Broadband Characteristics of Rounded Semi-Circular Antenna

Taisuke IHARA and Koichi TSUNEKAWA
Research and Development Department
NTT Mobile Communications Network Inc.
1-2356 Take, Yokosuka-Shi, Kanagawa, 238-03 Japan
ihara@mlab.nttdocomo.co.jp

1. Introduction

Among the many kinds of broadband antennas that have been investigated and developed, the circular and semi-circular element type of antenna have been noted for their simple configuration and omnidirectional pattern. However, they need a relatively large plane element, i.e., the diameter of the element is about a quarter wavelength in terms of their lower frequency limit.

In this paper, a small broadband antenna, based on the semi-circular element type, is proposed and its properties are studied experimentally and analytically. The proposed antenna achieves almost the same bandwidth and lower VSWR characteristics over the operational band as the semi-circular element type, which has a three-times wider element than the proposed type. The reasons for the low VSWR characteristics are clarified through numerical analysis of current distributions on the element and the mutual couplings between the arc segments of the element.

2. Antenna Structure

The proposed and basic antenna structures are shown in Figs. 1(a) and 1(b) respectively. The element is a curved-planar semi-circular cylindrical element and is placed above the ground plane such that the center of the arc faces the ground plane. The feed point is placed between the center of the arc and the ground plane. The antenna is fed by a coaxial cable that penetrates the ground plane perpendicularly. Therefore the element is rounded and the radiator width is reduced to about 1/3 that of the plane type.

3. Experimental Results

The measured input VSWR of the antenna is shown in Fig. 2. The solid and the broken lines indicate the rounded type and planar type respectively. The measurement was made on a ground plane of 300×300 mm, and the element height and diameter were 75 mm and about 50 mm designed to operate above the 800 MHz frequency band. The measured bandwidth with VSWR less than 1.5 is achieved from 800 MHz to 13 GHz. Figure 2 shows that the input VSWR of the rounded element improves in degrees and decreases periodically with variations in frequency compared to the planar type throughout the measured frequency bands.

Figure 3 shows the measured horizontal normalized radiation pattern at 0.9, 1.5, and 2.2 GHz. At 0.9 GHz, near the low-frequency limit of the antenna, the radiation pattern is omnidirectional. However, the radiation pattern has directionality as the frequency increases and this direction is in agreement with the direction that the element bends.

4. Numerical Analysis

Input VSWR

A numerical analysis is performed to evaluate the improvement in input VSWR characteristics. A pictorial view of the rounded element and the planar element numerical models for the moment method computer simulation are shown in Fig. 4. These numerical models are wire grid models that approximate the surface section. The calculated input VSWR are shown in Fig. 5. The calculation shows that rounded-type VSWR is smaller in degree and in variation over the calculated frequency band. Therefore this result is in agreement with the experimental data, thus showing that numerical models are appropriate.

Current distribution

Figure 6 shows the current amplitude distribution along the arc and the center of the element. It is clear that the higher current flows on the arc of the element in both the rounded and planar elements. It is also calculated that the current which flows on the arc is higher than any other part of the element. Therefore, it seems that the arc of planar or rounded semi-circular elements are important to the radiation mechanism.

Figure 7 shows the current distribution of the arc for both elements at 2.2 GHz and 2.8 GHz. These frequencies represent the high and low VSWR value of planar type shown in Fig. 5. In this figure, the current of the rounded element is smaller than that of the planar elements near the end of the arc at either frequency. It also shows the same tendency of the element current distribution at the other frequencies. It is found that current reflection from the end of the arc is decreased by changing the shape of the element. This changing current decreases the input VSWR.

Mutual impedance between segments

Mutual couplings between the arc segments on the rounded element are noteworthy and spur on an investigation as to why the current decreases toward the arc end, as shown in Fig. 7. In the moment method, a current distribution is determined by the impedance of each segment that flows through the current. The impedance of a segment is given as

$$Z_0 = Z_S + Z_C$$

where Z_0 is the impedance of the segment, Z_s is the self impedance of the segment, and Z_c is the total impedance of the mutual impedance between the segment and the other segments.

The arc segments of the semi-circular element have the same self impedance Z_s in both rounded and planar types because the size of each segment is the same. Then, the mutual couplings between two arc segments, where they are placed at the same height (Z), in the rounded and planar types are calculated as shown in Figs. 8 and 9 respectively. In the rounded type, the mutual couplings of the arc segments become higher toward the arc edge. On the other hand, in the planar type, they are still small near the arc edge. It is shown that the mutual impedance Z_c of the arc segments is increased by deforming the former plane semicircular element to the rounded one and this causes an increase in the segment impedance Z_0 of the arc segment. As a result, the effects of curving an element is the same as the impedance loading in the arc of a semicircular element and the loading impedance improves the VSWR characteristics.

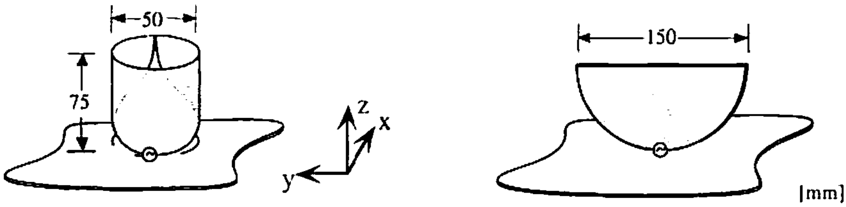
5. Conclusion

A new type of small broadband antenna is proposed. It is constructed to wrap around a semi-circular antenna element. This new antenna provides 0.8 - 13 GHz (VSWR < 1.5) bandwidth and over 0 dB in gain even at 75 mm in height and with a 50-mm radius cylinder. The broadband and radiation mechanism of this antenna was analyzed using the moment method. As a result, it was clarified that the arc of the element, where current flows intensively, plays a major role in the radiation and increasing of mutual coupling caused by deformation to the round element provides a low VSWR characteristic and wide bandwidth.

Reference

[1] R. M. Taylor, "A Broadband Omnidirectional Antenna," IEEE AP-S International Symposium, pp. 1294, 1994.

[2] S. Honda et al., "Characteristics of a disk monopole Antenna," Proceeding of the 1991 IEICE Shinetu Chapter Conference, 4 (1991.10)



(a) Rounded semi-circular monopole
(Proposed antenna)

(b) Semi-Circular monopole
(Basic antenna)

Fig. 1 Antenna structure
(lower frequency limit : 0.8 GHz)

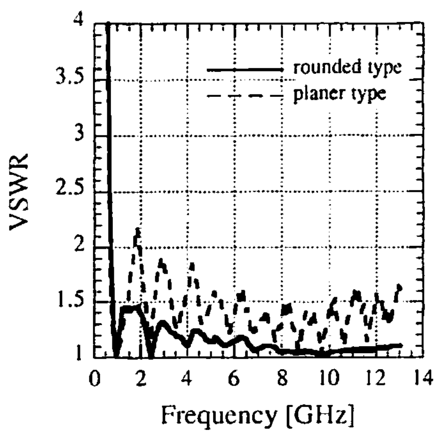


Fig. 2 Frequency characteristics of measured input VSWR

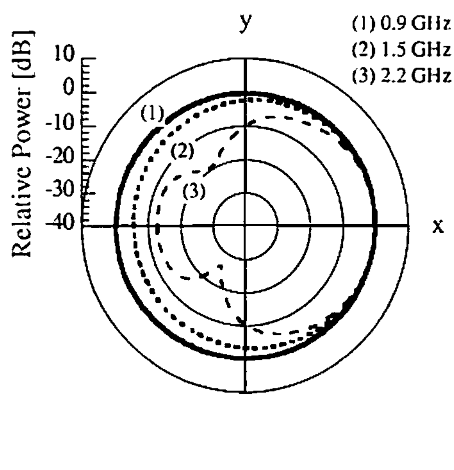


Fig. 3 Measured horizontal radiation pattern at 0.9, 1.5, 2.2 GHz (rounded type)

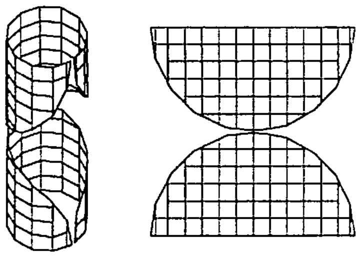


Fig. 4 Numerical antenna models

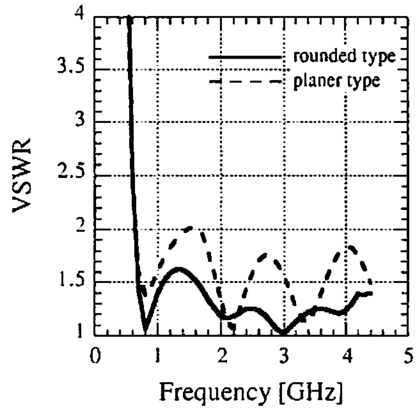


Fig. 5 Frequency characteristics of calculated input VSWR

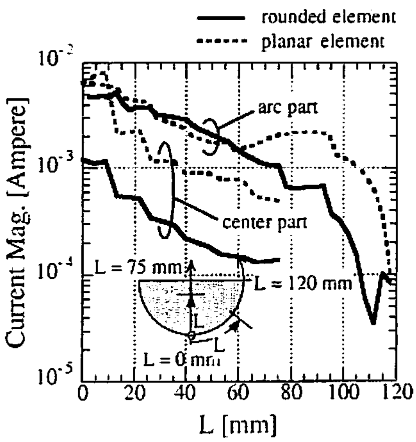


Fig. 6 Current distribution on the arc and center of the rounded and planar elements (f = 2.2 GHz, feed : 1V)

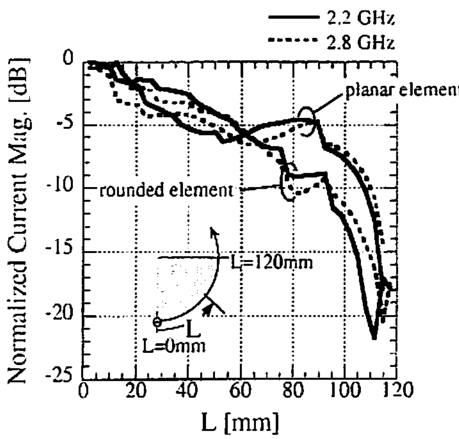


Fig. 7 Current distribution on the arc of the rounded and planer elements

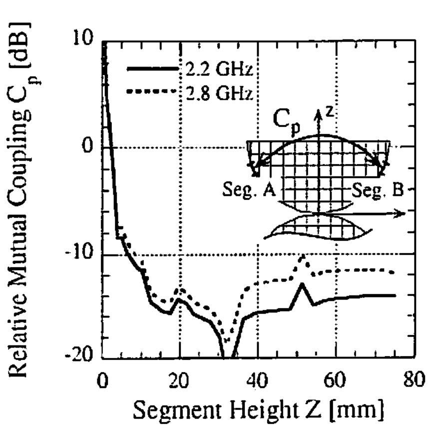


Fig. 8 Mutual coupling between the segments at the arc of the planar element

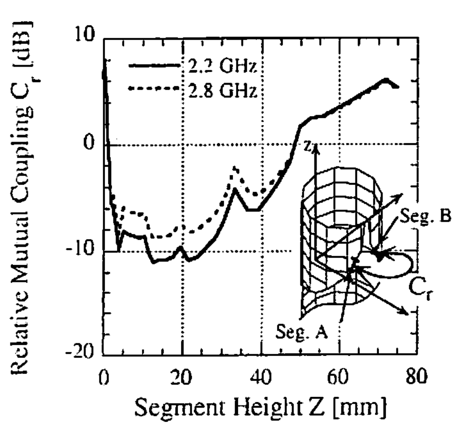


Fig. 9 Mutual coupling between the segments at the arc of the rounded element