Collinear Super Turnstile Antennas for 5G Sub-6 Base Station

Sirao Wu[1*], Lin Wang[2], Tetsu Kou[2], and Qiang Chen[1]
[1]Graduate School of Engineering, Tohoku University, Japan
[2]Nihon Dengyo Kosaku Co., Ltd., Japan
[*]email: wu-s@ecei.tohoku.ac.jp

***Abstract* - In the fifth-generation (5G) wireless communications, due to the advantages such as wide range and low cost, sub-6 frequency band is widely used. It is a challenge to develop the antennas for sub-6 base stations which are wide band, high gain and compact. In this paper, a center-fed collinear antenna array with a compact size is developed based on the super turnstile antenna. The antenna array works at 4.7 GHz, omni radiation pattern is obtained with the average gain of 8 dBi at a wide bandwidth of about 13%.**

***Keywords* — Super turnstile antenna, collinear antenna array, omnidirectional, sub-6.**

I. INTRODUCTION

5G communication is a network designed to connect virtually everything and everyone together including machines, objects and devices. To satisfy this massive Internet of Things (IOT) ecosystem, a large number of compact base stations with small cells are required. The super turnstile antenna [1] has the advantages of high gain in a range of wide bandwidth with omni radiation pattern, and it is widely used for VHF-TV broadcasting around the world [2]. Because the shape of the unit resembles the bat's wing, it is also called batwing antenna. The batwing radiator which is the element of the super turnstile antenna has broadband characteristics [3,4], so it is still using for TV broadcasting in Japan for the excellent characteristics of broadband and omnidirection which are also needed for the compact sub-6 base stations. Unlike the large base stations which have sufficient space to feed each array element separately, for compact base stations, it is required to reduce the number of ports as much as possible to reduce the size. Center-fed collinear array is applied to overcome this problem in this research.

In this paper, a collinear super turnstile antenna for Sub-6 base station is proposed. It works at 4.7 GHz. By implementing center feeding, the number of the ports is effectively reduced compared with the traditional super turnstile antenna for VHF-TV. By adjusting the distance between the turnstile antenna units, omni radiation patterns are achieved in wide bandwidth with the average gain of 8 dBi.

II. ANTENNA CONFIGURATION

The proposed antenna consists of 6 turnstile units as shown in Fig.1. Each unit is formed by two orthogonalized batwing antennas which are lying on *x*-axis and *y*-axis directions separately. The directivity of single batwing is the same as dipole. In order to obtain an approximately circular radiation pattern, the two orthogonalized batwing antennas should be fed with a 90-degree phase difference. Therefore, the collinear antenna array is fed by two ports in *x* and *y* directions respectively with the phase difference of 90-degree. And the ports are located in the center of the collinear array to avoid the beam tilt in horizontal plane

The distance between each turnstile unit is as shown in Fig. 1(c). Here, d=40 mm, d_1=d_2=60 mm which is approximately approach to one wavelength of 4.7 GHz. According to the simulation, d is strongly relative to the results of impedance matching, so it is determined by optimization. d_1 and d_2 are about one wavelength to make each unit radiate in phase, so that good radiation performance can be realized. This presented antenna can be restrained in a 290 mm-long circular cylinder with the diameter of 50 mm.

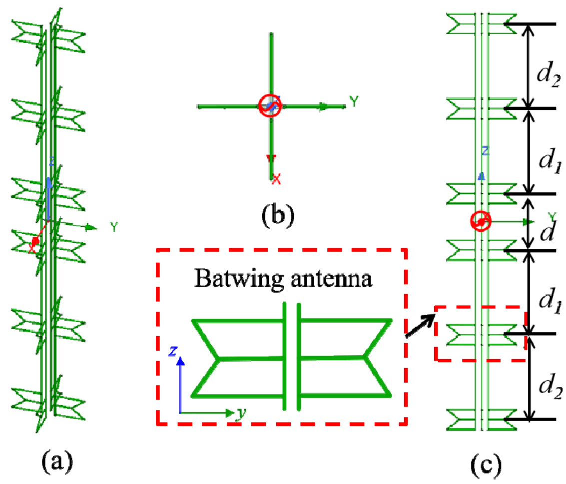

Fig. 1. Antenna configuration: (a) Collinear super turnstile antenna; (b) Top view; (c) Side view (*yoz* plane).

III. ANTENNA SIMULATION

Fig. 2 shows the radiation patterns of the proposed antenna at 4.4 GHz, 4.7 GHz and 5 GHz respectively. By feeding the orthogonalized elements with a phase difference of 90-degree, an approximately circular radiation pattern is obtained to achieve the omni characteristic which is similar with the super turnstile antenna for broadcasting. A stable high gain performance is achieved at above frequencies. The gain varies within 3 dB on the horizontal plane with an average value of 8.3 dBi at 4.4 GHz. Although the average gain decreases along with the frequency increasing, leading to a deteriorative roundness of the radiation pattern in horizontal plane. Under the limitation of small size, and the center-fed antenna array needs only two ports, the degeneration is acceptable.

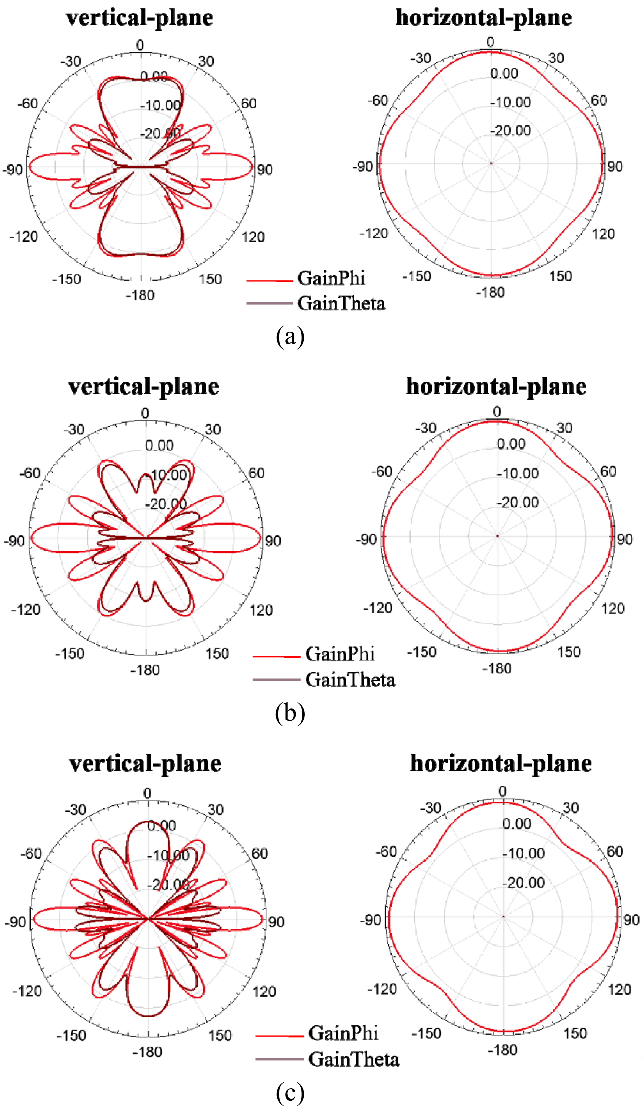

Fig. 2. Radiation patterns of the super turnstile antenna array:(a) 4.4 GHz; (b) 4.7 GHz ; (c) 5 GHz.

The gain of the proposed antenna is shown in Fig. 3. Because of a stable omni performance in horizontal plane, the gain in vertical plane is only presented to illustrate the influence of the distance between units. In order to make the units radiate in phase, d_1 and d_2 are required to be uniform close to one wavelength. As they are increasing at the same time, the frequency band of high gain shifts to a low frequency band. That means the high gain frequency band can be changed to our desired frequency band by adjusting d_1 and d_2 without changing the antenna size.

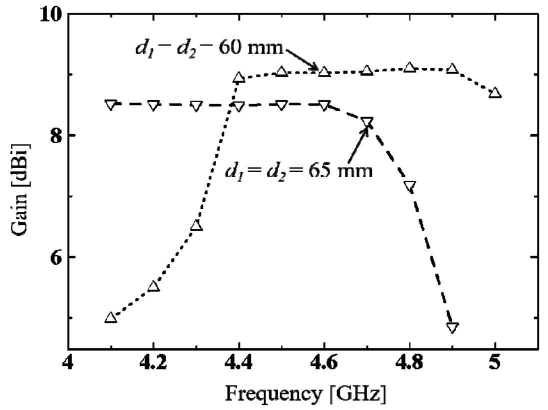

Fig. 3 The gain of the super turnstile antenna in vertical plane.

The reflection coefficient characteristics are not mentioned in this paper due to the complicated feeding circuit of super turnstile antenna in practical cases. A modified feeding network is eager to be proposed to satisfy the small size limitation. Moreover, using this kind of center-fed method reduces the number of ports effectively, but compared to feeding each unit individually, the impedance bandwidth narrows. Therefore, the work is continued to expand the impedance bandwidth based on obtaining a stable and omnidirectional radiation pattern with small size.

IV. CONCLUSIONS

The super turnstile antenna was developed for 5G sub-6 omni bastion station. A collinear center-fed array was proposed to reduce the ports for a compact geometry. The antenna operated at 4.7 GHz. By adjusting the distance of each unit, omni radiation pattern was obtained from 4.4 GHz to 5 GHz with the average gain of 8 dBi.

REFERENCES

[1] R. W. Masters, "The super turnstile antenna," Broadcast News, no. 42, January 1946.

[2] Y. Mushiake, (Ed.) *Antenna Engineeriag Handbook*, The OHM-Sha, Ltd., October, 1980.

[3] G. Sato, H. Kawakami, H. Sato and R. W. Masters, "Design method for fine impedance matching super turnstile antenna and characteristics of the modified batwing antenna," IEICE Transactions, vol. E-65, pp. 271-278, May 1982.

[4] H. Kawakami, G. Sato, and R. W. Masters, "Characteristics of TV transmitting batwing antennas," IEEE Transactions on Antennas and Propagation, vol. 32, no. 12, pp. 1318-1326, Dec. 1984 .