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 geometric design parameters are determined by a state-of-the-art AI-driven antenna design method. Analysis of the proposed antenna was carried out and its performance assessed in terms of bandwidth, gain, efficiency, and radiation pattern. Results investigated show that the rectangular slot antenna maintains its bandwidth when placed in closed contact with the human body phantom. The very close agreement between the simulated and measured results both in free space and on body indicates that the antenna performance is immune to variation in the presence of human body phantom and robust to fabrication tolerances.

Keywords— Monopole antenna**,** UWB 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 require 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 over narrow band antennas for body centric applications 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 guarantees the signal robustness for data transmission, which is one of the key advantages of a body-centric wearable device that operate in a very challenging environment. However, the design of UWB antenna could be very challenging 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 operating near 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 suffer 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 the design, optimisation and physical implementation of a compact ultra-wide band (UWB) monopole antenna with attractive features in terms of bandwidth, gain, efficiency, high fidelity, high immunity, and compactness suitable for body centric applications. The parallel surrogate model assisted differential evolution for antenna synthesis (PSADEA) [11], [12] algorithm is utilised to achieve the desired impedance bandwidth. 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 circular radiator driven by a 50 Ω microstrip line, two rectangular ground planes constituting a partial ground. The antenna is implemented on an FR-4 substrate of thickness 0.8mm with ε_r =4.3 and tan δ =0.025. The layout and dimensions of the proposed antenna are shown in Fig. 1. A slot is etched into the circular radiator to induce additional resonance across the UWB and control the input impedance. The physical implementation of the antenna is shown in Fig. 2.

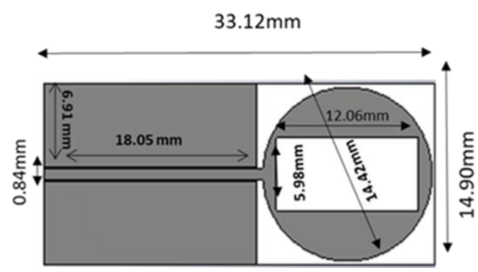

Fig.1. Geometry model of the proposed antenna.

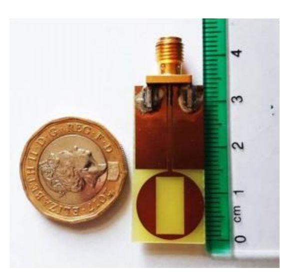

Fig.2. Physical implementation of the proposed antenna.

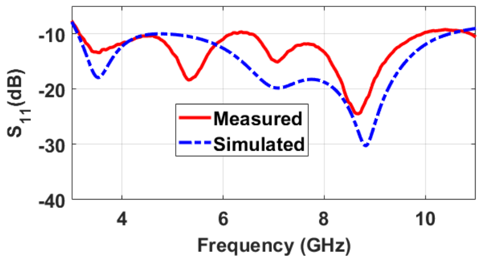

Fig.3. Free space simulated and measured results.

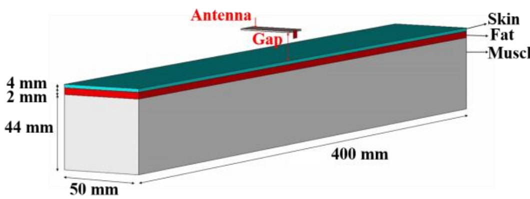

Fig.4. Body phantom model with the antenna.

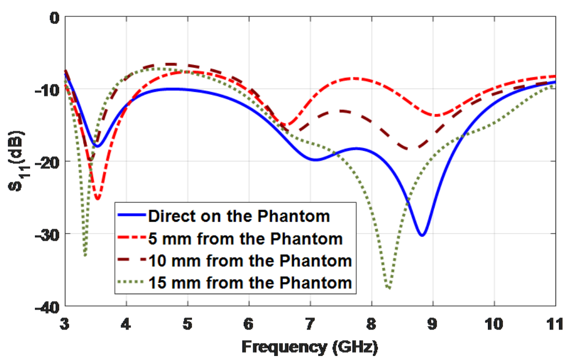

Fig.5. S_{11} plots of the antenna near the phantom.

III. RESULTS AND DISCUSSION

The proposed antenna was simulated in free space as shown in Fig. 3 and near 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 [13]. The dimension of the phantoms are according to [14] as shown in Fig. 4.

The effect of the human body was observed when the distance of the antenna from the human body is varied ranging from 3mm to 15 mm and the antenna response is studied and shown in Fig. 5. From Fig. 5, it can be seen that the antenna is a good candidate for the body centric applications because its S_{11} does not change significantly when in free space and near the phantom.

IV. CONCLUSION

A compact and low profile UWB antenna has been proposed for wireless body centric applications. A rectangular slot etched into the radiating circular patch is introduced to control the antennas performance and input impedance. The antenna performance is stable near the human body phantom. A very good agreement between the free space results and on body results makes the proposed antenna a good candidate for wireless body centric applications.

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