POS1-18

L-Probe Fed Stacked Rectangular Microstrip Antenna combined with Ring Antenna for Triple Band (GPS/VICS/ETC) Operation in ITS

Daisuke Tanaka[1#], Takafumi Fujimoto[2] and Takashi Takenaka[3]

Graduate School of Engineering, Nagasaki University
1-14 Bunkyo, Nagasaki, 852-8521, Japan
[1]bb52111227@cc.nagasaki-u.ac.jp, {[2]takafumi, [3]takenaka}@nagasaki-u.ac.jp

Abstract

Authors have proposed an L-probe fed stacked rectangular microstrip antenna combined with a ring antenna for triple-band operation in ITS. In this paper, the relationships between geometrical parameters of the antenna and antenna characteristics (VSWR, axial ratio and bandwidth) at three frequency bands are clarified by simulation. Moreover, antenna for GPS/VICS/ETC is designed.

Keywords: <u>Microstrip antenna</u>   <u>Circularly polarized wave</u>   <u>Triple band operation</u>   <u>ITS</u>

1. Introduction

ITS (Intelligent Transport Systems) has received much attention as a system for traffic safety and environmental protection. ITS applications such as ETC (electric toll collection system), GPS (global positioning system), SDRAS (satellite digital audio radio service) and VICS (vehicle information and communications system) are widely used presently. In order to use all these applications, multi band antennas represent an effective solution for the ITS. However, car antennas have to radiate both the circularly polarized wave and the linearly polarized wave. Authors have proposed an L-probe fed stacked rectangular microstrip antenna (MSA) combined with a ring antenna for triple-band operation in ITS [1]. However, the mutual couplings between the patches and rectangular ring are strong and the radiation patterns at the ETC band tilt. In [2], we have clarified that the mutual coupling at the ETC band could be controlled by arranging the ring antenna at the center between the upper and lower patches.

In this paper, the relationships between the height of the ring antenna and antenna characteristics (VSWR, axial ratio and bandwidth) at three frequency bands are studied by simulation. Moreover, antenna for GPS/VICS/ETC is designed.

2. Antenna Design

Figure 1 shows a proposed triple band MSA. The antenna consists of a stacked rectangular patch MSA with a shorting plates and a rectangular ring MSA with the T-shaped slits. The upper and lower rectangular patches are the same size and their widths and lengths are W_1 and L_1, respectively. Moreover, the slits have been installed at the each edge of the lower rectangular patch to control the axial ratio and the frequency giving the minimum axial ratio at the ETC band. T-shaped slits have been installed at the each edge of the rectangular ring to reduce the antenna size. Each parameter generated by installing the T-shaped slits has been designed by different lengths along x-axis and y-axis. A microstrip line of the L-probe feed lays around diagonal of the rectangular patches and the rectangular ring. Therefore, the proposed antenna radiates a circularly polarized wave. In [1], [2], the rectangular ring antenna is installed in the air space. In this paper, however, the rectangular ring antenna is mounted on the dielectric to fabricate the antenna more easily.
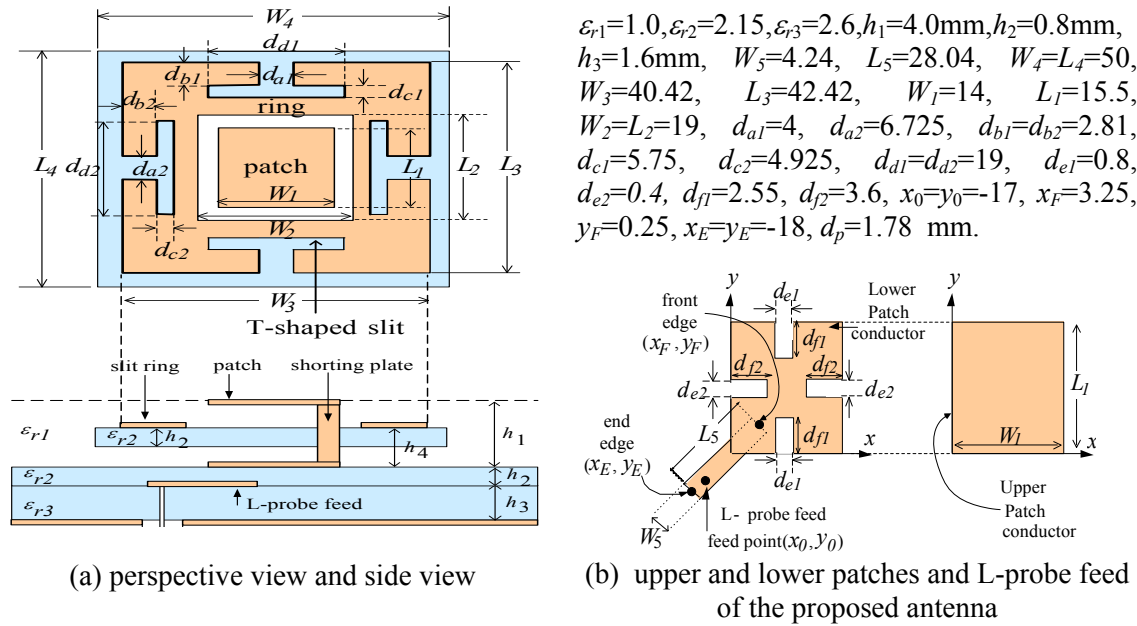
ε_{r1}=1.0,ε_{r2}=2.15,ε_{r3}=2.6,h_1=4.0mm,h_2=0.8mm, h_3=1.6mm, W_5=4.24, L_5=28.04, W_4=L_4=50, W_3=40.42, L_3=42.42, W_1=14, L_1=15.5, W_2=L_2=19, d_{a1}=4, d_{a2}=6.725, d_{b1}=d_{b2}=2.81, d_{c1}=5.75, d_{c2}=4.925, d_{d1}=d_{d2}=19, d_{e1}=0.8, d_{e2}=0.4, d_{f1}=2.55, d_{f2}=3.6, x_0=y_0=-17, x_F=3.25, y_F=0.25, x_E=y_E=-18, d_p=1.78 mm.

(a) perspective view and side view

(b) upper and lower patches and L-probe feed of the proposed antenna

Figure 1 Triple band (GPS/VICS/ETC) MSA

3. Results and discussion

In the calculations in this paper, the simulator software package XFDTD ver. 7 [3] is used. Three frequency bands used in this paper are GPS band (center frequency is 1.575GHz), VICS band (center frequency is 2.499GHz) and ETC band (center frequency is 5.8GHz).

### 3.1 Parametric study on height of ring MSA

Figures 2 (a) and (b) show the effects of the height of ring MSA on the antenna characteristics at the GPS band. As the height of the ring MSA increases, the frequency giving minimum axial ratio becomes high. This is due to the fact that the influences of the dielectric substrate with the lower patch become small. The minimum axial ratio and the bandwidth (axial ratio$\leqq$3dB) has changed and the bandwidth satisfies the specification of the GPS band when the height of ring MSA is arranged around the center between patches. The VSWR hardly changes. The bandwidth (VSWR$\leqq$2) satisfies the specification regardless of the height of ring MSA (but is omitted in this paper).

Figures 3 (a) and (b) show the effects of the height of ring MSA on the antenna characteristics at the ETC band. Although the ring antenna operates as a radiation element at the GPS band, it is observed that the height of the ring MSA also influences the axial ratio at θ= 0 and VSWR at the ETC band. When the ring antenna is arranged around the center between the upper and lower patches, the mutual coupling between the ring antenna and the patches is smallest and the angle distributions of the axial ratio at the ETC band are improved [2]. The bandwidth of the axial ratio $\leqq$3dB is also widest in the case of arranging the ring antenna around the center between the patches. At the GPS band, the bandwidth is widest at the frequency giving the minimum axial ratio for change the height of ring MSA. However, the frequency giving the minimum axial ratio is different from the one giving the widest bandwidth at the ETC band. This is due to the fact that the radiation patterns are distorted around the high elevation angles at the ETC band [2].

Similarly, the antenna characteristics at the VICS band have been studied. According to calculations, the height of the ring MSA hardly influence the minimum VSWR, the frequency giving the minimum VSWR and the bandwidth of the VSWR$\leqq$2 (but is omitted in this paper). It is desirable that the ring MSA is arranged around the center between upper and lower patches at the triple bands.
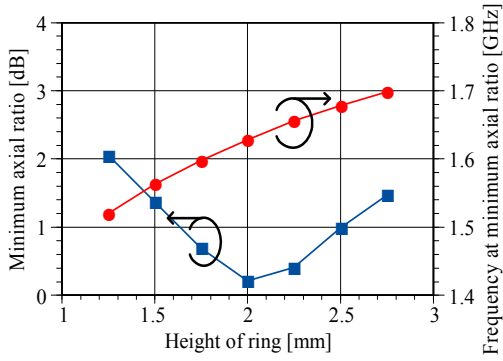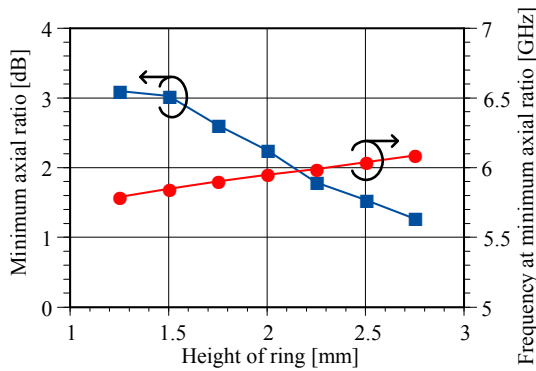
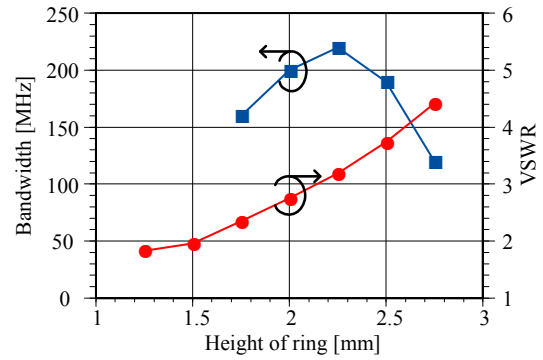(a) Minimum axial ratio and frequency at minimum axial ratio
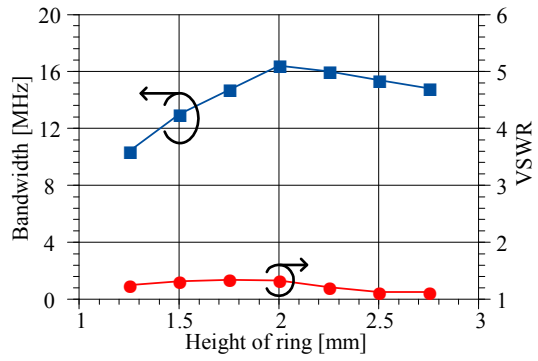
(b) bandwidth of axial ratio $\leqq$ 3dB and VSWR

Figure 2 Effects of height of ring MSA on antenna characteristics at GPS band

(a) Minimum axial ratio and frequency at minimum axial ratio

(b) bandwidth of axial ratio $\leqq$ 3dB and VSWR

Figure 3 Effects of height of ring MSA on antenna characteristics at ETC band

3.2 Design of triple band antenna for ITS

The triple band (GPS/VICS/ETC) antenna is designed in consideration of the results mentioned in the previous section. The height of the ring MSA is set at h_4=1.6mm which is around center between two patches. Figures 4 (a), (b) and (c) show the VSWR and axial ratio characteristics of the designed antenna at triple band. Moreover, table 1 shows the specification and calculated results at the triple band. The designed antenna satisfies the specification at the triple band. Moreover, the size of the outside ring MSA is equal to $0.218\lambda_{1.575}$(λ_f : the wavelength at f GHz). The proposed antenna is very small in size.
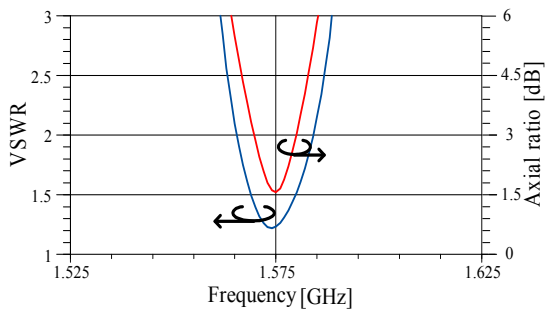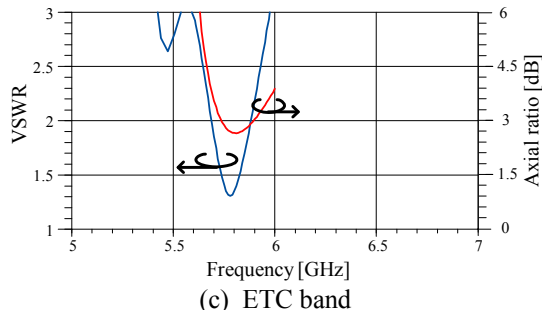

(a) GPS band
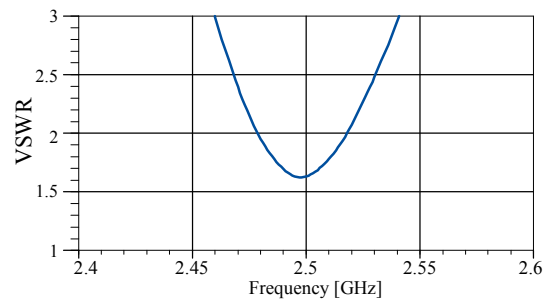
(b) VICS band

(c) ETC band

Table 1 : specification and calculated results of the triple band (unit:MHz)

	GPS	VICS	ETC
specification	10.0	40	100
calculated	10.2	41	157

Figure 4 VSWR and axial ratio characteristics

Figures 5 (a)-(f) show the calculated radiation patterns on *xz*- and *yz*-planes at GPS, VICS, and ETC bands. It is observed that the designed antenna radiates circularly polarized wave to high elevation angles at the GPS band and linearly polarized wave to low elevation angles at the VICS band, respectively. At the ETC band, although the radiation patterns on *xz*-plane deteriorates, the antenna radiates circularly polarized wave around from $\theta=0$ to $\theta=45$ degrees on yz-plane.
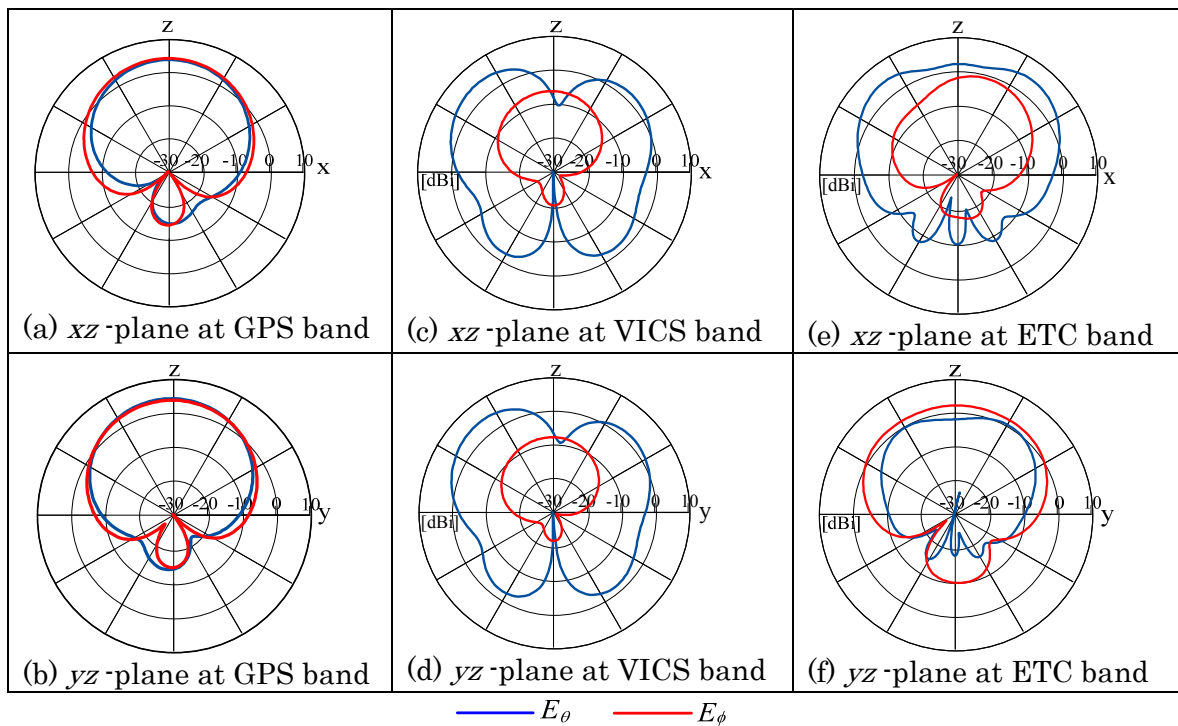

(a) *xz* -plane at GPS band (c) *xz* -plane at VICS band (e) *xz* -plane at ETC band

(b) *yz* -plane at GPS band (d) *yz* -plane at VICS band (f) *yz* -plane at ETC band

E_θ E_ϕ

Figure 5 Calculated radiation patterns at triple band

4. Conclusion

In this paper, the triple band antenna for ITS has been proposed and the relationships between the ring MSA and antenna characteristics at triple band has been clarified by simulation. Moreover, the triple band (GPS/VICS/ETC) antenna has been designed by referring to the calculated results. The designed antenna satisfies the specification of GPS, VICS and ETC.

References

[1] T. Fujimoto and R. Nakanishi, Proc. of IEEE AP-S, in CD-ROM, July, 2011.
[2] T. Fujimoto, D. Tanaka, and T. Takenaka, Proc. of KJMW, in CD-ROM, Nov. 2011.
[3] http://www4.kke.co.jp/network/xfdtd/