Circularly Polarized Magneto-Electric Dipole with Axial Ratio Enhancement

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***Abstract*—In this paper, we propose a new circularly polarized circular magneto-electric dipole antenna. The proposed antenna has a wide impedance bandwidth of 66.66% from 3.0 to 5.4 GHz, high stable gain with maximum gain of 9.3 dBi at 4.0 GHz and wide 3-dB axial ratio bandwidth of 44% from 3.5 to 5.35 GHz. The radiating element is smaller in size by 35% while maintaining a high stable gain, and wide 3-dB axial ratio bandwidth. To improve the 3-dB axial ratio, we introduced a pair of rectangular slots on the electric dipoles that can adjust the four ME-dipole modes for reducing the size of ground reflector. The antenna is designed on a RT/duroid® 5880LZ filled PTFE substrate with thickness of 1.27 mm and ϵr =2, tanδ = 0.0027.**

***Index Terms*—magneto-electric dipole, circular polarization, wideband, 5G, 3-dB axial ratio bandwidth.**

I. Introduction

In modern life, wireless communications systems and sensors have very important roles and are rapidly integrated into our daily activities. Thus, stringent requirements on the antennas for the wireless systems to have a high and stable gain, wide bandwidth, and unidirectional radiation pattern are imposed. In the literature, several solutions were proposed to achieve these requirements. Complex antenna structures or antenna arrays can achieve these requirements. However, they are bulky and lossy [1, 2].

In [3], a wideband circularly polarized antenna fed by a 90° hybrid coaxial balun is presented. The antenna has a wide bandwidth of 57%, a wide 3-dB axial ratio bandwidth of 51% and high stable gain of 9 dBi. The disadvantage of this design is that the antenna require a complex feed notwork and large ground reflector.

Magneto-electric (ME) dipole antennas are an innovative solution that fulfils these requirements. The fundamental principle of the ME dipole is to have the electric and magnetic dipoles oriented orthogonally and excited with equal power and phase. The resulted radiation patterns will be identical and unidirectional in the E-plane and the H-plane [4, 5].

In [6], a novel dual-polarized magneto-electric dipole antenna fed by two Γ-shaped strips is introduced. The antenna has a wide impedance bandwidth of 67%, a high and stable radiation pattern with a maximum gain of 9.5 dBi and 36 dB of isolation between the two input ports. The drawback is the antenna has 2.5 dBi of in-band gain variation and requires two ports which makes the design complex.

In [7], a novel crossed-feed circularly polarized magneto-electric dipole antenna was introduced. The cavityless with a single feed port antenna features a wide bandwidth of 70.4%, an axial ratio bandwidth of 43.5%, and the realized gain is 8.7 dBi (±0.9 dBi). The disadvantage of this antenna is the large ground reflector size due to the rhombic shape of the electric dipole.

In this paper, we proposed a circularly polarized circular magneto-electric dipole antenna (CME dipole) which has a wide impedance bandwidth of 66.66% from 3.0 to 5.4 GHz, high stable gain with peak gain of 9.3 dBi at 4 GHz and wide 3-dB axial ratio bandwidth of 44% from 3.5 to 5.35 GHz. The proposed radiating element is smaller in size by 35% mm compared to the CME dipole antenna in [7] while maintaining a high stable gain, and wide 3-dB axial ratio bandwidth. To improve the 3-dB axial ratio we introduced a pair of rectangular slots on the electric dipoles that can adjust the four ME-dipole modes while maintaining the ground plane size. Moreover, the proposed antenna can maintain a wide ARBW and a high gain of 8 dBi across the bandwidth while the ground reflector reduced to 60 mm ($0.83\lambda_0$).

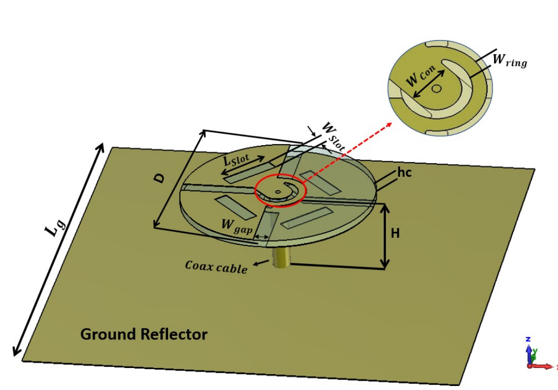

Fig. 1. Circularly polarized circular magneto-electric dipole antenna geometry.

II. Proposed Antenna Geometry

The CME dipole antenna consists of three main parts. 1) A circular shape radiating element. 2) A coaxial cable feeding the radiating element distanced by $0.25\lambda_0$ from the ground reflector. 3) A square ground reflector as shown in Fig.1. The radiating element printed on both side of a piece of RT/duroid® 5880LZ substrate. The top part will have two patches fed with 90° phase difference by a crossed feed network and connected to the inner conductor of the coaxial cable. Similarly, the bottom part will have two patches but it will be connected to the outer conductor of the coaxial cable. The antenna dimensions $L_g = 100\ mm$, $H = 18\ mm$, $D = 35.8\ mm$, $W_{gap} = 2.3\ mm$, $W_{con} = 5.2\ mm$, $W_{ring} = 1.5\ mm$, $L_{Slot} = 10\ mm$, $W_{slot} = 5\ mm$, and $h_c = 1.27\ mm$.

III. Antenna Analysis and Proposed Design

The ME dipole antenna reported in [7] has two orthogonal electric dipoles and two orthogonal magnetic dipoles for generating wideband circular polarization. The electric dipoles have a rhombic shape while the magnetic dipoles are in the form of open-slot. The antenna is circularly polarized in two different frequency bands, the lower band is corresponding to the electric dipoles and the higher frequency band is corresponding to the magnetic dipoles. We are proposing a circular shape CME dipole antenna that will have a symmetrical length on the electric and magnetic dipoles. We introduced a pair of rectangular slots on the electric dipole that can adjust the four ME-dipole modes while maintaining the antenna size. By introducing these slots, the electric dipoles will be electrically longer [9]. Hence, the axial ratio will be improved. The proposed antenna will have a smaller ground reflector due to the symmetrical length of the electric and magnetic dipoles and the axial ratio improvement. The CME dipole antenna is designed and simulated using CST STUDIO SUITE [8]

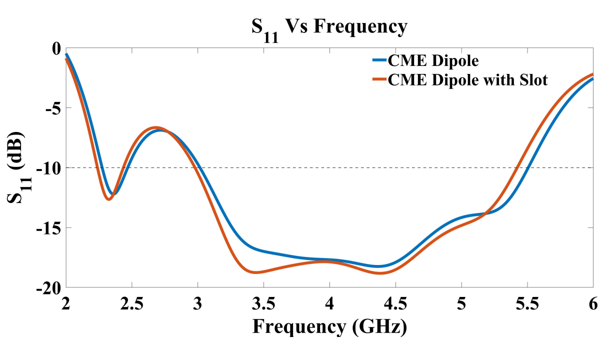

Fig. 2. Simulated reflection coefficient of the CME dipole and the CME with slot dipole and proposed CME dipole with slot.

IV. Results and Discussion

The simulated reflection coefficient of the CME dipole and CME with slot dipole are shown in Fig.2. The proposed antenna covers the required mid 5G frequency band. Fig.3 shows a slight frequency shift in the centre frequency introduced by the rectangular slots on the electric dipoles. The realized gain of the antenna is identical in both geometries as the size of the antenna are equal as shown in Fig.4. The axial ratio within the ARBW is improved by adding the slots as shown in Fig.5.

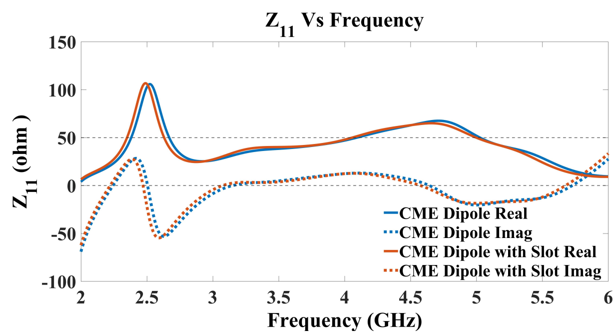

Fig. 3. Simulated Z_{11} of the CME dipole and the CME with slot dipole and proposed CME dipole with slot.

The parameter study of the ground plane size shows a stable and high realized gain in both geometries due to the symmetrical antenna size as shown in Fig.6. In addition, the axial ratio is improved within ARBW by adding the slots as shown in Fig.7.

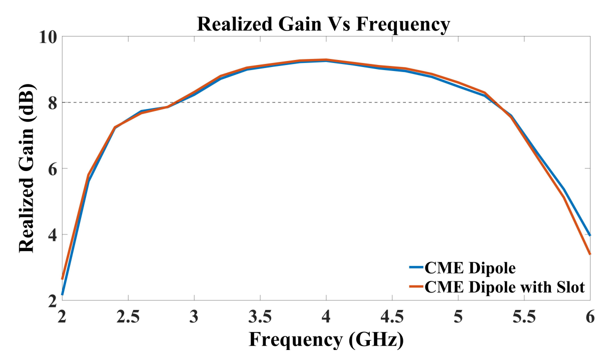

Fig. 4. Simulated realized gain over frequency of the CME dipole and the CME with slot dipole and proposed CME dipole with slot.

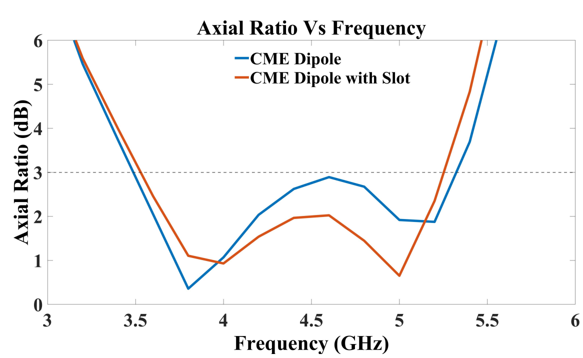

Fig. 5. Simulated Axial Ratio bandwidth of the CME dipole and the CME with slot dipole and proposed CME dipole with slot.

The proposed CME dipole with slot has a stable axial ratio bandwidth compared to the original CME dipole. The Axial

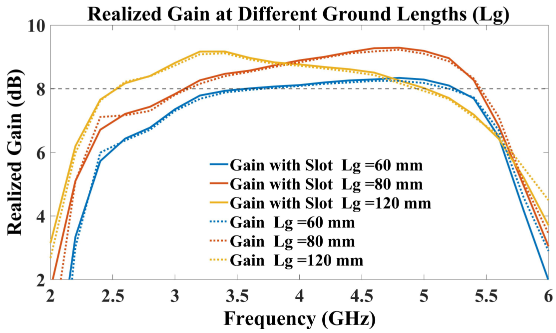

Fig. 6. Simulated Realized at Different Ground length (Lg) for the CME dipole and the CME with slot dipole.

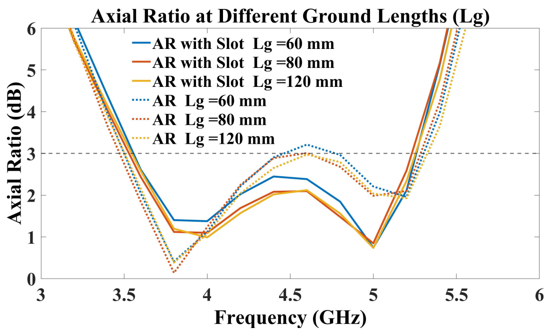

Fig. 7. Simulated Axial Ratio at Different Ground length (Lg) for the CME dipole and the CME with slot dipole..

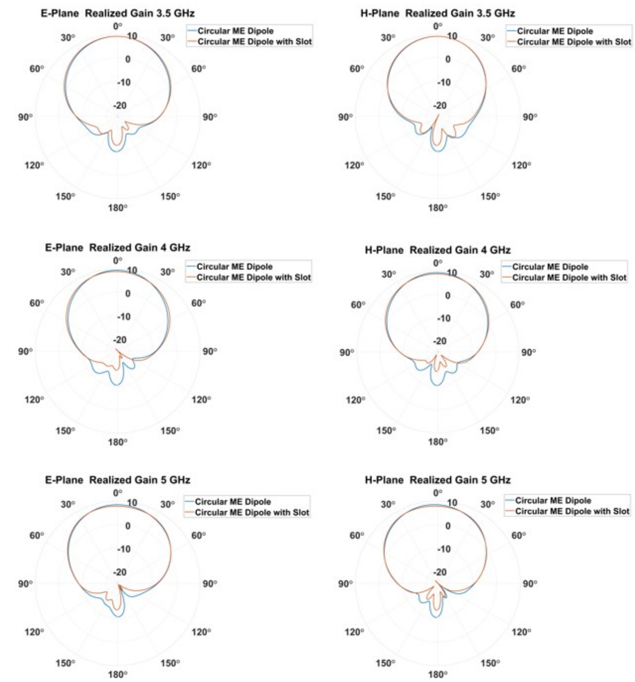

Fig. 8. Simulated radiation patterns at 3.5 GHz, 4 GHz, and 5 GHz of the CME dipole and the CME with slot dipole in the E-Plane and H-Plane.

ratio improvement allow the ground reflector to be reduced to 60 mm ($0.83\lambda_0$) while maintaining a wide ARBW and a high gain of 8 dBi across the bandwidth.

The radiation pattern at 3.5 GHz, 4 GHz and 5 GHz in the E-plane and the H-Plane are shown in Fig.8. The result shows a stable radiation pattern and low back-lobe of ($\leq$ -20 dB) across the entire bandwidth. The fabrication and measurement results will be presented at the conference.

V. Conclusion

A circularly polarized circular magneto-electric dipole antenna is designed and simulated. The antenna has a wide impedance bandwidth of 66.66%, high gain with peak gain of 9.3 dBi at 4 GHz and wide 3-dB axial ratio bandwidth of 44%. To improve the 3-dB axial ratio, we introduced rectangular slots on the electric dipoles that that can adjust the four ME-dipole modes while maintaining the antenna size. The axial ratio improvement allow the ground reflector to be reduced to 60 mm ($0.83\lambda_0$) while maintaining a wide ARBW and a high gain of 8 dBi across the bandwidth.

VI. References

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