A CARD-TYPE WIDE BAND ANTENNA

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1. Introduction

With the emergence of new wireless communications systems, such as the ultra wide band (UWB) system, wideband antennas have been receiving attention. Suh and et al. have already revealed that a teardrop-shaped monopole above a ground plate has a wideband VSWR characteristic [1]. Taniguchi and Kobayashi have found that a small monopole above a ground plate operates with low VSWR over a wide frequency band (ranging from 3 GHz to 11 GHz) [2].

This paper presents a new wide band antenna, called an elliptical ring antenna (ERA) [3]. The ERA is composed of an elliptically shaped ring radiation element and a ground plate, both lying in the same plane and forming a flat structure (card-type structure). This thin card-type structure differs from the monopole antennas in [1][2], where the monopole stands at right angles to a ground plate. The card-type structure facilitates the use of the ERA in PC card devices for personal computers or for use inside mobile phone handsets [4].

Analysis of the ERA is performed using the finite-difference time-domain method (FDTDM) based on Yee's algorithm. The radiation characteristics, including the VSWR, radiation pattern, and gain, are presented and discussed.

2. Configuration

Fig. 1 shows an ERA. The ERA is composed of an elliptical ring conductor and a conducting ground plate. The elliptical ring conductor (specified with outer major axis $2a_{out}$, outer minor axis $2b_{out}$, inner major axis $2a_{in}$, and inner minor axis $2b_{in}$) and the ground plate (of area $L_x \times L_y$) are made of a thin conducting film. The ERA is excited by a voltage source between point P_0 and point Q, where the distance between point P_0 and point Q is denoted by Δ_{FD}.

To simplify the discussion, the following parameters are pre-selected: $(2a_{out}, 2b_{out})$ = (24 mm, 15 mm) for the outer periphery of the ring conductor, (L_x, L_y) = (45 mm, 45 mm) for the ground plate, and Δ_{FD} = 0.375 mm for the feed spacing. The remaining parameters $(2a_{in}, 2b_{in})$ for the inner periphery of the ring conductor are varied subject to the objectives of the analysis.

3. Analysis and discussion

Fig. 2 shows the VSWR as a function of frequency, where the inner minor axis $2b_{in}$ is held at 7.5 mm $\equiv$ $2b_{in,\,0}$ and the inner major axis $2a_{in}$ is varied. The VSWR is evaluated for a 50-ohm line: VSWR = ($|Z_{in} + 50|$

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$+ |Z_{in} - 50|) / (|Z_{in} + 50| - |Z_{in} - 50|)$. Note that the input impedance Z_{in} is calculated from the ratio of the Fourier transform of $V_{in}(t)$ to the Fourier transform of $I_{in}(t)$, where $V_{in}(t)$ is the voltage applied to the input terminals and $I_{in}(t)$ is the current at the input terminals, obtained by integrating the magnetic field $\mathbf{H}(t)$ around the voltage source region. As seen from Fig. 2, if the inner major axis $2a_{in}$ is appropriately chosen, the ERA has low VSWRs over a wide frequency band; VSWRs of less than 2 are obtained within a frequency range of 2.9 GHz to 11 GHz, except for $2a_{in} = 18$ mm. This frequency range includes the UWB system frequency band (3.1 GHz to 10.6 GHz).

Next, the effects of the inner minor axis $2b_{in}$ on the VSWR are investigated. For this, the inner major axis $2a_{in}$ is held at 12 mm $\equiv 2a_{in,0}$. Fig. 3 shows the VSWR as a function of frequency. It is found that effects of the inner minor axis $2b_{in}$ on the VSWR are not remarkable. Low VSWRs are obtained over a frequency range of 2.9 GHz to 11 GHz. Note that, if $2a_{in}$ has a larger value than $2a_{in,0}$, the VSWR deteriorates (not illustrated).

Fig. 4 shows the current distributions ($J = J_x \hat{x} + J_y \hat{y}$, where J_x and J_y are complex numbers) over the elliptical ring and ground plate for $(2a_{in}, 2b_{in}) = (2a_{in,0}, 2b_{in,0})$ at f = 3.1 GHz. It is found that the current over the ground plate is concentrated at its edges. It is also found that the amplitudes of the current components J_x and J_y on the ring are almost symmetric with respect to the y-axis. In addition, detailed analysis reveals that the J_x current components at symmetric points with respect to the y-axis on the ring are nearly 180 degrees out of phase, while the J_y current components at the same symmetric points are nearly in phase.

Fig. 5 shows representative radiation patterns at 3.1 GHz and 10.6 GHz, where $E_\theta(r, \theta, \phi)$ and $E_\phi(r, \theta, \phi)$ are the radiation field components. These radiation field components are obtained using the equivalence principle [5]. For the equivalence principle, the electric current density $\mathbf{J}_s$ ($= -\mathbf{H} \times \hat{n}$) and magnetic current density $\mathbf{M}_s$ ($= \mathbf{E} \times \hat{n}$) are used, where $\mathbf{H}$ and $\mathbf{E}$ are the magnetic and electric fields on a surface enclosing the antenna, respectively, and $\hat{n}$ is the outward unit vector normal to the enclosing surface. As seen from Fig. 5(a), the co-polarization component in the x-z plane at 3.1 GHz is E_ϕ and the cross-polarization component is E_θ. As the frequency increases, the cross-polarization component E_θ increases due to the contribution from the current J_x, as shown in Fig. 5(b). However, note that polarization purity is not a requirement for mobile communications.

The gain in the z-direction ($\theta = 0$) is +1.3 dBi at 3.1 GHz and –1.9 dBi at 10.6 GHz, which is evaluated on the basis of the electric field components $E_\theta(r, \theta, \phi)$ and $E_\phi(r, \theta, \phi)$, obtained using the equivalence principle: $G(\theta, \phi) = [(|E_\theta(r, \theta, \phi)|^2 + |E_\phi(r, \theta, \phi)|^2) / 2Z_0] / [P_{in}/(4\pi r^2)]$, where Z_0 is the intrinsic impedance of free-space ($120\pi\ \Omega$) and P_{in} is the power input to the antenna. The frequency response of the gain reveals that the gain in the z-direction varies between –1.9 dBi and +4.3 dBi within a frequency range of 3.1 GHz to 10.6 GHz.

4. Conclusion

An ERA, composed of an elliptical ring conductor and a conducting ground plate, is investigated using the FDTDM. The ring and ground plate are specified with parameters ($2a_{out}$, $2b_{out}$, $2a_{in}$, $2b_{in}$) and (L_x, L_y), respectively. It is emphasized that the ring and ground plate lie in the same plane, forming a card-type structure suitable for, for example, mobile PC devices.

Analysis reveals that an appropriate choice of ($2a_{out}$, $2b_{out}$, $2a_{in}$, $2b_{in}$) leads to a wide VSWR frequency band. It is found that an ERA with ($2a_{out}$, $2b_{out}$, $2a_{in}$, $2b_{in}$) = (24 mm, 15 mm, 12 mm, 7.5 mm) and (L_x, L_y) =

(45 mm, 45 mm) shows low VSWRs of less than 2 within a frequency range of 2.9 GHz to 11 GHz. It is also found that, as the frequency increases, the cross-polarization component increases. However, this is not a factor when using the antenna for mobile communications. The frequency response of the gain reveals that the gain in the z-direction varies between –1.9 dBi and +4.3 dBi within a frequency range of 3.1 GHz to 10.6 GHz.

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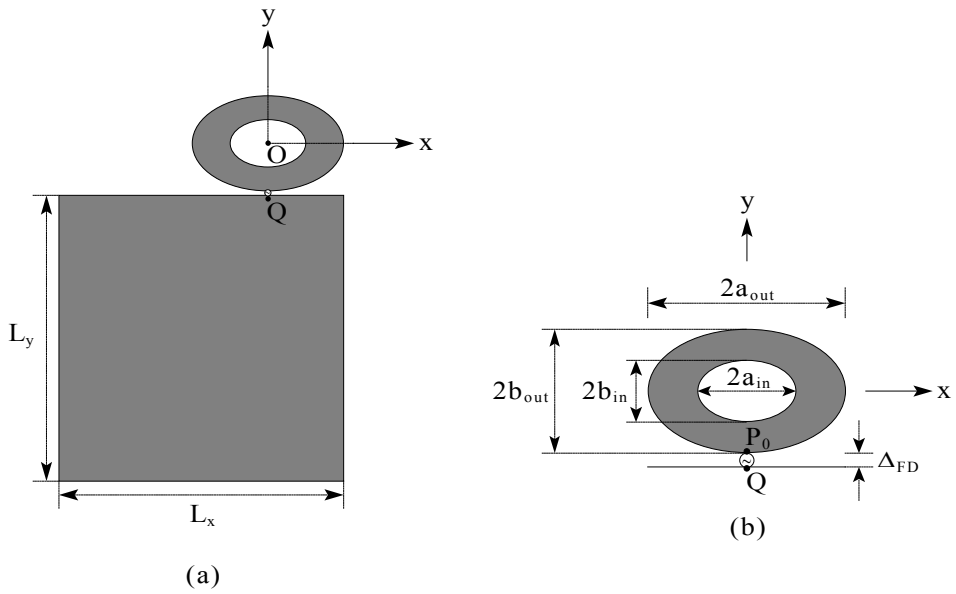

Fig. 1. An elliptical ring antenna.

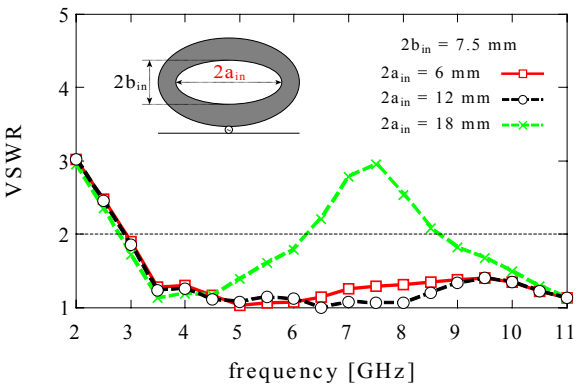

Fig. 2. VSWR as a function of frequency for $2b_{in} = 7.5$ mm $\equiv 2b_{in,0}$.

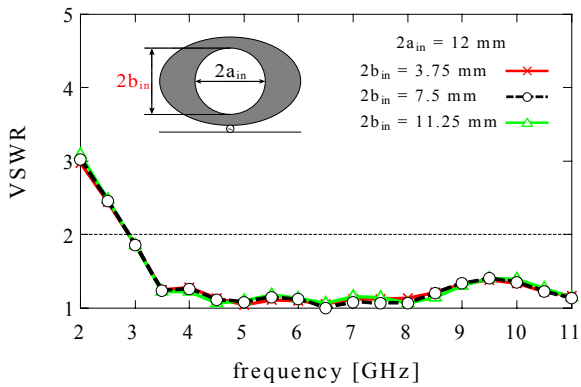

Fig. 3. VSWR as a function of frequency for $2a_{in} = 12$ mm $\equiv 2a_{in,0}$.

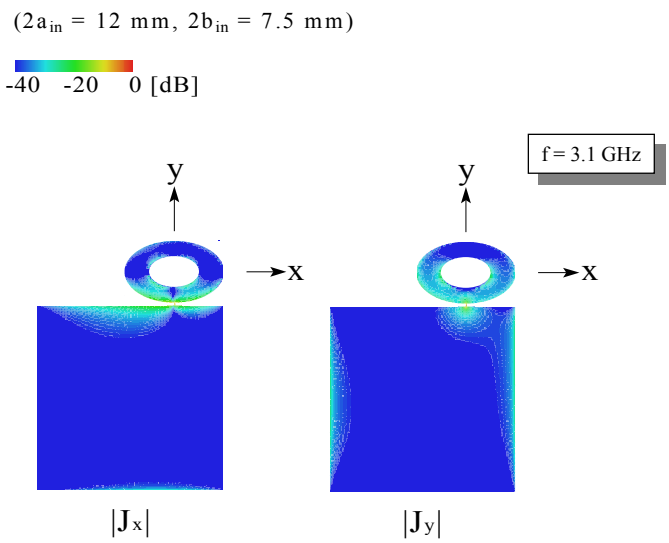

Fig. 4. Current distribution at 3.1 GHz.

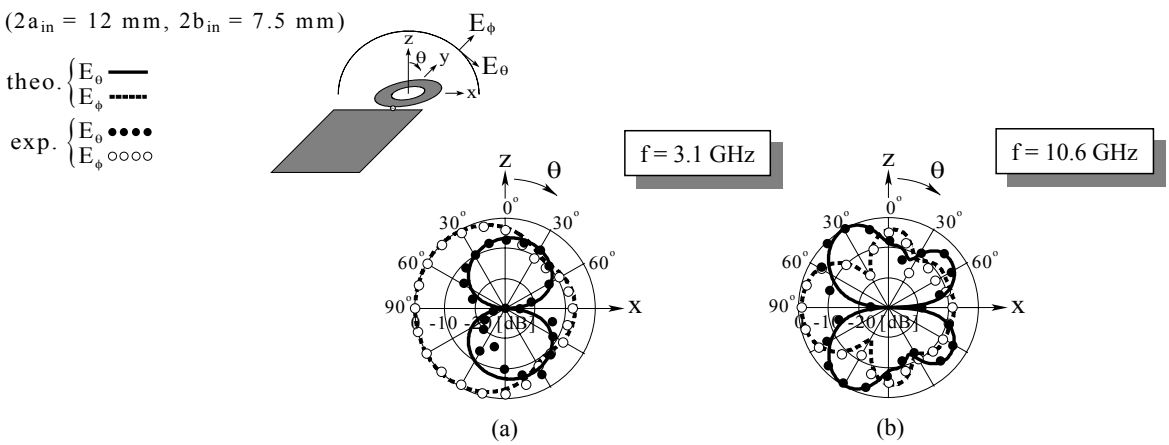

Fig. 5. Radiation patterns. (a) 3.1 GHz. (b) 10.6 GHz.