

An Elliptical Ring Excited by a Probe Radiating Bidirectional Pattern

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1. Introduction

It is well-known that cellular mobile system plays a role for life utility [1]. Therefore, the investigations of the mobile antenna at the base station are significant. Generally, the omnidirectional antenna is employed for circle area. However, it is evident that a bidirectional antenna that has suitable characteristics is desired for long and narrow path service area application such as the highway, the tunnel, and the corridor. Since the demand on cell is very large, cost effective must be considered. The authors have proposed a bidirectional antenna using a probe excited circular and rectangular rings [2]-[3]. However, the antenna characteristics such as half power beamwidth and directivity primarily depends on the ring dimensions. The ring cross section can be designed to achieve the dominant mode propagation. The elliptical ring has an advantage that the antenna characteristics can be chosen by varying the semi-major and semi-minor axes. This can be done by changing the eccentricity or the axial ratio. This paper describes the principle of an elliptical ring excited by a probe radiating bidirectional pattern. A decision of ring dimension that yields the propagation in dominant mode is selected. The design procedure to realize the optimum ring length that provides the maximum directivity is calculated subsequently. The fabricated antenna at the frequency of 1.9 GHz is measured and compared with the calculated results.

2. Antenna Structure

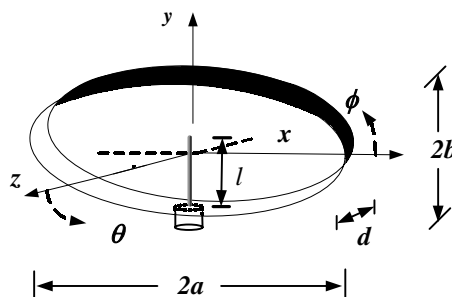


Fig. 1 An elliptical ring excited by a probe

The structure of an elliptical ring excited by a probe radiating bidirectional pattern consists of a linear electric probe of length l aligned along y axis, and this probe is surrounded by an elliptical ring of the semi-major axis a and semi-minor axis b . At the two ends of the ring, there are elliptical apertures on the planes $z = -d/2$ and $z = d/2$, respectively, as shown in Fig. 1.

3. Radiation Characteristics

Since the cross section of an elliptical ring is the same as an elliptical waveguide, the ring dimension must be properly chosen in dominant mode can be propagated. The mode configuration of this structure depends on the semi-major axis and semi-minor axis. When the probe directs in y direction, the

TE mode can be excited. The dominant mode for this case is TE_{C11} [4]-[5]. Therefore, the ring dimension of a and b should be designed for TE_{C11} mode and prohibited the higher order modes. It is found that the adjacent TE mode is TE_{S11} . The wavelength at the operating frequency can be written as

$$\lambda_{C11} < \lambda < \lambda_{S11} \quad (1)$$

where λ_{C11} and λ_{S11} are the cut-off wavelength of the TE_{C11} and TE_{S11} modes, respectively. Subsequently, the ring length must be designed. It is obvious that the ring length has influence to the beamwidth and directivity. Fig. 2 shows the radiation pattern in E-plane and H-plane of a bidirectional antenna using an elliptical ring excited by a probe for different ring lengths. It is noted that when the ring length is shorter than 0.15λ , the dominant mode can not be realized due to the complex field configuration near the probe. So, the ring length of 0.15λ is the shortest length to realize dominant mode. When the ring length is longer than 0.15λ , it is evident that the beam will be wider. Fig. 3 shows the radiation characteristics such as half power beamwidth and directivity of the antenna for various ring lengths. It can be observed that the beamwidth both E-plane and H-plane will be wider when the ring length is longer. The optimum ring length is 0.15λ that can obtain the beamwidth in E-plane and H-plane of 83 and 46 degrees, respectively. The maximum directivity is 7.07 dBi.

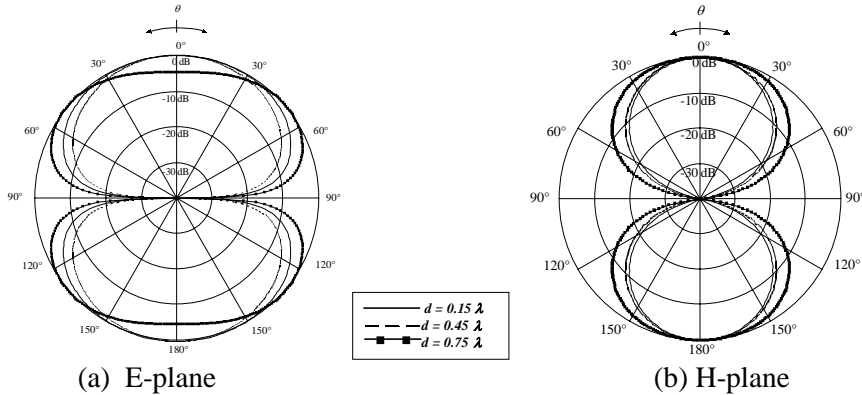


Fig. 2 Radiation pattern for various ring lengths

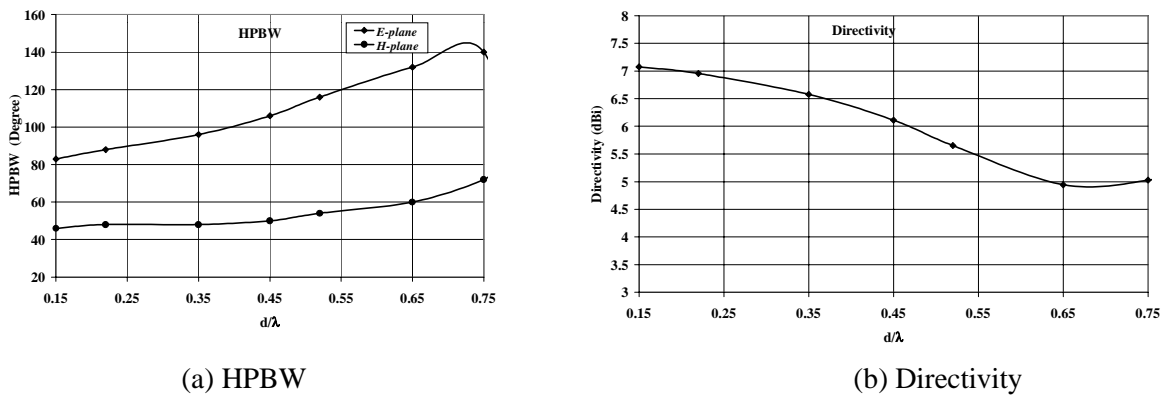


Fig. 3 Radiation characteristics

4. Experiments

In order to verify the proposed antenna, the prototype of an elliptical ring excited by a probe is fabricated at the operating frequency of 1.9 GHz. The antenna dimension can be tabulated in table 1.

Table 1 Antenna dimension

Dimension	Size at 1.9 GHz
a	7.5 cm.
b	2.5 cm.
d	2.3 cm.
l	4.0 cm

The photograph of the antenna prototype is depicted in Fig. 4. The radiation pattern in E-plane and H-plane are measured to compare with the calculation as illustrated in Fig.5. It is seen that the results are in good agreement especially in the 3 dB region. The deep of the null in the experiment is shallower because the coupling between two apertures of ring is omitted in the calculation. The matching of the antenna and the transmission line can be achieved by adjusting the probe length (l) to be lengthened or shortened. The impedance characteristics such as input impedance, reflection coefficients and SWR of optimum matching condition are shown in Fig. 6. The input impedance at the operating frequency is $52.338 - j1.4063 \Omega$ that corresponds to the reflection coefficient of -31.475 dB and SWR 1.0548: 1.



Fig. 4 Photograph of the antenna prototype

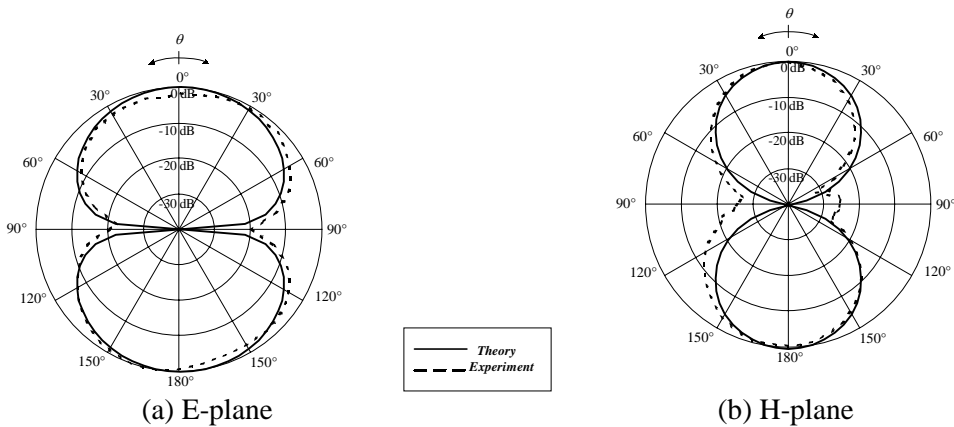


Fig. 5 Measured radiation pattern

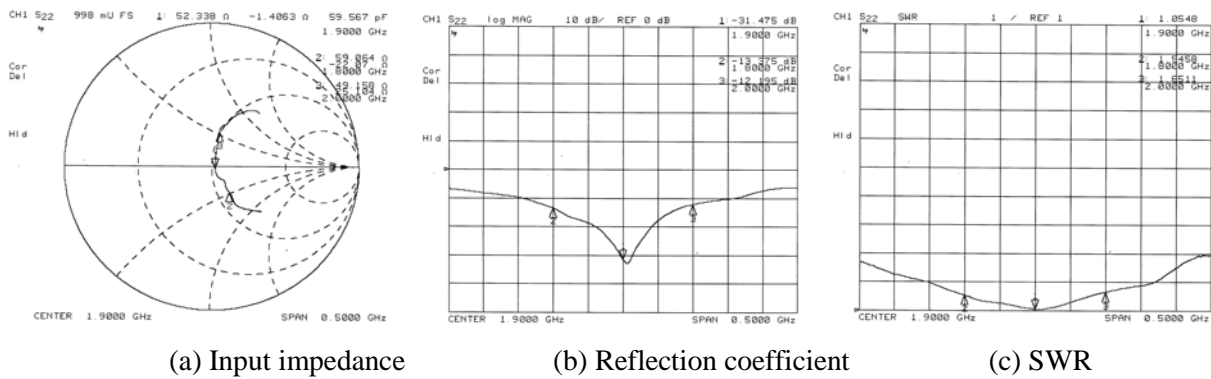


Fig. 6 Experimental results

5. Conclusions

An elliptical ring excited by a probe is proposed in this paper for radiating bidirectional pattern. The proposed antenna is suitable for long and narrow path service area of mobile communications. The radiation characteristics depend on the ring dimension. The semi-major and semi-minor axes are selected to let only the dominant mode can be propagated. The ring length that yields the maximum directivity is clarified. These parameters are used as the guide line for antenna design. The matching condition can be achieved by adjusting the probe length. From the results, it is revealed that the proposed antenna is efficient to use for the application with simple structure and cost effective.

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