Research on the Electromagnetic Interference of Antennas on the Satellite

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Abstract—The electromagnetic interference of the antenna system on the satellite is analyzed by the approximate algorithm-Uniform Geometrical Theory of Diffraction (UTD), associated with China Academy of Space Technology pre-research projects. The radiation patterns of the antennas on the satellite and the isolation between transmit antennas and receive antennas are investigated in detail, which provide the scientific proof of the position and frequency setting of antennas on the satellite. So, the mentioned method is widely applied to the engineering calculation, especially for the objects large in electrical size.

1. INTRODUCTION

The antennas on the satellite would interfere each other due to the complex framework of the satellite and the considerable quantity, the similar structure, the adjacent location, the superposed working frequency of antennas. The mutual influence between antennas and satellite, and the interference among the antennas would be inevitable. So, it is urgent for the antennas working normally under the complex electromagnetic interference conditions.

It would consume huge computing resource with low efficiency to analyze the radiation field of the satellite with electrically large size by full wave method, for example MoM and FEM. In 1970s, the patterns and the isolation of the antennas on the airplane were analyzed by UTD and UAT in Ohio State University and Illinois University, which had been applied to the military and civil aviation successfully. The error between the measured results and the calculated results is 3.76 dB. At present, the position of the antennas is decided by the experience and the repeating tests mostly at home, which would be difficult to realize optimization and would consume a lot of manpower and material resources.

In this paper, the approximate algorithm-UTD [1] with advantage of distinct conception and convenient calculation is adopted to analyze the electromagnetic interference of antennas on the satellite (Figure 1), associated with China Academy of Space Technology pre-research projects.

Figure 1: Equivalent model of the satellite and Cartesian coordinates.

2. UNIFORM GEOMETRICAL THEORY OF DIFFRACTION [1]

The problem about the radiation of the point source is solved by UTD. The antennas could be equivalent to the point sources with the same patterns as the antennas', which are located the phase center of the practical antennas. The paraboloid antennas in Figure 1 would be equivalent to the point source, which would bring some errors. The paraboloid antennas could also be equivalent
to the combination of many point sources, and the radiation field of the antenna would be the vector superposition of the fields of many point sources. However, this superposition model has the disadvantages of low computation speed and huge computer memory. So, according to the calculating precision and computer hardware, the equivalent model of antennas could be chosen. In this paper, the antennas in Figure 1 are equivalent to the point sources.

2.1. Incidence Field

The incidence field (Figure 2) is defined as the radial field from the source point to the observed point directly. Thus, in the shadow, the incidence field would be zero. We express the incidence field as

$$\vec{E}^i (\vec{r}) = \vec{E}^i (\vec{r}_0) \sqrt{\frac{\rho_1}{\rho_1 + s^i}} \sqrt{\frac{\rho_2}{\rho_2 + s^i}} e^{-jks^i}$$  \hspace{1cm} (1)

$s^i$ represents the distance along incidence radial, and $\vec{E}^i (\vec{r}_0)$ is the field-strength when $s^i = 0$, and $\rho_1$, $\rho_2$ are the curvature radius of the incidence wave front.

![Figure 2: Incidence field.](image)

2.2. Reflective Field

The reflective field (Figure 3) is defined as the radial field reflected by the conductor surface, in radial coordinate system which could be given by

$$\vec{E}^r (P) = \vec{E}^i (Q_R) \cdot \overline{R} \sqrt{\frac{\rho_1}{\rho_1 + s}} \sqrt{\frac{\rho_2}{\rho_2 + s}} e^{-jks}$$  \hspace{1cm} (2)

$Q_R$ is the reflective point, and $E_i(Q_R)$ is the incidence field at $Q_R$, and $s$ represents the distance from the reflective point to the observed point, and $\rho_1$, $\rho_2$ are the curvature radius of the reflective wave front, and $\overline{R}$ is the matrix of the reflection coefficient.

![Figure 3: Reflective field.](image)

2.3. Edge Diffraction Field [7]

As shown in Figure 4, when the conductor edge is irradiated by the electromagnetic wave, the diffraction field would occur at the edge. In radial coordinate system, the edge diffraction field could be written as

$$E^{ed}(P) = E^i(Q) \cdot \overline{D} \sqrt{\rho_c/(S + \rho_c)} e^{-jks}$$  \hspace{1cm} (3)

$E^i(Q)$ is the incidence field at the diffraction point $Q$, $\overline{D}$ is the edge diffraction coefficient, $\rho_c$ represents the difference between the two curvature radius of the diffraction wave front.

![Figure 4: Edge diffraction field.](image)

2.4. Surface Diffraction Field [2]

When the incidence wave sweeps past the curved surface, there would be surface diffraction wave on the curved surface, which could be express as

$$E^{sd}(P_s) = E^i(Q_1) \cdot \overline{T}(Q_1, Q_2) \sqrt{\rho^{sd}/S^d \cdot (S^d + \rho^{sd})} e^{-jksd}$$  \hspace{1cm} (4)
As shown in Figure 5, $Q_1$ and $Q_2$ are the two surface diffraction points, and $\mathcal{T}(Q_1, Q_2)$ is used to show the emission of the surface diffraction field from $Q_1$, and the attenuation of the surface diffraction field from $Q_1$ to $Q_2$, and the diffraction field at $Q_2$.

### 2.5. Corner Diffraction Field [4]

The corner diffraction field is equal to the sum of the diffraction field of every edge composed the corner. The experiential result was given by Sikta and Burnside, which was proved successful in practice.

$$ E^{dc}(P) = \vec{E}^j(Q_c) \cdot D_{s,h}^{c} \sqrt{s'/s''} / \sqrt{s(s+s_c)e^{-jks}} $$

(5)

where $D_{s,h}^{c}$ is the coefficient of the corner diffraction.

### 2.6. Total Field

After seeking the traces of the radials and judging whether the radials are obstructed or not, the total field would be equal to the vector sum of the fields mentioned above.

$$ \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} = \delta_i \begin{bmatrix} E^i_x \\ E^i_y \\ E^i_z \end{bmatrix} + \delta_r \begin{bmatrix} E^r_x \\ E^r_y \\ E^r_z \end{bmatrix} + \delta_{ed} \begin{bmatrix} E^{ed}_x \\ E^{ed}_y \\ E^{ed}_z \end{bmatrix} + \delta_{sd} \begin{bmatrix} E^{sd}_x \\ E^{sd}_y \\ E^{sd}_z \end{bmatrix} + \delta_{dc} \begin{bmatrix} E^{dc}_x \\ E^{dc}_y \\ E^{dc}_z \end{bmatrix} $$

(6)

where $\delta$ is the factor of obstruct.
3. NUMERICAL RESULTS

Compared with the full wave method, the accuracy and the validity of this approach mentioned above is explained in [3]. In view of the complexity of the satellite and the condition of the computer hardware, the model of point source is adopted on account of the observed points being far field points relative to the work wavelength. The pattern of the unit antenna in free space would have been solved by the software, which is the pretreatment to analyze the patterns of the antennas on the satellite according to the Equation (6). The antennas A, B and C in Figure 1 would be taken as examples.

Seen from Figure 7～Figure 9, whether the antennas are assembled on the satellite or not, there is little difference in the main lobe of the radiation pattern. Because of the influence of the satellite and the other antennas, the effect of the reflective field and the diffraction field on the side lobes is clear, and in some direction, the radiation is weakened due to the obstruction.

According to the total field of the antennas on the satellite by UTD, the isolation between transmit antennas and receive antennas could be calculated by followed equation,

\[(INS)_{dB} = 10\log(P_t/P_r)\]  \hspace{1cm} (7)

where, \(P_t\) is the output power of the transmit antennas, and \(P_r\) is the interference power received by receive antennas, which is solved by UTD. The isolations between A and B at two frequencies would be analyzed.

So, the relative position and orientation of antenna A and B could be determined by above results. Consequently, the position and frequency setting of antennas on the satellite could be optimized.
4. CONCLUSION

With the valid equivalent models of the satellite and antennas, the method mentioned in this paper is the effective technique to forecast the patterns and the isolations of the antennas on the satellite, which would be of great value in practice.

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