Low-Profile Proximity Coupled Cavity-less Magneto-electric Dipole Antenna

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***Abstract*—Magento-electric dipole antennas have a wide impedance bandwidth, high and stable gain and unidirectional low back-lobe radiation pattern, it can be utilized to support the modern wireless communication systems. However, the thickness of conventional ME-dipole antenna is about 0.25 λ_o at the center operating frequency. This work presents a new feeding method which can reduce the profile and ground plane size of magneto-electric dipole antenna. A suspended transmission line geometry is proposed to excite the antenna through proximity coupling. The antenna has a compatible wide impedance bandwidth of 43.6% (from 1.88 to 2.93 GHz) and a high gain of 9.8 dBi with stable 1.7 dBi in-band variation with a ground reflector of size about 1 λ_o^2. More importantly, the cavity-less geometry can reduce the overall thickness of the antenna to 0.16 λ_o at the center operating frequency.**

***Index Terms*—magneto-electric dipole, suspended transmission line, proximity coupled feeding.**

I. Introduction

Antennas with high specification attract the interest of researchers in academia and the wireless communications industry. Many wireless communication systems impose antennas with wide impedance bandwidth, high gain, high directivity, low back-lobe and stable unidirectional radiation patterns in the E- and H-planes to meet the high demand in wireless communications. Various types of antennas, such as microstrip patch antennas, horn antennas, log periodic antennas, and antenna arrays, have been proposed in the literature to address some of these requirements. However, these solutions often have drawbacks, such as limited impedance bandwidth or bulkiness. Additionally, achieving identical radiation patterns in both E- and H-planes may require antenna arrays in both planes [1, 2].

Electric dipoles and magnetic dipoles (slot antennas) are two types of well-known basic antenna elements. They have very simple, but complementary radiations features; the radiation pattern of an electric dipole has the shape of an "inverted-8" in the E-plane and an omni-directional radiation pattern in the H-plane, while the radiation patterns of a magnetic dipole is vice versa. Theoretically, combining these two sources of identical amplitude and phases will produce an antenna with similar radiation patterns in the E- and H-planes. Conventionally, it consists of a horizontal wide planar dipole (electric dipole) and a slot antenna (magnetic dipole) in the form of a cavity closed by vertical walls between the two patches. The two dipoles radiate at the adjacent frequency bands to provide the wide impedance bandwidth, stable and high gain, and similar radiation patterns in both E- and H-planes across the operation frequency band. The resulting antenna will have a wide impedance bandwidth and a unidirectional radiation pattern in the E and H planes. In [3], the authors introduced the ME dipole concept using a L-shaped feed to excite the two orthogonal modes with equal magnitude and phase. The resultant radiation patterns are identical in the E and H planes. The antenna has a wide bandwidth of 43.8% and a high gain 8 dBi. In [4], the authors introduced a dual polarized ME dipole antenna fed by L-shaped feeding system to excite the two modes. The ME dipole achieved a wide impedance bandwidth of 66%, high gain of 9.5 dBi and high isolation of 36 dB, but the thickness was about 0.23 λ_o. In [5], the author proposed a simple low-profile cavity-less ME dipole antenna fed by a coaxial cable. The antenna has a wide impedance bandwidth of 41% and high gain of 9.7 dBi with 2 dB in-band variation. Several methods and techniques were proposed in the literature to reduce the overall size of the antenna [2, 6]. Using bending cavity walls or a tilted coaxial feeding system to reduce the height of the antenna, however, the size of the ground reflector is usually larger than 1 λ_o^2. In [7], a wideband circularly polarized ME-dipole antenna of reduced thickness about 0.22 λ_o is reported.

In this paper, a simple cavity-less magneto-electric dipole antenna using a suspended transmission line to proximity-coupled feed the two dipoles is proposed. The ME dipole working principle has the electric dipole resonating at the lower frequency band and the magnetic dipole resonating at the higher band, making the antenna achieve a wide impedance bandwidth and high realized gain. The proposed antenna is fed by a vertical coaxial cable and a probe horizontal arm that excites the ME dipole and does not require the quarter wave cavity walls to excite the magnetic dipole, as reported in [2, 4]. As a result, the antenna can meet the low profile requirement to have a thickness about 0.16 % λ_o . The proposed feeding method also allows the antenna ground reflector to be reduced 0.78 λ_o while maintaining a wide impedance bandwidth of 40.7% and a high gain of 8 dBi. On the other hand, the antenna can provide a wide impedance bandwidth of 43.6% and a high gain of 9.8 dBi with 1.7 dB in-band variation when the length of ground reflector is about 1 λ_o^2.

II. ME-dipole Antenna Geometry and Design

The proposed ME dipole consists of two metallic patches fed by a horizontally oriented probe arm which is connected to a coaxial cable (RG 402, 50 Ω, ϕ 3.58 mm) and a square ground reflector, as shown in Fig. 1. The proposed feeding method is different from the conventional L-shaped feeding system used in [3, 4], which the vertical part of the line makes the feeding system highly inductive. We propose to connect the inner conductor of the coaxial cable a horizontal probe to feed the ME-dipole through the proximity coupling. The outer conductor of the coaxial cable is connected the ground reflector from one side and connected to the one of the patch using a grounding pin . The detailed parameter dimensions are listed in Table I.

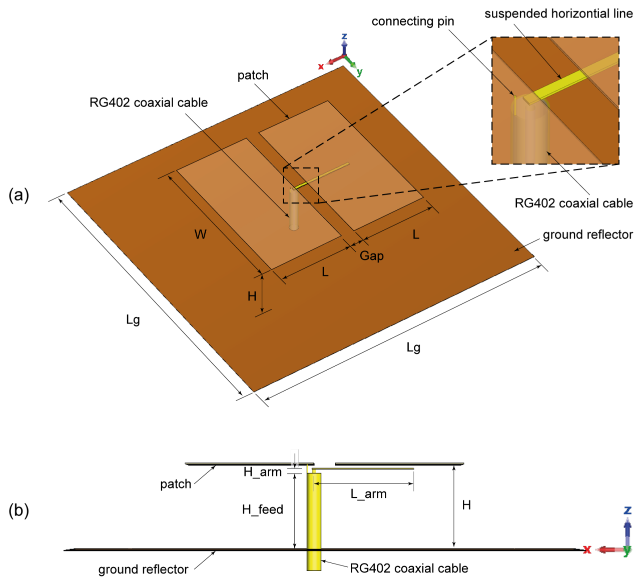

Fig. 1: Geometry proximity coupled fed cavity-less magneto-electric dipole antenna (a) prospective view (b) side view

TABLE I: Dimensions of the proposed antenna

Parameters	Lg	L	W	Gap
Values (mm)	120.0 (0.97 λ_o)	30.0 (0.25 λ_o)	60.0 (0.5 λ_o)	3.0
	H	H_feed	L_arm	H_arm
	20.0 (0.16 λ_o)	18.0	22.0	1.0

III. Result and Discussion

As shown in the simulation results, the suspending transmission line proximity coupled feeding method allows the reduction of the ground reflector while maintaining the radiation characteristics. As shown in Fig. 2, two modes have been excited around 2 GHz and 2.8 GHz. By adjusting the parameters L_arm and H_arm, proper impedance matching can be achieved for wide impedance bandwidth. The S_{11} of the proposed antenna with different ground reflector length Lg is shown in Fig. 3. The proposed antenna achieves a large bandwidth of ranges from 40.7 to 43.6 % with different ground reflector length Lg.

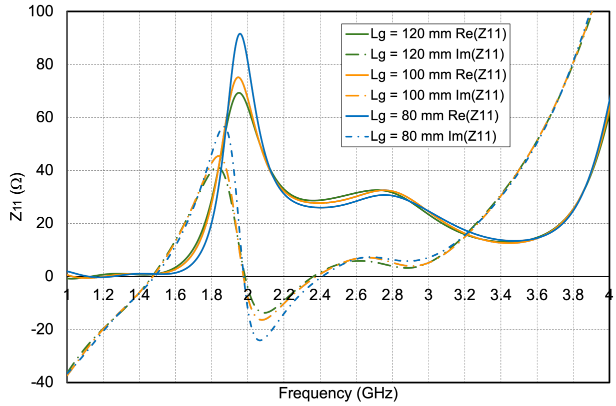

Fig. 2: Z_{11} of the proposed antenna with different ground reflector size

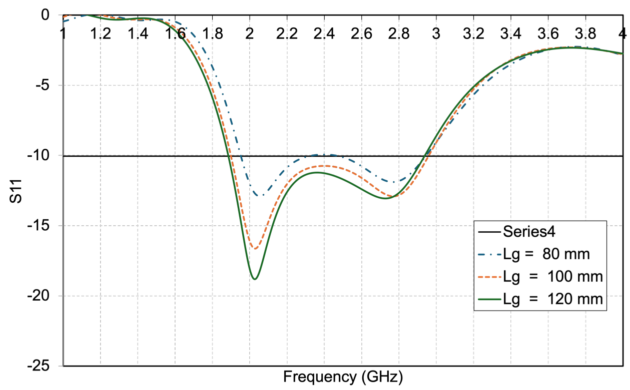

Fig. 3: S_{11} of the proposed antenna with different ground reflector size

Furthermore, the antenna achieves a gain higher than 8 dBi across the operational bandwidth, as shown in Fig. 4. The radiation patterns covering the operational bandwidth at 2 GHz, 2.5 GHz and 3 GHz are shown in Fig. 5. It can be observed that the antenna has a unidirectional stable radiation pattern with low back-lobe of (≤ -12 dB). Simiar to conventional ME-dipole antennas, reasonable crosspolarization level in the E-plane about 20dB is reported. Moreover, the cross-polarization level in the H-plane is below 80 dB.

To demonstrate the E-dipole and M-dipole modes of the antenna, E-field and H-field distributions at different time periods T (T denoting the period of the cycle) and planes are presented. Fig. 5 shows the E-field in the yz plane and the xy plane at t=0 and t=T/2. Fig. 6 shows the H-field in the yz plane and the xy plane at t= T/4 and t= 3T/4.

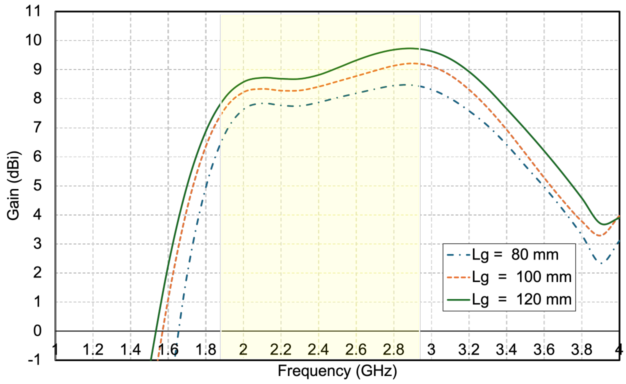

Fig. 4: Realized gain of proposed antenna with different ground reflector size Lg

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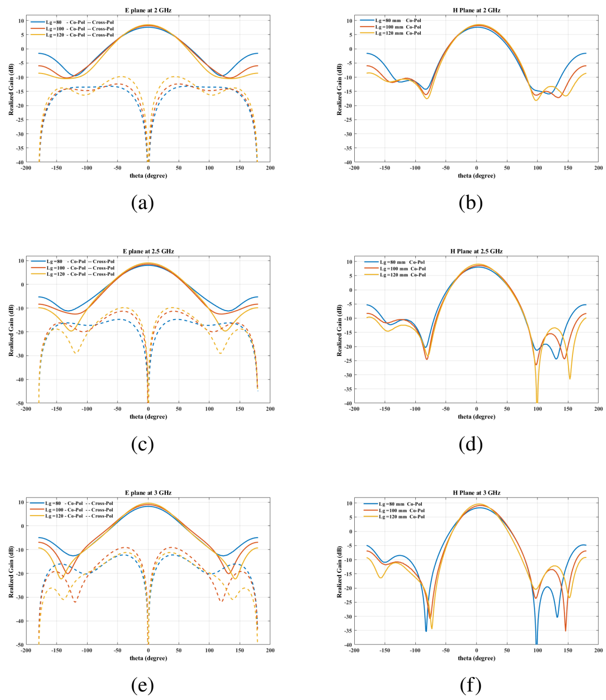

Fig. 5: The radiation patterns in E- and H- planes of the proposed antenna with different ground reflector size Lg and frequency points

IV. Conclusion

A new design for a low-profile proximity coupled cavity-less magnet-electric dipole antenna has been presented. This design utilizes a coaxial cable and a horizontal probe arm for feeding, effectively exciting the magneto-electric dipole without the quarter wave cavity walls to stimulate the magnetic dipole. The antenna achieved a wide impedance bandwidth of 43.6% and a maximum gain of 9.8 dBi, with an in-band variation of 1.7 dB. This proposed feeding approach also permits a reduction in the size of the antenna's ground reflector to less than 1 λ_o^2 while maintaining both a wide impedance bandwidth and high stable gain across its operational bandwidth.

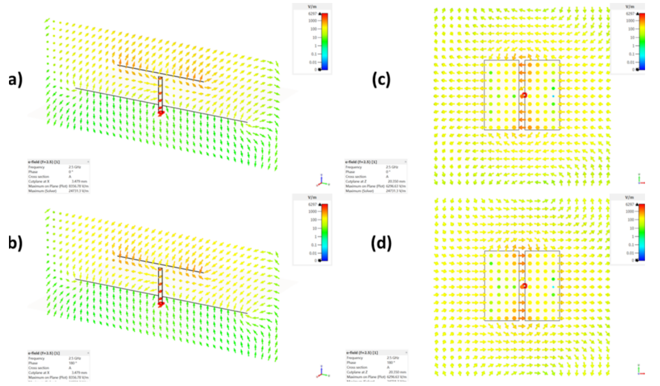

Fig. 6: E-field of electric dipole mode, YZ plane (a) t=0 (b) t=T/2, YX plane (c) t=0 (d) t=T/2

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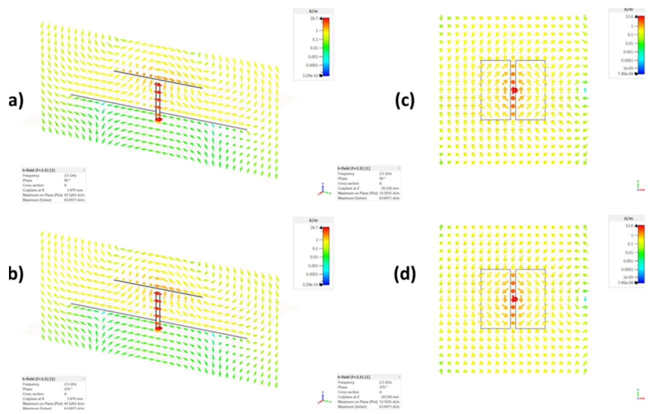

Fig. 7: H-field of magnetic dipole mode, YZ plane (a) t= T/4 (b) t= 3T/4 YX plane (c) t= T/4 (d) t= 3T/4

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