Curving Effect on The Curved Trapezoid Patch for On-Wrist Power Harvesting at 2.45 GHz

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***Abstract*—A curved trapezoid patch antenna to harvest RF power at 2.45 GHz ISM band (2.4 to 2.5 GHz) for wearable on-body sensor networks. The effect of curving around a cylinder with different diameters is investigated. Gain of the proposed antenna bent around a cylinder with 5cm diameter is 6.42 dBi. 3dB beam-width of the antenna is 90 and 80 degree on YOZ and XOZ planes, respectively. Antenna structure is planar one-layer and is excited by microstrip line proper for on-body wearable systems.**

I. INTRODUCTION

Development of low power miniaturized microwave components has led to ever growing interest on flexible wearable on-body systems with different applications such as entertainment and health-care. Gilbert has mentioned wireless sensor networks (WSNs) as the third wave of a revolution in wireless technology which more efficient utilization of resources, better understanding of the behavior of humans, natural and engineering systems, and increased safety and security are their benefits [1]. In a wireless body sensor network (BSN), different sensors continuously monitor humans physiological activities and actions for healthcare or entertainment applications.

In order to continuously provide DC power for a BSN node and avoid the difficulties with frequent replacement of the power source, ambient or dedicated power harvesting (PH) has gained the researchers interest. RF radio wave (e.g. WiFi and etc) can be subjected to EH [2]. The ambient harvesting uses conventional bandwidths while in the dedicated type there is a dedicated transmitter to provide RF power for the harvester [2]. Antenna of an RF harvester receives the Rf power in the environments and give it to a AC-DC converter. It is well known that gain, efficiency and bandwidth of the antenna has a major effect on the amount of harvested power by the antenna. Many works have been proposed for RF power harvesting such as antenna [3], [4] or rectifier [5] design . These reports have different properties (i.e. working frequency, dimension, gain) depending on the application and the available source. Effect of the human body and physical stress due to wearing should be considered on the design of a on-body antenna.

In this work the effect of the curving diameter on the performance of a curved patch for PH is investigated and one-layer curved trapezoid patch for RF-PH at industrial scientific medical (ISM) 2.45 GHz for BSNs is proposed. Design specification and result of simulation and measurements are proposed in Section II and III, respectively.

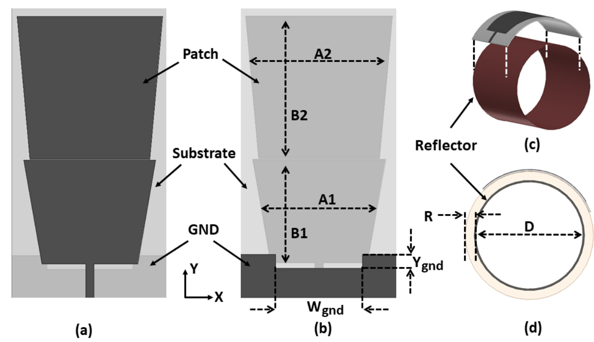


Fig. 1: Proposed curved antenna consisting two trapezoid patch and a reflector. a) Top view. b)Bottom view. c) Curved over a 6o mm diameter cylinder and 5mm away from the curved reflector. d) Side view. $A1(min-max) = 21.8-29.7, A2(min-max) = 27.5-32, B1 = 25.2, B2 = 23.5, W_{gnd} = 20.2, Y_{gnd} = 3.6, R = 5, D = 50, dimensions are in mm.$

II. THE PROPOSED CURVED ANTENNA

The proposed antenna is consist of two trapezoid patch with 0.2 mm distance and a reflector as illustrated in Fig. 1. The trapezoid patches are based on the work reported in [6] in which two groundless trapezoid patches are capacitively loaded to provide a wide band resonance. In order to prevent undesired radiation toward the human wrist, the reflector shown in Fig. 1(c) is used. The reflector is curved around a cylinder with diameter of 50 mm as a human wrist and the distance between the antenna and the reflector is considered as 5 mm (it can be considered as a thickness of a plastic wristband.). At the first step the antenna was designed as a planar structure to have a resonance frequency equal to 2.45 GHz. But, curving this structure over a 60 mm Cylinder (as a modeled wristband) resulted to an upward frequency shift and also considerable degradation in maximum radiation gain. This phenomenons are related to reduction in antenna aperture size due to curving. In addition the coupling coefficient between two patches will vary with curving as the angle between their normal surface vector will change. Table I shows the details regarding curving the antenna over a cylinder with different diameters in which bigger radius results in lower frequency

TABLE I: Resonance Frequency, Gain and bandwidth comparison variation due to curving the antenna over different size cylinders.

Parameter	Flat version	Curving diameter (mm)					
		50	55	60	65	70	75
Frequency (GHz)	2.45	3.32	2.8	2.75	2.65	2.58	2.57
Bandwidth (MHz)	330	0	150	140	150	110	130
Radiation Gain (dBi)	7.28	5.9	6.44	6.33	6.25	6.08	5.98

shift. However, an optimum point exist for the maximum gain. It is noteworthy achieving the maximum bandwidth require different impedance matching for each case while in this procedure, the antenna with flat version's dimensions is curved without any change on its dimensions. Microstrip line feeding is utilized to achieve wearable properties. The fabricated antenna using Rogers 6002 (with permitivity of 2.9 and thickness of 0.762 mm)is illustrated in Fig. 2. This thickness allows the antenna to easily be curved around a cylinder.

III. Performance Evaluation of the Proposed Antenna

In order to consider the curving and also presence of human wrist near the antenna, structure shown in Fig. 4(a) is considered in the simulations. In this structure the antenna and reflector are placed on the outer and inner side of a hollow cylinder (as illustrated in Fig. 1(d)) with inner and outer diameter of 50 and 60 mm as a plastic wristband with permitivity of 2. The human wrist is modeled as a cylinder of 50mm diameter with conductivity of 1.95 (S/m) and relative permittivity of 52.7 at 2.45 GHz [7]. Fig.3 shows the simulated and measured reflection coefficient of the proposed curved antenna. The results show a shift frequency in the measurement due to presence of water. The radiation gain of proposed antenna in YOZ and XOZ planes are illustrated in Fig.4(b). The maximum gain of the antenna toward broadside is 6.2 dBi which considering the patch antennas nature is high. In addition, the 3dB beam-width of the antenna is 90 and 80 degree on YOZ and XOZ planes, respectively.

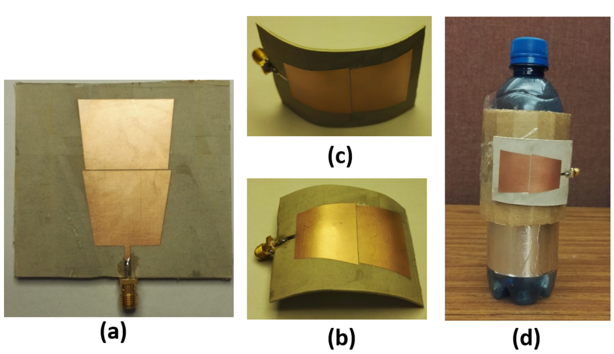
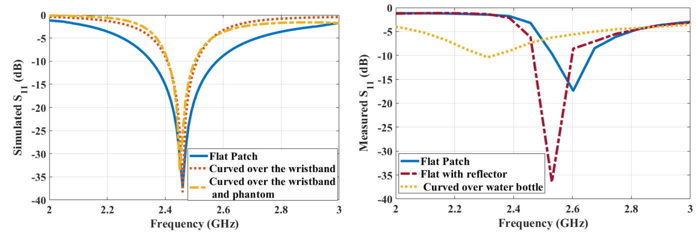
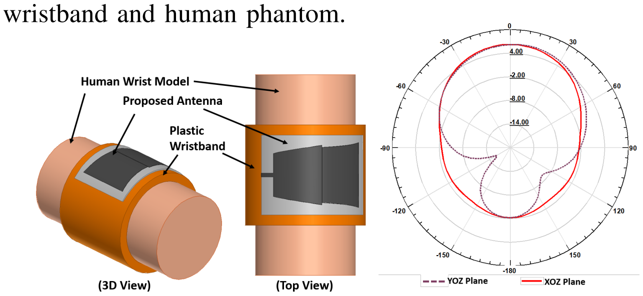


Fig. 2: Fabricated prototype of the proposed antenna. a)Top view b)Curved version top view. c)Curved version side view d) Setup used as the reflector and wristband.



(a) (b)

Fig. 3: (a) Simulated and (b) measured reflection coefficient of the proposed antenna for flat version and curved over wristband and human phantom.



(a) (b)

Fig. 4: (a) Simulated antenna over a plastic wristband and a body phantom and (b) Radiation gain of the proposed curved antenna in dBi.

IV. Conclusion

A curved trapezoid patch for RF power harvesting at 2.45 GHz ISM band was proposed. The effect of curving on the performance was investigated. Frequency shift and gain variation due to curving diameter were observed. The maximum gain of the antenna is 7.2 dBi. the 3dB beam-width of the antenna is 90 and 80 degree on YOZ and XOZ planes, respectively. Adding a rectifier to produce DC power is the future objective of the authors.

References

[1] James M. Gilbert and Farooq Balouchi,"Comparison of energy harvesting systems for wireless sensor networks", International Journal of Automation and Computing journal, vol.5, no.4, pp. 334–347, Oct 2008.

[2] N. A. Moghaddam, A. Maleki, M. Shirichian and N. S. Panah, "RF energy harvesting system and circuits for charging of wireless devices using spectrum sensing," 2017 24th IEEE International Conference on Electronics, Circuits and Systems (ICECS), Batumi, Georgia, 2017, pp. 431–436.

[3] K. Niotaki, S. Kim, S. Jeong, A. Collado, A. Georgiadis and M. M. Tentzeris, "A Compact Dual-Band Rectenna Using Slot-Loaded Dual Band Folded Dipole Antenna," in IEEE Antennas and Wireless Propagation Letters, vol. 12, pp. 1634–1637, 2013.

[4] V. Rizzoli, G. Bichicchi, A. Costanzo, F. Donzelli and D. Masotti, "CAD of multi-resonator rectenna for micro-power generation," 2009 European Microwave Conference (EuMC), Rome, 2009, pp. 1684–1687.

[5] N. Souzandeh, M. Dashti Ardakani, S. Aissa, and S. O. Tatu, Frequency Selective CMOS RF-to-DC Rectifier for Wireless Power and RFID Applications, Proc. 2020 International Symposium on Networks, Computers and Communications (ISNCC 2020), Montreal, Canada, 2020.

[6] R. Zaker, C. Ghobadi, and J. Nourinia, " a modified microstrip - fed two - step tapered monopole antenna for UWB and WLAN applications ," Progress In Electromagnetics Research, Vol. 77, pp. 137–148, 2007.

[7] J. Gemio, J. Parron, and J. Soler, " human body effects on implantable antennas for ISM bands applications : models comparison and propagation losses study ," Progress In Electromagnetics Research, Vol. 110, pp. 437–452, 2010.