Hemispherical Dielectric Loaded Monopole Antenna

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***Abstract*— This paper presents a study of a compact hemispherical dielectric loaded monopole antenna. The effect of the dielectric loading on the, resonate frequency, radiation pattern, gain and directivity is presented. Its performance is compared to that of an unloaded monopole antenna. The effect of air gap between the dielectric and the monopole has been discussed. The importance of the gap is crucial in the antenna design during manufacture.**

Keywords—dielectric loaded antenna; monopole antenna; air gap; hemispherical dielectric

I. INTRODUCTION

Dielectric Loaded Antennas (DLA) can be made low-profile and compact, provided a suitable and pre-deterministic space filling material could be found [1]. DLAs can also be used for the enhancement on bandwidth. In [1], the bandwidth was improved up to 40GHz and it was also shown that the radiation pattern of the loaded monopole antenna was not distorted and remained omnidirectional at higher frequencies (20-40GHz). Realising dual-band operation by using DLA was demonstrated in [2].

This work investigates a hemispherical dielectric loaded monopole antenna. The effect of the air gap between the dielectric and the monopole is also described, as it is impractical to make the dielectric perfectly adhering to the monopole. Moreover, the sizes of the air gaps can be varied with temperature and environmental conditions. All simulations are performed using the CST FDTD solver, and measurements are implemented on VNA.

II. HEMISPHERICAL DLA GEOMETRY

The proposed hemispherical DLA geometry is shown in Fig.1. It comprises of a monopole, a hemispherical dielectric and a ground plane. The diameter of the monopole is 0.9mm which is the inner pin of the semi-rigid RG402 cable. The monopole length is 15 mm. The radius of the hemispherical is 15 mm. And they are placed on a 50mm diameter circular ground plane. At the bottom side of the ground plane, the pin is connected with SMA connector for feeding.

Generally, it is a solid hemispherical loaded dielectric with a hole whose diameter is 0.9mm through it. 3D-printing could be easily used for fabricating the hemispherical shape. A typical relative permittivity of the 3D- printed material is 2.7 which is used here throughout. This material has been studied in [3], the loss tangent at 2.4GHz is 0.008, which has been considered in the simulations.

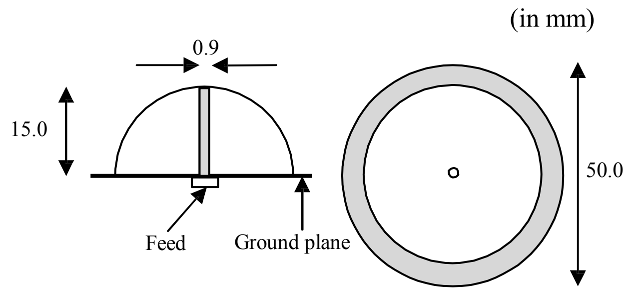

Fig. 1. Geometry of the grounded hemispherical dielectric loaded monopole (zero air gap).

III. RESULTS

A. Effect of Loaded Dielectric

The simulated and measured S11 from 2GHz to 18GHz of the hemispherical DLA is shown in Fig.2. Fig. 2 (a) shows the S11 of the monopole antenna without dielectric loaded, the resonant frequencies were approximately at 4.77GHz and 14.56GHz, and the S11 values are -14.6dB and -35dB respectively. Fig. 2 (b) shows that the two distinct resonant frequencies of the hemispherical DLA at 3.55GHz and 10.02GHz. Results show that with dielectric loaded, resonant frequency and the bandwidth can both be tuned.

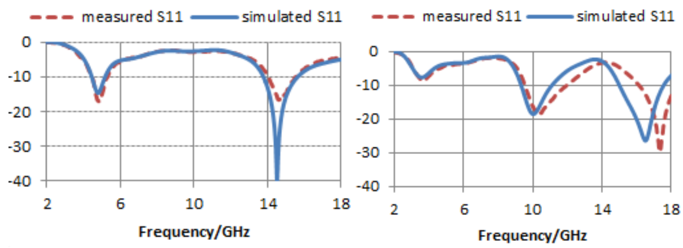

Fig. 2. S11 of (a) grounded monopole antenna and (b) hemispherical dielectric loaded monopole antenna (without air gap between).

The radiation patterns of grounded monopole antenna and hemispherical DLA at their second resonant frequency are shown in Fig. 3. The gain of the antenna decreases to 4.71dBi from 7.02dBi after the dielectric loading.

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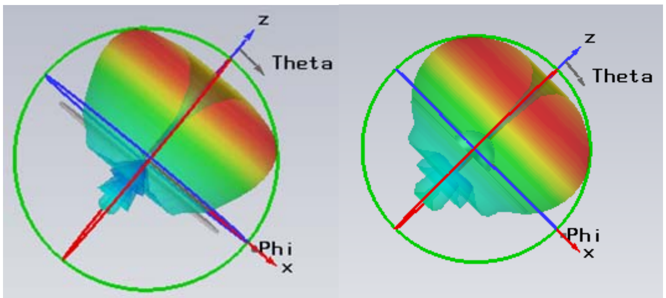

(a) (b)

Fig. 3. Radiation patterns of (a) grounded monopole antenna and (b) hemispherical dielectric loaded monopole antenna.

B. *Effect of Air Gap*

Fig. 4 presents the simulated and measured S11 of the hemispherical DLA with four different sized holes, i.e. 0.9mm, 2mm, 3mm and 4mm of diameter whilst maintaining the same diameter of the monopole (0.9mm).

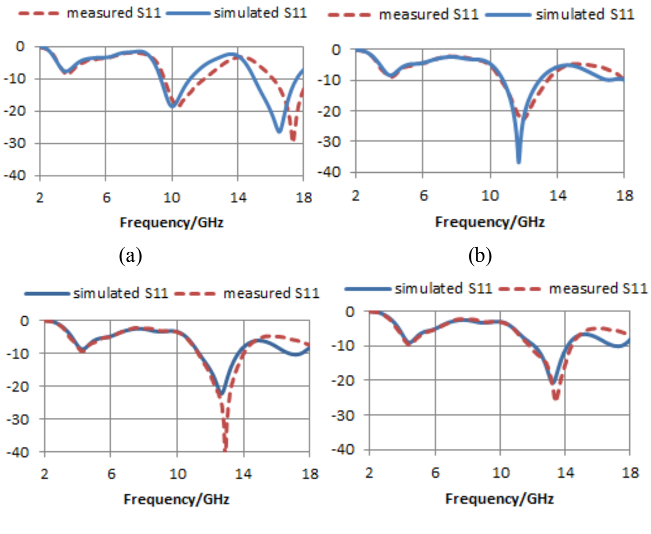

Fig. 4. S11 of the hemispherical DLA with different hole diameters: (a)0.9mm (0mm airgap), (b)2mm, (c)3mm, and (d)4mm.

Increasing the air gap, there is a tendency of the two resonances moving further. This indicates that the potential air gap should be accounted for when designing DLA.

The simulated radiation patterns of the DLA with different air gaps at the first resonance are shown in Fig. 5, whilst Table I gives the data of the main lobes, gain and total efficiency. The shapes of radiation patterns remains broadly similar, with the exception of increasing the air gap the main lobe magnitude increases while the side lobe level decreases. Furthermore, the direction of main lobe moves towards x-y plane.

At low frequencies, the measured S11 agree with that of simulation. But due to the imperfection during fabrication, S11 at high frequencies is affected.

IV. CONCLUSION

The performance of a grounded monopole antenna loaded with a hemispherical dielectric is examined using CST simulations. While the antenna maintains a low profile a lower resonant frequency response is achieved with similar characteristics at both frequencies. The effect of the incurring air gap is shown to have a significant influence on the return loss and radiation characteristics, and it needs to be taken into account in the design of these types of antennas.

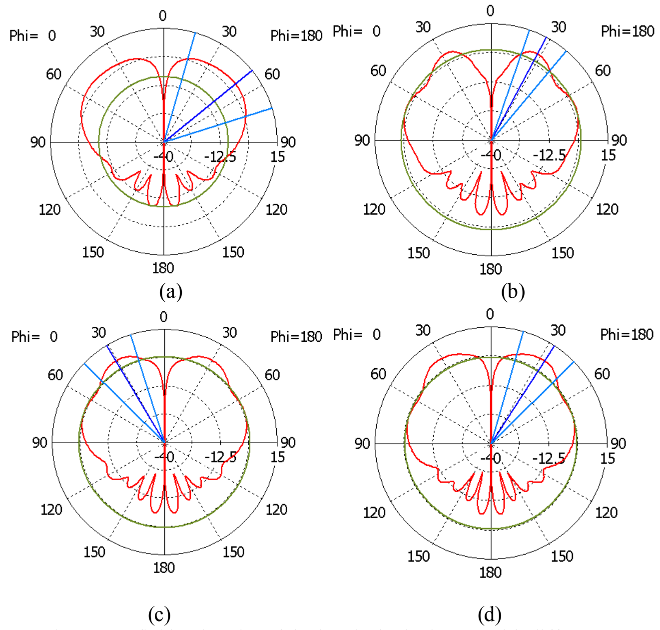

Fig. 5. Far-field polar plot of the hemispherical DLA with different hole diameters (a)0.9mm, (b)2mm, (c)3mm, and (d)4mm

TABLE I. FAR-FIELD PERFORMANCE OF THE HEMISPHERICAL DLA WITH DIFFERENT HOLE DIAMETERS

Diameter of hole (mm)	**Parameters**				
	Resonant frequency (GHz)	***Main lobe direction (deg)***	***Gain (dBi)***	***Directivity (dBi)***	***Total Efficiency (%)***
0.9	10.022	51.0	4.6	4.7	95.3
2.0	11.719	28.0	5.8	6.0	95.9
3.0	12.684	31.0	6.0	6.2	94.9
4.0	13.248	33.0	6.3	6.5	94.5

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