Design of UWB Wearable Conformal Antenna for Body Area Networks

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Abstract - In this paper, a wearable ultra-wideband (UWB) micro-strip antenna is designed to meet the demand for Wireless Body Area Network (WBAN). This is a wearable textile antenna, which was formed on a jeans fabric substrate to reduce surface-wave losses. The single-fed circular strip monopole antenna provides good impedance matching over the entire UWB frequency range of 2.9∼10.6 GHz. The dielectric constant εr 2.2, and the loss tangent tan δ 0.04 of the jean substrates are measured by using the coaxial ring method. The proposed antenna consists of an improved circular radiation patch with the defective ground structure to expand the frequency band of the antenna and improve the radiation characteristics of the antenna with small dimensions of 20 × 30 × 1.4 mm3. In addition, structural deformation of the proposed antenna is performed to analyze the flexibility of the proposed antenna. The simulated SAR values follow the FCC limit, making it most suitable for wearable applications.

***Key Words*:** Antenna, S-Parameters, Far Field Directivity, Applications of Antenna, HFSS.

1.INTRODUCTION

In this paper, a wearable antenna with an improved circular patch for WBAN is proposed, which uses denim fabric as the substrate and consists of a circular radiating patch with a square slot in the middle, a rectangular micro-strip line, and a defective ground structure to achieve the coverage of the whole UWB frequency range from 3.1 GHz to 10.6 GHz. A stable omnidirectional radiation pattern is obtained with the required gain and efficiency over the entire UWB frequency range. The antenna is small in size, bendable, easy to integrate, easy to process, and suitable to be integrated to wear on a hat.

WBANs are networks distributed around the human body. WBAN is mainly used to detect and transmit the user's physiological data and cooperates with other networks to integrate the human body into the overall network [1]. Nowadays, wearable electronics are becoming popular and usability, functionality, durability, safety, and comfort have become essential elements of wearable systems [2]. The potential applications of wearable antennas for tracking, navi gation, public safety, and health monitoring are also

increasing [3]. In military applications, wearable antennas can provide personal positioning and mobile communication through helmets [4, 5]. In healthcare, wearable antennas can monitor physiological information, such as blood pressure, blood glucose concentration, temperature, weight, and heartbeat [6–8]. These applications face limitations due to electromagnetic coupling between the human body and the antenna, changing physical deformations, highly variable operating environments, and manufacturing processes [9–11]

2. Body of Paper

The structure of the circular ultra-wideband antenna designed in this article is shown in Figure 3. The dielectric substrate is 20 × 30 × 1.4 mm3, and studies on all impedance matching have resulted in a 50 Ω micro-strip feeder for antenna feed achieved by the HFSS 19.0. The key parameters of the antenna are optimized with the optimization goal of performance and impedance matching, and the specific antenna size parameters are shown in Table 1. As shown in Figure 4, the design process of the ultra-wideband antenna structure is described in this paper. Figure 5 and Figure 6 show the s11 and surface current distribution of the antenna at different stages. Figure 4(a) depicts the original structure of the antenna design, using a 50 Ω rectangular micro-strip line, a circular radiation patch, and a rectangular ground plate. The antenna model is a simple and small-size antenna. The original model's working band is 3.5 GHz to 10 GHz and 10.3 GHz to 14.5 GHz (stage 1).

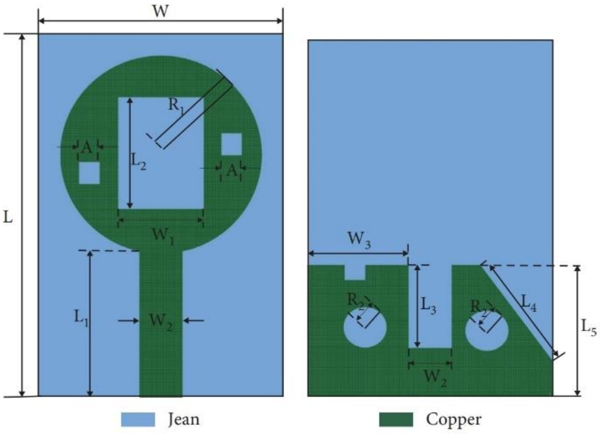


FIGURE 3: Geometry of the proposed antenna. (a) Front view. (b) Rear view.

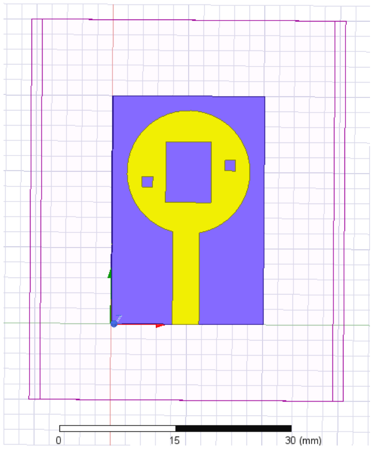


Fig.Front View

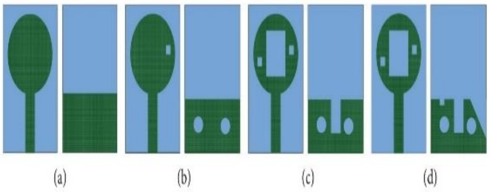


FIGURE 4: The design process of the UWB antenna. (a) Round monopole antenna. (b) Slotted circular antenna. (c) Microstrip anten rectangular slot. (d) Improved circular microstrip antenna with asymmetric defect ground.

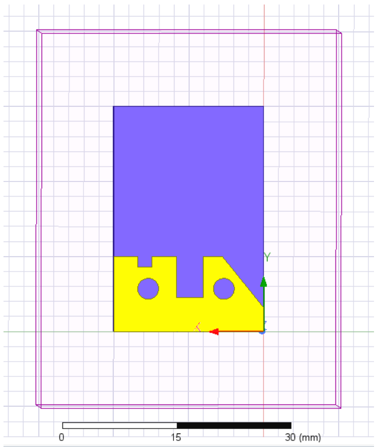


Fig.Back View

Table -1: Antenna Basic Size Parameters

TABLE 1: Antenna basic size parameters.

Parameters	Sizes (mm)	Parameters	Sizes (mm)	Parameters	Sizes (mm)
W	20	L	30	L_4	10
W_1	6	L_1	12	L_5	10
W_2	3.5	L_2	8	R_1	8.1
A	1.4	L_3	5.5	R_2	1.4

Fig.1

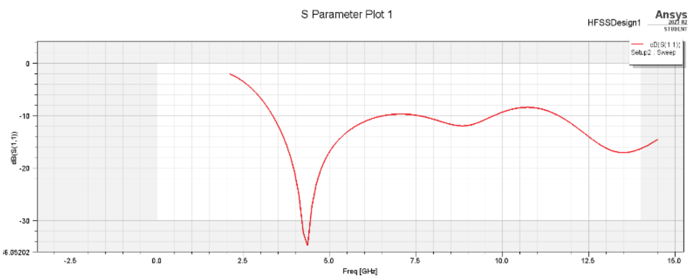


Fig.Stage-1

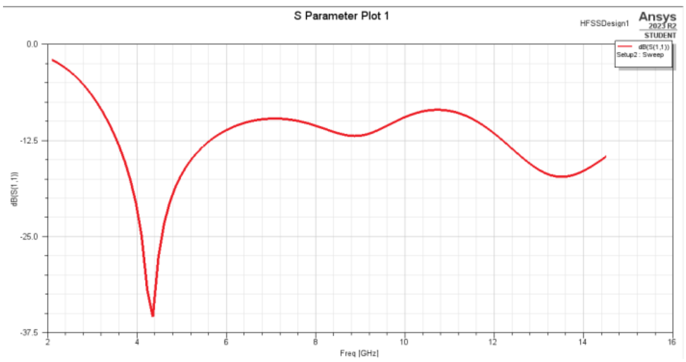


Fig.Stage-2

Rectangular slots are cut in the antenna base plate and asymmetric rectangular slots are cut in the center of the circular radiating patch at stage 2. After adding slots, the current paths have been changed by the inserted structures at 8 and 10 GHz separately.

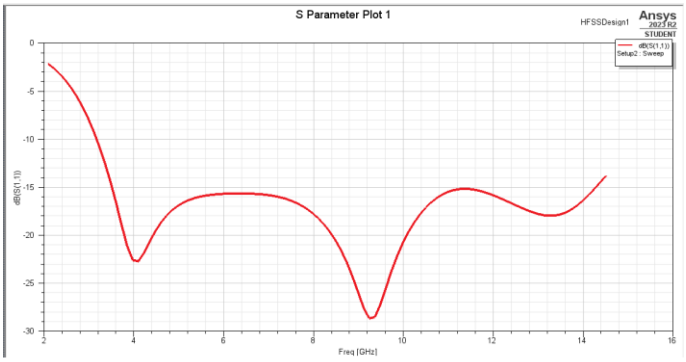


Fig.Stage-3

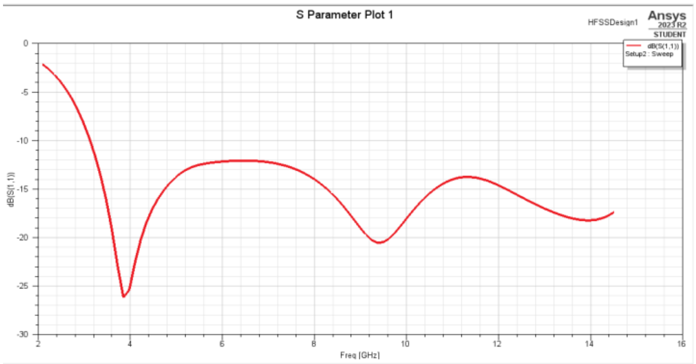
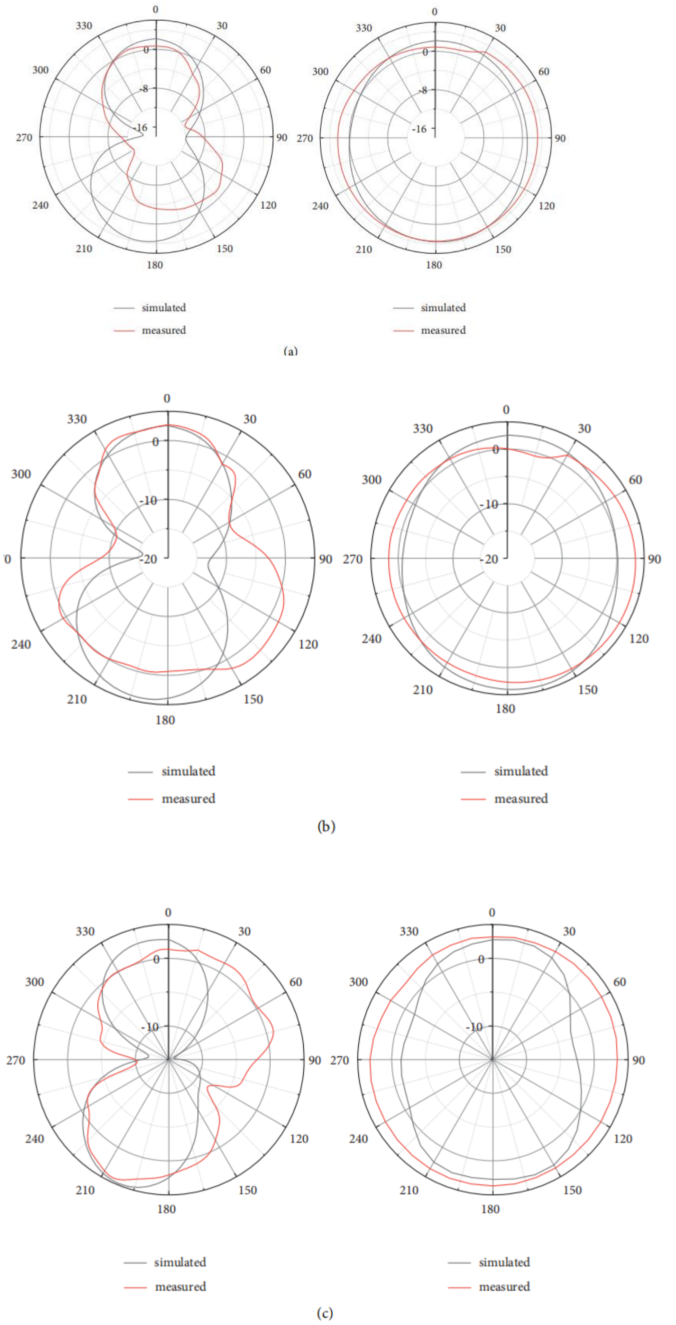


Fig.Stage-4

The antenna is based on denim fabric with copper as the conductive material. Due to the limitations of the process, copper cannot be directly attached to the fabric substrate. The adhesion of the conductive material to the fabric substrate is very important. In antenna fabrication, direct metal soldering is used to connect the top radiating patch and ground plane to the coaxial connector. Antennas are manufactured to meet the requirements of the wearer's demands for compact size,

flexible materials, easy to clean, and very attractive wearable devices.

3. FARFIELDS



Free space comparison of simulated and measurement radiation pattern in the YOZ-plane and XOZ-plane.

(a) 4 GHz. (b) 6.5 GHz. (c) 8 GHz.

The radiation patterns are measured in the anechoic

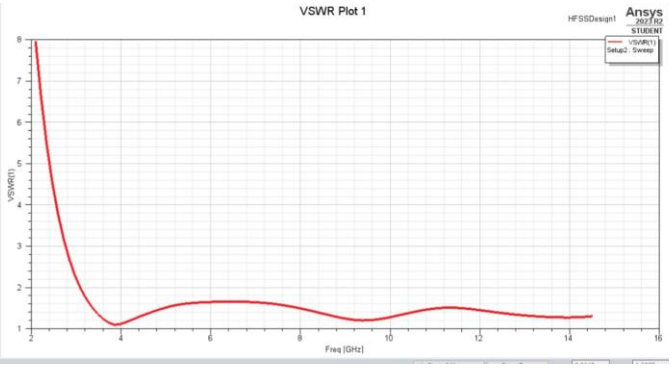
chamber. The comparison of the simulated and measured normalized directional maps of the proposed antenna in the YOZ-plane and XOZ-plane of the free space at diferent frequencies, such as 4 GHz, 6.5 GHz, and 8 GHz.

4. VSWR

These values are crucial indicators of the effectiveness of power transfer between the antenna and transmission line. A VSWR value nearing 1 indicates optimal impedance matching and minimal signal reflection, while higher values suggest impedance mismatches and potential signal degradation. Understanding these VSWR values is pivotal as they validate the antenna's performance and its suitability for operation at designated frequencies, guaranteeing reliable signal

transmission and reception capabilities.

The performance of the antenna is analyzed by using parameters such as refection coefficient, radiation pattern, gain, and efficiency.



5. CONCLUSIONS

An ultra-wideband wearable conformal antenna based on jean fabric is designed. The antenna satisfies the WBAN requirements and uses denim fabric as the substrate, which can be integrated into a hat. The proposed antenna provides good impedance matching throughout the UWB frequency range through a circular radiating patch with a rectangular slot in the middle, a rectangular micro-strip line, and a defective ground structure. While examining the performance of the antenna under bending and on the head, a slight shift in resonant frequency is observed. The antenna has the features of small size, easy integration, bendability, and low impact on antenna performance when placed in front of a human head, which makes it a wearable antenna with use-value.

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