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A Study of a High-gain Antenna Mounted on a Vehicle for Digital Terrestrial Broadcasting

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1. Introduction

The digital terrestrial broadcasting service launched in Japan uses the UHF band from 470MHz to 710MHz. Some sophisticated technologies such as OFDM, guard interval and interleave have been applied to make this service suitable for TV reception on vehicles. The demand for the reception of this service in vehicles has been increasing.

Vehicle antennas designed to be installed on the windshield of a vehicle for the digital terrestrial broadcasting service have been developed [1-2]. For the vehicle application, the monopole antenna employing the vehicle body as the ground plane has wideband property but its radiation pattern has many null points because of the undesired radiation from the vehicle body. On the other hand, the dipole antenna that does not employ the vehicle body as the ground plane has narrowband property but the radiation pattern can be designed as desired. We have developed a multi-element antenna that has wideband property due to its multi-resonances. If the proposed antenna is installed on a windshield, it has high gain in the direction of the front of the vehicle matched to the propagation environment as the street cell and has no null point in the direction of the side of the vehicle.

In this paper, we have proposed a multi element antenna whose characteristics are wideband and high gain of the proposed antenna and has a high reception probability of the DTV signals. First, we show the wideband properties of the proposed antenna by simulation results. Second, with a pair of the proposed antennas installed on the windshield of a vehicle, we show the validity of the proposed antenna by means of a field test in an urban area.

2. Proposed antenna

Figure 1 shows the proposed antenna and the installation location of the proposed antenna on a vehicle. This antenna is attached at the upper corner of the windshield of a vehicle. The proposed antenna has a multi element, which consists of a modified V-shaped dipole structure and a parasitic element for the wideband property. The numbers in Fig. 1 indicate the sequence of the resonances and resonance modes. The series and parallel resonances occur alternately for the wideband property. The outer conductor of the cable of the proposed antenna is connected to the pillar and a balun is unnecessary for this antenna because the current distribution is dominant on the antenna and the influence of the vehicle body to the radiation pattern is small.

3. Simulation results

Figure 2 shows the simulation results of the impedance characteristics of the proposed antenna. The simulation tool is the NEC2 (Numerical Electromagnetic Code 2) based on the moment method. The simulation model is composed of the proposed antenna and a vehicle body whose windshield is replaced by air. The frequency range of the simulation is from 470MHz to

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710MHz. From the Fig. 2, this proposed antenna has a wideband property due to the sequence of the series and parallel resonances and the VSWR (Z0 = 75Ω) of the proposed antenna is lower 3 at the frequency from 470MHz to 710MHz.

Figure 3 shows the simulation results of the horizontal-plane radiation patterns of the proposed antenna for the horizontal polarization at the frequencies of 470MHz, 550MHz, 630MHz and 710MHz. For comparison, the radiation pattern of a dipole antenna is shown at 550MHz in Fig.3 and has null points on +-x axis. On the other hand, the radiation patterns of the proposed antenna have no null point on +x axis and have high gain on +y axis. It is clear that the radiation pattern has been improved by applying the proposed antenna. Using the two pairs of the proposed antennas on a windshield and a rear glass, the radiation pattern without null points on horizontal plane is achieved and is matched to the propagation environment as the street cell.

4. Field test

The proposed antenna was designed in order to have high gain for front and back of a vehicle because a street cell is dominant on the propagation. To confirm the validity of the radiation pattern of the proposed antenna, the reception properties were evaluated by means of a field test in an urban area, using a pair of the proposed antennas on either side of the windshield. The antenna system is composed of a pair of the proposed antennas, two LNAs and an ISDB-T receiver. A combining diversity is employed for the receiving system.

Figure 4 shows the proposed antenna installed on a windshield of a vehicle, the course of the field test and the reception property of the proposed antenna. In Fig. 4(b), the black circles indicate the error-free points and the white ones the error points. At each point, the reception property is judged to be error-free if the error rate after the Viterbi decoding is lower than 2*10^ (-4). For comparison, the reception properties of the monopole antenna on the roof end and the monopole antenna on the C-pillar of either side glass (see in Fig.1(b)) were tested on the same course. A vehicle antenna mounted on the roof of the vehicle has a better reception property than one installed on its glass because of the shadowing of the vehicle body. Table 1 shows the reception probabilities of the three kinds of antennas. The reception property of the monopole antenna on the roof end is the best. The reception property of the proposed antenna on the windshield is nearly equal to that of the monopole antenna on the roof end, because the proposed antenna has high gain in the direction of the front of the vehicle and this property is matched to the propagation environment as the street cell.

5. Conclusion

The novel vehicle antenna with wideband, high-gain and high reception probability for DTV receiving was proposed. This proposed antenna has the usage of multi-resonance and no balun. With a pair of the proposed antennas installed on the windshield of a vehicle, we evaluated the reception property of the proposed antenna by means of a field test in an urban area and compared it to that of the monopole antenna on the roof end. The results show the validity of the proposed antenna whose radiation pattern is designed to match a street cell.

References

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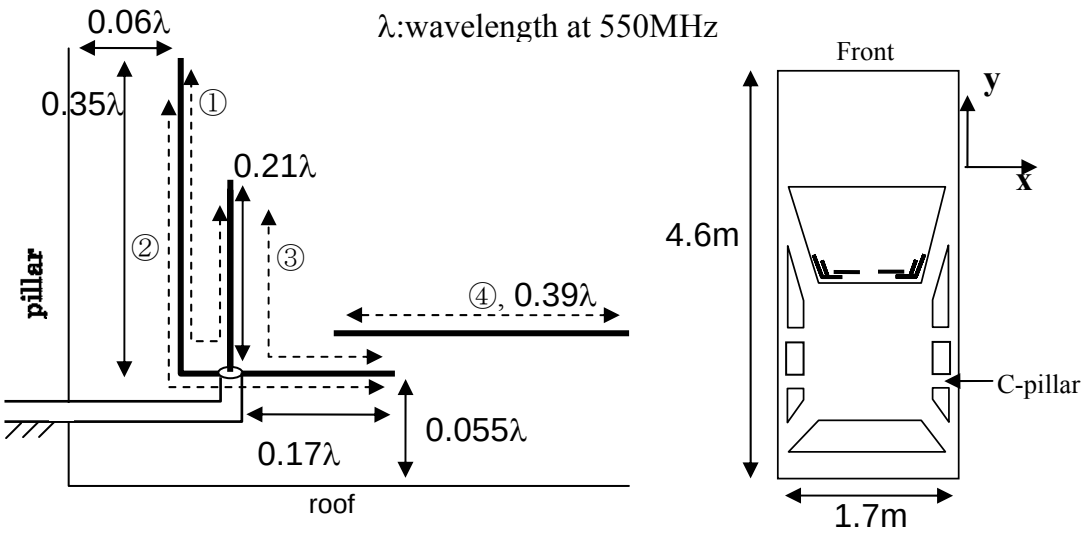
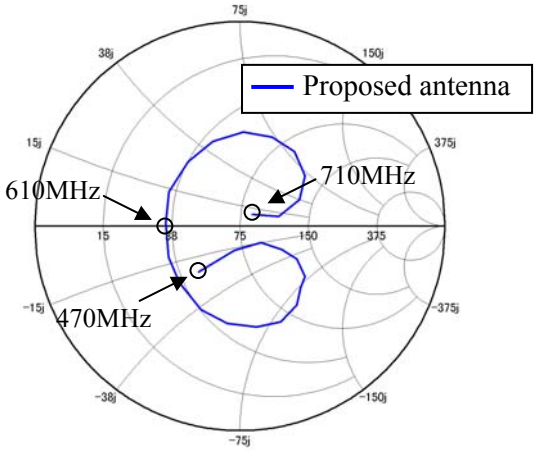
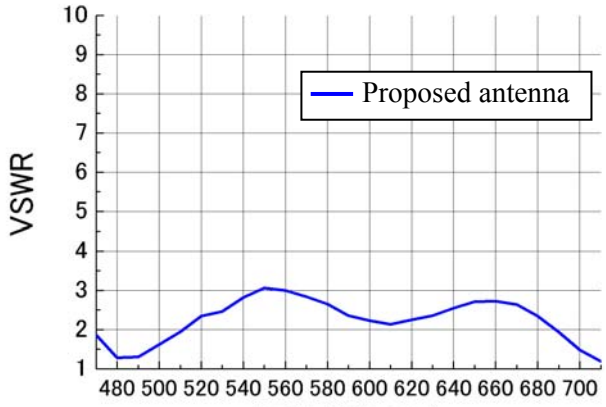


(a)Proposed antenna (b) Top view of a vehicle

Figure 1: Proposed antenna and installation location on a vehicle

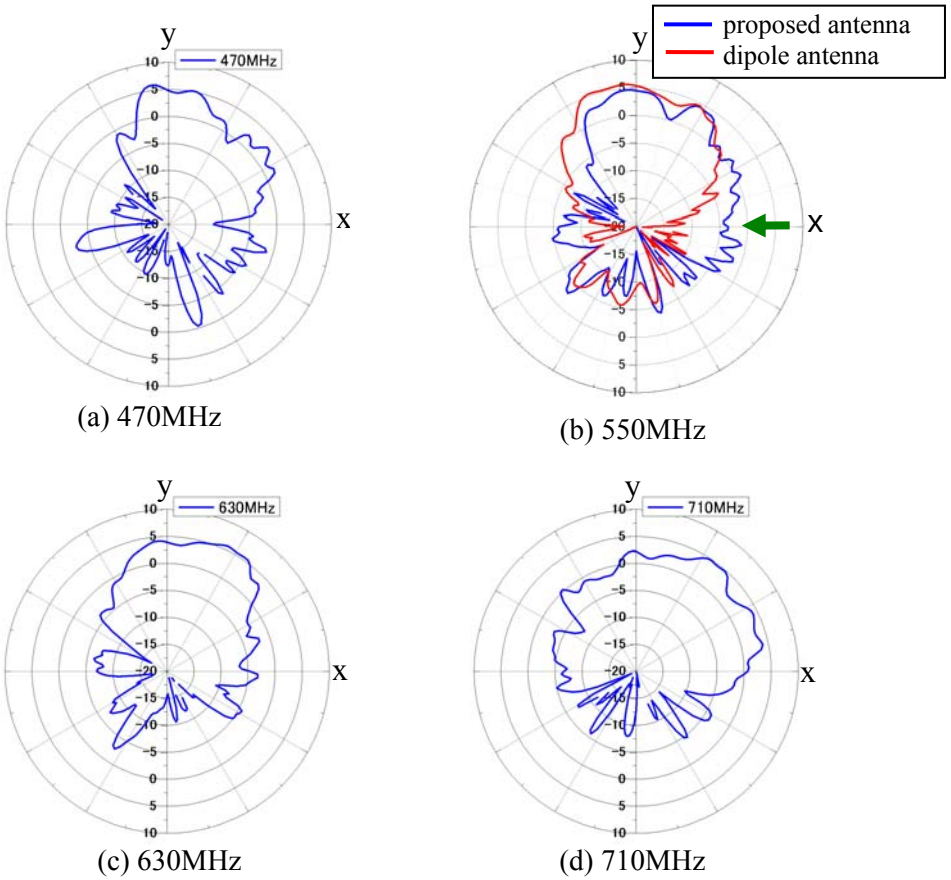


(a) Smith chart



(b) VSWR (Z0 = 75Ω)

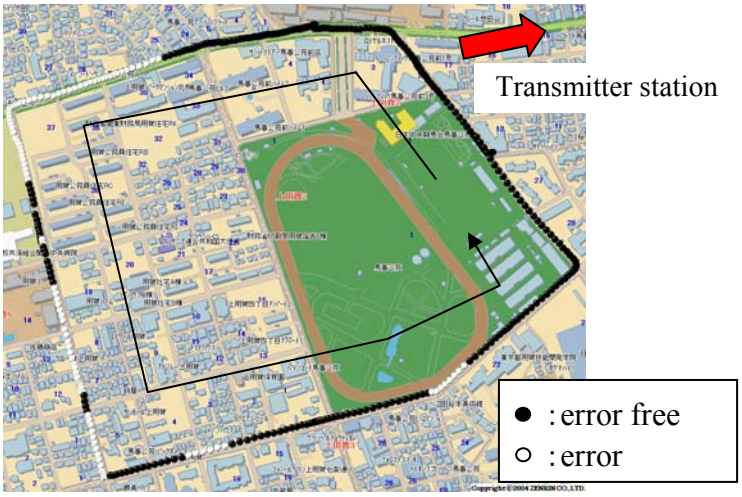
Figure 2: Impedance characteristics of the proposed antenna



(a) 470MHz (b) 550MHz

(c) 630MHz (d) 710MHz

Figure 3: Radiation patterns of the proposed antenna and a dipole antenna



(a) Proposed antenna mounted on a windshield (b) Course of the field test

Figure 4: Course of the field test and reception property of the proposed antenna

Table 1: Reception probabilities of the three kinds of antennas (%)

	proposed antenna	monopole on the C-pillar	monopole on the roof
clockwise	71.5	58.3	75.6
counterclockwise	70.7	45.3	76.4