Symmetrical small trapezoid dipole antenna for broadband wireless communications

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Abstract: This letter proposes the symmetrical small trapezoid dipole antenna for lower distorted radiation patterns. For broadband communication, a non-uniform planar antenna has been proposed; however, the radiation pattern at the high-frequency band is distorted. When the cell area is designed, it becomes difficult to design the directivity due to distortion of the radiation pattern. To overcome this issue, this letter proposes the symmetrical small trapezoid dipole antenna, which has the same dimension conductors at the opposite angle. The electromagnetic field simulation results evaluate that the proposed antenna has a small deviation of the radiation patterns at the high-frequency band.

Keywords: Broadband antenna, trapezoid dipole antenna, non-uniform planar antenna

Classification: Wireless communication technologies

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1 Introduction

For the fifth-generation mobile communication system (5G), standardization to provide various services has been discussed. In 5G, the control signal (control plane) and user data (user plane) are transmitted with another frequency band to achieve efficiently wireless communication. The user plane uses electromagnetic waves at the millimeter-wave band, and the control plane uses those at under 6 GHz. In the millimeter-wave band that is the frequency range 2 [1], the massive multiple-input multiple-output (MIMO), which is the key technology of 5G, changes the cell area according to the placement of each user, called beamforming. On the other hand, in the microwave band that is the frequency range 1 [2], the directional antenna which employs the metal reflector designs the macrocell area. In order to achieve that there is no radio quiet zone, it is important to design the macrocell area in charge of control signals. In 5G using frequency range 1, it is difficult to design the beamwidth for every frequency band because it uses multiple frequency bands [2].

To design the beamwidth at each frequency band, the multiband sector antenna employing the multiple reflectors and the broadband radiator has been proposed [3]. The reflector, which consists of the frequency selective surface (FSS) [4] reflects the electromagnetic waves at the specific frequency band and transmits them through the air at the other band. Each FSS, which reflects the electromagnetic waves at different frequency bands, is placed to the distance of the equivalence by the wavelength ratio. This multiband sector antenna can design the same beamwidth at every frequency band because the electromagnetic waves at each frequency band are reflected at each reflector according to the reflection band. Designing the same beamwidth in this antenna, small distorted radiation patterns in every frequency band, like an Omni-direction, are required for the broadband radiator. Furthermore, the thickness of the broadband radiator must be small because the radiator intersects multiple FSSs. For small antenna placement, the broadband planar antennas have been studied [5], [6]. To improve the relative bandwidth, the asymmetric trapezoid dipole antenna has been proposed. Since the antenna shape becomes non-uniform to make the wider bandwidth, it is a problem that the high-frequency radiation pattern is distorted. Considering the change of the radiation pattern, this letter proposes a planar dipole antenna that reduces the distortion of high-frequency radiation patterns.

2 Antenna configurations

Fig. 1 (a) shows the conventional asymmetric trapezoid dipole antenna [7]. The conventional antenna consists of the upper and lower asymmetric trapezoid conductors based on [8]. To expand the frequency band, each conductor is different in shape in the right and left as shown in Fig. 1 (a). The conven-
The electromagnetic field simulation evaluates the performance of the proposed antenna. Table I lists the dimensions of each antenna. The conductor interval and the conductor thickness were set to 1.0 mm and 0.3 mm, respectively. These characteristics are designed using ANSYS HFSS.

Fig. 2 (a) shows a comparison of the conventional and proposed antenna of voltage standing wave ratios (VSWRs). For comparison, the result of the trapezoid dipole, which is a symmetrical shape, is also shown. The dimen-
Table I. The dimension of each antenna

|            | Asymmetry trapezoid dipole | Proposed antenna |
|------------|-----------------------------|------------------|
| B_{11}     |                             | 5.0 mm           |
| B_{12}     |                             | 6.5 mm           |
| B_{22}     |                             | 7.5 mm           |
| B_{1}      | 10.0 mm                     |                  |
| B_{2}      | 15.0 mm                     |                  |
| C_{11}     | 15.0 mm                     | 15.0 mm          |
| C_{12}     | 11.0 mm                     | 14.3 mm          |
| C_{21}     | 15.0 mm                     |                  |
| C_{22}     | 22.5 mm                     | 22.5 mm          |
| H_{11}     | 17.5 mm                     | 17.5 mm          |
| H_{12}     | 11.0 mm                     | 14.3 mm          |
| H_{21}     | 13.0 mm                     |                  |
| H_{22}     | 26.0 mm                     | 26.3 mm          |
| α          | 60°                         | 60°              |

sions of this trapezoid dipole antenna is used [8]. The relative bandwidth is defined as the bandwidth when VSWR < 2.0. The relative bandwidth of the proposed antenna, 2.16–10.0 GHz (129%), is wider than that of the conventional trapezoid antenna, 2.79–11.2 GHz (120%). However, the conventional asymmetry trapezoid dipole has the widest relative bandwidth, 2.21–12.0 GHz (137%). This is because the conventional C_{12}, which corresponds to the higher frequency band, is smaller than the proposed one.

Fig. 2 (b), (c), (d), and (e) show the radiation patterns in the horizontal plane for each frequency band. In the lower frequency bands at 2.4 GHz and 5.0 GHz, radiation patterns become Omni-directions. The conventional asymmetry trapezoid antenna has the distorted radiation pattern in the higher frequency bands at 9.4 GHz and 10.0 GHz. On the other hand, the proposed antenna does not have distorted radiation patterns at every frequency band. To make the same size of conductors, the radiation pattern at the higher frequency band becomes Omni-direction.

Finally, Fig. 2 (f) shows a deviation of radiation pattern as a function of the frequency. The deviation denotes the difference between the maximum and minimum gain in the horizontal radiation pattern. In the range above 8.2 GHz, the proposed antenna can decrease the deviation of the radiation pattern compared with the conventional antenna. As a result, the effectiveness of the proposed antenna was validated in terms of these performances.

4 Conclusion

This letter proposed a symmetrical small trapezoid dipole antenna for broadband wireless communications. Placing the same dimension conductors, which are small and corresponds to the higher frequency band, at the opposite angle realized the broadband antenna with less distortion of the radiation pattern.

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Fig. 2. Electromagnetic field simulation results.