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ORIGINAL CONTRIBUTION

The performance of a wearable antenna under bending conditions Designed on a Used Jeans for the ISM band

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ABSTRACT

In recent days, an increase in healthcare activities has prompted the importance of the Wearable Body Area Network (WBAN). In a WBAN, sensors and devices are integrated around the body to measure and track the blood pressure, temperature, oxygen level in blood, pulse rate, etc. WBAN ensures that the data are collected and transmitted without hampering the comfort of the individual. A wearable antenna, which is placed either on the clothes or any other wearable material, is used to connect the WBAN with the LAN for transferring data to the outer world. So far, many researchers have reported wearable antennas that are designed on low-loss engineered material. In our work, we have designed a wearable antenna on highly lossy, day-to-day used jeans. The jeans used here is collected from a local market. It is characterized in the dielectric probe kit using the Open-Ended Coaxial Probe technique. The dielectric constant and loss tangent of jeans are tanδ=0.1152 and r=1.7976, respectively. The antenna is designed to resonate at 2.45 GHz. The gain obtained is 1.8 dBi, and the radiation efficiency is 19%. The gain obtained is sufficient for indoor operation. The antenna is integrated on the human body; thus, the bending effect on the performance of the antenna is also studied. The antenna is optimized for optimal performance.

KEY WORDS: Wearable Antenna, Wearable Body Area Network (WBAN), ISM Band

1. INTRODUCTION

The use of electronic gadgets in the healthcare sector is increasing day by day to measure and track patients' health conditions. The sensors and devices that are integrated around the body to measure and track parameters like blood pressure, temperature, oxygen level in blood, pulse rate, etc., form the WLAN. These data are transmitted to the outer world by establishing a connection between the LAN and WLAN wirelessly. It must be wireless, considering the mobile condition of the patient. Therefore, the wearable antenna integrated on the clothes or any otherwearable things is suitable to establish the link [1-2]. The wearable antennas reported so far are designed on engineered low-loss fabric, which also increases the cost [3-6]. In our work, we have used highly lossy, day-to-day used jeans to design wearable antennas.

Since wearable antennas are integrated with wearable garments without hampering the comfort of the individual, a planar structure configuration is suitable for the purpose. Specific absorption rate (SAR) plays an important role here. The back radiation of the patch antenna is very poor because of the presence of the Ground plane, thereby reducing the SAR value [7-10].

Bin Hu et. al. have designed two dipole antennas on a low-loss felt fabric for wearable applications [3]. B. Mandalet. al. have reported a circular-shaped monopole printed antenna on low-loss cotton fabric [4]. A rectangular-shaped patch antenna designed on low-loss jeans substrate for the 2.45GHz ISM band is reported by Sweety Purohit and Falguni Raval [6].

A wearable antenna may deform and bend while being worn on the body. It affects the resonant frequency and antenna performance. Lingnan Song and YahyaRahmat-Samii have studied the bending effect on a patch antenna [11]. In another study by Ivo Locher et al., a purely textile wearable antenna was designed to resonate at 2.4GHz and studied the bending effect [12].

In our work, we have used day-to-day jeans as the substrate to design the wearable antenna. The jeans is collected from a local market and is characterized using Open Open-Ended Coaxial Probe (OECP) technique. The dielectric constant of the material is 1.7976, and the loss tangent is 0.1125. The thickness of the single-layer jeans is 0.425mm. The jeans fabric is highly lossy compared to an engineered wearable material [13]. The highly lossy material poses a challenge to designing antennas as it results in poor gain and efficiency.

In our previous work, we have designed and reported a wearable antenna using a single layer of the same lossy jeans. The antenna has a gain of -9.26 dBi and a radiation efficiency of 1.83% at 2.4GHz [13]. The poor gain and radiation efficiency are due to the high loss of the material.

In our present work, the antenna height is optimized to improve the gain and efficiency. The antenna is designed on five layers of jeans; thereby, the height of the substrate is increased to 2.125mm. A wearable antenna is integrated with cloth, which might bend and tends to take a curvature depending on the shape of the body parts, like biceps, thighs, belly, back, etc. The radius of curvature depends on the location of the body where the antenna is integrated. We have studied the bending effect on the resonant frequency, radiation efficiency, and radiation pattern. The performance is studied for different radii of curvature. It is found that the resonant frequency shift is negligible, but the 2.45 GHz ISM band remains unchanged. The gain remains greater than 1.5 dBi, and the radiation efficiency is greater than 19 % for all radii of curvature. The designed antenna may be used for health monitoring, tracking, and management systems, fitness trackers, for health care data transmission, and the Internet of Things, etc. The antenna has been designed, and the performances are studied in the Finite Element Method (FEM) based simulator CST Microwave Studio.

2. ANTENNA DESIGN AND RESULTS

The geometry of the proposed antenna is shown in Fig. 1.The width of the patch (W), the effective dielectric constant (ϵ_{eff}), and the length (L) are calculated using equations (1), (2), and (3)[14].

$$W = \frac{c}{2f_r}\sqrt{\frac{\epsilon_r + 1}{2}} \quad (1)$$

Where fr = Resonant frequency, C = Speed of light.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \quad (2)$$

$$L = \frac{C}{2f_r\sqrt{\epsilon_{eff}}} - 2 \triangle L \quad (3)$$

Where, ΔL is the increased length of the patch due to fringing effect, and it is calculated using equation (4) [14].

The calculated length (L) and Width(W) of the patch are 44.22 mm and 51.73mm, respectively. Here inset feeding technique is used. The antenna is simulated using calculated dimensions on FEM based CST Microwave Studio [15] at different bending conditions.

$$\Delta L = 0.412h\frac{\left(\epsilon_{eff}+0.3\right)\left(\frac{w}{h}+0.264\right)}{\left(\epsilon_{eff}-0.258\right)\left(\frac{w}{h}+0.8\right)} \quad (4)$$

2.1 OPTIMIZED DIMENSIONS OF THE ANTENNA

The optimized dimensions of the antenna under flat conditions are tabulated in Table 1.

Table 1: Optimized dimensions of the antenna

Variables	Optimized values
Dielectric constant (ϵ_r)	1.7976
Loss tangent (tan δ)	0.1152
Substrate height (h)	2.125 mm
Patch length (L)	42 mm
Patch width (W)	67 mm
Ground Length (LG)	120 mm
Ground Width (WG)	120 mm
Inset Depth (ID)	4.8 mm
Inset Spacing (IS)	4.9 mm
Feed Length (LF)	20 mm
Feed Width (WF)	1.8 mm

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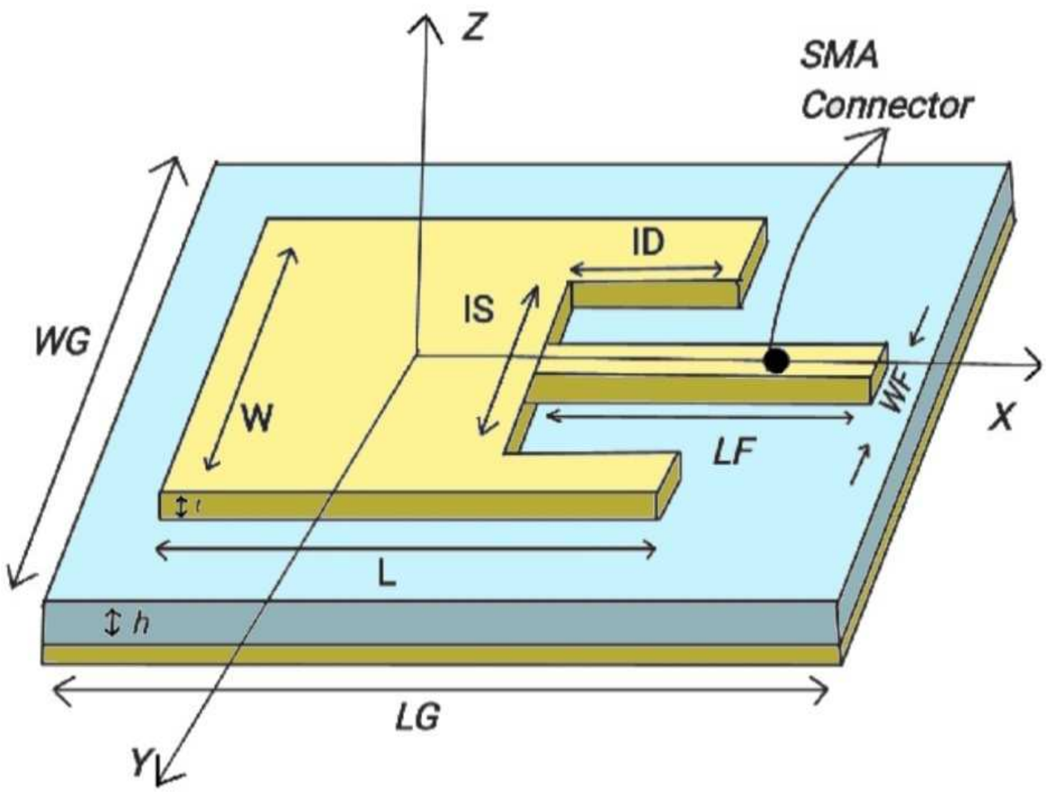

Figure 1: Geometry of the antenna

The geometry and dimensions of the antenna are shown in Fig. 1.

The antenna is simulated under different bending conditions, but the dimensions are kept unchanged. The pictures of the antenna at different radii of curvature are shown in Fig. 2.

Simulated S11 plots under different bending conditions are shown in Fig. 3.Simulated Gain vs frequency plots under different bending conditions are shown in Fig. 4.

Simulated Radiation efficiency vs frequency plots under different bending conditions are shown in Fig. 5.

Simulated Co and Cross-Pole Radiation patterns at 2.45GHz under different bending conditions are shown in Fig. 6.

Simulated 3D Radiation patterns at 2.45 GHz under different Bending Conditions are shown in Fig. 7.

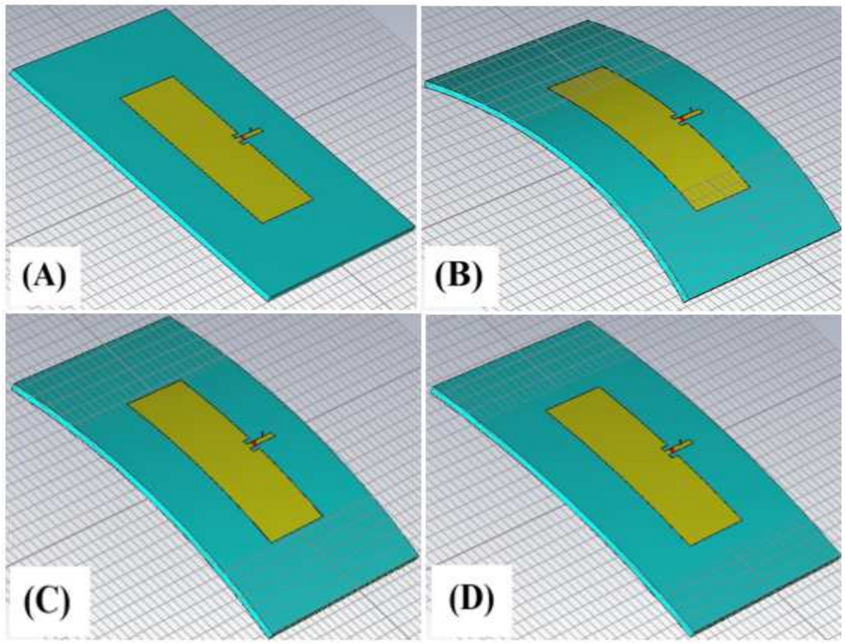

Figure 2: The pictures of the antenna at (A) Without Bending, (B) Bending with Radius of Curvature 300mm, (C) Bending with Radius of Curvature 600mm, (D) Bending with Radius of Curvature 900mm.

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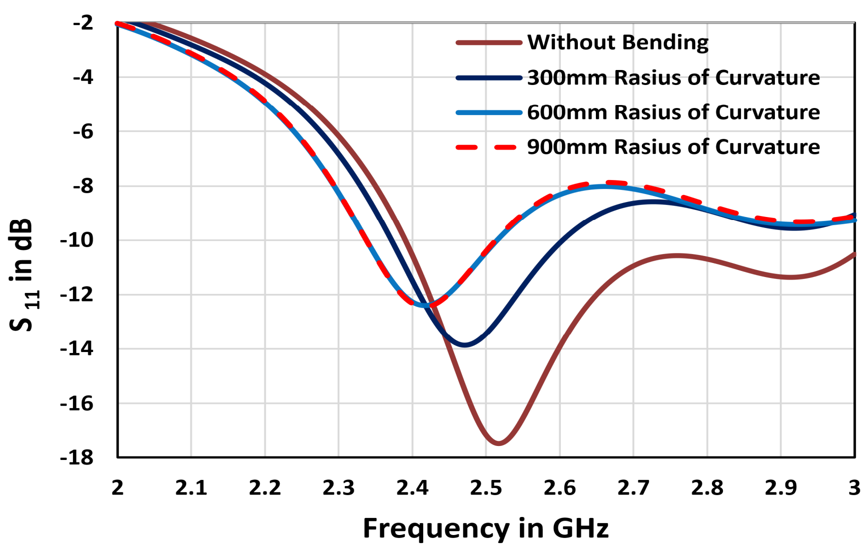

Fig. 3. Simulated S_{11} Plots under different bending conditions.

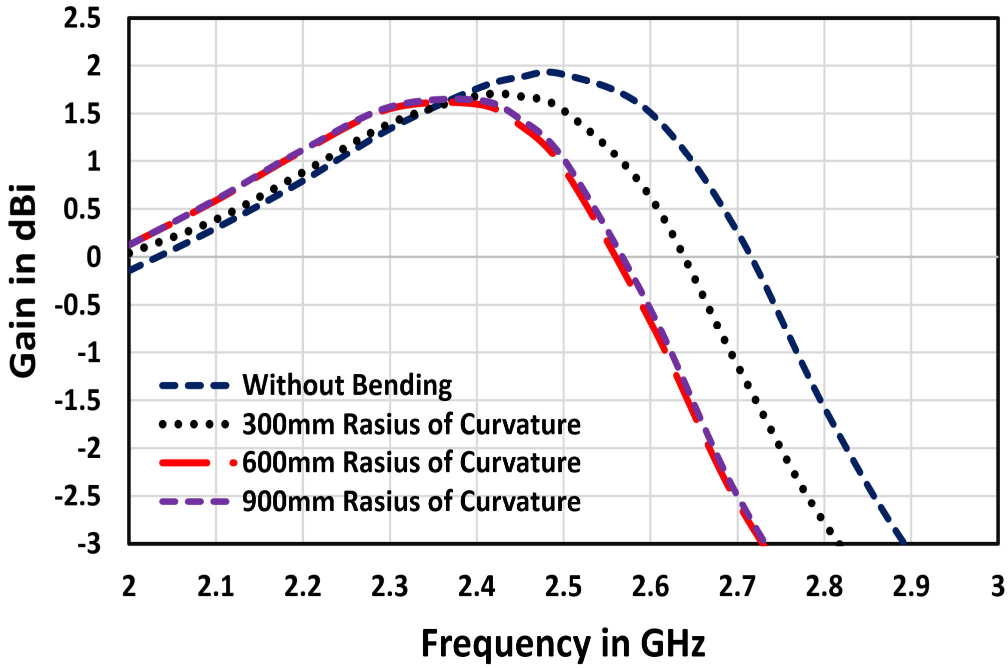

Figure 4: Simulated Gain vs frequency plots under different bending conditions.

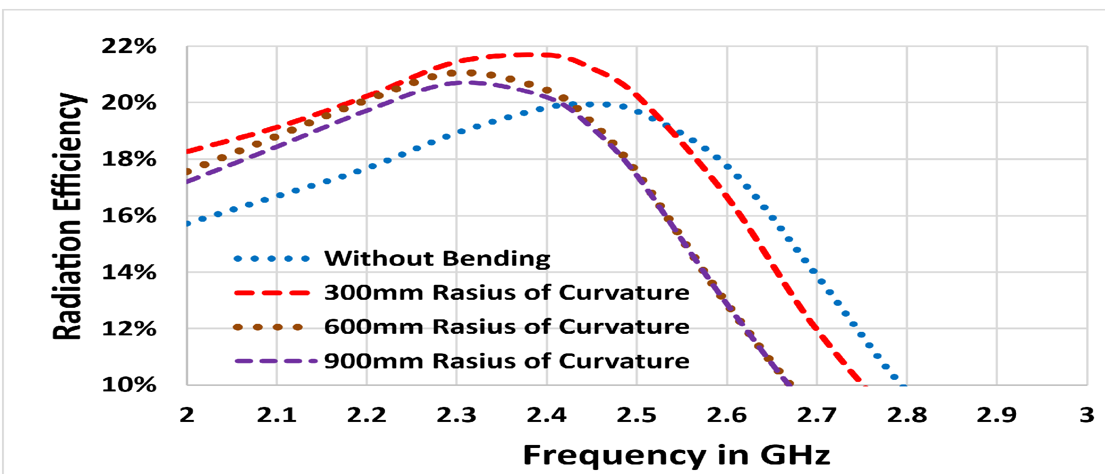

Figure 5: Simulated Radiation Efficiency vs frequency plots under different bending conditions.

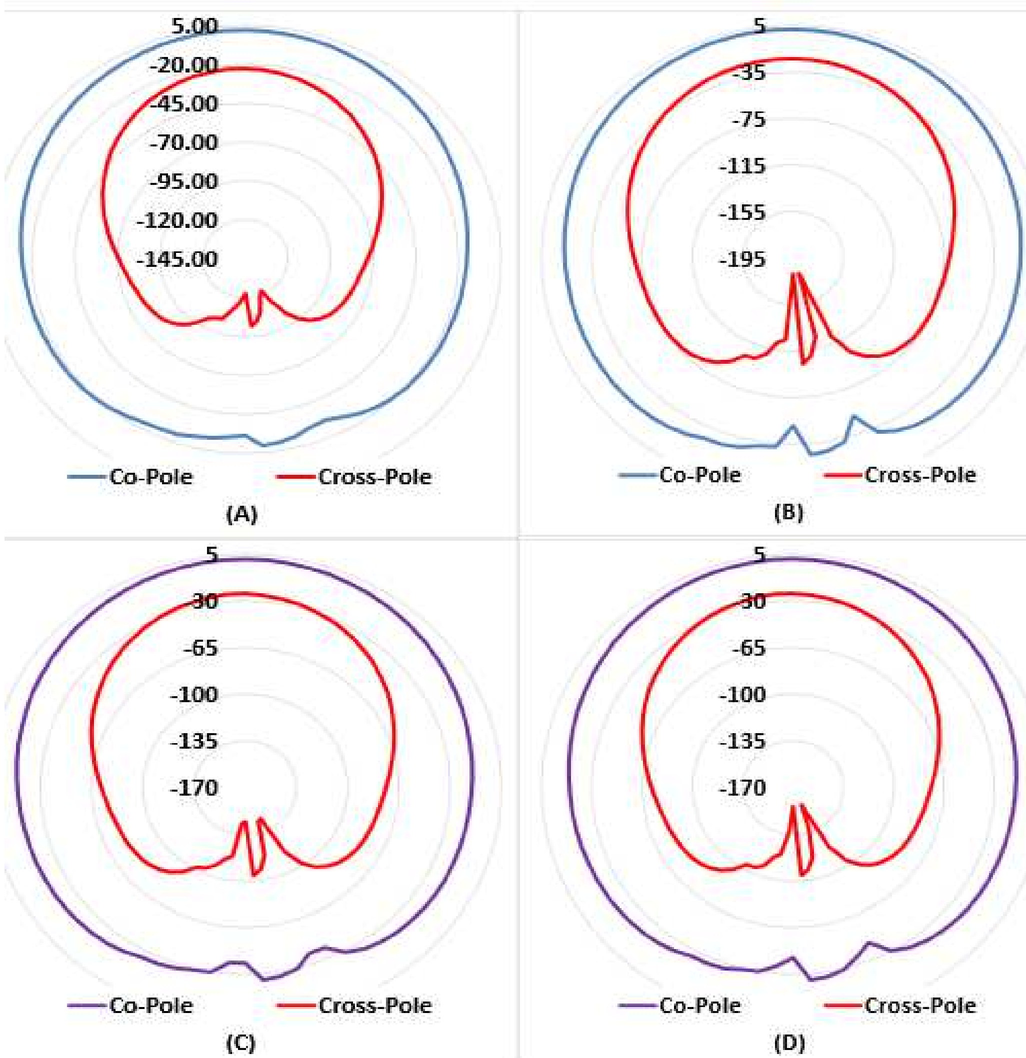

Figure 6: Simulated Co-Pole and Cross-Pole radiation patterns for (A) Without Bending, (B) Bending with Radius of Curvature 300mm, (C) Bending with Radius of Curvature 600mm, (D) Bending with Radius of Curvature 900mm.

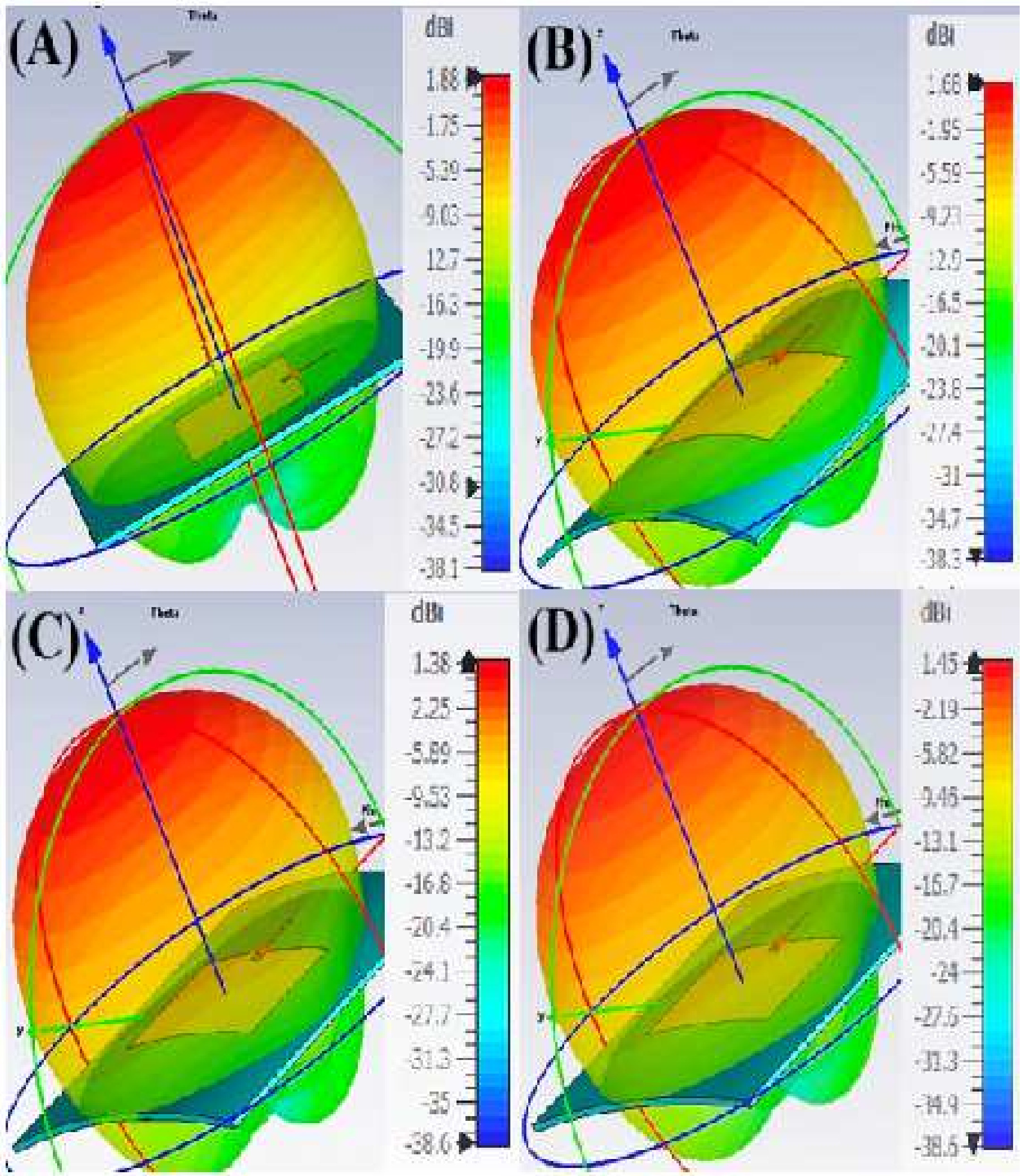

Figure 7: Simulated 3D Radiation patterns at 2.45 GHz for (A) Without Bending, (B) bending with a Radius of Curvature 300mm, (C) bending with a Radius of Curvature 600mm, (D) bending with a Radius of Curvature 900mm.

3. **CONCLUSION**

In this research work, a wearable antenna is designed to resonate at the 2.45 GHz ISM band on highly lossy day-to-day used jeans, and the antenna dimensions are optimized for different bending situations to get optimum performance, keeping the resonant frequency unchanged. The antenna is designed on day-to-day jeans, which reduces the cost and technical complexity, and also, the antenna performance is good enough to use in WBAN for short-distance communication.

The antenna fabrication and experimental verification are in progress. The designed antenna may be used for health monitoring, tracking, and management systems, fitness trackers, various health care data transmission, Internet of Things, etc.

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