Open Journal of Antennas and Propagation, 2015, 3, 19-26
Published Online September 2015 in SciRes. http://www.scirp.org/journal/ojapr
http://dx.doi.org/10.4236/ojapr.2015.33003

Multiband LTE-A/WWAN Antenna for a Tablet

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Received 13 August 2015; accepted 18 September 2015; published 21 September 2015

Abstract

In this paper, an internal multiband antenna is proposed for LTE-A/WWAN wireless applications in tablet computer. The proposed antenna is configured to have two branch radiators. These two branch radiators are a U-shaped driven monopole and a nonuniform wrapped inverted U-shaped monopole. The impedance bandwidths across dual operating bands are 89.7 MHz and 4185 MHz at the LTE-A/WWAN bands. Various techniques, such as branching and parasitic element are used to enhance the antenna's bandwidth, the matching, and the size of the proposed antenna. The antenna is presented on an area of 50 × 15 mm². Experimental results of this antenna show nearly omni-directional coverage and stable gain variation across the LTE-A/WWAN bands.

Keywords

Long Term Evolution (LTE), Mobile Antennas, Tablet Computer Antennas, Monopole Antenna, Dual Wide Bands, Portable Devices, WWAN/LTE Antenna

1. Introduction

One of the main advantages of Long Term Evolution Advanced (LTE-A) which makes it a good candidate for 4G wireless communication is the large bandwidth. The candidate deployment frequency bands of LTE-A proposed by World Radio Conference in 2007 (WRC07) include 450 MHz - 470 MHz, 698 MHz - 787 MHz, 790 MHz - 862 MHz, 2.3 GHz - 2.4 GHz, 3.4 GHz - 4.2 GHz, 4.4 GHz - 4.99 GHz [1]. LTE-A provides much higher data rate for real-time voice and data transmission than WWAN operation. This is the motivation for different researchers to introduce different LTE antenna configurations which are suitable to be integrated with mobile wireless systems like tablet and laptop computers. The challenge in this case is the wide operating bandwidth

How to cite this paper: Elshennawy, W.S., Hashish, E.A. and Attiya, A.M. (2015) Multiband LTE-A/WWAN Antenna for a Tablet. *Open Journal of Antennas and Propagation*, **3**, 19-26. http://dx.doi.org/10.4236/ojapr.2015.33003

and the limited size which can be reserved for the antenna. Thus the required antenna should be compact and low profile [2]-[4].

Several planar LTE/WWAN internal monopole antennas have been developed for tablet computer [5]. The most common method to design a small and compact printed antenna is to use Planar Inverted-F Antennas (PIFAs) [6] which can be bent to achieve a small size with a low profile. Unfortunately, the proposed antenna in [7] has a drawback of slotted grounded plane which causes RF interference between excited modes and with the placement of electronic components such as battery, display and RF chips. The three-dimensional structure of PIFA requires an additional height clearance leading to a more complex manufacturing process and therefore higher cost. Another form which is commonly used for LTE/WWAN antenna is based on embedding a chip inductor on the radiating path of an antenna [4] [8] [9] to reduce the antenna size and match in the input impedance of the antenna at the required operating frequency band. Though, the lumped elements in the external matching circuit introduce additional losses which decrease the efficiency of the antenna, the designers have to control the number of matching components and their associated losses in consumers products.

Coupled fed antennas are found more appropriate to achieve multiband operation and wider operating bandwidth compared with direct fed antennas [10] [11]. A properly formed coupled-fed antenna like slotted ground structure is found to be suitable to obtain eight-band operation. Fractal antennas are another promising configuration which is characterized by the ability to fit large electrical lengths into small physical volumes and subsequently to overcome the problem of limited space [12].

Combination of planar monopole antenna branches can introduce a wider operating bandwidth [5] [13]-[15]. In addition, this configuration is more suitable for PCB fabrication process [16] [17]. Though, these self-resonant antennas are widely used and well performing, the geometry of antennas become very complex with the increased number of the frequency bands.

This paper employs techniques of binding dual-arm monopole strips into a rectangular shape combined with parasitic elements to obtain a compact structure and offers multiband operations. Direct feeding mechanism is applied to realize the required two wide operating bands for LTE-A and WWAN applications. The proposed antenna provides wide operating bands, covering the GSM1800/1900 bands, LTE700/2300 bands (698 - 787 MHz/ 2305 - 2400 MHz), Wideband Code-Division Multiple Access (WCDMA) band (2100 - 2170 MHz), Universal Mobile Telecommunications System (UMTS) band (1920 - 2170 MHz), Wireless Local Area Network (WLAN) dual bands (Bluetooth) (2400 - 2497 MHz/5150-5350 MHz), WiFi bands (2412 - 2483 MHz/4900 - 5900 MHz), WiMAX system bands (2300 - 2400 MHz/3300-3800 MHz) simultaneously, and RFID bands (2400 - 2483 MHz/5725 - 5875 MHz). Thus, the proposed antenna covers LTE/WWAN bands in addition to other applications such as IEEE802.15 and UWB-L.

All antenna strips in this paper have the same width (0.5 mm) to simplify the dimensional parameters and minimize manufacturing defects. The proposed antenna has a small size of 50 × 15 × 1.5 mm^3. The presented design is more feasible for embedding into a tablet computer. Details of the antenna design are described in Section 2. Experimental measurements of the fabricated prototype are presented in Section 3.

2. Antenna Design

The proposed antenna is designed to have multiple resonances. The specified required bands are LTE700/2300 bands (698 MHz - 787 MHz/2305 - 2400 MHz) and WWAN bands (1600 - 2690 MHz). The required matching criteria of the proposed antenna is to introduce VSWR below 3:1 corresponding to a return loss below −6 dB. To reduce the size of the proposed antenna to fit inside the tablet, the shape of the antenna is suggested to be U-shape monopole. On the other hand, to achieve multi-band operation, two U-shape monopoles with different lengths are combined and directly fed with a common feeding port as shown in **Figure 1**. The U-shape monopole BCDE in **Figure 1** correspond to the lower frequency band while the U-shaped monopole HIJK in **Figure 1**, corresponds to the higher frequency band. To enhance the radiation properties at lower frequency band around 700 MHz, it is found that the length of the corresponding U-shaped monopole antenna would be greater than the specified area allocated to the antenna structure. This was the motivation here to introduce loading the free arm of the long U-shaped monopole antenna with an additional U-shape configuration GEF as shown in **Figure 1**. The proposed antenna is printed on an FR-4 substrate of ε_r = 4.5 and tanδ = 0.02. The substrate thickness is 1.5 mm. The substrate of the proposed antenna is not grounded. The ground plane of the antenna, which is not shown in **Figure 1**, is assumed to be extended under the substrate which includes the other circuits of the tablet. The antenna is assumed to be located on an area of 50 × 15 mm^2 t o the top-right corner of the ground plane which is selected to

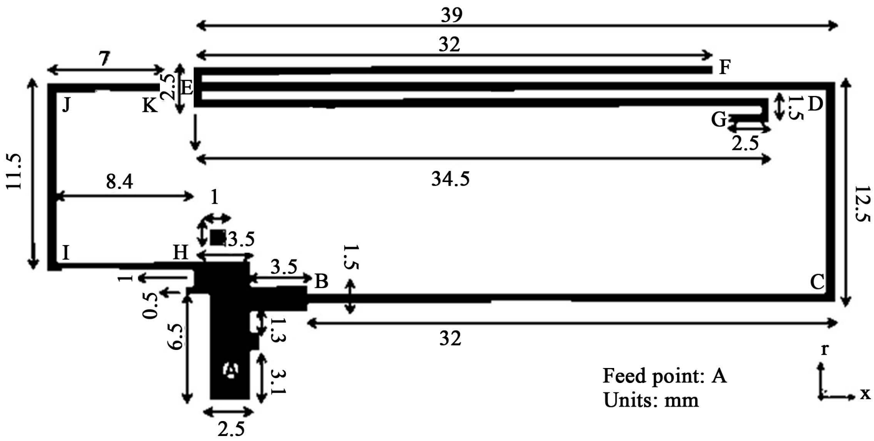


Figure 1. Geometry of the proposed antenna structure.

have a size of 170 × 231 mm^2 to support a 10-in. display. Thus, the antenna placement to the edge side leaves a sufficient space in order to accommodate the camera device and provides isolation with other antennas such as GPS. Figure 2 shows the fabricated antenna structure.

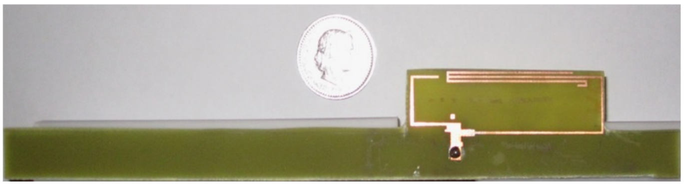
The dimensions of the different sections of the proposed antenna in mm scale are presented in Figure 1. These dimensions are obtained via different simulation trials to verify the required specifications. These simulations were carried out by using ANSOFT HFSS. Figure 3 shows a comparison between the simulated and measured reflection coefficient for the antenna structure shown in Figure 1. It can be noted that the simulated results of proposed antenna satisfy the required S_{11} to be below −6 dB in the frequency ranges 698 - 787 MHz and 1329.7 - 6561.2 MHz. However, due to the connector and soldering effects, slight increase in the reflection coefficient is obtained in the measured results around 1.6 GHz and 2.75 GHz. This drawback can be overcome in realized configuration where the antenna structure would be connected to a feeding cable covered with an EMI suppressant material to absorb unwanted EM radiation or directly to RF circuits of the tablet without the need to extra connectors or soldering process.

Table 1 represents the applicability of the proposed antenna based on the measured reflection coefficient and the requirements of the different wireless applications. It can be concluded that the present antenna structure is suitable for most important applications in wireless systems which can be integrated with tablets.

3. Results and Discussions

To present the physical interpretation of the role of each part of this antenna, Figure 4 shows the simulated current distribution at different frequencies. It can be noted from Figure 4(a) that at the lower frequency band of 700 MHz, the right arm plays the main role in the resonance of the antenna. Around the frequency band of 1500 MHz, the loading U-shape of the right arm is the main resonator. In the 2.2 GHz band, the left arm of the antenna becomes the dominating resonant one, while third resonance behavior slightly appears on the right arm. Exceptionally, at higher frequency range around 3.6 GHz, the fourth resonance behavior on the right is the dominant due to meandering created along path length BCDEG.

Figure 5 shows the corresponding gain radiation patterns at different frequencies. It can be noted that at 700 MHz band, the antenna acts nearly as a monopole antenna directed in y-axis with "8" shape pattern with peaks in broadside direction in its E-plane and nearly omni-directional pattern in H-plane. Around 1.4 GHz, the radiation becomes due to a combination of a y-oriented monopole and another x-oriented monopole as shown in the current distribution shown in Figure 4(b). In this case the total gain radiation pattern is characterized by a tilted beam in its E-plane as shown in Figure 5(b). However, the H-plane radiation pattern is only reduced in its value but its omni-directional property is not affected. This effect of different combination of y-oriented and x-oriented monopoles is also noted at 2.2 GHz and 3.6 GHz bands as shown in Figure 5(c) and Figure 5(d) respectively in different ways according to the corresponding current distributions. It can be noted that 3.6 GHz, the dominant monopole is nearly the x-directed monopole such that the "8" shape beam is nearly rotated by an angle of π/2 as shown in Figure 5(d).



(a)

(b)

Figure 2. Fabricated antenna (a) Front side of the antenna; (b) Back side of the antenna.

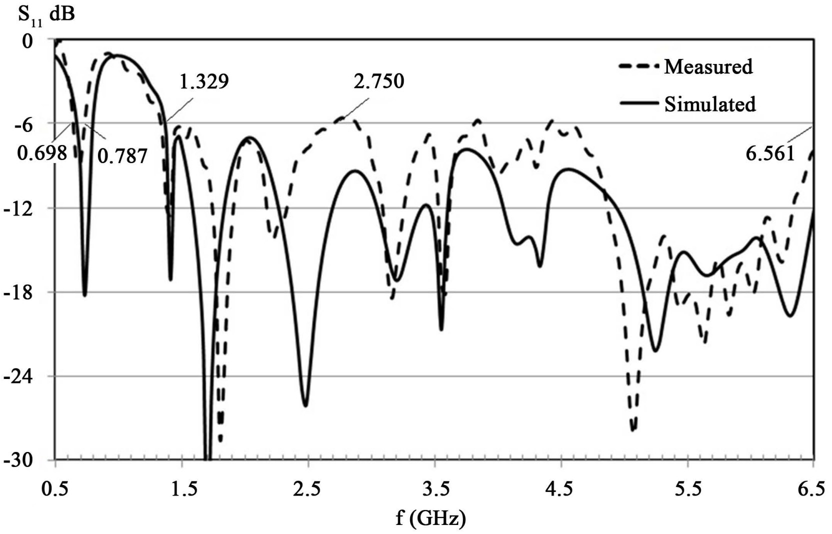
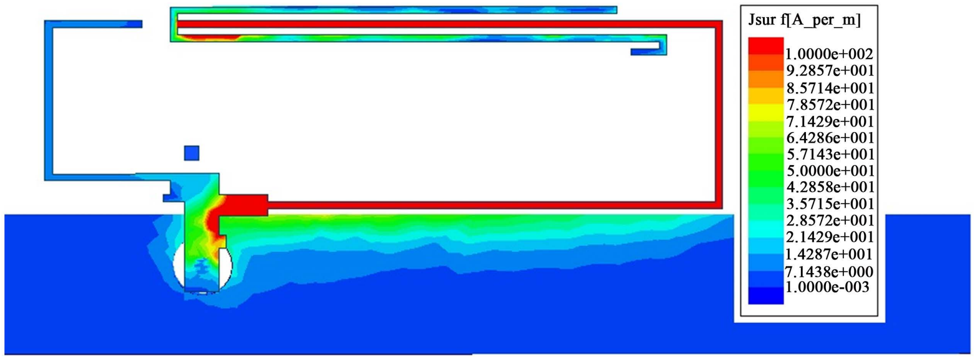


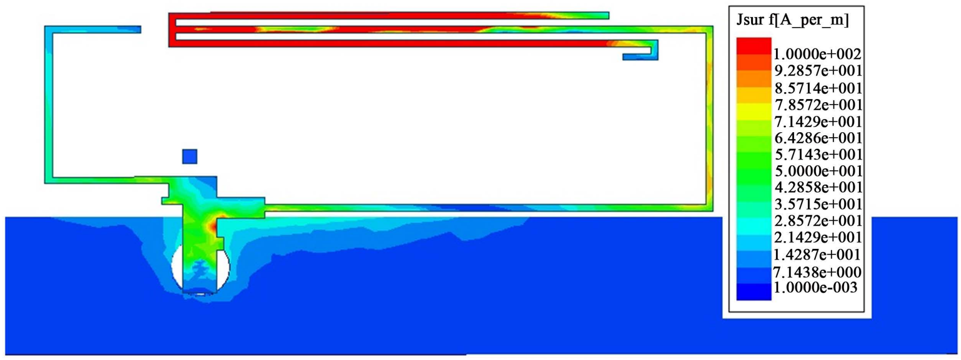
Figure 3. Simulated and measured reflection coefficient of the antenna structure shown in **Figure 1**.

Table 1. A plethora of wireless services supported by the proposed antenna.

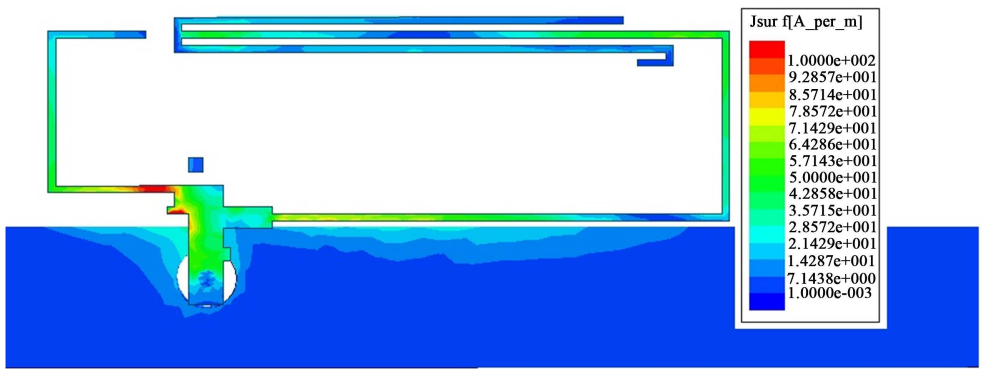
Service	Frequency Bandwidth (GHz)	Application/Standard
LTE 700	0.698 - 0.787	4G
GSM 1800 (DCS)	1.71 - 1.88	2G
GSM 1900 (PCS)	1.85 - 1.99	2G
UMTS	1.92 - 2.17	3G
WCDMA	2.1 - 2.17	IEEE802.11
Mobile WiMAX	2.11 - 2.2	IEEE802.16
Mobile WiMAX	2.3 - 2.4	IEEE802.16
Bluetooth	2.402 - 2.48	IEE802.15.1
RFID	2.4 - 2.4835	IEEE802.15.4f
UWB-L	3.1 - 3.8	IEEE802.15.3
Moblie WiMAX	3.4 - 3.6	IEEE802.16
Wifi	4.9 - 5.9	IEEE802.11a/j
RFID	5.725 - 5.875	IEEE802.15



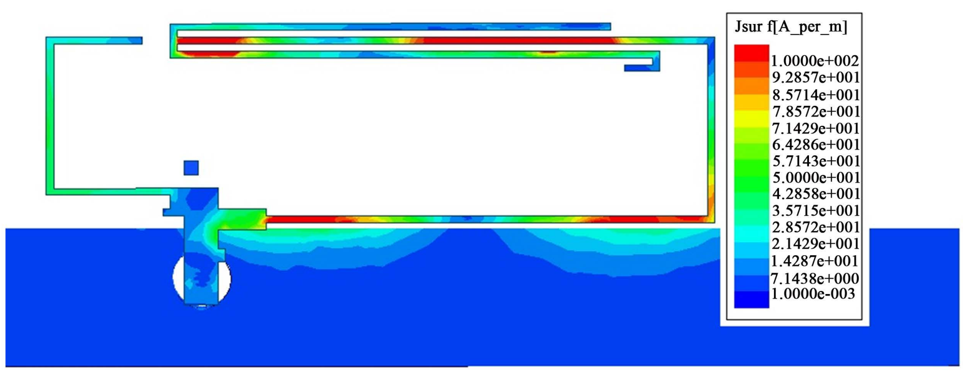
(a)



(b)



(c)



(d)

Figure 4. Simulated current distributions at different frequencies. (a) f = 0.7 GHz; (b) f = 1.4 GHz; (c) f = 2.22 GHz; (d) f = 3.587 GHz.

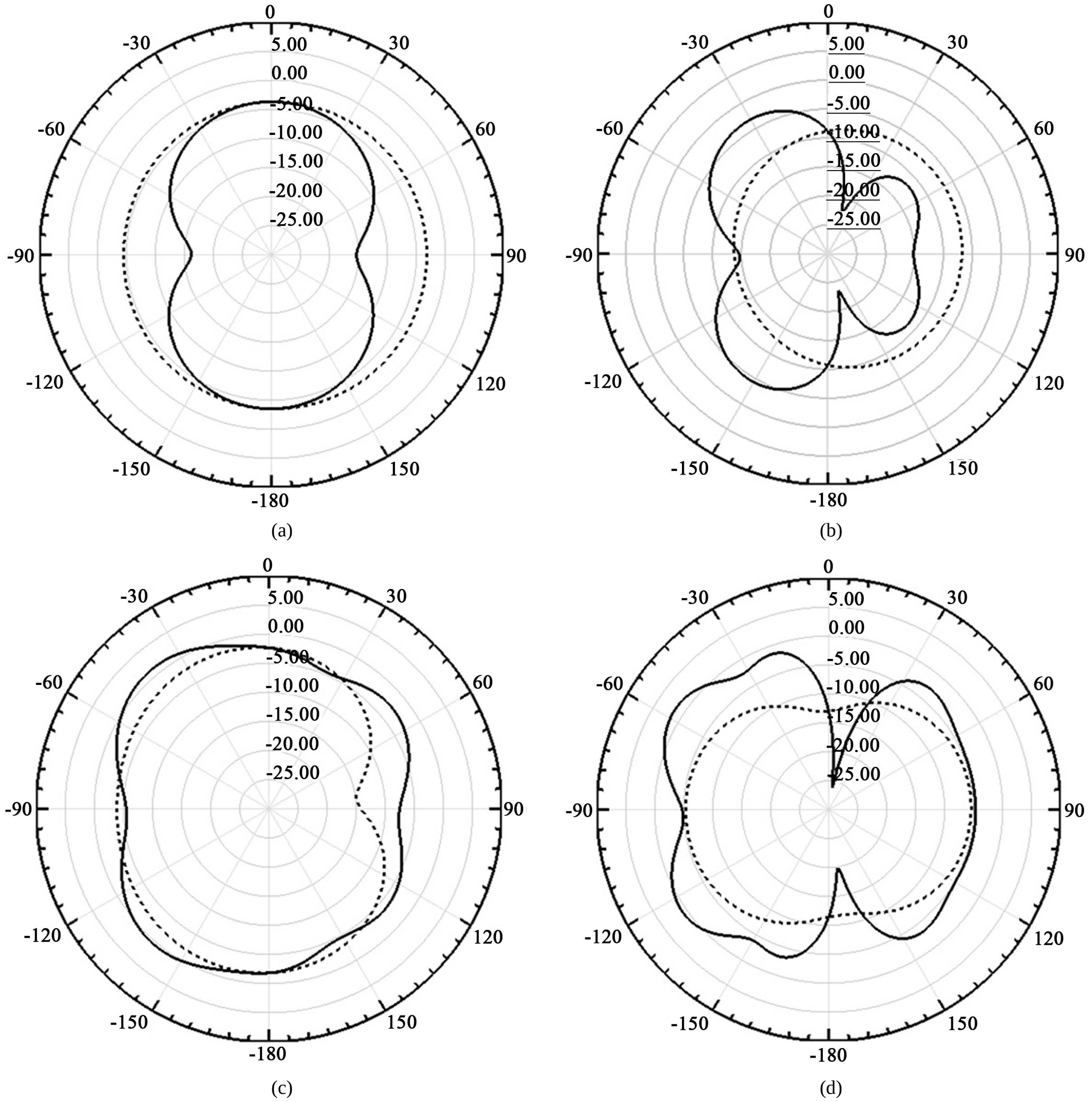


Figure 5. Radiation pattern of the proposed antenna at different frequencies. Solid line in E-plane at $\varphi = 0^\circ$ and dashed line is H-plane at $\varphi = 90^\circ$. (a) f = 0.7 GHz; (b) f = 1.4 GHz; (c) f = 2.22 GHz; (d) f = 3.587 GHz.

Figure 7 shows a comparison between the peak measured gain and the corresponding simulated result. The measurements were performed in antenna anechoic chamber of Ain Shams University—Faulty of Engineering. **Figure 6** shows the radiation measurement setup. It can be noted in **Figure 7** that there is a good agreement between measured and calculated gain measurements which consolidates the applicability of the proposed antenna structure for LTE-A and WWAN applications.

4. Conclusion

This paper presents a new antenna structure which is suitable to be embedded in tablets and laptop computers to enable LTE-A and WWAN communication systems. The proposed antenna occupies an area of $15 \times 50\ mm^2$ on an FR-4 substrate of a thickness 1.5 mm. The results of the proposed antenna show that it will be suitable for LTE 700, GSM 1800 (DCS), GSM 1900 (PCS), UMTS, WCDMA, Mobile WiMAX, Bluetooth, RFID, UWB-L,

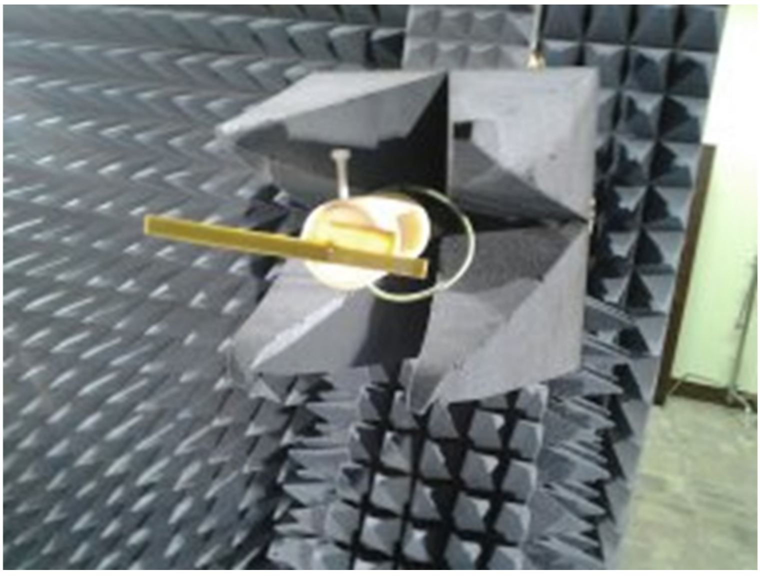


Figure 6. Radiation measurement setup.

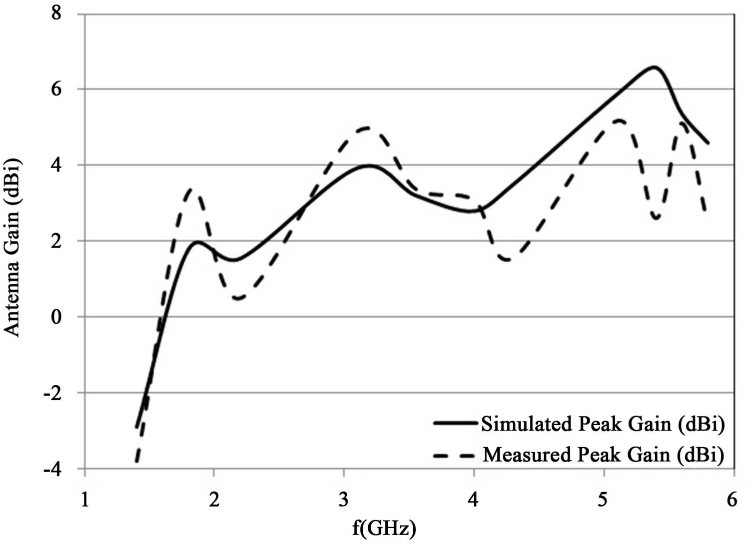


Figure 7. Comparison between calculated gain (solid lines) and measured gain (dashed line) of the proposed antenna structure.

Mobile WiMAX, Wifi, and RFID applications. Good agreements between simulated and measured results are obtained.

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