A MIMO H-shape Dielectric Resonator Antenna for 4G Applications

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ABSTRACT

In this article, a Multiple-Input-Multiple-Output (MIMO) H-shape Dielectric Resonator Antenna (DRA) is designed and simulated at 2.6 GHz for 4G applications. The proposed structure consists of H-shape DRA (ε_r=10) which is mounted on FR4 substrate (ε_r=4.6), and feed by two different feeding mechanisms. First, microstrip with slot coupling as Port 1. Second, coaxial probe as Port 2. The electrical properties of the proposed MIMO H-shape DRA in term of return loss, bandwidth and gain are completely obtained by using CST Microwave Studio Suite Software. The simulated results demonstrated a return loss more than 20 dB, an impedance bandwidth of 26 % (2.2 – 2.9 GHz), and gain of 6.11 dBi at Port 1. Then, a return loss more than 20 dB, an impedance bandwidth of 13 % (2.2 – 2.7 GHz), and gain of 6.63 dBi at Port 2. Both ports indicated impedance bandwidth more than 10 %, return loss lower than 20 dB, and gain more than 10 dBi at 2.6 GHz. The simulated electrical properties of the proposed design show a good potential for LTE applications.

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1. INTRODUCTION

Wireless communication nowadays has been part of human life where people can send data information to communicate everywhere and anywhere with the high speed of transmission. Introducing the LTE with high speed of data transmission, data rates, throughput, and spectrum efficiency make user's life easy where they can surf the internet anytime with happily since it become necessary in our life [1] and [2]. This makes the use of devices such as smart phones, laptop and computers become more attractive which required more advanced RF and communication components [3]. In order to fulfill all the needs in wireless communication community, the designers are required to pursue and optimize available RF components in the mobile wireless network.

Multiple-Input–Multiple-Output (MIMO) technology has been developed and used for several times in mobile wireless networks which provide an excellent channel capacity and high data rates. MIMO technology is implemented by utilizing multiple antennas at the input and output side of the communication system to exploit multipath fading to improve channel capacity, data rates, link reliability, and network coverage [4].

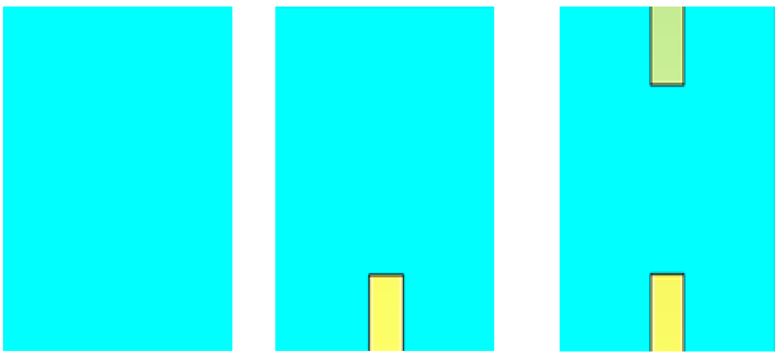
In past few years, microstrip technology has been used to develope MIMO antennas for lower frequency applications. For example, a MIMO antenna for Wi-fi applications is presented with two planar inverted-F antennas (PIFAs) [5]. This MIMO ferrite antenna is proposed at 720 MHz which demonstrated a return loss of 16.4 dB. While in [6], a meander line MIMO antenna for mobile LTE handsets is proposed. The return loss of 12 dB is observed at 800 MHz. All the proposed MIMO antenna with microstrip technology shows a good electrical performance at desired operating frequency. However, the use of microstrip technology in developing MIMO antenna usually suffer from radiation and metallic loss, especially at higher frequency design.

Then, Dielectric Resonator Antenna (DRA) is introduced to develop MIMO antenna. DRAs have several benefits for implementation in wireless communication system due to their small size, light weight, high radiation efficiency, small conductive loss, and ease of excitation and fabrication [6]. DRAs also have versatility and simplicity in shape [7]–[10] and feeding mechanisms [11]–[16]. A few research works have been reported such as MIMO DRA with dual polarization [14]. The proposed antenna produced return loss more than 15 dB. In [17], a 700 MHz dual-mode MIMO DRA is proposed for LTE base stations. The antenna demonstrated a return loss more than 12 dB at the operating frequency. In [18], a MIMO Rectangular Dielectric Resonator Antenna (RDRA) for LTE applications is presented. The proposed antenna is excited using coplanar waveguide (CPW) for Port 1 and coaxial probe for Port 2 which demonstrated a return loss more than 20 dB. However, all the proposed MIMO DRA commonly developed by implementing a basic rectangular shape dielectric resonator as the radiation element which is limit the bandwidth performance.

Therefore, a MIMO H-shape dielectric resonator antenna (DRA) is designed and simulated for LTE applications. Ceramic DRA with dielectric constant of 10 and tan loss 0f 0.0019 has been used in this project. Basically, H-shape DR is developed by removing several parts of the Rectangular-shape DR. By doing this, the effective permittivity of the whole DR volume is reduced and consequently increased the impedance bandwidth (BW) of the proposed DRA [17]. In this work, a MIMO H-shape DRA is designed and simulated using CST software with two different feeding mechanisms at Port 1 and Port 2. The obtained simulated results of MIMO H-shape DRA are compared to the simulated results of basic Rectangular-shape DRA for design verifications.

2. RESEARCH METHOD

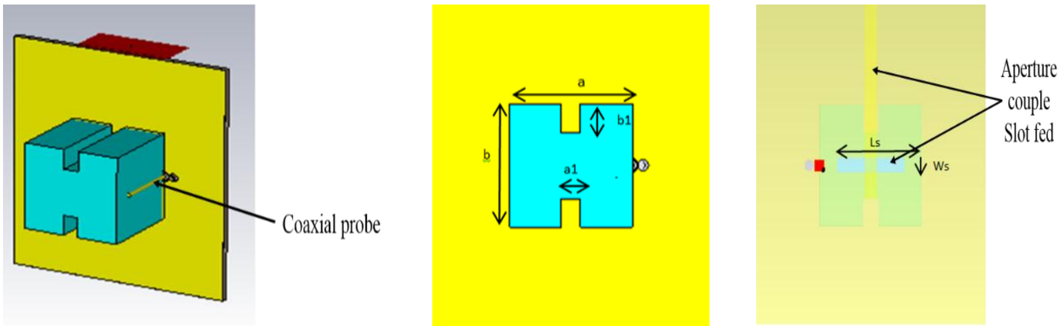
Basically, the H-shape DRA is developed from the basic Rectangular-shape Dielectric Resonator Antenna (RDRA) as can be seen in Figure 1. There are three stages in order to construct H-shape DRA from the basic RDRA. The first stage, a size of Rectangular Dielectric Resonator (RDR) with dimensions of (70 × 60 × 1.6) mm3 (L × W × H) is designed and mounted on FR4 substrate as shown in Figure 1 (a). The second stage, a portion of vacuum filled cube with dimensions of a1 x b1 is inserted and removed from the lower side of RDR, which causes empty cube to remain at the lower side of RDR as shown in Figure 1 (b). This makes U-shape DR is formed from the basic RDR. The third stage, a portion of vacuum filled cube with dimensions of a1 x b1 is inserted and removed from the upper side of U-shape DR, which causes two empty cubes to remain at both sides of the basic RDR. This makes H-shape DR is formed from the basic RDR. Note that, the selected values for a good impedance matching and return loss is decided as a1= 4 mm and b1= 12 mm after performing parametric studies.



(a) (b) (c)

Figure 1. DRA Cutting Procedures (a) Rectangular Shaped (b) U-Shaped and (c) H-Shaped

Then, two feeder mechanisms are integrated into the H-shape DRA in order to make it behave like a MIMO antenna as shown in Figure 2. First is microstrip line with slot coupling and second is coaxial probe. The length slot of the aperture couple is Ls = 17 mm and the width of the aperture couple is Ws = 2 mm. The radius for all the probe is, c1 = 1.1 mm, c2 = 2.4mm, and c3 = 3.0 mm. The height of probe is H = 18 mm. The input impedance for both feeders is 50 Ohm.



(a) (b) (c)

Figure 2. MIMO H-Shaped DRA Geometry (a) Perspective View (b) Top View (c) Back View.

3. RESULTS AND ANALYSIS

In this section, the obtained simulated results from MIMO H-shape DRA is discussed and compared to the simulated results of the basic rectangular-shape DRA. First, the simulated return loss, bandwidth, and resonant frequency of MIMO H-shape DRA is presented in Figure 3. From this simulated results, both ports of the proposed MIMO H-shape DRA shows a slightly different in term of resonance frequency, impedance bandwidth, and return loss. As can be seen, Port 1 is resonated at 2.6 GHz with a return loss of 19 dB and impedance bandwidth of 26.0 % from 2.2 GHz to 2.8 GHz. Meanwhile, Port 2 is resonated at 2.65 GHz with a return loss of 18 dB and impedance bandwidth of 11.5 % from 2.5 GHz to 2.8 GHz. A slight difference is due to the use of different types of feeding mechanism between both ports. However, in this case, Microstrip with slot coupler at Port 1 shows a good feeder mechanism compared to coaxial probe at Port 2 based on the simulated resonant frequency, bandwidth, and return loss performance. Therefore, simulated data of MIMO H-shape DRA at Port 1 is used to compared with simulated data of the basic Rectangular-shape DRA.

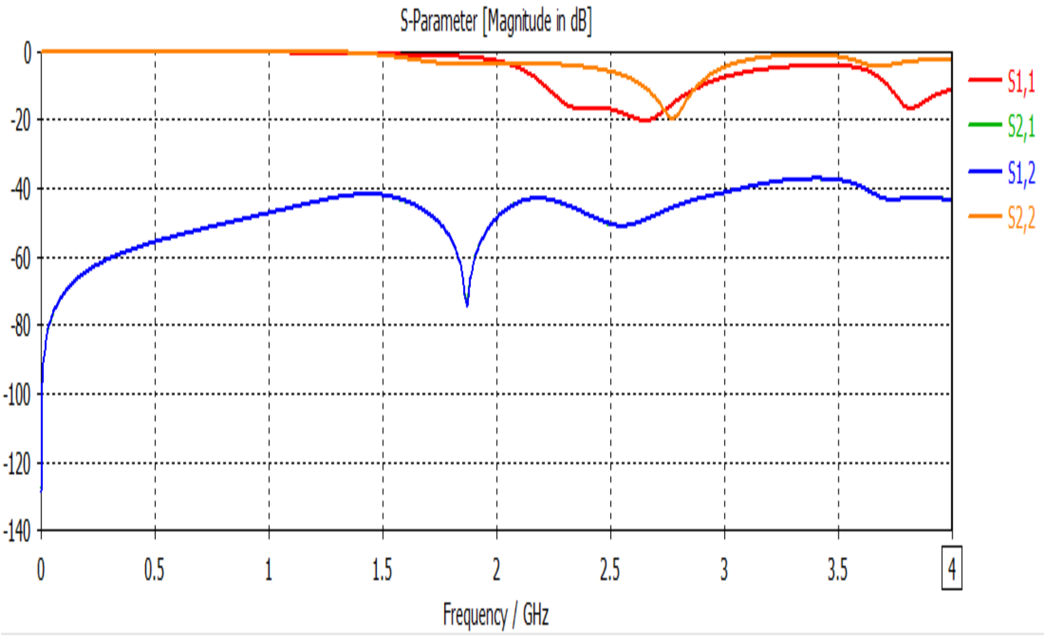


Figure 3. Simulated Return Loss, Bandwidth and Resonant Frequency of MIMO H-Shaped DRA.

Then, a comparison between simulated return loss and impedance bandwidth between the basic rectangular-shape DRA and MIMO H-shape DRA at Port 1 is demonstrated in Figure 4. For the basic rectangular-shape DRA, a return loss of 35 dB is observed with an impedance bandwidth of 15.4 % from 2.4 GHz to 2.8 GHz at 2.6 GHz. Then, for the MIMO H-shape DRA, a return loss of 19 dB is observed with an impedance bandwidth of 26.0 % from 2.2 GHz to 2.8 GHz at 2.6 GHz for Port 1. As can be seen, the proposed MIMO H-shape DRA has indicated an improved bandwidth performance of 10.6 % compared to the basic Rectangular-shape DRA. However, the simulated return loss of MIMO H-shape DRA is smaller than simulated return loss of basic rectangular-shape DRA due to the effect from the second feed mechanism at Port 2.

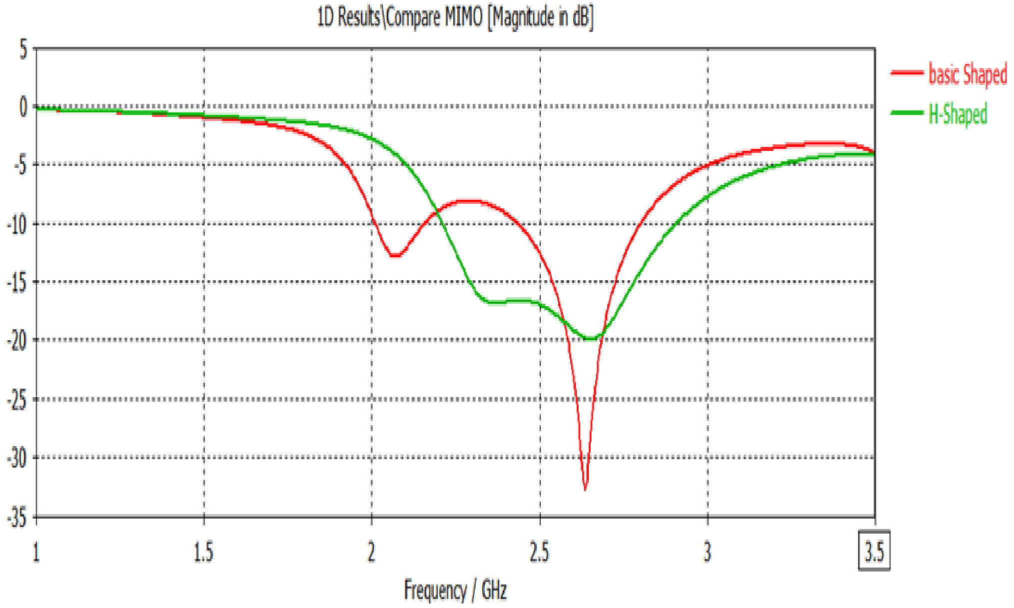


Figure 4. Comparison of Simulated Return Loss and Impedance Bandwidth between Basic Rectangular-Shape DRA and MIMO H-Shape DRA at Port 1.

Finally, the comparison of simulated radiation pattern between the basic rectangular-shape DRA and MIMO H-shape DRA is presented in Figure 5. Simulated radiation patterns for both antennas are indicated almost similar pattern at 2.6 GHz. For the simulated E-plane radiation patterns, both antennas show the directional pattern with a gain of 6.08 dBi for MIMO H-shape DRA at Port 1, 6.66 dBi for MIMO H-shape DRA at Port 2, and 6.05 dBi for basic rectangular-shape DRA. Then, for the simulated H-plane radiation patterns, both antennas show almost an omnidirectional pattern at 2.6 GHz, which received almost same power at any directions.

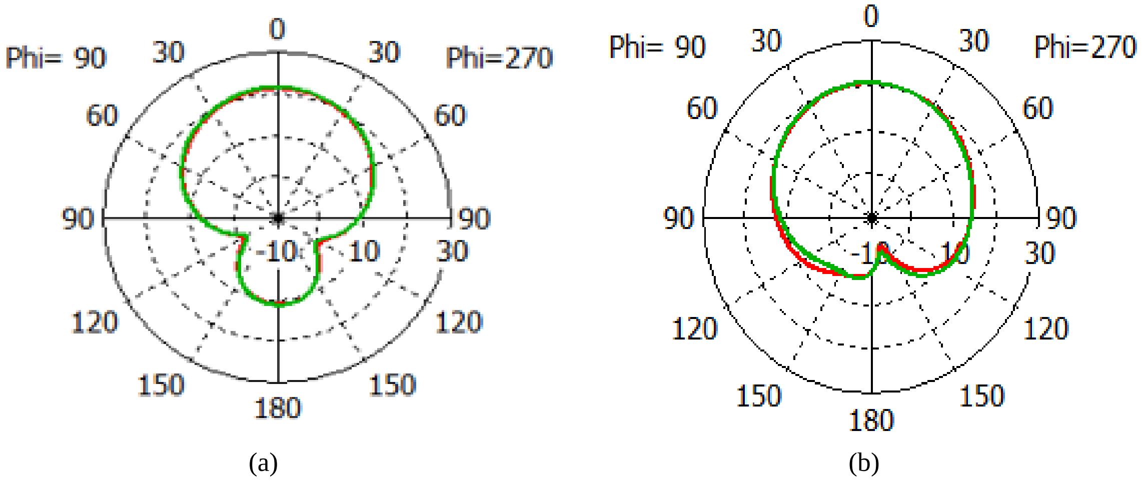


Figure 5. Comparison of Simulated Radiation Patterns between Basic Rectangular-Shape DRA and MIMO H-Shape DRA at 2.6 GHz (a) E-Field (b) H-Field.

A MIMO H-shape DRA for 4G applications is presented in this article. The H-shaped DRA is mounted on FR4 substrate with two different feeding mechanisms to obtain a MIMO characteristics. The simulated antenna has a bidirectional and almost omnidirectional radiation pattern with reasonable electrical properties at the operating frequency of 2.6 GHz. The simulated return loss is lower than 10 dB with an impedance bandwidth of 26 % (2.22 - 2.9 GHz) at Port 1 and impedance bandwidth of 13 % (2.2–2.7 GHz) at Port 2. Then, the simulated gain has demonstrated a value of 6.08 dBi at Port 1 and 6.66 dBi at Port 2. At the same time, the impedance bandwidth of the MIMO H-shape DRA show improvement of 10.6 % compared to the impedance bandwidth of basic rectangular-shape DRA. These electrical properties show a good potential for LTE applications.

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REFERENCES

[1] J Lee, Y Hong, S Bae, GS Abo, W Seong, G Kim. “Miniature Long-term Evolution (LTE) MIMO Ferrite Antenna”. in *IEEE Antennas Wireless Propagation Letter*. 2011; 10: 603– 606.

[2] HS Wong, MT Islam, S Kibria. “Design and Optimization of LTE 1.8 GHz MIMO antenna”. in *Science World Journal*. 2014: 1–10.

[3] J Lu, Z Lin. “Planar Compact LTE/WWAN Monopole Antenna for Tablet Computer Application”. in *IEEE Antennas Wireless Propagation Letter*. 2013; 1: 147–150.

[4] GT Jeong, S Choi, K Lee, WS Kim. “Low-profile Dual-wideband MIMO Antenna with Low ECC for LTE and Wi-Fi Applications”. in *International Journal Antennas and Propagation*. 2014: 1-6.

[5] MS Sharawi, SS Iqbal, YS Faouri. “An 800 MHz 2 × 1 Compact MIMO Antenna System for LTE Handsets”. in *IEEE Transaction and Antennas Propagagion*. 2011; 59: 3128–3131.

[6] H Bae, FJ Harackiewicz, M Park, T Kim, N Kim, D Kim, B Lee. “Compact Mobile Handset MIMO Antenna for LTE 700 MHz Applications”. in *Microwave Optic and Technology Letter*. 2016; 52: 2419–2422.

[7] SF Roslan, MR Kamarudin, M Khalily, MH Jamaluddin. “An MIMO Rectangular Dielectric Resonator Antenna for 4G Applications”. in *IEEE Antennas Wireless Propagation Letter*. 2014; 13: 321–324.

[8] RK Chaudhary, R Kumar, KV Srivastava. “Wideband Ring Dielectric Resonator Antenna with Annular-shaped Microstrip feed”. in *IEEE Antennas Wireless Propagation Letter*. 2013; 12: 595–598.

[9] R Chair, AA Kishk, KF Lee, CE Smith. “Wideband Flipped Staired Pyramid Dielectric Resonator Antennas”. in Electronic Letter. 2004; 40: 13–14.

[10] R Selvaraju, MR Kamarudin, M Khalily, J Nasir, MH Jamaluddin. “Dual Band Rectangular Dielectric Resonator Antenna for WLAN Application”. in *JURNAL TEKNOLOGI*. 2016; 78 (6-2): 65-69.

[11] M Abedian, SKA Rahim, M Khalily. “Two-segment Compact Dielectric Resonator Antenna for UWB Application,” in *IEEE Antennas Wireless Propagation Letter*, Vol. 11, pp. 1533–1536, 2012.

[12] EKI Hamad, HA Atallah. “*Bandwidth Improvement of Compact High Permittivity RDRA using Parasitic Conducting Strips*”. In: 6th European Conference on Antennas and Propagation. Prague. 2015: 5–8.

[13] A Buerkle, K Srabandi, H Mosallaei. “Compact Slot and Dielectric Resonator Antenna with Dual-resonance Broadband Characteristics,” in *IEEE Trans. Antennas Propag*. 2005; 53(3): 1020–1027.

[14] TA Denidni, Z Weng. “Hybrid Ultrawideband Dielectric Resonator Antenna and Band-notched Designs”. in *Microwave Antennas and Propagation*. 2011; 5(4): 450–458.

[15] R Selvaraju, MR Kamarudin, M Khalily, MH Jamaluddin, J Nasir. “Dual-Port MIMO Rectangular Dielectric Resonator Antenna for 4G-LTE Application”. in *Applied Mechanics and Materials*. 2015; 781: 24-27.

[16] R Selvaraju, MR Kamarudin, M Khalily, MH Jamaluddin, J Nasir. “Dual band rectangular dielectric resonator antenna design”. in *Progress in Electromagnetics Research Symposium*. 2014: 2244-2247.

[17] L Zou, D Abbott, C Fumeaux. “Omnidirectional Cylindrical Dielectric Resonator Antenna with Dual Polarization”. in *IEEE Antennas Wireless Propagation Letter*. 2012; 11: 515–518.

[18] B Yan, JT Bernhard. “Design of a MIMO Dielectric Resonator Antenna for LTE Femtocell Base stations”. in *IEEE Trans. Antennas Propagation*. 2012; 60(2): 438–444.

[19] P Rezaei, M Hakkak, K Forooraghi. “Design of Wide-band DRA with a Two-Segment Structure”. in *Progress In Electromagnetics Researc (PIER)*. 2006; 6: 111-121.

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