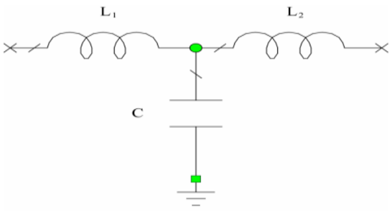


Fig.9. Equivalent circuit of step discontinuity

When a notch is incorporated into the patch, the resonance features change. An equivalent circuit for a switch branch is modelled as a parallel LC circuit.

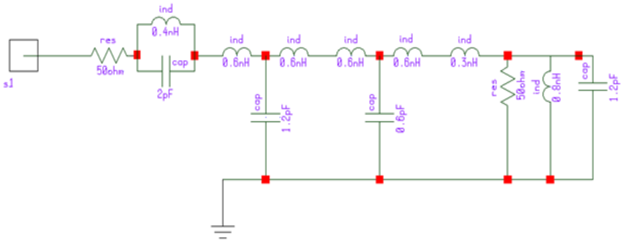


Fig.10. Equivalent circuit of proposed antenna

Fig. 10shows the equivalent circuit of UWB patch antenna with circular slot. The proposed antenna is designed by using equivalent circuit of step discontinuity, rectangular patch antenna and circular slot for notch. In the proposed antenna two steps are used. In this model the patch cavity is modelled as a parallel RLC circuit, while the probe inductance is modelled as a series inductor. A parallel LC circuit shows the notch characteristic. When a notch is incorporated into the patch, the resonance features change. An equivalent circuit for a switch branch is modelled as a parallel LC circuit.The circuit model had been simulated in Serenade simulator and the S-parameter is compared with the obtained scattering parameter from simulating the EM structure in EM simulator. Fig. 11 shows simulated return loss of the UWB patch antenna with circular slot. For theoretical analysis code this circuit on MATLAB. Fig.12 shows the simulated return loss of the UWB patch antenna with circular slot on MATLAB.

The reflection coefficient and return loss can be computed.

Reflection Coefficient

$$\Gamma = \frac{Z_0 - Z_{in}}{Z_0 + Z_{in}} \qquad (1)$$

Return Loss

$$20 \log |\Gamma| \qquad (2)$$

For the calculation of input impedance we have to solve the complete circuit in simplified way. The calculation is-

$$P_1 = j\omega(L_2 + L_3) + \frac{(R_1).(1/j\omega C_1).(j\omega L_1)}{(R_1)(1/j\omega C_1)+(1/j\omega C_1)(j\omega L_1)+(R_1)(j\omega L_1)} \qquad (3)$$

$$P_2 = j\omega(L_3 + L_3) + \frac{(1/j\omega C_2).(1/P_1)}{(1/j\omega C_2)+(1/P_1)} \qquad (4)$$

$$Z_{in} = R_1 + \frac{(1/j\omega C_4).j\omega L_4}{(1/j\omega C_4)+j\omega L_4} + j\omega L_3 + \frac{(1/j\omega C_3).(1/P_2)}{(1/j\omega C_3)+(1/P_2)} \qquad (5)$$

For theoretical analysis we can calculate input impedance by putting the value of L_1, L_2, L_3,L_4, C_1, C_2, C_3 ,$C_4$and R_1 in above equations. In the equivalent circuit of band notched UWBpatch antenna L_1=0.8nH, L_2=0.3nH, L_3=0.6nH, L_4=0.4nH, C_1=1.2pF, C_2=0.6pF, C_3=1.2pF, C_4=2pF and R_1=50ohm.

From equation (1) and (2), we can calculate reflection coefficient by putting value of Z_{in} and Z_o=50 ohm.

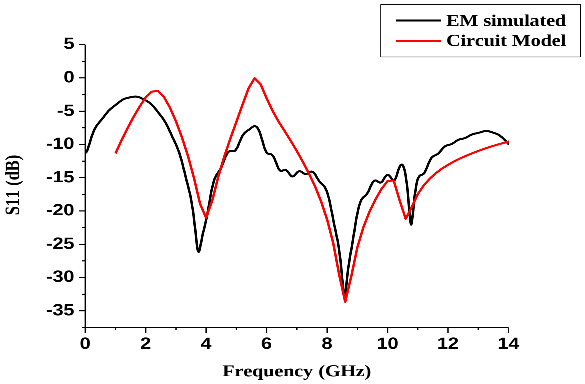


Fig.11.Simulated return loss of the proposed antenna

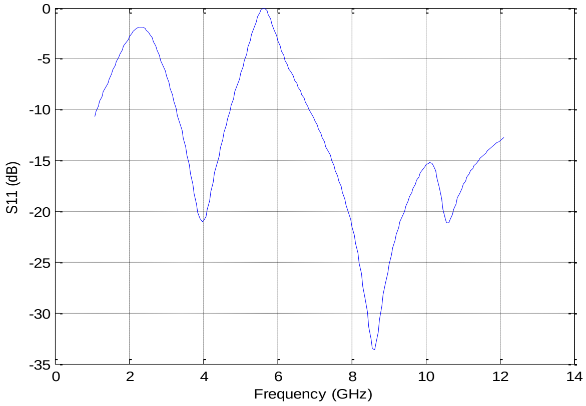


Fig.12. Simulated return loss of the proposed antenna on MATLAB

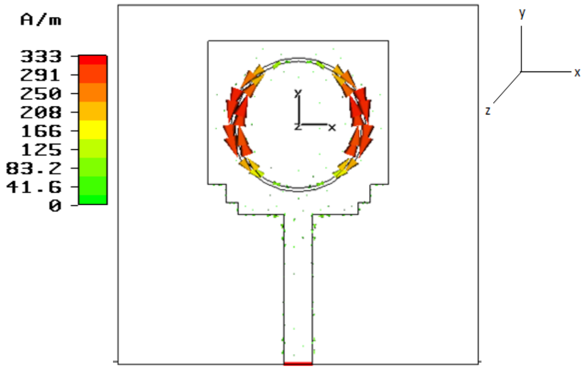


Fig.13. Simulated surface current distribution at the center-rejected frequency of 5.48 GHz for the proposed antenna

The surface current distribution of the antenna at the center-rejected frequency 5.48 GHz has been simulated in fig. 13. We can see a stronger resonance surrounding the circular slot has occurred apparently.Fig.14 shows the simulated delivered power v/s frequency graph. At the notched frequency band the delivered power is below 0.8 watt.

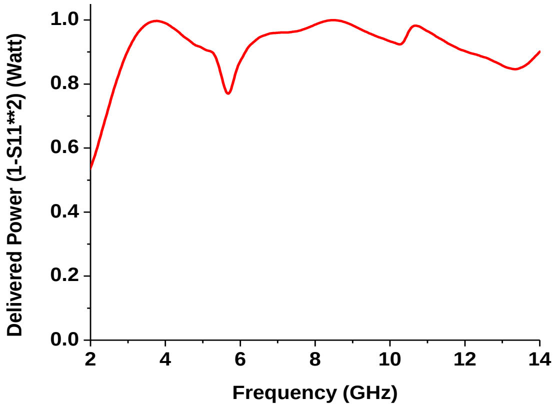
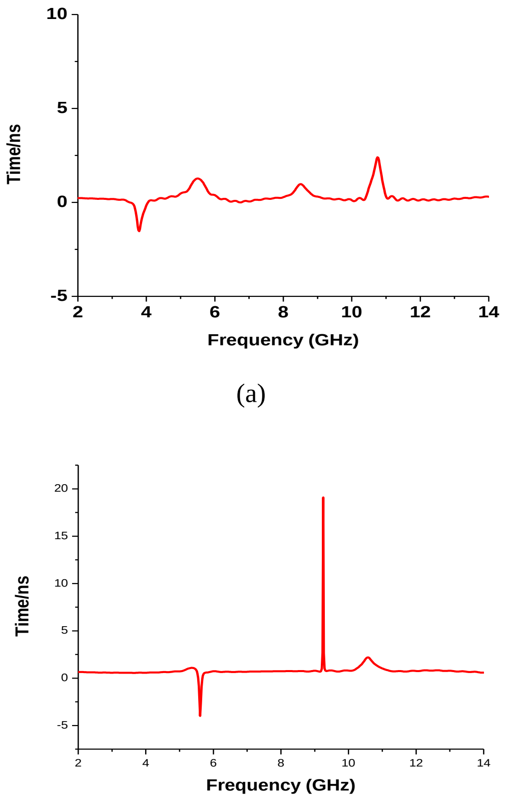


Fig.14. Simulated delivered power v/s frequency graph



(a)

(b)

Fig.15. Simulated group delay of the antenna (a) S_{11} (b) S_{21}

This design provides UWB antenna with a group delay ripple of less than 0.5 ns in complete frequency band except notched range. This is an important parameter that represents the degree of distortion of pulse signal. Only at the notched frequency and abrupt change in the antenna geometry, the group delay ripple above the 0.5 ns as shown in the group delay plot. Fig. 15 shows simulated group delay of the antenna.

4. CONCLUSIONS

In this paper, circuit modeling of band notched rectangular patch antennas with partial ground for UWB communication systems has been modeled. Anultra-wideband patch antenna is presented with 2.99-12GHzfrequency range, and rejecting the frequency band of about 5.07–5.89GHz. The simulated results of the proposed antenna satisfy the 10-dB return loss requirement for UWB as defined by the FCC.The proposed UWB antenna structure can be used in future UWB systems. It can tackle the frequency interference from WLAN and WIMAX.The antenna structure is flat, and its design is simple and straightforward geometrically small, hence embedded easily in wireless communication systems.
With the help of this tunable stopband, frequency interference issues may be better addressed as well. Furthermore, properties such as good omnidirectional coverage, stable transmission characteristics indicate that the proposed compact antenna is well suitable for integration into UWB portable devices.

REFERENCES

[1] G. Brzezina, Q. Ye, L. Roy, "Development of a practical ultra- wideband antenna with planar circuit integration possibilities" *in IEEE Antenna and Propogation Soc. Int. Symp. 2005,* 3-8 July 2005, pp. 504- 507.

[2] Ching-Fang Tseng," Planar UWB dipole antenna with band-notched characteristic"*in IEEE 2009,pp. 1825-1828*

[3] M. K. A. Rahim, M. N. A. Karim, T. Masri, A. Asrokin, "Comparison between Straight and U shape of ultra-wideband microstrip antenna using log periodic technique" in *IEEE International Conference on Ultra-Wideband 2007,* 24-26 September 2007, pp. 696 - 699.

[4] Mohammad HadiBadjian, Chandan Kumar Chakrabarty, Goh Chin Hock, and Sanjay Devkumar , "An impulse UWB patch antenna with integrated bandpass filter" *Proceedings of IEEE 2008 6th National Conference on Telecommunication Technologies and IEEE 2008 2nd Malaysia Conference on Photonics,* 26-27 August 2008, Putrajaya, Malaysia, pp166 – 169.

[5] Denidni, T.A., L., Lim, Y., and Rao, Q., 'Wide band high efficiency printed loop antenna design for wireless communication systems', *IEEE Trans. Veh. Technol., 2005, 54, (3), pp. 873-878.*

[6] Wong, T.P., and Luk, K.M.,'A wide bandwidth and wide beamwidth CDMA/GSM base station antenna array with low backlobe radiation',*IEEE Trans. Veh. Technol., 2005, 54, (3), pp. 903-909.*

[7] Xiao, S.Q., Shao, Z.H., Fujise, M., and Wang, B.-Z., 'Pattern reconfigurable leaky-wave antenna design by FDTD method and Floquet's theorem', *IEEE Trans. Antenna Propagation., 2005, 53, (5), pp. 1845-1848.*

[8] Yang, F., and Rahmat-amii, Y., "Patch antennas with switchable slots (PASS) in wireless communications: concepts, designs and applications", *IEEE Antenna Propag. Mag., 2005, 47, (2) pp.645-654.,*

[9] Peroulis, D., Sarabi, K., and Katehi, L.P.B., 'Design of reconfigurable slot antenna'. *IEEE Trans, Antennas Propag., 2005, 53, (2), pp. 645-654.*

[10] Freeman, J.L., Lamberty, B.J., and rews, G.s., 'Optoelectronically reconfigurable monopole antenna', *Electron Lerr. 1992, 28, (16), pp. 1502-1503*

[11] Hsien-Wen Liu, Chia-Hao Ku, Te-Shun Wang, and Chang-Fa Yang, "Compact monopole antenna with band-notched characteristic for UWB applications", *IEEE Antenna and Wireless Propagation Letters,* Vol. 9, 2010.

[12] Nader Behdad, Kamal Sarabandi, "Dual-band reconfigurable antenna with a very wide tunability range", *IEEE Antenna and Wireless Propagation Letters,*Vol. 54, No. 2, 2006.

[13] The-Nan Chang and Min-Chi Wu, "Band-Notched Design for UWB Antennas", *IEEE Antenna and Wireless Propagation Letters,* Vol. 7, 2008.

[14] NuurulHudaa M. Sobli and Hany E. Abd-El-Raouf, "Design of a compact band-notched antenna for ultra-wideband communication", 2008 *IEEE.*

[15] Mohammad HadiBadjian, Chandan Kumar Chakrabarty, "Circuit modeling of an UWB patch antenna", *IEEE International RF and Microwave conference Proceeding*, 2008, Kuala Lumpur, Malasiya.

[16] Y. Wang, J. Z. Li, L. X. Ran, "An equivalent circuit modeling method for ultra-wideband antenna", *Progress In Electromagnetics Research, PIER 82,* 433–445, 2008.

[17] Shilpa Jangid and Mithilesh Kumar, "Design of band notched UWB patch antenna with circular slot", in *National Conference RACCCT 2012,* Surat, pp. 64-67.