A GTD APPROACH TO THE STUDY OF FIELD PATTERN OF TV REFLECTOR ANTENNAS

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1. INTRODUCTION

In TV transmitting , a scheme of dipole antennas or loop antennas installed on each side of a rectangular cylinder reflector, as shown in Fig.1, has been widely adopted.[1][2] In reference[1], the problem was analyzed by considering each face of the cylinder reflector as an infinite reflecting plane, in which the diffraction effect of the reflector and the difference of the region of existence of the reflected fields between the case of a cylinder of finite width and that of infinite width were neglected. In this paper, the effects of diffracted fields on the field pattern are studied by GTD.

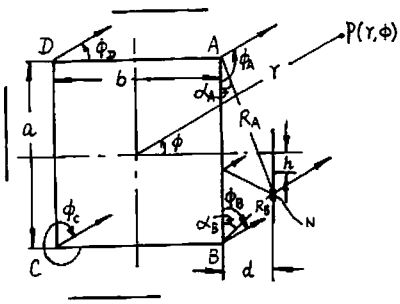

Fig.1 Antenna model

2. THEORY AND TECHNIQUE

Referering to Fig.1, the field intensity at P(r,φ) due to a current element N can be written as

$$\bar{E}(r,\phi)=\sum_{1}^{M}\bar{E}_m(r,\phi) \tag{1}$$

where $\bar{E}_1$ and $\bar{E}_2$ denote the direct and reflected field intensities, $\bar{E}_3$ and $\bar{E}_4$ the first order diffracted field intensities, $\bar{E}_5$ to $\bar{E}_8$ the second order ones.

The formulae for the computation of $\bar{E}_3$ to $\bar{E}_8$ are

$$\bar{E}_{\substack{3\\4}}(r,\phi)=\pm\bar{\bar{D}}(r,R_{\substack{A\\B}},\tfrac{\pi}{2}\pm\phi,\alpha_{\substack{A\\B}},\tfrac{\pi}{2},\hat{\phi}_{\substack{A\\B}},\hat{\phi}'_{\substack{A\\B}},\hat{\beta}_{\substack{A\\B}})\cdot\bar{E}^i(R_{\substack{A\\B}},\alpha_{\substack{A\\B}},\hat{\alpha}_{\substack{A\\B}})A_d(r,R_{\substack{A\\B}})e^{-jk(r-\Delta r_{\substack{A\\B}})}\cdot\hat{\phi}\,\hat{\phi} \tag{2}$$

$$\bar{E}_{\substack{5\\6}}(r,\phi)=\pm\tfrac{1}{2}\bar{\bar{D}}(r,\{\substack{b\\a}\},\{\substack{\phi\\\frac{\pi}{2}-\phi}\},0,\tfrac{\pi}{2},\hat{\phi}_B,\hat{\phi}'_B,\hat{\beta}_B)\cdot[\bar{\bar{D}}(\{\substack{b\\a}\},R_A,\{\substack{\frac{3\pi}{2}\\0}\},\alpha_A,\tfrac{\pi}{2},\hat{\phi}_A,\hat{\phi}'_A,\hat{\beta}_A)$$
$$\cdot\bar{E}^i(R_A,\alpha_A,\hat{\alpha}_A)]A_d(\{\substack{b\\a}\},R_A)A_d(r,\{\substack{b\\a}\})e^{-jk(\{\substack{b\\a}\}+r-\Delta r_{\substack{A\\B}})}\cdot\hat{\phi}\,\hat{\phi} \tag{3}$$

$$\bar{E}_{\substack{7\\8}}(r,\phi)=\pm\tfrac{1}{2}\bar{\bar{D}}(r,\{\substack{a\\b}\},\{\substack{\phi+\frac{\pi}{2}\\-\phi}\},0,\tfrac{\pi}{2},\hat{\phi}_C,\hat{\phi}'_C,\hat{\beta}_C)\cdot[\bar{\bar{D}}(\{\substack{a\\b}\},R_B,\{\substack{0\\\frac{3\pi}{2}}\},\alpha_B,\tfrac{\pi}{2},\hat{\phi}_B,\hat{\phi}'_B,\hat{\beta}_B)$$
$$\cdot\bar{E}^i(R_B,\alpha_B,\hat{\alpha}_B)]A_d(\{\substack{a\\b}\},R_B)A_d(r,\{\substack{a\\b}\})e^{-jk(\{\substack{a\\b}\}+r-\Delta r_C)}\cdot\hat{\phi}\,\hat{\phi} \tag{4}$$

where $$\Delta r_i = r - r_i \quad (i = A, B, C, D) \tag{5}$$

$\bar{E}^i$ is the appropriate component of the incident field at the edge.
$\bar{\bar{D}}(r,r',\phi,\phi',\beta',\hat{\phi},\hat{\phi}',\hat{\beta})$ is the diffraction coefficient in dyadic form. [4][5]

Three methods of feeding are considered in this paper. They are: (a) four antennas all fed in phase, (b) upper and lower in phase, left and right in phase, left leading lower in 90°, (c) one leading the next in 90° in counter clock-wise direction in order. The computational formula for the resultant pattern of the system with four antennas around the reflector is

$$\bar{E}_{total}(r,\phi)=\bar{E}(r,\phi)+(j)^t\bar{E}(r,\phi+90^\circ)+(-1)^u\bar{E}(r,\phi+180^\circ)+(j)^v\bar{E}(r,\phi+270^\circ) \tag{6}$$

where (t,u,v) has the values (0,0,0), (1,0,1) and (2,1,1) for methods of feeding (a),(b) and (c) respectively. $\bar{E}(r,\phi)$ is the field pattern of the system when there is only one antenna around the reflector with the phase of the antenna current equal to zero. In the computation, the antenna current distribution is assumed to be sinusoidal.

3. RESULTS OF COMPUTATION AND DISCUSSIONS

(1) Computation of the direct, the reflected and the diffracted field intensities and comparison of the field patterns with diffracted fields considered or neglected, when there is only one double loop antenna around a

square cylinder reflector

A case with parameters a=b=0.7λ, d=0.25λ, h=0 is considered. Results obtained are shown in Fig.2. From the results it can be seen that the offect of the diffracted field on the main lobe of the pattern is not obvious, but is very obvious on its back lobe; the effect of the second order diffracted field on the back lobe is great and therefore should not be neglected; an interference phenomena is observed between the first order and the second order diffracted fields. The effects of the third and higher order diffracted field were studied and found to be very small.

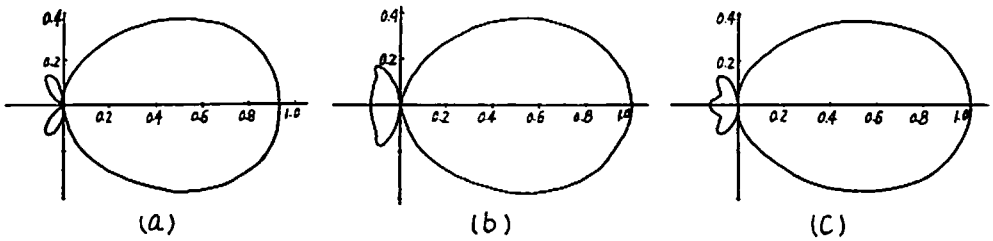

Fig.2 Comparisons of field patterns obtained with diffracted fields considered and neglected, (a) M=2, (b) M=4, (c) M=8

(2) Comparison of the results obtained by GTD and those obtained by the method in reference [1], i.e., by considering the reflector as an infinite conducting plane

The curves shown in Fig.3(a) are the variational characteristics of r against d for the case a=b=1λ and h=0, where r is the ratio of the minimum field intensity to maximum field intensity of the radiation pattern and d is the distance of the antenna from the reflector. The curves in Fig.3(b) are the variational characteristics of the ratio r against h, which is the

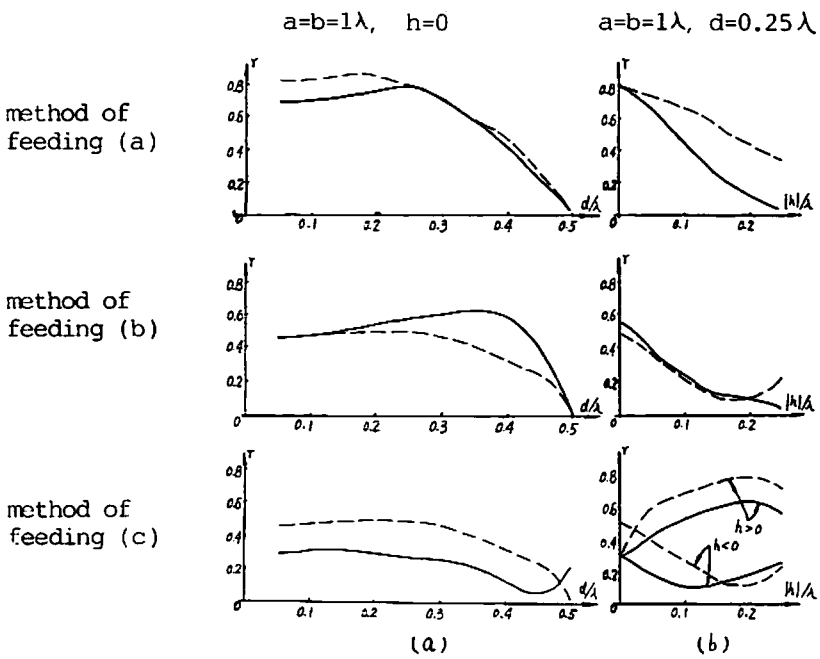

Fig 3 Comparison of results obtained by GTD and by the method in reference [1]

deviation of the antenna from the center line of the reflector, when a=b=1λ, d=0.25λ. It can be seen from these curves that results obtained by both methods are close to each other in certain cases, but by the large their difference is obvious. Sometime, we may get incorrect conclusions from the results obtained by the method in reference [1]. For instance, the variational characteristics of r against d and h calculated by the method in [1] for method of feeding (b) and those for method of feeding (c) are exactly the same, but those calculated by GTD differ from each other to a great extent. The error of the value of the ratio r obtained by the method in [1] relative to that obtained by GTD is given in Table 2. From the Table, it can be seen that in some cases the relative error reaches a value as high as a few hundreds per cent. It means that in certain cases the method in [1] may not be reliable.

Table 2 The relative error (%) of r calculated by the method in [1] with respect to r by GTD (d=0.25λ)

h	0					a/4 or b/4				
a/λ or b/λ	1.0	1.5	2.0	2.5	3.0	1.0	1.5	2.0	2.5	3.0
method of feeding (a)	+0.6	-6.7	-11.1	-1.5	-9.8	+1111.0	+108.0	-30.8	-1.9	-13.1
method of feeding (b)	-12.9	+21.5	-14.8	-9.1	+10.8	+320.8	+106.1	-31.3	-22.1	+13.6
method of feeding (c)	+73.9	-21.1	-9.6	+13.7	-18.2	-6.0	+24.3	-11.5	+2.7	+6.1

(3) The variational characteristic of r against d with double loop antennas installed at the center line of the cylinder reflector

Calculated results are shown in Fig.4. The curves shown by the solid line are the results for the method feeding (a), those shown by dash line are the results for the method of feeding (b) and those shown by dash-dot line are the results for the method of feeding (c). We can see from the curves: (A) In the range of d< 0.3λ, the variation of the ratio r is small, but the value of r drops rapidly when d becomes larger. It means that it is allowable to adjust the distance between the antenna and the reflector in a certain range to meet the requirement of the impedance of the antenna, and the use of too large a value of d is not appropriate . (B) In the runge d< 0.3λ, the value of ratio r for the method of feeding (a) is greater than that for methods of feeding (b) and (c). Four antennas fed in phase is the best of all when they are installed at the center line of the cylinder reflector. (C) The merit of methods of feeding depends on the dimension of the reflector.

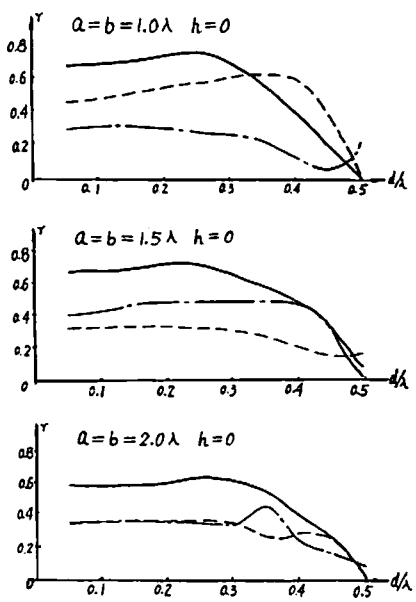

Fig.4 Variational characteristics of r against d for different values of a or b, h=0

(4) The variational characteristics of the field intensity ratio r against h, when the distance between the antenna and the cylinder reflector is 0.25λ

Calculated results are shown in Fig.5. It can be seen from the curves in the figure that the ratio r decreases linearly with the increase of h in a certain range of h when the method of feeding (a) is adopted. This indi-

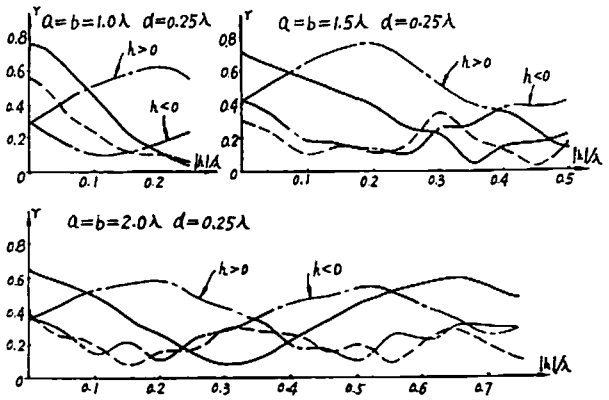

Fig.5 Variational characteristics of r against h for different values of a or b with d=0.25λ

cates that deviation from the center line is unfavourable. When h increases beyond a certain value, r decreases no more but increases or varies in an oscillating manner. When the method of feeding (c) is adopted, the variational characteristics of r against h differ greatly for the two cases $h>0$ and $h<0$. The ratio r increases with increase of $|h|$ when $h>0$, but decreases with $|h|$ when $h<0$.

The computational results obtained in this paper by the method of GTD was checked by the authors with the experimental results. [3]

4. CONCLUSION

In this paper, the radiation characteristic of a TV reflector antenna is analyzed by the method of GTD. The result obtained is more accurate as compared with that obtained by the method in reference [1], as a consequence of the consideration of the diffracted fields from the edges of the reflector. GTD is therefore a more reliable method for the analysis of the type of antenna considered.

The computaional results show that the resultant field pattern of a TV antenna system with antennas installed adjacent to a square cylinder reflector depends on many factors such as: the width of the face of the cylinder, the relative position of the antennas with respect to the cylinder, and the method of feeding of the antennas around the cylinder. For the method of feeding (a), i.e., currents on all antennas fed in phase, it is most favourable to install the antennas at the center line of the cylinder. For the method of feeding(c), the direction of deviation is important. For the case a=b=1λ and d=0.25λ, a favourable value of h for omni-directional characteristic of radiation is around +0.2λ.

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