A Compact Dual-Band Antenna for Wearable e-Health Devices

Haider Khaleel Raad[1*], Casey White[2], Hussain Al-Rizzo[3], Ayman Isaac[3], and Ali Hammoodi[3]
[*1]Department of Physics, Engineering Physics Program
Xavier University
3800 Victory Pkwy, Cincinnati, OH 45207, USA
[2]Deposition Sciences Inc., Lockheed Martin
Santa Rosa, California 95403, USA
[3] Dept. of Systems Engineering
University of Arkansas at Little Rock
2801 S. University Ave., Little Rock, Arkansas 72204, USA
raadh@xavier.edu, whiteca@seawolf.sonoma.edu, hmalrizzo@ualr.edu, axabbosh@ualr.edu, aihammoodi@ualr.edu

***Abstract*- In this paper, a flexible, compact, ultra-low profile dual band antenna is presented. The proposed design is suitable for wearable and flexible Wireless Body Area Network (WBAN) devices geared for tele-health technology. The antenna has a 50.8 µm thickness and fed by a Coplanar Waveguide (CPW) structure. The proposed design is based on a planar monopole and resonates at 2.45 GHz and 5.2 GHz which makes it suitable for Wireless Local Area Network (WLAN) technologies. Design and analysis of the proposed printed monopole antenna have been carried out using the full wave simulation software CST Microwave Studio, which is based on the Finite Integration Technique (FIT). The proposed design has the merits of compactness, light weight, wide bandwidth, and high efficiency which suggest that the proposed design is a reasonable candidate for integration within wearable and flexible telemedicine systems.**

Keywords*- *e-Health; Telemedicine; WBAN; Wearable Antennas; WLAN.

I. INTRODUCTION

The light weight, efficient energy consumption, low manufacturing cost, fabrication simplicity, convenience, in addition to the abundance of inexpensive synthesized films and substrates, make wearable and flexible electronics an appealing candidate for the modern electronics market. Moreover, recent developments in miniaturized energy storage, flexible photo voltaics, and auto-powered electronic components have paved the road for the commercial success to such devices [1] [2].

Wearable electronics, which can be bent, reconfigured, and flexed, would substantially expand the applications of conventional electronic devices.

Generally, wearable and flexible electronics would often require the integration of antennas operating at specific frequency bands to provide wireless connectivity which is considered an essential requirement and greatly demanded by today's information oriented consumers [3]. Applications of wearable wireless systems include but not limited to the fields of personal communication, medical devices, warfare, aeronautics, and entertainment [4]-[6]. Obviously, the efficiency of flexible wireless systems directly relies on the characteristics of the integrated antenna unit, which must be light weight, conformal, low profile, electrically and physically small, and robust. At the same time, these antennas have to exhibit high efficiency and good radiation characteristics [7]-[11].

On the other hand, Wireless Local Area Network (WLAN) is recognized as the most reliable standard for short range wireless connectivity. The continuous developments in WLAN technologies require the integration of all IEEE 802.11a/b/g/n standards of the 2.4 GHz (2400 –2484 MHz), and 5.2 GHz (5150–5350 MHz) bands into a single radiating element. In the past decade, a plethora of flexible and wearable antenna designs have been reported in the literature, which are based on different topologies and substrate types. Electro textile based antennas seem to be a flexible, low profile solution for wearable applications; however, their substrate materials are likely to introduce discontinuities [12]. Technically, conventional microstrip (patch) antennas are not preferred in wearable electronics since the bandwidth is a function of the substrate's thickness. In [13], a flexible inverted-F antenna printed on a paper-based film was proposed for integration within flexible displays. Although paper based substrates are cost effective, they are found to lack mechanical robustness when used in applications that require high extents of flexing and bending. Moreover, they tend to have a high loss factor which compromises the efficiency of the antenna.

In [14], a wearable and flexible aperture coupled antenna is reported. This technique significantly enhances the impedance bandwidth, however, it leads to a serious increase in the antenna's overall thickness; moreover, it involves a multi-layer fabrication process.

In this paper, we propose a Co-Planar Waveguide (CPW) fed dual band antenna deposited on a 50.8 µm Kapton Polyimide substrate. In addition to its ultra-low

 ISBN: 978-1-61208-470-1

thickness, compactness, and flexibility, the design has a more reasonable feed than the abovementioned feeding techniques since it offers several advantageous characteristics such as: reduced radiation losses, improved impedance bandwidth, and more importantly, lower fabrication cost and reduced complexity since both radiating element and ground plane are laid on the same side of the substrate, which enables roll to roll production and a consistent thickness.

In Section II, the design of the proposed wearable dual band antenna is presented. In Section III, simulation results of return loss and radiation patterns of the proposed design are discussed. Finally, conclusions are given in Section IV.

II. ANTENNA DESIGN

The topology of planar monopole and dipole antennas have received significant attention over other antenna types especially in wearable applications. For WLAN technologies, printed monopoles are preferred over other antenna topologies due to their relatively large impedance bandwidth, low thickness, fabrication simplicity, and omni-directional radiation pattern, which is highly desired in WLAN schemes.

As shown in Figure 1, the antenna consists of a winding branched radiating element fed by a CPW (please note that the grey colored area represents the metallization of ground plane and the radiating element). This miniaturization technique lengthens the current path, which consequently gives rise to a lower resonance and in turn reduces the structure size without significant degradation to the radiation characteristic of the antenna. The antenna structure is positioned on a 31 mm × 34 mm Kapton Polyimide substrate with a dielectric constant of 3.4 and a loss tangent of 0.002. To feed the radiating element, a CPW transmission line, which consists of a central strip with a width of 4 mm and a 1 mm gap between the central strip and the coplanar ground plane is used.

To achieve the desired dual-band behavior, U-shaped structures, which comprise both horizontal and vertical sections are introduced. The introduction of these sections is to produce two distinct current paths and thus dual resonant modes are enabled. Obviously, the longer arm gives rise to the lower resonance while the short arm is responsible for the upper resonance. It is worth mentioning that a parametric study was conducted to investigate the gaps and ground plane size effects on the resonant frequencies and return loss of the antenna. As mentioned previously, the branched radiating element is fed by a CPW feed reduces the fabrication complexity as both the radiating element and ground plane are deposited on the same side of the substrate. The dimensions of the antenna are depicted in Table I.

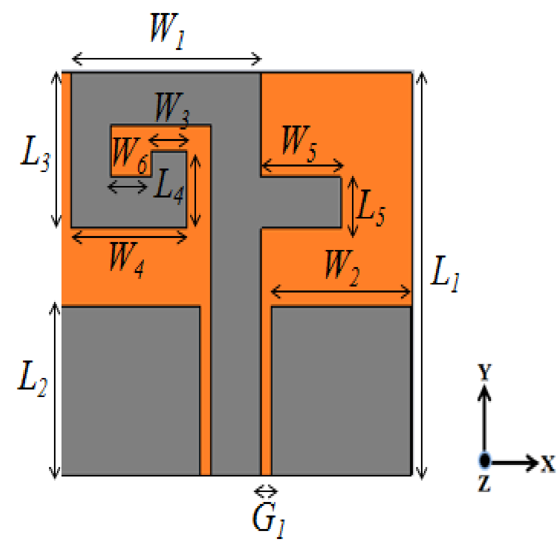


Figure 1. Geometry and dimensions of the proposed dual band printed monopole antenna.

TABLE I. DUAL BAND PRINTED MONOPOLE ANTENNA (DIMENSIONS IN MILLIMETER)

L1	31	***W2***	14
L2	13	***W3***	3.5
L3	12	***W4***	11.5
L4	6	***W5***	8
L5	4	***W6***	4
W1	19	***G1***	1

III. RESULTS

Design and analysis of the proposed printed monopole antenna have been carried out using the full wave simulation software CST Microwave Studio which is based on the Finite Integration Technique (FIT) [18].

As can be seen in Figure 2, the simulated return loss for the antenna is 22.8 dB at 2.5 GHz, with a -10 dB bandwidth of 662 MHz (27%), while the simulated return loss is 25 dB at 5.35 GHz with a bandwidth of 2125 MHz (40%). The principal planes (E and H) were also obtained using CST microwave studio. E-plane (*YZ* cut) and H-plane (*XZ* cut) far-field radiation patterns for the resonances under consideration are depicted in Figure 3.

 ISBN: 978-1-61208-470-1

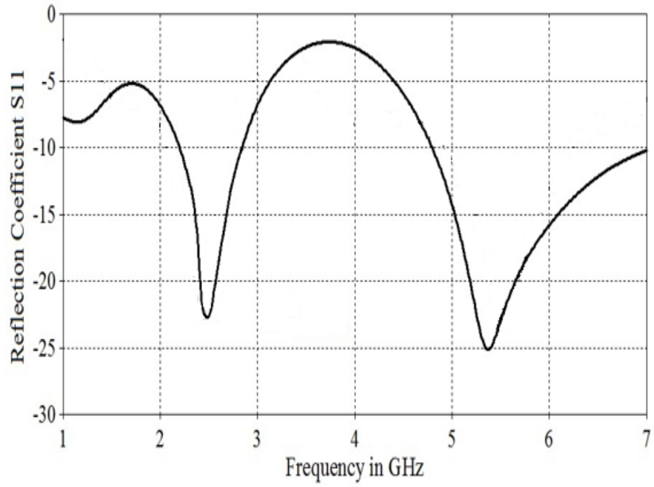
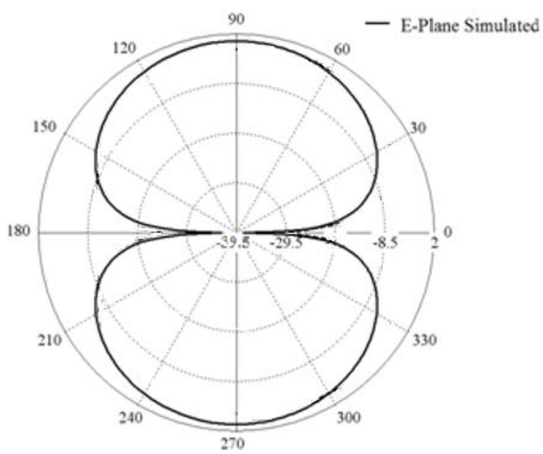
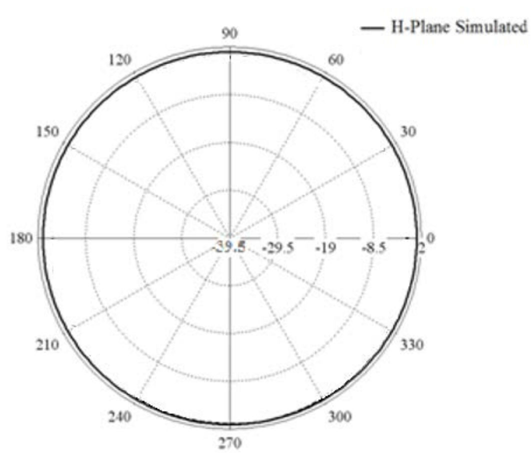


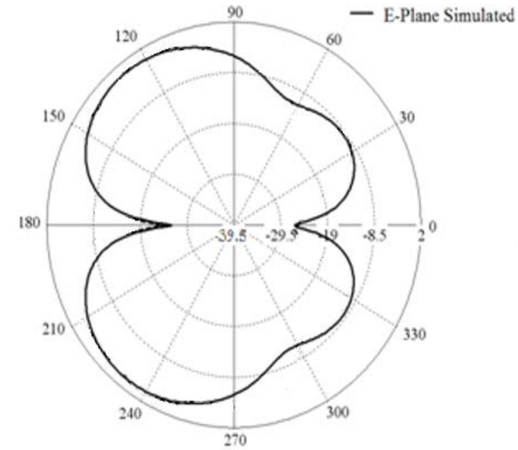
Figure 2. Simulated reflection coefficient S_{11} for the dual band printed monopole.



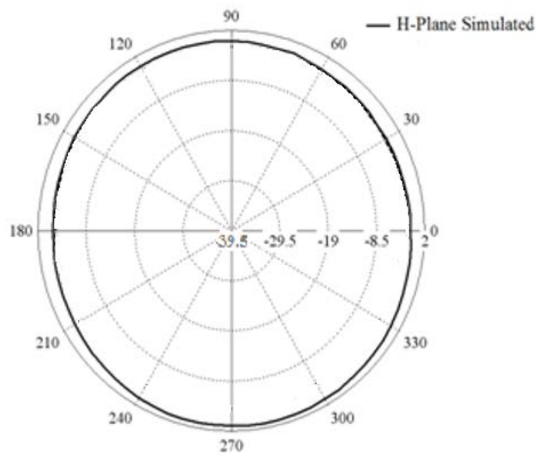
(a)



(b)



(c)



(d)

Figure 3. Simulated E-plane (*YZ*) and H-plane (*XZ*) radiation patterns for the dual band printed monopole at 2.45 GHz ((a) and (b)); and at 5.35 GHz ((c) and (d)).

It can be seen that the radiation power is omni-directional at both resonant frequencies. The antenna achieved gains of 1.68 dBi and 1.64 dBi at 2.45 GHz and 5.35 GHz, respectively, which are typical values for omni-directional antennas. It is worth mentioning that the proposed antenna is suitable for low-power applications (less than 10 mW), hence, it is not expected to expose the user to any significant hyper-thermal effect due to electromagnetic radiation, and thus, Specific Absorption Rate (SAR) analysis would be redundant in this case [15]-[17].

IV. CONCLUSION

In this paper, the design, and simulation of wearable, flexible and compact printed dual band antenna are discussed in details. The reported design is based on a Kapton Polyimide substrate, which is known for its flexibility, mechanical robustness and low dielectric losses. Ultra flexibility, compactness, mechanical robustness, along with excellent radiation characteristics and efficiency suggest that the reported design is a feasible candidate for integration within wearable and flexible WBAN systems.

REFERENCES

[1] H. Bahrami, S. A. Mirbozorgi, R. Ameli, L. A. Rusch and B. Gosselin, "Flexible, Polarization-Diverse UWB Antennas for Implantable Neural Recording Systems," in *IEEE Transactions on Biomedical Circuits and Systems*, vol. 10, no. 1, pp. 38-48, Feb. 2016. [accessed May 2015]

[2] P. Vanveerdeghem, P. Van Torre, C. Stevens, J. Knockaert and H. Rogier, "Flexible dual-diversity wearable wireless node integrated on a dual-polarised textile patch antenna," in *IET Science, Measurement & Technology*, vol. 8, no. 6, pp. 452-458, 11 2014. [accessed January 2016]

[3] J. Hu, "Overview of flexible electronics from ITRI's viewpoint," VLSI Test Symposium (VTS), 2010 28th , vol., no., pp.84, April, 2010. [accessed March 2016]

[4] H. R. Khaleel, H. Al-Rizzo, D. Rucker, and Y. Al-Naiemy, "Flexible printed monopole antennas for WLAN applications," Antennas and Propagation (APSURSI), 2011 IEEE International Symposium on , vol., no., pp.1334-1337, 3-8 July, 2011. [accessed January 2016]

[5] M. N. Srifi, S. K. Podilchak, M. Essaaidi, and Y. M. M. Antar, “Compact disc monopole antennas for current and future ultrawideband (UWB) applications,” IEEE Trans. Antennas Propag., vol. 59, no. 12, pp. 4470–4480, Dec. 2011. [accessed September 2015]

[6] M. Hack, R. Hewitt, K. Urbanik, A. Chwang, and J. J. Brown, “Full color top emission AMOLED displays on flexible metal foil,” in IMID/IDMC’06 Dig., vol. 16, no. 1, p. 305, 2006. [accessed July 2015]

[7] C. Hertleer, H. Rogier, L. Vallozzi, and L. Van Langenhove, "A Textile Antenna for Off-Body Communication Integrated Into Protective Clothing for Firefighters," Antennas and Propagation, IEEE Transactions on , vol.57, no.4, pp.919-925, April 2009. [accessed March 2016]

[8] R. K. Raj, M. Joseph, C. K. Aanandan, K. Vasudevan, and P. Mohanan, “A new compact microstrip-fed dual-band coplanar antenna for WLAN applications,” IEEE Trans. Antennas Propag., vol. 54, no. 12, pp. 3755–3762, Dec. 2006. [accessed November 2015]

[9] H.-D. Chen, J.-S. Chen, and Y.-T. Cheng, “Modified invertedL monopole antenna for 2.4/5 GHz dual-band operations,” IEE Electron. Lett., vol. 39, no. 22, Oct. 2003. [accessed September 2015]

[10] J. W. Wu, H. M. Hsiao, J. H. Lu, and S. H. Chang, “Dual broadband design of rectangular slot antenna for 2.4 and 5 GHz wireless,” IEE Electron. Lett., vol. 40, no. 23, Nov. 2004. [accessed January 2016]

[11] P. Salonen, J. Kim, and Y. Rahmat-Samii, “Dual-band E-shaped patch wearable textile antenna,” IEEE Antennas and Propagation Society Symposium, vol. 1 , pp. 466– 469, 2004. [accessed December 2015]

[12] D. Anagnostou, A. Gheethan, A. Amert, and K. Whites, "A Direct-Write Printed Antenna on Paper-Based Organic Substrate for Flexible Displays and WLAN Applications," Display Technology, Journal of , vol.6, no.11, pp.558-564, Nov. 2010. [accessed June 2015]

[13] H.R. Khaleel, H. Al-Rizzo, and D. Rucker, "Compact Polyimide-Based Antennas for Flexible Displays," IEEE Display Technology, Journal of , vol.8, no.2, pp.91-97, Feb. 2012. [accessed January 2016]

[14] Hertleer, C., Tronquo, A.; Rogier, H., Vallozzi, L., and Van Langenhove, L., "Aperture-Coupled Patch Antenna for Integration Into Wearable Textile Systems," Antennas and Wireless Propagation Letters, IEEE , vol.6, no., pp.392-395, 2007. [accessed August 2015]

[15] H. Ko, R. Kapadia, K. Takei, T. Takahashi, X. Zhang, and A. Javey, **“**Multifunctional, flexible electronic systems based on engineered nanostructured materials”, Nanotechnology, Vol. 23, pp.11, 2012. [accessed April 2015]

[16] A. Rida, S. Nikolaou and M. M. Tentzeris, “Broadband UHF RFID/sensor modules for pervasive cognition applications,” IEEE Conferences Ant. & Prop., pp. 2344-2347, Nov., 2009. [accessed January 2016]

[17] H. R. Khaleel, A. Abbosh, H. Al-Rizzo, and D. Rucker, "Flexible and Compact AMC Based Antenna for Telemedicine Applications," Antennas and Propagation, IEEE Transactions on , vol. 61, no. 2, pp. 524-531, Feb. 2013. [accessed February 2015]

[18] Software information can be accessed online at: http/www.cst.com. [accessed January 2016]