

# Measured Separation of Sectorized Reception for ITS V2V Relay-Assisted Communication in Urban Environment

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**Abstract** — Packet relay-assisted scheme using sectorized receiving at relay station has been proved as an effective solution to mitigate hidden terminal problem, and then improve performance of ITS V2V communication. In addition, it is also shown that performance of the relay-assisted scheme relies on separation of the sector antenna unit which is basically expressed as front-to-back (F/B) and front-to-side (F/S) ratios. In this paper, a sectorized antenna is designed and the actual separation is measured under multipath environment. The results show that actual F/B and F/S separations are 7–18 dB lower than the designed values. Based on the results, some suggestions to improve the separation are presented.

**Index Terms** — ITS, V2V, relay-assisted, sectorized receiving, actual separation.

## 1. Introduction

Highly reliable vehicular communication is a key technology for the future automated driving [1]. CSMA/CA packet relay-assisted schemes can improve reliability of ITS vehicle-to-vehicle (V2V) communications by compensating shadowing loss and fading [2]. However, their performance is affected by hidden terminal (HT) problem. An improved relay-assisted V2V scheme employing a sectorized relay station (RS) was proposed to mitigate the problem, and its effectiveness has been shown by theoretical analysis and computer simulations [3].

Performance improvement of the relay-assisted scheme relies on the separation of sectorized antenna which is basically expressed as front-to-back (F/B) and front-to-side (F/S) power ratios [3–4]. In the urban street environment, however, the separation of sectorized receiving scheme is further affected by multipath propagation caused by surrounding buildings. For future deployment of the relay-assisted scheme using sectorized receiving, actual separation performance in the urban environment should be taken into account, as well as optimizing the antenna parameters. In this paper, a four-sector prototype antenna is designed to measure the actual F/B and F/S separations under multipath environments.

## 2. Measurement Setup

The measurement is conducted at a T-junction in the west campus of the University of Electro-Communications, Tokyo, Japan. Fig. 1 shows the experimental ground with radio equipment. The T-junction is surrounded by buildings which may cause reflection and diffraction. An on-board unit (OBU) device which is based on ARIB STD-T109 standard for V2V and V2I communication in Japan [5] is installed in an experimental vehicle. The OBU transmits packets in 760

MHz bands. Its transmitting antenna is a monopole antenna and installed on the top of the vehicle with the height of around 1.5 m. The sectorized antenna with the height of around 5.2 m is set at a roadside. Each sector unit simultaneously receives packets from the OBU.

We set the origin of xy-plane at the sectorized antenna. Three positions of the experimental vehicle, (8.3 m, 0 m), (8.3 m, 39 m) and (8.3 m, 78 m), are considered. Hereafter, we call them Position 1, 2 and 3, respectively. The corresponding path lengths of direct wave from the OBU to the sectorized antenna are 9 m, 40 m and 78.4 m.

Measurement set up is described in Fig. 2. Sector antenna unit facing to the OBU is always connected to spectrum analyzer 1 (we call it front-unit). For measuring F/B separation, the opposite sector unit is connected to spectrum analyzer 2 (we call it back-unit). On the other hand, for measuring F/S separation, one of the two side sector units is connected to the spectrum analyzer 2 (we call it side-unit). From zero-span sweep waveform captured by spectrum analyzers, received power is measured and stored in two note PCs. By calculating the difference between the values measured by the two spectrum analyzers (in dBm), F/B or F/S separation is obtained.

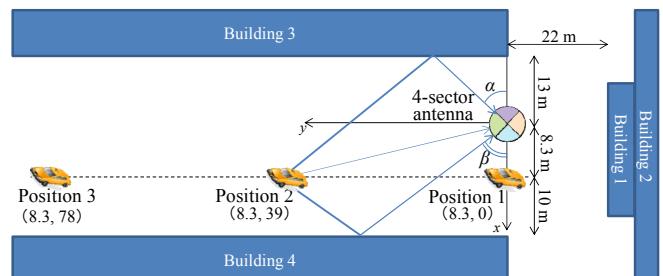


Fig. 1. Experimental ground with buildings.

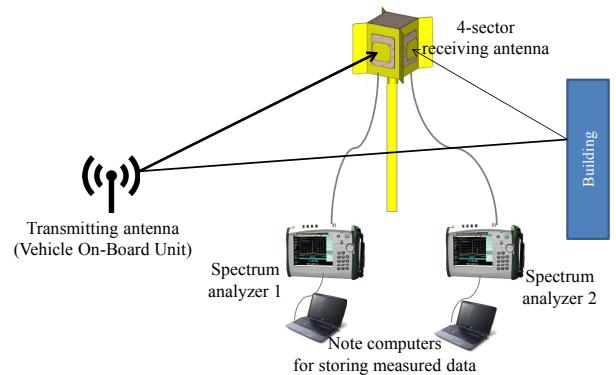
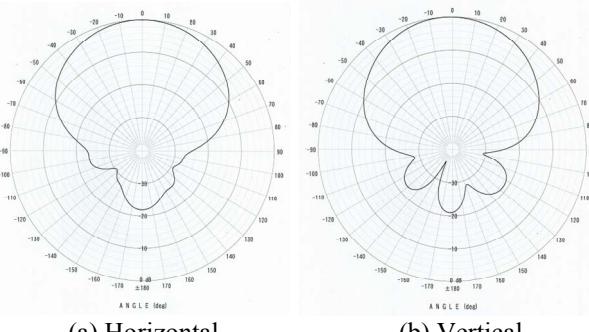


Fig. 2. Measurement set up



Fig. 3. Four-sector receiving antenna



(a) Horizontal (b) Vertical  
Fig. 4. Radiation patterns of sector antenna unit

The four-sector receiving antenna is shown in Fig. 3. It has the outside dimension of 347 mm×347 mm×320 mm. Horizontal and vertical radiation patterns of a sector antenna unit are shown in Fig. 4. The F/B and F/S (+ or - 90°) of each unit are better than 22 dB. The horizontal and vertical beam widths are 65° and 63.6°, respectively. The directional gain of sector antenna unit is 7.5 dBi.

### 3. Measurement Results

#### (1) Front-to-back separation

Table I shows the results of F/B separation for the three positions of OBU. It can be seen that actual F/B separation is 4~14 dB lower than that of sector antenna unit. This shows that multipath propagation in urban environment severely affects the separation of sectorized receiving scheme. Among three position of the OBU, Position 1 shows the highest separation. It can be explained as follows. Since a path loss depends on its path length, the higher ratio in path length gives higher separation. For the back-unit, the signal reflected from Building 1 and 2 (Fig. 1) is the dominant incoming wave. Then the ratio of path lengths for the direct wave (front-unit) to the reflected wave (back-unit) decreases as OBU gets closer to the sector-antenna, and the separation becomes better. For Position 3, the path length ratio is highest (nearly 1) then the F/B separation is the lowest.

#### (2) Front-to-side separation

Table II shows the results of F/S separation. We measured the F/S separations for side-units on the left and right when viewed from the OBU. It can be seen that actual F/S separations are remarkably deteriorated from the original F/S of the sector antenna unit, even for Position 1.

For Position 1, reflecting objects such as building on the left are far away from the transmitting point. Therefore the front-to-left side separation is kept more than 15 dB. On the other hand, the front-to-right side separation decreases down to 11.2 dB. This is because the signal reflected from Building

TABLE I Front-to-back separation

Measurement	Position 1	Position 2	Position 3
Front-to-back separation (dB)	18.1	10.8	7.9

TABLE II Front-to-side separation

Measurement	Position 1	Position 2	Position 3
Front-to-left side separation (dB)	15.7	7.3	8.4
Front-to-right side separation (dB)	11.2	10.8	10.2

1 and 2 (Fig. 1) obliquely incide at right side-unit then the received power increases.

For Position 2, the left and right front-to-side separations are 7.3 dB and 10.8 dB, respectively. At left- and right-side units, received power of direct waves are almost negligible. Signals reflected from Building 3 and 4 are the dominant waves. The corresponding arrival angles  $\alpha$  and  $\beta$  are 48.6° and 54°, respectively. From the radiation pattern of Fig. 4, receiving power of reflected waves with the arrival angles is 6dB ~ 8dB lower than that of the direct wave with arrival angle of 0°. Taking the reflection loss into account, the measured values seem to be reasonable. For Position 3, the left and right F/S separations are 8.4 dB and 10.2 dB, respectively, which are close to the left and right separations for Position 2.

### 4. Conclusions

In this paper, inter-sector separation of a four-sector receiving scheme is measured under multipath environment. Measured results show that the separation deteriorates 4~10 dB from that of a sector antenna unit, and the deterioration is greater as distance between a transmitter and the receiving sector antenna increases. In the future study, narrowing the beam width of a unit antenna may improve the separation of sectorized receiving scheme under multipath environments.

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