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Analysis of Design Structuring and Performance of CPW Fed UWB Antenna in Presence of Human Arm Model

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Abstract**—**A compact Ultra Wide Band (UWB) antenna with co-planar waveguide feed has been designed and results are verified in this paper. The antenna has been designed on FR4 substrate with dielectric constant (ε_r) of 4.4 and dimensions of 32mm x 26mm x 0.8mm. The presented antenna shows return loss characteristics in the band of 3.1 to 10.6 GHz as prescribed by FCC, USA. Parametric studies have been done and results thus obtained have been presented. Simulated results have been verified on Rohde & Swartz VNA. The measured results are in good agreement with simulated results which make the presented antenna suitable to be used for wearable applications. Performance analysis of antenna has also been shown in the presence of three layered Human Arm model. Results obtained in presence of Human Arm model has been compared with that in free space.

Keywords**—**CPW feed, Human Arm model, UWB, wearable antenna.

I. Introduction

ULTRA Wide Band system, an extremely effective broadband system have been launched in the frequency range from 3.1–10.6 GHz, which has drawn the attention of a large number of researchers because of its advantages of low cost, resistant to jamming, severe multipath fading etc. [1], [2]. UWB systems cover a large spectrum and interfere with existing users. UWB bandwidth is the frequency range bounded by the points that are 10 dB below the highest power emission with the upper edge f_h and lower edge f_l. Thus, the centre frequency f_c of UWB bandwidth is given by:

$$BW = 2\frac{f_h - f_l}{f_h + f_l} \times 100\%$$
$$BW = \frac{f_h - f_l}{f_c} \times 100\%$$

In order to keep the interference of UWB system in coherence with other existing systems to a minimum level, the FCC and other regulatory groups specify certain spectral masks for different applications, which show the eligible power output for specific frequencies. A large contiguous bandwidth of 7.5 GHz is available between 3.1 GHz and 10.6 GHz at a maximum power output of −41.3 dBm/MHz.

To develop a suitable or optimal antenna moreover for UWB systems is always been a challenging task. Also, feeding of the antenna is an important task in the design. Feed system may include microstrip feed, coplanar waveguide feed, co-axial feed, aperture coupled feed etc. The type of feed to be used in any design has its own positives and negatives [3]. In some applications, the use of microstrip lines or striplines is prohibitive due to unavailability to access the ground plane and/or high line-to-line isolation requirements. In such situations, the coplanar waveguide (CPW) structure can be used. CPW was first reported in the literature by Wien [3].

The physical size of device determines not only possible dynamics, but also the practical size of antennas. Merging both these characteristics has shown significant influence on the radio propagation channel. Various researchers proposed various designs like diamond dipole, ellipsoidal monopoles and dipoles. Generally, in UWB antenna design, both “frequency” as well as “time domain response” should be taken into account. The frequency domain response includes input impedance and radiation characteristics. The impedance bandwidth is measured in terms of return loss or VSWR. Usually, return loss should be less than -10 dB or VSWR < 2. Antennas having an impedance bandwidth narrower than the operating bandwidth tailors the spectrum of transmitted and received signals, acting as a band pass filter in the frequency domain and reshape the radiated or received pulse in time domain [4]. For UWB antennas there are several additional requirements that have to be fulfilled for body centric applications, in terms of both physical size and radiation characteristics in the proximity of the human body as well [5].

In this paper, a compact UWB antenna has been presented, which works perfectly for ultra wideband from 3.1 GHz to 10.6 GHz. CPW feeding has been used to feed the antenna. Various design issues which are being addressed in literatures have been taken care of like bandwidth, physically compact and low profile. Frequency domain analysis in terms of return loss, VSWR has been presented here. In section II, simulated and measured radiation patterns of the proposed antenna are also being compiled and verified. Radiation pattern as measured in an anechoic chamber is also presented in this section. Section III provides the performance parameters of the antenna simulated in the presence of human arm model.

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II. Design of CPW Fed UWB Antenna

The majority of UWB antennas derived from monopole/ dipole, are generally tapered slot antennas, or loop antennas [5]. Different antenna types are expected to have dissimilar effects on the radio channels, especially in wireless body area network. Monopole and Dipole antennas are easy to model and analyze therefore they are used as reference. The commonly available UWB antennas are low profile monopoles. Fig. 1 shows front view of the proposed antenna.

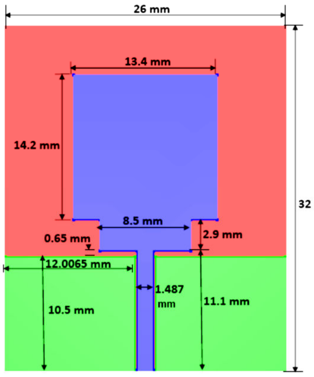

Fig. 1 Front view of proposed UWB Antenna

Optimized values for the presented design are given in Table I:

TABLE I
Patch Dimensions

Description	Value
Patch length (pl)	14.2 mm
Patch width (pw)	13.4 mm
Step length (sl)	2.9 mm
Step width (sw)	8.5 mm
Ground length (gl)	10.5 mm
Ground width (gw)	12.0065 mm

All the results for optimized design are shown in Figs. 2-11. Fig. 2 shows optimized return loss (S_{11}) characteristics. From the figure it is clear that the lower cut off occurs at 3.3 GHz and higher cut off is at 14.29 GHz, which is well within the prescribed limits for UWB. Total 10 dB bandwidth is 11 GHz.

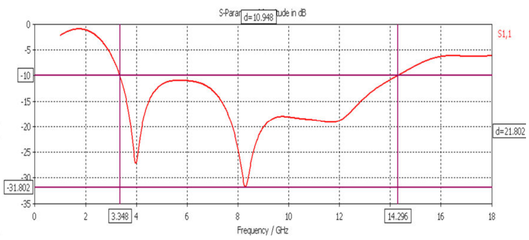

Fig. 2 Optimized reflection coefficient characteristics.

Fig. 3 shows VSWR characteristics of the antenna. Throughout the range from 3.3 GHz to 14.29 GHz, the VSWR is below 2.

Figs. 4 and 5 show "Radiation Efficiency" and "Gain Curve" respectively of the proposed antenna. It is shown that radiation efficiency is varying between 80-90 % in the entire band of interest. Total efficiency is almost constant and around 90% for entire band.

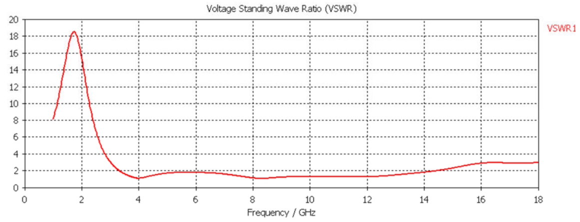

Fig. 3 VSWR characteristics

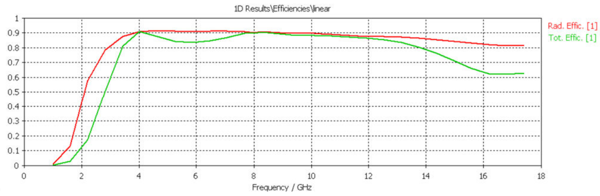

Fig. 4 Radiation Efficiency

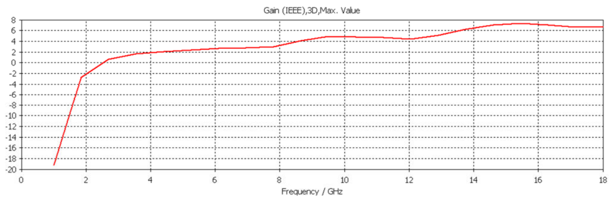

Fig. 5 Gain Vs Frequency

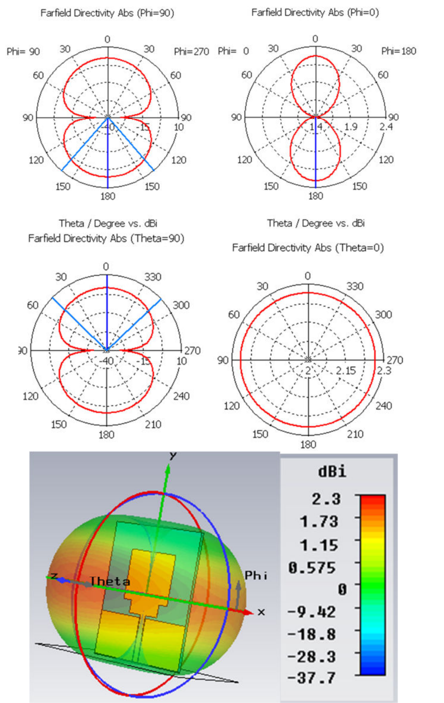

Fig. 6 Far field and polar radiation pattern at 4 GHz

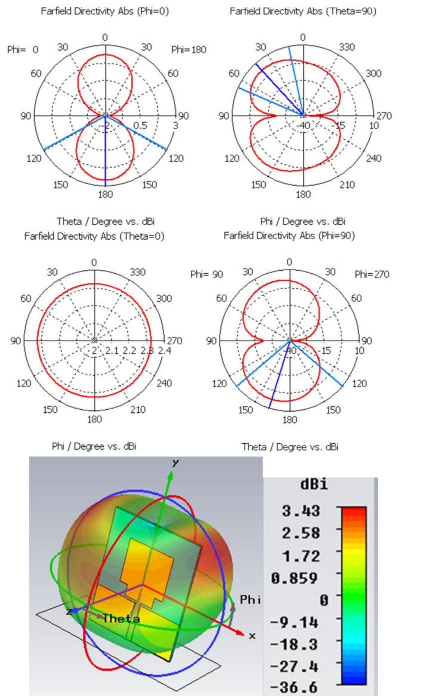

Fig. 7 Far field and polar radiation pattern at 8 GHz

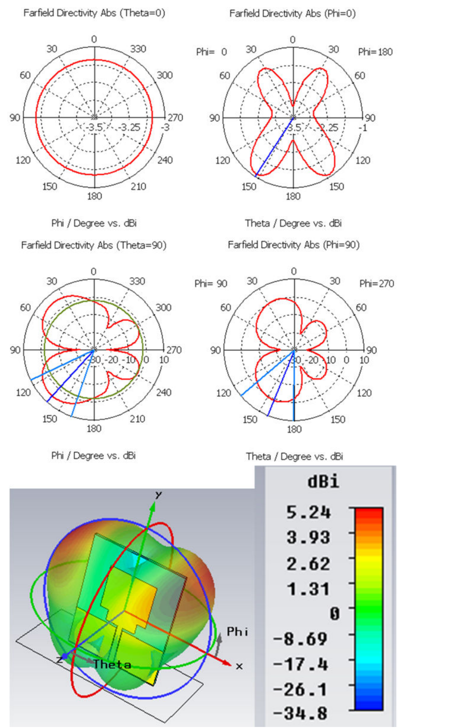

Fig. 8 Far field and polar radiation pattern at 10.6 GHz

Gain of the antenna is almost constant; in fact it is slowly increasing between 2 to 5 dB with frequency. It is increasing as we see it in the higher frequency range.

Figs. 6-8 show E-plane & H-plane radiation patterns of the antenna at 3.1 GHz, 5.8 GHz and 10.6 GHz respectively. It is shown that, as the frequency increases the radiation becomes directive. The reason being the antenna becomes electrically large at higher frequencies.

Figs. 9 and 10 show current distribution in antenna structure at 3.1 GHz and 10.6 GHz respectively. It clearly shows that at lower frequency, most of the current is concentrated near to the input line and ground. So, lower frequency is mostly affected by these parameters (input line width and spacing between line and ground). At higher frequencies, current is mostly concentrated near to the patch ends and ground. So, the higher cutoff frequency is much affected by patch dimensions and ground length. It is also verified through return loss characteristics.

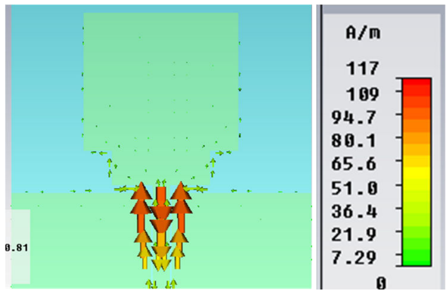

Fig. 9 Current distribution at 3.1 GHz

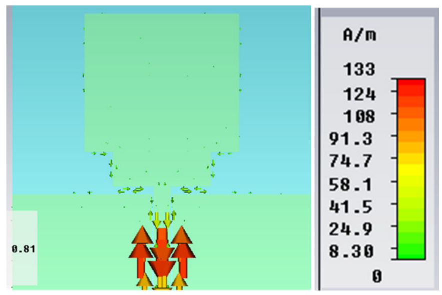

Fig. 10 Current distribution at 10.6 GHz

A prototype as shown in Fig. 11 has been designed using MIC technology. It is fabricated through photolithography process.

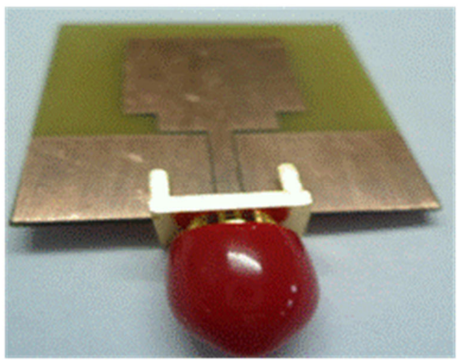

Fig. 11 Prototype of designed antenna

Fig. 12 shows the measured return loss parameter on VNA for the proposed antenna. Fig. 13 compares the measured parameter with simulated result. Lower -10 dB cut off occurs at 3.5 GHz and higher cut off occurs at 12.04 GHz. So, the proposed antenna can easily be employed for UWB applications.

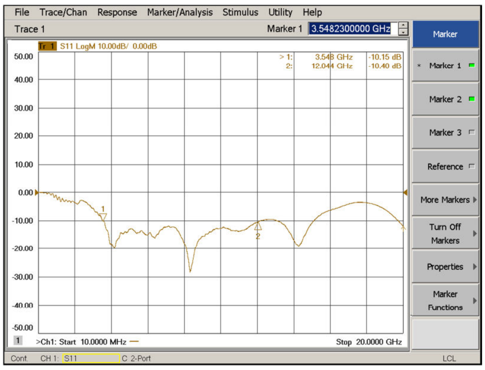

Fig. 12 Scattering parameter measured on VNA

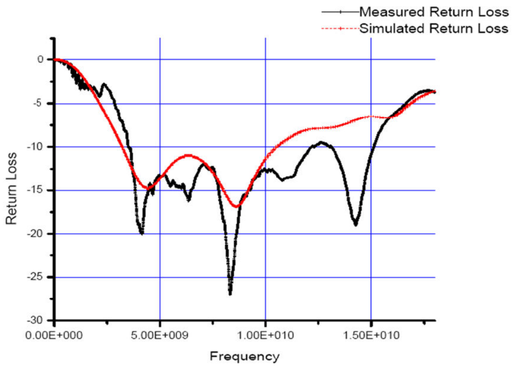

Fig. 13 Comparison of Simulated and measured reflection coefficient

Figs. 14-16 show the radiation pattern of printed antenna as measured in anechoic chamber at 4 GHz, 7 GHz and 10 GHz respectively. It clearly shows that the radiation pattern becomes directive at higher frequency as was also shown in simulated results.

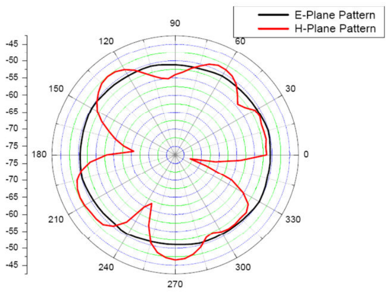

Fig. 14 Radiation pattern of UWB Antenna 4GHz

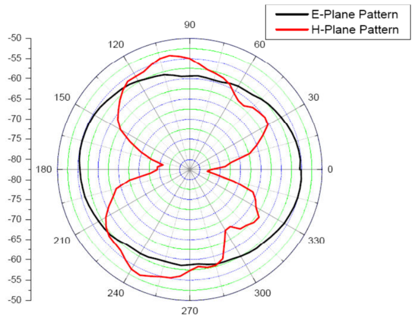

Fig. 15 Radiation pattern of UWB Antenna 7GHz

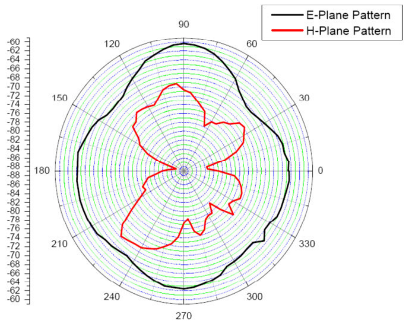

Fig. 16 Radiation pattern of UWB Antenna 10GHz

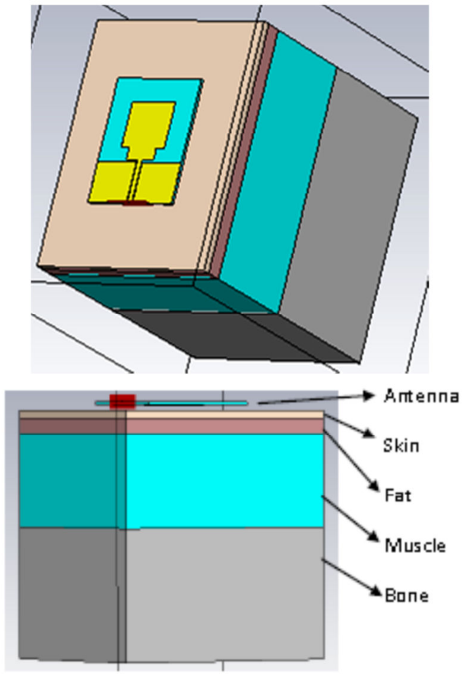

Fig. 17 UWB Antenna with Human Arm Model

TABLE II
ARM MODEL DIMENSIONS

Description	Value
Skin Thickness	2 mm
Fat Thickness	4 mm
Muscle Thickness	25 mm
Bone Thickness	35 mm

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III. Performance Analysis of Antenna in Presence of Human Arm Model

After the verification of various parameters of the proposed antenna, it was simulated in the presence of human arm model. Various literatures are browsed on "layered structure of the body with its biological tissue values" [6], [7]. A three layered structure with dimensions 64 mm by 52 mm has been considered as human arm to test the affectivity of the antenna. Various dimensions of the arm are given in Table II. The model has been considered to be lossy for UWB band as provided in literatures. Fig. 17 shows the antenna structure with arm model as designed in CST simulator.

Return loss for the proposed structure has been presented in Fig. 18. It is shown that lower 10 dB cut off occur at 3.1 GHz. Return loss occurs below -10 dB between 3.1 GHz to 5 GHz. It again becomes below -10 dB between 7.3 GHz to 14.6 GHz.

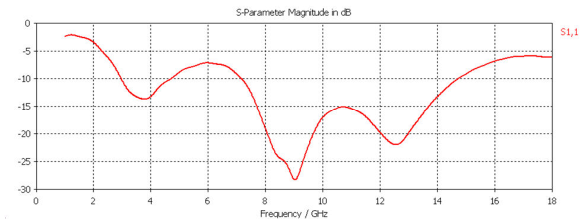

Fig. 18 Scattering parameter of Antenna with Human Arm Model

Fig. 19 compares scattering parameter of antenna for two conditions one in free space and other in the presence of human arm.

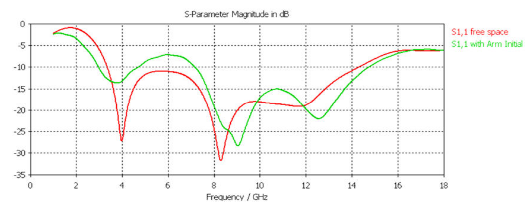

Fig. 19 Comparison of return loss of Antenna with and without Human Arm Model

Fig. 20 compares the radiation pattern of the antenna when placed in free space and in proximity to the "human arm". Green color shows pattern in free space and red shows pattern in presence of arm model. It is observed from the figures that radiation of the antenna at higher frequencies becomes unidirectional and little directive. It is shown clearly in the figures that presence of human arm greatly affects the radiation.

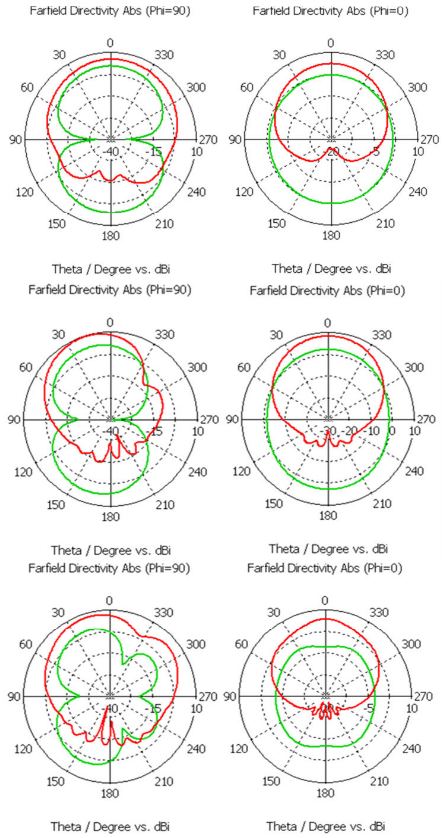

Fig. 20 Comparison of E-plane and H-plane radiation patterns with and without Arm Model at 3.5 GHz, 8 GHz and 10.6 GHz

IV. Conclusion

A compact CPW fed UWB antenna on FR4 substrate with 0.8 mm thickness and dielectric constant of 4.4 has been presented. It has an Ultra Wide Band of 8.5 GHz between 3.3 GHz to 14.2 GHz, which is well within the prescribed standards and requirements. Results have been verified on VNA. Radiation patterns at various frequency points have been measured for fabricated antenna in an anechoic chamber. Measured results are in close agreement with simulated results. The antenna has been simulated in the presence of human arm model. Simulated results in the presence of arm are presented. Performance of the antenna with that of antenna in free space has been compared. Results show that the presented antenna can easily be employed for wearable applications.

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