A Substrate Integrated Magneto-Electric Dipole Antenna Using Metasurface for 2G/3G/LTE/5G Applications

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***Abstract*—A substrate integrated magneto-electric dipole antenna using metasurface is proposed for 2G/3G/LTE/5G applications. By employing the technology of metasurface and using the substrate with high relative permittivity, the height of the proposed antenna is reduced from 0.25 to 0.12 wavelength operating at 2.68 GHz. The metasurface consists of 40 unit cells and is arranged atop the second layer. In addition, by adopting the dual-layer H-shaped ground planes, the front-to-back ratio can improved and the impedance bandwidth can also be broaden. The proposed antenna achieves an impedance bandwidth of 75% (1.67-3.69 GHz) with a stable gain of 5.14±1.24 dBi. Therefore, this antenna is suitable for 2G/3G/LTE/5G applications.**

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

I. Introduction

Due to the rapid development of modern wireless communication systems, the demands of wideband antennas with stable gain are sharply growing for 2G, 3G, LTE and 5G communications. In 2015, the frequency band from 3.4-3.6 GHz has been assigned as the future communication by the World Radio Communication Conference 2015 (WRC-15). On the other hand, as is known to all, the magneto-electric (ME) dipole antenna owns many excellent electrical characteristics such as wide impedance bandwidth, stable gain, good front-to-back ratio (FBR) and low cross-polarization. The wideband ME dipole antenna can be designed to operate at many wireless communication bands, such as 2G/3G/LTE [1] - [2], WLAN/WiMAX [3], and ultra-wideband systems [4]. These ME dipole antennas exhibit wideband and stable gain feature. However, their structures are still bulky, especially for the height. For example, the heights of many previous ME dipole antennas are more than 0.25 wavelength. Therefore, the low profile ME dipole antenna with less than 0.2 wavelength is urgently needed.

Metasurface (MS), a planar equivalent of metamaterial, has attracted many attention in recent years. The MS which consists of electrically small scatters has been used to improve the performance of the antenna and miniaturize its size. By arranging the MS below or above microstrip patches, the impedance bandwidth can be broaden and the gain can be improved [5]-[8]. In addition, by placing the MS above of the linear polarization source antenna, the linearly polarized signal can be converted into circularly polarized signal [9]. However, there is an air gap between the source antenna and the MS, which will increase the volume of the antenna. In order to obtain a compact size, the MS should be placed atop the source antenna without air gap. By rotating the MS around the center of antenna, it can mechanically reconfigure the frequency [10] or reconfigure the polarization between linear polarization, left-hand circularly polarization and right-hand circularly polarization [11]-[12]. However, this kind of MS antenna still exists the non-negligible drawback of narrow bandwidth.

In this paper, a wideband and low-profile ME dipole antenna using MS is presented for 2G/3G/LTE/5G applications. The proposed antenna can realize an impedance bandwidth of 75%, ranging from 1.67 to 3.69 GHz. The antenna can also achieve a stable gain of 5.14 dBi. Instead of the three-dimensional ME dipole antenna, a six-layer substrate integrated ME dipole antenna is utilized to acquire the low-profile property. By placing the MS atop the second layer, the gain of the antenna can be increased and the height of the antenna can be reduced. The stair-shaped feeding structure and the dual-layer H-shaped ground planes can achieve a better impedance matching. The radiation pattern of the ME dipole antenna with cross polarization less than -30 dB can also be obtained over the entire operating frequency.

II. Antenna Geometry

The geometry of the proposed antenna is shown in Fig. 1, and the detailed dimensions of the antenna are shown in Table I. The substrate integrated ME dipole antenna is printed on the Taconic RF-35 substrate with a dielectric constant of 3.5 and a loss tangent of 0.0018. As shown in Fig. 1, the metal patch with bowtie slot is printed atop the first layer, which is

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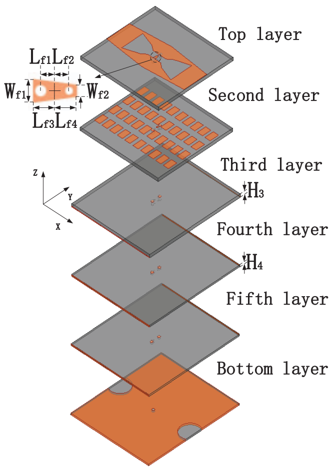
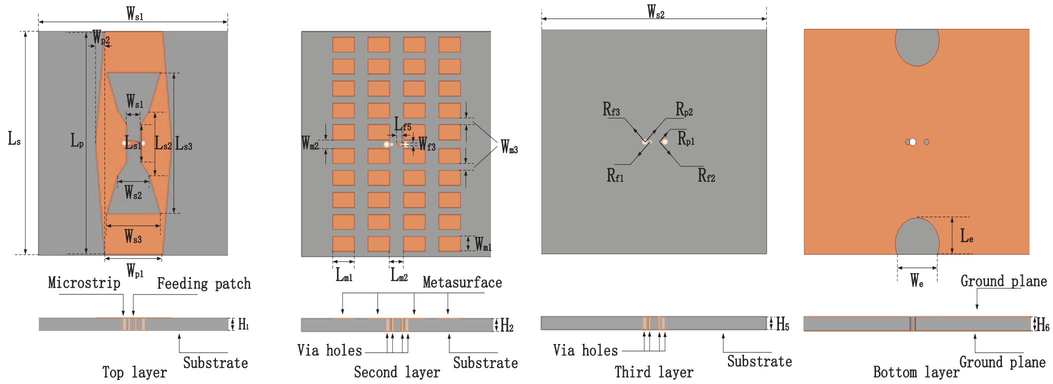


(a) 3D view of the antenna element



(b) Different layers of the antenna

Fig. 1 Geometry of the ME dipole antenna.

TABLE I Dimensions For The Proposed Antenna

Parameters	L_s	W_{s1}	W_{s2}	Lp	W_{p1}	W_{p2}	L_{s1}	L_{s2}
Values/mm	72	70	85	71.4	21.3	3.3	12	20.2
Parameters	L_{s3}	W_{s1}	W_{s2}	W_{s3}	L_{m1}	L_{m2}	W_{m1}	W_{m2}
Values/mm	45.2	5.2	11.5	19.9	8	4	4.8	2.8
Parameters	W_{m3}	L_{f1}	L_{f2}	L_{f3}	L_{f4}	L_{f5}	W_{f1}	W_{f2}
Values/mm	2.2	1.6	0.8	2.3	1.4	2	2	1
Parameters	W_{f3}	L_e	W_e	H_1	H_2	H_3	H_4	H_5
Values/mm	1	11.8	15.1	3	3	3	1.5	1.5
Parameters	H_6	R_{f1}	R_{f2}	R_{f3}	R_{p1}	R_{p2}		
Values/mm	1.5	0.5	0.35	0.9	0.45	1		

designed to achieve a wide impedance bandwidth. The electric dipole patches are connected with the ground plane by a pair of via holes. By placing the MS which consists of 40 unit cells atop the second layer, the gain of the antenna can be enhanced and the height of the antenna can be reduced. The proposed antenna is excited by a stair-shaped feeding structure which is located at the center of the electric dipole patch. The dual-layer H-shaped ground planes are printed at the front-side and back-side of the bottom layer, respectively.

III. Results and Discussion

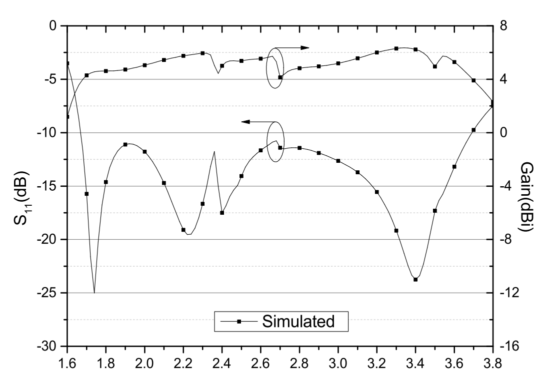
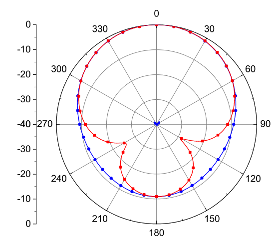
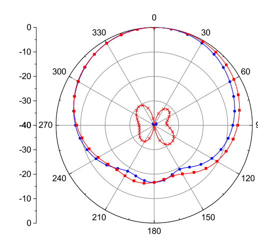


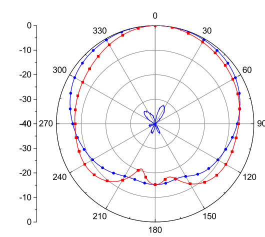
Fig. 2 Simulated S_{11} and gain of ME dipole antenna.



(a) 1.8 GHz



(b) 2.7 GHz



(c) 3.5 GHz

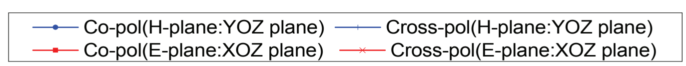


Fig. 3 Simulated radiation patterns of single antenna element at 1.8, 2.7 and 3.5 GHz.

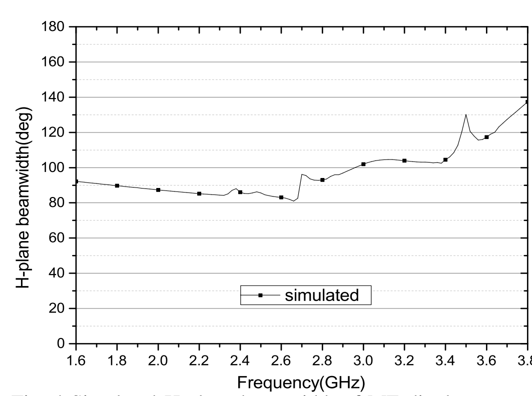


Fig. 4 Simulated H-plane beamwidth of ME dipole antenna.

The simulated S-paremeter and gain of the ME dipole antenna are shown in Fig. 2. The simulated result has shown that impedance bandwidth is 75%, ranging from 1.67 to 3.69 GHz, which covers the 2G/3G/LTE/5G frequency bands. The gain of the antenna is 5.14 ± 1.24 dBi. Fig. 3 depicts the simulated radiation patterns at the frequency of 1.8, 2.7 and 3.5 GHz. It can be seen that nearly the symmetrical E- and H- plane radiation patterns can be obtained. In addition, the cross-polarizations of both planes are less than -10 dB over the entire bandwidth. Furthermore, a wide H-plane beamwidth can also be achieved, as shown in Fig. 4. The beamwidth in the H-plane is more than 80° over the entire operating frequency band.

IV. Conclusion

A substrate integrated ME dipole antenna using metasurface is proposed for 2G/3G/LTE/5G applications. By combining the inherent properties of ME dipole and metasurface, the antenna can achieve wideband and low-profile properties. In addition, by introducing the dual-layer H-shaped ground planes, the FBRs of the ME dipole antenna are enhanced. The ME dipole antenna can achieve an impedance bandwidth of 75% (1.67-3.69 GHz) with a stable gain of 5.14 ± 1.24 dBi. With the above-mentioned features, the antenna can be suitable for the 2G/3G/LTE/5G applications.

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