A USE OF UTD IN H-PLANE PATTERN ANALYSIS OF RECTANGULAR PATCH MICROSTRIP ANTENNA WITH FINITE GROUND PLANE

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1 Introduction

Huang proposed an approach of combining the UTD[1] with slot theory or modal expansion theory to predict the radiation pattern of a rectangular patch microstrip[2]. However in the H-plane pattern calculation, he employed another method, so called equivalent current method(ECM)[3] to evaluate the E-plane edges contributions. It is necessary in ECM to execute numerically the radiation integrals of edge equivalent currents which are derived from edge diffraction. It is hoped that this numerical integration can be avoided. This report presents a direct process which applies edge diffraction plus corner diffraction and not the equivalent current in considering the contributions from E-plane edges for the H-plane pattern analysis. In our analysis the double diffractions are also included, which may be very tedious if the equivalent current method would be used.The computed result by present approach is compared with that by ECM for a square microstrip antenna. The measured result is also given for comparison.

2 Analysis of the H-plane radiation pattern

According to the slot theory, a rectangular microstrip antenna radiates field from a pair of slots each lying at the fed patch edges as shown in Fig.1. The slot width w is approximately equal to the substrate thickness h, and the length l equals the patch length plus the substrate thickness[4]. The radiation field of a slot as shown in Fig.2 can be calculated by [4]:

$$E_\phi \sim \frac{\sin(\frac{\pi w}{\lambda}\sin\theta\cos\phi)}{\frac{\pi w}{\lambda}\sin\theta\cos\phi}\frac{\sin(\frac{\pi l}{\lambda_0}\cos\theta)}{\frac{\pi l}{\lambda_0}\cos\theta}\sin\theta\frac{e^{-jkr}}{r} \qquad (1)$$

where λ_0 is the wavelength of vacuum and $\lambda = \sqrt{\epsilon_r}\lambda_0$ is the wavelength in the substrate dielectric. UTD enables one to calculate the radiation patterns with the finite ground effect being accounted for.

In the E-plane pattern calculation, only the edge diffractions (multiple diffractions should be considered if the ground plane is not large enough.) from E-plane edges need be combined into the direct geometrical optics field to get a satisfactory radiation pattern, because the first order H-plane edges contributions cancel each other. In the H-plane, however, the slop diffractions from the H-plane edges become important due to the zero prediction of the first-order edge diffraction. The contributions from E-plane edges, unlike in the E-plane pattern calculation, are much stronger than those slope diffractions from the H-plane edges in the back-lobe directions, so it must be included. The E-plane edges contributions are conventionally, as done in [2], evaluated by equivalent current method(ECM) in which the diffraction field is obtained by the equivalent currents radiation integral along the edge. In fact, one can predict them more simply and directly by using edge diffraction embodied corner diffraction as described below.

Figure 3 shows the mechanism of the equivalent magnetic current and the single edge diffraction plus the single corner diffraction associated with one slot and one E-plane edge. The equivalent magnetic current $I_m(y')$ is obtained from the edge diffraction at y'. The diffracted field is computed by the radiation integral of $I_m(y')$ as

$$\bar{E}_{eq}(p) = \frac{jk}{4\pi} \int_{-\frac{b}{2}}^{\frac{b}{2}} \hat{S} \times \bar{I}_m(y') \frac{e^{-jkS}}{S} dy' \qquad (2)$$

where S and $\hat{S}$ are the distance and its unit vector from the edge diffraction point to the observation point respectively.The corner diffraction from corner A or B with edge AB is introduced to compensate the edge diffraction trancation when the edge diffraction point does not fall into the limit of AB. The corner diffractions associated with the H-plane edges of the two slots cancel each other if the patch is arranged symmetrically over the ground plane. To such a planar right corner, two corner diffraction formulae are available, in which the total corner diffraction are made up of two corner diffractions to each edge of this corner. One has been proposed by Burnside and Pathak and successfully applied to the pattern analysis of airborne antennas[5]. The other one was derived by the authors, in which the invalidity was removed which existes in Burnside and Pathak's formula when the edge diffraction shadow boundary is close to the geometrical optics shadow boundary[6]. In this report the double diffraction, diffraction from edge DC−diffraction from edge AB, diffraction form edge DC−diffraction from corner A or B, and diffraction from corner C or D−diffraction edge AB, are also included in the computation. It will be very laborious if the equivalent current method is used to evaluate those multi-diffraction.

3 Solution and discussion

The H-plane radiation pattern of a square patch over a square ground plane has been calculated and compared with the measured result as shown in Fig.4. The antenna dimensions are:

$$a = b = 15.0cm \quad , \quad l = l' = 5.0cm$$

$$h = 0.08cm \quad , \quad \epsilon_r = 2.5$$

$$operating \;\; frequency = 1.8222GHz$$

Good agreement has been achieved between the measurement and calculation in the overall main lobe. In the back lobe direction both the measured and the predicted patterns behave in the analogous shape, but about 4dB deviation is observed. The double diffractions indicated previously should be included in the calculation, as the ground plane is less than one wavelength. The corner diffraction formula of [6] has been applied. In Fig.5 the E-plane edges contributions computed by the equivalent magnetic current and by the edge diffraction plus corner diffraction are illustrated. Almost the same result can be obtained by the two methods. However the simplicity of UTD is most attractive for practical application.

References

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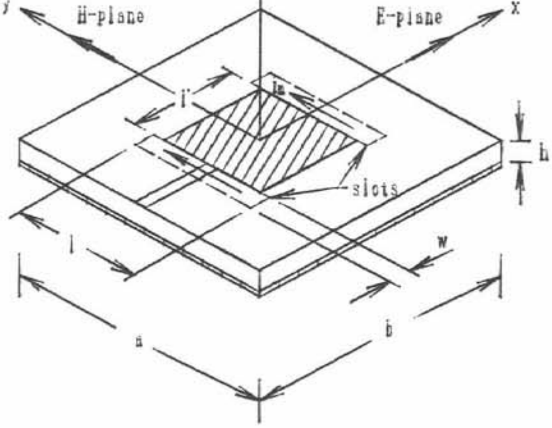

Fig. 1. Slot model of rectangular microstrip antenna.

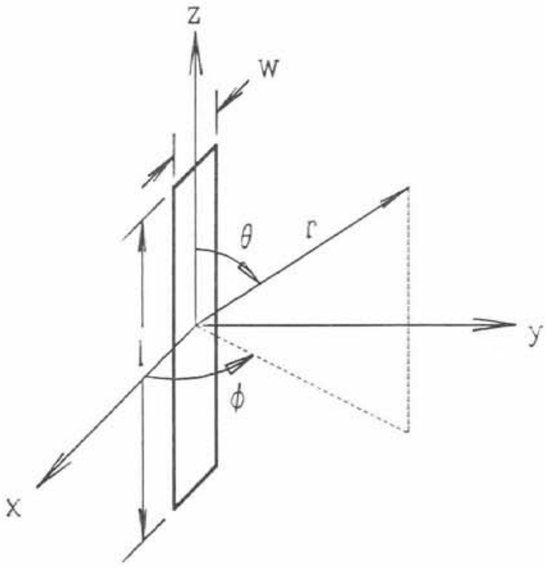

Fig. 2. Geometry of radiating slot.

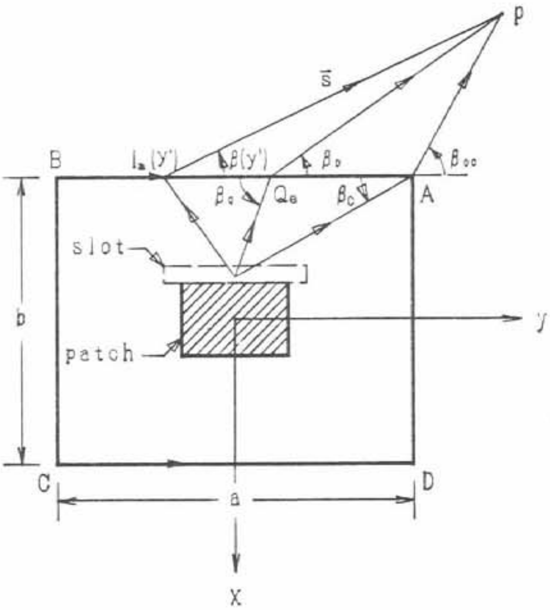

Fig. 3. Mechanism of equivalent magnetic current and edge diffraction plus corner diffraction for the H-plane pattern calculation,

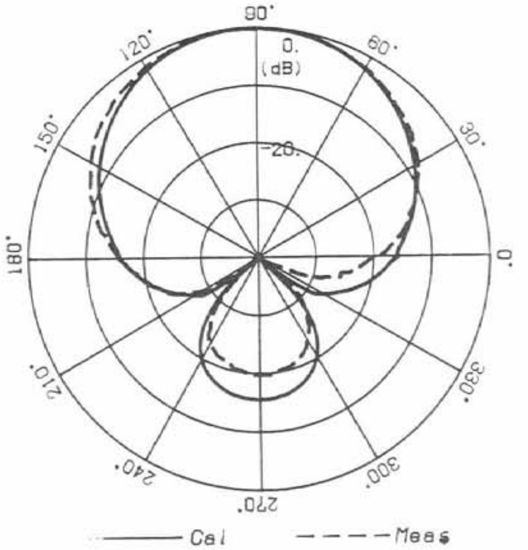

Fig. 4. The H-plane pattern. (a=b=15.cm, l=5.cm, h=0.08cm, εr=2.5, f=1.822GHz)

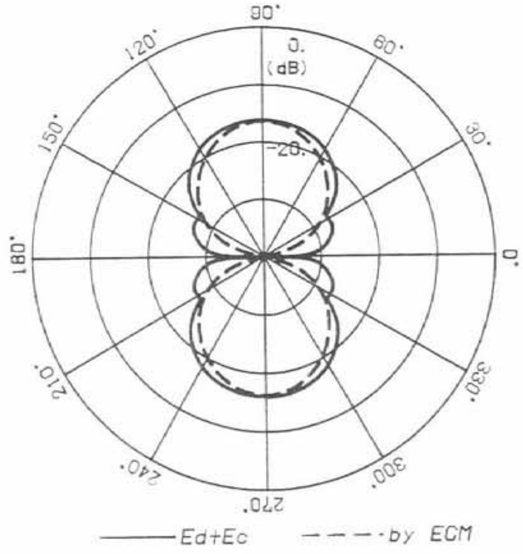

Fig. 5. The E-plane edges contributions to the H-plane pattern.