SRR Shape Dual Band CPW-fed Monopole Antenna for WiMAX / WLAN Applications

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Received: 30/Jun/2014 Revised: 04/Sep/2014 Accepted: 07/Oct/2014

Abstract

CPW structure is became common structure for UWB and multi band antenna design and SRR structure is well-known kind of metamaterial that has been used in antenna and filter design for multi band application. In this paper, a SRR dual band monopole antenna with CPW-fed for WLAN and WiMAX is presented. The prototype antenna is designed for wireless communication such as WLAN and WIMAX respectively at 2.4 GHz and 5 GHz. The HFSS and CST microwave studio are used to simulate the prototype antenna for two different FEM and time domain method and they have also been compared with the experimental results. The total size of the antenna is 60mm×55mm×1.6mm and it is fabricated on FR-4 low cost substrate. The antenna is connected to a 50 Ω CPW feed line. Its bandwidth is around 3% for 2.45 GHz (2.4-2.5 GHz) and 33% for 5.15GHz (4.3-6 GHz).Its limited bandwidth in 2.4 GHz frequency is benefit for power saving at indoor application. The antenna has 2-7 dBi gain in the mentioned bands with an Omni-directional pattern. The antenna experimental result shows good similarity to simulation kind for return loss and pattern. Here, the effect of parasitic SRR on current distribution has been studied in presence and absence of parasitic element. The simulation of polarization is confirmed that the antenna has linear polarization. Here comparison between antenna return losses in absence of each parasitic element is presented.

Keywords: CPW-fed; SRR; Dual Band Antenna; WLAN.

1. Introduction

Wireless communication systems have progressed too fast in the last decade. It is widely used in notebooks and cellular phone because of mobility and low cost and These days WLAN systems due to reasonable prices and high-speed data transfers are widely used [1-2]. A WLAN links two or more devices, by providing a high speed connection through an access point to the wider internet. This gives users the ability to move around in a local coverage area and still be connected to the network. Nowadays, broadband systems have been designed for faster communication and high data transfer rate [3]. IEEE 802.11 is a standard for WLAN system. IEEE 802.11a standard considers 5.15-5.35 GHz and 5.725-5.825 GHz as sending and receiving band respectively. The IEEE 802.11bg is applied for 2.4GHz (2.4– 2.484 GHz) applications. The frequency range 3.5 GHz (3-5 GHz) is used for WiMAX applications [4]. It is need to design small size, easy fed and low cost antenna for multi band applications. CPW fed antenna is the common type for UWB applications with all properties that are needed for WLAN communication systems and circular arc is used to increase the bandwidth in antenna at WLAN frequency [5]. Microstrip compact antennas can be used in mobile communication and WLAN systems because of their benefits. Different methods have been used to design multi band antenna, such as notch technique, metamaterial, CRLH or ZOR (zeroth order resonator),slot and fractal methods like Minkowski, Hilbert, Koch, Sierpinski, tree [6-8]. The bandwidth of microstrip antennas is low and it is one of the main drawbacks of them. Different ways are used for improving its bandwidth such as increasing the substrate thickness, using substrate with low permittivity, proper feeding techniques for better impedance matching, multi resonance technique, slots on the antenna and inserting parasitic element in antenna geometry [9-10].

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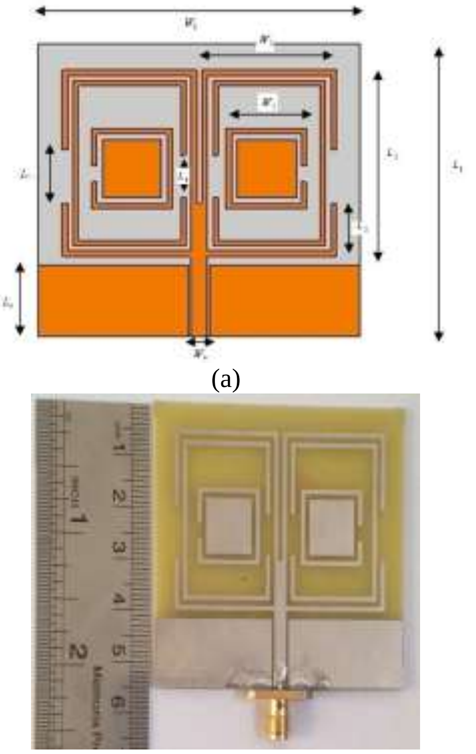
Nowadays, CPW-feed technique has become one of the most popular methods in feeding micros trip antennas for wide band application. Low radiation loss, low leakage, wide band width, improved impedance matching and easy integration with RF circuit are known as benefits for CPW-feed antenna [11-12].The high electromagnetic coupling between the patch and the parasitic element improves impedance bandwidth and miniaturizes the antenna. Parasitic elements resonate near the patch resonance frequency and leads to higher bandwidth. Bandwidth can be controlled by adjusting the distance between parasitic element and the patch .Different model of parasitic element are used in antenna such as U-Shaped parasitic elements or Split ring resonator (SRR) element [13-15]. Parasitic ring element has been employed in slot antenna with microstrip feed for dual band compact antenna [16].Negative index metamaterial are known as composite materials that show negative effective permittivity and negative effective permeability and in those material Negative permeability was obtaining by structure such as SRRs, spiral resonators (SR), V-shaped resonators [17] Metamaterials are artificial structures that have been known with unusual properties such as anti parallel phase and group velocities, and negative reflection index. In Metamaterials relationship between electric field, magnetic field and wave vector follows left-hand rule, so they are called left-handed materials (LHM). They show negative permittivity and permeability. When both ε and μ are negative in a structure, we call it double negative (DNG). Metamaterials make it possible to design a miniaturized, multi band antenna. Split ring resonator (SRR) is a type of metamaterial which is used in microwave devices or absorber to improve the bandwidth and the gain of the antenna. It can produce the negative permeability and positive permittivity around the resonance frequency. The main feature of SRR is the quasi-static resonance at a larger wavelength in spite of its own size. This leads to use of SRR in designing small antenna [18-19]. In this paper, a SRR structure which is most famous in metamaterial is presented. Dual band Microstrip antenna is designed for wireless applications with Omni directional pattern. The effect of parasitic SRR on current distribution has been studied. The simulation results are compared with experimental results for VSWR and radiation pattern. The SRR parasitic structure is used for antenna miniaturization. The antenna experimental result shows good similarity to simulation kind for return loss and pattern. The simulation of polarization is confirmed that the antenna has linear polarization. Here comparison between antenna return loss in absence of each parasitic elements is presented.

2. Antenna Design

CPW-fed antenna is the common model antenna for UWB and multi band applications [20]. Also SRR structures are used for design multiband and small antenna. Our proposed antenna is a dual band CPW-feed monopole antenna with SRR structure for using in WLAN and WIMAX applications. The effect of parasitic element is studied here. Fig. 1(a) and (b) shows the geometry and fabricated antenna on FR-4 layer respectively. The antenna is fabricated on FR-4 low cost substrate with dielectric constant ε= 4.4 and loss tangent of tan δ=0.02. The substrate height and the substrate dimension are h=1.6 mm and 60mm ×55mm, respectively. The antenna is connected to SMA with CPW 50 Ω feed line. All gaps width of the antenna are assumed 1mm and the gap between CPW grounds and radiation elements are 1.6 mm. The inner square length is 5mm and other dimensions of the antenna are as shows in Table 1:

Table 1. The geometrical parameter of antenna

parameter	mm
L_1	55
L_2	35
L_3	10
L_4	8
L_5	10
L_6	13.4
W_1	60
W_2	24
W_3	15
W_4	3


(a)

(b)

Fig.1 a) Antenna geometry and b) fabricated antenna

3. Simulation Result

The final model of antenna is simulated with HFSS and CST for two different full wave simulation methods. The fabricated final antenna is measured by Agilent 8720ES. The simulated and measured return losses are shown and compared in Fig.2. The presented antenna operates at two bands at 2.45 and 5.15 GHz with return loss less than -10dB as shows in Fig.2. The first band is occurred from 2.40 to 2.5GHz which allotted for Wi-Fi and WLAN-2.4 application. The second band happened from 4.3 to 6 GHz which are used in WLAN and WiMAX applications such as 5.15-5.35 GHz and 5.725-5.825 GHz as sending and receiving band in WLAN. Its bandwidth is around 3% for 2.45 GHz (2.4-2.5 GHz) and 33% for 5.15GHz (4.3-6 GHz)

Fig. 3 shows the comparison between the effects of parasitic elements at antenna return loss. Fig 3.a, b, c, d shows 4 step of antenna designing. The final antenna is presented in Fig.3.d and this antenna result shows in Fig.2. As shown in Fig. 3 the resonance frequency decreased as the number of parasitic elements increases. Small parasitic element decreases the first resonance to 2.45 GHz. In the first antenna, First resonance is occurred at 2.55-2.675 GHz and second band is at 4.35-6 GHz but at this frequency range from 4.75-5.55 GHz the return loss is increased to -8 dB .In second antenna the first resonance is shifted to higher frequency and it is happened at 3.075-3.2 GHz but second resonance at 4.3-6 GHz with sufficient return loss. At third model antenna the first resonance is matched with our request band at 2.45 GHz and second resonance is occurred in range of 4.3-5.6.25 GHz so it cannot cover the receiving band for WLAN at 5.725-5.825 GHz so with adding last parasitic element as shows in Fig.3.d the final antenna is achieved with good performance at both band.

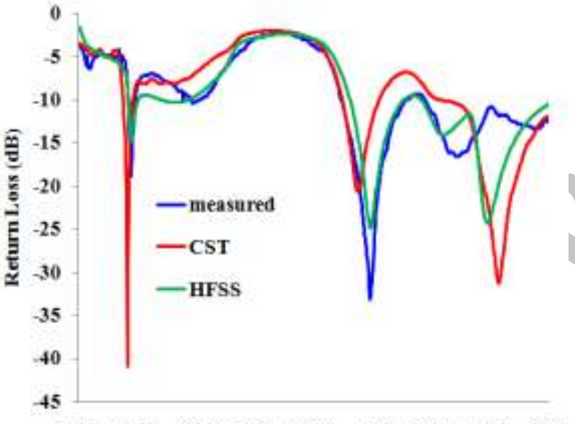
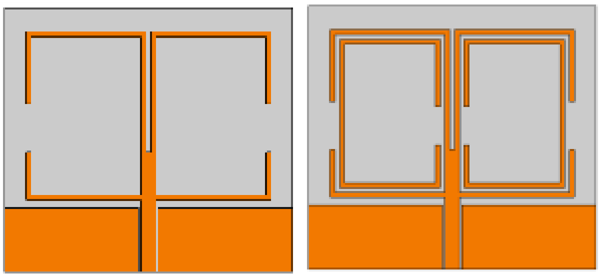
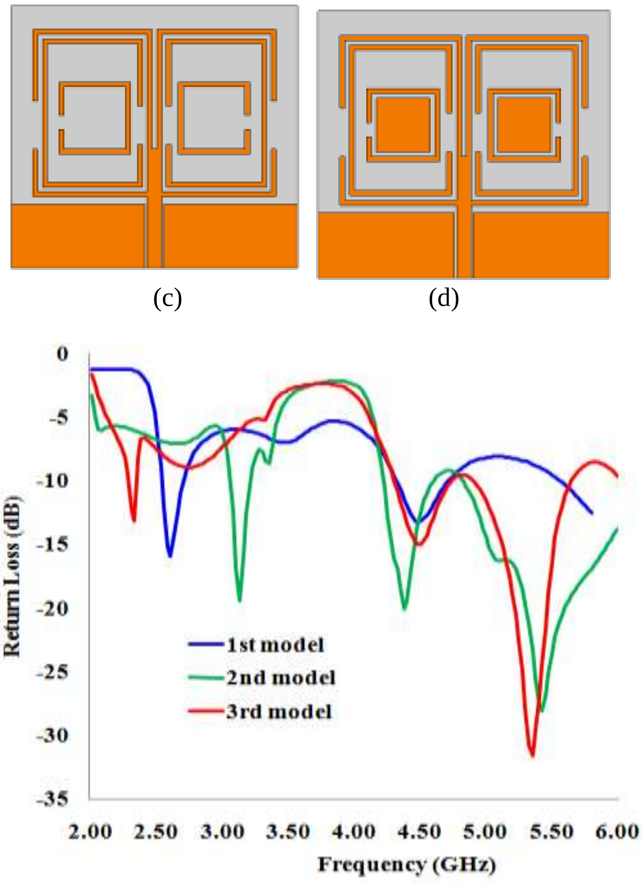


Fig.2 Comparisons of return losses among CST, HFSS and experimental results.



(a) (b)

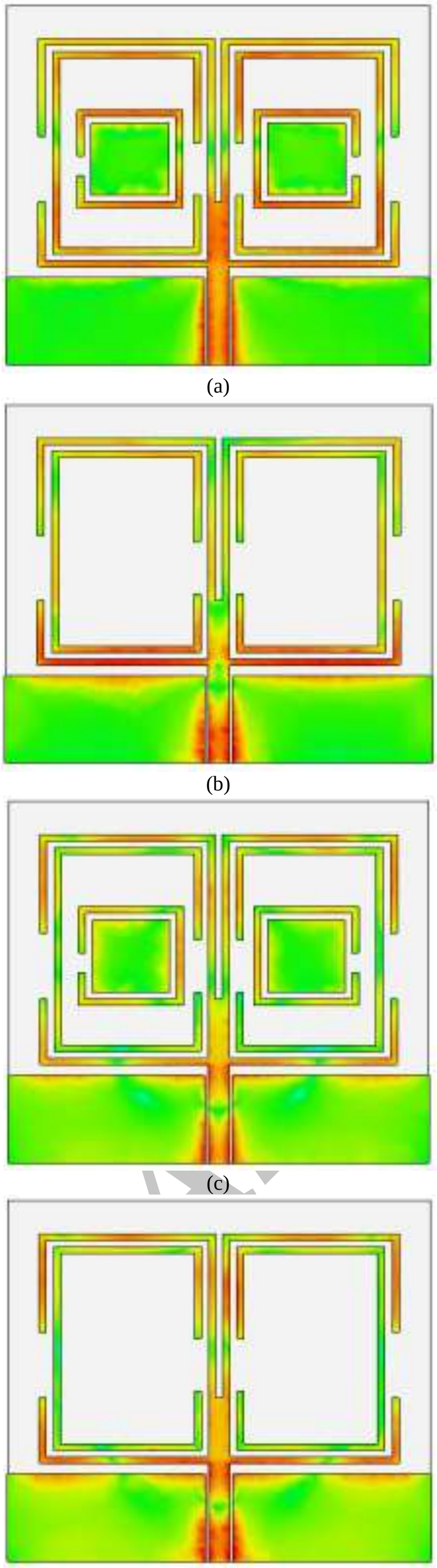


(c) (d)

(e)

Fig.3 The prototype antenna return loss in comparison with the antenna without parasitic element and all simulated antenna a)1st model b)2nd model c)3rd model d) final model e) first to third antenna return loss simulation in HFSS

Fig.4 shows the current distribution comparison for final antenna and second model at 2.45 and 5.15 GHz. As shown in Fig.4 (a) the inner small ring helps to increase the antenna effective length based on coupling effect between bottom and top part of the antenna. Based on Fig.4 (a), the current distribution enhance in the outer ring in comparison with second model that given in Fig.4.b. As shows in Fig.4 (b) the antenna current is concentrated at the bottom of the radiator so the antenna effective length is reduced and the antenna first resonance is shifted to higher frequency. Fig.4 (c) and Fig.4 (d) shows the inner parasitic element has less effect at 5.15 GHz and in both structure the antenna has similar current distribution form.



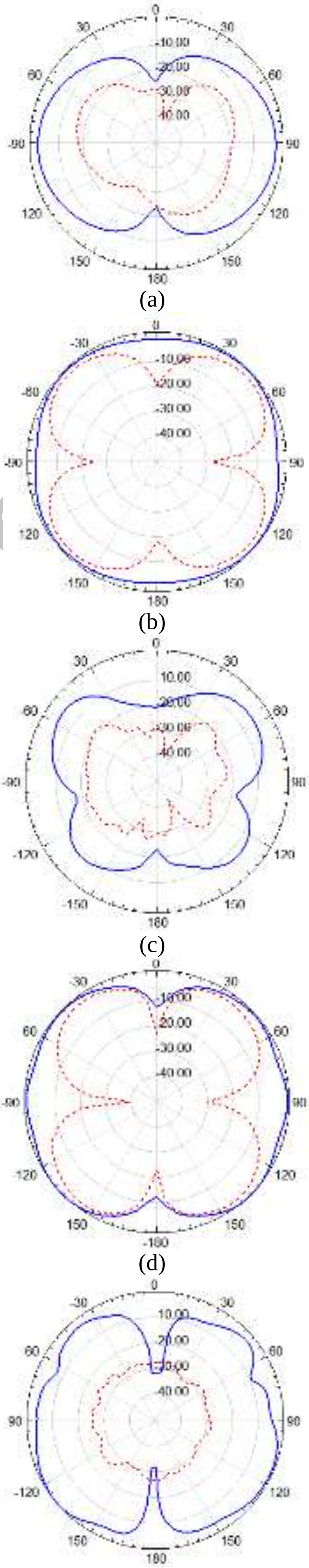
(a)

(b)

(c)

(d)

Fig.4 The current distribution comparison between prototype antenna and second antenna at a) final antenna at 2.45 GHz, b) second antenna at 2.45 GHz, c) final antenna at 5.15 GHz d) second antenna at 5.15 GHz



(a)

(b)

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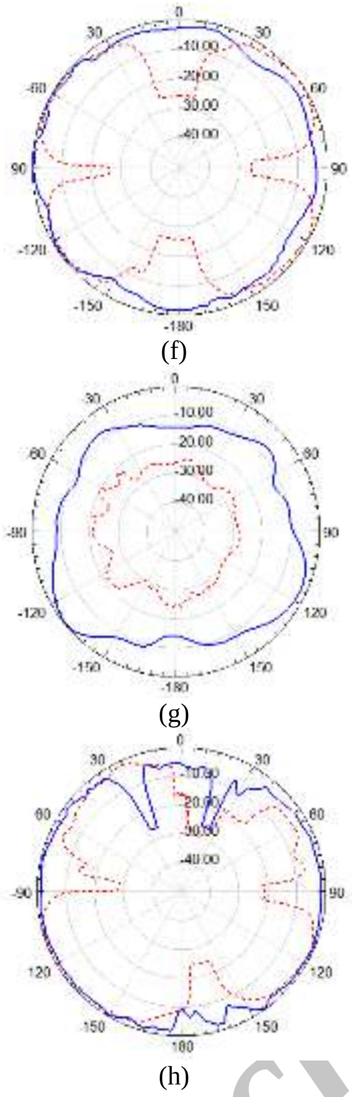

Fig.5 The prototype antenna pattern in a) E-Plane at 2.45 GHz simulation b) H-Plane at 2.45 GHz simulation c) E-Plane at 5.3 GHz simulation d) H-Plane at 5.3 GHz simulation e) E-Plane at 2.45 GHz measured f) H-Plane at 2.45 GHz measured g) E-Plane at 5.3 GHz measured h) H-Plane at 5.3 GHz measured

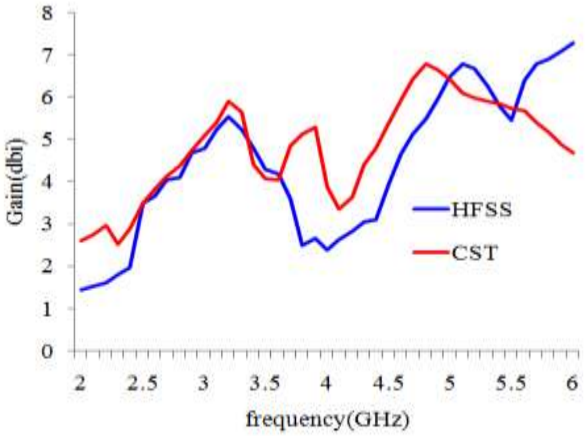

Fig .6 the antenna gain simulation

The measured and simulation radiation patterns (co-polarization and cross-polarization (dash-line)) in E-plane (*y-z* plane) and H-plane (*x-z* plane) at 2.45 and 5.3 GHz of the prototype antenna are shown in Fig. 5. The antenna radiates Omni-directionally in the E-plane and approximately bi-directionally in the H-plane. Obviously, the antenna shows good performances over the frequency range.

Fig. 6 presents gain of the antenna which is between 2 and 7dBi and HFSS result is compared with CST microwave studio.

The axial ratio is used to measure the quality of the field polarization, as shows in (1). AR is the ratio of major and minor axes of the polarization along the bore-sight for the proposed antenna, derived from the measured results on the fabricated antenna.

$$(1)\ AR[dB] = 20\log\frac{E_{\max}}{E_{\min}}$$

So when axial ratio is more than 3 the antenna polarization is linear. Axial ratio that is shown in fig 7, confirmed the vertical linear polarization of antenna.

The simulated efficiency is more than 80% for first band and more than 65% for second band. Fig 8 shows the efficiency of the antenna. Table 2 shows comparison between prototype antenna and some previous research [21-22] for bandwidth, size and gain. The prototype antenna shows good quality and has mediocre gain or bandwidth.

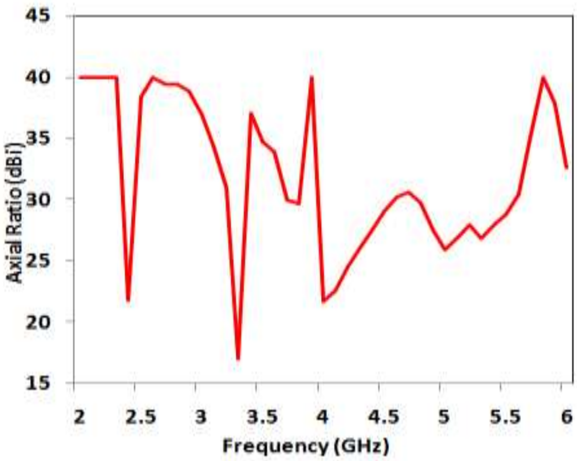

Fig7. Axial ratio of the proposed antenna

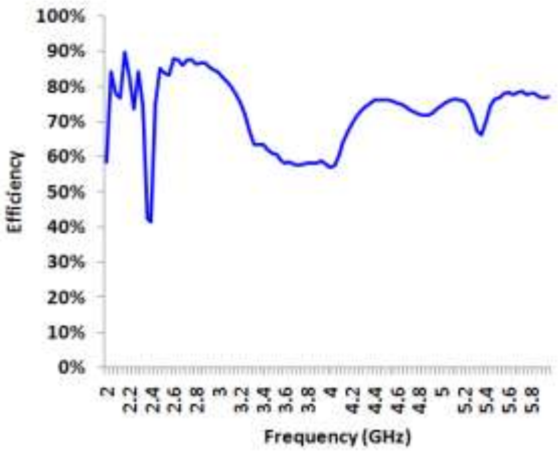

Fig 8. Efficiency of the proposed antenna

Table .2 comparisons between prototype antenna and some previous research

	Our purpose	Ref 20	Ref 21	Ref 22
First Band (GHz)	2.4-2.5	2.32-3.3	2.45	1.8-2.53
Second Band(GHz)	4.3-6	4.96-6.34	5.85	2.9-6.04
Gain (dBi)	2-7	2.4-4.5	-1.7-5.2	3.4-9.2
Size (mm)	60×55	69.3×68	30×30	52×54
First Bandwidth	3%	35.8 %	1.2%	33.7%
Second Bandwidth	33%	24.4 %	12.24%	20%

4. Conclusions

Here presented an antenna with limited bandwidth in comparison to conventional UWB CPW antenna so it is useful for power saving at indoor application and also antenna has Omni directional pattern such as other CPW antenna. In other hand SRR parasitic elements are used to reduce the antenna resonance to 2.4 GHz. The bandwidths are around 3% for 2.45 GHz (2400-2500 MHz) and 33% for 5.15GHz (4300-6000MHz). The antenna has 2-7 dBi gain in the operation band. The final model of antenna is simulated by HFSS and CST microwave studio with FEM and time domain full wave methods. The results are compared with experimental. The simulation of polarization confirmed that the antenna has linear polarization. The comparison between antennas in absence of each parasitic element is presented. The final antenna shows Omni directional pattern with sufficient gain for wireless applications

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