A Millimeter-wave Aperture-coupled Simple Low-Profile Magneto-Electric Antenna

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***Abstract*—A millimeter-wave low-profile magneto-electric(ME) dipole antenna is presented in this paper. The proposed ME dipole antenna is designed on two pieces of substrate with different materials and fed by aperture-coupled technique. Unlike the previously reported ME dipole antennas, there is no vertical-cavity serving as a magnetic dipole in this design, while the magnetic dipole is formed by the gap between the two horizontal patches, this design makes the geometry of the ME dipole antenna simple and easy to be fabricated. Simulated results show that the proposed ME dipole has impedance bandwidth (VSWR≤2) of 29.1% from 23.5 GHz - 31.5 GHz and a stable high gain of 8.3 ± 0.7 dBi across the operating frequency band.**

***Index Terms*—magneto-electric dipole,low-profile, simple geometry, high gain, wide band**

I. Introduction

Antenna with high-gain characteristic is critical to wireless applications in the millimeter-wave frequency bands, as it can compensate the high free space path loss. Also, the physical size of high-frequency antennas is usually small as a result of the short wavelength. Therefore, it is desirable to have simple antenna geometry to respond to the challenges in fabrication. A design of combining magnetic dipole and electric dipole of identical amplitude and phases with similar radiation patterns in the E- and H-planes [1], [2]. Based on this concept, a wideband and high gain unidirectional antenna named as magneto-electric dipole antenna has been designed [3]. An ME-dipole of simple geometry which has eliminated the half-wavelength cavity of the magnetic dipole in the sub-6GHz band was reported [4]. In this paper, an aperture-coupled magneto-electric (ME) dipole antenna with simple geometry operates at the 5G millimeter-wave band is reported. The simulated impedance bandwidth of the proposed antenna (VSWR≤2) is 29.19% from 23.7 GHz- 31.8 GHz and a stable high gain of 8.3 ± 0.7 dBi across the operating frequency band is obtained. CST Microwave Studio 2020 was used in the simulation.

II. Antenna Geometry

The geometry of the proposed antenna and detailed dimensions are shown in Fig. 1. The proposed antenna is designed on two pieces of dielectric substrate with different materials.

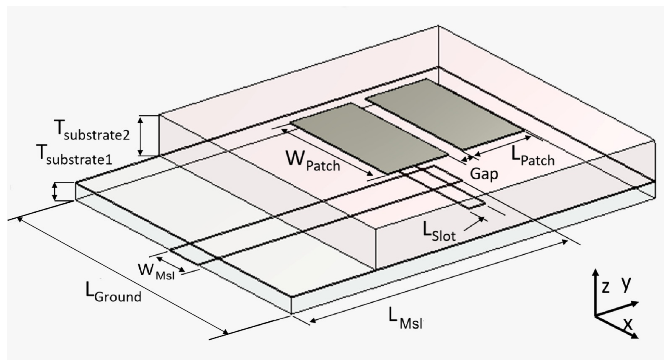

Fig. 1. The geometry of the proposed antenna.

On the bottom layer, Substrate1 (Rogers TMM4, ε_r= 4.5, tanδ = 0.002 @ 10 GHz), the antenna was fed by a microstrip line through a slot aperture. The two copper patches radiating elements are realized on the top layer, Substrate 2 (Rogers RT5880LZ, ε_r = 2.0, tanδ = 0.0021 @ 10 GHz). The lower feed layer is designed to be thinner (0.508 mm) and of a higher value of relative permittivity which will reduce the amount of spurious radiation in the feedline. While the upper radiating layer is thicker (1.27 mm) and of lower permittivity for achieving better radiation efficiency.

TABLE I
Dimensions of the propose d antenna

Parameter	L_{Patch}	W_{Patch}	Gap	W_{Slot}	L_{Slot}
Value(mm)	2.2	4.5	0.5	6.5	0.6
Parameter	L_{Msl}	W_{Msl}	L_{Ground}	T_{Sub1}	T_{Sub2}
Value(mm)	0.47	1.2	10	0.508	1.27

III. Radiation Principle

ME dipole antennas usually have the features of wide bandwidth and stable high gain. Such advantages come from the fact that the electric dipole mode and the magnetic dipole mode of the antenna radiate simultaneously with the same amplitude and phase. In the proposed ME dipole antenna, the two horizontal patches, in y-direction, form to a wide electric dipole antenna, while the narrow slot between the two patches forms to a magnetic dipole antenna in the x-direction.

Meanwhile, the separation between radiating elements and ground plane is 1.27mm (0.16), the ground plane generates a reflection of the back-going field and increases the gain and front-to-back ratio of the proposed antenna. In contrast to the previously reported high frequency planar ME dipole antennas, which require an array of via-hole to create the specific cavity to excite the magnetic dipole mode [5], a much simple design, which can be easily fabricated, is proposed in this design. The magnetic dipole mode of the proposed antenna is generated by activating the slot between two horizontal patches through an aperture on the bottom layer. The antenna has a comparable wide impedance bandwidth and stable high gain.

Fig. 2 shows the electric field distribution of the proposed antenna at different times of a period T, which can help to explain how the magnetic dipole and the electric dipole radiate simultaneously. when t = 0 or T/2, the electric field has the strongest distribution along the gap between the two horizontal patches, hence, the magnetic dipole is excited at those moments. While when t = T/4 or 3T/4, the electric field has significant distribution at the end of the horizontal patches, therefore, the electric dipole is activated.

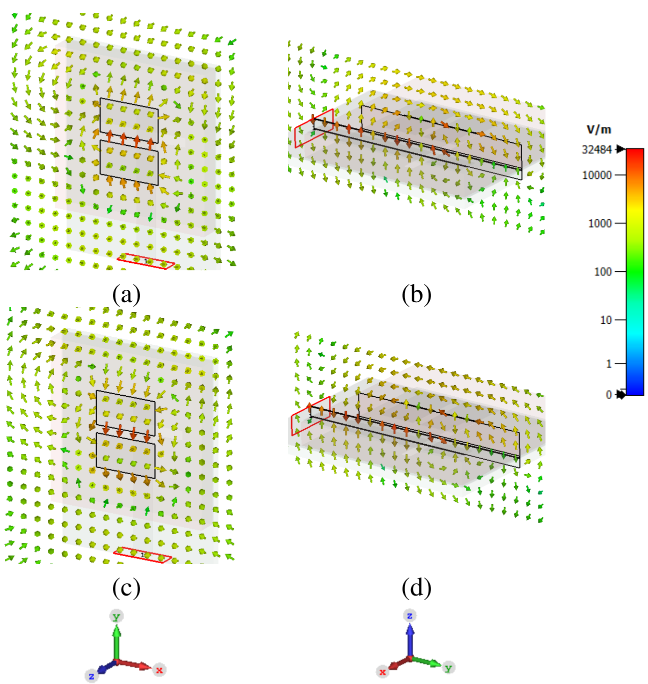

Fig. 2. E-field of the proposed antenna. xy plane (a). t = 0; (b). t = T/4; xz plane (c). t = T/2; (d). t = 3T/4

IV. Simulated results

Fig. 3 has shown the simulated gain and VSWR of the proposed antenna. The proposed antenna has impedance bandwidth (VSWR$\leq$2) of 29.1% from 23.5GHz to 31.5GHz, and the simulated realized gain is 8.3 $\pm$ 0.9dBi over the frequency band.

Fig. 4 and Fig. 5 show the radiation pattern of E-plane and H-plane at different frequencies respectively. The radiation patterns show good consistency over the frequency band.

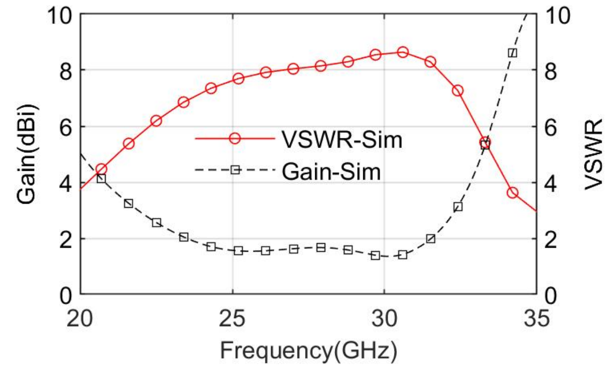

Fig. 3. Simulated Gain and VSWR of the proposed antenna .

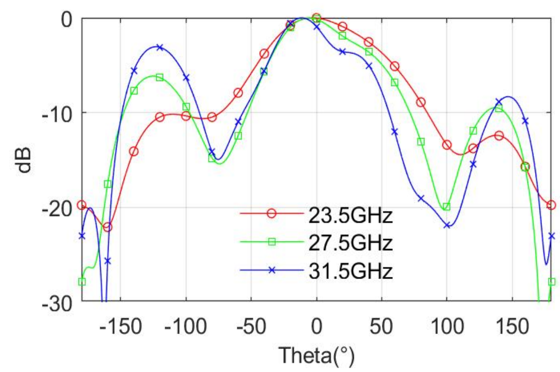

Fig. 4. The E-plane of the proposed antenna at different frequencies

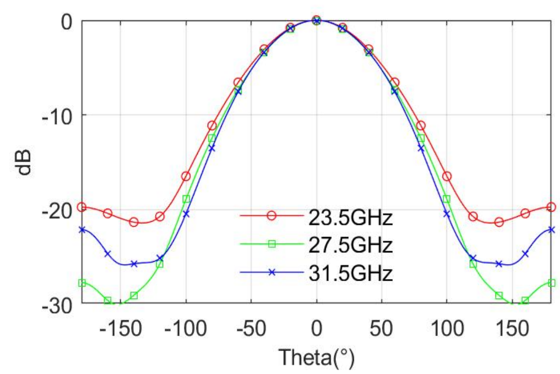

Fig. 5. The H-plane of the proposed antenna at different frequencies.

However, due to the disadvantage results from the aperture-coupled fed technique, the side-lobe level increased with frequency.

V. Conclusions

A millimeter-wave low-profile magneto-electric dipole antenna structure has been designed and simulated. By only activating the gap between the two horizontal patches to generate the magnetic dipole mode, the structure of the antenna becomes very simple and make it easy to be fabricated.

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