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Meander bowtie Antenna for Wearable Application

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Abstract

This paper proposes a flexible compact bowtie antenna for medical application that operates at 2.45 GHz. The proposed antennas are miniaturized using meander technique. Both substrates and conducting material of the antenna are made of flexible material semi-transparent film as the substrate and shieldit fabric as the conducting material which suitable for wearable and on body application. The results show that the total length of the antenna is significantly reduced by up to 38%. However, the gain of the antenna is slightly decreased when the size of the antenna become smaller. The results of this research could provide guidance and has significant implication for future development of wearable electronics especially in medical monitoring application.

Keywords*: Flexible antenna, Compact meander bowtie, Wearable antenna, Medical application*

1. Introduction

In recent years, the wearable antenna has become an attractive research area to its persistent in medical monitoring applications [1-7]. The application of wearable antenna especially in medical industry has to be low-profile, robust, light-weight, compact geometry, flexible and convenient to wear [8-10]. Since the antenna in medical industry is operated in close proximity or directly attached to the human body, a compact design of antenna geometry must be taken into consideration. Thus, the antenna will be easier to be mounted on human body at various positions. However, designing a compact wearable antenna is still a challenge to the researchers in order to sustain its performance.

Various techniques have been used in the past research in order to design a compact antenna including defected ground structure [11]. Researches in [12-13] show that the introduction of meander line into the monopole antenna can significantly reduced the total length of the straight dipole antenna. Therefore, this research proposed to use this technique into bowtie antenna for miniaturization purpose. Besides that, a suitable material for substrate is crucial in order to develop the flexible antenna and choosing a suitable conducting material is also important to prevent even a minor crack on the radiating element which may result in performance degradation. Semi-transparent film is proposed to be used as the substrate. The proposed substrate material is easy to attach to the human skin and does not limit the possible antenna placements on the human body.

2. Research Method

Bowtie antenna is choosen as the radiation source in this paper. This is due to the simple structure and ease of fabrication. Besides, bowtie antenna has an omnidirectional pattern which is suitable to be used for wearable and monitoring application [14]. The geometry of the conventional bowtie antennas and meandered bowtie antenna are illustrated in Figure 1 and

Figure 2 respectively. Both conventional and meandered bowtie antennas are design on flexible semi-transparent film (relative permittivity, ε_r = 2.1373, loss tangent, tan δ = 0.0024) as a substrates whilst the radiating element is made of shieldit fabric (conductivity, σ = 100 S/m, surface resistivity, ρ = 0.01 Ω/m). This material is choosen due to its reliability to be used up to

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several times without affecting the antenna performance [15]. The dimension of conventional bowtie antenna can be obtained by using equation 1 [16]:

$$l = \frac{1}{2}\lambda_0 \times \frac{1}{\sqrt{\varepsilon eff}} \quad (1)$$

where l is the total length of the bowtie antenna, λ_0 is the wavelength is the air, and ε_{eff} is the effective dielectric constant. In order to determine the value of ε_{eff}, similar equation used in previous research [16] is applied. Besides that, the input impendence (Z_{in}) of the antenna can be calculated using equation (2) where α is the flare angle of the antenna.

$$Z_{in} = 120 \ln\left[\cot\frac{\alpha}{4}\right] \quad (2)$$

In order to design a compact bowtie antenna, a meandering technique is applied to the conventional bowtie design. By referring to

Figure 2, l_m is the total length while w_m is the width of the meandered bowtie antenna, and *n* is the number of meander arms. In this paper, *n* is varied from 0 to 3 where *n*=0 is a conventional bowtie design and *n*=1, 2, 3 is the number of meandered arms.

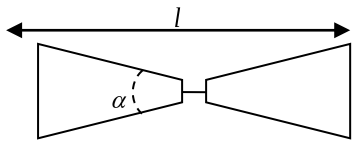

Figure 1. Conventional bowtie antenna design

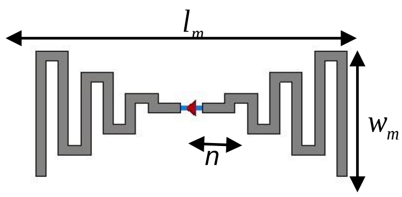

Figure 2. Geometry of meander bowtie antenna

The dimension of the meandered bowtie antenna is optimized in order to make sure the antenna resonates at 2.45 GHz. The configuration of the bowtie antenna for *n* = 0, 1, 2, 3 are illustrated in Figure 3.

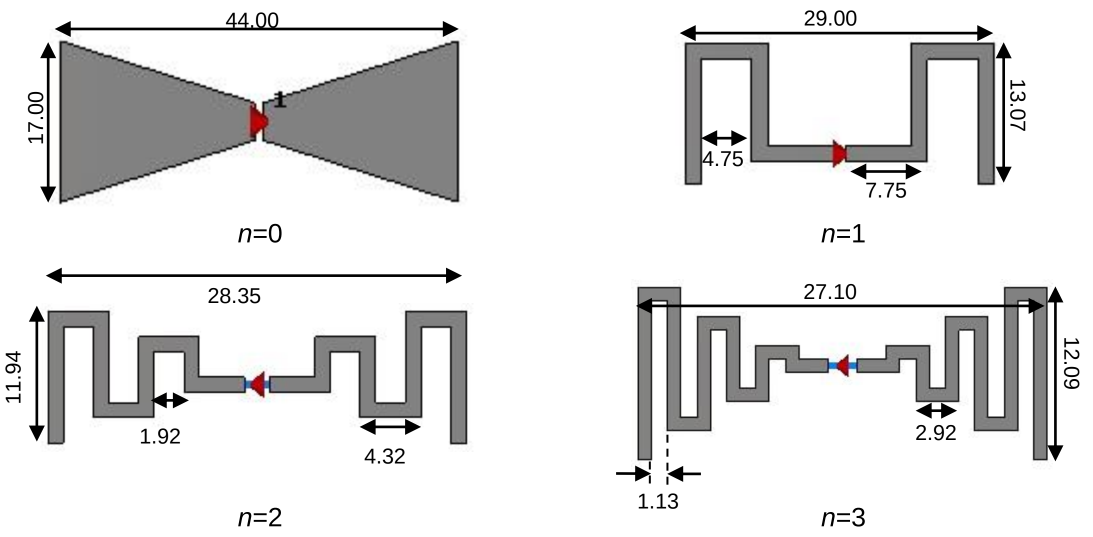

Figure 3. Dimension of conventional bowtie antenna and meander bowtie antenna operated at 2.45 GHz. All dimensions are measured in mm

3. Results and Analysis

3.1. Return Loss of the Proposed Meander Bowtie Antenna

Figure 4 represents a clear comparison between simulated and measured reflection coefficient for conventional bowtie antenna. The results show a reasonable agreement between simulation and measurement. The measured reflection coefficient has a return loss depth of -17 dB at 2.4 GHz. The discrepancies between simulated and measured results are expected due to the dissimilarity between simulated and fabricated prototype.

Besides, Figure 5 depicts the return loss of the meander bowtie antenna. Although there were variations between conventional bowtie and meandered bowtie, the results presented in Figure 5 show that the meander bowtie antenna able to cover the desired ISM frequency (2.45 GHz) with the return loss below than 10 dB. This is due to the effect of additional capacitance and inductance value between each mandering turns [17]. The antenna impedance matching can be improved using several techniques such as parallel matching stub, reactive network or impedance transformer.

Table 1 delineates the percentage of size reduction of meander bowtie antenna compared to conventional bowtie antenna. Based on the result summarized in Table 1, we observed that the total length, l of the conventional antenna can be reduced by using meandering technique. In this paper, we found that the total length of the antenna can be reduced up to 38.4 % for n=3.

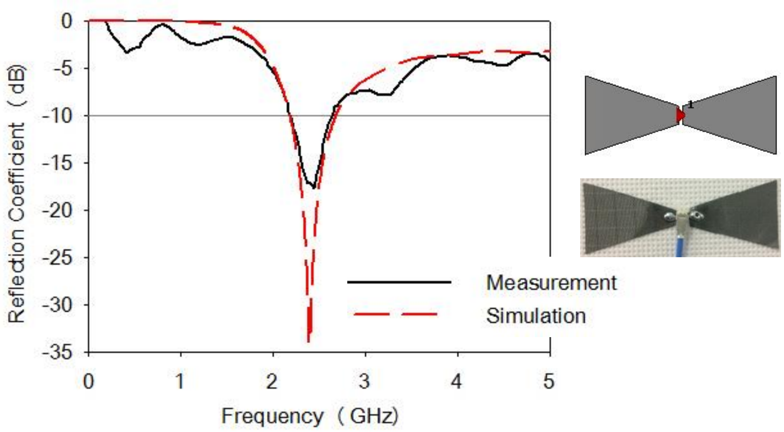

Figure 4. Measured and Simulated Reflection Coefficient of Conventional Bowtie Antenna.

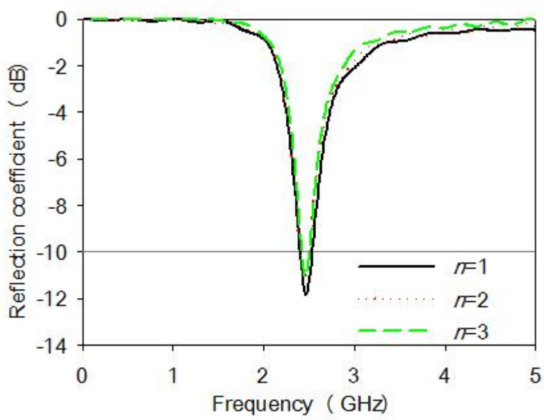

Figure 5. Reflection Coefficient of Proposed Antenna. *n* Represents the Number of Meander Arms

Table 1. Percentage of Length Reduction of Each Meander Antenna Compared to Conventional Antenna

No. of meander arms	*n*=1	*n*=2	*n*=3
Percentage of length reduction %	34.0 %	35.6 %	38.4 %

3.2. Analysis on Current Distribution

Current distribution represents the current flow in the conducting area of the antenna. Figure 6 depicts the surface current distribution for conventional bowtie antenna and meandered bowtie antenna which used flexible semi-transparent film as the substrate. From Figure 6, higher surface current density is only concentrated at the center of the antenna for conventional bowtie antenna while the surface current distributed along the meander line for meandered bowtie antenna. These results show that the meander bowtie antenna has larger surface current path (larger electrical length) compared to the conventional bowtie antenna. Thus, the total length of meandered antenna is reduced. This results agreed well as the results published in [18].

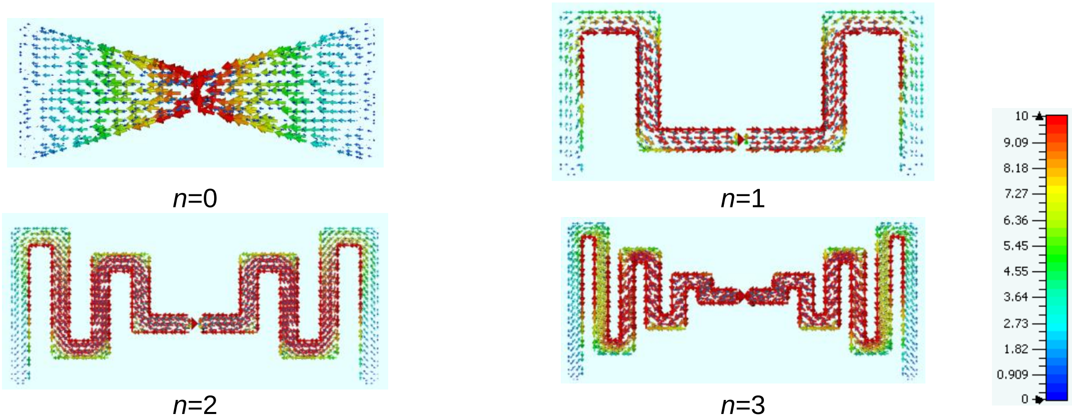

Figure 6. Surface Current Density at 2.45 GHz of Bowtie Antenna for *n*=0,1,2,3

3.3. Simulated Gain and Efficiency of the Mander Bowtie Antenna

Table 2 tabulates the simulated gain for conventional bowtie antenna and meander bowtie antenna. The results show that the antenna gain is decreased when the total length of the antenna is reduced. However, high gain antenna is essential in order to obtain high efficiency and high directivity antenna. Thus, lead to minimal loss in data transmission. The relation between gain and efficiency is discussed in [19]. Besides, the total efficiency of each antenna is also presented in Table 2. The meander bowtie antenna has a total efficiency of at least 88 %.

Table 2. Simulated Gain and Efficiency of Conventional Bowtie and Meander Bowtie Antenna at 2.45 GHz.

No. of meander arm		*n*=0	*n*=1	*n*=2	*n*=3
Bow-tie antenna	Gain (dB)	1.568	1.473	1.490	1.477
	Efficiency (%)	98	88	89	89

4. Conclusion

In this paper, a compact bowtie antenna is design using meander technique for miniaturization purpose. The results presented in this paper show that the total length of the bow-tie antenna can be reduced by the introduction of a meander line into the bowtie shape antenna. The proposed antenna is design to operate at 2.45 GHz and the total length of the proposed antenna is reduced up to 38 % compare to the total length of the conventional bowtie antenna. However, the return loss of the antenna decreases when designing the miniature antenna. Therefore, an optimization method will be done in latter study in order to improve the antenna performance.

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References

[1] S. Agneessens, S. Member, S. Lemey, T. Vervust, H. Rogier, and S. Member. *Wearable, Small, and Robust : The Circular Quarter-Mode Textile Antenna.* IEEE Antennas and Wireless Propagation Letters. 2015; 14: 1482-1485.
[2] M. A. Antoniades, M. A. B. Abbasi, M. Nikolic, P. Vryonides, and S. Nikolaou. *Conformal Wearable Monopole Antenna Backed by a Compact EBG Structure for Body Area Networks*. European Conference on Antennas and Propagation (EUCAP). Paris. 2017; 164-166.
[3] M. A. R. Osman, M. K. A. 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. 2011; 117: 321-337.
[4] M. Tanaka and J. Jang. Wearable Microstrip Antenna. *IEEE Antennas and Propagation Society International Symposium.* Colombus. 2003; 2(2): 704-707.
[5] S. S. Bhatia and J. S. Sivia. A Novel Design of Wearable Fractal Antenna for Wideband Applications. *International Conference on Advances in Human Machine Interaction (HMI).* Doddaballapur. 2016; 5-8.
[6] D. D. Cara, J. Trajkovikj, R. Torres-sánchez, J. Zürcher, and A. K. Skrivervik. A Low Profile UWB Antenna for Wearable Applications : The Tripod Kettle Antenna (TKA). *European Conference on Antennas and Propagation (EuCAP)*. Gothenburg. 2013; 3257–3260.
[7] P. Salonen, Y. Rahmat-samii and M. Kivikoski. Wearable Antennas in the Vicinity of Human Body. *IEEE Antennas and Propagation Society International Symposium*. Monterey. 2004; 467–470.
[8] A. Y. I. Ashyap, W. N. N. W. Marzudi, Z. Z. Abidin, S. H. Dahlan, H. A. Majid and M. R. Kamaruddin. Antenna Incorporated with Electromagnetic Bandgap (EBG) for Wearable Application at 2 . 4 GHz Wireless Bands. *IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE).* Langkawi. 2016; 11–13.
[9] A. Foroozesh, D. Psychoudakis, J. Homer, and I. Kim. *Compact Wideband Stacked Microstrip Patch Antenna for a Medical Application*. Fajardo. 2016; 283–284.
[10] A.Y.I. Ashyap, Z. Z. Abidin, S. H. Dahlan, H. A. Majid, S.M. Shah, M. R. Kamarudin, A. Alomainy. *Compact and Low-profile Textile EBG-based Antenna for Wearable Medical Applications*. IEEE Antennas and Wireless Propagation Letters. 2017;16: 2550-2553.
[11] N. N. Tawfeeq. *Size Reduction and Gain Enhancement of a Microstrip Antenna using Partially Defected Ground Structure and Circular/Cross Slots*. International Journal of Electrical and Computer Engineering (IJECE). 2017; 7(2): 894-898.
[12] N. A. Borhan and N. A. Murad*. A Compact CPW-Fed Curved Meander Line Monopole Antenna (MLMA) for GSM Application.* International Journal of Electrical and Computer Engineering (IJECE). 2017; 6(1): 207-211.
[13] A. Sofi, K. Roky, M. Bouhorma, and I. H. Baraka. *Novel antennas for UHF RFID tags: Design and miniaturization*. International Journal of Electrical and Computer Engineering (IJECE). 2014; 4(1): 75-80.
[14] Y. Tawk, K. Y. Kabalan, A. El-Hajj, C. G. Christodoulou, and J. Costantine. *A simple multiband printed bowtie antenna.* IEEE Antennas and Wireless Propagation Letters. 2008; 7: 557-560.
[15] N. Othman, N. A. Samsuri, M. K. A. Rahim, and K. Kamardin. *Design and Analysis of Flexible Bow-Tie Antenna for Medical Application*. Journal of Electrica Engineering. 2017; 16(1): 17–21.
[16] J. G. and L. Jin. A *Compact Multiband Bow-Tie Dipole Slot Antenna for WLAN and WiMAX Applications.* Progress In Electromagnetics Research Letters. 2015; 56: 17-23.
[17] J. Fan, Z.-Y. Lei, Y.-J. Xie, and M. Man. Bandwidth Enhancement for Low Frequency Meander Line Antenna. *Progress In Electromagnetics Research C*. 2014; 51: 169-177.
[18] H. Y. Wang and M. J. Lancaster. Aperture-Coupled Thin Film Superconducting Meander Antennas. *European Microwave Conference*. 1998; 1(5): 684–689.
[19] M. A. R. Osman. The Developement Of Textile Ultra Wide-Band Antennas for Wearable Applications. PhD Thesis. Johor:Postgraduate UTM; 2012.