Report on a study of mmW Magnetoelectric Dipole Antenna with Endfire Radiation

Submitted by

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Assigned Research Paper Title

Millimeter-Wave Wideband Endfire Magnetoelectric Dipole Antenna Fed by Substrate Integrated Coaxial Line

Acknowledgement

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Regards,
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Introduction to Magnetoelectric dipole

The term **magnetoelectric** is the combination of magnetic and electric. So, this type of dipole antenna contains the combination of both types of dipole antennas. From the figure, it can be seen that the magnetoelectric dipole contains both **M** and **J.**

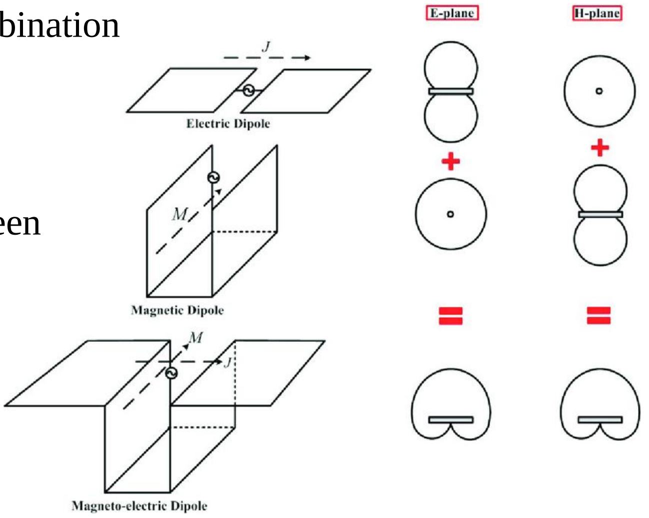


Figure 1: Magnetoelectric Dipole

The **magnetoelectric dipole** antenna is a complementary antenna. The basic antenna geometry includes a **planar electric dipole** and a **vertical shorted quarter-wave patch antenna**. Generally, a proximity coupled feed is utilized to excite the antenna which performs as a combination of an electric dipole and a magnetic dipole. Due to that, the antenna gets a **stable gain**, and a **stable radiation pattern** with **low cross-polarization** and back radiation levels over the operating frequencies. Some research works, focusing on designing magnetoelectric dipoles with different polarizations, are carried out in the recent years. The magnetoelectric dipole antenna is also modified for the fulfilments of various applications, such as UWB and 60-GHz wireless communications. Other than the magnetoelectric dipole, several other types of complementary antennas are also introduced.

In the adjacent figure it is shown how the combination of the electric and magnetic dipoles results in a magnetoelectric dipole radiation.

Broadside and Endfire Radiation

Sometimes, the major lobe of an antenna is intended to face in some particular direction(s). To achieve that, in an antenna array, several methods can be used. In case of **broadside radiation**, the major lobe is in the $\theta = 90^{o}$ direction. For **endfire**, the direction is $\theta = 0^{o}$ or $\theta = 180^{o}$ or simultaneously both also can happen. In this report, an endfire radiation is to be implemented from a mmW magnetoelectric dipole (ME dipole) antenna.

The both types of radiations are shown in the figures aside.

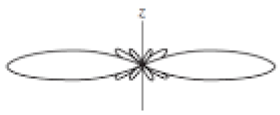


Figure 2:Broadside Radiation

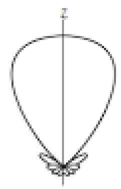


Figure 3:Endfire Radiation

In this report, we will be discussing and try to achieving endfire radiation for a ME dipole antenna. Let us take a look at the configuration of the proposed ME dipole.

In this case, from the first figure, it can be seen that two λ/4 shorted patches are used to build the magnetic dipole and two metal plates are used as the planar electric dipole. But that configuration generates a broadside raduation. So, to get an endfire radiation, the whole figure is rotated by 90^{o}. Thus, an End-fire radiation can be achieved.

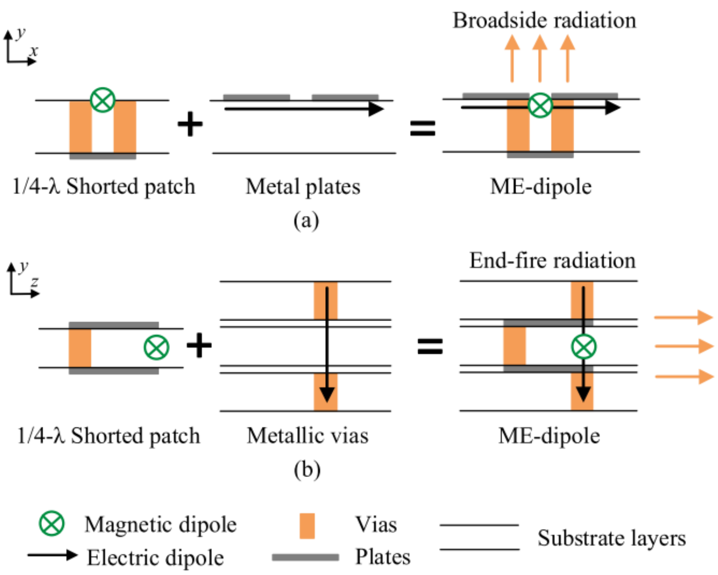


Figure 4:Proposed ME dipole Endfire Radiation

The whole antenna is designed in **Ansys HFSS** simulation software and simulated with different frequencies. The radiation patterns and the graphs for S_{11} parameters for different values of the dimensions are noted and presented.

Substrate Integrated Coaxial Line (SICL)

SICL is the planar version of coaxial line. It was first introduced as a shielded, TEM mode non dispersive structure. The technology utilizes double layer conventional copper cladded dielectric substrate whose top and bottom metallic plate along with rows of metallic vias creates outer conductor which along with middle planar strip creates coaxial environment.

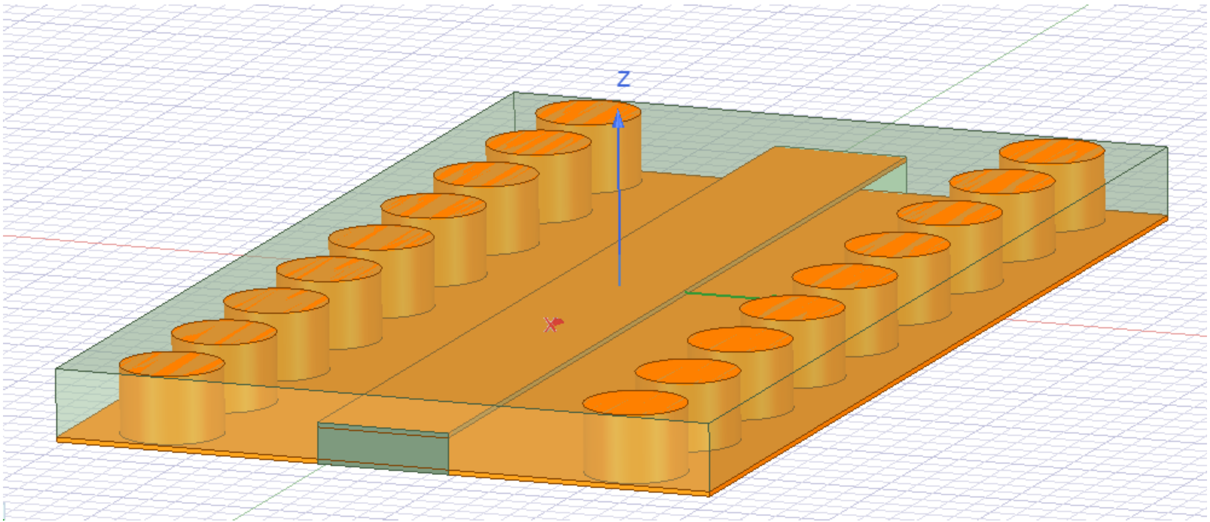


Figure 5:SICL

In the above figure, a SICL has been presented and it can be seen that there is a central conductor and there is two metal planes upper and lower (upper metal plane has been omitted to get a clear view of the overall structure). And there are metal vias connecting the two planes that creates a stripline like structure. **In the presented report, the ME dipole will be fed by an SICL**.

The S_{11} and S_{21} parameters are shown in the below graph –

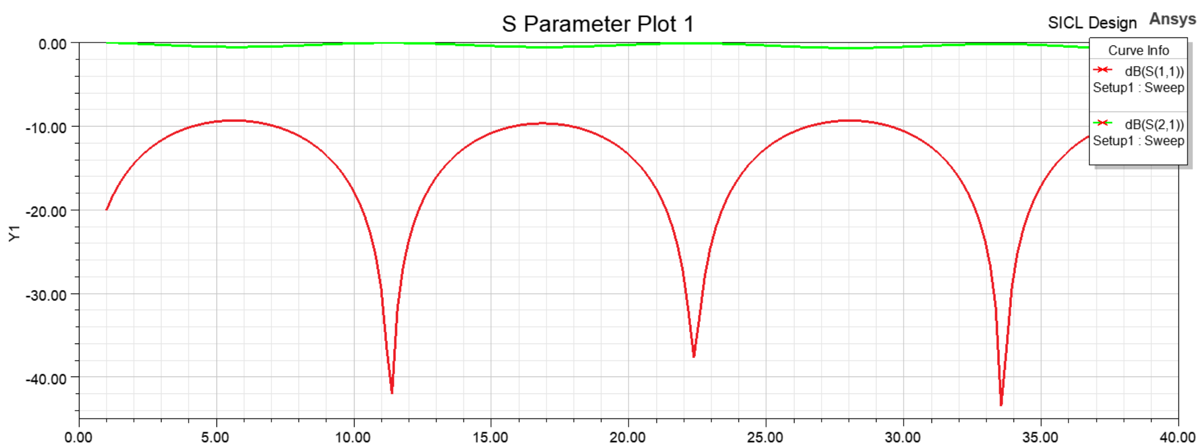
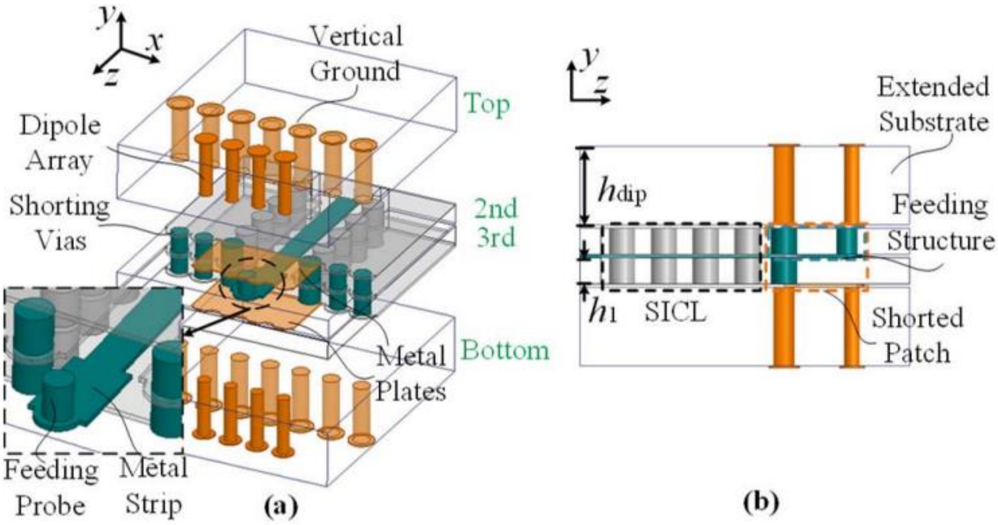


Figure 6: S-parameters if SICL

Design of the proposed ME Dipole Antenna

Let us take a look at the antenna dimensions presented at the assigned paper.



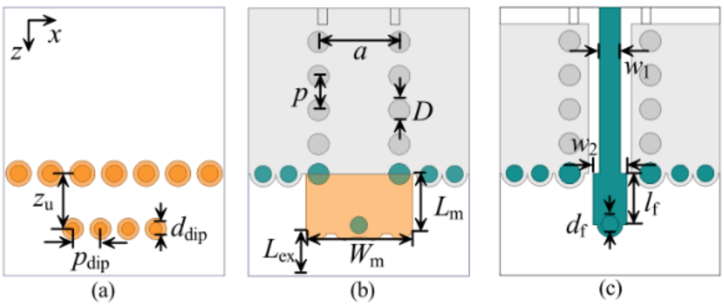


Fig. 3. Layout of the different substrate layers of the proposed antenna. (a) Top layer. (b) Second layer. (c) Third layer.

The following table tabulates the dimension values-

Parameters	p	D	a	h_1	h_{dip}
Values	0.8	0.5	1.9	0.508	1.524
Parameters	d_{dip}	p_{dip}	z_u	L_{ex}	L_m
Values	0.3	0.65	1.4	1	1.4
Parameters	W_m	w_1	w_2	d_f	l_f
Values	2.5	0.5	0.8	0.4	1.2

Following the dimensions, the antenna is designed in **Ansys HFSS**.

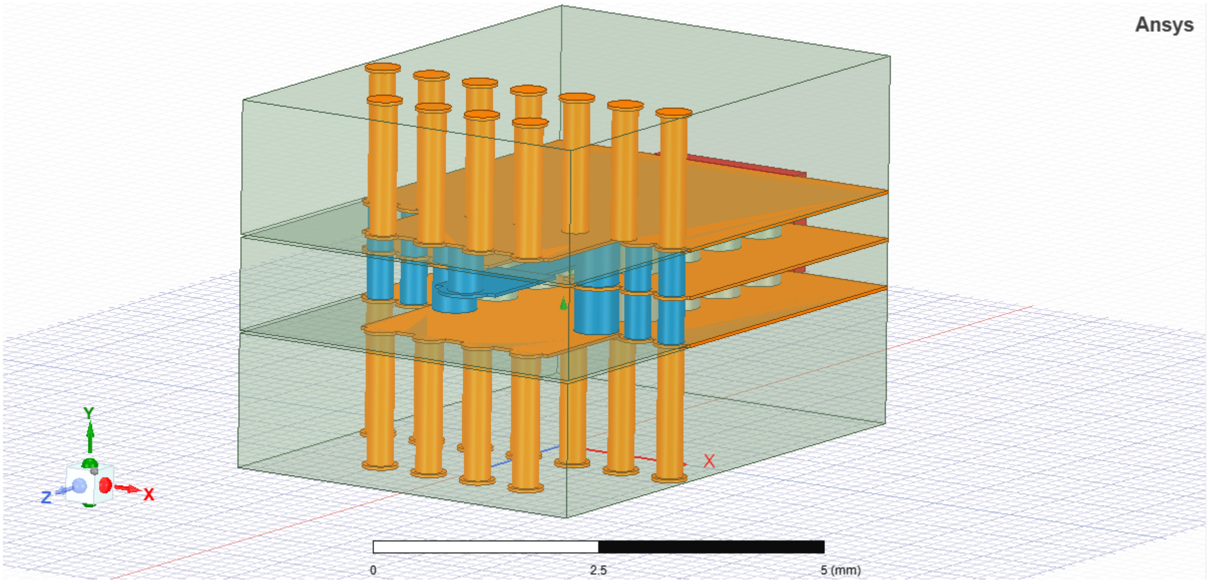
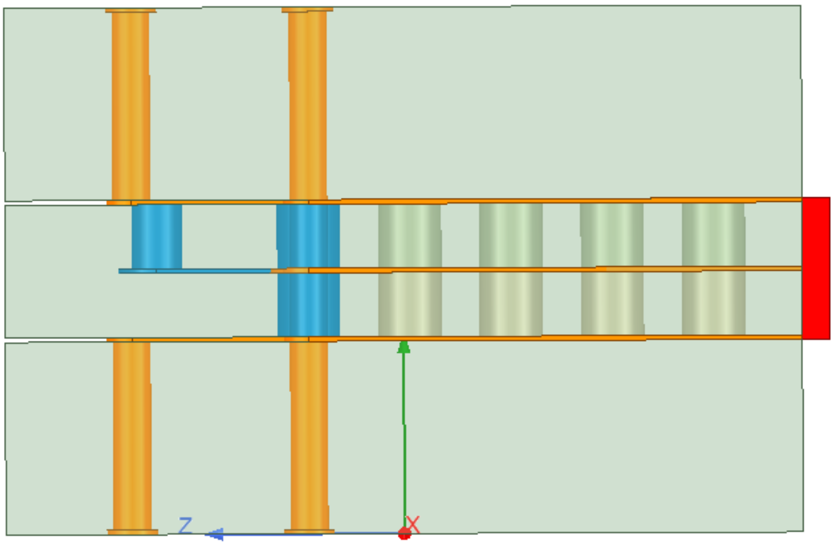


Figure 7: Design of the proposed antenna

The side view of the antenna can be seen like –



At first the antenna is simulated at three different frequencies – 24 GHz, 44 GHz and 50 GHz. The radiation patterns for the **E** and **H** planes are shown below –

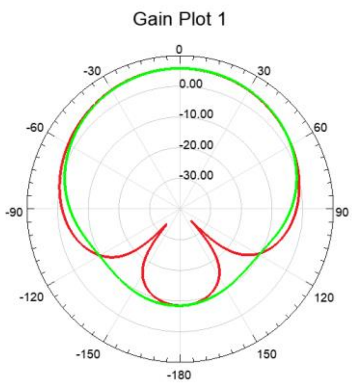


Figure 9:Rad pattern at 24 GHz

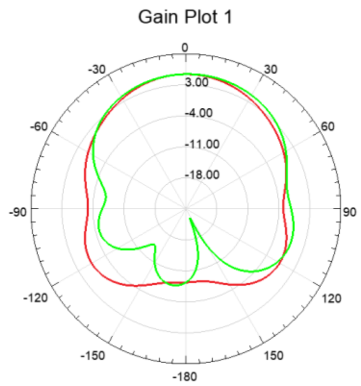


Figure 8:Rad pattern at 44 GHz

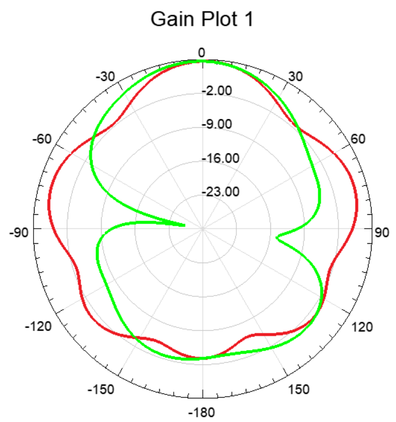


Figure 10:Rad pattern for 50 GHz

Comparison with the paper –

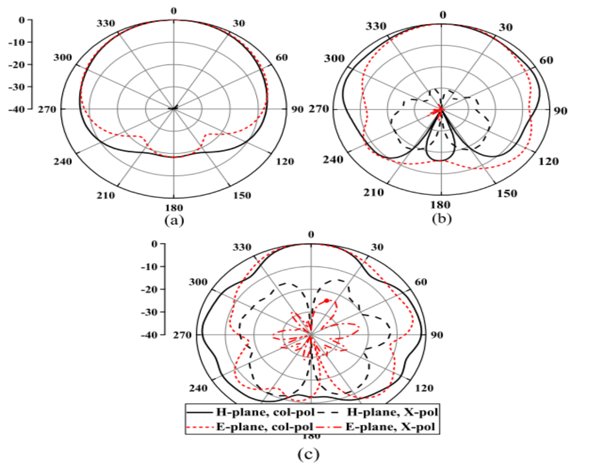
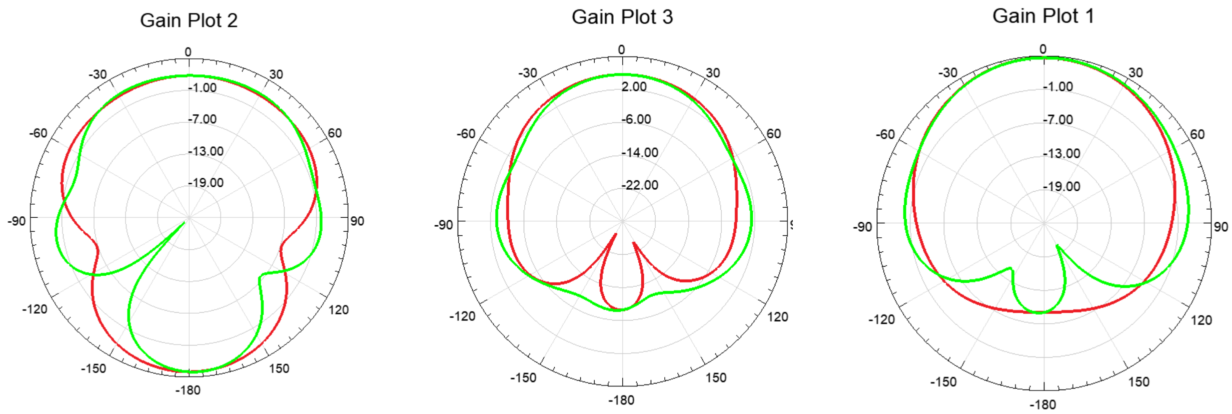


Fig. 11. Simulated radiation patterns of the proposed ME-dipole antenna at (a) 24, (b) 44, and (c) 50 GHz.

The antenna is also simulated with only shorted patch, ME dipole with and without the vertical ground (from left) –



Comparison with the paper—

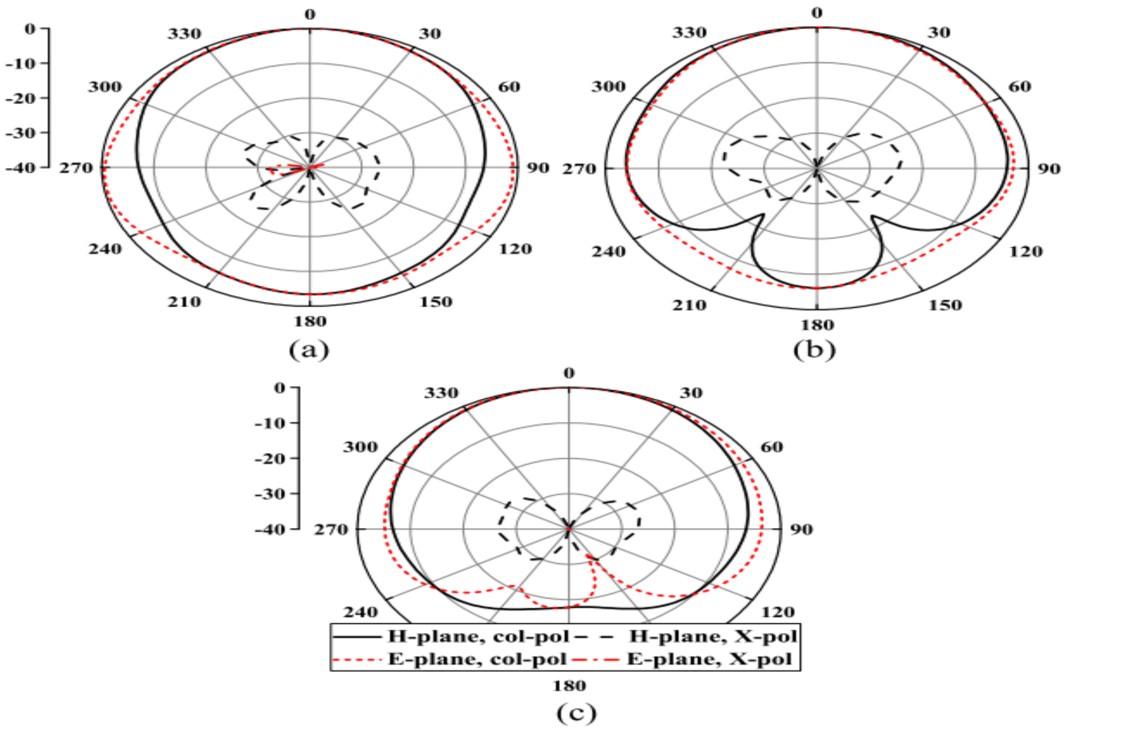


Fig. 10. Simulated radiation patterns at 34 GHz of the shorted patch, ME-dipole antenna with and without vertical ground. (a) Shorted patch. (b) ME-dipole without vertical ground. (c) ME-dipole with vertical ground.

Analysis of S-parameters for several values of dimensions and their comparison with the paper

In this section, different dimensions are swept for different values and the S-parameters are plotted for different values –

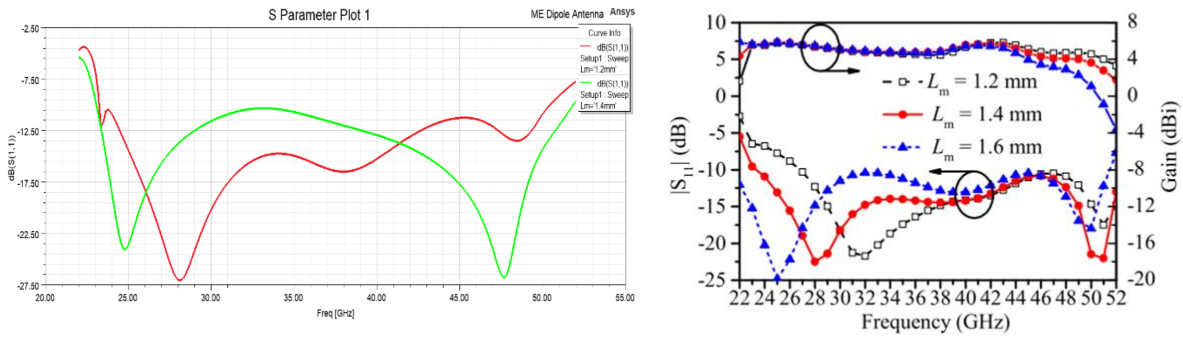


Figure 11:S-11 parameter for different values of "Lm"

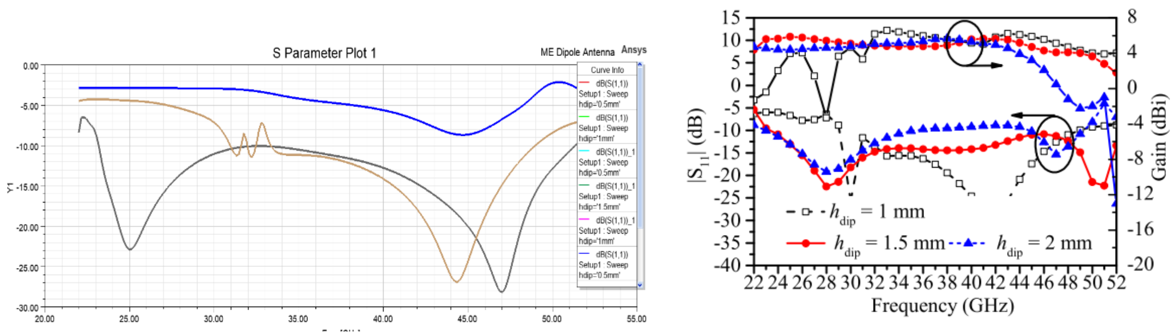


Figure 12:S-11 parameter for sweep values of "hdip"

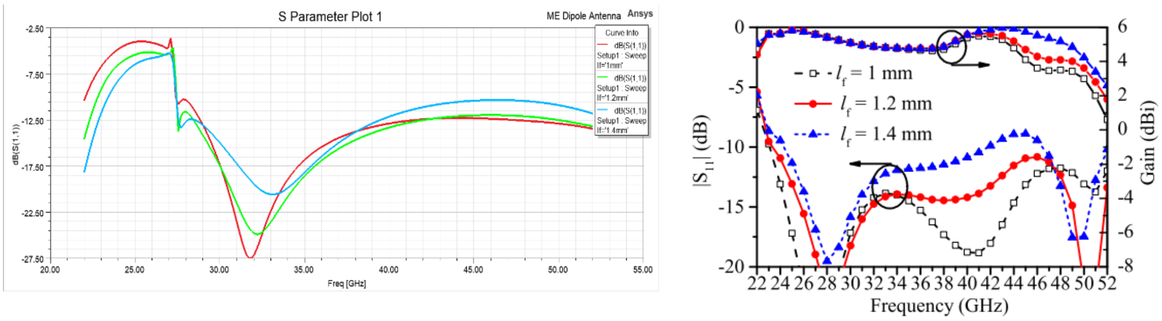


Figure 13:S-11 parameter for sweep values of "lf"

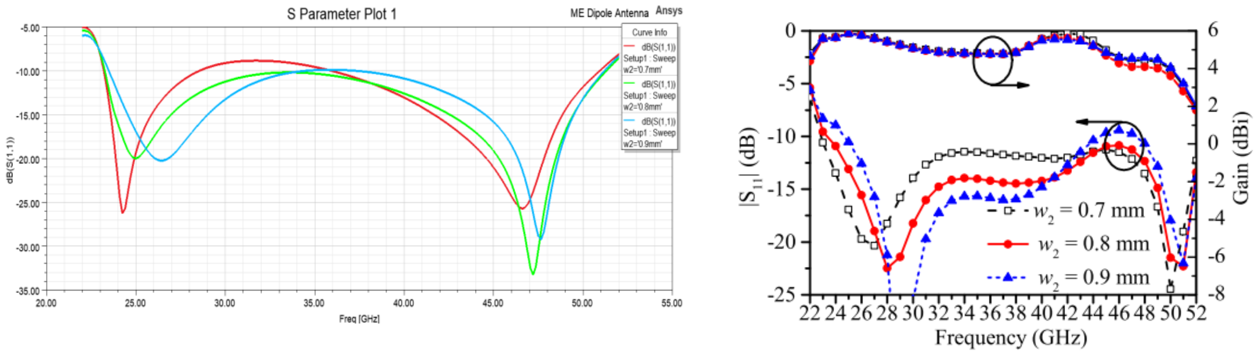


Figure 14:S11 parameter variation for variable "w2"

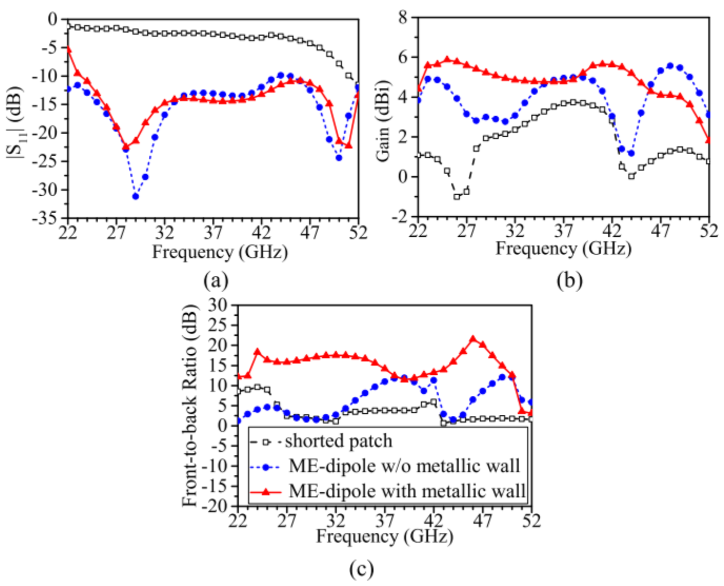


Figure 15:(a)S11 (b)Gain (c)FTBR

The above figure shows the variation of S_{11}, Gain and FTBR for the specified configurations symbolically mentioned. It is clear that –

- For the shorted patch only, S_{11} value is not satisfactory and gain is also less with a low FTBR.
- ME dipole w/o metallic wall gives a better performance in S_{11} but gain can still be improved.
- ME dipole with metallic wall gives the best performance for gain, and also for FTBR.

Some conclusions

- In case of sweep of “Lm”, that is the length of the quarter wave patch, the resonant frequency depends on the length of it. So, whenever it is increased, the matching at LF is improved. But large values cause a gain drop at higher frequencies. So, a medium value must be chosen.
- The resonant frequency and radiation of the electric dipoles depend on the parameter “hdip”. So, when it is changed, there is an effect on the S-parameters. It has a good impact on S_{11} and gain value.
- It is observed that the dimensions of the metal strip, lf and w2, are effective to adjust the impedance matching within the band of interests because the metal strip is responsible for the impedance transformation as mentioned in Section II. Meanwhile, as “lf” determines the location of the feeding via, it also has an impact on the antenna gain. For the sake of achieving a wide impedance bandwidth and a stable gain, “lf” and w2 are set to be 1.2 and 0.8 mm, respectively.
- The antenna has a good S_{11} response in the frequency band of near 28 GHz. And all-over reflection coefficient value below -10 dB. So it can be well fit for some 5G FR2 band applications (24-52 GHz).
- The antenna maybe made circularly polarized by introducing some dissimilarity in feeding structure and thus by introducing some orthogonal modes simultaneously. Just like by feeding it through a point somewhere on the diagonal of the shorted patch but not at the exact middle. Though this is yet to be experimented.