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DESIGN AND DEVELOPMENT OF ORTHOMORPHIC AND RECONCILABLE ULTRA WIDE BAND ANTENNA FOR WEARABLE APPLICATIONS

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Abstract: Wearable antenna for body centric communication for medical application is a challenging task because of environmental parameters changes with respect to time. Ultra-wideband (UWB) antenna provides a particular solution for millimeter range wireless communication in the domain of the medical applications. A main requirement for the UWB antenna design is large bandwidth and low power consumption both in transmission and reception. The important design considerations for the construction of UWB antenna includes stable gain, omni directional radiation pattern and wide bandwidth which are very much essential for optimal transmission and reception of signals. The antenna system is an essential part of any wireless system hence care should be taken at each step of the design process to retain their properties over the entire band. In this research, an UWB antenna for body centric communication for short range has been proposed. This requires a large bandwidth and low power consumption in body communication purpose and this is a main provocation for the design of the Wearable Antenna for Body Centric Communication (WABCC). Firstly, the antenna has been designed on the three different types of the substrates such as FR4, Duroid and textile fabrics. The WABCC fabricated on a planner FR4 substrate with ε_r of 4.4 tan δ is 0.02 and a dimension of $32 \times 25\text{mm}^2$. The thickness of the substrate is 0.75mm^2. Simulation results shows the design of an UWB antenna using HFSS tool and distinct key parameters were reported to validate the design requirements. The return loss characteristics is calculated in UWB range from 3.1 GHz to 10.6 GHz as prescribed by FCC and the Gain of an antenna is obtained for 2.5 to 5 dB for the frequency range from 3.1 GHz to 10.6 GHz. The efficiency of an antenna under test ranges between 90 to 98%.

Keywords: Ultra Wide band Antenna, Wearable Antenna, Body Centric Communication, Gain, Efficiency.

1. Introduction

Body-centric Wireless communication (BCWC) has become a very crucial and upgrowing in the field of wireless communications. Wearable antenna is Prime device for BCWC is the term wearable antenna means customized antenna to wear on Human Body. In conventional way we say that the wearable antenna operates as Part of clothes, whose intention is performing tasks related to telecommunication such as tracking and navigation, remote computing and communication tasks related to public safety. Essential requirements for wearable antennas include Compact size, low weight, low cost, virtually maintenance free, no needs for installation and safe to person health when placed close to the body [1].

Ultrawideband Technology is the wireless communication techniques (3.1–10.6 GHz) have earned a lot of attention due to their merits such as high data rate, small emission power, and low cost. To tackle the effect caused by the frequency interference from WLAN and Wi MAX systems, some UWB antennas with band-notched feature have been designed, One simple way is to etch thin slots on the antenna surface, such as L-shaped slot , U-shaped slot,, and T-shaped slot . By adding either a split-ring resonator (SRR) [7] or a multi resonator load [8] in the antenna structure, the undesired frequencies can be rejected so that the system performance may be enhanced well, therefore all of these designs need a complex structure to generate and control the stop band property, so that the cost in fabricating antenna will be increased for practical applications.

Here we propose a printed monopole antenna that simply employs a vertical coupling strip to flexibly controlling the rejection frequency band for UWB system operation. Unlike those conventional designs, quite stable radiation pattern of the antenna can be achieved as the major design parameters of the stop band are modified. This makes possible for the proposed UWB band-notched antenna with a com pact size of 18(L) × 18(W) × 1.6 mm to be integrated within different portable devices without the need for retuning the whole design structure. Details of the design concept of the antenna are then described in Section II, and the proposed antenna is constructed and experimentally studied in Section III. Moreover, a number of design parameters in regard to the stop band feature are analyzed for the antenna. Section-IV Explained the Simulation Parameters. Section-V Includes the conclusion.

2. Antenna Design

Fig. 1 shows the whole detailed design parameters of the proposed UWB band-notched antenna, which is fabricated on a 1.6-mm-thick FR4 substrate with dielectric constant and loss tangent. This antenna is fed by a 50- micro strip line with a width of 3.4 mm and is implemented using a square slot patch with a vertical coupling strip**.**

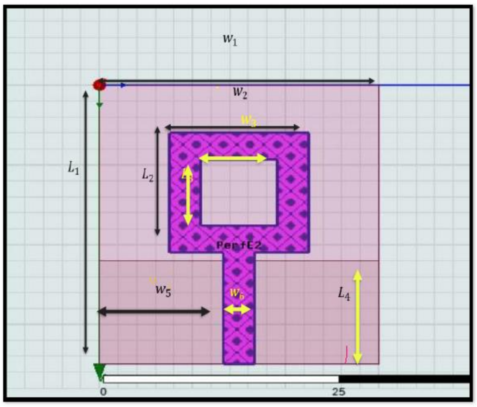

Fig.1 Geometry of the proposed UWB band-notched antenna.

Following table shows that the overall dimensions of the antenna as shown in Table1.

Antenna Dimension	Optimized Value
Substrate Dimension	35mm × 30mm
Patch Dimension	15mm × 15mm
Ground Dimension	13mm × 30mm
Feed Dimension	14mm × 3mm

Table1. Overall dimensions of the antenna

A longest resonant length of the antenna was designed about a quarter-guided-wavelength at 3.68 GHz, which was equal to mm and also similar to that of the resonant monopole antenna. Spacing between the slot patch and the ground plane has been optimized to be about mm, so that good impedance matching across the operating band can be obtained. As shown, the coupling strip placed at the center of the slot patch can be devoted to generating desirable resonance for the stopband operation. In our antenna design, this coupling strip acts as a quarter-guided-wavelength resonator.

$$f_r \approx \frac{c}{4\sqrt{\frac{\varepsilon_r+1}{2}}\cdot(\mathrm{L}_3-2\mathrm{G}_1)} \qquad (1)$$

where is the speed of light in free space and is the dielectric constant Since the center-rejected frequency is expected about 5.6 GHz, the strip length of the antenna can be calculated to be 7.9 mm, suitable for those optimum design parameters as listed below. Besides, to overcome the effects due to the frequency shifting for practical applications, the stopband property of the antenna can be controlled by flexibly tuning either the width or the gap for the strip. An electromagnetic software package, HFSS, has been utilized to simulate and analyze the electrical features and radiation performance of the proposed antenna.

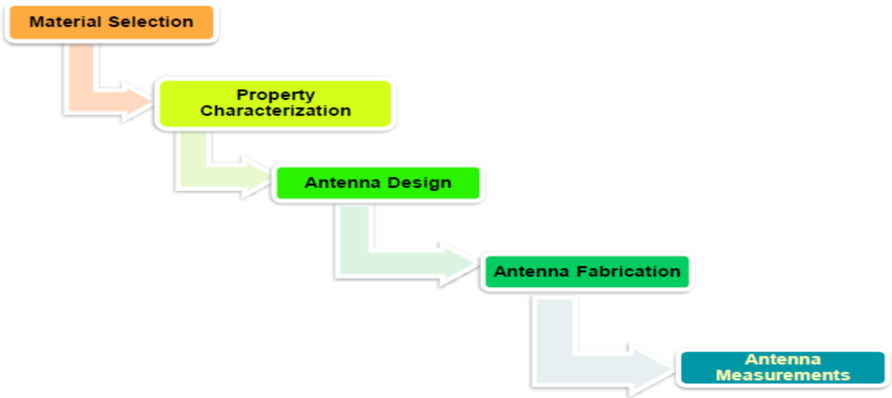

Fig2. Design flow of the Proposed Antenna

Following table shows that the formulas for the calculations of the antenna design parameters.

Design Parameter	Formula
Patch Width (W)	$w = \frac{c}{2fr}\sqrt{\frac{2}{(\varepsilon r + 1)}}$
Effective dielectric constant (ε_{reff})	$\varepsilon reff = \left[\frac{\varepsilon r + 1}{2}\right] + \left[\frac{\varepsilon r - 1}{2}\right]\left[1 + \frac{12h}{W}\right]^{-1/2}$
Actual Patch Length(L)	$L = \left[\frac{c}{(2fr\sqrt{\varepsilon reff})}\right] - 2\Delta L$
Extension length (ΔL)	$\frac{\Delta L}{h} = 0.412\left[\frac{(\varepsilon reff + 0.3)}{(\varepsilon reff - 0.258)}\right]\left[\frac{\left(\frac{W}{h} + 0.264\right)}{\left(\frac{W}{h} + 0.8\right)}\right]$
Effective Patch Length	$\mathrm{Le} = \mathrm{L} + 2\Delta \mathrm{L}$

Table2. Formulas for the design parameters

The width of patch has adequately small effect on the shape of the antenna radiation pattern, but it affects the input impedance and antenna's operating bandwidth. The length of patch is critical parameter for patch antenna designing because resonance frequency of patch antenna mainly depends on length of its patch. Due to the effect of fringing field generated at both ends of the patch length the effective patch length is given by formula as shown in table 2. Following Table 3 Shows that the calculated dimension of the patch antenna.

Antenna Parameter	Results
Substrate Dimensions	35mm × 30mm× 1.6mm
Ground Dimensions	13mm × 30mm
Patch Dimensions	15mm × 15mm
Resonant Frequency(GHz)	5.6 GHz
Return Loss	-21.00, -12.47
Gain(dB)	2.6951dB
Directivity(dBi)	2.98dBi
UWB Bandwidth	7.6GHz
Operational Frequency Range	3.1GHz to 10.7GHz
VSWR(Maximum 2)	For 3.8GHZ- 1.1926 ,10.6834GHz- 1.98

Table3. Calculated dimensions of the Patch antenna

3. Simulation Results and Discussion

This simulation results of the proposed antenna were performed using HFSS simulation software 2018 version and antenna characteristics are studied.

3.1 Return loss characteristics

Return loss or reflection coefficient or S11 represents the quantity of power which gets reflected by the antenna and is numerically determined by

$$S_{11} = 10 \log (P_r / P_i) \quad (2)$$

Here

p_r = power from the antenna

p_i = incident power on to the antenna.

Antenna's fractional bandwidth (FBW) is a mean to explain how wideband the antenna is and it is obtained by dividing impedance bandwidth by center frequency. For calculation of antenna's bandwidth, the return loss plot showing a variation of S11 with respect to frequency is taken into account. It is considered as the frequency span over which S11 value is below − 10 dB from the return loss plot, − 10 dB line is identified This line intersect S11 curve in two points which are known as flower and f_{higher}. The frequency range between this minimum frequency (f_{lower}) and maximum frequency (f_{higher}) is known as impedance bandwidth. If the antenna operates at center frequency f_{center} between minimum frequency flower and maximum frequency f_{higher}, then mathematically it is expressed as

$$\text{fractional Bandwidth} = (f_{higher +} f_{lower}) / f_{center} \quad (3)$$

$$\text{Centre Frequency } f_{center =} (f_{higher +} f_{lower}) / 2 \quad (4)$$

The obtained value of S11 should be below − 10 dB for the whole UWB frequency band. It has been seen that simulated values of S11 at operating frequency 3.8 GHz and 10 GHz are − 21 dB and − 12.47 dB, respectively. The designer of UWB antenna given the − 10 dB bandwidth (impedance bandwidth) value 7.6 GHz over a span covering 3.1 GHz to 10.7 GHz which make use of the whole frequency spectrum of the UWB band and it provides the 120% as fractional bandwidth. Figure 3 denotes the return loss characteristics for an antenna having FR4 as substrate material.

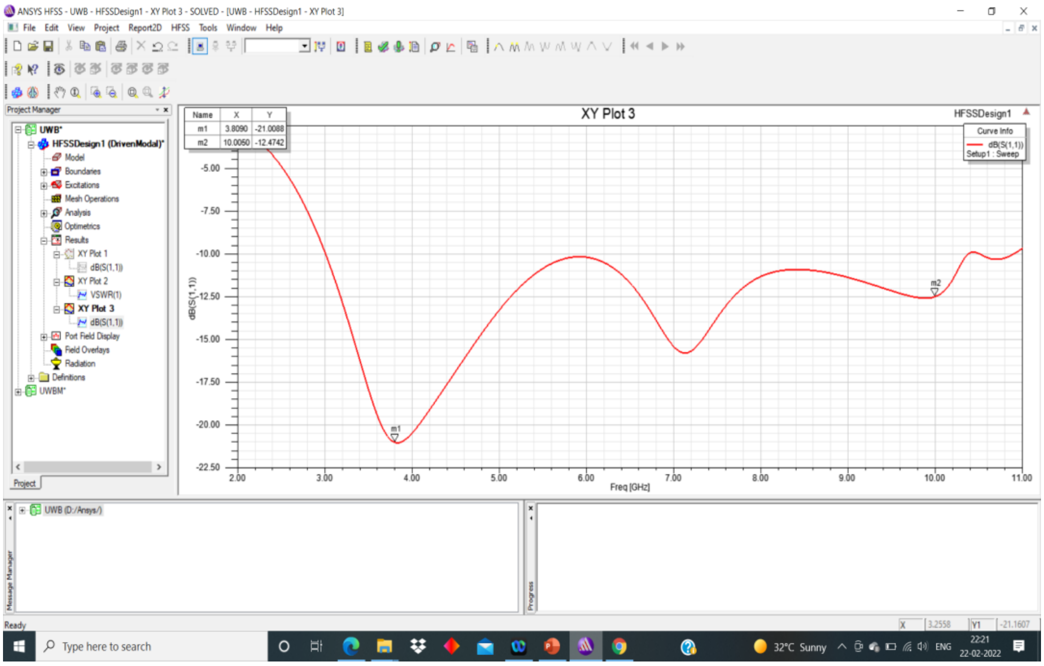

Fig 3. Return Loss (S11) Characteristics of antenna

3.2 Characteristics of VSWR

Voltage standing wave ratio (VSWR) indicates how an antenna is matched with its connecting feed. The expected value of VSWR is 2.0 or lesser than 2.0. VSWR value 2 indicated the antenna is closely 90% matched to its connected feed line and only 10 percent power is there which gets reflected from an antenna. The range of voltage standing wave ratio (VSWR) lies between 1 and ∞. The minimum value of VSWR is 1.0 for which no power is reflected from the antenna, which happens in a perfect system. In real practical condition, irregularities in transmission with mismatched impedance causes power to be reflected back to the source. The VSWR lesser than 2 is accepted in suitable and acceptable in most antenna applications for the communication system in practical conditions. In general, if VSWR is under 2, the antenna match is considered fairly good. It is ascertained from Fig. 4, that specific values of VSWR at resonant frequency 3.8 GHz and 10.68 GHz are 1.1926 and 1.98 respectively. This value is in the desired range (i.e.<2).

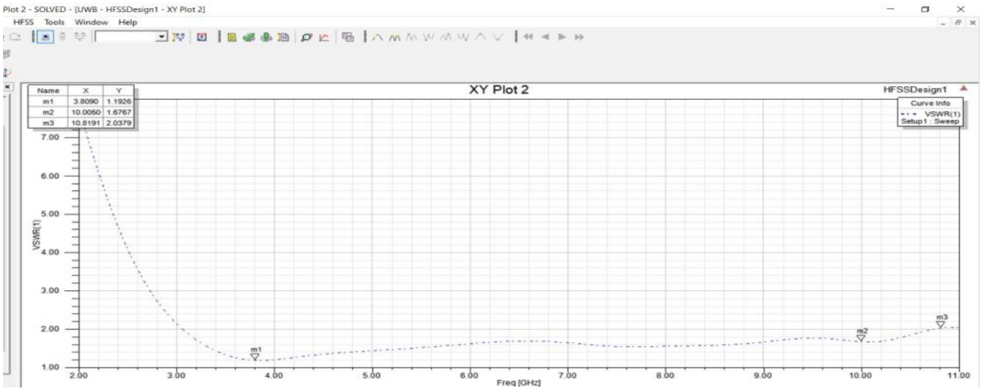

Fig. 4 VSWR Characteristics of an antenna

3.3 Characteristics Radiation Pattern

Radiation pattern graphically represents the antenna's radiation characteristics as a function of space. Radiation pattern 3D plots indicate a variation of gain and directivity with respect to frequency over a complete specified frequency range. Efficiency is an important parameter to describe how efficiently an antenna transmits and receives RF signals which can be expressed a

efficiency in % = (gain / directivity) × 1 (5)

Figure 5 and Figure 6 shows the gain and directivity magnitude plot for an antenna having FR4 as a substrate at resonant frequencies. At 5.53 GHz, gain and directivity are observed to be 2.6951 dB and 2.98dBi, respectively. Efficiency of 90.3% is observed at 5.53 GHz.

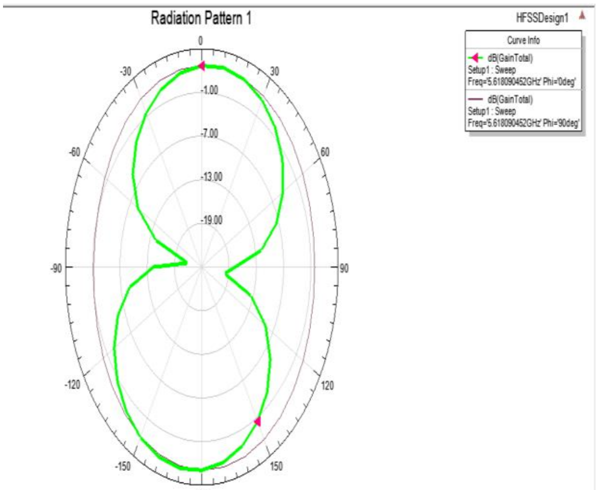

Fig.5 Radiation Pattern Characteristics of an antenna

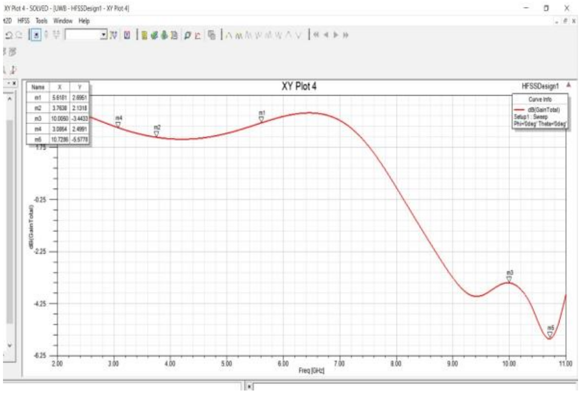

Fig.6 Gain(dB) of an antenna

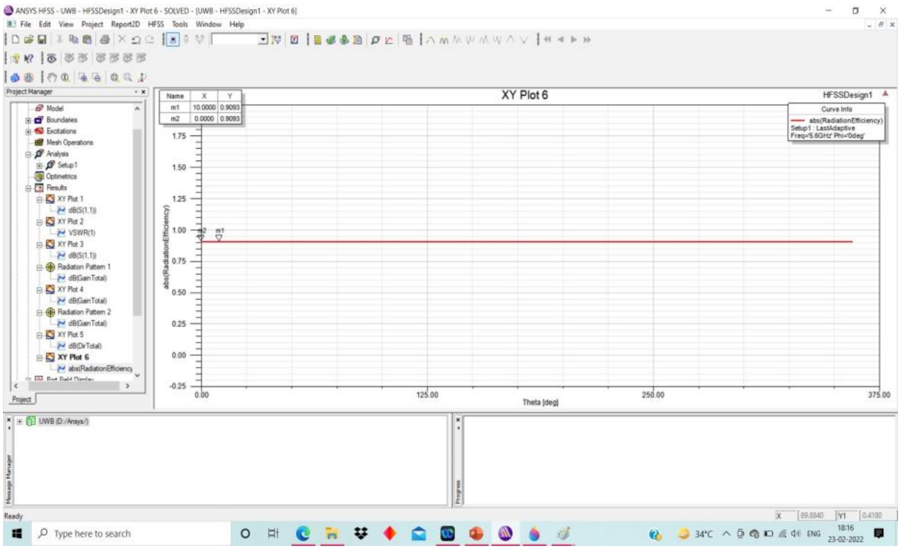

Fig.7 Radiation efficiency of proposed antenna

4. Conclusion

The main important goal of this work is to Create and simulate compact UWB antenna design using FR4 Substrate which can provide large impedance bandwidth, miniature in shape, size, it provides the large gain and directivity. The research initiative is also moto on the comparative analysis of different performance parameters of antenna such as refection coefficient, VSWR, directivity, impedance bandwidth, gain, and antenna's radiation efficiency. The proposed compact antenna has return Loss(S11) value below −10 dB was obtained from simulation results for frequency ranging from 3.1 to 10.7 GHz, therefore, conforming ultra-wideband operation. The performance parameters of the presented antenna design confirm its superior with respect to other related antennas mentioned in references and fulfill the requirements to be used for body worn applications. It can be used for WBAN applications in the UWB range.

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