Research on Side-lobe Radiation Characteristic of Printed Dipole Array

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***Abstract*-In the paper, the radiation characteristic of printed dipole array along side-lobe direction is researched. The electric field intensity values in side-lobe area are calculated using FEKO under different situation. It is also analyzed how metal plate and scanning angle influence electric field intensity values in side-lobe region. Besides, through the peak values and valley values of electric field intensity along side-lobe direction, the possibility of using peak value and valley value identify the number of side lobe is discussed.**

I. INTRODUCTION

A large number of array antennas are equipped in very limited platform, so the near-field high-power radiation is the potential electromagnetic hazards to open-air electronics equipment, fuel and staff [1]. In order to control and resolve the electromagnetic hazards, the designer would like to originally predict the distribution of the near-field radiation and potential hazards of array antenna, which is a new challenge for electromagnetic compatibility design of platform.

Research on the radiation characteristics of antenna array in literatures mainly focus on the main-lobe radiation characteristics, but few on the side-lobe radiation characteristics. Therefore, it will research side-lobe radiation characteristics of printed dipole array and the coupling between printed dipole array and surrounding metal plate. The radiation characteristic of printed dipole array along side-lobe direction has been researched by simulation method, electric field intensity values in side-lobe area are calculated under different situations. It is also analyzed how metal plate and scanning angle influence side-lobe area. Besides, through the peak values and valley values of electric field intensity along side-lobe direction, the possibility of using peak value and valley value identify the number of side lobe is discussed.

II. MODELING

The radiating elements of array antenna are generally organized and fed in the light of some rules. The most common forms of the array are rectangular array and triangular array, and triangular array has the advantages of saving elements and relevant components, curbing grating lobe near the main lobe [2]. In addition, the triangular array could be considered as the sum of the two rectangular arrays, so the basic theory of rectangular array can be valid while triangular array is analyzed.

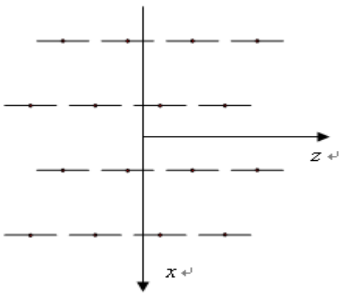

Figure 1. The whole dipole array sketch map

In view of above reasons, in this paper, the triangular array has been chosen as the object making use of EM simulation software FEKO which is based on MOM. As shown in figure.1, the printed dipole array is working in S band. The whole array includes 16 elements which are organized as triangular array with 4 rows and 4 columns, each element is a printed dipole antenna. As shown in Figure 2, the radiating elements distance along X and Z axis are respectively $dx = \lambda$ and $dz = \lambda / 2$.

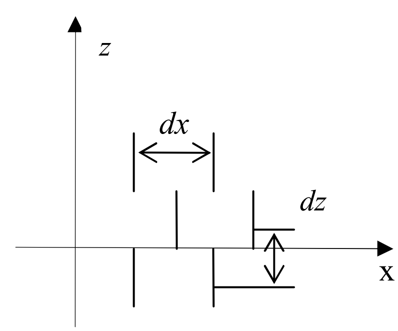

Figure 2. Triangular array model

It is also shown in the figure.3 that the elevation plane is YOZ plane and the azimuth surface is XOZ plane. The normal direction of the printed dipole array is Y direction and the tangential direction is X direction. Each printed dipole antenna is vertically placed on the 1×1m perfect conducting plane and the printed dipole array is placed on the center of the plane. The ground plane (XOY surface) is infinite perfect conducting plane. The height between the center of printed dipole array and the ground plane is 0.9m. What's more, the height between the ground plane and the measuring point is h.

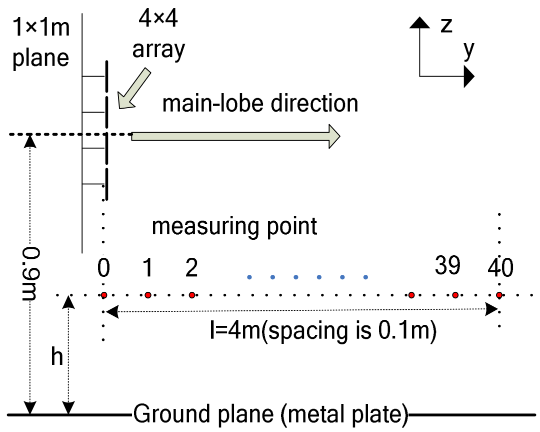

Figure 3. Measuring point of side-lobe radiation field sketch map

As shown in Figure.3, in order to analyze the side-lobe radiation characteristic of printed dipole array, we prefer to radiation characteristics just below h of the main-lobe direction as the measuring point. The first measuring point just below the printed dipole array and the spacing along the horizontal direction is 0.1m.

In fact that printed dipole antenna in S band is made of metal and media, so if calculating the antenna based on MOM will generate a large number of unknowns and can't finished. In order to reduce the number of unknowns, we make an equivalent model which is only consisted of metal, as shown in the figure 4.

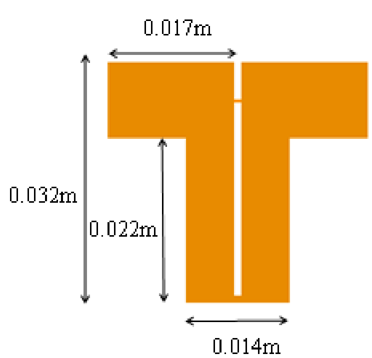

Figure 4. Equivalent model of printed dipole antenna

Based on the theory of planar array, the beam of planar array can be controlled in two-dimensional space. In the spherical coordinate system, the space direction of half spherical space is according to the two coordinate of θ and φ. According to the simplified method proposed by Von Aulock, the phase of the mnth element (x_m, z_n) can be given as follows on the condition that the main beam is available [3].

$$\Psi_{mn} = \frac{2\pi}{\lambda}(x_m \sin\theta\cos\varphi + z_m \cos\theta) \qquad (1)$$

Where x_m is the coordinate of antenna along X axis and z_n is the coordinate along Z axis. According to formula (1), it is very easy to obtain the phase of each element, where θ is the elevation angle and ϕ is the azimuth angle.

III. SIMULATION RESULT ANALYSIS

The electric field intensity values in side-lobe area are calculated under following different situations, the radiation characteristic of print dipole array along side-lobe direction is researched by the simulation results.

1) Analyze how the horizontal metal plate influences the side-lobe radiation characteristic of printed dipole array.

2) Analyze how the scanning angle influences the side- lobe radiation characteristic of printed dipole array.

3) Through the peak values and valley values of electric field intensity along side-lobe direction, the possibility of using peak value and valley value identify the number of side lobe is discussed.

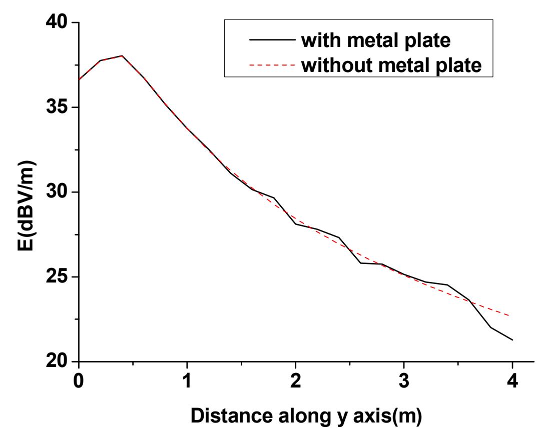

Figure 5. Comparison of the simulation result with the situation of existing metal plate and without metal plate, while h=0.8m

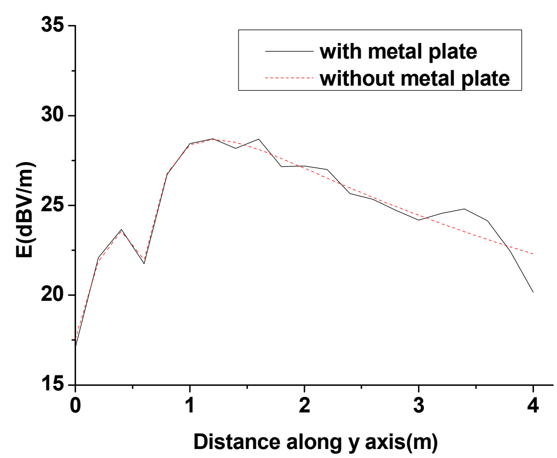

Figure 6. Comparison of the simulation result with the situation of existing metal plate and without metal plate, while h=0.6m

In order to analyze how the horizontal metal plate affects the side-lobe radiation characteristic of printed dipole array, figure 5 and 6 provide the electric field intensity values of the measuring points along y axis when h=0.8m and h=0.6m respectively. The solid line indicates the situation of existing metal plate and the other dotted line indicates the situation without metal plate. From the curves, it is clear to find that the electric field intensity values under the situation of existing metal plate and without metal plate agree well when the distance along y axis is less than 1.3m. However, the electric field intensity values under the situation of existing metal plate is oscillated in both sides of that without metal plate when the distance is greater than 1.3m. What's more, the oscillation is more obvious with the distance increasing. That is due to the mirror effect caused by metal plate [4]. Because the printed dipole antennas in model are perpendicular to the ground metal plate, the current amplitude in printed dipole and its mirror are equal and the phase is the same. The superposition of phase is changed with the distance along y axis, then the electric field intensity values under the situation of existing metal plate is oscillated.

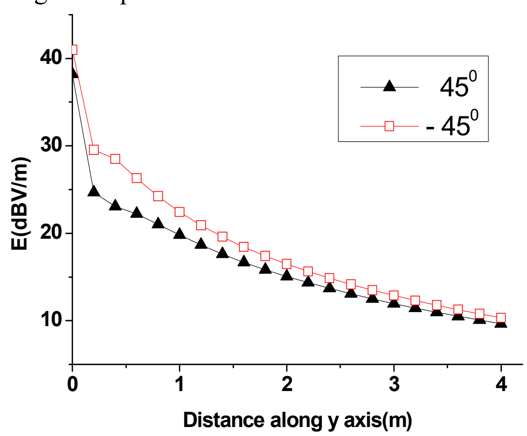

Figure 7. Simulation result vary with the azimuth angle

In figure.7, the two curves respectively indicate the electric field intensity values of measuring points along y axis when $\theta = 90$ and $\phi = -45, 45$ degree. It is clear to find that the electric field intensity values under the situation of $\phi = -45$ degree are greater than that under the situation of $\phi = 45$ degree and the difference of curves starts to decrease with distance increasing. The reason for this phenomenon is the edge effect of printed dipole array antenna. The edge effect is significant when the measuring point distance is near, so the difference of curves is significant; the edge effect is weakened with the distance increasing and the electric field intensity value tends to be same.

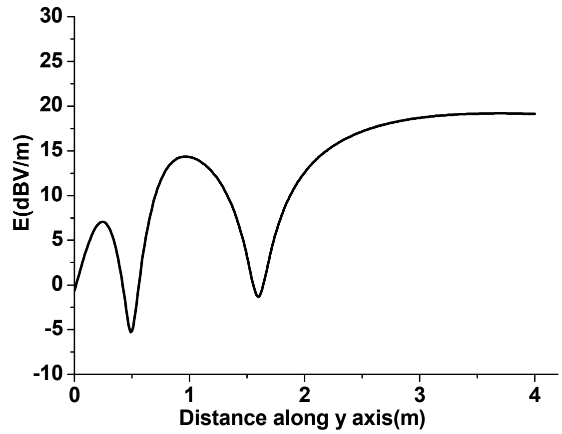

Figure 8. Electric field intensity of measuring points along y axis, while h=0 m

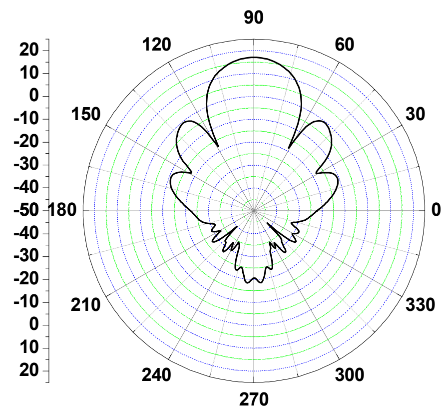

Figure 9. The far-field pattern

In figure.8, the curve indicates the electric field intensity values of measuring points along y axis when h=0m. It can be clearly find that the electric field intensity value is oscillated along the Y axis and that tends to be stable with the distance increasing. This is because the distribution of main lobe and side lobe in this area. The electric field intensity value is the peak point which is on the maximum radiation direction of side lobe and it is the valley point which is on the minimum radiation direction of side lobe. What's more, the electric field intensity value tends to be stable in the region which is the area of main lobe. From the peak and valley points alternating occur, we can identify the number of side lobe and main lobe in this region. There are two peak points in the region, so the number of side lobe in the region is two. There is just a main lobe in this region because of the one and only stable region, which is verified by the far-field pattern, as shown in figure 9.

IV. CONCLUSION

According to above simulation results, the impact from metal plate should be taken into account when side-lobe radiation characteristic is to be researched. Due to the mirror effect, electric field intensity values under the situation of existing metal plate is oscillated in both sides of that without metal plate with the distance increasing. The scanning angle is the other factor which influences the side-lobe radiation characteristic, and the difference will be decrease with the distance increasing. Finally, the simulating results of radiation characteristic in this region do not correspond with the desired result, which is because that the side-lobe effect cannot be ignored, hence the number of side lobe and main lobe in this region can be identified.

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