A Low-profile Bi-directional Cavity Antenna

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1. Introduction

In recent years, much attention has been paid to the removal of radio wave blind zones such as tunnels and underground areas in mobile communications. For indoor antennas, a low–profile structure is desired owing to an inconspicuous shape. A bi-directional pattern in azimuth is suitable since a lengthwise propagation structure is required in the tunnels and subway stations [1]. In addition, a strong radiation in the horizontal direction in elevation is desirable so as to improve the cell length. A microstrip antenna and a top-loaded monopole antenna have been used in practical applications as a low-profile antenna. However, they have drawbacks such that a microstrip antenna operates only over narrow bandwidth due to its resonant nature and its radiation directs perpendicularly against the ground plane, and a top-loaded monopole antenna has an omni-directional pattern in azimuth. An array configuration, another method for producing a bi-directional pattern, is difficult to miniaturize due to a complicated feed network with a power loss.

In this paper, the bi-directional cavity antenna for IMT-2000 pico-cell cellular phone base stations has been presented. This antenna features its low-profile structure providing a bi-directional radiation pattern in azimuth with its maximum radiation directing toward the horizontal direction in elevation, which enables the antenna to be mounted on a wall and a ceiling to establish a longitudinal propagation environment. In addition, broadband impedance characteristics suitable for IMT2000 applications are obtained.

2. Antenna Configuration and Operating Principle

The configuration of the bi-directional cavity antenna is shown in Fig. 1. Two wide slots are formed on the top metal plate of the rectangular cavity symmetrically. The feed probe connected to the central top plate is located at the center of the bottom plate forming the ground plane.

In this structure, the central top plate and the ground plane are regarded as a parallel plate transmission line with two shorted ends, creating the electric fields mainly generated at the two open edges between the central top plate and the bottom plate of the cavity as shown in Fig. 2. The electric fields along y-axis are considered to have sinusoidal distributions with a maximum at the center and minima at the two shorted ends of the side metal plates, and to be equal in magnitude and in phase due to its symmetrical configuration with respect to y-axis. Thus, we can assume the two equivalent magnetic currents with sinusoidal distributions, which are equal in magnitude and opposite in phase as shown in Fig. 3.

Figure 4 shows the operating model for this antenna representing the magnetic currents. As can be seen from Fig. 4 (a), the radiation pattern in the horizontal plane is obtained by the array comprising the two linear magnetic currents excited opposite in phase. On the other hand, in Fig. 4 (b), the radiation pattern in the vertical plane is obtained by the array comprising the two isotropic magnetic point sources excited opposite in phase. A total pattern of an array is obtained from the product of the element pattern and the array factor [2].

Figure 5 shows the radiation patterns for the magnetic currents of L=120 mm at 1.93GHz. As can be seen from Fig. 5 (a), a bi-directional pattern in the horizontal plane is obtained since both the element pattern of the linear magnetic source and the array factor are bi-directional with respect to x-axis in the horizontal plane. In Fig. 5 (b), the radiation pattern in the vertical plane has a maximum in the horizontal direction since the array factor is also bi-directional with respect to x-axis in the vertical plane.

3. Experimental Results

The dimensions of the prototype antenna are determined to be 120W×120L×12H mm^3, and Wc=1.6mm, Ws=30mm so that good VSWR characteristics for a 50-Ohm feed line at 1.93GHz are achieved with a low profile structure. The radiation patterns of E_θ components at 1.93GHz are shown in Fig. 6. The calculated results by means of the moment method are also shown in the figure. As shown from the figure, the experimental results are in good agreement with calculated ones. In Fig. 6 (a), the bi-directional pattern in the horizontal plane is obtained as in Fig. 5 (a). However, the radiation pattern in the vertical plane shown in Fig. 6 (b) is different from the one shown in Fig. 5 (b). This discrepancy is caused by diffracted waves from the edges of the antenna due to the finite ground plane [3]. The experimental VSWR at the input terminal as a function of frequency is shown in Fig. 7. The input impedance at 1.93GHz is 48.0 + j5.5 Ohms so that a good matching condition to a 50-Ohm feed line is obtained. As can be seen from the data, the antenna provides VSWR of better than 2:1 over the frequency range of 1.87GHz to 2.12GHz, which corresponds to a fractional bandwidth of 13%, satisfying broadband impedance characteristics for the 3rd generation cellular radio.

References

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[2] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 2nd. ed. John Wiley & Sons, 1998.

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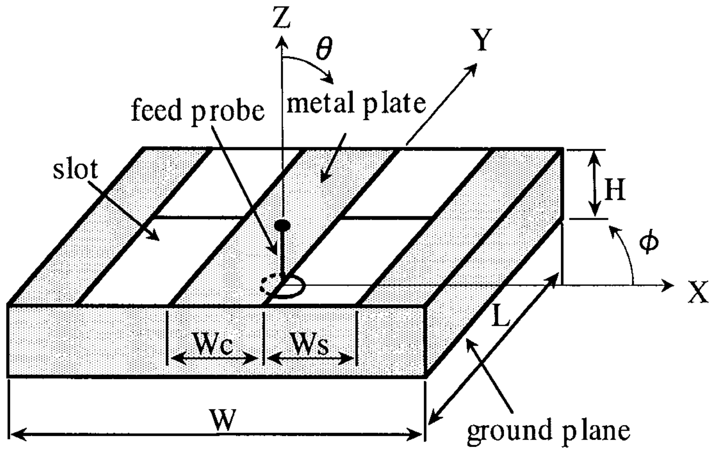


Fig.1 Configuration of the bi-directional cavity antenna

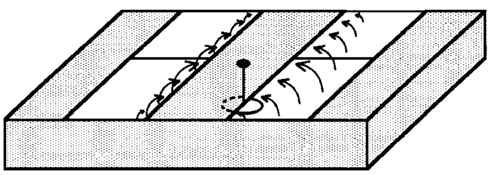


Fig. 2 Electric field distributions

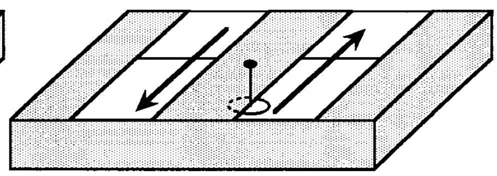
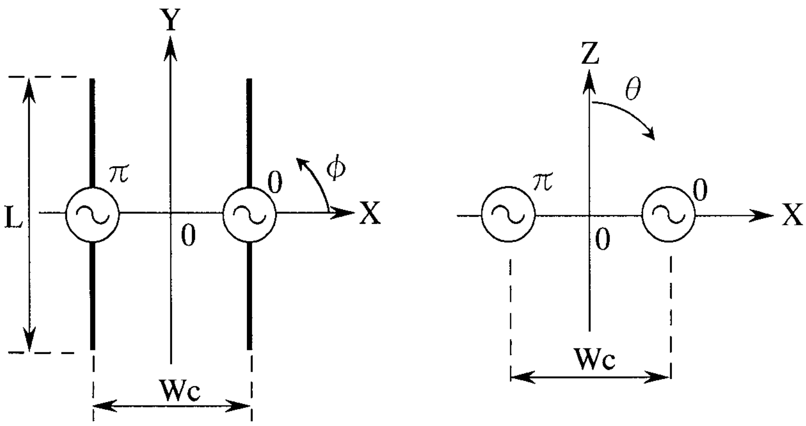
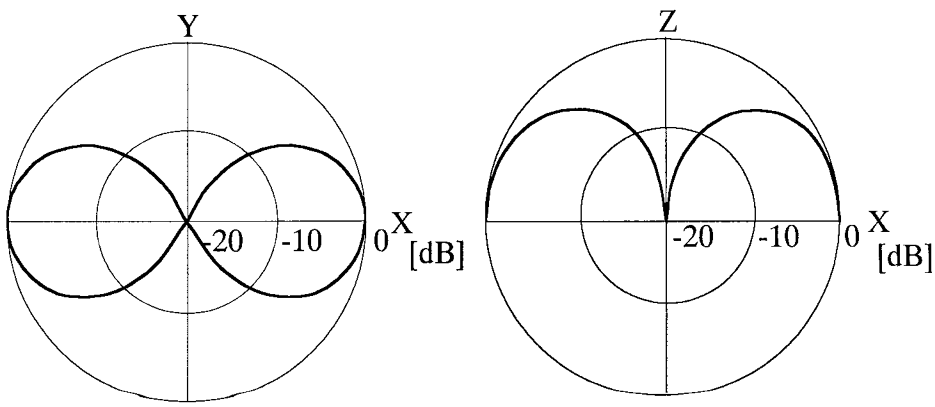


Fig. 3 Equivalent Magnetic currents



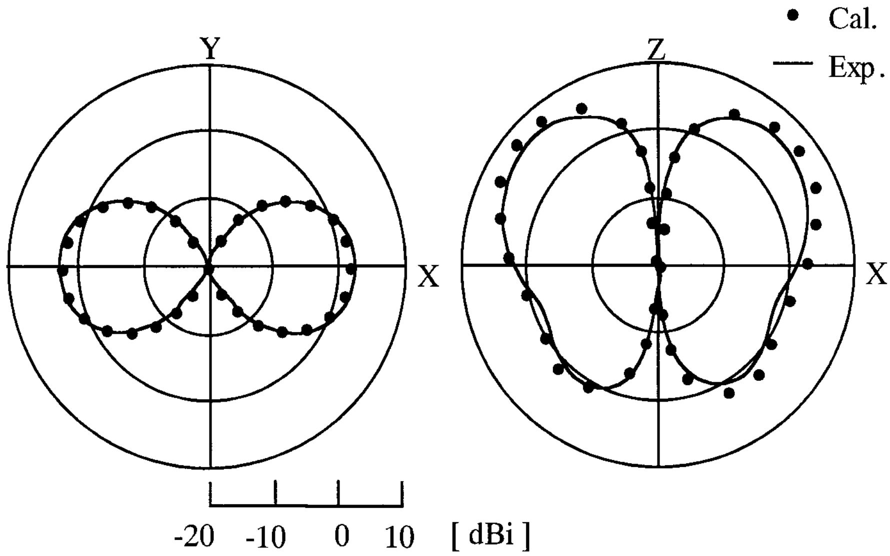
(a) Horizontal plane (b) Vertical plane

Fig. 4 Operating models representing magnitic currents



(a) Horizontal plane (L=120mm) (b) Vertical plane (W=∞)

Fig. 5 Radiation pattern of the operating models



(a) Horizontal plane (b) Vertical plane

Fig. 6 Radiation patterns

W=L=120mm, H=12mm, Wc=1.6mm, Ws=30mm

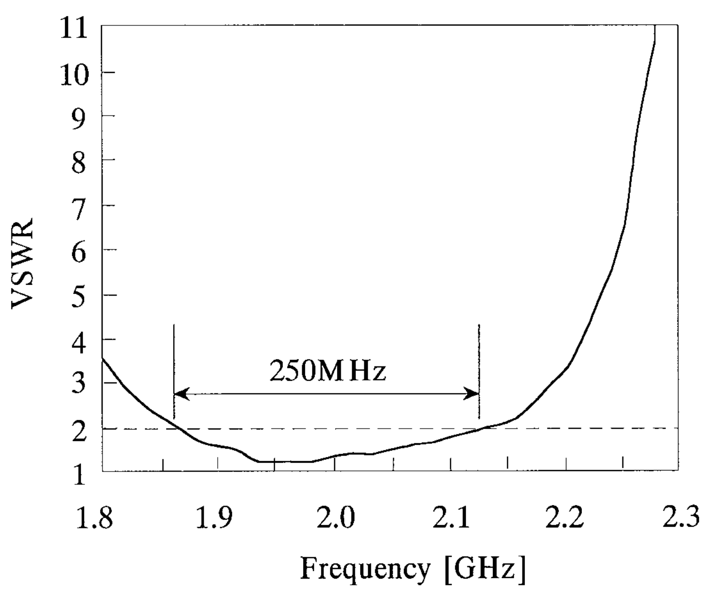


Fig. 7 VSWR characteristics