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Pattern Reconfigurable Dielectric Resonator Antenna Using Parasitic Feed for LTE Femtocell Base Stations

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Abstract: In this study, A cuboid shape dielectric resonator antenna has been proposed. The feeding mechanism of the proposed antenna is probe feed by using parasitic feed element with switch to steer the radiation pattern of the antenna. The operating frequency range of the antenna is 200 MHz (2.5-2.6) GHz that is suitable for Long Term Evolution (LTE) femtocell base stations. A formula of waveguide mode used to obtain the optimum dimensions of the dielectric resonator. The surface current distribution has been studied when the switch being on and off. A good agreement observed between the simulated and measured return loss values.

Key words: Antenna, dielectric resonator antenna, LTE, distribution, agreement, simulated

INTRODUCTION

Recently, many communication devices used Long Term Evolution (LTE) technology especially the band 7 (2.6 GHz). The Dielectric Resonator Antenna (DAR) has interesting attention by many researchers due its compact size, low profile and low power dissipation. Many proposed DAR design reported with different shaped such as rectangular (Bernabeu-Jimenez *et al*., 2015), cylindrical (Prasanth and Velmathi, 2016), hemispherical (Fang and Leung, 2014), triangular (Maity and Gupta, 2016) geometries. One of the famous geometry used is the rectangular shape. Two ratios (width/length and height/length) effected on the properties of the DAR and must be taken care during the process of designing. To get more degree of freedom, cuboid shapes used to control antenna patterns. Many techniques used in feeding DAR such coaxial probe feed (Khaleel *et al*., 2015), microstrip line (Khaleel *et al*., 2016), aperture coupling and proximity coupling (McAllister *et al*., 1983). Femtocells used for serving indoor areas as low-power access points (Yan and Bernhard, 2012).

Pattern reconfigurable antenna has been used widely used in antenna design due to reducing interference, noise source and power consumption. Furthermore, security improvement by directs signals to desired direction.

The aim of this study is to design and prototype single element reconfigurable radiation pattern cuboid shaped DRA with switched parasitic feed. Ceramic material used in designing the cuboid shaped dielectric resonator which is laid on commercial substrate (FR-4) board with ε = 4.3 while the permittivity of the ceramic dielectric is equal to 30. The antenna is normalized to 50 Ω.

MATERIALS AND METHODS

Design and analysis: The proposed antenna is designed according to Dielectric Waveguide Model (DWM) of the TE_{111} mode (Mongia and Ittipiboon, 1997):

$$k_x^2+k_y^2+k_z^2 = \left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2+\left(\frac{l\pi}{2h}\right)^2 = \varepsilon_r k_0^2 \quad (1)$$

$$f_{res} = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2+\left(\frac{l\pi}{2h}\right)^2} \quad (2)$$

$$K_\circ = \frac{2\pi f_\circ}{C_\circ} \quad (3)$$

Where:

F = The operating frequency
K = The free space wavenumber
C = The speed of light in vacuum
k_X, k_Y = The wave number inside the DR in three and k_Z directions
L = The length of dielectric resonator
W = The width of dielectric resonator

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Table 1: Dimensions of the antenna

Parameters	Dimensions (mm)	Descriptions
Wd	15	Width of DR
Ld	15	Length of DR
Hd	20	Height of DR
hf	5	Probe feed line length
hs	1.6	Height of substrate
ht	0.035	Height of copper
L	60	Length of ground and substrate
W	60	Width of ground and substrate

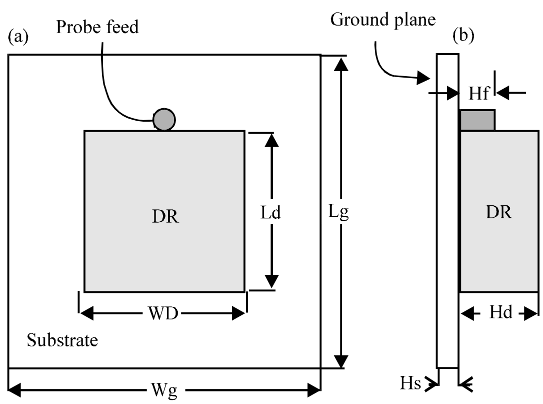

Fig. 1: The structure of cuboid DRA: a) The front view and b) The side view

The structure of the antenna is shown in Fig. 1. The cuboid dielectric resonator based on the FR4 substrate with permittivity of 4.3 with height is 1.6 mm while the width and length were 60 mm for both was chosen as infinite ground plane this antenna was feed by probe SMA 50 Ω touched the dielectric resonator from one side, the height of probe is 5 mm from the ground plane and the radius of probe is 0.62 mm. The width and length of the cuboid dielectric resonator is 15 mm and the height is 20 mm. Table 1 is shown the parameter of the antenna.

To obtain the reconfigurable radiation pattern by add one parasitic feed element inside the dielectric resonator with switch to the ground plane as shown in Fig. 2. The length of parasitic probe feed line element is 5 mm and the distance between the center of dielectric resonator and the parasitic feed line is 2 mm. Figure 3 illustrates the surface current distribution for the proposed antenna when switch on and off. It's clear that the current mainly distributed around the switch when it is on (Fig. 2b) while it distributes around the feeder when the switch off (Fig. 2a). So, the radiation pattern will be steered toward the switch when it's on by using a set switcher t o change the radiation pattern.

Parameter study: This presented antenna is simulated using CST microwave studio. First, the parameter was obtained from the dielectric waveguide model DWM for the dimensions of the dialectic resonator was optimized according to get better results.

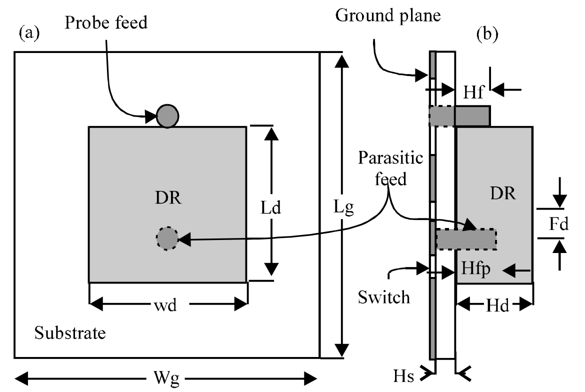

Fig. 2: The structure of cuboid DRA with parasitic feed and switch: a) The front view and b) The side view

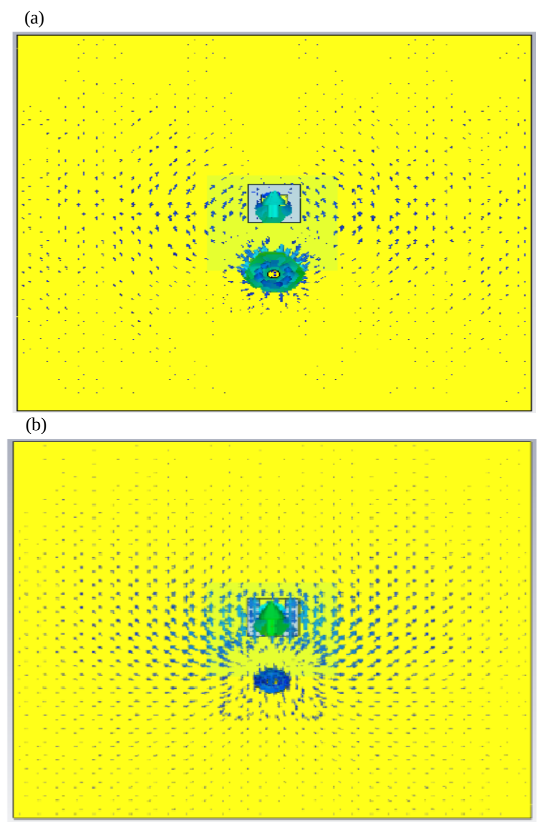

Fig. 3: a, b) The surface current distribution: a) Switch off and b) Switch off

The antenna with parasitic feed element while the switch is off, the probe feed excitation was found that the radius of probe is 0.62 mm to matched with 50 Ω and the heights is equal $\lambda/16$, Fig. 4 shows the return loss of different value of the height of probe feed. Thus, the best S-parameter result at value of the height of probe feed is equal 5 mm.

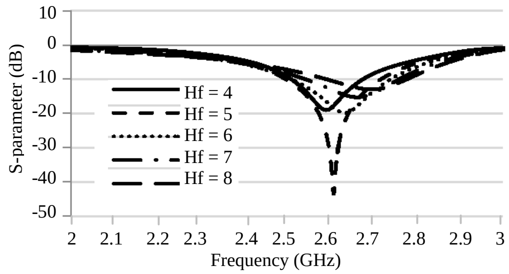

Fig. 4: The return loss of the antenna for different probe feed hight

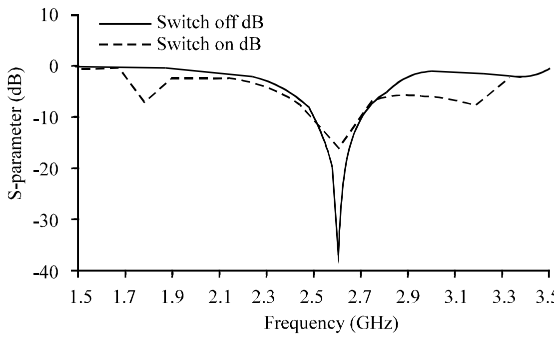

Fig. 5: The return loss of the proposed antenna antenna for switch on and off

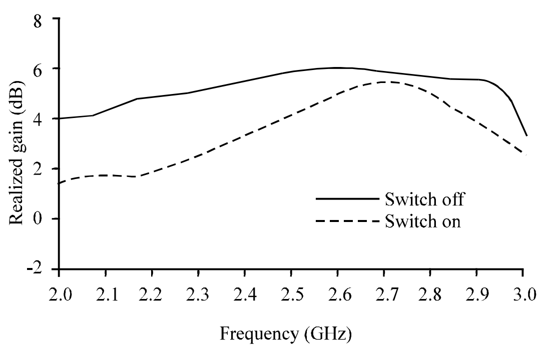

Fig. 6: The maximam gain over frequency of the antenna for switch on and off

RESULTS AND DISCUSSION

After design, the antenna the transient solver was used to obtain the result. The return loss is below -30 dB at 2.6 GHz and the impedance bandwidth is above 200 MHz for both cases switch off and switch on as shown in Fig. 5, this bandwidth is fit to cover the LTE band 7 and band 38 range. And the realized gain is 5.99 dB at 2.6 GHz for switch off and 5.76 dB at 2.6 Ghz for switch on as shown in Fig. 6.

The radiation pattern in E-plane of the propose antenna repesented in Fig. 7. When the switch off (Fig. 7a) the main lobe direction at angle 11° while by switching on the radiation pattern steering to the angle 27° as shown in Fig. 7b.

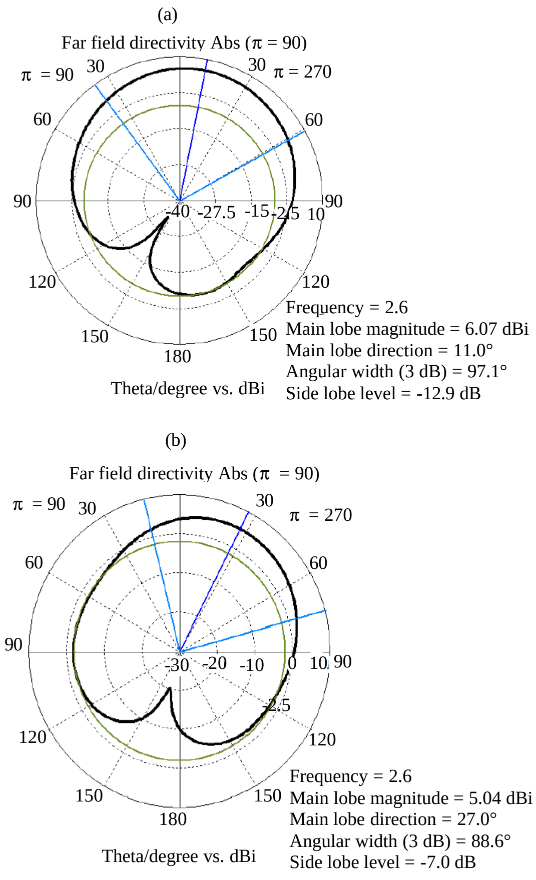

Fig. 7: a, b) The radiation pattern for: a) Swich off and b) Swith on

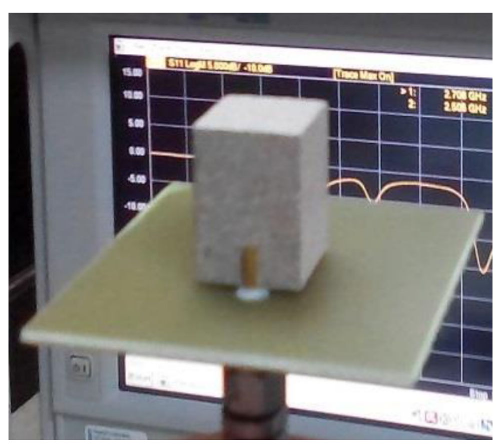

Fig. 8: The proposed antenna after fabrication

This propost antenna without parasitic feed elements was fabricated as shown in Fig. 8. And the measurement and sumulated return loss of the antenna without parasitic

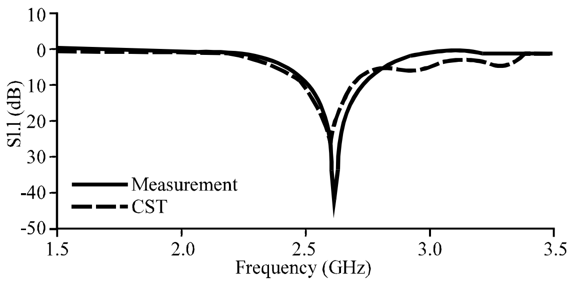

Fig. 9: The measurement and sumulated return loss of the antenna without parasitic feed element

Table 2: The comperation between the antenna with switch off and switch on

Variables	Antenna with switch off	Antenna with switch on
Effecency (%)	98 (%)	94 (%)
Gain at 2.6 (GHz)	5.99 (dB)	4.76 (dB)
Directivity at 2.6 (GHz)	6.07 (dBi)	5.01 (dBi)

feed element is shown in Fig. 9. Table 2 is tabulate the effecency, gain and directivity for switch off and switch on cases.

CONCLUSION

This study present cuboid dielectric resonator antenna fed by coaxial probe. The probe feed excitation parameter was studied, the desired antenna has impedance bandwidth more than 200 MHz, the realized gain is 5.99 dB and the directivity is 6.06 dBi at 2.6 GHz. By using the switch, the radiation in E-plane steered by 16°. The proposed antenna is suitable for femtocell base stations devices. This antenna research at LTE band7 which is (2500-2570 MHz, 2620-2690 MHz) and LTE band 38 (2.57-2. 62 GHz).

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