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Research paper

Pattern reconfigurable dielectric resonator antenna based on phased array switches

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Abstract

This study examines a cuboid dielectric resonator antenna with partial ground plane. The dielectric resonator of the antenna is designed with high permittivity, εr=30. The dimension used to design this cuboid dielectric resonator antenna was based on the dielectric waveguide model (DWM). Meanwhile, the feeding structure depends on the microstrip feed line that resides above the FR4 substrate. The significance of this study is to obtain a reconfigurable radiation pattern. Switches were used to operate the two array elements with phased control in order to obtain reconfigurable pattern, by controlling the switches, the results produced three different radiation patterns at 2.6 GHz with total efficiency 88%. Hence, this proposed antenna can be used for Long Term Evolution (LTE) of band 7 and band 38 with an impedance bandwidth of more than 200 MHz. This study was implemented in a CST Microwave Studio.

Keywords: *hased Array Switches; LTE; Dielectric Resonator Antenna*

1. Introduction

The demands for the current wireless communication network is on the rise. This is mainly attributed to growing use of wireless devices and applications; hence it is crucial to emphasize on novel advances in antenna designs. As such the development of dielectric resonator antennas has received much interest because of their attractive features such as wide bandwidth, high efficiency (1, 2), effective feeding mechanisms (3, 4) and flexibility in their shapes (5). One example is the LTE femtocell base stations that represent a compact devise that is easy to install inside the building (6).
Nowadays wireless communication devices require the use of reconfigurable antenna because it provides various features: frequency, polarization and radiation pattern to improve the overall system performance (7). The reconfigurable radiation pattern has drawn significant interest among researchers in the field of reconfigurable antenna. The reconfigurable radiation pattern not only reduces interference and noise source. But also improves security. Above all, its power consumption is optimized as it directs signals to desired direction effectively (8).
Microstrip feed lines are widely used in current wireless network and sensor devices for several reasons. One of the reasons is microstrip transmission lines help the antennas to be integrated with microwave circuits easily. Another reason is the microstrip feed lines can form an array with microstrip power divider easily, with little hassle (9). Due to this reasons, many research studies have been conducted with the aim of enhancing the bandwidth as using a vacuum between ground plane and dielectric resonator (10-12), a multi segment dielectric resonator antenna(13), and tapered microstrip lines (14). The authors have presented the results obtained from the simulation and fabrication processes of the single element cuboid shape dielectric resonator antenna in a conference paper(15) In literature, no one use phased array switches technique on DRA. meanwhile many techniques are used to obtain reconfigurable pattern for the dielectric resonator antenna. Some of the techniques are multi feed (16), material change (17) and switches (18).
This research study emphasizes on an antenna of two elements array based on cuboid dielectric resonator antenna (DRA) with partial ground plane. Also, this proposed antenna which first to be experimented in this research study uses phased array switches technique on DRA to control the radiation patterns. The finding revealed three different switch cases. Each case illustrated a different radiation pattern. It can be concluded that this proposed antenna is suitable for Long Term Evolution (LTE) of band 7 (2.50-2.57 GHz, 2.62-2.69 GHz) and LTE of band 38 (2.57-2.62 GHz).

2. Antenna Design and Parameters

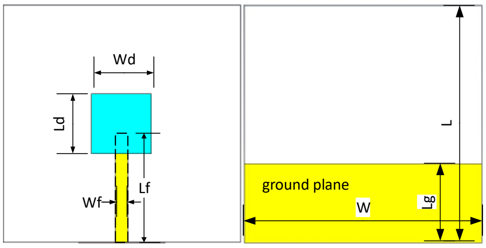
2.1. Single Element

The single element antenna is driven using the dielectric waveguide model (DWM) for TE_{111} mode which is used to calculate the parameter of the rectangular dielectric resonator antenna. The calculation as follows(19):

$$K_z \tan\left(\frac{K_x H}{2}\right) = \sqrt{(\varepsilon_r - 1)K_\circ^2 + K_z^2} \quad (1)$$

$$K_x^2 + K_y^2 + K_z^2 = \varepsilon_r K_\circ^2 \quad (2)$$

The parameters of the dielectric resonator antenna are obtained from the formula of the dielectric waveguide model (DWM) of the TE_{111} mode were used to obtain. The microstrip feeding line was designed in the way that matches the input impedance of 50 Ω. And the feed line is located in the middle of the dielectric resonator antenna.



a b

Fig 1: (a) the geometry of top view for single element antenna (b) the geometry of back view for single element antenna

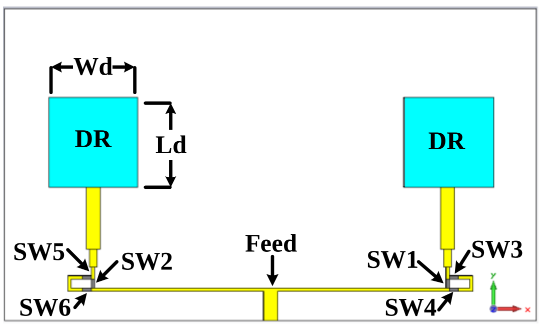
Figure 1 illustrates the geometrical design of the proposed single element antenna. While figure 1(a) is an illustration of the top view, figure 1(b) is an illustration of the bottom view. For this design, the cuboid DRA is placed on top of the square FR4 board of height 1.6 mm and dielectric constant of 4.3. The dimensions of the square FR4 board are 60X60 mm. This proposed antenna is fed by a microstrip feed line with the following dimensions: length (Lf) of 25 mm and width (Wf) of 3.137 mm. Meanwhile, the length and width of the cuboid dielectric resonator are the same; Ld = Wd = 18 mm but the height (Hd) is 12 mm. Table 1 tabulates the dimensions and descriptions of all the parameters for the single element antenna.

Table 1: Dimensions of The Single Elements Antenna

Parameters	Dimensions (mm)	Descriptions
Wd	18	Width of dielectric resonator
Ld	18	Length of dielectric resonator
Hd	12	Height of dielectric resonator
Wf	3.137	Microstrip feed line width
Lf	25	Microstrip feed line length
hs	1.6	Height of substrate
ht	0.035	Height of ground and feed
Lg	20	Length of ground
L	60	Length of ground
W	60	Width of ground and substrate

2.2. Two Elements Array

After obtaining the desired bandwidth from the single element antenna, the researchers decided to improve the gain, directivity and beamwidth of the antenna. The enhancement can be achieved by rearranging the antenna into a two elements array antenna. Besides that, it is necessary to use delay line to change the phase of the elements in order to obtain different radiation patterns.



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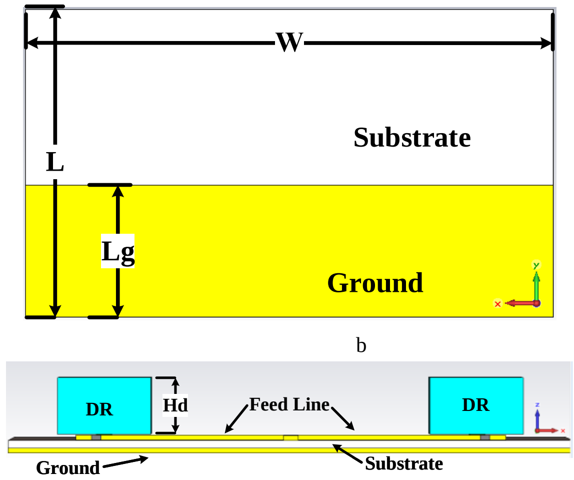

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Fig 2: The Dual Element Array Antenna Structure for (A) Top View (B) Back View (C) Bottom View

Figure 2 illustrations the geometry of dual elements antenna with delay lines and switches. The two cuboid DRAs are placed on top of the rectangular FR4 board. While the FR4 substrate has a dielectric constant of 4.3, the thickness of FR4 substrate is 1.6 mm. The dimensions of the rectangular board are 70 X 120 mm. Then the antenna is fixed with linear feeding array with line delay. Table 2 tabulates the three switches cases.

Table 2: Switches Cases

Cases	SW1	SW2	SW3&SW4	SW5&SW6
Case 0	on	on	off	off
Case 1	off	on	on	off
Case 2	on	off	off	on

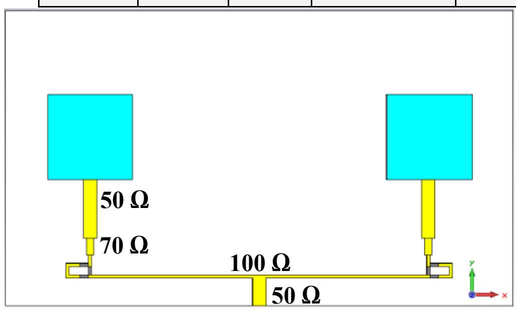


Fig 3: Microstrip Feed Line Power Divider

The power divider is designed to connect the input feed of 50 Ω to a dual input of 50 Ω for each element (see figure 3). The length and width of each cuboid dielectric resonator are the same Ld = Wd = 18 mm but the height is Hd = 12 mm. Table 2 tabulates the dimensions and descriptions of all the parameters of dual elements antenna.

Table 3: Dimensions of Dual Elements Array Antenna

Parameters	Dimensions (mm)	Descriptions
Wd	18	Width of dielectric resonator
Ld	18	Length of dielectric resonator
Hd	12	Height of dielectric resonator
Wf 50 Ω	3.137	Microstrip feed line width (50 Ω)
Lf	25	Microstrip feed line length
hs	1.6	Height of substrate
ht	0.035	Height of ground and feed
Lg	30	Length of ground
L	70	Length of substrate
W	120	Width of ground and substrate
W 100 Ω	0.723	Microstrip feed line width (100 Ω)
W 70 Ω	1.677	Microstrip feed line width (70 Ω)

3. Results and Discussion

In this section, the parameters and conditions for the implementation of this study. We used a CST Microwave Studio(20), and optimized parameters in order to get a better result. The calculations for the parameters were based on the dielectric waveguide model (DWM) formulas for the TE_{111} mode. The finding of return loss for all cases 1, 2 and 3 is above -20 dB at 2.6 GHz. Meanwhile, the impedance bandwidth of the antenna for case 1 is 0.515 GHz and cases 2, 3 is 1.12 GHz. It is evident that, this achieving bandwidth is appropriate for LTE of band 7 and LTE of band 38. Figure 4 illustrates the results of return loss for cases 1, 2 and 3.

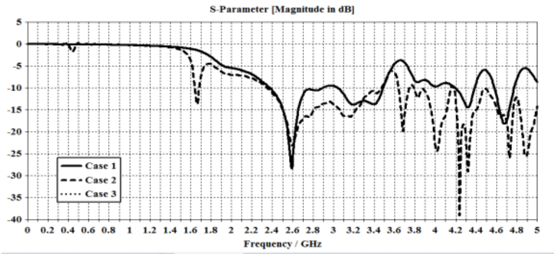


Fig 4: The S-parameters of All Cases

Fig. 5 shows that the maximum gain over frequency occurs at 2.6 GHz. The maximum gain over frequency for cases 1, 2, 3 are at 5.87 dB, 5.47 dB and 5.47 dB respectively.

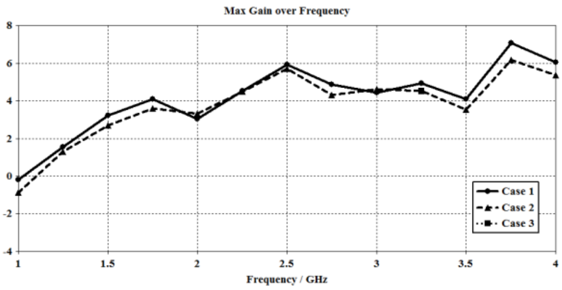
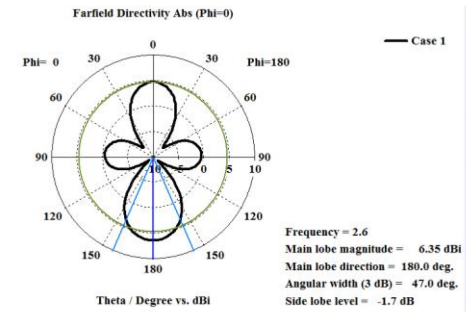


Fig 5: Maximum Gain (dB) Over Frequency for All Cases

Fig. 6 illustrates the radiation patterns for all cases. Figures 5a, 5b and 5c show the radiation patterns at 2.6 GHz for cases 1, 2 and 3 respectively. The radiation patterns at 2.6 GHz are different for each of the cases.



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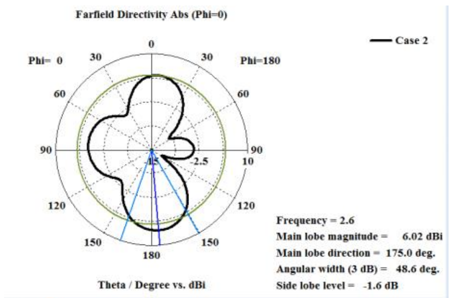

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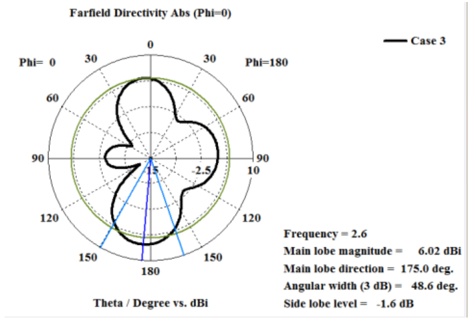

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Fig 6: The Radiation Pattern for All Cases

4. Conclusion

This research study presents the investigation of using phased array switches of dual elements in a dielectric resonator antenna array in order to obtain three different radiation patterns. The driving element is based on a cuboid shape dielectric resonator antenna with partial ground. The results obtained from the proposed antenna supported on impedance bandwidth for case 1 is 0.515 GHz and cases 2, 3 is 1.12 GHz. Hence, this antenna is suitable for LTE band 7 which ranges from (2.500 – 2.570 GHz) for uplink and (2.620 – 2.690 GHz) for downlink and LTE band 38 which ranges from (2.57-2.62 GHz). In Addition, the use of switches to change the length of the feeding line has successfully produced three different radiation patterns.

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