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CPW-FED TEXTILE ANTENNA FOR WEARABLE WIRELESS COMMUNICATION APPLICATIONS

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Abstract:

Textile-based miniaturized antennas (20×26×1mm^3)are designed and analyzed for wearableC-band applications. The proposed antenna uses two rectangular slots to form the first aid-structured antenna. The antenna uses copper foil as a conductive for ground and radiator layers and denim as a dielectric substrate. The structure is simple, compact, conformal, and easy to manufacture using only fabric material. Usually, a primary rectangular antenna has a narrow bandwidth. This paper proposes a rectangular and circular textile-based first-aid structured antenna for wearable applications with enhanced bandwidth. The two antennas resonate at 6.5GHz, 7.3GHz frequencies with reflection coefficients of -28.9dB and -36.4dB. The gains are observed at 4.37dBi, 5.07dBi, and obtained bi-directional radiation patterns. Bending analysis is also performed to prove sustainability under deformation.

Key Words: Coplanar Waveguide (CPW), Compact Antenna, Textile Antenna &Wearable Antenna.

1. Introduction:

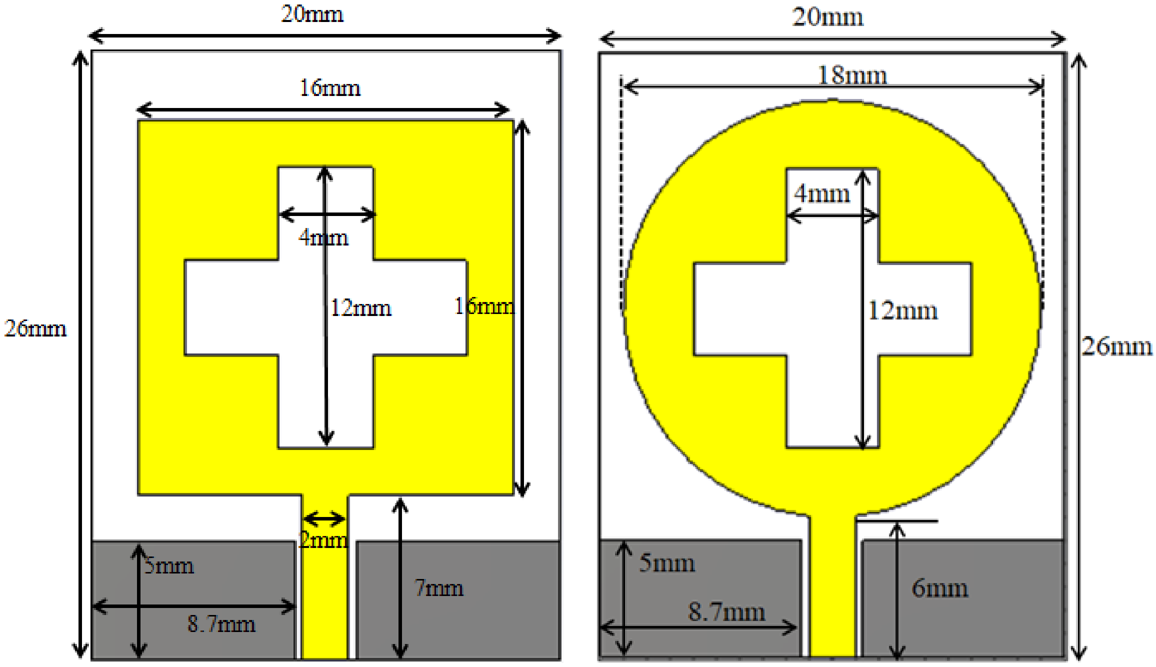
Wearable communication devices have been an exciting research topic nowadays. The advancements it would be useful in many applications such as medical communication devices, broadcasting, modern warfare, personal communications, avionics, and emergency rescue forces. Wearable antennas with flexibility, compactness would spread the scope of traditional microstrip antennas [1], [2], [3]. Flexible and wearable devices often need to incorporate an antenna that operates in a specific frequency band to provide wireless communication, which is the essential requirement for wearable communication devices [4].

There is increasing demand and development in the wearable antenna design that is comfortable and easy to integrate into integrated microwave systems. Traditional microstrip antennas often suffer from the inherent drawback of being stiff, as they often limit their applicability to wearable technologies. Textiles, which are flexible substrates, can be effectively used to bridge the gap between current wearable technology and smart textiles. Such systems can be used in emergency services and connect to general networks. Body-worn antennas can be made from textiles [5], [6], [7], [8], [9], and attached to the body or clothing or worn as button antennas [6]. Miniaturization of wearable antennas, along with recent advances and developments, is a well-documented topic. Microstrip patch antennas (MPAs) are widely used in this regard because of their capabilities and are limited by their narrow bandwidth. Furthermore, the physical size of conventional MPAs can be too large for applications operating at low frequencies [10]. Several techniques for reducing the physical size of patches, such as using high-dielectric substrates [11], DGS based antennas [12], [13], extending radiator current paths [7], [14], [15], [16], capacitive loading, etc. Have been proposed [17] short pins/walls [18], tail embedding on the edge [19], fractal planar IFA [20], [21], [22] and quarter mode design [23], CPW fed antennas [24], [25]. Achieving a compact, thin, and simple antenna structure while maintaining reasonable performance remains a challenging task.

In this work, wearable compact CPW-fed textile antennas have been proposed with square and circular shapes. The proposed textile patch antennas with plus-shaped slots made these antennas look like a first aid symbol, which will be used as the logo on the uniforms in emergency rescue systems. The bending analysis is also considered for the two antennas to check the performance of the antenna under deformation.

2. Antenna Design:

The textile wearable antenna geometries is shown in Figure 1. The proposed antennas are designed in CST microwave studio [26]. Denim textile is used as a substrate material. The dielectric constant (ε_r) and loss tangent (δ) of the denim textile substrate are 1.8 and 0.08, respectively. The antenna size is measured 20×26×1mm^3 for both the antennas and the shape of the patches are different. Figure 1(a) shows a square patch antenna with a plus-shaped slot. The length and widths of the square patch are 16×16mm^2, and the length and widths of the plus-shaped slots are 12mm and 4mm for both the antennas. Coplanar waveguide feed (CPW) is considered with a 50Ω impedance feed line.



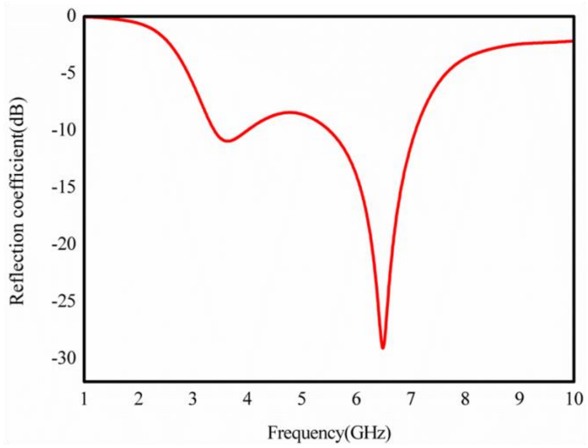
(a) (b)

Figure 1: The geometry of the textile-based (a) Square, (b) Circular antenna.

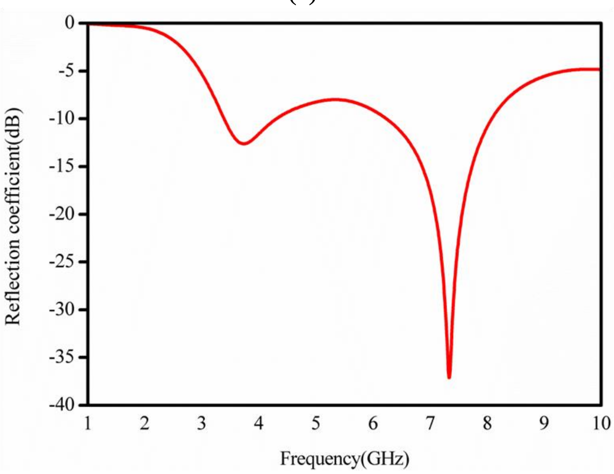
The lengths of feed lines are 7mm and 6mm for the square and circular patch antennas. The ground planes are located both sides for the feed line with sizes 5×8.7mm^2. The circular-shaped textile antenna is shown in Figure 1(b). The diameter of the circle is observed as 20mm.

3. Results and Discussions:

The simulated reflection coefficient (s_{11}) response of the textile-based proposed antennas is shown in Figure 2. Figure 2(a) shows the S_{11} response of the square textile antenna. It is observed that the antenna resonates at 6.48GHz frequency with an S_{11} of -28.98 dB. The impedance bandwidth is observed as 1600MHz (5.48-7.08GHz) with the 10dB reference line. Figure 2(b) shows the S_{11} response of the circular textile antenna. It is observed that the antenna resonates at 7.34GHz frequency with a S_{11} of -37.09 dB. The impedance bandwidth is observed as 1870MHz (6.19-8.06GHz).



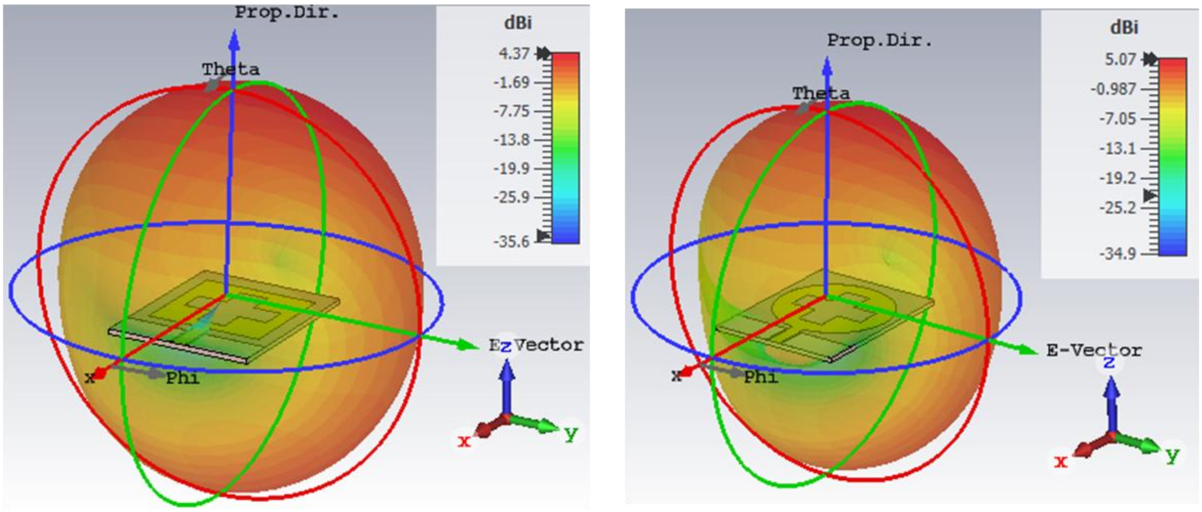
(a)



(b)

Figure 2: S_{11} response of the textile (a) Square, (b) Circular antenna

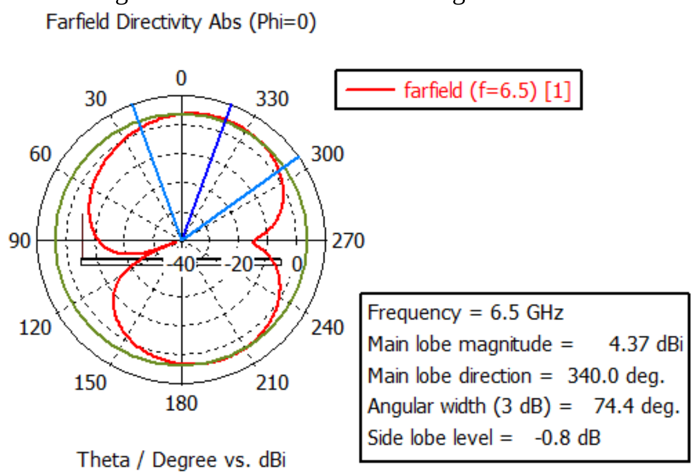
Figure 3 shows the 3D-gains of the proposed textile antenna. The gains are observed 4.37dBi and 5.07dBi for the two antennas, respectively. The directivity of the antennas is focused in Z-direction for the two antennas.



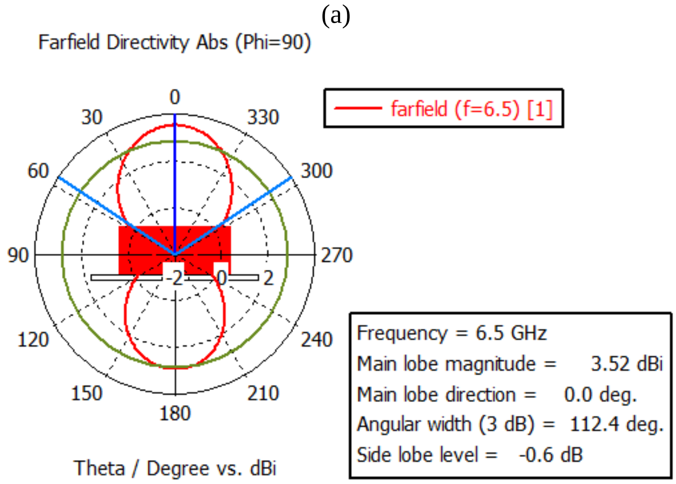
(a) (b)

Figure 3: 3D-gains of the textile (a) Square, (b) Circular antenna.

The E-plane and H-plane radiation patterns of the square textile antenna are shown in Figure 4. Figure 4(a) shows the E-plane radiation pattern of the proposed antenna, the semi-omni directional pattern is observed with 74.4dB of angular width with a main lobe magnitude 4.37dBi directed in 340deg. Figure 4(b) shows the H-plane radiation pattern of the proposed antenna, the bi-directional radiation pattern is observed with 112.4deg of angular width with a main lobe magnitude 3.52dBi directed in 0deg.



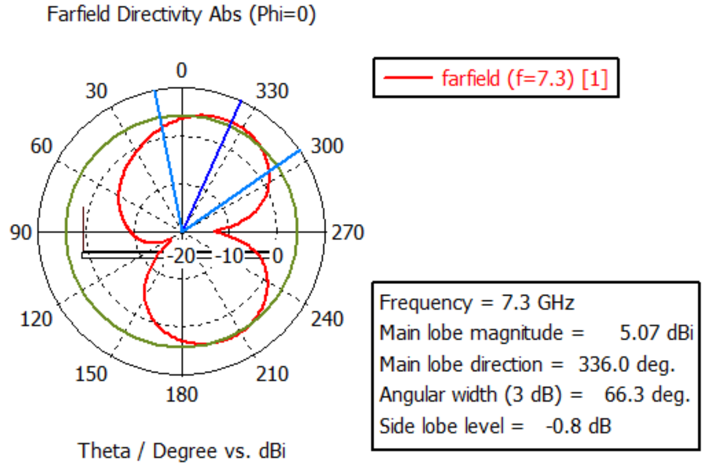
(a)



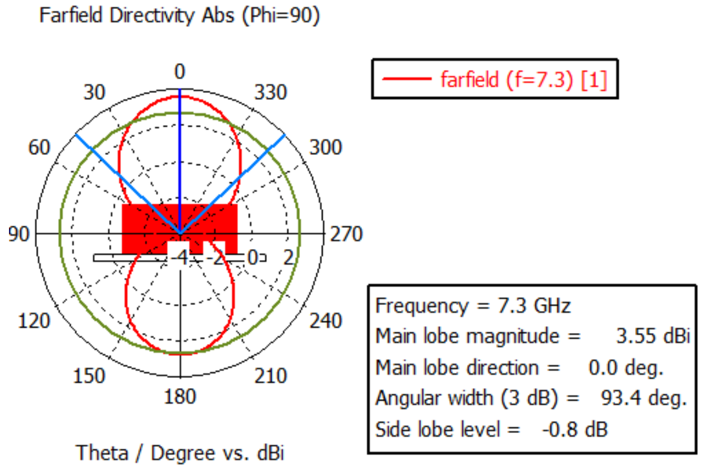
(b)

Figure 4: Radiation patterns of the square textile antenna (a) E-plane, (b) H-plane.

The E-plane and H-plane radiation patterns of the circular textile antenna are shown in Figure 5. Figure 5(a) shows the E-plane radiation pattern of the proposed antenna, the semi-omnidirectional pattern is observed with 66.3deg of angular width with a main lobe magnitude 5.07dBi directed in 336deg. Figure 5(b) shows the H-plane radiation pattern of the proposed antenna, the bi-directional radiation pattern is observed with 93.4dB of angular width with a main lobe magnitude 3.55dBi directed in 0deg.



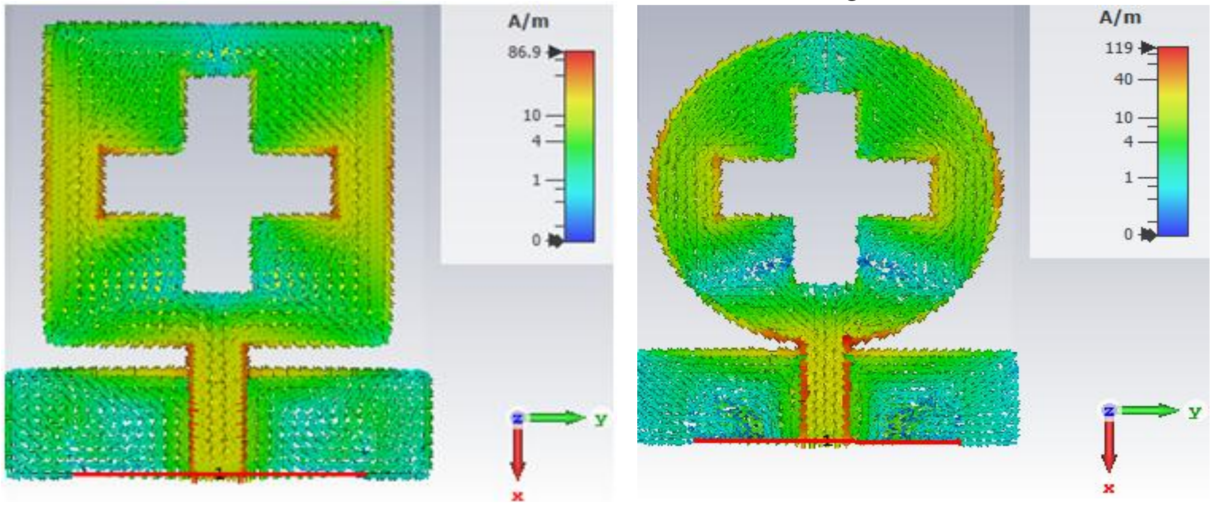
(a)



(b)

Figure 5: Radiation patterns of the circular textile antenna (a) E-plane, (b) H-plane.

The surface current distributions of the square and circular textile antennas are shown in Figure 6. Figure 6(a) observed that the maximum current concentration of 86.9A/m is at a horizontal slot. In circular textile antenna, the maximum concentration 119A/m is observed at the outer edges of the circle.



(a) (b)

Figure 6: Surface Current Distributions of the textile (a) Square, (b) Circular antenna.

The proposed antenna is a textile-based antenna for wearable applications. So, it is necessary to analyze the antenna performance in terms of S_{11} under bending characteristics. Different radius cylindrical shapes are considered for antenna deformation, as shown in Figure 7 and Figure 8. For each radius cylinders from R=10mm to R=20mm, the performance of the antenna slightly changed, but the bandwidth is maintained the same. So, from the bending analysis, it is observed that the antenna performance remains the same for the bending characteristics.

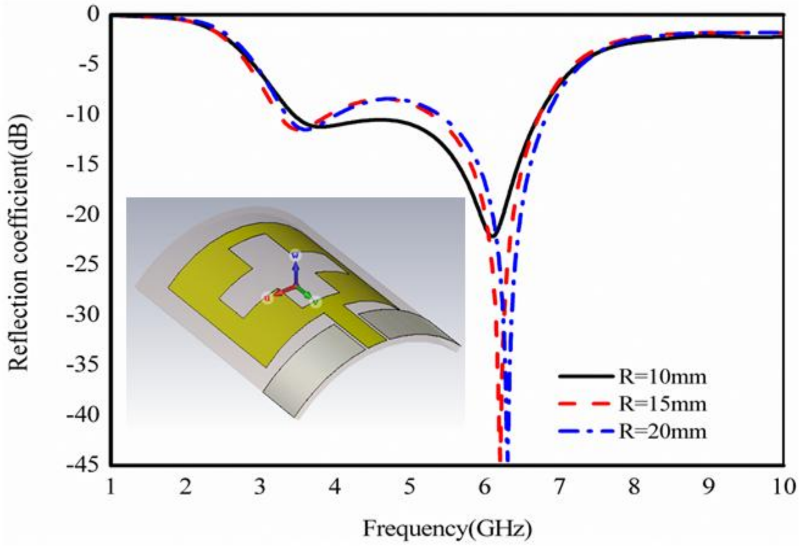


Figure 7: S_{11} response of the square-shaped textile antenna for different bending angles.

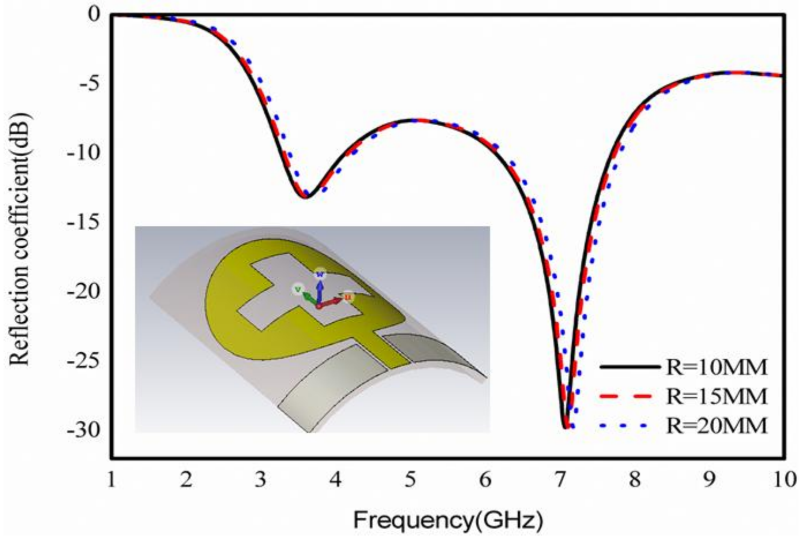


Figure 8: S_{11} response of the circular shaped textile antenna for different angles.

4. Conclusion:

A compact textile-based antenna is proposed for wearable applications. The antenna was designed on denim fabric. The size is reduced by considering plus-shaped slots on the radiating patch to modify the antenna geometry as the first aid logo. The performance of the antenna is considered with both square and circular patches with CPW feeding. The S_{11} response of square textile antenna and circular textile antennas are -28.98 dB, -37.09 dB operating at 6.48GHz and 7.34GHz, respectively. The impedance bandwidths are observed 1600MHz (5.48-7.08GHz) and 1870MHz (6.19-8.06GHz) for the two shapes. Good radiation patterns are observed with 4.37dBi, 5.07dBi gains. The bending analysis is also considered for the two antennas, and the performance remains the same in the bandwidth range. With compactness and textile material as substrate, the proposed antennas are suitable for wearable communication applications.

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