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Electromagnetic Compatibility of an Aperture Antenna

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Abstract

Nowadays the great attention is paid to the problem of compatibility of antennas with surrounding and receivers in order to reach the signals of highest quality level. paper deals with estimation of electromagnetic compatibility (EMC) of circular aperture antenna. The antenna is excited by a plane elect¬romagnetic wave normally incident on it. Within the investigation process the ful¬fill¬ment of so condition on sharp edges is provided. The radiation charac¬te¬ristic of the antenna is calculated as well as its compatibility function, providing the selection of the optimal functioning regime of the antenna.

Keywords: Aperture antenna, pattern, electromagnetic compatibility.

Introduction

Theory and discussion of the problem

The figure represents the orientation of the aperture antenna in the rectangular *XYZ* reference frame. Consider the antenna in the form of infinite thin metal surface *(∑)*, where the circle (aperture) of *S* area and of α radius is cut out; thus, this system as a whole relates to the class of aperture antennas. Assume a plane electromagnetic wave normally incident on this antenna from the left-hand-side (from negative *z-s*). Its electric strength vector posseses only vertical component $E_z=Ae^{ikx}$, where $k=2\pi/\lambda$, λ - the wavelength in free space; this wave, diffracting on the aperture, creates the electromagnetic field in the observation point *M* in far zone *(kr >>1)* with the meridian and azimuth components of the electric vector given as follows [1]:

(1) $$E_\theta = C\frac{e^{ikr}}{r}(1+cos\theta)F(\theta)sin\varphi, \quad E_\varphi = C\frac{e^{ikr}}{r}(1+cos\theta)cos\varphi,$$
$$\left(C = const,\ 0 \le \varphi \le 2\pi,\ -\pi/2 \le \theta \le \pi/2\right)$$

(2) $$F(\theta) = \int_0^{\alpha}\int_0^{2\pi} U(\rho',\varphi')e^{-ik\rho' sin\theta cos(\varphi-\varphi')}\rho' d\rho' d\varphi'.$$

ρ',φ' are the polar coordinates of arbitrary selected *M'* point of observation on S aperture *(0≤φ'≤2π,0≤ρ'≤α)*.

In order to calculate the integral (2) in an evident form, it is necessary to know the structure of *U(ρ^',φ')* function in an analytical form. This problem is not yet solved due to the certain mathematical difficulties and for simplicity of calculations the approximation is rather often used, i.e. the presentation of the signed function in the simplified form, assuming it as the constant quantity; the integral (2) then reduces to the table integral and we get:

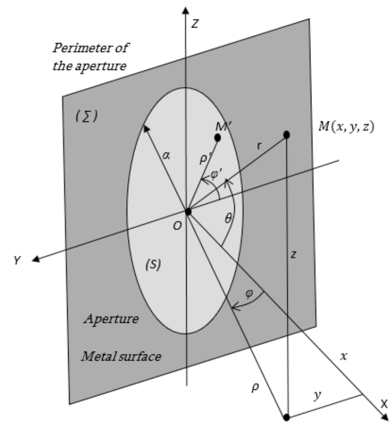

Fig. 1. *Aperture Antenna*

(3) $$F(\theta,\varphi) = C\frac{I_1(kasin\theta)}{kasin\theta} \quad (C = const).$$

In the scientific literature other approximations of U(ρ^',φ') function are suggested as well [2], but they just like of (3) are unable to give results, adequate to the real situation. The reason is that no approximation takes into account that U(ρ^',φ') function at sharp edges (perimeter) of the aperture satisfies the following conditions [3]:

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(4) $U(\rho', \varphi') = const, \quad \lim_{\rho' \to a} \sqrt{1 - \left(\rho'/_a\right)^2} = 0,$

that provides the real singularity of the solution of corresponding electrodynamic problem, which is adequate to the real conditions from physical point of view. The expression (4) points on the situation, when due to conditions of the axial symmetry the field is independent of *φ'* coordinate and, thus, *U(ρ^',φ')=U(ρ')* function should be presented by the Fourier generalized series:

(5) $U(\rho') = \sum_{a=0}^{\infty} X_m U_{2S+1}\left(\rho'/_a\right),$

(6) $U_{2S+1}\left(\rho'/_a\right) = sin\left[(2S+1)arccos\left(\rho'/_a\right)\right]$

is Chebishev's function of the second order, which is proportional to $\sqrt{1-\left(\rho'/_a\right)^2}$.

It is possible to represent (6) as follows:

(7) $U(\rho') = \sqrt{1 - \left(\rho'/_a\right)^2}\left[X_0 + \sum_{S=0}^{\infty} X_S U_{2S+1}\left(\rho'/_a\right)\right].$

In this series X_S coefficient should be determined at the aperture from conditions of continuity of the field and its derivative. This s to the system of so called dual functional equations, given as follows:

(8) $$\begin{aligned} &\sum_{S=0}^{\infty} X_S G_S(\xi,\gamma) = f(\xi) \quad (\text{when } \xi \leq 1) \\ &\sum_{S=0}^{\infty} X_S G_S(\xi,\gamma) = 0 \quad (\text{when } \xi > 1) \end{aligned} \quad \left(\xi = \rho'/_a\right).$$

(γ=ka)

$G_S(\xi,\gamma)$ and *f(ξ)* are continuous functions within [0, 1] interval.

Denoting the solution of this system by X_S and restricting in (6) series by *S=0* index term only, instead of (7) we get the approximate relation

(9) $U(\rho') \approx \widetilde{X_0}\sqrt{1-\left(\rho'/_a\right)^2}.$

Inserting it into (2) and integrating we get:

(10) $F(\theta,\gamma) = K\left[\frac{sin(2\pi\gamma sin\theta) - 2\pi\gamma sin\theta cos(2\pi\gamma sin\theta)}{(2\pi\gamma sin\theta)^3}\right], \quad (K = const)$

(here we had taken into account that the right-hand-side of (2) depends on γ parameter), after that the expression (1) will be written down as follows::

(11) $E_\theta = K_0 \frac{e^{ikr}}{r}(1+cos\theta)F(\theta,\gamma)sin\varphi,$

(12) $E_\varphi = K_0 \frac{e^{ikr}}{r}(1+cos\theta)F(\theta,\gamma)cos\varphi.$
$(K_0 = KCX_0)$

Squaring the expressions (11) and (12) and adding received results, we arrive to the following expression:

(13) $F_{nor}(\theta,\xi) = \frac{E(\theta,\gamma)}{K_0} = 1{,}5(1+cos\theta)F(\theta,\gamma),$

where *F(θ,γ)* is given by (10) without K coefficient. (13) presents the radiation charac-teristic of the circular aperture antenna. This is the main result of our investigations.

Now it is possible to calculate the compatibility function G(γ), of the antenna, given by the following relation [4, 5]:

(14) $G(\gamma) = \left|\int_{\theta_1}^{\theta_2} F(\theta,\gamma)d\theta\right|,$

where $\Delta\theta=\theta_2-\theta_1$- is the compatibility sector.

Conclusion

The electromagnetic compatibility of considered antenna is rather high from practical point of view; the reliability of received results is supported by the circumstance that at the aperture of the antenna the law of distibution of the field, from physical point of view, has been presented adequately to (6), that satisfies the conditions of behavior of the field at sharp edges, that in turn provides the unique solution of the electrodynamic problem being set up in the work.

References

Вайнштейн Л. А. (1988). Электромагнитные волны. М., «Радиосвязь».

Корбанский И. Н. (1973). Антенны. М., «Энергия».

Mittra R., Lee S. W. (1971). Analytical Techniques in the Theory of Guided Waves. Macmillan: New York.

Kevanishvili G. Sh. et al. (2007). On the Problem of Electromagnetic Compatibility of Antennas. GEN,№3.

Kevanishvili G. Sh. et al. (2012). IEEE, XIIth International Seminar/Workshop on DIPED.. Proceedings, pp. 73-76.