A compact size and low profile rectangular slot monopole antenna for UWB body centric applications

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Abstract - A compact-size rectangular slot antenna required for ultra-wide band body centric applications is presented. The antenna design is based on etching a rectangular slot on a circular radiator. The antenna is optimized using a surrogate assistance differential evolution algorithm to produce the largest bandwidth in free space and close to the human body. Analysis of the proposed antenna was carried out and its performance assess in terms of bandwidth, gain, efficiency, and radiation pattern. Results investigated shows that the rectangular slot antenna maintains its bandwidth when placed in closed contact with the human body. The very close agreement between the simulated and measured results both in free space and on body indicates that the antenna is immune to variation in the human tissues and also robust to fabrication tolerances.

Keywords—Monopole antenna, ultra-wide band antenna, body-centric communications.

I. INTRODUCTION

The release of the ultra-wideband (UWB) spectrum ranging from 3.1 – 10.6 GHz for unlicensed use by the Federal Communications Commission (FCC) in the US in February 2002 [1], has led to numerous UWB technology applications. Amongst these applications are in the area of through the wall imaging radar [2],breast cancer imaging [3], ground penetrating radar[4], and body centric wireless applications[5]. Body centric wireless communications required UWB antennas to communicate in the off-,in-, and on-body and this has led to rapid development of UWB antennas for wearable applications in military gadgets, sports, and biomedical applications[6, 7].

The advantages of UWB antennas on body centric applications over narrow band antennas include large bandwidth, high resolution, and high data rate, low cost, resistance to interference, reasonable gain, and low power consumption. These attractive features enable UWB antennas to have high resilience to fading, low probability of detection, and also guarantees the signal robustness for data transmission, which is one of the key advantage of a body-centric wearable device that operate in a very challenging environment. However, the design of UWB antenna is very difficult as compared to narrow band antennas due to the requirement of broadband operation in terms of return loss, impedance matching, group delay, radiation pattern and fidelity.

In the past, many UWB antennas have been designed for body centric wireless applications [8-10]. Body centric UWB antenna performance are best evaluated when the antennas are designed in close proximity to the body. Body tissues absorbs some of the power supplied to the antenna and this reduces the radiation efficiency of the antenna which would in turn affect the radiation efficiency and gain of the antenna. As antennas for body centric applications suffers set back from radiation efficiency when in close contact to the human tissues due to electromagnetic radiation, effective and efficient antennas need to be designed in order to evaluate the antenna performance in close proximity to the human tissues.

This paper presents design, optimisation and physical implementation of a compact ultra-wide band (UWB) monopole antenna with attractive features including bandwidth, gain, efficiency, high fidelity, high immunity, and compactness suitable for body centric applications. Parallel Surrogate model assisted differential evolution for antenna synthesis (PSADEA) [11] algorithm is utilised to achieve the desired impedance bandwidth both in free space and close to the human tissues. The remainder of the paper is structured as follows: Section II presents proposed antenna design and prototype, while section III investigates the results and finally conclusions are drawn in Section IV.

II. PROPOSED ANTENNA DEDSIGN AND PROTOTYPE

The proposed antenna geometry consists of a L_s x W_s = 33.12 x 14.90 mm^2 fabricated on a FR-4 substrate of thickness 0.8mm (with ε_r = 4.3 and tan δ = 0.025). On the top of the substrate is a circular radiator with radius of 14.42 mm consisting of a rectangular slot having length and width of L x W = 12.06 x 5.98 mm^2 respectively. The slot is generated to create additional resonant across the whole UWB frequency and also control the input impedance. At the bottom of the substrate are two partial rectangular structure acting as the ground planes measuring L x W = 18.05 x 6.19 mm^2 as shown in Fig.1. The physical implementation of the antenna is depicted in Fig.2. A 50 Ω coaxial transmission line is used to excite the antenna.

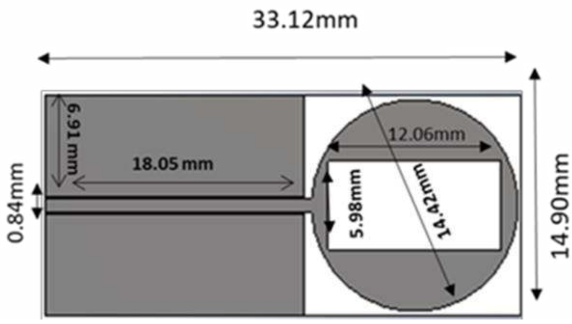

Fig.1. Geometry model of the proposed antenna.

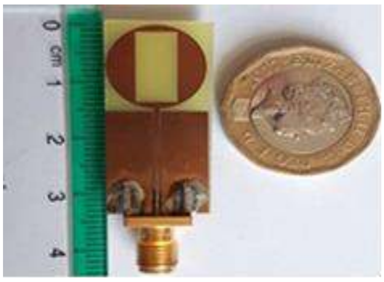

Fig.2. Prototype of the proposed antenna.

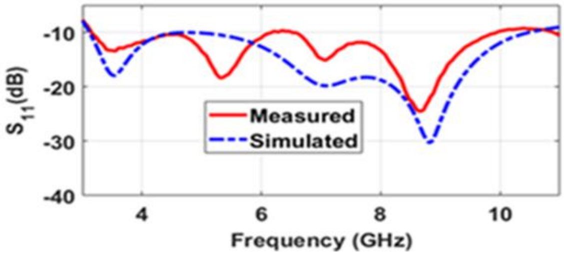

Fig.3. Free space simulated and measured results.

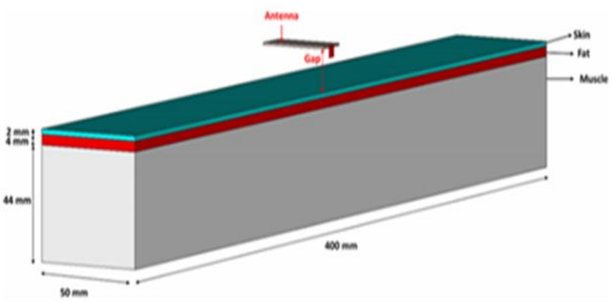

Fig.4. Body phantom model with the antenna.

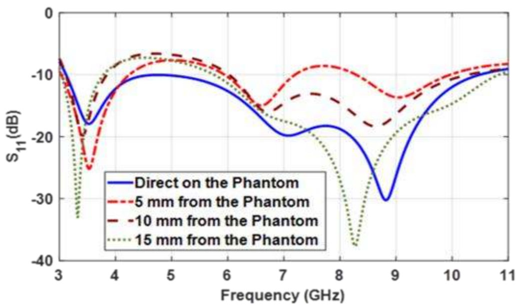

Fig.5. S11 plots of the antenna in close proximity to the phantom.

III. RESULTS AND DISCUSSION

The proposed antenna was simulated in free space as shown in Fig.3 and in close proximity to a three-layer phantom mimicking the human arm model. The model composed of skin (ε_r = 45.85, σ = 1.59), fat (ε_r = 5.28, σ = 0.1), and muscle (ε_r = 52.73, σ = 1.74), all these are calculated at the lower edge band of the UWB spectrum of 3.1GHz[12]. The dimension of the phantoms were taken from [13] as shown in Fig. 4.

The effect of the human body was observed when the antenna is varied in distance dimensions ranging from 3mm to 15 mm and the response of the antenna performance were investigated as shown in Fig.5.

The antenna response and performance in Fig.5 indicates that the antenna is a good candidate for the body centric applications as it S_{11} does not change significantly when in free space and in close proximity to the phantom.

IV. CONCLUSION

A simple and compact ultra-wide band antenna has been proposed for body centric wireless applications. A rectangular slot on the radiating circular patch is introduced to control the antennas performance and input impedance. The antenna performance is stable in close proximity to the body tissues. The very good agreement between the free space results and on body results make this antenna a good candidate for body centric applications.

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