Fully Textile Slot Antenna with Curvature Analysis

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***Abstract*— This paper present the investigation on wearable textile slot antenna under flat and curvature conditions in free space. The antenna can be used for smart clothing at 2.45 GHz Industrial, Scientific and Medical (ISM) band. A 0.78 mm denim fabric is used as the substrate. A monopole antenna is patented on the fabric with a ground plane at the other side. The monopole and the ground is made of a 0.17 mm shield-it fabric. Simulated results of proposed design in term of bandwidth, return loss, realized gain, efficiency and radiation pattern are presented and discussed thoroughly. Results show that the antenna curve significantly detuned the antenna resonance frequency and altered the antenna radiation pattern.**

Keywords*— *textile slot antenna; wearable antenna; fabric substrate; conductive textile; curvature analysis

I. INTRODUCTION

Nowadays, healthcare sector has revolutionized with wearable technology applications where it enables patients health records to be access in remote and real time monitoring by doctors and medical staffs. Wearable technology can be defined as a wireless communication system embedded in clothing. Adequate power sources, flexible circuitry and flexible antennas are key components to have efficient and reliable communication link of any wearable technology [1]. Lots of sensor prototypes for wearable health monitoring system have been developed by researchers. However, in order to make it wireless monitoring, there is a need to develop wearable antennas that can be incorporated into those systems [2].

The wearable antenna can be referred as an antenna which is designed and intends to be an integral part of clothing [3]–[5]. There are common requirement in wearable antenna design such as light weight, inexpensive, zero maintenance, no set-up requirements, and no damage from obstacles [6]. The advantages of wearable antenna compared to conventional antenna are that it does not limit the possible antenna placement onto body.

In this paper, the author aimed to investigate the possibility of designed wearable slot antenna where fully textile materials are used for the substrate and conducting parts of the designed antenna. The textile slot antennas are suitable for applications that needs uniform coverage on body communication such as smart clothing, mobile device and base station where 360 degree coverage is required [7].

II. ANTENNA STRUCTURE

The antenna is designed with a monopole feed line on top of a denim fabric substrate with an L-shaped slotted ground at the other side of the substrate. The non-conductive denim has a thickness of 0.78 mm, permittivity of 1.7 and tangent loss of 0.025 at 2.45 GHz. A conductive Shieldit textile from LessEMF.Inc is used for the monopole and the ground. The conductive material is chosen due to its feasible features. Different from the copper sheet, Shieldit is a washable material and it can resist high temperature up to 200°C. It has thickness of 0.17 mm and conductivity of 1.96x105 S/m.

The feed line is designed at 50 ohm characteristic impedance to match the SMA port. The physical width of the feed line is designed at 3 mm and the length is 52mm. The overall size of the antenna is 73.28 mm x 67 mm.

In this work, all simulations are carried out by using CST simulation microwave studio. Fig. 1 shows the antenna design configuration. Based on parametric study, the best dimensions of textile slot antenna are obtained. The value of a= 14mm, b=25.36mm, c=41.14mm, d=35.5mm and e=42.2mm.

The slot is designed using half wavelength equation. Position of the slot is off center to the monopole feed line which is approximately λg/4 in order to achieved better reflection coefficient. In order to design the antenna, few parameters such as the dimension of the slot are calculated based on eq. (1) and eq. (2). The λg value represents the wavelength of the slot, while λo and Ɛr represent wavelength values in free space and dielectric constant respectively.

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_r}} \qquad (1)$$

For monopole slot antenna, the slot length is given as:

$$\text{Slot length } = \frac{\lambda g}{2} \qquad (2)$$

In this paper, the antenna is studied at two bending position: horizontal convex and horizontal concave. For each curvature position, the antenna is curve along the principle of H-plane with three curvatures: 25, 30 and 35 mm. Small curving radius indicated a high curvature while large curving radius represents low curvature. The results will be compared with the 0 mm representing the flat condition (no curvature). Simulated reflection coefficient and radiation pattern are demonstrated in fig. 2 and fig. 3 respectively.

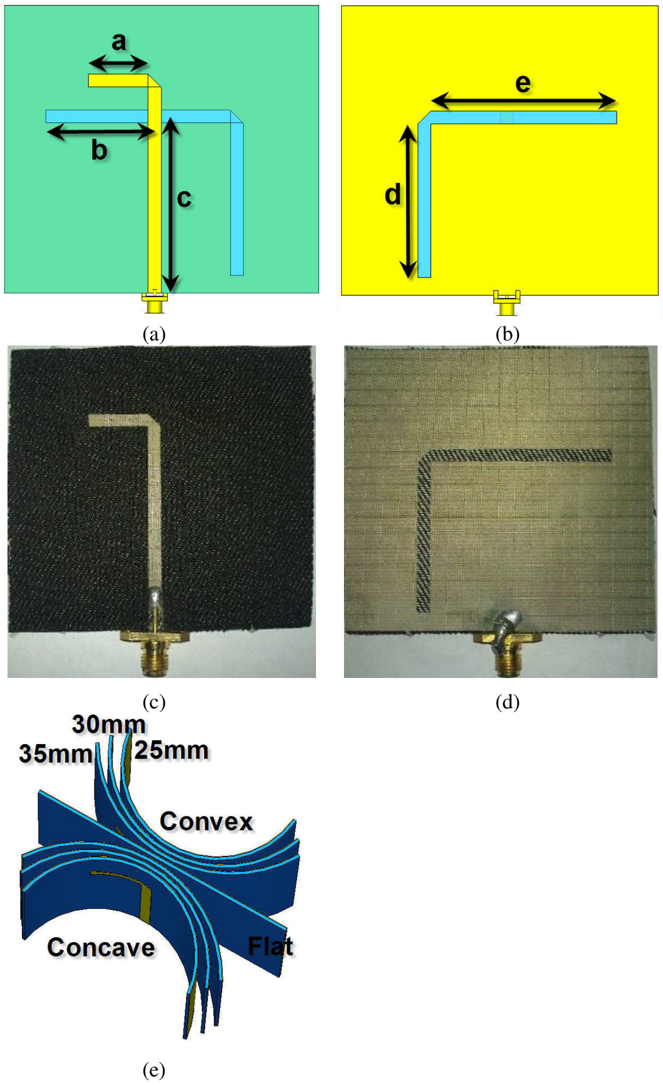


Fig. 1. Antenna design configuration. (a) simulated front view (b) simulated back view (c) fabricated front view (d) fabricated back view (e) overview curvature description

III. Results And Discussion

A. The Antenna Resonance

Fig. 2 shows the simulated reflection coefficient of the textile slot antenna. The monopole antenna is operating at 2.44 GHz with a return loss of -53.38 dB in flat condition (no curvature). It verified from measurement that the antenna operated in desired frequency band. From simulations, it is noticed that the curvature of the antenna has caused a slight shift of the antenna resonant frequency and reduced the return loss value for all curving condition investigated. This could be due to the fact that the low resonant of the slot under three curvatures is generating only on certain point of slot ground plane. However, the return loss remains below -10 dB and bandwidth virtually unchanged for all curvature condition investigated.

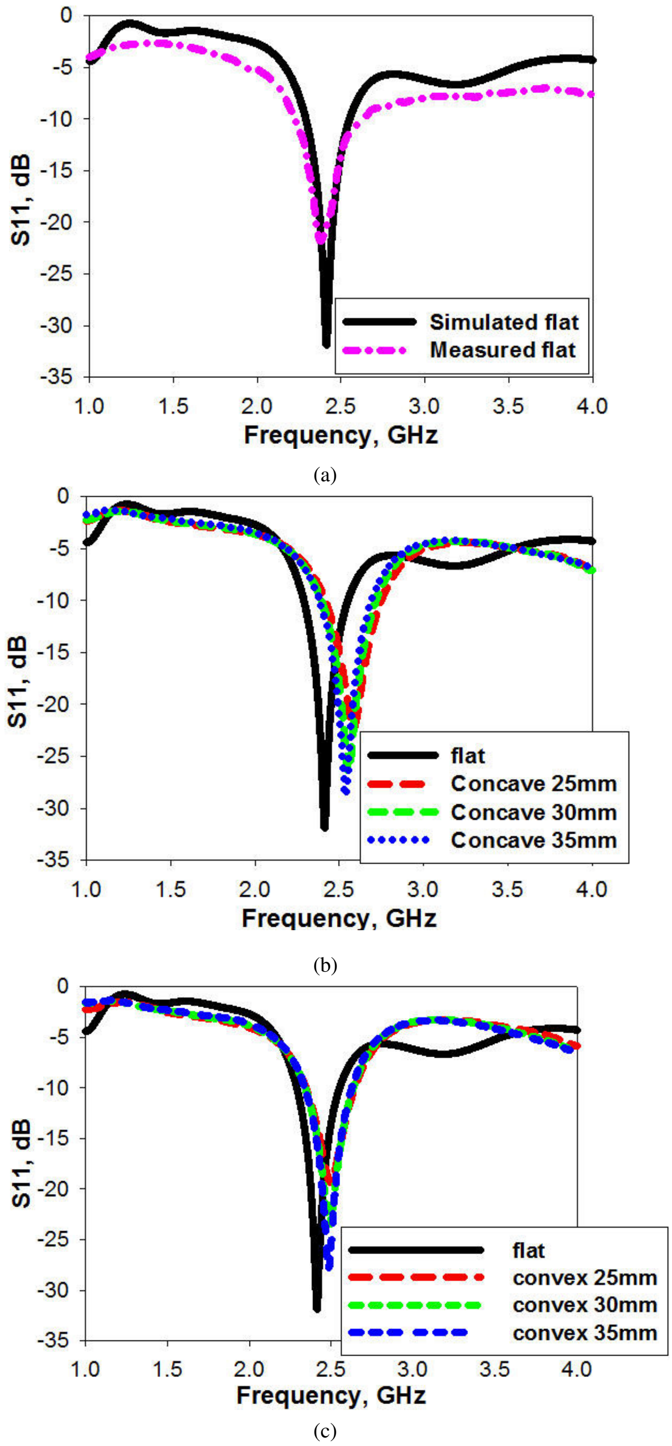


Fig. 2. Reflection coefficient of curvature. (a) Simulated and measured S11 (b) Concave S11 (c) Convex S11

TABLE I. FREQUENCY VERSUS REALIZE GAIN COMPARISON OF FLAT AND CURVATURE STRUCTURES

Structure	Frequency [GHz]	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
Flat	Gain [dB]	0.73	1.64	2.67	3.63	4.38	4.65	4.53	4.25	4.04	3.90	2.86
	Efficiency [%]	44	53	66	80	90	89	81	72	66	63	63
Convex 25 mm	Gain [dB]	0.69	1.00	1.37	1.82	2.22	2.39	2.25	1.81	1.23	0.70	0.31
	Efficiency [%]	56	62	70	79	88	91	85	74	61	51	44
Convex 30 mm	Gain [dB]	0.55	0.98	1.48	2.07	2.61	2.88	2.80	2.35	1.78	1.29	0.98
	Efficiency [%]	52	59	68	79	88	91	85	72	60	51	45
Convex 35 mm	Gain [dB]	0.50	1.02	1.62	2.36	3.10	3.45	3.37	2.92	2.38	1.94	1.64
	Efficiency [%]	51	58	68	79	89	91	83	71	59	50	44
Concave 25 m	Gain [dB]	0.70	1.02	1.37	1.80	2.23	2.55	2.60	2.36	1.97	1.59	1.36
	Efficiency [%]	51	56	63	72	82	89	91	85	75	65	58
Concave 30 m	Gain [dB]	0.81	1.23	1.68	2.21	2.72	3.05	3.05	2.97	2.66	2.25	1.92
	Efficiency [%]	50	56	64	74	84	90	90	81	71	61	55
Concave 35 m	Gain [dB]	0.85	1.33	1.89	2.49	3.06	3.40	3.56	3.44	3.09	2.68	2.36
	Efficiency [%]	49	56	64	75	85	91	88	79	68	59	53

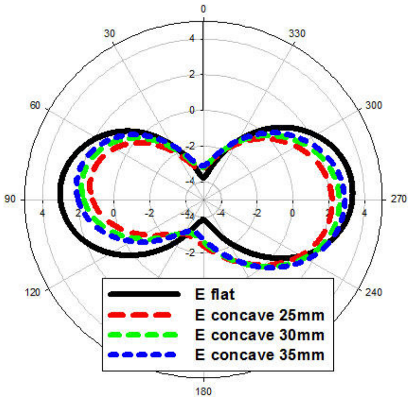
B. The Antenna Radiation Pattern

Fig. 3 shows the simulated radiation pattern of the textile slot antenna under several curvatures. It is apparent that the antenna curvature significantly distorts the radiation pattern in the H-plane, but not much on the E-plane. Furthermore, results have show that the affect on the radiation pattern is also depends on the degree of the curvature. The radiation pattern of the monopole antenna with 25 mm curvature is significantly distorted compared to other bending radius.

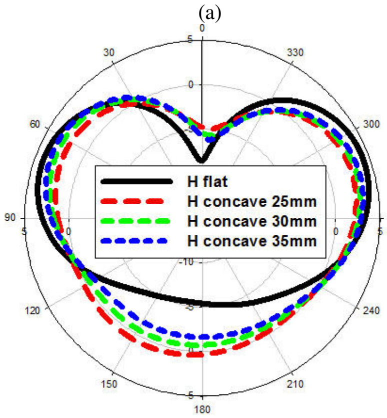
C. The Antenna Realized Gain and Efficiency

The variation of frequency versus realized gain of textile slot antenna is tabulated at Table 1. The maximum realize gain achieved at 2.5 GHz for flat and curvature structure.

The highest percentage of efficiency achieved up to 80 % is between 2.4 GHz and 2.6 GHz. However, the lowest efficiency recorded at 2 GHz for all structure. It can be said that the high curvature lead to decrease in realized gain. Consequently, result showed that this antenna has considerate low power consumption due to gain recorded at most frequency between 2 GHz and 3 GHz that less than 5 dB.



(a)



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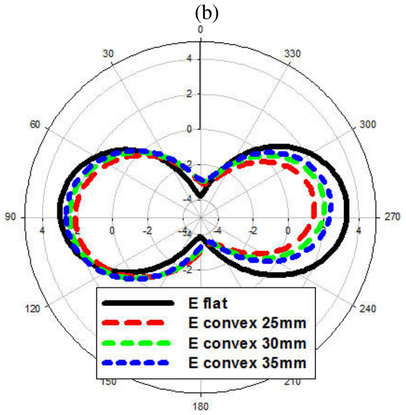

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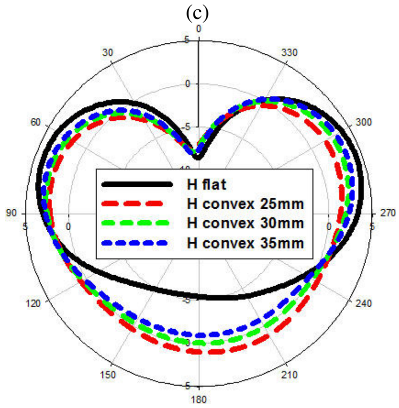

(d)

Fig. 3. Simulated radiation pattern. (a) E-plane concave (b) H-plane concave (c) E-plane convex (d) H-plane convex

IV. CONCLUSION

This paper demonstrates the capabilities of textile slot antenna to be used on curvature structure. The proposed antenna provides good return loss and narrow bandwidth, bidirectional pattern as well as considerate gain and efficiency at desired frequency. However, the antenna curve significantly detuned the antenna resonance frequency and altered the antenna radiation pattern as well reduced antenna realized gain. Therefore, due to this curving effect it is better to minimize curvature structure so it flat as possible.

ACKNOWLEDGMENT

The authors thank the Ministry of Education (MoE), Research Management Centre (RMC), School of Postgraduate (SPS) and Department of Communication Engineering, Universiti Teknologi Malaysia (UTM) for the support of the research under grant no 4S007, 04H38 and 4L811.

REFERENCES

[1] Haiying Huang, "Flexible Wireless Antenna Sensor: A Review," Sensors Journal, IEEE , vol.13, no.10, pp.3865,3872, Oct. 2013

[2] El Khashab, E.O.; Hammad, H.F., "A size-reduced wearable antenna for Zigbee indoor localization," Radio and Wireless Symposium (RWS), 2012 IEEE , vol., no., pp.95,98, 15-18 Jan. 2012

[3] Kamardin, K.; Rahim, M.K.A.; Hall, P.S.; Samsuri, N.A.; Jalil, M.E.; Ayop, O., "Textile Artificial Magnetic Conductor waveguide sheet with monopole antennas for body centric communication," Antennas and Propagation (EuCAP), 2013 7th European Conference on , vol., no., pp.366,370, 8-12 April 2013

[4] M. A. R. Osman, M. K. Abd Rahim, N. A. Samsuri, H. A. M. Salim, and M. F. Ali, "Embroidered fully textile wearable antenna for medical monitoring applications," Progress In Electromagnetics Research, Vol. 117, 321-337, 2011.

[5] Salonen, P.; Sydanheimo, L.; Keskilammi, M.; Kivikoski, M., "A small planar inverted-F antenna for wearable applications," Wearable Computers, 1999. Digest of Papers. The Third International Symposium on , vol., no., pp.95,100, 18-19 Oct. 1999

[6] Salonen, P.; Rahmat-Samii, Y.; Kivikoski, M., "Wearable antennas in the vicinity of human body," Antennas and Propagation Society International Symposium, 2004. IEEE , vol.1, no., pp.467,470 Vol.1, 20-25 June 2004

[7] Salonen, P.; Rantanen, J., "A dual-band and wide-band antenna on flexible substrate for smart clothing," Industrial Electronics Society, 2001. IECON '01. The 27th Annual Conference of the IEEE , vol.1, no., pp.125,130 vol.1, 2001