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Optimal Design of 6.1 GHz UWB Antenna for off Body Communication

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Abstract: In this study report that the design of 6.1 GHz Ultra Wide Band (UWB) antenna for off body communication is fabricated and measured. The overall dimension of proposed antenna is 7×4×1 mm and mould by FR4 epoxy substrate material with dielectric loss tangent of 0.02. In this optimal design, the wide feeding slot has been introduced in this research to discover the wide bandwidth and carry out the VSWR<2. The parametric study has been analyzed with different dimensions of feeding slot to attain the bandwidth of >20% of its centre frequency. This proposed UWB antenna has been simulated and measured by High Frequency Structure Simulator (HFSS) which shows that the return loss of -31.47 dB and its expose omni directional pattern. This low profile and compact design antenna is finest system for off body communication and also adoptable for LTE network communication.

Key words: LTE, off body communication, optimal design, UWB antenna, wide feeding slot

INTRODUCTION

In the need of body centric communication using tiny node playing important role in Wireless Body Area Network (WBAN) for habitual activities of human behaviour in recent days. The compact size and high data rate transmission antenna with UWB characteristics is very essential for off body communication and patch antenna performing spectacular function of body centric communication. The wearable antenna performing recent research for portable devices in human body because of low profile nature, compact size, low electrical absorption rate and high efficiency between on/off body is discussed (Haga *et al*., 2009; Kim *et al*., 2013). The body area network is recommended for use UWB frequency because of high data rate wide bandwidth, lower power and short rage communication (See and Chen, 2009). In last decades the growing of UWB technology in the body wearable antennas is adopted in both academia and industry applications and operated at lower and upper range frequencies from to 3.1-4.8 and 6-8.5 GHz is reported in (Hall *et al*., 2007; Nechayev *et al*., 2010; Sanz *et al*., 2006; Alomainy *et al*., 2007; Conway and Scanlon 2009). The 2.45 GHz narrow band antenna for on-body communication characteristics is discussed (Hall *et al*., 2007; Nechayev *et al*., 2010). A button antenna for WLAN applications operated at 2.45, 5.2 GHz and result shows that radiation characteristics is same at both the frequencies with narrowband (Sanz *et al*. 2006). The quasi omni directional pattern with impedance matching for footwear application antenna is presented in (John and Ammann 2009; Liang *et al*., 2005) and its operated at 6-8.5 GHz frequencies with overall width of 15.7 mm (Chen and Ku 2008) explore UWB antenna between 6 and 8.5 GHz and report that impedance bandwidth is considered at 2.2-6.1 GHz frequency range. Klemm *et al*. (2005) exhibiting UWB wearable antenna and comparing directive and omni directional pattern and shows that the impact of reducing backward radiation and power absorption rate. Alomainy *et al*. (2005) analysis the effect of frequency and time domain functions of human presence on UWB antenna with various parameters of body absorption rate and RF energy calculation. Moradi *et al*. (2012) investigated the embroidered antenna for wearable application and analysis with result of human body RF energy level, power ratio and antenna efficiency. The 40×40 and 60×60 mm size wearable antenna is proposed with jeans and flannel fabrics material for wireless body area network applications which is reported by Osman *et al*. (2011). The wearable antenna performing at multiband frequencies, i.e., L, S, C band for wireless application is discussed by Gupta *et al*. (2010),

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Thalmann *et al*. (2009), Salonen *et al*. (2004) and Kellomaki *et al*. (2006). The overall review and studies of wearable and body mounted antenna design and application is shown by Gupta *et al*. (2010) and 800-2700 MHz wearable antenna with close proximity of a human body is presented by Thalmann *et al*. (2009). Salonen *et al*. (2004) the vicinity of the human body textile antenna operated at 2.4 GHz performance analysis is presented and the portable radio antenna operated at 100 MHz for human body wearable application is studied. Wearable antenna for FM reception the antenna length in free-space should be 15-25% and dipole size is 116×10 cm is reported by Kellomaki *et al*. (2006). The proposed research work satisfy the off body antenna behaviour with UWB characteristics and highly recommend for off communication at the optimal frequency of 6.1 GHz.

Scope of the work: With reference of above literature the essential of off body antenna in modern day's communication, antenna design parameters and application results has been studied and analyzed. For the need of compact design and optimal frequency of 6.1 GHz author motivated to design the UWB antenna for off body communication link applications. This compact size and portable antenna highly adopt of off body system and also used in mobile network applications. This proposed design configuration and results have been exhibited in the following points:

- The optimal radiation dimensions proposed UWB antenna is 5×1.529 mm with overall dimensions of 7×4 mm which is highly compact nature and easily adoptable for off body communication system
- The optimal resonant frequency of 6.1GHz has been achieved with return loss of -31.47 db and VSWR of 0.46
- The overall radiation efficiency is 90.67% and it satisfies the UWB characteristics

MATERIALS AND METHODS

Antenna design: The geometry and overall structure of proposed antenna is shown in Fig. 1. It consists of pair of circle shaped with open slot attached with rectangular slot on the ground plane. For designing an antenna and modelling the parameters of substrate material, permittivity and dimensions of patch to be characterize. Based on the requirements of proposed UWB antenna for off body communication link the antenna constructed by FR4 epoxy substrate material with thickness of 1 mm, dielectric loss tangent of 0.02, the overall dimension is 7×4 mm size and radiation size is 5×1.529 mm. To achieve the optimal frequency of 6.1 GHz the feeding slot is to be assigned with position of the axis. In this proposed antenna wide slot rectangular path placed in linear model method with position of Y-Z axis with characteristics impedance of 50 oham. Instead of using a narrow feeding slot, the wide feeding slot has been used for achieving the required band structure which is shown in Fig.1 with overall structure. In the patch design the central width of the patch and feed line dimensions are an important parameter to exhibit the performance and determine the required resonant frequency.

The required optimal dimension of proposed UWB antenna is L_{sub} = 7 mm, W_{sub} = 4 mm, L_{patch} = 5 mm, W_{patch} = 1.529 mm, L_1 = 1.5 mm, L_2 = 1.2 mm, W_1 = 1 mm, R_1 = 1 mm, W_{slot} = 2 mm, L_{slot} = 1 mm. The length, width and impedance calculation is necessary to estimate the resonant frequency and the derived calculation is shown below. The feeding slot W_{slot} and L_{slot} can be evaluated from Eq. 1 at 50 ohms impedance 10 = Zo:

$$I_0 = \frac{2\times 60\pi}{\sqrt{\varepsilon r}\left[\frac{h1}{W_d}+1.3+0.6\ln\left(\frac{h1}{W_d}+1.4\right)\right]} \quad (1)$$

where, Io= Zo (Impedance) the patch length (L_g), Width (wd) and permittivity (ε_r) of proposed design is calculated from Eq. 2-5:

$$W_d = \frac{c_v}{2f_{res}}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (2)$$

$$L_g = \frac{c_v}{2f_{res}\sqrt{\varepsilon_{eff}+1}} - 2\Delta L_n \quad (3)$$

Where:

$$\Delta L_n = 0.4h_l\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.2}\left[\frac{\frac{W_d}{h_l}+0.2}{\frac{W_d}{h_l}+0.8}\right] \quad (4)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h_l}{W_d}\right]^{-\frac{1}{2}} \quad (5)$$

with reference of above equation to calculate the proposed antenna design and feeding slot dimensions to attain the required bandwidth.

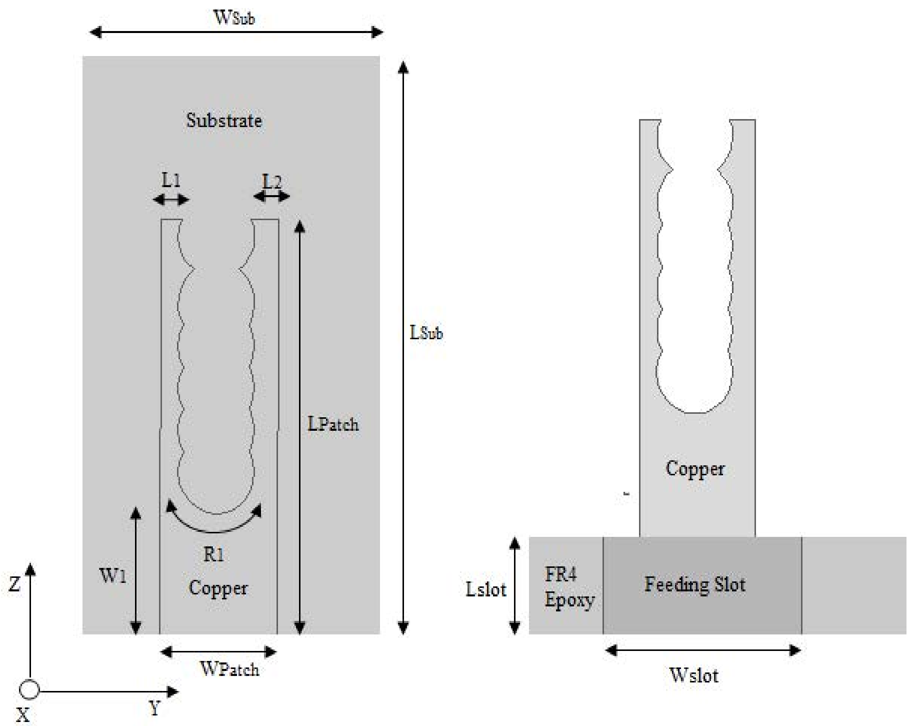


Fig. 1: The geometry of proposed UWB antenna with overall structure

RESULTS AND DISCUSSION

In this study, parametric study of the proposed UWB antenna was carried out with different dimensions of feeding slot to achieve the required resonant frequency also analysis of antenna characteristics for enhanced outcome results. First discuss about the parametric study of feeding slot dimensions and influence of each parameter has been analyzed in this section. To obtain the optimal frequency of 6.1 GHz, the feeding slot size i.e., Wslot size 2mm is to be changed and other parameters are kept constant. When adjust the size of Wslot from 2 mm to 1.8 and 1.529 mm the return loss slowly degrade from -32 to 20 and -14 dB also the difference between lower band and higher band frequencies is vary which is shown in Fig. 2. It is clearly observed that Wslot size 2mm is achieved required frequency with UWB characteristics. If taking Voltage Standing Wave Ratio (VSWR), the proposed antenna reflection coefficient is better than other different dimensions feeding slot and having good impedance matching between feeding slot and radiating patch which is shown in Fig. 3. The photograph of the prototyped antenna is shown in Fig. 4. It is observed that the proposed antenna size is compact nature with portable compatibility.

It is necessary to compare the measured and simulated result for investigation of antenna system. The simulated and measurement return loss curve of proposed UWB antenna is shown in Fig. 5. it shows that at -10 dB return loss the bandwidth has been calculated and both simulated and measurement result satisfy the UWB characteristics, i.e., >500 MHz and resonant frequency of simulation is 6.1GHz and measurement resonant frequency is 6.0 GHz which is measured at air. In the resultant return loss value of simulation and measurement is -31.47 to 20.16 dB and VSWR<2.

The radiation characteristic of antenna design defines about polarization and strength of the signal. The far field of simulated and measured radiation patterns of E-plane and H-plane at the resonant frequency of 6.1 GHz which is shown in Fig. 6. It was observed that the radiation occur entire bandwidth and omni directional pattern which is recommended of UWB antenna for medical applications. When the simulated results are compared with measured values of both E-plane and H-plane appeared equivalent pattern and it proves that the radiation occurs at omni directional radiation pattern. Figure 7 shows that the current distribution of proposed antenna and its observed that current distributed all the direction equally and most the current flows from bottom to top layer. Figure 8 shows that simulated radiation efficiency proposed UWB antenna. It was observed the radiation curve appeared above 90%, overall radiation efficiency of proposed antenna is 90.67% and it was

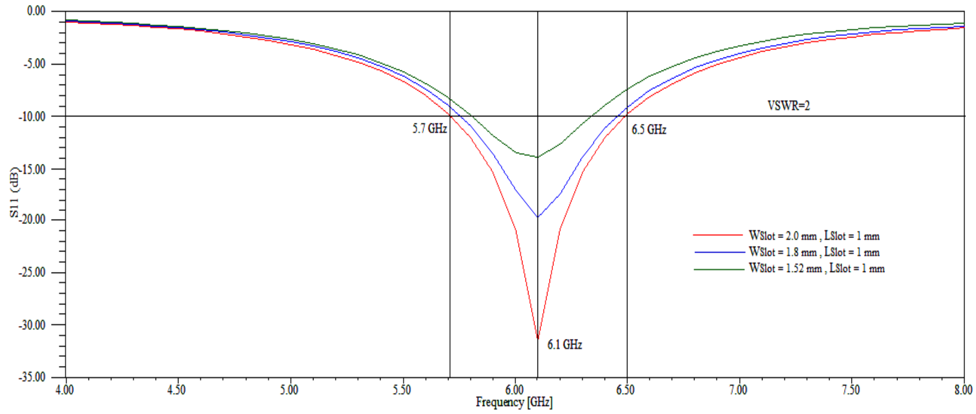


Fig. 2: Simulated return loss S11 curves with different dimensions feed slot

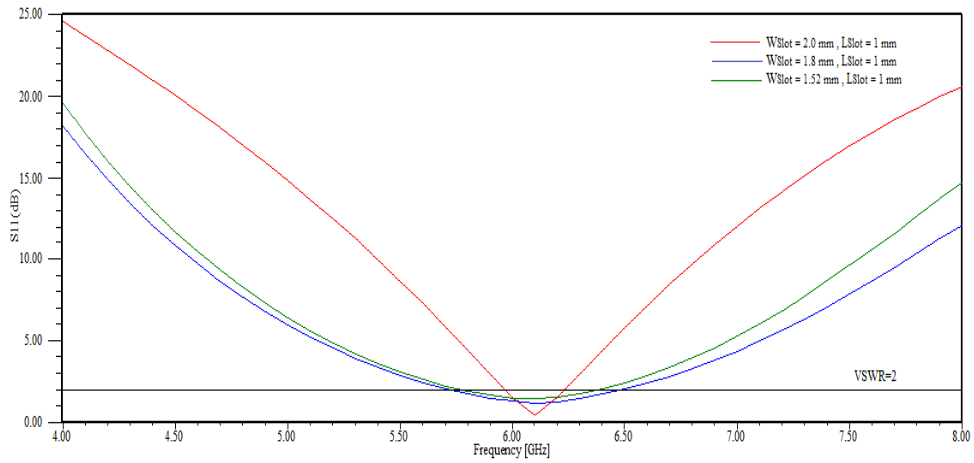


Fig. 3: Simulated VSWR S11 curves with different dimensions feed slot

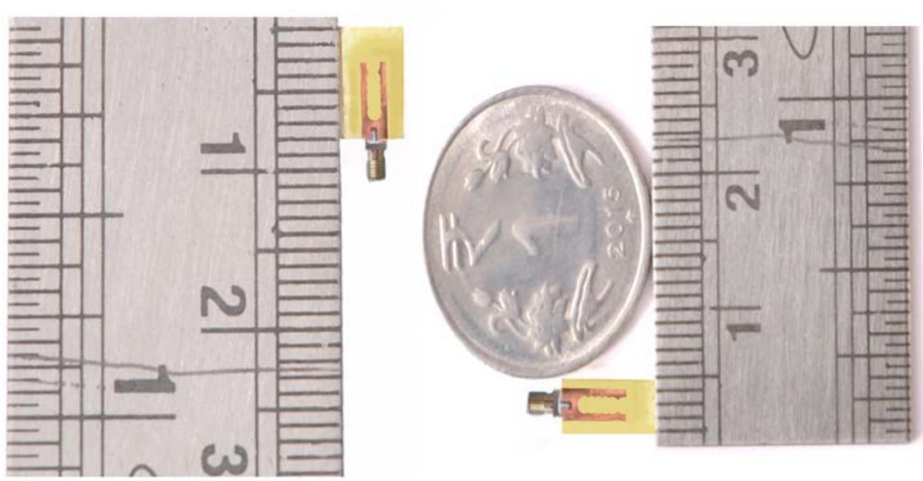


Fig. 4: Prototype model of proposed UWB antenna

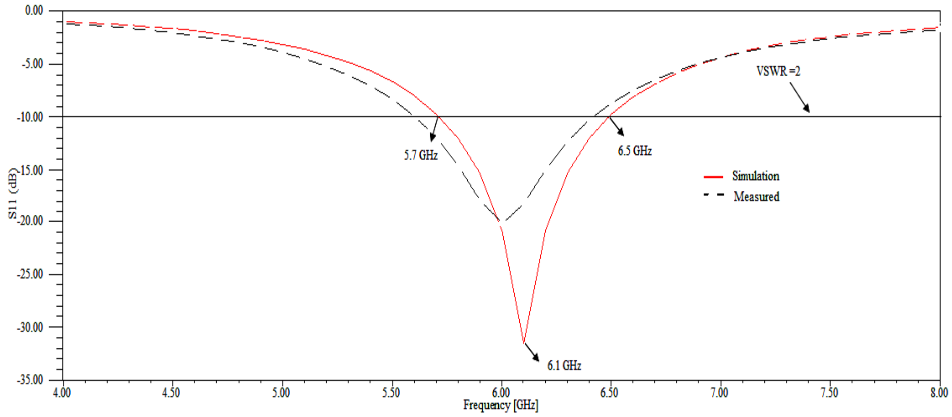


Fig. 5: Simulated and measured curve of return loss of proposed UWB antenna

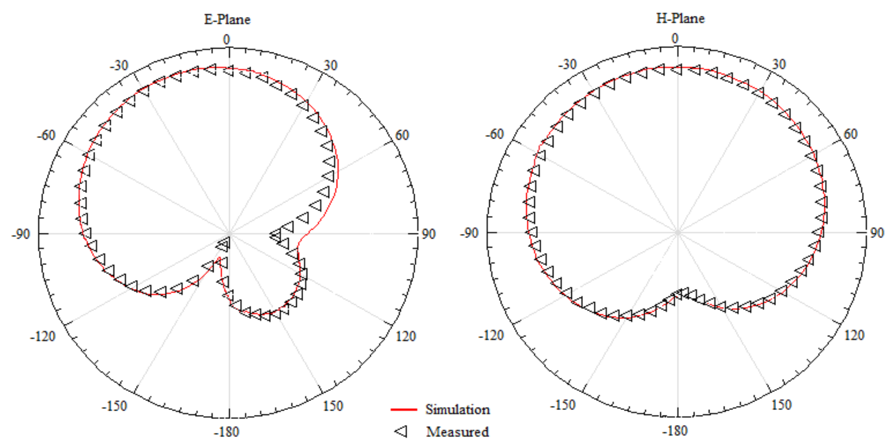


Fig. 6: Simulated and measured results of radiation pattern of E-plane and H-plane of proposed UWB antenna

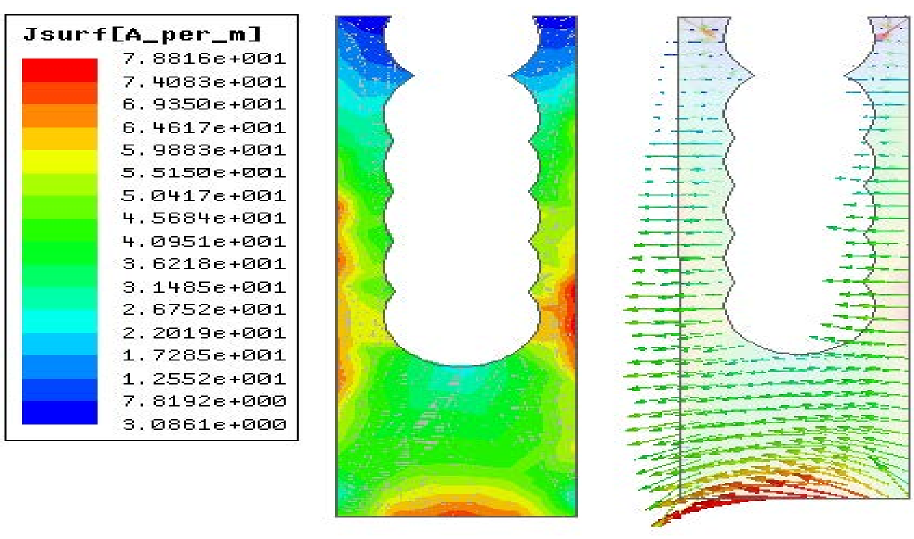


Fig. 7: The current distribution of proposed UWB antenna

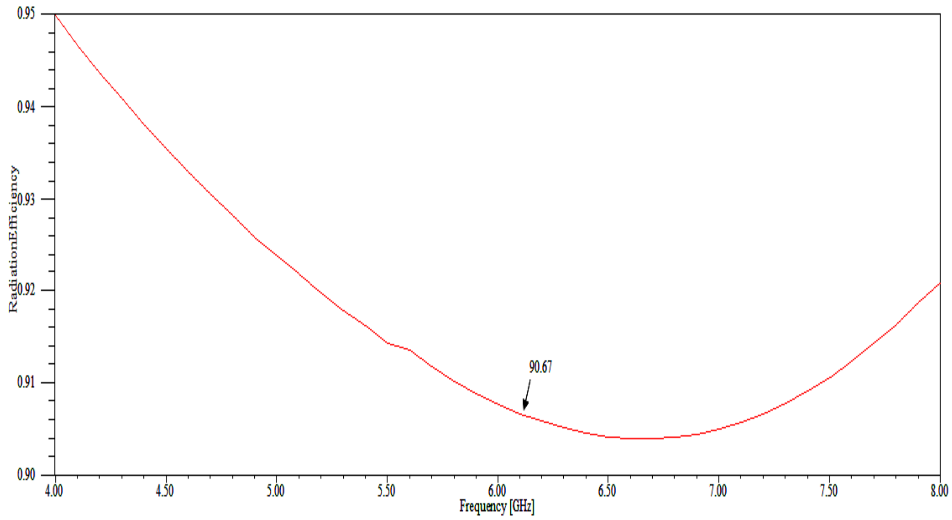
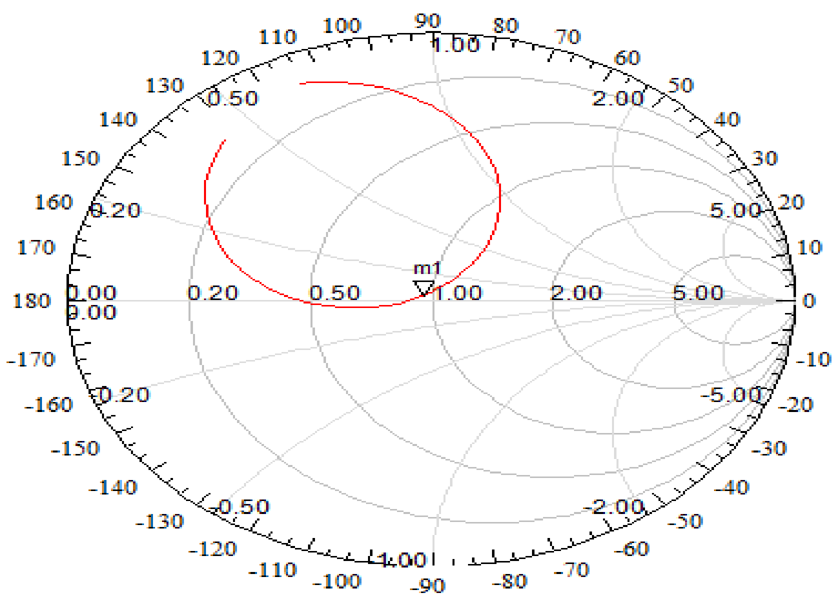


Fig. 8: Simulated radiation efficiency of proposed UWB antenna



Name	Freq	Ang	Mag	RX
m1	6.1000	121.8594	0.0267	0.9712 + 0.0441i

Fig. 9: Simulated smith chart of proposed UWB antenna

stated the proposed antenna produce good radiation at the resonant frequency of 6.1 GHz. Figure 9 shows that smith chart analysis of the proposed UWB antenna. It shows that resonance loop appeared centre of the smith chart and frequency occurred at between 0-2 of VSWR which indicate that no mismatch between transmitter and receiver. The omni directional radiation pattern was observed at resonant frequency of 6.1 GHz. The angle and magnitude indicates the coupling between transmitter and receiver. This proposed UWB antenna having good impedance matching and highly suitable for medical applications.

CONCLUSION

In the evaluation of medical applications the compact size, optimal design of 6.1 GHz UWB antenna is tested in this research work. To obtain the required bandwidth the rectangular shape patch with open circle slot is designed with overall all dimensions of 7×4mm and radiation size of 5×1.529 mm. The compatibility and low profile nature FR4 epoxy substrate material is fabricated and measured in this research and both the simulation and measured results satisfy the UWB characteristics with return loss of -31.47 and 20.16 dB. This miniature pattern and portable antenna is highly suitable for off body communication and also adoptable for LTE network communications.

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