A Low-cost CPW-fed Conformal Antenna for Wearable Applications

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***Abstract*—A low-cost CPW-fed conformal antenna has been presented in this paper for wearable applications of MBAN band (2.36-2.40GHz), ISM band (2.40-2.48GHz) and WiMax band (3.4-3.6GHz) standards. The proposed design is composed of low-profile octagonal shaped geometry fabricated on photo paper with a measured impedance bandwidth of 58% centred at 3.23GHz (from 2.30-4.16GHz), radiated efficiency of 93% and a peak gain of 2.14dB at 2.45GHz frequency. The flexibility of an antenna is analyzed by applying curvature radii along x and y-direction that results into maximum frequency shift of 4% with omni-directional gain patterns for all selected bending radii. Numerical and experimental results of proposed antenna emphasize on its suitability for the wearable applications with extremely good conformability to structural deformation along its both axes.**

Keywords— Broadband; coplanar waveguide (CPW); flexible antenna; patch antennas; wearable applications.

I. Introduction

In recent years, extensive growth and development have been seen in the field of wearable devices and sensors due to their potential applications for healthcare monitoring systems. Such systems include devices that can sense, monitor and transmit the vital signals of human body to the receiving nodes [1]. This reinforces a need of specialized wearable antenna that can operate in the close vicinity of human body and should be low-profile, lightweight, water resistant and mechanically robust to structural deformation for ease of integration on the wearer's body. In available literature, several antennas have been proposed having desired characteristics for body-worn applications using different specialized polymer-based flexible substrates like Kapton [2], PTFE [3] and PDMS [4]. Their higher cost and limited availability emphasize the need to used low-cost and easily available flexible materials for wearable applications.

In this work, octagonal shaped CPW-fed wideband flexible antenna has been proposed using low-cost and widely available photo paper substrate for wearable applications. Structural conformability of proposed antenna is tested by bending it in two directions with different curvature radii. This analysis reveals its successful operation for wireless bands of MBAN band, 2.45GHz ISM band and WiMax band with extremely low-performance degradation with structural deformation. Furthermore, the performance of designed antenna has been validated using both numerical and experimental analysis for its suitability of body-worn applications.

II. Antenna Topology

The design of the prototype is initiated by the selection of low-cost widely available substrate material, which satisfies the properties of flexibility, robustness to mechanical deformation and low moisture absorption. For this purpose, readily available low-cost photo paper with a thickness of 0.27mm, dielectric constant of 3.2 and loss tangent of 0.05 [5], is used as a flexible substrate and copper tape as a conductive material. The final optimized antenna geometry is designed using CST Microwave Studio [6], as shown in Fig.1. The proposed design is composed of a simple square patch of 23.5 x 23.5mm^2 with chamfered edges to form an octagonal geometry fed using exponential CPW-feed to improve its impedance matching and to achieve wideband impedance bandwidth (BW) with a ground plane of 19.5 x 34mm^2. The overall size of an antenna is 45.5 x 34 x 0.27mm^3 (length, width and thickness) with an electrical length of (0.35λ_o x 0.26λ_o x 0.002λ_o). The proposed antenna topology is manually fabricated and fed using a 50Ω SMA connector, as shown in Fig.1 (b). Table 1 illustrates the detailed parametric dimensions of proposed design.

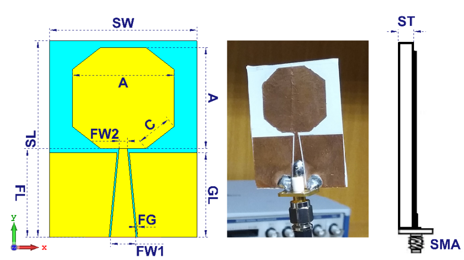

Fig. 1. Optimized antenna topology, dimensions in millimeter. (a) Top view (b) Fabricated antenna prototype (c) Side view

TABLE 1. Optimized Parameters of Proposed Antenna

Parameter	Length (mm)	Parameter	Length (mm)
A	23.5	**FW2**	2
C	8	**GL**	19.5
FG	0.35	**SL**	45.5
FL	20.5	**ST**	0.27
FW1	6	**SW**	34

III. Numerical and Experimental Results

For performance evaluation, a commercially available full wave simulator CST microwave studio and NI PXIe-5630 two-port RF network analyzer are used for numerical and experimental verification of the fabricated prototype, respectively. Fig. 2 shows the comparison of simulated and measured return loss of fabricated prototype. Slight variation in the resonance frequency of these results is attributed to the manufacturing and measuring errors along with environmental effects during testing. As for wearable applications, antenna needs to be operated in the close vicinity of the human body, which requires a lot of structural deformation at various scenarios. Therefore, for its validation, return loss and far-field radiation patterns are evaluated for two different curvature radii and directions along x-axis and y-axis, as shown in Fig. 3, Fig. 4 and Fig. 5. The chosen curvature radii for conformability test of designed antenna are 20mm and 40mm. For measurement of the return loss of bending analysis, semi-cylindrical foam fixtures are built as shown in Fig. 3 and Fig. 4. Measured results of proposed topology show that it has extremely good mechanical robustness to the structural deformation in both directions with minor shift of 4% in the centre frequency and with comparatively constant BW. Table 2 summarizes the return loss evaluation of antenna under test for structural deformation under chosen curvature radii for both of the antenna axes.

For further validation of antenna performance for wearable applications, its far-field radiation patterns are studied using CST Microwave Studio for selected bending radii, as shown in Fig. 5. Table 3 summarizes the radiation pattern results of designed antenna at 2.45GHz, which results into omni-directional patterns with slight variations for specified structural deformation curvature radii and a peak gain of 2.28dB with maximum radiated efficiency of 93%.

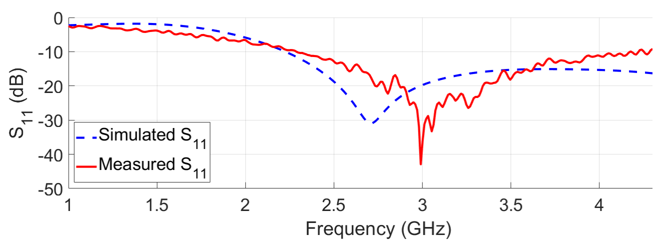

Fig. 2. Simulated and measured reflection coefficient of proposed antenna.

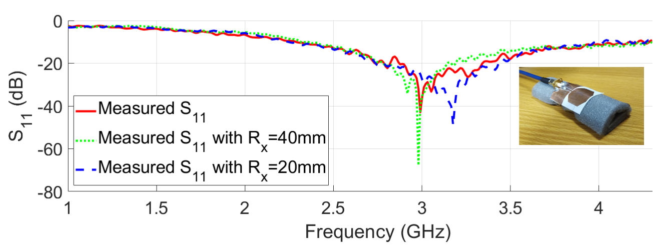

Fig. 3. Measured reflection coefficient of proposed designed with structural deformation along x-direction.

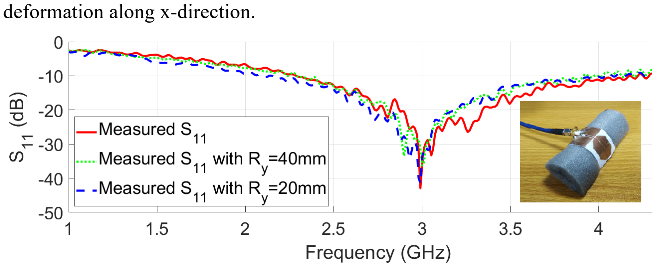

Fig. 4. Measured reflection coefficient of proposed designed with structural deformation along y-direction.

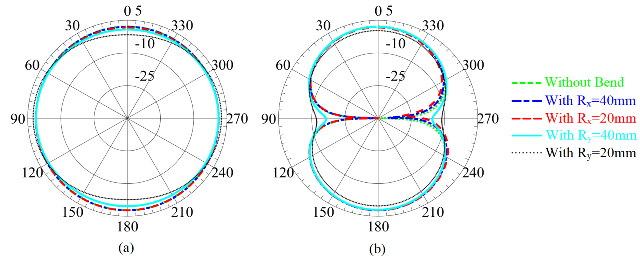

Fig. 5. Radiation patterns of designed antenna with and without structural deformation at 2.45GHz. (a) XZ-plane (b) YZ-plane

TABLE 2. SUMMARY OF MEASURED RETURN LOSS FOR CONFORMABILITY TEST

Bend Radii (mm)	Bend Along X direction		Bend Along Y direction	
	BW/ f_c (GHz)	%BW	BW/ f_c (GHz)	%BW
No bend	2.30-4.16/ 3.23	57.6	2.30-4.16/ 3.23	57.6
40	2.32-4.30/ 3.31	59.8	2.29-3.90/ 3.1	52
20	2.25-4.14/ 3.2	59.2	2.15-4.00/ 3.1	60

TABLE 3. SUMMARY OF RADIATION PATTERN OF PROPOSED ANTENNA FOR CONFORMABILITY TEST AT 2.45GHZ

Bend Radii (mm)	Bend Along X direction		Bend Along Y direction	
	Gain (dB)	Radiated Efficiency	Gain (dB)	Radiated Efficiency
No bend	2.14	0.93	2.14	0.93
40	2.28	0.93	2.05	0.92
20	2.28	0.92	1.77	0.91

IV. CONCLUSION

In this work, a conformal and low-cost CPW-fed patch antenna has been proposed for wearable applications with measured BW of 58% at center frequency of 3.23GHz. The detailed analysis of proposed antenna reveal its ineffectual response to structural deformation along its both axes with maximum measured central frequency shift of 4% and minimum measured BW of 52%. Furthermore, the omni-directional radiation patterns of proposed design remain ineffective of bending with a radiated efficiency of 90% and above, for all the selected curvature radii. Both numerical and experimental results show that the proposed antenna geometry is mechanically robust to structural deformation and highly suitable for the wearable applications of MBAN band, 2.45GHz ISM band and WiMax band standards with good operational BW, efficiency and gain.

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