MICROSTRIP ANTENNA RADIATION PATTERN ANALYSIS CONSIDERING THE GROUND PLANE EFFECT

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ABSTRACT

This paper describes the application of the geometrical theory of diffraction (GTD) method to predict the ground plane effect on the rectangular microstrip antenna radiation pattern. In the analysis, we used a Matlab software version 4.2c.1 to develop a rectangular microstrip antenna software. The results verify that the antenna radiation pattern is affected significantly by the ground plane.

I. INTRODUCTION

The expensive prices of the commercial microstrip antenna softwares become one of obstacles in the microstrip antenna research and development at universities' laboratories. Besides, most of the available softwares do not consider the ground plane effect. As far as authors known, only one paper discussed the ground plane effect on the microstrip antenna radiation pattern using the geometrical theory of diffraction (GTD)[1]. Based on paper[1] we developed a rectangular microstrip antenna software at our laboratory. The software was developed using a Matlab software version 4.2c.1. Instead of combining the slot theory and GTD method which was used in paper [1], we combined the cavity model and GTD method in this analysis.

The cavity model was chosen because of its simplicity. The cavity model analysis assumes that the ground plane of the microstrip antenna has an infinite size. In reality, however, the ground plane always has a finite size, so the ground plane dimension should affect the antenna performance. This effect is caused by ground plane edges and known as the edge diffraction effect. The effect of a finite ground plane or ridges can be quite accurately predicted using GTD. This paper only analyzes the ground plane effect on the E-plane radiation pattern simply because the E-plane edge diffraction has a much larger magnitude than that of the H-plane edge slope diffraction.

II. THEORY

Figure 1a is used to analyze the ground plane effect on the microstrip antenna radiation pattern. The microstrip antenna is considered as an antenna system that is equivalent to two parallel radiating slots. In this analytic model, the slots are represented by a magnetic current source $\mathbf{I_m}$ [2].

E-plane pattern (x-z plane) of a rectangular microstrip antenna having a magnetic current source $\mathbf{I_m}$ can be calculated by summing three fields: E^i, E_1^d, and E_2^d [1]. E^i is incident field, while E_1^d and E_2^d are diffracted fields at ground edge #1 and #2, respectively, as shown in Figure 1b.

The incident field E^i is considered as the E-plane field of a microstrip antenna having an infinite ground plane. The equation of this field is given by the cavity model analysis [3],

$$E^i = E_\theta(\theta)\big|_{\phi=0} = K\frac{\exp(-jkr)}{r} \cdot \cos\left(\frac{ka}{2}\sin\theta\right) \qquad -\pi/2 \le \theta \le \pi/2 \tag{1}$$

where $K = -j\dfrac{4V_0 k}{\lambda_0}$

V_0 is peak voltage on the corner of the patch, k is a wave number, a is patch length, r is the range of far field observation, and λ_0 is free space wave length.

Using the GTD method, E_1^d and E_2^d are given by [3]:

$$E_1^d(\theta) = \frac{K}{2}\cos\left(\frac{ka}{2}\right)\left[\frac{e^{-jkd}}{\sqrt{d}} D_h(\beta)\right] \times e^{jkd\sin\theta}\frac{e^{-jkr}}{r} \qquad (2)$$

$$E_2^d(\theta) = \frac{K}{2}\cos\left(\frac{ka}{2}\right)\left[\frac{e^{-jkd}}{\sqrt{d}} D_h(\beta)\right] \times e^{jkd\sin\theta}\frac{e^{-jkr}}{r} \qquad (3)$$

where d is the distance between the radiating source which is a magnetic current source $\mathbf{I}_m$ and the ground edge. D_h is diffraction coefficient for vertical polarization (hard polarization) and is function of β. Here, the vertical polarization is used because the radiating source is magnetic current $\mathbf{I}_m$. To find D_h, some specific parameters of the rectangular microstrip antenna system are substituted to general equation of D_h in[4]. Some of the specific parameters are $n = 2$ showing the ground plane angular dimension, $\rho' = d$ showing the distance between the radiating source and the ground edge, $\phi' = 0$ showing that the radiating source is placed right on the ground plane, and β showing the observation angle.

Equation $E_1^d(\theta)$

$$\beta = \psi_1 = \begin{cases} 5\pi/2 - |\theta| & -\pi \le \theta < -\pi/2 \\ \pi/2 - |\theta| & -\pi/2 \le \theta < 0 \\ \theta + \pi/2 & 0 \le \theta \le \pi \end{cases} \qquad (4)$$

Equation $E_2^d(\theta)$

$$\beta = \psi_2 = \begin{cases} |\theta| + \pi/2 & -\pi \le \theta < 0 \\ \pi/2 - \theta & 0 \le \theta \le \pi/2 \\ 5\pi/2 - \theta & \pi/2 < \theta \le \pi \end{cases} \qquad (5)$$

Using the above equations, a program of the ground plane effect on the antenna radiation pattern is developed. The algorithm of the program is as follow:

(input values)
{count incident field}
{count diffraction coefficient }
{count diffracted field}
{ radiation field of an antenna having a finite ground plane
= incident field + diffracted field }

III.RESULT AND ANALYSIS

Figure 2a shows the radiation pattern of a microstrip antenna calculated by assuming an infinite ground plane. It shows that the radiation pattern exists only above the antenna. Figure 2b – 2f show the radiation patterns of a microstrip antenna having different finite ground planes which are 38 cms, 80 cms, 164 cms, 500 cms, and 1000 cms, respectively. They show the ground plane effect caused by edge diffraction on the antenna radiation pattern. For very small ground planes, ripples are introduced into the pattern over a wide range of angles. Also much radiation spills over onto the backside of the ground plane. This creates a very broad pattern. As the size of the ground plane increases, the ripples in the main pattern and the backlobe radiation behind the ground plane diminish.

IV. CONCLUSION

We have successfully deve-loped the software using a Matlab software version 4.2c.1. The results verify that the microstrip antenna ground plane affects significantly the E-plane radiation pattern.

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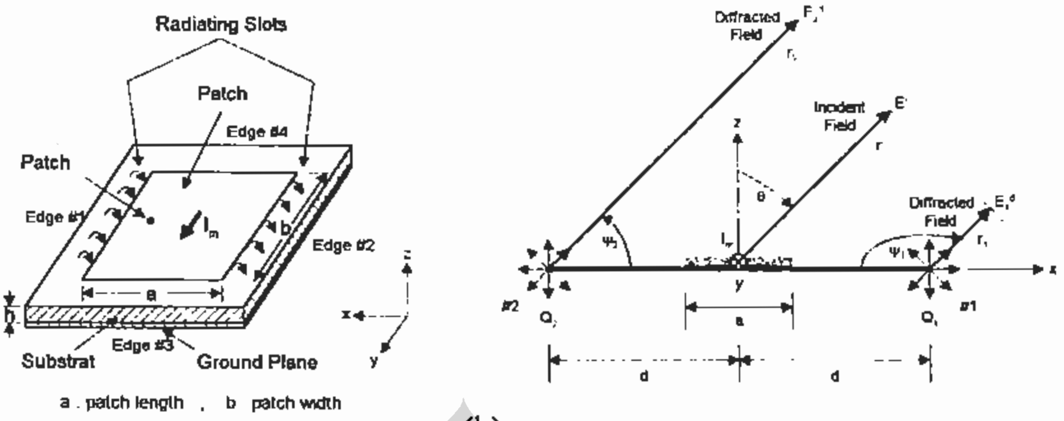

(a) (b)

Figure 1. (a) Edge diffraction analytic model for magnetic current source; (b) E-plane pattern analytic model.

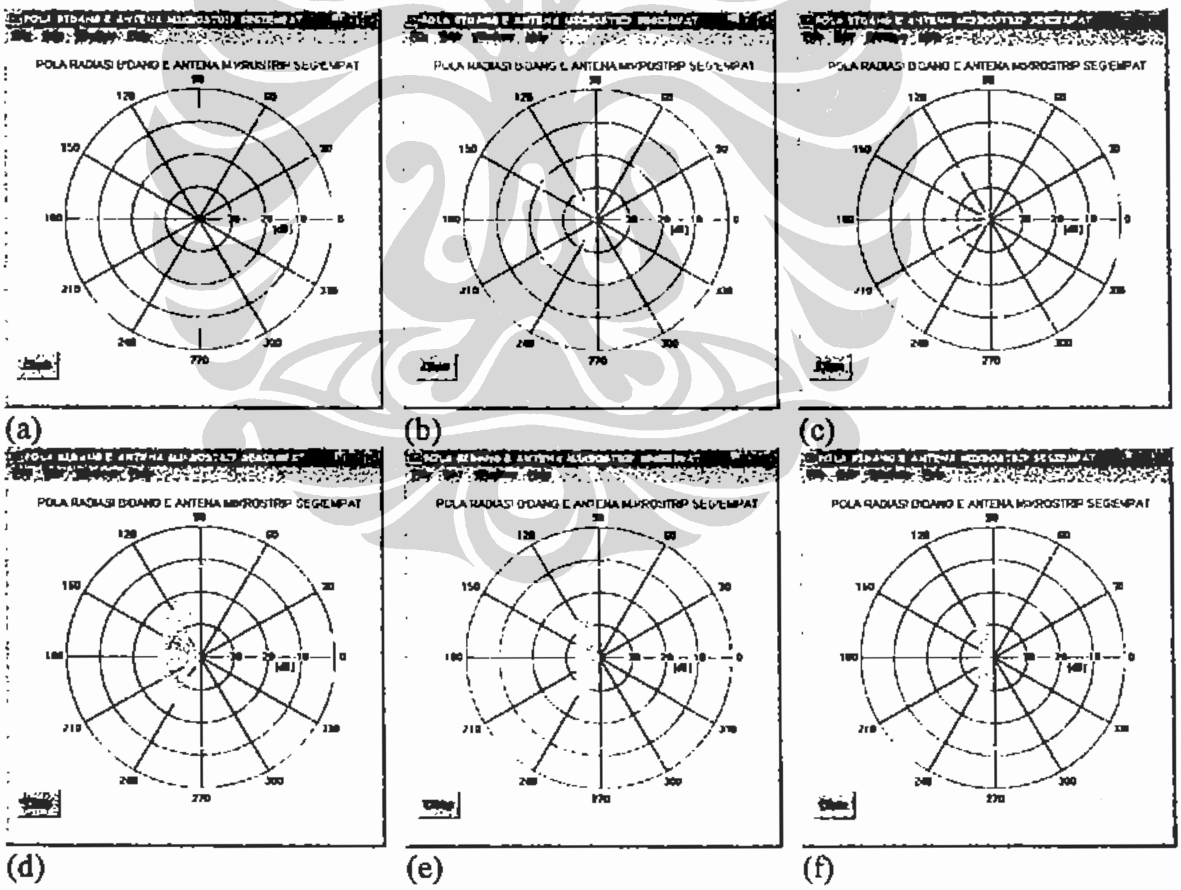

Figure 2. Rectangular microstrip antenna radiation pattern: (a) not considering the ground plane effect (assuming that the ground plane dimension is infinite); (b) the ground plane length is 38 cms; (c) the ground plane length is80 cms; (d) the ground plane length is 164 cms; (e) the ground plane length is 500 cms; (f) the ground plane length is 1000 cms.