Jurnal Teknologi

Full paper

A Coplanar Waveguide Rectangular Dielectric Resonator Antenna (RDRA) for 4G Applications

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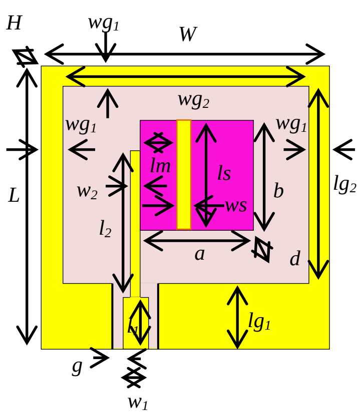
Article history

Received: 13 May 2014
Received in revised form:
13 November 2014
Accepted: 1 February 2015

Graphical abstract



Abstract

This paper presents the design of coplanar waveguide (CPW) rectangular dielectric resonator antenna (RDRA) with and without metallic strip, operating at 2.6 GHz for long term evolution (LTE) applications. The CPW RDRA without metallic strip produces impedance bandwidth of 51 %. Then, a metallic strip was added on top of the dielectric resonator (DR) in order to enhance the impedance bandwidth; thus give more flexibility for the system to cover more applications. A good agreement between simulation and measurement results, in terms of reflection coefficient magnitude and radiation pattern is presented. The simulated and measured impedance BWs for S_{11} < -6dB are 67 % (1.74-3.47 GHz) and 66 % (1.83-3.54 GHZ) respectively, with the gain of 3.12 dBi is obtained at 2.6 GHz. The mode excited for this antenna is $TE^{y}_{1\delta1}$ mode.

Keywords: Coplanar waveguide; rectangular dielectric resonator antenna; long term evolution

Abstrak

Kertas ini membentangkan reka bentuk sesatah pandu gelombang (CPW) antena dielektrik resonator berbentuk segi empat tepat (RDRA) dengan dan tanpa jalur logam, beroperasi pada 2.6 GHz untuk aplikasi evolusi jangka panjang (LTE). CPW RDRA tanpa jalur logam menghasilkan jalur lebar sebanyak 51%. Kemudian, jalur logam diletakkan di atas dielektrik resonator (DR) untuk meningkatkan jalur lebar; dengan itu memberikan lebih banyak fleksibiliti untuk sistem ini meliputi lebih banyak aplikasi. Kesefahaman di antara keputusan simulasi dan pengukuran dari segi pekali magnitud renungan dan corak sinaran dibentangkan. Jalur lebar bagi simulasi dan pengukuran adalah 67% (1.74-3.47 GHz) dan 66% (1.83-3.54 GHz), dengan gandaan yang diperolehi sebanyak 3.12 dBi pada 2.6 GHz. Mode yang di ransang oleh antenna ini adalah mode $TE^{y}_{1\delta1}$.

Kata kunci: Sesatah pandu gelombang; antenna dielektrik resonator berbentuk segi empat tepat; evolusi jangka panjang

1.0 INTRODUCTION

Nowadays, the emerging technologies in wireless communications have become the main part of human life. Sending short message service (SMS), file transferring, voice and video calls, on-line games, and so on are made possible anytime and anywhere around the world without limitation. The increasing number of mobile internet users has motivated the need for high-speed mobile telephone networks, with high data rate and channel capacity for better performances [1]. LTE, the fourth generation mobile wireless communication, provides high speed performances, above 100 Mbps, high channel capacity, improved efficiency and good quality of services (QoS). LTE provides better mobile broadband and multimedia services, compared to the existing mobile network. LTE operates at forty different bands which cover frequency range from 600 MHz to 3 GHz [2].

Dielectrics resonators antennas (DRAs) have few attractive features, such as small size, light weight, low profile, high radiation efficiency, high impedance BW and low loss [3]. A DRA can be designed and fabricated in a variety of shapes (spherical, cylindrical and others) [4]. DRAs also can produce circularly polarized fields by exciting orthogonal modes [5] and capable to integrate with MIMO systems with good MIMO performance such as isolation and diversity gain to increase channel capacity [6]. It must also have efficient radiation at high frequency (1 – 40 GHz) with a dielectric constant of $8<\varepsilon_r<100$ [7]. The DRA's impedance BW is related to the material permittivity. High permittivity reduces both antenna size and BW; while low permittivity widens antenna BW. Simple RDRA can produce 10 % impedance BW with permittivity of 10 or less [8].

One major advantage of RDRA, compared to spherical and cylindrical shapes, is that two out of its three dimensions can be chosen independently for a fixed resonant frequency and known dielectric material [9]. This feature makes RDRA versatile and flexible in design. It can also have varieties of feeding positions in order to reduce the antenna size and make it compact. Furthermore, it offers simple structure and ease of fabrication. There is a common feeding technique used to excite DRA, such as probe [10], microstrip slot coupling [11], microstrip line [12] and coplanar waveguide [13].

Other than that, there are few designed that have been proposed in designing the wideband DRA. In [14], the rectangular DR are lifted above ground plane by some distance. The air gap between DR and ground plane improves the BW. Multilayer cylindrical DRA with different permittivity value of the same diameter, are mounted one on top of the other are proposed in [15]. In [16], flipped stair shaped DRA are presented and optimized to produce the wideband application.

In this paper, a compact-sized CPW RDRA operating at LTE 2.6 GHz is proposed. The antenna is designed with a metallic strip and can provide a wide impedance BW.

The wider BW could cover PCS - 1900MHz, WiMAX - 2300MHz, WiFi - 2400MHz, LTE - 2600 MHz, and WiMAX - 3300 MHz applications. The mode excite in this design is $TE^{y}_{1\delta 1}$. Since new communication devices are designed with small and thin shapes, it requires small size of antenna. DRs is therefore an excellent choice to be implemented in a limited mobile device areas for LTE/LTE-Advanced application, due to it DRs behaviour. The parametric studies simulated and measured results and the performances of proposed antenna are discussed in the following sections.

2.0 ANTENNA GEOMETRY

The proposed antenna configuration is shown in Figure 1. RDRA with dimensions of ($a \times b \times d$), permittivity ($\varepsilon_r = 10$) and loss tangent ($\delta = 0.019$) were used as radiating element. It is mounted on the FR4 board ($L \times W \times H$) with permittivity of 4.4; by using CPW as feeding mechanism. DRA can produce a higher impedance BW, compared to microstrip antenna. It is therefore an added advantage, since it can operate at 2.6 GHz and yield a large impedance BW without degrading the antenna performance. The impedance BW can be easily enhanced achieved with addition of metallic strip ($ls \times ws$) [17], or metallic patch on top of DRA [18]. CST Microwave Studio Software 2013 was used for designing, simulating and optimizing the proposed RDRA; and it was excited by a designed 50 Ω CPW line. The proposed antenna has a simple geometry and compact size, and its prototype of CPW RDRA is shown in Figure 2.

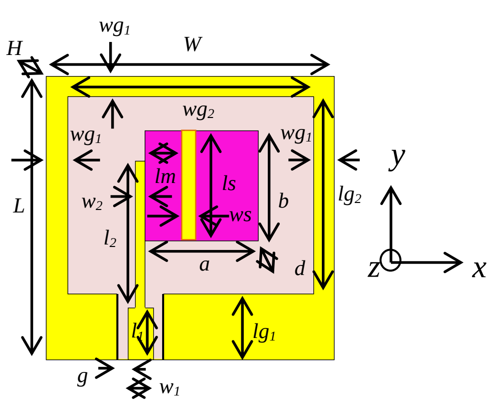
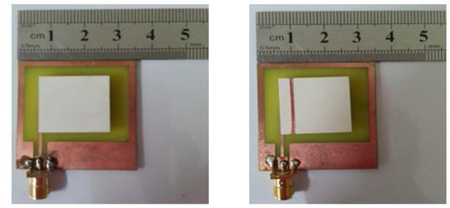


Figure 1 Proposed antenna geometry



(a) (b)

Figure 2 CPW RDRA prototypes (a) Without vertical metallic strip (b) With vertical metallic strip

3.0 ANTENNA DESIGN AND ANALYSIS

Parametric study was carried out in order to evaluate the proposed antenna peformances. The distance of the metallic strip on top of the RDRA lm, DR thickness d, length of feed line l_2, and ground frame size $wg_2 \times lg_2$ were varied while other parameters are fixed are as follows; lg_1 = 10mm, wg_1 = 2.3mm, l_1 = 5mm, l_2 = 17.5mm, w_1 = 3.2mm, w_2 = 1mm, g = 0.4mm, ls = 20mm and ws = 1mm. The proposed antenna produces a reflection coefficient magnitude below -6dB for desired band which is acceptable for mobile antennas [2]. The RDRA simulated reflection coefficient magnitudes for different ground frame sizes, $wg_2 \times lg_2$ are shown in Figure 3. As shown in Figure 3, by decreasing the size of the rectangular slot, the resonance frequency has shifted to slightly higher and at the same time has reduced the impedance BW. Note that, the dimension of 31 mm × 28 mm is chosen for this design as it covers many bands including the LTE band.

The variation of reflection coefficient magnitudes with respect to DR height d (from 4 to 7mm) is shown in Figure 4. It can be seen that the upper frequency decreases with increasing value d, while the lower frequency is keep maintain at the same frequency. By helping of a parallel process, the optimum values of the other parameters are achieved. In this case, by considering the distance of the metallic strip on top of the RDRA lm = 3mm, length of feed line l_2 = 17.5mm, and ground frame size $wg_2 \times lg_2$ = 31 mm × 28 mm, the optimal value of d has been achieved which is 4 mm. Therefore, it has been chosen for this design.

Comparison of simulated reflection coefficient magnitudes for different feed lengths is presented in Figure 5; where a similar effect was observed when feed line l_2 was varied from 17.5 to 20.5mm. As shown in Figure 5, increasing antenna feed line will reduce the upper frequency and impedance BW. The optimum value of l_2=17.5mm was chosen in this design.

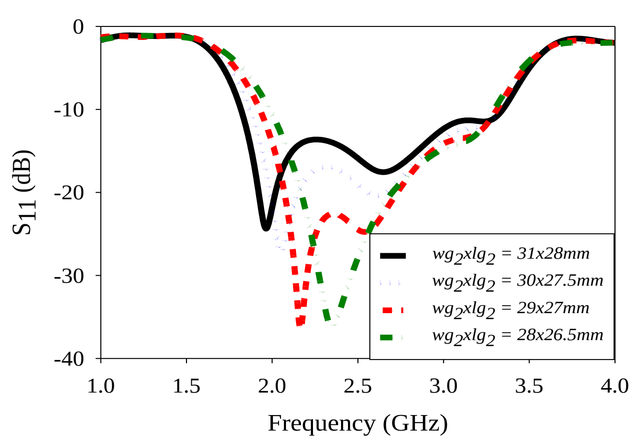


Figure 3 Comparison of simulated reflection coefficient magnitudes for different ground frame sizes

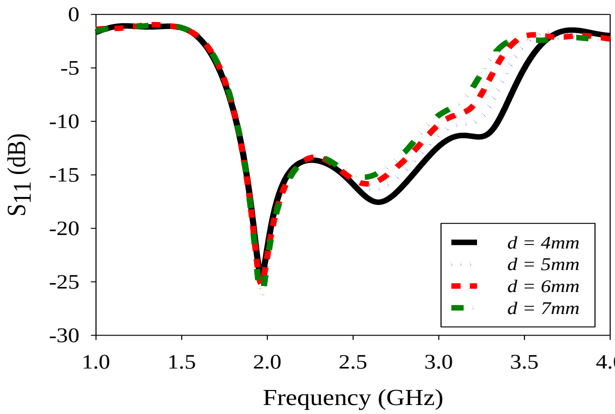


Figure 4 Comparison of simulated reflection coefficient magnitudes for different thickness of DR

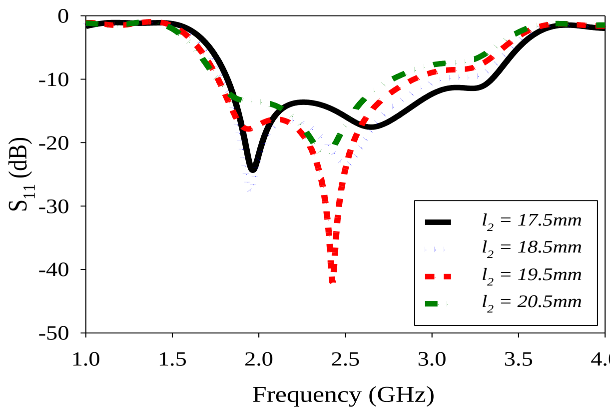


Figure 5 Comparison of simulated reflection coefficient magnitudes for different feed lengths

With an addition of metallic strip on top of the RDRA with different distance along *x*-direction, the antenna impedance BW was increased, as shown in Figure 6. However, the optimal distance of metallic strip is *lm* = 3mm (black line), which produces simulated and measured impedance BW of 67 % (1.74 - 3.47 GHz) and 66 % (1.83 – 3.54 GHZ) respectively.

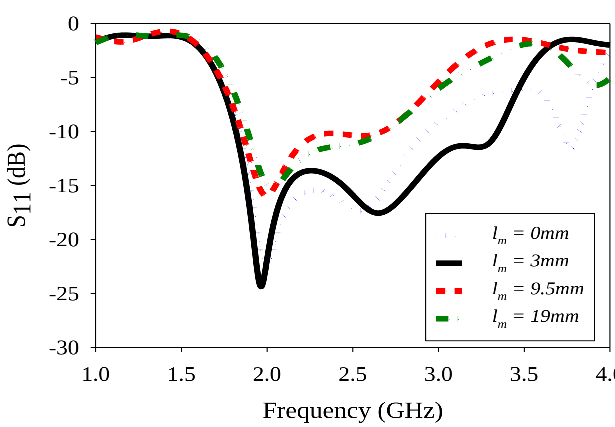


Figure 6 Metallic strip (*ws*=1mm, *ls*=20mm) was moved along RDRA in x-direction

■4.0 RESULTS OF PROPOSED ANTENNA

There is good agreement between simulation and measurement results, respectively. The comparison of reflection coefficient magnitudes (with and without a metallic strip on top of RDRA) is shown in Figure 7. It can be observed that, by adding a metallic strip with a suitable length, *lm* enables the antenna to produces wider impedance BW, as shown in Figure 1(b) [18]. The metallic strip act as a parasitic element with a new resonant frequency which is lower than DR's resonant. Here, by carefully adjust a metallic strip distance, both resonance from DR and parasitic element, have overlap to produce wideband antenna [17]. Based on the results shown in Figure 7, the RDRA without metallic strip produces impedance BW of 51 % (1.80 - 3.12 GHz) and 66 % (1.83-3.54 GHz), respectively. The mode in RDRA can be dividing into TE and TM. But with the RDRA mounted on the ground plane, it is the TE modes which are typically excited [19]. The mode excited for this antenna is $TE^{y}_{1\delta 1}$ mode as shown in Figure 8.

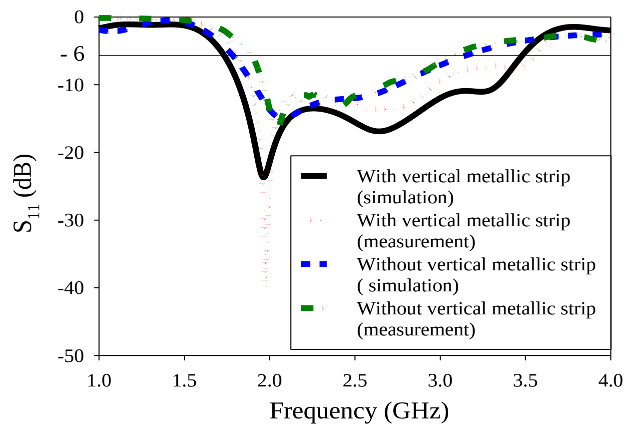


Figure 7 Comparison RDRA with and without a metallic strip

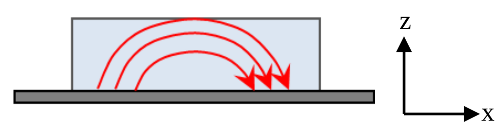


Figure 8 Simulated electric field distribution in the DR

Figure 9 shows the gain for RDRA with and without a metallic strip. The gains obtained for RDRA with and without a metallic strip are 3.13 and 2.92dBi at 2.6 GHz, respectively The RDRA simulated and measured radiation patterns at 2.6 GHz for LTE mobile applications are shown in Figure 10. The proposed antenna approximately shows nearly omnidirectional radiation patterns for E-plane and H-plane in Figures 10(a) and 10(b), respectively.

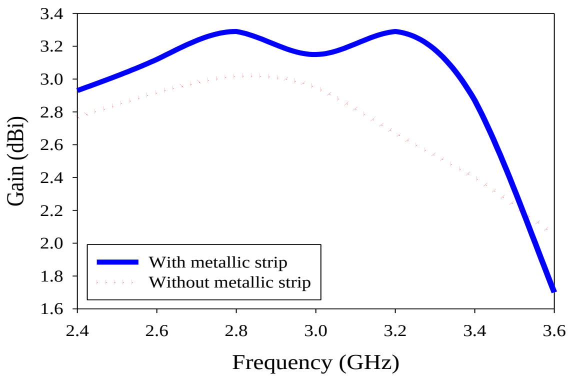
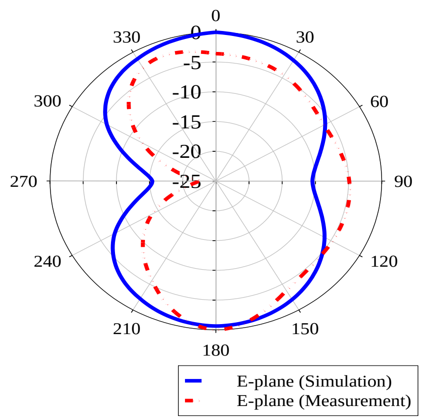
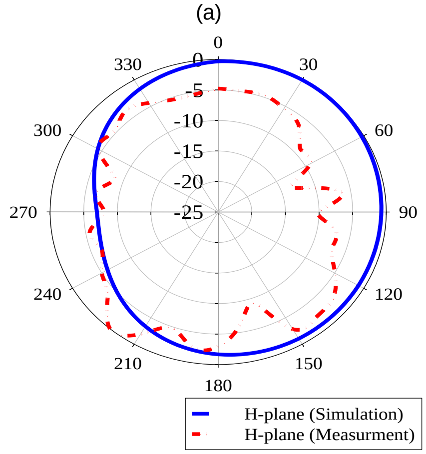


Figure 9 Gain for the RDRA with and without metallic strip



(a)



(b)

Figure 10 Simulated and measured 2-D radiation pattern of the proposed DRA at 2.6 GHz (a) E-plane (b) H-plane

5.0 CONCLUSION

A CPW RDRA with metallic strip operating at 2.6 GHz with wide impedance BW for LTE mobile device was presented in this paper. The proposed antenna has simulated and measured wide impedance BWs of 67 % (1.74 - 3.47 GHz) and 66 % (1.83–3.54 GHz) respectively. The antenna has a nearly omnidirectional radiation pattern and it provides gain of 3.12dBi. The presented results have shown that the proposed antenna is efficient and has satisfactory performances. The CPW RDRA has small size, wide BW and other attractive features, suitable for implementation in mobile devices for LTE applications.

Acknowledgement

The authors would like to thank the Ministry of Education (MOE) and UTM GUP (Votes 05H34 and 08J81) and FRGS (Vote 4F283) for sponsoring this work. The members of Wireless Communication Centre (WCC) and UniMAP are also acknowledged for providing facilities and rendering necessary technical assistances.

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