A Substrate Integrated Magneto-Electric Dipole Antenna and Its 3D MIMO System with Metasurface for 5G/WiMAX/WLAN/X-Band Applications

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***Abstract*—A substrate integrated magneto-electric (ME) dipole antenna with metasurface is proposed for the 5G/WiMAX/WLAN/X-Band MIMO applications. In order to provide the low profile characteristic, the radiated electric dipoles and the shorted wall are integrated in the multi-layer substrates at different altitudes. Unlike the conventional metasurface antenna, by introducing the ME dipole structure with modified zigzagged radiated dipole, the wideband and unidirectional features can be achieved. As a result of the 3D hexagonal structure, the good ECC performance can be obtained by the MIMO antenna system. Also, a 360° full unidirectional coverage in the operating frequency bands can be acquired.**

***Index Terms*—Metasurface antenna, magneto-electric antenna, MIMO antenna.**

I. Introduction

With the explosive growing need of high-speed data transmission and the coexistence of many different kinds of wireless networks, multi-frequency and wideband mobile communication system is in urgent need. Besides, due to the outstanding advantages such as enhancing channel capacity, improving the performances of transmitting and receiving signals, arranging massive antennas into a limited space and so on, the MIMO technology has become a core and hot technology for 5G application. However, few literatures on the MIMO antenna for 5G/WiMAX/WLAN/X-Band communication have been reported owing to its design difficulty in such a wideband. Recently, because of its splendid characteristics, such as high gain as well as complementary E- and H-plane unidirectional radiation patterns, magneto-electric (ME) dipole antenna, which is proposed by Profs. Luk and Wong, has been widely investigated [1]. More recently, metamaterials have attracted much attention in physics and communication engineering fields for its outstanding electromagnetic characteristics such as enhancing the effective ratio between permeability and permittivity to reduce the size, frequency reconfiguration,improving gain and so on [2].

In this paper, based on the beam steering concept, in order to provide a 360° complete coverage of H-plane radiation pattern with high gain and low profile in a wideband, a substrate integrated magneto-electric (ME) dipole antenna with metasurface is proposed for the for 5G/WiMAX/WLAN/X-Band MIMO applications. Unlike the conventional metasurface antenna, by introducing the ME dipole structure with modified zigzagged radiated dipole, the wideband and unidirectional features can be achieved. In addition, owing to the coordination of the metasurface and the ME dipole, the gain of the antenna can be improved obviously. Finally, due to the 3D hexagonal structure, the good ECC can be obtained for the MIMO antenna system.

II. Antenna Geometry and Working Mechanism

As shown in Fig. 1, the proposed antenna is printed on the three-layer Rogers 5880 substrate with a dielectric constant of ξ_r=2.2 and a loss tangent of δ=0.0009. From top to bottom, their thicknesses are 1.52 mm, 3.75 mm and 3.75 mm, respectively. The total size of the antenna element is $60\times60\times7.92$ mm^3. The arc-shaped electric dipole radiated patch together with zigzagged slot is employed to provide dual wideband characteristics. The pair of via-hole shorted walls and the ground between them form a basic magnetic dipole. The η-shaped feeding structure which comprises a transmission line, a horizontal and a vertical coupling strips is introduced to excite the ME dipole. The metasurface patch is made up of the I-shaped patches, which are used to improve the antenna gain and shorten the height of the antenna. By using the stable H-plane with an angle of 60° of the proposed antenna element, six-element MIMO antenna system which can provide a 360° full coverage in H-plane is presented, as shown in Fig. 1(c). Table I lists the detailed dimensions of the antenna and its MIMO system.

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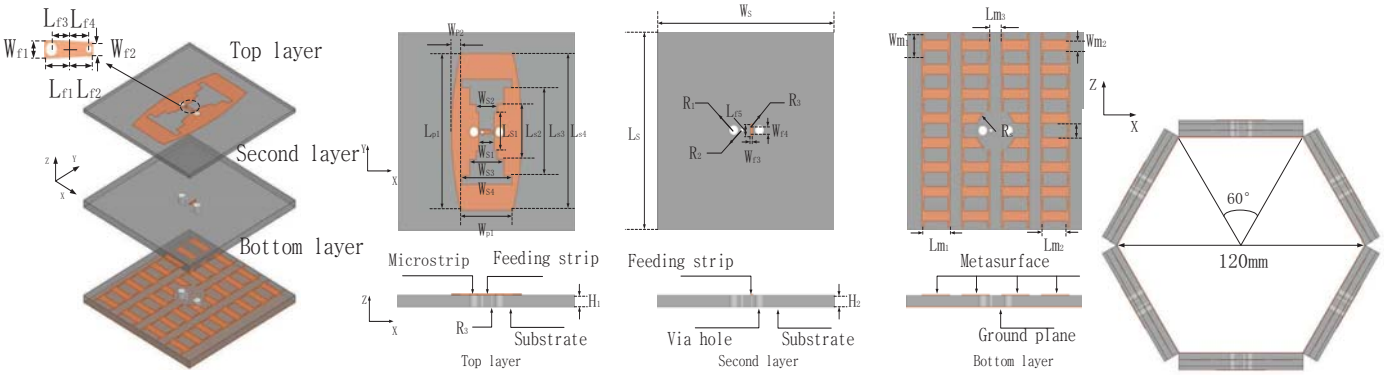


(a) 3D view of the antenna element (b) Different layers of the antenna (c) Side view of the MIMO antenna system

Fig. 1 Geometry of the proposed antenna and its MIMO system.

TABLE I Dimensions For The Proposed Antenna

Parameters	L_s	W_s	L_p	W_{p1}	W_{p2}	L_{s1}	L_{s2}	L_{s3}
Values/mm	60	60	47.23	17.62	3.04	11.55	16.55	26.55
Parameters	L_{s4}	W_{s1}	W_{s2}	W_{s3}	W_{s4}	L_{f1}	L_{f2}	L_{f3}
Values/mm	31.75	5.2	7.06	11.5	17.05	2.16	2.1	1.55
Parameters	L_{f4}	L_{f5}	W_{f1}	W_{f2}	W_{f3}	W_{f4}	L_{m1}	L_{m2}
Values/mm	1.75	3.74	1.47	1	0.8	2.26	9.4	8.16
Parameters	L_{m3}	W_{m1}	W_{m2}	W_{m3}	H_1	H_2	H_3	R_1
Values/mm	3.95	6.91	3	4.37	1.57	3.175	3.175	1.5
Parameters	R_2	R_3	R_s					
Values/mm	0.5	0.25	6.5					

III. Results and Conclusion

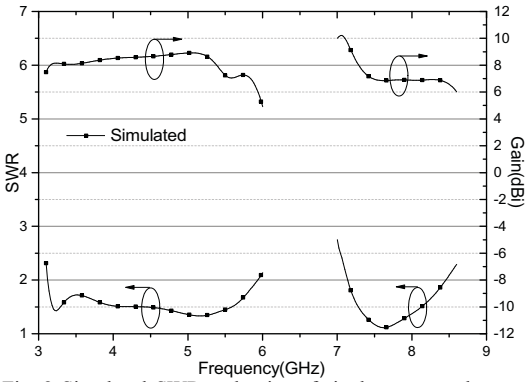
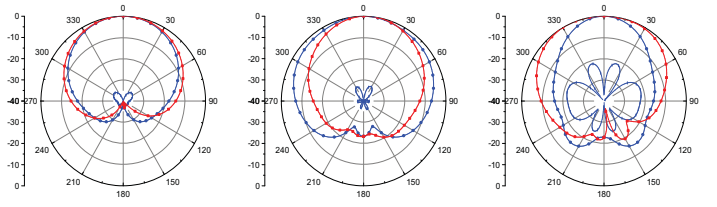


Fig. 2 Simulated SWR and gains of single antenna element.



(a) 3.4 GHz(simulated) (b) 5.5 GHz(simulated) (c) 7.8 GHz(simulated)

Co-pol(H-plane:YOZ plane) Cross-pol(H-plane:YOZ plane)
Co-pol(E-plane:XOZ plane) Cross-pol(E-plane:XOZ plane)

Fig. 3 Simulated radiation patterns of single antenna element at 3.4, 5.5 and 7.8 GHz.

As shown in Fig. 2, the impedance bandwidth ranges from 3.12 to 5.92 GHz, 7.14 to 8.45 GHz ($SWR \leq 2$) for the lower and upper frequency bands, respectively. The gain varies between 6.0 dBi and 8.9 dBi in the lower band, and between 6.7 dBi and 9.6 dBi in the upper band, respectively. Fig. 3 shows the simulated radiation patterns of the single antenna element at different frequencies. Nearly symmetric unidirectional radiation patterns in the E- and H-planes over the operating frequency band can be obtained. The cross-polarization levels in E- and H-planes are generally below -22 dB while the front-to-back ratios are larger than 20 dB. In addition, the simulated ECCs of the MIMO antenna system are shown in Fig. 4. The parameters of ECC are all below 0.0005. With the above-mentioned characteristics, the proposed antenna can be potentially suitable for 5G/WiMAX/WLAN/X-Band MIMO unidirectional communications.

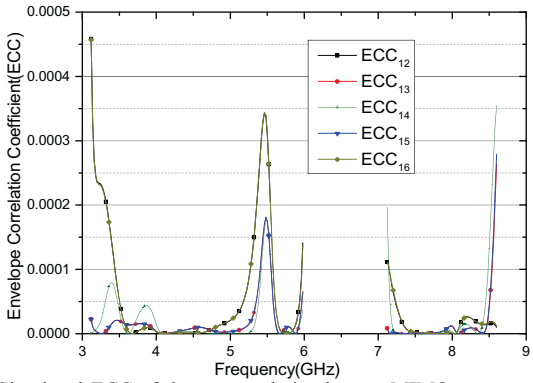


Fig. 4 Simulated ECC of the proposed six-element MIMO antenna system.

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