Bending Analysis on Circular Polarization Array Textile Antenna

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***Abstract* — This paper presents the performances of circular polarization (CP) array textile antenna in different bending condition. The antenna composed four circular patches in array formation where the patches composes a cross slot at the centre of the patch. In flat condition, a good bandwidth (2.06 GHz – 2.49 GHz), axial ratio (2.38 GHz – 2.62 GHz) with realized gain of 3.09 dB is presented and compared with other bending condition to suits with application of rectenna for energy harvesting system and antenna for monitoring system.**

***Index Terms* — circularly polarized, array antenna, sloted, textile antenna.**

I. INTRODUCTION

The number of wireless wearable application is continuously increasing and attracted more report related to the wearable antenna. The conditions of lightweight and low cost attracted to more invention of wearable antenna by the researcher to integrate into a garment. There are several reports presents various application for textile antenna such as Wireless Local Area Network (WLAN), Global Positioning System (GPS), and energy harvesting system [1-5]. All these applications need the antenna in flat surface to acheived maximun performances. However, the textile antenna at garment surface gives the uncertain condition either in flat, crumple or bend condition. Hence, the performances of textile antenna in bending and crumpling condition should be analyzed. In [6-8], the discussion about bending analysis has been done to study the effect towards the textile antenna's performance in term of return loss, gain and radiation pattern.

This paper presents the performances of the CP textile antenna for RF energy harvesting system and wireless monitoring communication system in bending condition The denim material is chosen as the substrate material due to low cost material. The antenna is designed with cross slotted at the radiating patch to perform circularly polarized conditions. The performance of the CP textile antenna in term of bending condition also presented. The antenna is design to cover the 2.4 GHz wireless networking band to suit with further applications. The invention of the array textile antenna can increase the gain of the antenna and can be use for long range application such as wireless power transfer. The CST Microwave Studio has been used as simulation purposes.

II. ANTENNA DESIGN

The antenna composes four circular patches fed by a corporate feeding network as shown in Figure 1. The textile material, denim, is employed as a substrate with a dielectric constant, ε_r of 1.7, tangent loss, *tan δ* of 0.085 and thickness of 1.6mm. The dimension of the denim substrate is a = 150 mm × b = 150 mm. The characterizations of permittivity and tangent loss for denim textile are determined by the open ended coaxial probe method as mention in [4].

The dielectric was sandwiched by a full ground plane at the bottom and a radiating patch at the upper layer. An unequally length of slots is cross orthogonally at the centre of each slots, which is at the centre of the radiating patch. The length of slots are sa = 31.25 mm and sb = 24.32 mm while the radius of the radiating patch is a_e = 21.3 mm. The length of slots is calculated by quarter of guided wavelength, λ_g at operating frequency, 2.45 GHz. The radius of the patch can be determined by using equation 1 [9].

$$a_e = a\left[1+\frac{2h}{\pi a \varepsilon_r}\left\{\ln\left(\frac{a}{2h}\right)+(1.41\varepsilon_r+1.77)+\frac{h}{a}(0.268\varepsilon_r+1.65)\right\}\right]^{1/2} \quad \ldots(1)$$

Where, $a = \dfrac{1.841}{k_0\sqrt{\varepsilon_r}}$

$k = 2\pi\sqrt{\dfrac{\varepsilon_r}{\lambda_o}}$

h = thickness of substrate

ε_r = relative permittivity of substrate

Fig. 2 shows the proposed antenna with different bending condition. The antenna is differed by the radius, R of the bending in Y-axis. There are three bending conditions which are 100 mm, 300 mm, and 500 mm to compare with the antenna in flat condition.

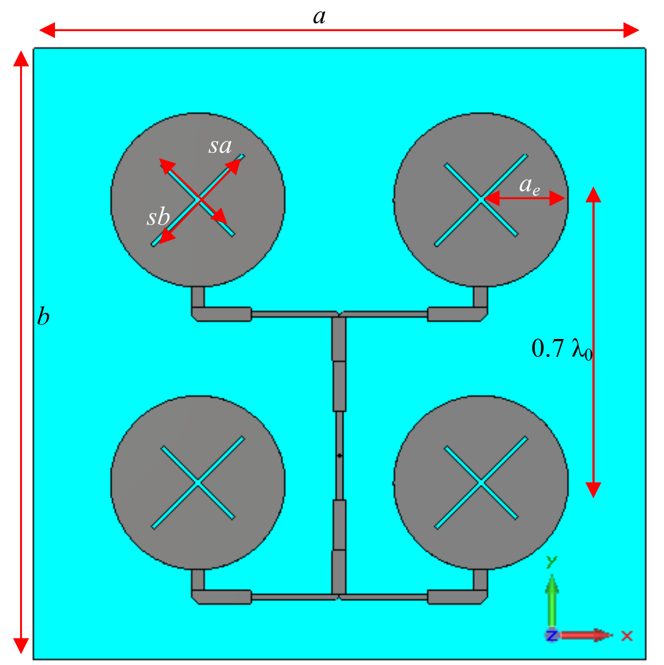


Fig. 1. The dimension of proposed antenna

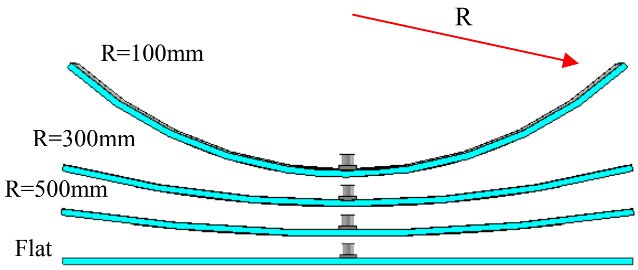


Fig. 2. The bending condition for proposed antenna

III. Result And Discussion

This section discus the performances of the proposed antenna in bending condition. The discussion include the performances of input impedance matching (S_{11}), the 3-dB axial ratio and the pattern of radiation. These analysis are compared with the antenna's performances in flat condition. The antennas will be bended along the principle of Y-axis, as shown in Fig. 2. The antenna are bended at three bending radius which are 100 mm, 300 mm, and 500mm

The simulated impedance matching of the antenna under Y-axis bending condition are shown in Fig 3. In flat condition case, the input impedance matching is 2.06 GHz to 2.49 GHz or bandwidth of 19% (taking -8dB of return loss). From the results, the resonant frequency is shifted to lower frequency when the bending becomes smaller. This occurs due to the location of patches is at the critically bend location. However, the reflection coefficient for all condition is approximately same with flat condition.

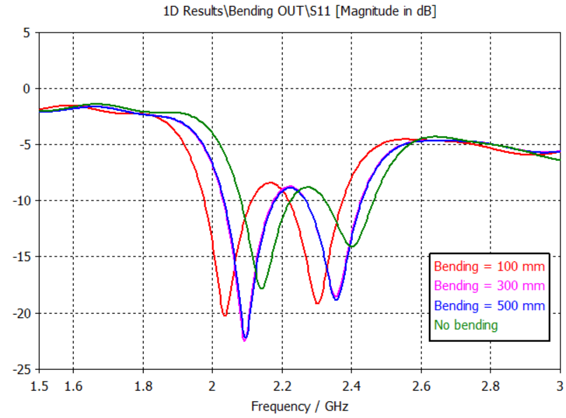


Fig. 3. Simulated Return Loss of the antenna in different bending condition

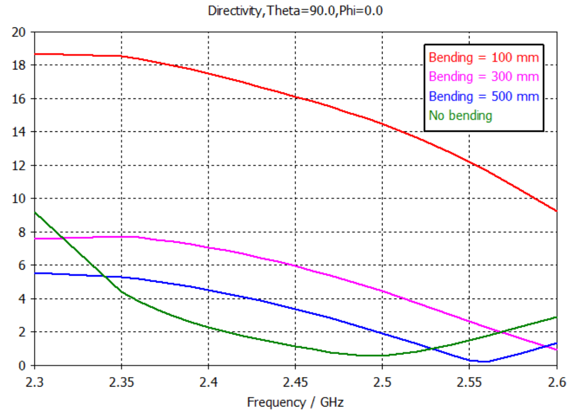
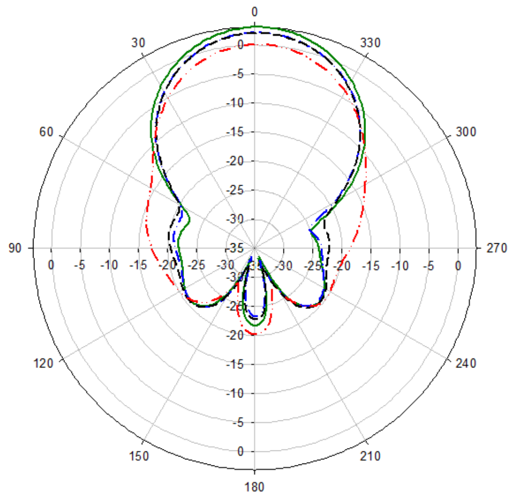
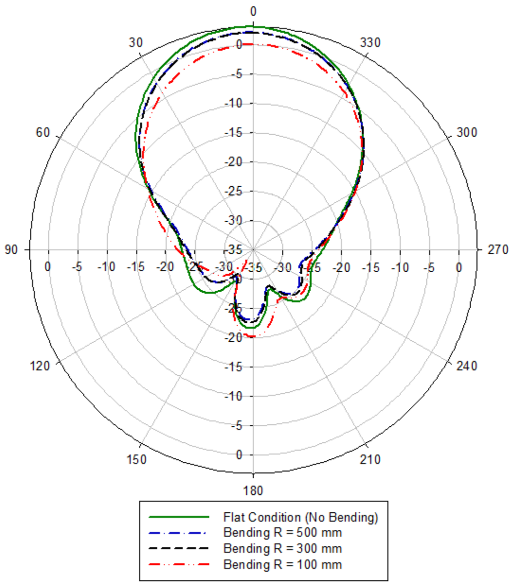


Fig. 4. Simulated Axial Ratio of the antenna in different bending condition



(a)



(b)

Fig. 5. Simulated pattern of the proposed antenna in different bending condition (a) E-plane, (b) H-plane

The simulated 3-dB axial ratio of the bended proposed antenna is presented in Fig. 4. The antenna is defined as CP antenna when the axial ratio is below than 3 dB. The result shows the best axial ratio under flat condition is 0.5 dB at 2.50 GHz. The value of axial ratio becomes worst when the bending of the antenna become smaller. This is due to the low resonance at the slots to generate circular polarization. The radiation patterns for the antennas under different bending conditions are show in Fig. 5. The results shows that the beamwidth of the radiation pattern becomes smaller compared to the flat condition while the directivity is reduces by several value of dB. The summary of the antenna's performances are shown in Table 1.

TABLE I. SUMMARY OF ANTENNA PERFORMANCE

Proposed Antenna	**Result Analysis**		
	Return Loss (GHz)	***Axial Ratio (GHz)***	***Maximum Gain [a] (dBi)***
Bending R= 100mm	1.95 – 2.40	NA	0.50
Bending R= 300mm	2.01 – 2.45	NA	2.062
Bending R= 500mm	2.01 – 2.45	2.46 – 2.80	2.127
No Bending	2.06 – 2.49	2.38 - 2.62	3.67

a = the maximum gain at 2.45 GHz
NA = The value is not available

IV. CONCLUSION

The performances of the CP textile array antenna in term of input impedance matching, the axial ratio, the radiation pattern and gain has been presented and discussed. The antenna appears robust performance under bending conditions. The input impedance matching and the axial ratio of the antenna show major changes at bending radius of 100 mm. The gain of directivity and the radiation pattern of the antenna also distorted when the antenna in bending condition. It is shows that the textile antenna is very sensitive and there are several conditions to apply in stated applications.

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