# Radiation Characteristics Improvement of Monopole Antenna Above Glass Substrate for WBAN Applications

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**Abstract:** A P-shaped monopole antenna (PSMA) attached with a glass substrate is proposed for wireless body area networks (WBAN) applications. The study investigates the performance of PSMA above reflection plane substrates with di□erent material of glass and a perfect electric conductor (PEC). The PSMA prototype is fabricated on the FR4 substrateto be operated between 3.1 to 5.1 GHz frequency band. It is discovered that the PSMA efficiency could be enhanced by integrating the ground plane with a glass for the brain and chest human body. For brain model, the antenna efficiency of 78.8%, 80.3% and 85.6% is achieved for 3.3, 4.45 and 5 GHz respectively. The antenna efficiency in the chest model is improved to 75.2%, 76.35% and 81.2% at particular 3.3, 4.45 and 5 GHz respectively. Therefore, this study concludes that the reflection plane help to increase the gain and efficiency of close proximity of body surface. Additionally, the PSMA with reflection plane improves SAR when placed near human body if compared to the other antennas. A fascinating conformity was found between the simulation and measurement results that potentialto be deployed for WBAN applications.
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**Keywords:** WBAN Applications, Monopole Antenna, Glass Reflection Plane Substrate.

## 1. Introduction

In the past few year's, ultra-wideband (UWB) technology has gain huge attention among the researchers in the wireless communications world. These are due to the UWB benefitsover conventional (narrow band) wireless communications systems: low transmit power levels, high-data rates, and possibly simpler hardware configurations. Wireless personal area networks (WPAN) and wireless body area networks (WBAN) are perceived to be among the key areas where potentially UWB features could be adopted [1-3].

The UWB WBAN/WPAN applications necessitate that antennas should have small form factor (esp. in WBAN), good efficiency, easy incorporation with circuitry and efficient transient properties (short impulse response). UWB antennas have numerous designs availability which meet some of the compulsory requirements [4-6].

Further UWB WBAN requirements are required since the near distance to the human body canessentially transform their impedance bandwidth and the radiation features, thus customizing the transient properties of the antenna [7]. The major clarification has resulted to the suggestion of UWB WBAN antennas have to be structured and tested in their usual operating environment. Based on the literature [8-10], not many UWB antenna designed are concerned with this factor.

Majority of the antenna designs proposed to date for UWB WBAN, comprise radiation patterns comparable to the conventional dipole or monopole antennas. Nonetheless, a directional radiation pattern of an antenna would be pleasing for body-worn applications (WBAN) so as to reduce the impact on the human body interaction and body contact to electromagnetic radiation.

In order to achieve this, the radiation to the body requires either not to occur or to be drastically reduced. Universally, directivity can be derived if the antenna is huge in the direction of attention [11].

The main setback on the effect on the human body is dispersive. Designing antennas for WBAN adoption is daunting task. The reflection coefficient magnitude of the antenna in nearness to the human body is dropped and shift relationship in the free space. Additionally, gain and efficiency decline is the major impact on human body on performance of the antennas [12]. In this study, new approach to lessen the impact of human body on reflection coefficient magnitude and gain is suggested.

This research, however, proposed a novel small-size antenna with the reflection plane for UWB systems, with the key emphasy on the WBAN (body-worn) devices. The suggested antenna for WBAN devices to the lower frequency band from 3.1 to 5.1 GHz of the UWB band is shown in this article.

The simulation and evaluation results of the proposed antenna in the brain and the chest to body tissues have been indicated considering various dimensions of the antenna and the human body tissues. The antenna has been simulated adopting CST microwave Studio 2012 software package based on finite integral technique [13]. The parametric investigation of the proposed antenna have been carried out for various parameters to derive the concluding optimized design.

## 2. Design and Analysis

The PSMA [14] is designed with a glass substrate as illustrated in Figure 1.

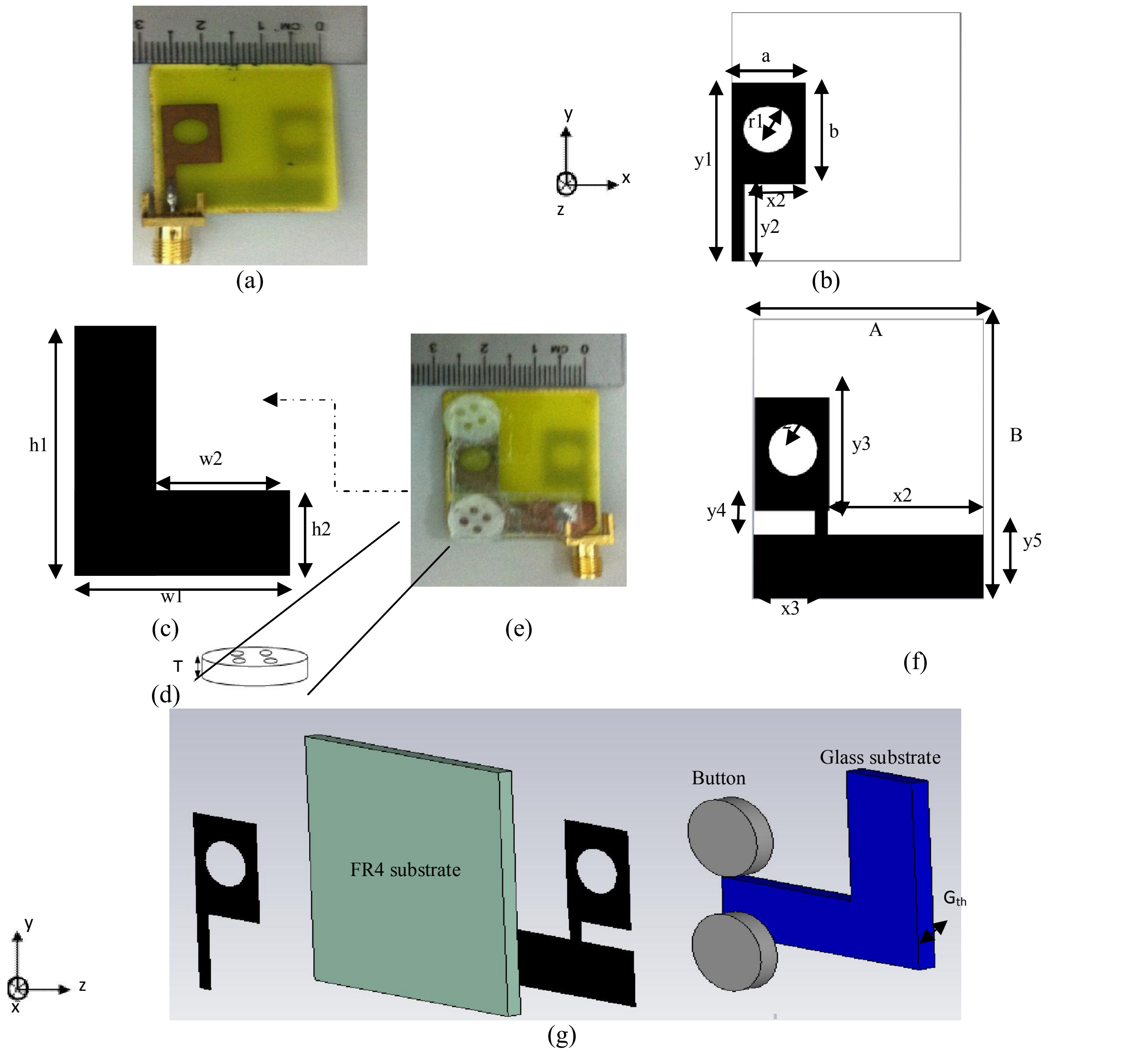
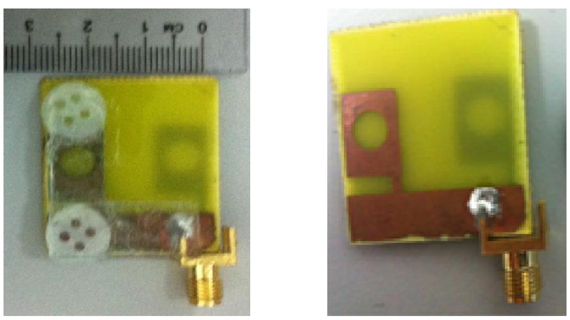



Figure 1. The proposed P-shaped monopole antenna with glass reflection plane (a) Front view (Prototype) (b) Front view (Geometry) (c) Glass substrate (Geometry) (d) Button (Geometry) (e) Back view (Prototype) (f) Back view (Geometry) (g) Isometric side (Simulation)

The proposed antenna is fabricated on FR4 substrate material with loss tangent of 0.02, dielectric constant of 4.4 and a thickness of 1.6mm.While, the reflection plane is fabricated on glass substrate material with epsilon and thickness of 4.82 and 2mm respectively. After a lot of optimization routine, the finalized glass substrate dimension is 26 mm × 24.25 mm with a thickness of 2mm. This research adopts buttons for gapwhich indicates gap between PSMA and reflection plane is 2mm (thickness). As shown in Figure 1, the optimized antenna with glass substrate design has dimensions of *A*=28mm, *B*=32mm, *a*=10mm, *b*=13mm, *y1*=23mm, *y2*=10mm, *y3*=15.75mm, *y4*=2.75mm, *y5*=8.5mm, *x1*=8.5mm, *x2*=19mm, *x3*=7.5mm, , *r1*=*r2*=3mm, *w1*=28mm, *w2*=18mm, *h1*=24.25mm, *h2*=8.5mm, *T*=2mm and $G_{th}$= 2mm. The antenna parameters are as shown in Table 1. Figure 1 (e) shows the back side of the proposed antenna attached the glass substrate with silicone material.

**Reflection Plane Attachment Effect of the Proposed Antenna**

One of the major challenge of the WBAN antenna is the gain and efficiency degradation when the antenna is positioned close to human body [15-20]. In this article, it was discovered that such antenna parameters can be increased by attaching the reflection plane at particular antenna position as shown in Figure 2. The impact of the reflection plane to the PSMA antenna has been studied for with and without the reflection plane attachment to the antenna ground as. The improved PSMA radiation efficiency and gain characteristics for with and without the reflection plane are summarized in Table 1.

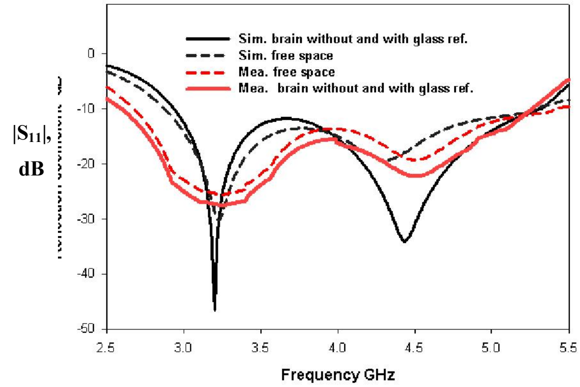


(a) (b)

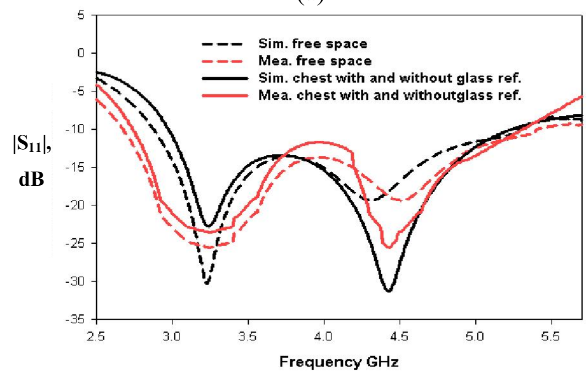
Figure 2. The back view of the proposed P-shaped antenna (a) With glass substrate (b) Without glass substrate

Moreover, of the WBAN antenna with close proximity to the human body has shifted the $S_{11}$ to the undesired frequency resonant

if compared to the antenna in free space environment [21-25]. The simulated and measured reflection coefficient magnitude are shown in Figure 3. It can be seen that the S11 have the similar graph pattern for with and without the reflection plane attachment that covered the desired frequency range of 3.1 - 5.1 GHz with VRWR < 2. The glass substrate placement to the PSMA does not influence the simulated reflection coefficient magnitude either in the free space or near the brain and chest of the human body. This is proven as depicted in Figure 3. However, the measured and simulated reflection coefficient magnitude are slightly different for dissimilar model..




(a)




(b)

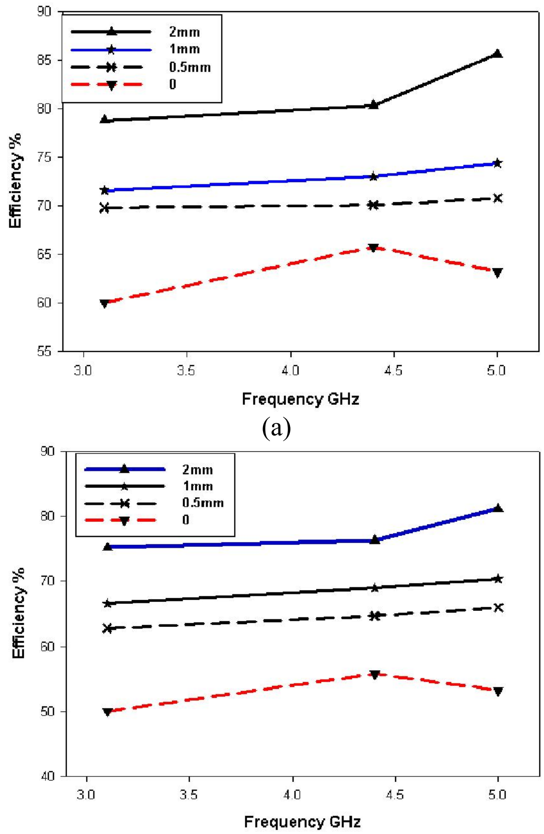
Figure 3. Comparison of the simulated and measured reflection coefficient magnitude in the proposed antenna (a) Close brain human and in free space (b) Close chest human and in free space

It is observed that the glass reflection plane did not have an effect on the reflection coefficient magnitude results. We conclude that the glass substrate has stable reflection coefficient magnitude when attached to the proposed antenna.

**The Reflection Plane thickness effect of the Proposed Antenna**

The effect of the reflection plane thickness on the proposed antenna has been investigated. The thickness of the reflection plane ($G_{th}$) (see Figure 1(g)) has an effect on the performance of the proposed antenna, which has been investigated in this study.

The optimized gap thickness of the proposed antenna and the reflection plane is B = 2 (see Figure 1 (d)) and reflecton plane thickness of $G_{th}$ = 0 (meaning the proposed antenna without the reflection plane), 0.5, 1 and 2 mm. The radiation plane thickness effected the antenna radiation efficiency as illustrated in Figure 4.




(a)

(b)

Figure 4. The P-shaped antenna with glass substrate placed close to the chest and the brain of human body (a) In the human brain (b) In the human chest

Figure 4 indicates the proposed antenna with glass reflection plane placed near the brain resulted to 85.6% at 5 GHz, while near the chest is 81% at 5 GHz. This is due to the fact that the chest consist of more muscles layer., The muscle layer helps to reduce the radiation efficiency, whereas the brain does not has muscle layer. Therefore, the radiation efficiency in the brain is found to be better than the chest. This further shows that an improved radiation efficiency for the proposed antenna when the thickness of glass substrate is increased for the reflection plane. The final optimized reflection plane design has a thickness of 2 mm. The improved antenna efficiency in the brain model is 78.8%, 80.3% and 85.6% at targetted frequency of 3.3, 4.45 and 5 GHz respectively. While the improved antenna efficiency in the chest model is 75.2%, 76.35% and 81.2% at 3.3, 4.45 and 5 GHz respectively.

This study involved two dissimilar models of the human body. The first one is a chest model comprising of three layers are designed for the chest of human body tissues, which consists of muscle, fat and skin. The chest body dimensions are (300 × 300 × 37) mm and the thicknesses of skin; fat and muscle are 2, 5 and 30 mm, respectively. The second model is a brain that comprises of white and grey layers . The brain chest body dimensions are 200 mm × 200 mm × 37 mm. The measured of reflection coefficient magnitude and radiation pattern of the male human body has height and wieight of 1.77 m and 83kg respectively.

Table 1. The proposed antenna with reflection planes for radiation efficiency, gain and SAR when at $G_{th}$=0, 0.5mm, 1mm and 2mm

| Parameter At $G_{th}$=0mm | PEC substrate in the human chest / brain at 3.3, 4.45 and 5 GHz | Glass substrate in the human chest / brain at 3.3, 4.45 and 5 GHz |
|---|---|---|
| Gain (dB) | 5.17, 5.44, 4.9 / 4.86, 5.81, 5.7 | 5.4, 5.8, 5.76 / 4.98, 5.6, 5.81 |
| Efficiency (%) | 48.2, 50.5, 49 / 56, 53.6, 59.7 | 50, 53.76, 51.24 / 60.04, 65.7, 63.2 |
| SAR (W/kg) | 4.1, 5.6, 7.1 / 4.9, 4.79, 4.03 | 4.1, 5.2, 6,67 / 5.45, 4.4, 4 |
| Parameter at $G_{th}$=0.5mm | | |
| Gain (dB) | 5.9, 6.1, 5.6 / 4.95, 5.96, 5.88 | 6.0, 6.43, 6.36 / 5.03, 5.87, 5.92 |
| Efficiency (%) | 55.1, 57, 60.8 / 61, 58.6, 67.3 | 62.8, 64.7, 66.0/ 69.8, 70.1, 70.8 |
| SAR (W/kg) | 3.8, 4.9, 5.7 / 4.6, 4.47, 3.9 | 3.67, 4.6, 5.1 / 5.52, 4.1, 3.86 |
| Parameter at $G_{th}$=1mm | | |
| Gain (dB) | 6.2, 6.6, 5.8 / 5.1, 6.08, 6.15 | 6.24, 6.77, 6.51 / 5.36, 6.0, 6.21 |
| Efficiency (%) | 62, 64, 67 / 66.4, 64.13, 70.3 | 66.68, 69.0, 70.4 / 71.6, 73.0, 74.4 |
| SAR (W/kg) | 3.44, 4.06, 3.4 / 4.53, 4.3, 3.8 | 3.41, 3.9, 3.26 / 5.31, 3.9, 3.5 |
| Parameter at $G_{th}$=2mm | | |
| Gain (dB) | 6.5, 7.2, 6.3 / 5.4, 6.48, 6.54 | 7.2, 8.14, 7.7 / 5.6, 6.3, 6.6 |
| Efficiency (%) | 66.1, 69.6, 71 / 69.4, 72.23,77.2 | 75.2, 76.35, 81.2 / 78.8, 80.35, 85.58 |
| SAR (W/kg) | 3.37, 3.84, 2.73 / 4.22,4.1, 3.55 | 3.1, 3, 1.66 / 4.7, 3.79, 3 |

## 3.Experimental Result Verification

The simulated reflection coefficient magnitude, radiation efficiency, gain and SAR of the proposed antenna with reflection planes is verified through measurement. All results of the two models of the human body used are presented. The section also reveals the adopted P-shaped antenna with the glass and PEC substrate reflection plane of a chest and brain models of the human body. Table 1 shows the antenna's radiation efficiency and SAR (10g) when the gap at $G_{th}$=0, 0.5, 1 and 2 mm are used on the proposed antenna. The meaning of $G_{th}$=0 referred to the PSMA has direct contact to the indication surface. $G_{th}$=2mm is the optimum value to realize the optimum results of the antenna radiation efficiency and SAR in WBAN applications.

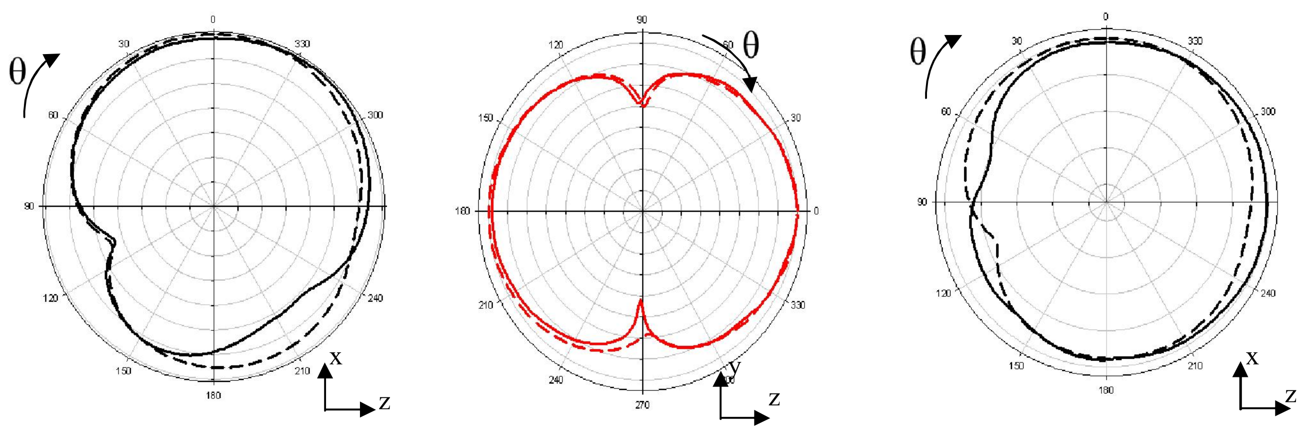
On the body, the directivity of the antenna increases because the wave is reflected from the human body, while the efficiency decreases due to the tissue absorption. The reflected wave from the body could be combined in phase with the directed wave in different signal directionthus influence the gain direction against frequency with respect to the free space case.

This study implemented the P-shaped antenna with the glass substrate and a perfect electric conductor (PEC) substrate. Such proposed antenna is placed close to the chest and the brain of human body as tabulated in Table 1.

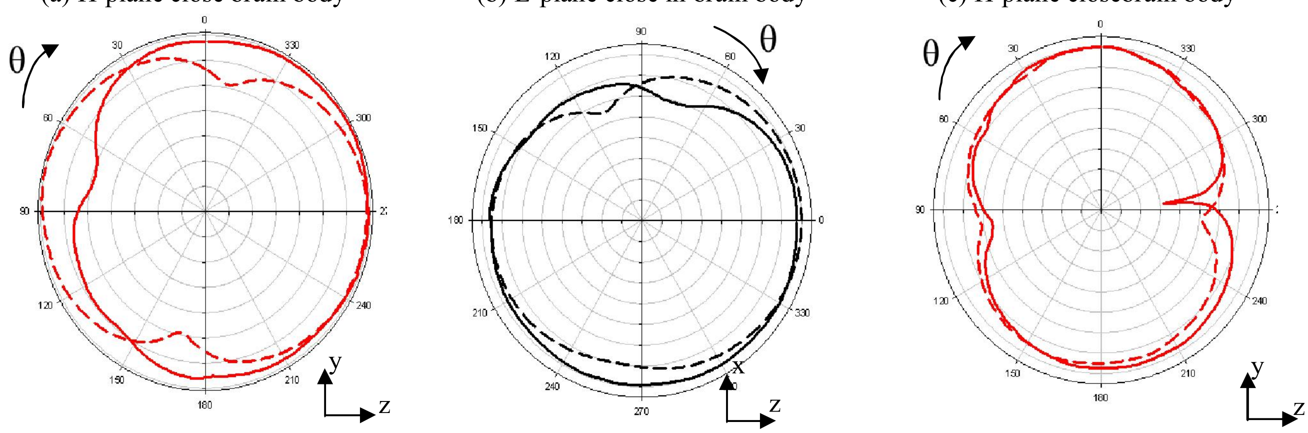
It is observed that gain enhancement would occur when there are variance of the substrate indication surface. As tabulated in Table 1, the recommended antenna gain is enhanced with PEC substrate indication surface at 5 GHz are 5.79, 5.88, 6.15 and 6.54 dB in the brain structure is amplified with reflection plane thickness ($G_{th}$) width are 0, 0.5, 1, 2 mm, correspondingly. Additionally, the gain of the recommended antenna enhanced with glass substrate flat surface at particular 5 GHz are 5.81, 5.92, 6.21 and 6.6 dB has amplify the reflection plane thickness are 0, 0.5, 1, 2 mm, in that order. The glass manifestation plane with $G_{th}$=2mm achieved the best consequences of the antenna radiation efficiency, gain and SAR in WBAN applications.

The simulated and measured radiation patterns at 3.3, 4.45 and 5 GHz close to human body tissues from brain and chest model are shown in Figure 5. It can be seen that the E- and H-plane radiation patterns are affected when the antenna is placed close to the brain and the chest human body. PSMA has improved the gain when attached to the glass reflection plane near the human body in the brain and chest area if compared to the PSMA without a reflection plane.

**At 3.3GHz** **At 4.45GHz** **At 5 GHz**



(a) H-plane close brain body (b) E-plane close in brain body (c) H-plane closebrain body



(d)E-plane closebrain body (e)H-plane close brain body (f)E-plane close brain body

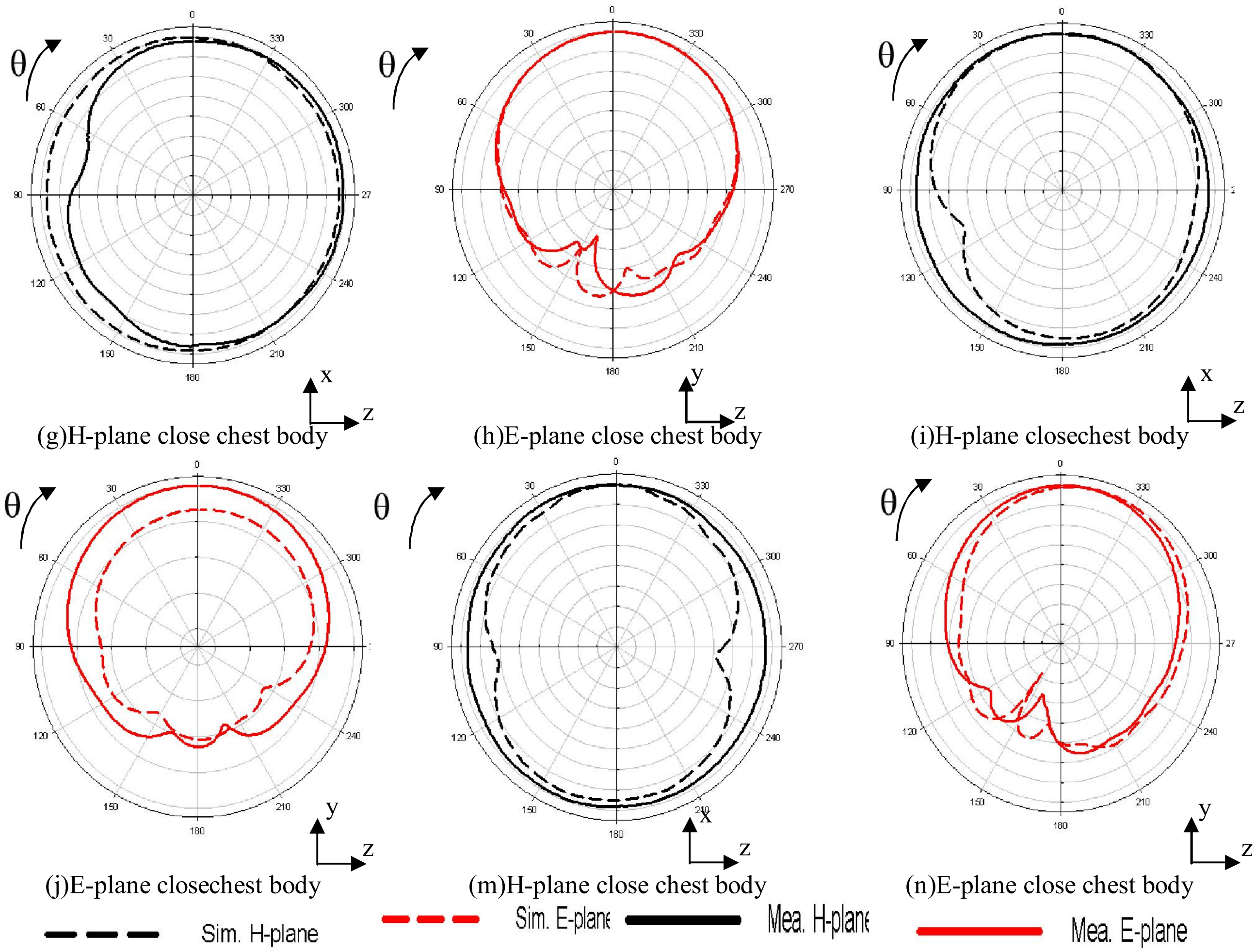



Figure 5. Simulated and measured radiation pattern of the proposed antenna with glass substrate

The simulated and measured radiation pattern of the proposed antenna with reflection plane in the brainhas achieved gain of 2.2, 2.5 and 2.6 dB at 3.3, 4.45 and 5 GHz. When the PSMA integration with glass substrate is placed close to the brain, the simulated gains are 5.6 dB, 6.3 dB and 6.6 dB at 3.3 GHz, 4.45 GHz and 5 GHz. The similarity of suggested antenna performance with and without glass substrate near to human body is shown in Figure 2. The PSMA with glass substrate has made superior the performance near the human body in the brain and in the chest as juxtaposed with other antennas. An observation of the suggested antenna performance in the human brain and chest was increased with glass substrate of indication plane better than PEC substrate as revealed in Table 1. The PSMA with glass substrate at $G_{th}$=2mm ( standard rate) resulted to the best antenna radiation performance and SAR in WBAN applications.

**4. Conclusion**

A novel small-size directional UWB antenna with glass substrate for WBAN applications is proposed. The presented P-shape in close proximity to chest and brain models of human tissue performances of gain and radiation efficiency is improved by attaching to the glass substrate. Moreover, the PSMA antenna capable to solve the influence of the human body to the radiation efficiency and dispersive frequency. Instead of improved the gain, it has enhanced the antenna efficiency in the brain model of 78.8%, 80.3% and 85.6% at particular 3.3, 4.45 and 5 GHz, respectively. While the improved antenna efficiency in the chest model is 75.2%, 76.35% and 81.2% at 3.3, 4.45 and 5

GHz, respectively. Both measured and simulated results shown the integration of the proposed glass substrate provides good performance in terms of reflection coefficient magnitude, radiation pattern and efficiency of WBAN applications. The afore mentioned results leads to the conclusion that our new directional UWB antenna is indeed very suitable for UWB WBAN applications, being a more efficient design with radiation characteristics less influenced by the human body proximity.

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**References**

1. Klemm, M. and Troester, G. (2006) EM energy absorption in the human body tissues due to UWB antennas, Progress In Electromagnetics Research, 62: 261-280.
2. Peiravi, Ali (2010) Connectance and Reliability Computation of Wireless Body Area Networks using Signal Flow Graphs, Life Science Journal, 7(2):52-56.
3. Peiravi, Ali (2009) Reliability of Wireless Body Area Networks used for Ambulatory Monitoring and Health Care,", Life Science Journal, 6(4): 5-14.
4. Schantz,G. H. and Fullerton,L. (2001) The diamond dipole: a Gaussian impulse antenna, presented at the IEEE Antennas and Propagation Soc. Symp., 8-13.
5. Klemm, M. and Troester, G. (2004)Characterization of an aperture-stacked patch antenna for ultra-wideband wearable radio systems, in Proc. 15th Int. Conf. Microwaves, Radar and Wireless Communications-MIKON, Warsaw, Poland, 2: 395-398.
6. Kwon, H. D. and Kim, Y. (2004) A small ceramic chip antenna for ultra-wideband systems, presented at the Int. Workshop on Ultra Wideband Systems Joint With Conf. Ultra Wideband Systems and Technologies, Kyoto, Japan, May 18-21.
7. Klemm, M. and Troester, G. (2004) Small patch antennas for ultra-wideband wireless body area netwroks, presented at the EUROEM 2004 Conf., Magdeburg, Germany, Jul. 12-16.
8. Kohno, R. Hamaguchi, K. Li, H. B. and Takizawa, K. (2008) R&D and standardization of body area network (BAN) for medical healthcare, Proc. IEEE Int. Conference on Ultra-Wideband, (ICUWB), 3: 5-8.
9. .Zhu S. and Langley, R. (2009) Dual-band wearable textile antenna on an EBG substrate, IEEE Trans. Antennas Propag., (4)57: 926-935.
10. Zhu S. and Langley, R. (2007) Dual Band Body Worn Antenna, Antennas and Propagation Conference, 137-140.
11. Qing, X. and Chen, Z. N. (2004) Antipodal vivaldi antenna for UWB applications," presented at the EUROEM 2004 Conf., Magdeburg, Germany, Jul. 12-16.
12. karimabadi,S. and Attari,A. R. (2010) Gain Enhancement of Small Size UWB Antenna for Wireless Body Area Network Applications.
13. CST Microwave Studio [Online] http://www.cst.com
14. Alabidi, E. S. Kamarudin,M. R. Rahman,T. A. and Iddi, H. U. (2013) P-shape Monopole Antenna Design for WBAN Application, PIERS Proceedings, Taipei, March 25-28,.
15. Rahman, A. Alomainy A. and Hao, Y. (2007) Compact Body-Worn Coplanar Waveguide Fed Antenna for UWB Body Centric Wireless Communications,The Second European Conference on 11-16 Nov. 1-4.
16. Rahman, A. and Hao, Y. (2007) A Novel Tapered Slot CPW-fed Antenna for Ultra-Wideband Applications and Its On/Off Body Performance, International Workshop on Antenna Technology, 21–23 March, Cambridge, UK.
17. Alomainy, A. Sani, A. J. Santas, A. Rahman, A and Hao, Y. (2009) Transient Characteristics of Wearable Antennas and Radio Propagation Channels for Ultra Wideband Body-Centric Wireless Communications, IEEE Transactions in Antenna and Propagation, 57: 875-884.
18. Suh, S.Y. Stutz man W. L., and Davis, W. A. (2004) A New Ultra Wideband Printed Monopole Antenna, The Planar Inverted Cone antenna (PICA), IEEE Transaction on Antennas and Propagation, 52: 1361-1364.
19. Alomainy, A. Hao, Y. Parini, C. G. and Hall, P. S. (2005) Characterisation of Printed UWB Antenna for On-Body Communications, IEEE Wideband and Multiband Antenna Arrays.
20. Alomainy, A. and Hao, Y. (2006) Radio Channel Models for UWB Body Centric Networks with Compact planar Antenna, in Proc. IEEE APS Int Symp. Antennas Propag., Albuquerque, NM, 2173-2176.
21. Suh, S.Y. Stutz man W. L., and Davis, W. A. (2004) A Novel CPW fed Disk Antenna, in

Proc. IEEE Antennas Propag. Soc. Symp., 3: 2919-2922.

22. Chen, Z. N. See, T. S. Qing, P. X. (2007) Small Printed Ultra Wideband Antenna with Reduced Ground Plane Effects, IEEE Transactions on Antenna and Propagation, 55:971-976.
23. Sani, A. Santas, J. Alomainy, A. and Hao, Y. (2008) Time Domain Characterisation of Ultra Wideband Wearable Antennas and Radio Propagation for Body-Centric Wireless Networks in Health Care Applications, Proceeding of the 5th International Workshop on Wearable and Implantable Body Sensors Networks.
24. Abbasi, Q. H. Alomainy, A. Hao, Y. (2010) Recent Development of Ultra Wideband Body-Centric Wireless Communications, Proceeding of 2010 IEEE International Conference of Ultra-Wideband.
25. Guo, L. Wang, S. Chen, X. and Parini, C. G. (2009) A Small Printed Quasi-Self Complementary Antenna for Ultra Wideband Systems, IEEE Antennas and Wireless Propagation Letter, 8:781-786.

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