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STACKED RECTANGULAR MICROSTRIP ANTENNA WITH A SHORTING PLATE FOR DUAL BAND OPERATION

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1. Introduction

Recently, intelligent transport system (ITS) is developed and used to enhance traffic safety and the smooth flow of traffic. The road vehicle communications system (VICS) and the electric toll collection system (ETC) are the ITS application. The authors have proposed a stacked square microstrip antenna (MSA) with a shorting post as the car antenna for the VICS [1]. The proposed antenna receives signals with uniform level within the communication area for the VICS and its size is much smaller than that of the conventional rectangular MSA used presently. In this paper, the antenna proposed in [1] is redesigned as a car antenna for the ETC and the antenna is proposed as a MSA with dual band (VICS/ETC) operation.

2. Specification of VICS and ETC

The center frequency and the bandwidth of the VICS in Japan are 2.4997GHz and 85 KHz and those of the ETC are 5.8GHz and 100MHz. Linear polarization is used for the VICS and circular polarization for the ETC. The bandwidth of the axial ratio less than 3 dB are 100 MHz for the ETC.

The communication area for the VICS extends 35m in both directions from the beacon antenna installed at the shoulder of the road. In such a case, the radiation peak must be at the low–elevation angles along the road [1][2]. The communication area for the ETC is very narrow compared with that for the VICS (the extent is 4m in one direction from the toll gate antenna) and the toll gate antennas are installed above the car antenna. Therefore, it is desirable that the car antenna for the ETC has the radiation peak at the high–elevation angles.

3. Antenna Design

Fig. 1 shows a stacked rectangular MSA with a shorting plate. The antenna consists of a dielectric substrate and an air layer with a rectangular patch. In [1], the square patches were used. In this paper, however, the rectangular patches are used to radiate circularly polarized waves at the ETC band. The upper patch is shorted to the lower patch. The shorting point is at the apex of the rectangular patch and the narrow plate ($d_w = 1.0$mm) is used to miniaturize the size of the patch. The upper and lower patches are same size and the width and length of the rectangular patches are $W = 13.7$mm and $L = 15.0$mm, respectively. The relative dielectric constant and thickness of the upper air layer are $\varepsilon_{r1} = 1$, $h_1 = 2.4$mm and those of the dielectric layer are $\varepsilon_{r2} = 2.60$ and $h_2 = 1.6$mm, respectively. The antenna is excited at $x_0 = 4.4$mm, $y_0 = 5.6$mm around the diagonal on the lower patch by a coaxial feeder thorough the lower dielectric substrate.

4. Results and Discussion

The calculated results are obtained by a simulator software package IE3D 9.0 based on the method of moment in the spectral domain [3].

Figs. 2 and 3 show the electric current distributions on the upper and lower patches. The calculation frequencies are the center frequencies of the VICS and ETC, 2.5GHz and 5.8GHz, respectively. The intensities of the electric current around the shorting plate at 2.5GHz are

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maximum and those on the opposite apexes to the shorting point are approximately zero on the upper and lower patches. The sum of the lengths of the diagonal of the upper and lower patches and the shorting plate approximately becomes a half wavelength at 2.5GHz. The intensity of the electric current on the lower patch at 5.8GHz is maximum around the centers of the width and length of the rectangular patch and zero around the four apexes of the patch. The width and length of the patch approximately becomes a half wavelength at 5.8GHz. The intensity of the electric current on the upper patch is much smaller than that on the lower patch.

Fig. 4 shows the VSWR. The measured bandwidths of the VSWR less than 2 are 40 MHz for the VICS and 630MHz for the ETC, respectively. Fig. 5 shows the axial ratio for the ETC. The measured bandwidth of the axial ratio less than 3 dB are 130 MHz. The bandwidths of the proposed antenna are satisfied with the specification of both the VICS and the ETC.

Figs. 6 and 7 show the radiation patterns at 2.5GHz and 5.8GHz, respectively. In the calculation by IE3D, the size of the ground plane is infinite. In the measurement, however, the finite ground plane (50cm×50cm) is used. The intensities of the radiation fields at the low–elevation angles in the xz and yz planes at 2.5GHz are large compared with those at the high–elevation angles [1]. At 5.8GHz, however, the antenna has the radiation peak around the high–elevation angles where the toll gate antennas are installed. This is due to the fact that the width and length of the rectangular patch approximately becomes a half wavelength at 5.8GHz.

In order to estimate the car antenna for the VICS with consideration of the beacon antenna's the radiation pattern and the direction of the beacon antenna as seen from the car antenna, the authors have proposed the modified effective directivity [1]. Fig. 8 shows the modified effective directivity E_{eff}. E_{eff} of the rectangular MSA used presently is shown for comparison. r_B indicates the horizontal distances from the beacon antenna to the car antenna along the road. E_{eff} of the proposed antenna is bigger than that of the rectangular MSA within the communication area of the VICS. This is due to the fact that the proposed antenna has the radiation peak at the low–elevation angles along the road [1].

The size of the rectangular patch of the proposed antenna, with 1.6mm–thick lower dielectric substrate, is approximately 1/2 of that of the conventional rectangular MSA with 2.4mm–thick dielectric substrate.

5. Conclusion

The stacked rectangular MSA with a shorting plate has been proposed for dual band (VICS and ETC) operation. The proposed antenna can receive signals with uniform level within the communication area for the VICS and the antenna radiates the circularly polarized waves to the direction of toll gate antenna at the ETC band. Moreover, the proposed antenna is much smaller compared with the rectangular MSA used presently for the VICS.

Acknowledgments

The return loss and the radiation patterns of the MSA were measured at the Joint Research and Development Center, Saga University. The authors would like to thank Research Associate E. Nishiyama of Saga University for his valuable advice on the measurement of MSA.

References

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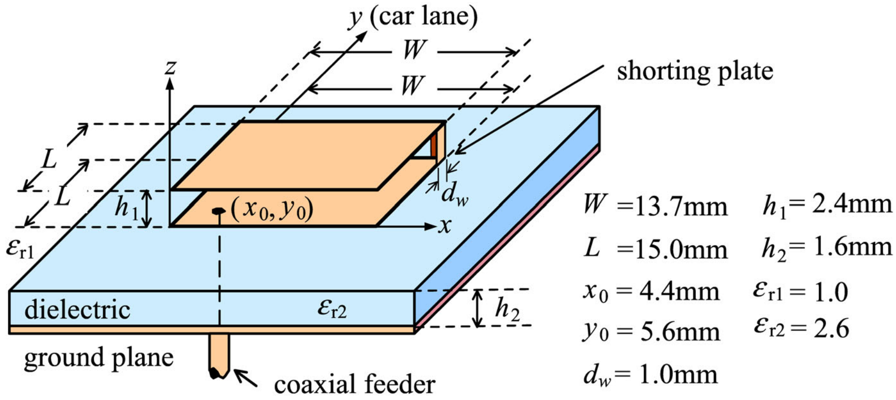
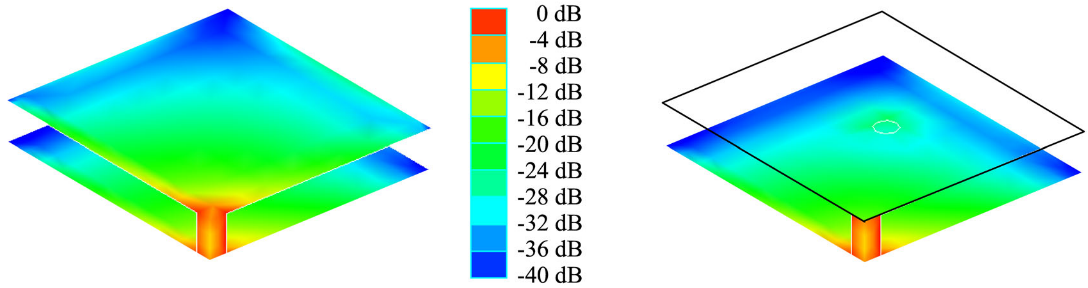
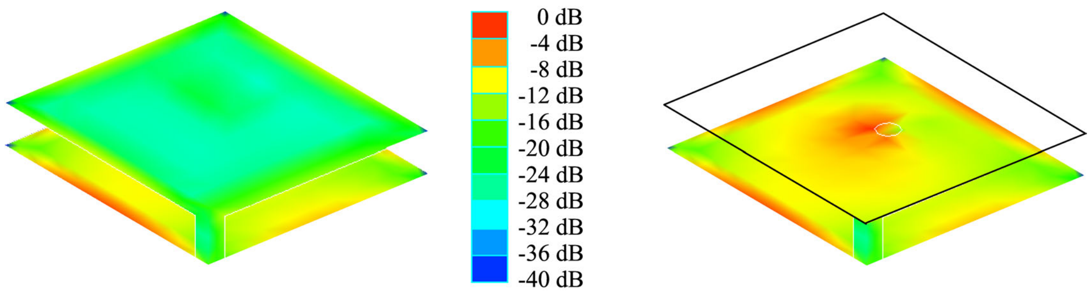


Fig. 1 Geometry of a stacked rectangular MSA with a shorting plate



(a) Upper patch (b) Lower patch

Fig. 2 Electric current distributions (frequency=2.5GHz)



(a) Upper patch (b) Lower patch

Fig. 3 Electric current distributions (frequency=5.8GHz)

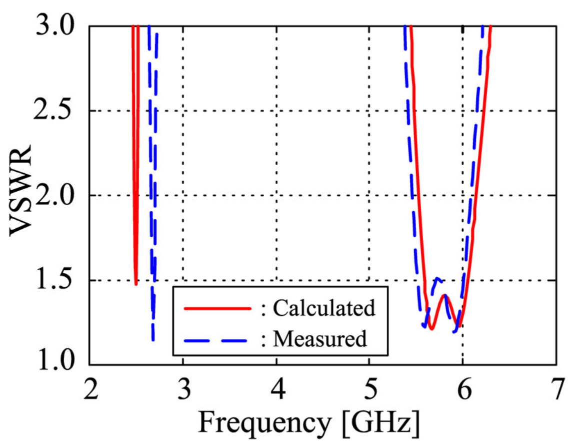


Fig. 4 VSWR

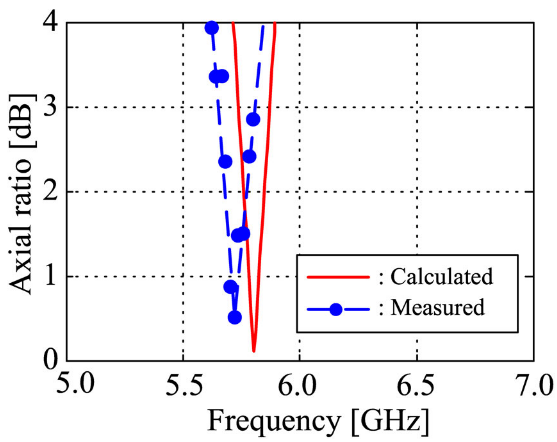
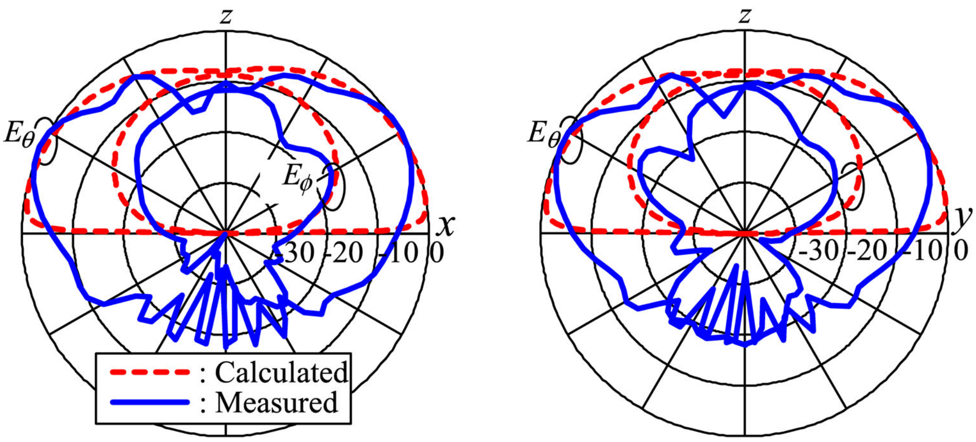
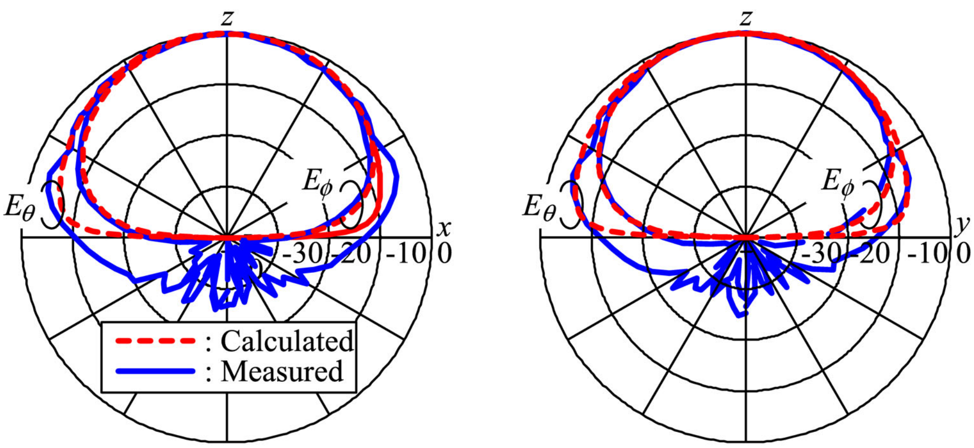


Fig. 5 Axial ratio



(a) xz plane (b) yz plane

Fig. 6 Radiation patterns (frequency=2.5GHz)



(a) xz plane (b) yz plane

Fig. 7 Radiation patterns (frequency=5.8GHz)

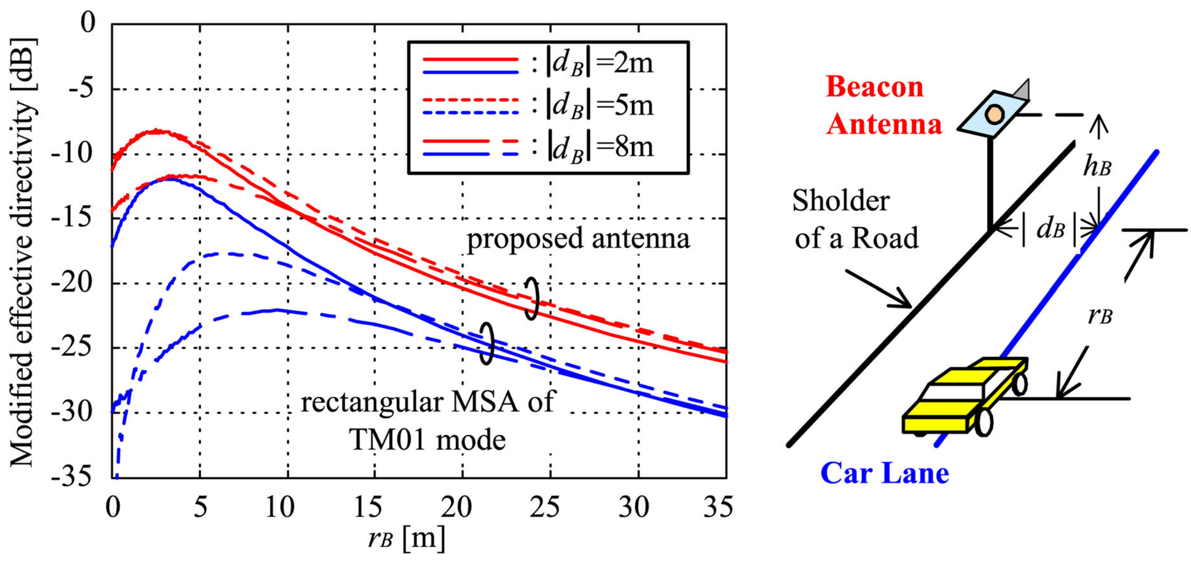


Fig. 8 Modified effective directivity

(frequency=2.5GHz, h_B=4.0m)