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Characterization of Radiation Behavior of Ultra-Wide Band Antenna for Body Area Network

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***Abstract*— Ultra-Wideband (UWB) antennas play a crucial role in modern wireless communication systems as they have capability to work over a very wide frequency range with high data transmission rates and low power consumption. This paper presents the radiation characteristics analysis of a Ultra Wide Band antenna designed for broadband communication applications which is suitable for wireless body area networks. The proposed antenna is analyzed in terms of key performance parameters such as radiation pattern, gain, bandwidth, efficiency, and impedance matching across the UWB frequency spectrum.**

The antenna is designed and simulated using appropriate electromagnetic simulation tools, and its performance is evaluated over the designated Ultra Wide Band frequency range. The radiation pattern is examined to determine the antenna's directional behavior and stability throughout the operating band. Results demonstrate that the antenna exhibits nearly omnidirectional radiation patterns with stable gain and good radiation efficiency across the UWB range. Additionally, the antenna maintains acceptable impedance matching and low return loss, ensuring reliable signal transmission.

The analysis confirms that the proposed UWB antenna provides consistent radiation performance, making it suitable for various applications such as wireless body area networks (WBAN), short-range high-speed communication systems, and wearable wireless devices. The obtained results indicate that the antenna design satisfies the requirements of UWB communication systems and offers potential for integration in compact and portable wireless platforms.

***Index Terms*— Antenna, Body Worn Antenna, radiation characteristics, wearable.**

I. INTRODUCTION

The rapid growth of wireless technology in recent years has led to increased research interest among engineers and researchers in the design of low-profile antennas for wireless communication devices. The miniaturization of electronic devices is a key factor that is used in wearable computer technology. As a result, numerous compact devices have been developed that can be conveniently carried in pockets or worn on the body. If these devices have been properly designed and made portable, these would offer more effective ways to access the information on demand [1], [3]. This technology and devices are used in Body Area Network (BAN). In the body area network compact and thin devices are used and are implemented on clothes. These devices are termed as wearable devices which are the parts of intelligent clothing. The wired connection between devices in a BAN may be inconvenient for a user as devices are to be worn on the clothes. Hence small size, thin devices, antennas are crucial components in the designing of body area networks.

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Transmission and reception of a signal depend on the proper antenna design. These antennas are used near the human body environment. The human body affects the performance of antennas and reduces the radiation efficiency, changing the radiation characteristics, operating frequency and bandwidth. It also changes the matching conditions and hence impedance provided by the antenna.Similarly, antenna radiations also affect the human body. Hence, careful design of an antenna is a crucial and a challenging task [3]. Variations of microstrip patch antennas are used in wearable applications.

The main aim of this work is to implement a compact and thin ultra-wide band antenna which provides high bandwidth, high antenna efficiency and along with improved performance of the antenna useful for body area networks.

In the body area network, a wide range of devices that can be attached to their bodies or in some cases carried by users in their pockets. If these devices are properly designed and made portable, compact these would provide more effective ways for people to use in Body Area Network (BAN). These devices are termed as wearable devices which are the parts of intelligent clothing. As such devices should be worn on the clothes, the wired connection between devices in a BAN may be inconvenient for a user. Hence, the main motivation is to develop compact, lightweight and thin ultra-wide band antennas for such a network.

The following figure 1 shows the example of the Body Area Network which contains various sensors, displays, base devices etc and connected to the internet for further assistance or services.

Figure 1. Example of Body Area Network [13]

Major elements of the body worn wearable system are as shown in figure 2 [3]

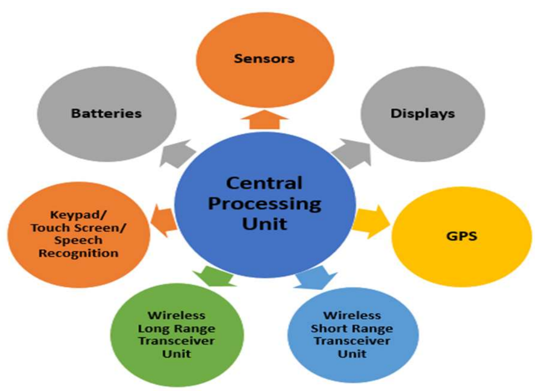

Figure 2. Elements of the Body Worn Wearable System [3]

II. ANTENNA DESIGN AND METHODOLOGY

A. Antenna Modelling

Antenna contains substrate, ground, patch. Substrate is of 50*45mm and having thickness of 1.5mm. Whereas the patch has a radius of 10mm. Following figure shows the designed antenna under test

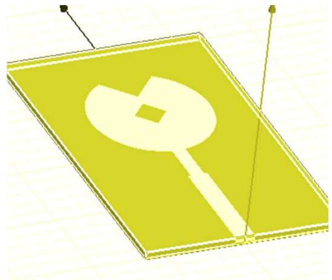

Figure 3. Antenna Under Test

B. Antenna Design

The actual radius of the Patch (a) [2]

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\pi F/2h\right)\right] + 1.7726\right]\right\}^{1/2}} \quad (1)$$

$$\text{where, } F = \frac{8.791 \times 10^9}{fr \times \sqrt{\varepsilon_r}} \quad (2)$$

h - height of the antenna (cm)
εr - dielectric constant / permittivity
fr - resonant frequency (Hz)

Effective Radius of the patch [2]
Fringing makes the patch electrically longer and it was corrected by taking length correction factor, to replace the actual radius of the patch,a.

$$a_e = a\left\{1 + \frac{2h}{\pi \varepsilon_r a}\left[\ln\left(\pi a/2h\right)\right] + 1.7726\right]\right\}^{1/2} \quad (3)$$

In circular patch antennas there is negligible difference in ae and a. Hence dominant mode is to be considered for resonant frequency calculation. Only a single parameter radius of the circle decides the frequency of operation.

Resonant frequency and other frequency dependent parameters [2]
Resonant frequency of Circular patch antenna is given as:

$$fr = \frac{1.8412 * vo}{2 * \pi * a_e * \sqrt{\varepsilon_r}} \quad (4)$$

Here,
v_o = velocity of light = $3*10^8$ m/s
a_e = effective radius of the patch
f_r - Resonant frequency - (for dominant mode TM_{110} mode)
TM - Transverse magnetic mode - E-mode i.e. only
Antenna has been designed for the specific resonant frequency and effective radius of the patch

C. Methodology

Various methods are available for feeding the signal to the antenna. They are Microstrip Line Feed, Coaxial Feed, Aperture-coupled Patch (ACP), Proximity-coupled Feed- Electromagnetically-coupled Feed) Microstrip line feeding, coaxial or probe feeding are the contacting feeding technique. Aperture coupled feeding, proximity coupled feeding are the two non-contacting types of feeding techniques. Even though various feeding methods are available, Microstrip line feeding is used to feed the antenna, as it is simple to implement and easy to model.

There are various fabrication methods to fabricate wearable antennas. As antennas are compact in size, light weight and thin and should be sturdy in nature, these antennas are to be made very carefully. Hence fabrication is a crucial challenge in implementing such antennas.There are various methods to fabricate these antennas such as screen printing, flexography, inkjet printing or direct ink writing, stitching, sewing, embroidery, adhesives etc.While preparing antennas using screen printing is used as it is widely used in industries for antenna fabrication.

III. DISCUSSION AND RELATED WORK

A. Analysis of Antenna characteristics

To analyze the radiation characteristics of the antenna, an anechoic chamber is used. An anechoic chamber is a non-reflective, non-echoing, echo-free room. A specifically designed door absorber is provided to absorb the reflections of sound or any electromagnetic waves. The waves entering from the surroundings are isolated from the antenna kept for observation. Only direct sounds or reverberant sounds are available in anechoic chamber. It represents that the antenna under test is simulated or observed inside an infinitely large room without any external noise and echo. RF anechoic chambers eliminate the reflections and external noise generated by electromagnetic waves.

Testing of the antenna is done by MVG-orbit FR-PNA-Network Analyzer, which is a shielded anechoic chamber that works in the frequency range of 400MHz to 20GHz. Indoor far field antennas can be tested with the help of this chamber.

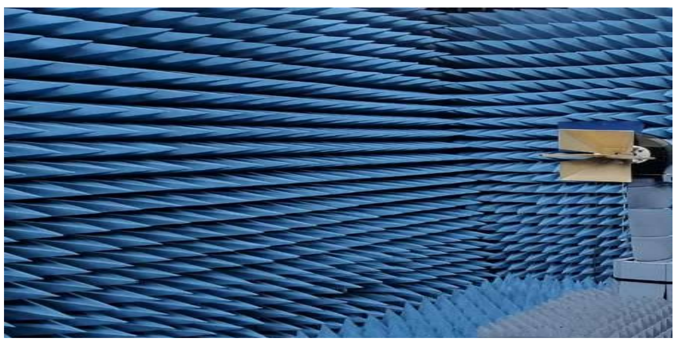

Figure 4. An anechoic chamber

While testing an antenna, the fabricated antenna and horn antenna are used as a receiving and transmitting antenna respectively. The transmitting antenna is to be kept at one position and the receiving antenna, which is the test antenna, is moved circularly in all directions from 0 to 180 degrees.

The radiation pattern parameters like amplitude, beamwidth, null depth are obtained for various positions of feed. The graph of amplitude phase angle is plotted.

The following figure depicts radiation characteristics at 12GHz, 15 GHz, 17 GHz and 18GHz plotted when feed position is 0° and 90°.

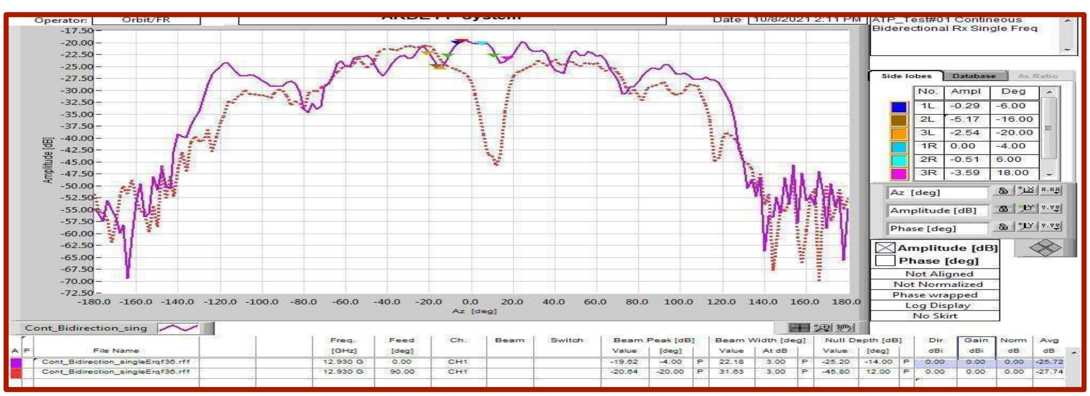

Figure 5. Radiation pattern at 12 GHz

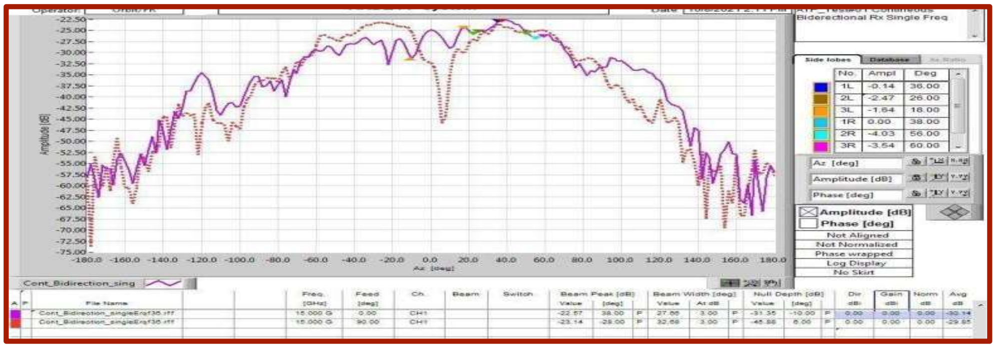

Figure 6. Radiation pattern (Cartesian coordinate system) at 15 GHz

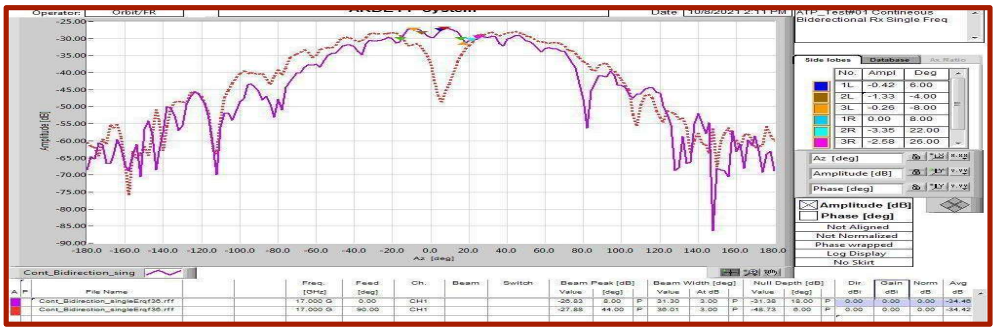

Figure 7. Radiation pattern (Cartesian coordinate system) at 17 GHz

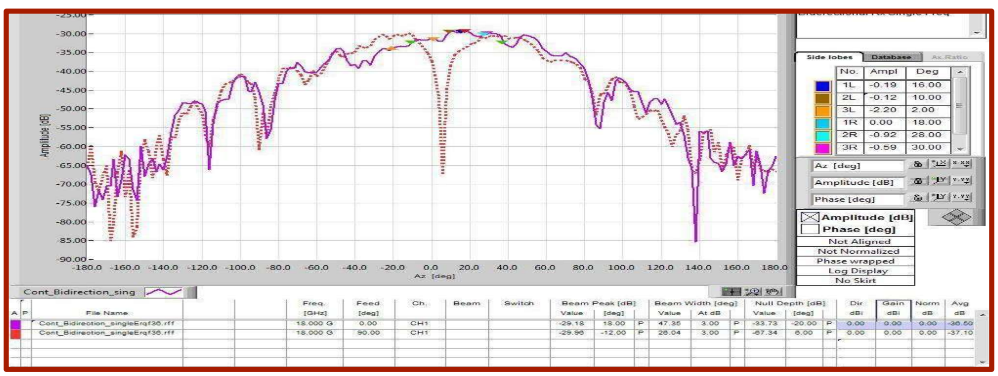

Figure 8. Radiation pattern at 18 GHz

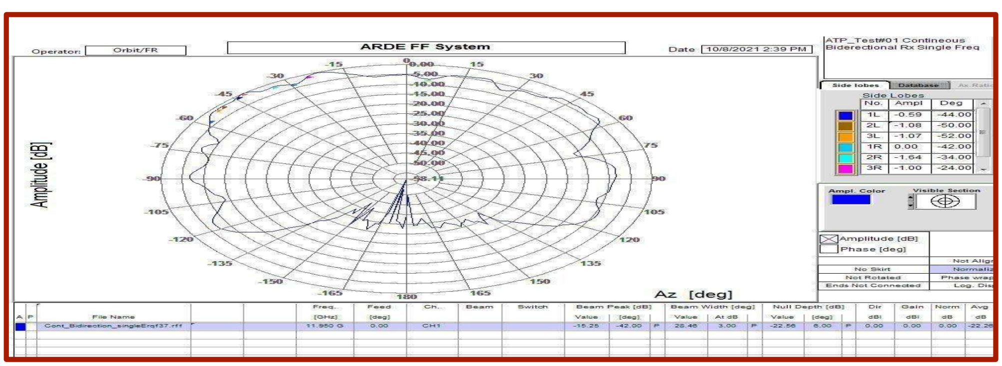

Figure 9. Polar Pattern at 12 GHz

From figure 8, it is observed that, for graphs of higher frequencies, both graphs are approximately matching with each other. The differences between the graphs with 0° and 90° are less, as compared with the lower frequency graphs.

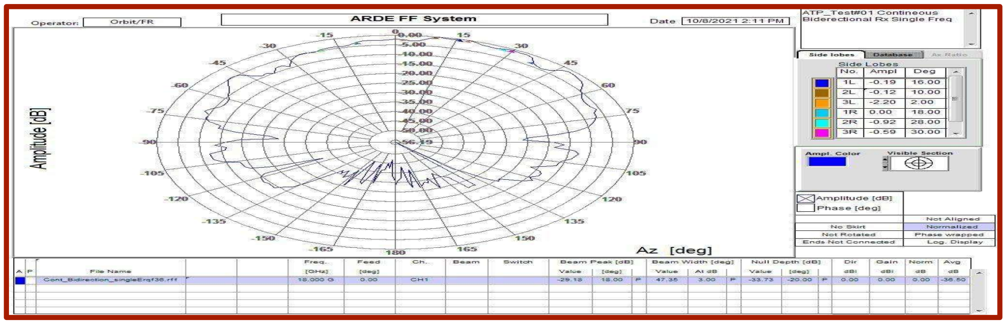

Figure 10. Polar Pattern at 18 GHz

Similarly, when a polar radiation pattern is observed at 18GHz, side lobes are very less in magnitude, indicating maximum radiation is towards 0 °. Here, beam width is 47.35° with beam peak value of -29.18dB. When frequency of operation goes on increasing, the radiation pattern is closer to the pattern as desired.

The radiation pattern of the antenna is of great significance in the calculation of the SAR value because it affects the distribution of the power of the electromagnetic field in the body of the human being. A radiation pattern describes how an antenna radiates power in different directions. The main lobe shows direction of maximum radiation, side lobes show smaller radiation directions. If the antenna radiates more toward the body, then it gives higher SAR and if radiation is directed away from the body SAR is lower. When more radiation is towards the human body, hotspots i.e localized regions where high SAR is there will be generated. It may create harmful effects on the human head, brain and skin tissue. In this proposed structure of antenna, the antenna is prepared such that radiation is away from the human body. From the above patterns, it is observed that radiations are away from the human body, so less SAR and less effect on the human body.

IV. RESULTS

Return Loss-(dB) and Radiation efficiency (%) is also measured and compared with measured results. Results are as below.

TABLE I: SIMULATED AND MEASURED RESULTS

Substrate Material	Return Loss (dB)		Radiation efficiency (%)	
	Simulated	Measured	Simulated	Measured
Polytetrafluethelyne	-16.89	-16.59	100	97.63

TABLE II: COMPARISON OF RESULTS FOR DIFFERENT ANTENNA STRUCTURES

Ref. no.	Size (mm3)	Shape of the patch	Substrate	Return Loss (dB)	Radiation Efficiency (%)
[6]	50.37×52.7	H Slot	Fleece	<-10	57.1
[7]	60×60×1.1	Square ring patch	Felt	<-10	-
[8]	50×40 0.712 50×40 0.8	Rectangle	Teslin paper, Polyamide	<-10	96
[9]	30×20×0.7	Inverted E	Denim	<-10	79
[10]	40×26 ×0.787	Circular monopole patch 3 stepped. block	Rogers 5880 printed circuit board	<-10	-
[12]	40*40	E	Jeans	<-10	60
Implemented structure	50×45×1.5	Simulated	Polytetrafluethelyne	-16.89	100
	40.×28×1.5	Measured		-16.595	97.63

V. CONCLUSIONS

From the above radiation pattern measurements and observation made, for the designed antenna, side lobes are less in number as frequency increases. With high frequency the radiation characteristics are near to the semicircle on one side which indicates a major lobe and on the other side very low signal strength. Hence, specific absorption rate is also within the acceptable limits. This antenna is used for wearable body area network applications in the UWB range and above, less energy is directed towards the human body, which reduces harmful effects on the human being. Return loss and radiation efficiency also gets improved for the designed structure.

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