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A CAVITY MODEL ANALYSIS ON A TILT OF THE POLARIZATION OF A SMALL PLANAR LOOP ANTENNA

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1. INTRODUCTION

The radiation efficiency and the gain of a small planar loop antenna for a paging system, are extremely low. The restriction of the physical limitation in the receiving system makes it difficult that the sensibility of the antenna can be improved without the active circuit. In order to overcome its difficulty, we have proposed a small planar loop antenna of which polarization can be electrically switched[1,2]. In this antenna, the location of short pin can be changed by the electrical switch so that the polarization of the antenna can be immediately switched. It is necessary to find two orthogonal pattern for an efficient polarization switching. As a result, the antenna can perform no null pattern on temporary average, because a null situation on a moment can be changed to a receivable situation when the electrical switch changes. The interval of switching is selected to compensate the null situation. Therefore, the proposed antenna can maintain the receivable gain so that the sensibility of the antenna can be remarkably improved.

There is a tilt of the polarization pattern of the planar loop antenna which is fed at the point A and is shorted at the point B as shown in Fig.1. As we can see from Fig.2, which is obtained by the method of moment with wire-grid model[3], a 73° tilt is observed. To direct the maximum of the pattern to AB line, it is necessary to move the location of the short pin to the point C [2]. It is known that the amplitude of the mode varies and the tilt of the polarization rotates by moving the location of the short pin[4]. In this paper, we analyze the tilt phenomenon by means of the cavity model which has been developed in the area of the microstrip antenna analysis. And we give consideration to the determination on the location of the short pin to form two orthogonal pattern.

2. OVERVIEW OF ANALYTICAL PROCEDURE [5]

Our analytical model and coordinate system are also shown in Fig.1. Two conducting rectangular plates ($a \times b$) with the separation d ($\ll a, b$), are parallel to the x-y plane. This model can be regarded as a microstrip antenna of which a conducting patch is mounted on a grounded dielectric substrate with dielectric constant $\varepsilon_r = 1$. This is the reason why we adopt the cavity model analysis to the antenna shown in Fig.1.

The side wall of the planar loop antenna can be approximately considered to be magnetic wall. Then, eigenfunctions are given as

$$\varphi^{(l)}(x,y)=\sqrt{\frac{\varepsilon_{om}\varepsilon_{on}}{ab}}\cos\left(\frac{m\pi}{a}\right)\left(x+\frac{a}{2}\right)\cos\left(\frac{n\pi}{b}\right)\left(y+\frac{b}{2}\right) \tag{1}$$

where $l=(m,n)$, $m=0,1,2,\cdots$, $n=0,1,2,\cdots$, and ε_{om} is Neumann number. In our analysis, the effective dimension due to the edge extension is adopted[5]. At the port q, a z-component of the electric field in the cavity can be expanded as

$$e_z(x,y)=\sum_{l=1}^{N}(\Omega_1^{(l)}+\Omega_2^{(l)})\varphi^{(l)}(x,y) \tag{2}$$

where N is the number of modes. The relation between port voltages, V_q and currents, I_q is given as

$$\begin{bmatrix} Z_{11}+Z_0+jX_L & Z_{12} \\ Z_{21} & Z_{22}+jX_L \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix}=\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \tag{3}$$

where Z_{pq} is mutual impedance between the port p and q, Z_0 is characteristic impedance of the feed line, and jX_L is the correction term of the self-impedance due to inductance of feed and short pins. From (3), the port currents I_q and the coefficients $\Omega_q^{(l)}$ can be determined by the driving condition, that is, by giving the values of the port voltages V_q. The total far field is given as

$$\overline{E}(\theta,\phi)=\sum_{l=1}^{N}(\Omega_1^{(l)}+\Omega_2^{(l)})\,\overline{E_0}^{(l)}(\theta,\phi) \tag{4}$$

where $\overline{E_0}^{(l)}$ is a far field when $e_z=\varphi^{(l)}$ is assumed.

3. NUMERICAL RESULTS

One of assigned frequencies for a paging system in Japan is about 0.28GHz, which is much smaller than the 2nd or 3rd resonant frequency, 2.14GHz, of the planar loop antenna with $V_1=1$, $V_2=0$ excitation. (The 2nd mode is (1,0) mode, the 3rd is (0,1) mode.) This means that the antenna cannot be employed at resonance. Therefore, we cannot ignore the higher modes when we apply the cavity model to our model. For example, we can find that the less the number of the modes is, the smaller the tile angle is. In this paper, we take account of the modes from (0,0) to (5,5).

The radiation pattern in $\theta=0$ plane is depend on (1,0), (0,1), (3,0), (0,3), (5,0) and (0,5) modes. The tilt angle measured from x axis is $\phi=75^\circ$ as shown in Fig.3. Let us consider the synthetic pattern of (1,0) and (0,1) modes in $\theta=0$ plane. In this case, $\Omega_1^{(2)}=-\Omega_1^{(3)}$, $\Omega_2^{(2)}=\Omega_2^{(3)}$, $\Omega_2^{(2)}/\Omega_1^{(2)}=-1.74$, and the far field is given as

$$\overline{E}=(\Omega_1^{(2)}+\Omega_2^{(2)})\overline{E_0}^{(2)}+(-\Omega_1^{(2)}+\Omega_2^{(2)})\overline{E_0}^{(3)} \tag{5}$$

where $\overline{E_0}^{(2)}$ is the far field of $\varphi^{(2)}$ which causes the x directed electric field to the cavity and $\overline{E_0}^{(3)}$ is the far field of $\varphi^{(3)}$ which causes the y directed field. Then, the tilt of the polarization measured from x axis could evaluate the following:

Table 1 : Relation between Frequency and Tilt Angle below resonance

Frequency(GHz)	0.05	0.10	0.20	0.28	0.30	0.40	0.50
Tilt Angle(Deg.)	90	88	83	75	72	54	28

$$\psi = \tan^{-1}\frac{-\Omega_1^{(2)}+\Omega_2^{(2)}}{\Omega_1^{(2)}+\Omega_2^{(2)}} \approx 75^\circ \qquad (6)$$

The angle is approximately agreed with one of the wire-gird calculation. More accurate agreement is observed when the higher modes are added. As a result, we can see that the far field of the antenna is not composed from only $\overline{E}_\theta^{(3)}$ and the tilt of the polarization is observed. For $\psi = 90^\circ$ tilt, it is necessary to adjust the location of the feed or short pins to satisfy the condition $\Omega_1^{(2)}+\Omega_2^{(2)}=0$.

The relation between the tilt angle and the operating frequency is shown in Table 1. The tilt angle is smaller as the frequency is lower. This is correspondent that the angle becomes small when the number of the modes is not enough.

The polarization patterns with/without the inductance effect of the feed and short pins is also shown in Fig.3. As we can see this figure, we can see that the tilt angle is large when the effect of the pins is taken in.

4. CONCLUSION

In this paper, we analyze the tilt of the polarization of the planar loop antenna using the cavity model analysis. The tilt phenomenon is mainly caused by the superposition of (1,0) and (0,1) modes. To obtain accurate orthogonal patterns, it is necessary that whether (1,0) or (0,1) is uniquely excited, and a clue is to move the location of the short pin[2]. Moreover, we can find that the inductance of the pins also contributes to the tilt of the polarization.

ACKNOWLEGEMENT

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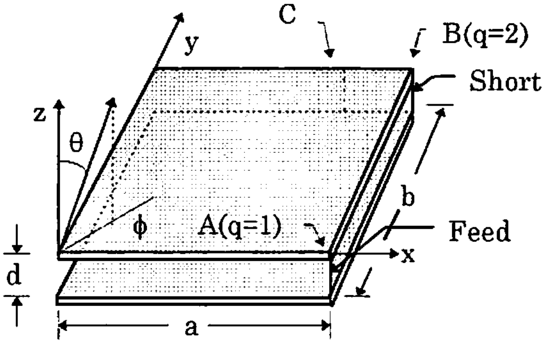

(a=b=70mm, d=6mm, $\varepsilon_r = 1$)

Fig.1 : A View of a Planar Loop Antenna

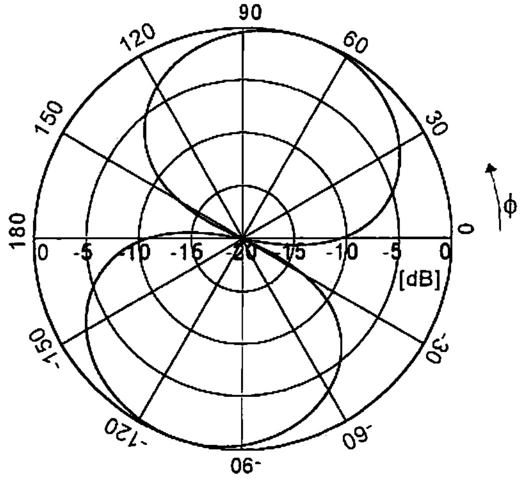

Fig.2: Polarization Pattern of the Planar Loop Antenna using MM.

($\theta = 0^\circ$ plane at 0.28GHz)

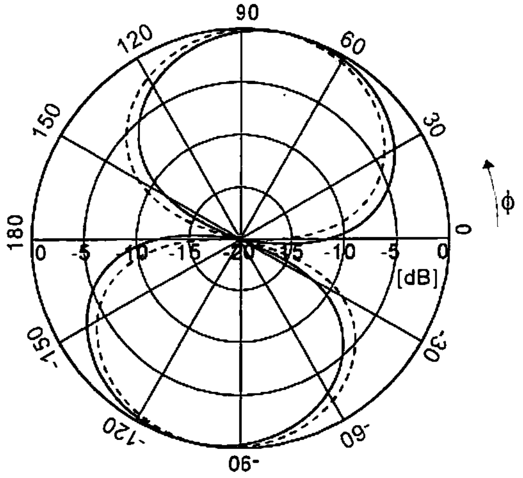

Fig 3: Polarization Pattern of the Planar Loop Antenna using Cavity Model Analysis

($\theta = 0^\circ$ plane at 0.28GHz, solid/dotted lines : with/without pin's inductance)