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Radiation Pattern Measurement for UWB Body Worn Antenna

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Abstract

In today's fast-growing world of various wireless communication applications low-profile devices are preferable. In the body area network (BAN) light weight, low profile devices are implemented on clothes. These devices are called wearable devices which are the parts of intelligent clothing. In the recent era ultra-wide band (UWB) technology is also a promising and challenging technology. In this paper, UWB is incorporated with a wearable antenna which is useful for wireless application. The presented antenna is developed using Teflon material as a substrate and radiation pattern measurement is done in the UWB range and beyond. Ultra-wideband (UWB) technology's fast data rate, low power consumption, and superior resolution capabilities have made it very popular in many applications. UWB body-worn antennas are essential for military communications, sports performance tracking, and healthcare monitoring, among other applications. The radiation pattern of an antenna, or how it radiates energy into space, is a crucial component of antenna performance. To maximise the functionality of UWB body-worn antennas and guarantee dependable communication, precise radiation pattern assessment is essential.

Keywords: Antenna radiation pattern, specific absorption rate, Teflon UWB, wearable antenna.

INTRODUCTION

In recent days of fast-growing wireless technology, the research on low profile antennas for wireless communication devices have increased the interest of researchers and engineers. Nowadays, growing miniaturization of electronic devices is combined with recent developments in wearable computer technology. This creates a wide range of devices that can be carried by users in their pockets or in some cases attached to their bodies. If these low-profile devices have been properly designed and made portable, these would provide more effective ways for people to access this information on demand [1], [3].

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This technology and devices are used in Body Area Network (BAN). In body area network light weight, low profile devices are to be used and have to be implemented on clothes. These devices are called 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. Following figure 1 various components of the body worn wearable system [3]. Above figure 1 shows that various components can be worn by the person as a part of intelligent clothing. The size of such a system becomes very large and complicated. Hence, to avoid this, all the parts should be low profile and light in weight.

Antenna Design:

Transmission and reception of a signal basically depend on the optimal antenna design. Such antennas have to be used near the human body environment. 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.

Sr. No.	Parameter		Dimensions (mm)
1	Substrate	Length	50
		Width	40
		Thickness	1.4
2	Ground	Length	25
		Width	30
3	Patch	Radius	10
5	Step	Length	5.3

Table: 1

Along with these all the considerations, optimal design of antenna is a vital part of the development of the antenna. As discussed earlier, these antennas should have low profile, lightweight and should be very flexible for wearing. To improve bandwidth and reduce surface wave losses, fabric dielectric constant should be as low as possible. Specific Absorption Rate (SAR) is a key factor in designing such antennas and must be within the standard limit [1]. UWB technology is used in this antenna implementation to work the antenna in the UWB range. The frequency range of 3.1 to 10.6 GHz band is for ultra- wideband [2]. There are various advantages of UWB, due to which UWB technology is

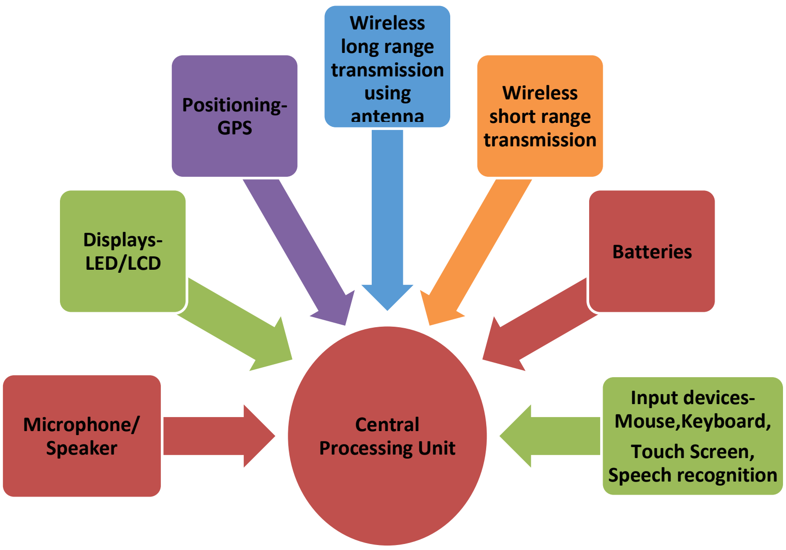

Fig.1. Block diagram of a typical body worn wearable system [3].

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adopted by most of the researchers for optimum antenna design.These advantages include, large bandwidth, large channel capacity, low transmission power, low values of signal to noise ratio, good performance in multipath channels, no interference occurs while sharing frequency with the current radio system etc.[2]. UWB along with the wearable technology gives the better performance of an antenna. [4], [5].

Radiation Pattern Measurement

The energy radiated by an antenna is represented by the Radiation pattern of the antenna. Radiation Patterns are diagrammatic representations of the distribution of radiated energy into space, as a function of direction. Radiation specifies the antenna strength and the radiation pattern term used to representthe emission or reception of the wave front at the antenna. Using radiation patterns we can understand the function and directivity of an antenna.[1] For the implemented antenna, the radiation pattern is observed by keeping the antenna in an anechoic chamber.

Fig.2 a: Anechoic Chamber for antenna

Feeding Network

- Following methods are available to feed the signal to the antenna
- Microstrip Line Feed
- Coaxial Feed
- Aperture-coupled Patch (ACP)
- Proximity-coupled Feed - (Electromagnetically-coupled Feed)

Out of all these methods Microstrip line feeding is used to feed the antenna, because ofits simplicity in connections and ease of modeling.

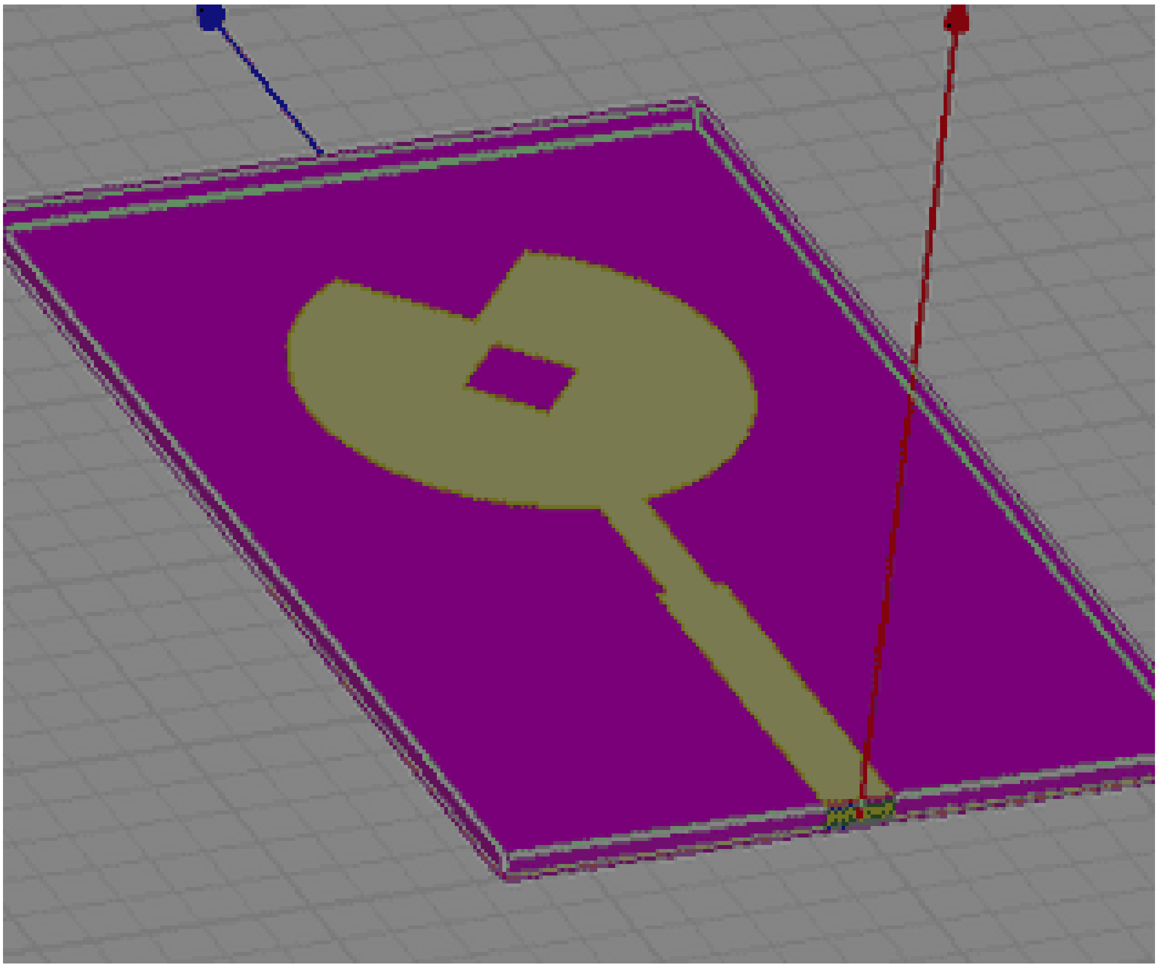

Fig.2 b: Designed Antenna under test

Above figure 2a shows the chamber used for radiation pattern parameter measurements. Antenna under test shown in figure 2b is to be kept inside the chamber.An anechoic chamber, its name implies that an-echoic, means that it's a non-reflective, non-echoing, echo-free room. It also has a special door absorber and it is designed to absorb the reflections of either sound or electromagnetic waves. These waves are isolated from waves entering from the surroundings. A person or detector in a room exclusively hears direct sounds or reverberant sounds. It represents that the antenna under test is simulated or observed inside an infinitely large room without any external noise and echo. This room is also called as RF anechoic chambers, which eliminates reflections and external noise caused by electromagnetic waves.

Antenna is tested in MVG-orbit FR -PNA-Network Analyzer, which is a shielded anechoic chamber working within the frequency range of 400MHz to 18GHz which provides indoor far field antenna test facility.

Here, the fabricated wearable antenna is used as a receiving antenna and horn antenna is used as a transmitting antenna. Transmitting antenna is to be kept still and the receiving antenna under test is rotated in all directions from 0 to 180 degrees. Then the radiation pattern parameters like amplitude in dB, beamwidth value in dB and degrees, null depth value in dB and degrees will be available for position of feed is 0°and 90°. The graph of amplitude in dB Vs. phase angle in degrees is available.

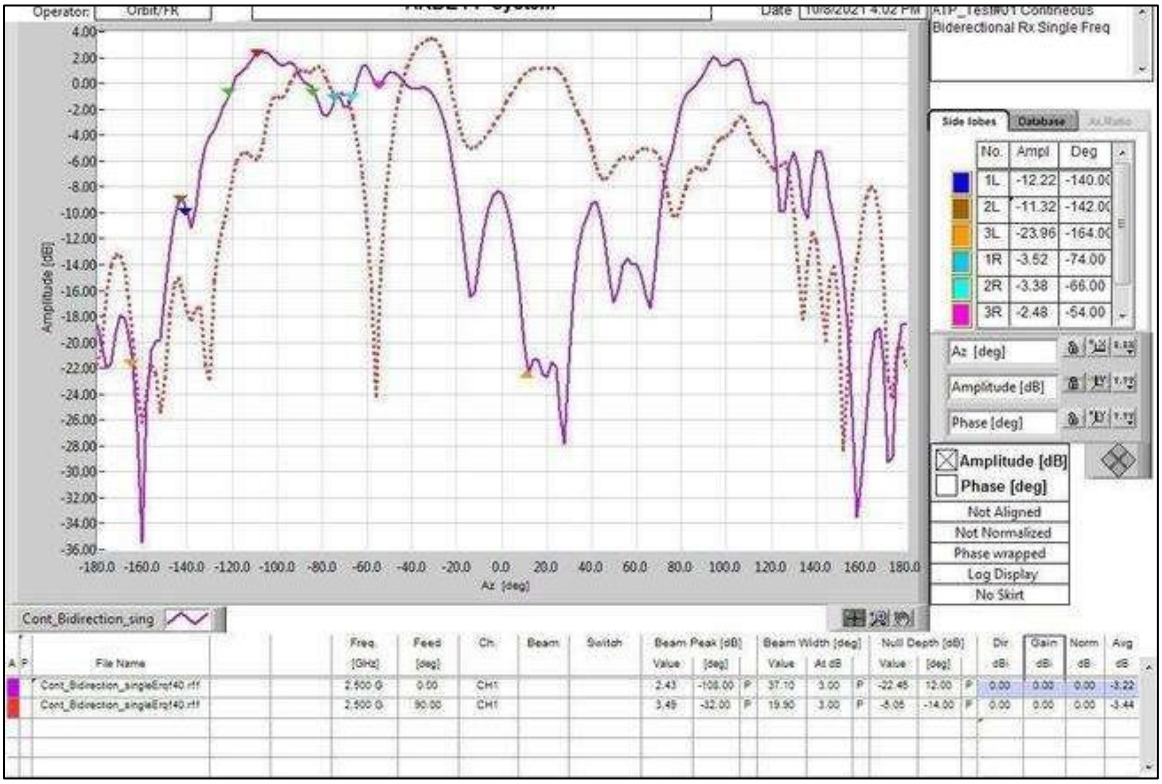

Fig.3: Radiation pattern at 2.5GHz when feed is at 0^0 and 90^0

Above figure 3 shows the radiation pattern in the Cartesian coordinate system. Hence, it contains a linear relationship between Amplitude in dB Vs.Azimuth angle in degrees. It shows the Violet color graph is for 0 degree and the red color graph is for 90 degree. The graph shows beam value, peak value in dB, beam width in degrees. The beam width is 37.10 degree for 0 degree and 19.90 degrees at 90 degree feed.

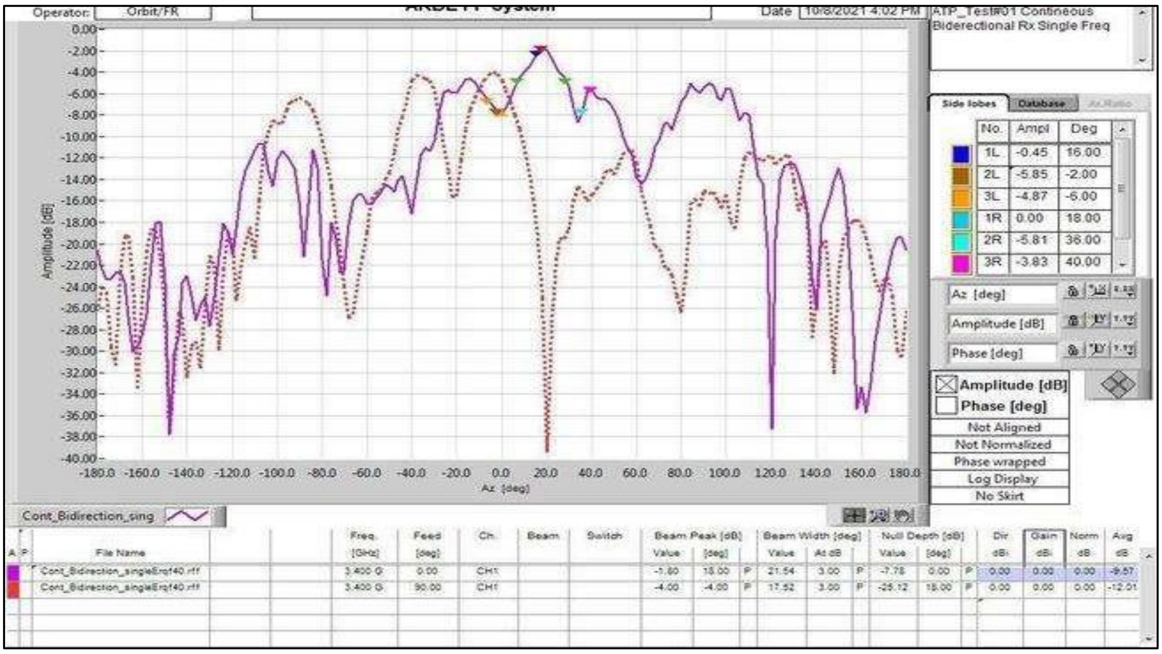

Fig.4. Radiation pattern at 3.4G

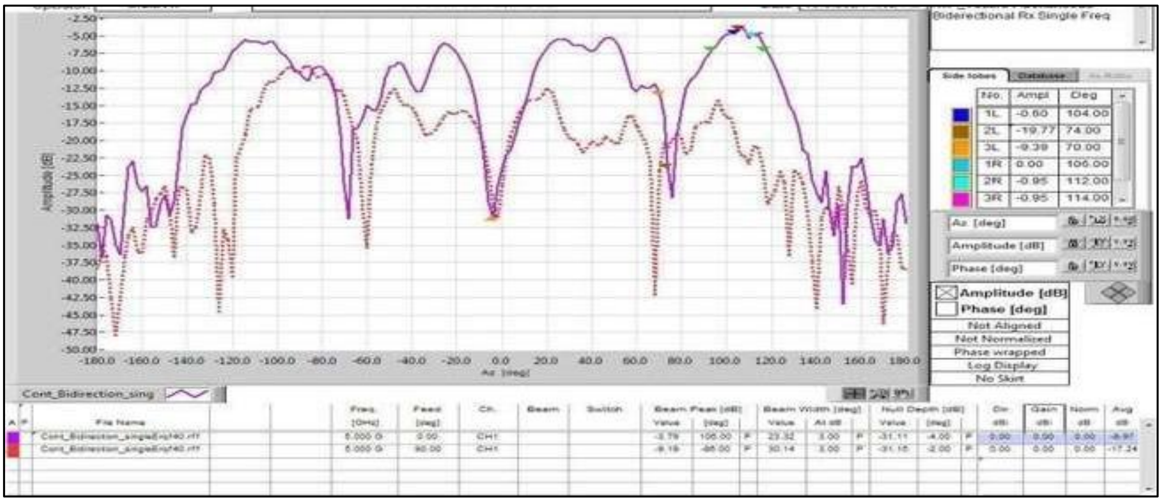

Fig.5. Radiation pattern at 5 GHz

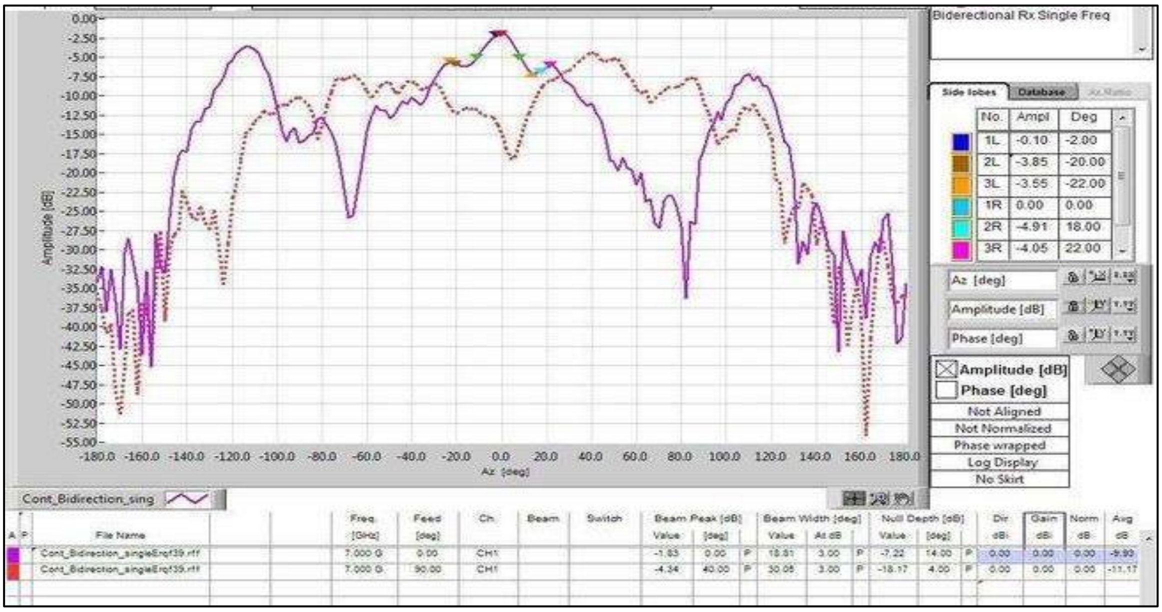

Fig.6. Radiation pattern at 7 GHz

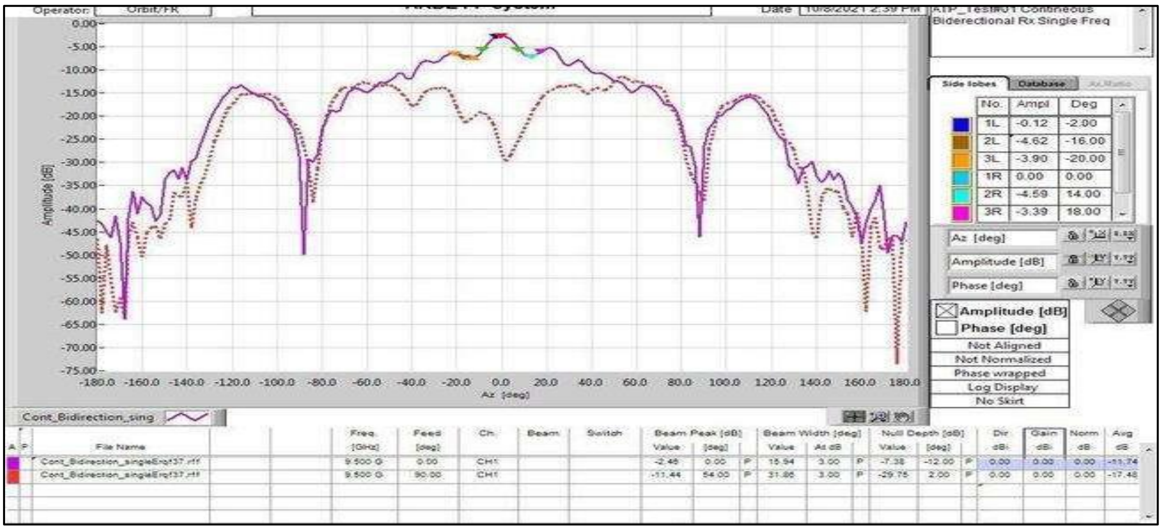

Fig.7. Radiation pattern at 9 GHz

Fig.8. Radiation pattern at 12 GHz

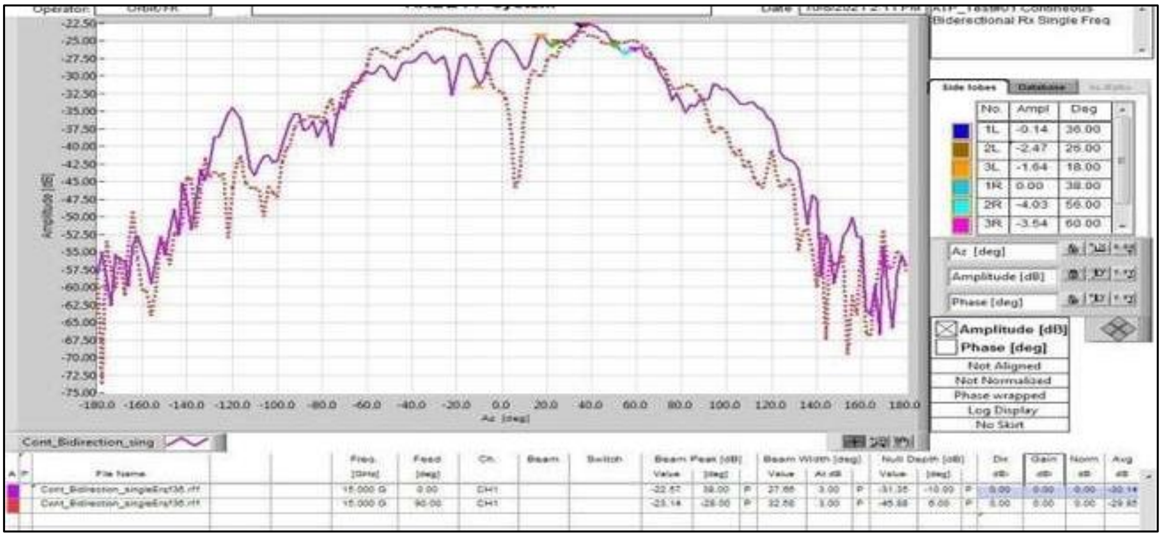

Fig.9. Radiation pattern (Cartesian coordinate system) at 15 GHz

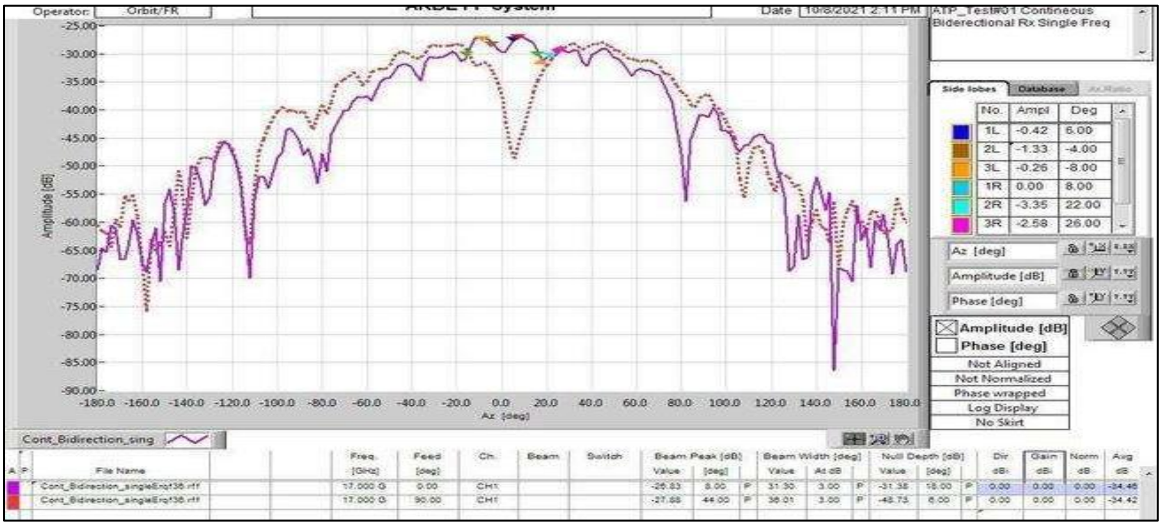

Fig.10. Radiation pattern (Cartesian coordinate system) at 17 GHz

Figure 4 to 10 shows radiation patterns at 3.4GHz to 17 GHz when feed position is 0°and 90°.

Fig.11. Radiation pattern at 18 GHz (Cartesian coordinate system)

From figure 11 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. After 7GHz frequency, the closeness between these two graphs goes on increasing.

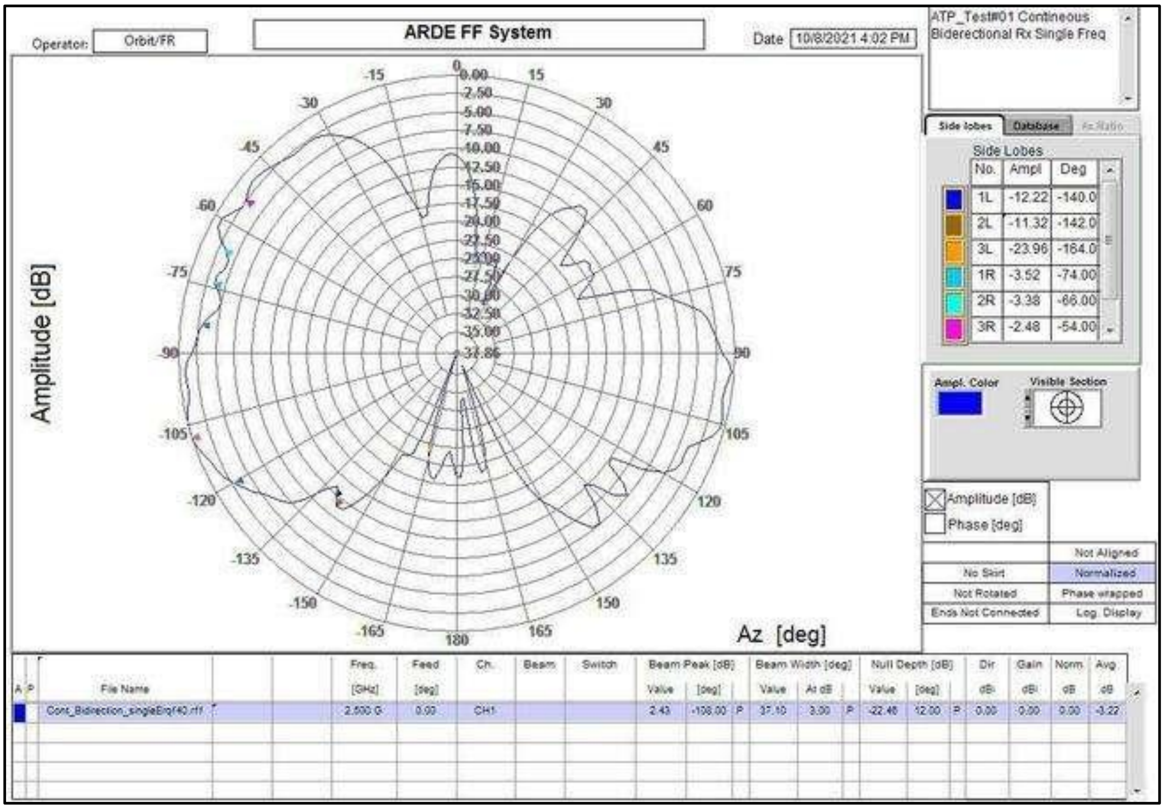

Fig.12. Polar Pattern at 2.5GH

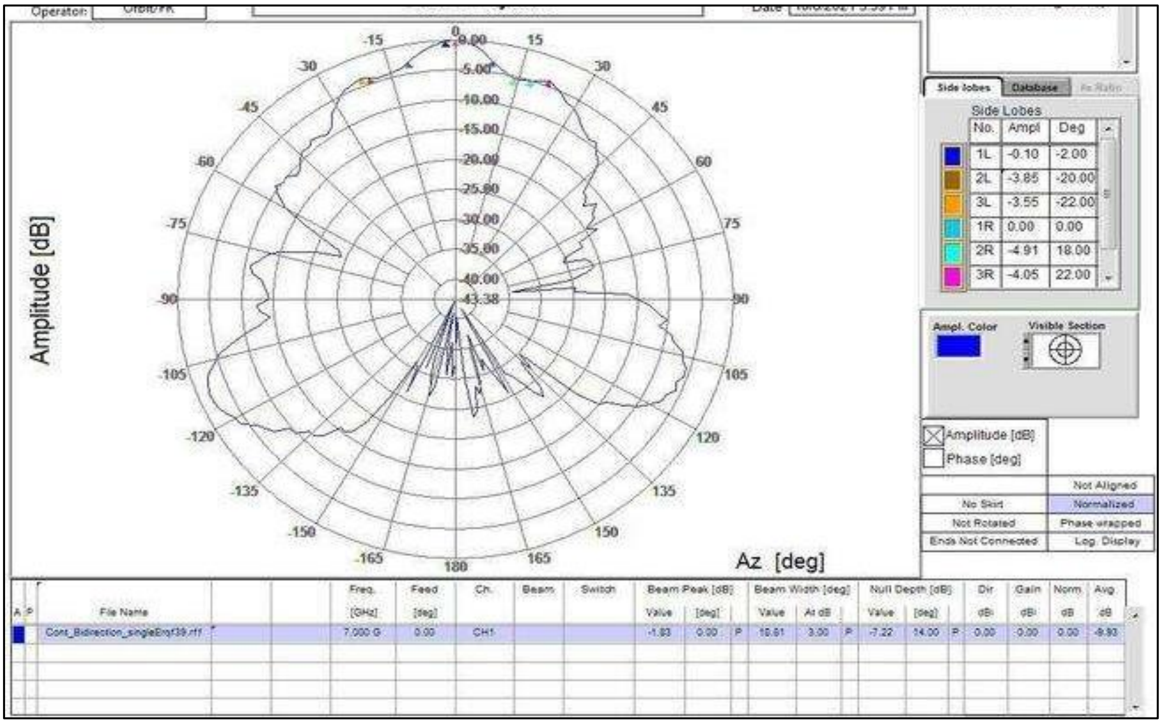

Fig. 13. Polar Pattern at 7 GHz

Figure 13 shows a radiation pattern in dB, called a polar pattern measured at 7 GHz. Beamwidth measured is 18.81°. It is observed that there are side lobes on both sides of the pattern. These side lobes need to be reduced for better performance as shown in figure 15 and figure 16.

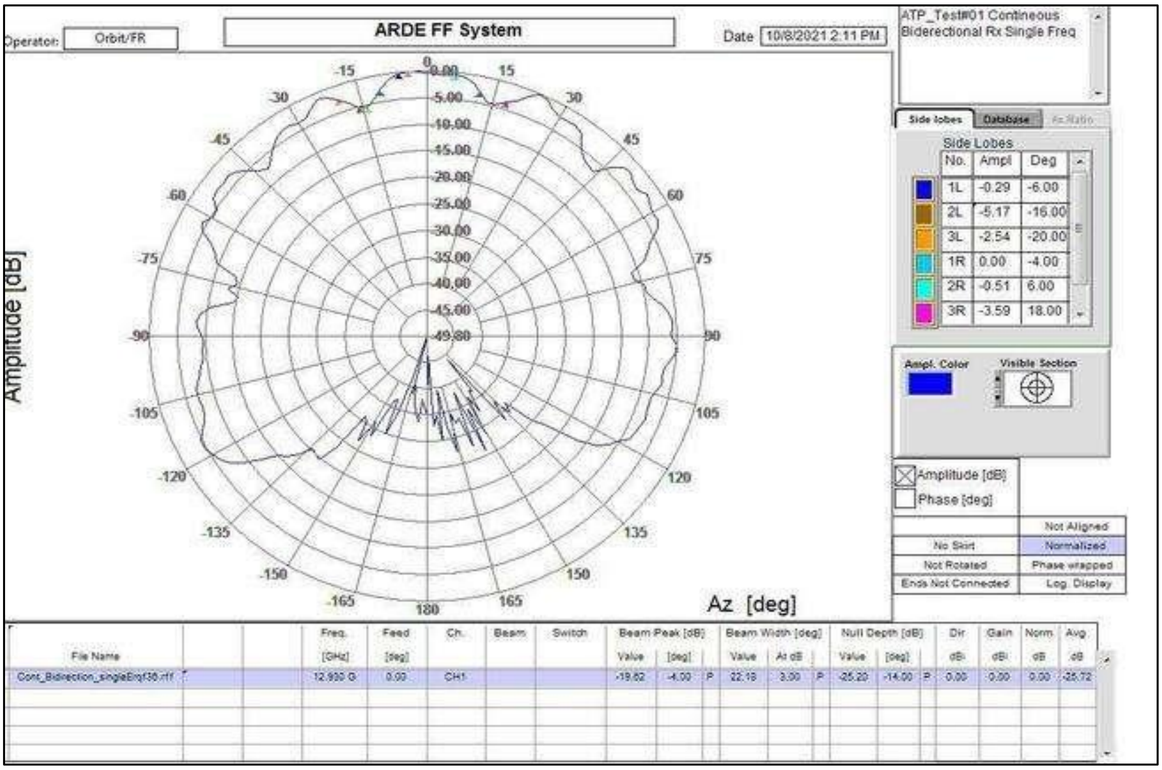

Fig. 14: Polar Pattern at 11.95 GHz

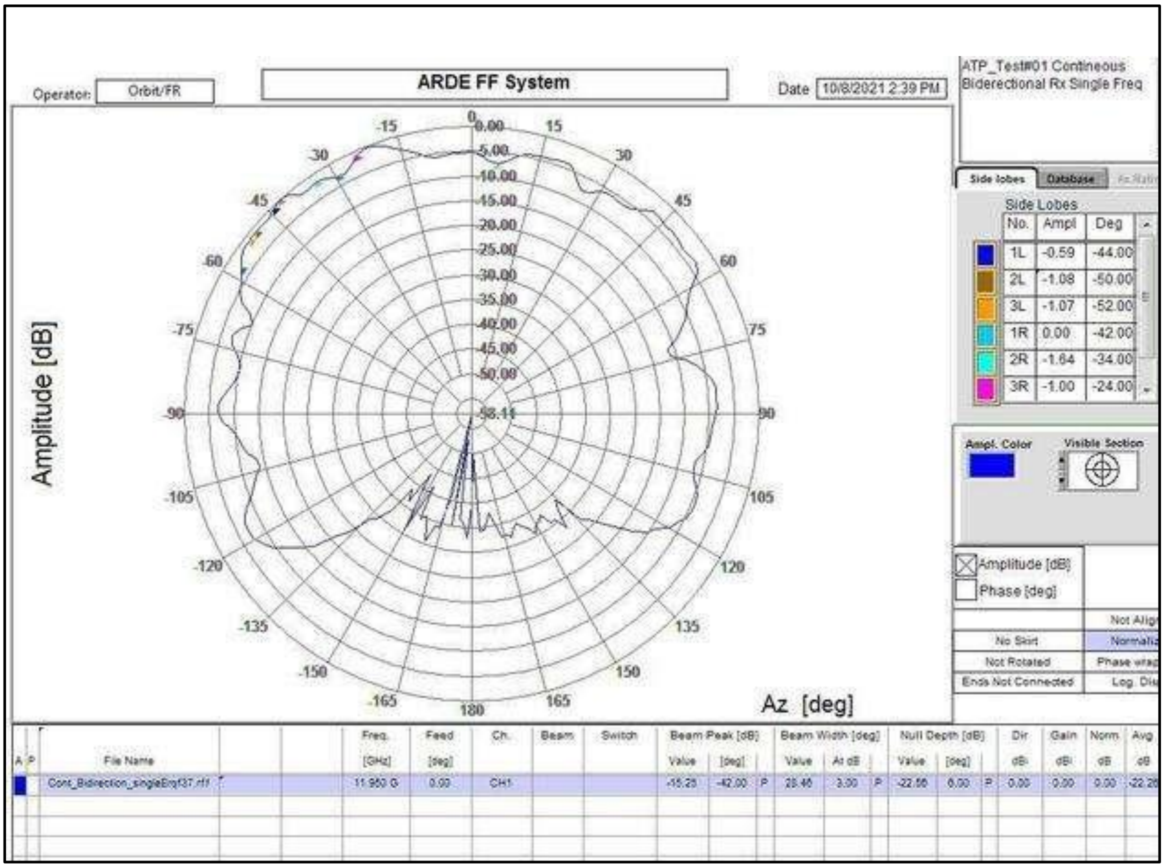

Fig. 15: :Polar Pattern at 12 GHz

Side lobes get reduced at 9.5 GHz, than previous figure side lobes. Beam width measured is 15.54° as shown in figure 16 and figure 17.

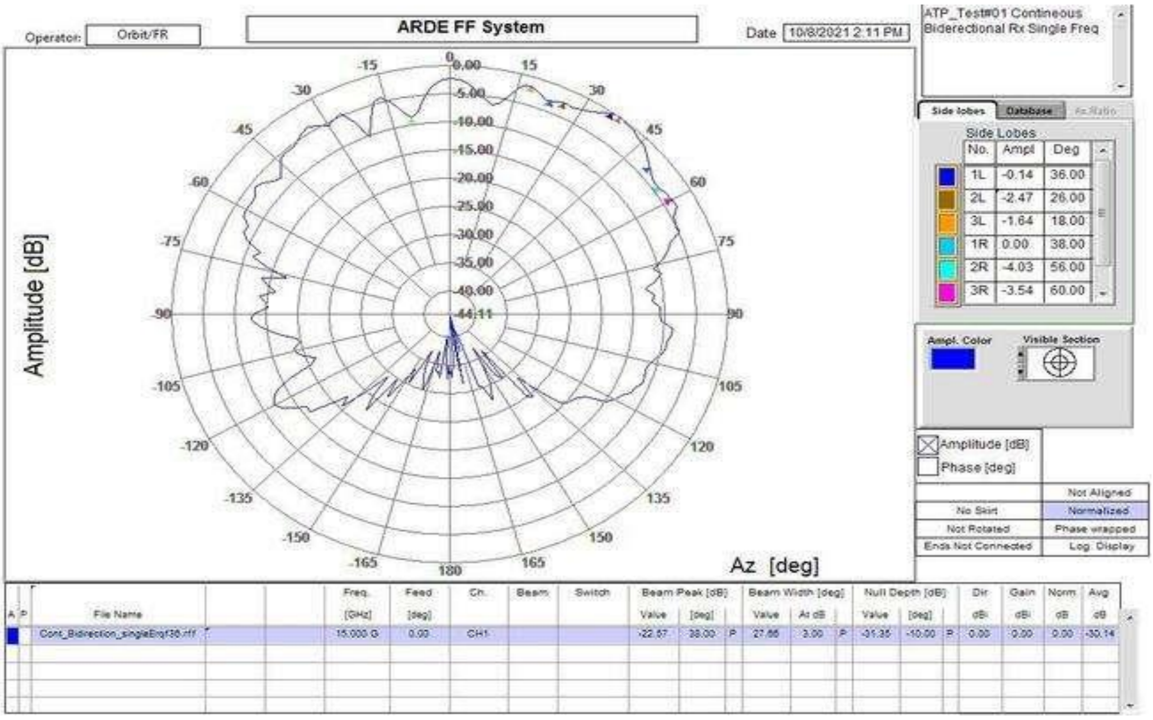

Fig.16. Polar Pattern at 15 GHz

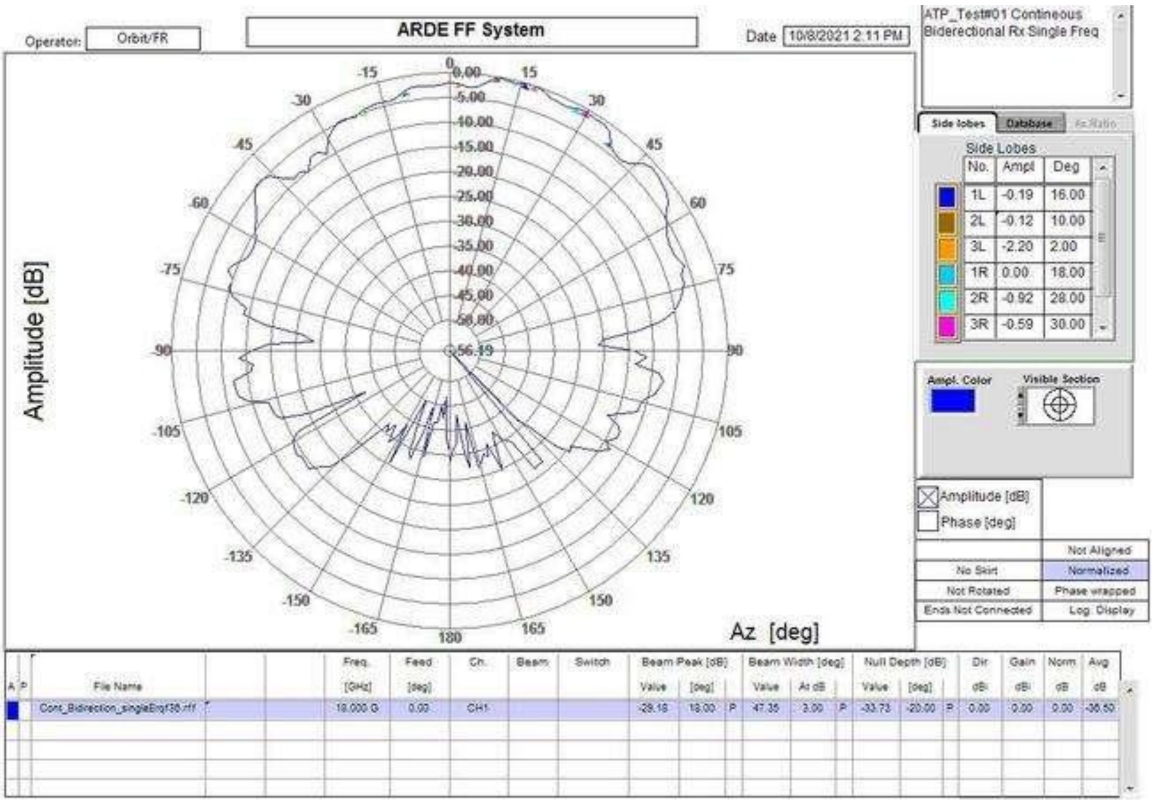

Fig.17. Polar Pattern at 18 GHz

Similarly, when 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, radiation pattern is closer to the pattern as desired.[11]

Simulated and Measured Results

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

Table: 2

Substrate Material	Return Loss-(dB)		Radiation efficiency (%)	
	Simulated	**Measured**	**Simulated**	**Measured**
Teflon	-16.846	-16.59	100	97.75

Comparision Wearable Antenna Structures:

Table: 3

Ref. no.	Size (mm^3)	Shape of the patch	Substrate	Return Loss (dB)	Radiation Efficiency (%)
[2]	60×60×1 40×401	Circular patch	Denim	<-10	95

[3]	60×60×1.5	Circular patch	Jeans	<-10	95
[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 patch3 stepped .block	Rogers 5880 printed circuit board	<-10	-
[12]	40*40	E	Jeans	<-10	60
[1, 4]	37271.524	Dual U-Slot H-Shape	FR4	-	-
Implemented structure	50401.4	**Simulated**	**Teflon**	**-16.846 (28.44max)**	**100**
	35240.787	**Measured**		**-16.595**	**97.75**

CONCLUSION

From the above radiation pattern measurements and observation made, we can conclude that for the designed antenna, side lobes get reduced as frequency goes on increasing. For higher frequency the radiation pattern is closer to the semicircle on one side which indicates a major lobe and on the other side very less signal strength. Hence, specific absorption rate is also within the acceptable limits. We can say that, when this antenna is used for wearable applications in the UWB range and beyond, very less energy is directed towards the human body, which does not cause any harmful effect on the human being. Return loss and radiation efficiency also gets improved for the designed structure.

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