特集 Onboard Antenna for 700 MHz Band V2X Communication*

鈴木忠男 Tadao SUZUKI　　杉本勇次 Yuji SUGIMOTO　　溝口　幸 Miyuki MIZOGUCHI

In recent years, vehicle to vehicle and vehicle to infrastructure wireless communication has been developed for automotive use. In Japan, the government is preparing the 700 MHz band for this type of application. For product deployment, the antenna installation on the vehicle is one of the major issues. In this paper, we introduce the study results of our own antenna development. We developed a small directional antenna that can be installed at inner rear view mirror, and performed tests to make sure its potential benefit.

Key words：V2X communication, 700MHz, Antenna

INTRODUCTION

In recent years, cooperative system using V2X wireless communication has been developed for automotive safety. **Fig. 1** shows samples of cooperative safety application. One tells the information about forward obstacles by vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) wireless communication [1]. Another one tells the driving assistance information around the intersection such as the car behind the truck and/or pedestrian using V2V and/or V2I wireless communication. These V2V and V2I communication are altogether called V2X communication today.

Cooperative safety application using V2X wireless communication have been expected to assist safety driving, especially by informing real-time traffic situation in non line of sight (NLOS) area. Also, this V2X wireless communication is considered to be utilized for energy saving. So the V2X wireless communication became important technology for ITS and has been developed globally.

In Japan, 700MHz frequency band has been assigned for this V2X communication. Because this frequency is good for the NLOS communication required for most of safety applications. We, DENSO, have worked on the development of radio unit, antenna and application, in order to deploy the reliable and cost effective product using 700MHz band V2X communication. Through the development work, we realized that the installation of 700MHz band antenna is one of big issue. Because the space for antenna is limited on present-day vehicle and remarkable equipment may not be accepted from exterior design viewpoint.

According to our previous study, the roof top is usually the best position for V2X antenna installations. It shows Omni antenna pattern and its gain should be enough for various V2X cooperative system scenarios. However, it will not necessarily be the preferred location for many automotive OEMs, because it may adversely impact vehicle external appearance.

To solve this issue, we developed small antennas that do not impact exterior design. One of developed antennas is for Interior Rear View Mirror (IRVM). In this paper, we introduce the study results of IRVM antenna.

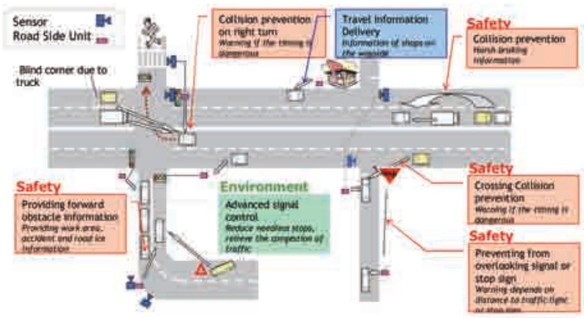

Fig. 1　V2X Application

1.　INTERIOR REAR VIEW MIRROR ANTENNA

1-1　DESIGN

There would be various positions where are good for antenna installation. We chose IRVM for primary study, because it is expected to have similar radiation to Omni direction. Also the emission gain would be relatively high compared with other position e.g. dashboard.

IRVM antenna has to be enough small that can be installed

＊2011年ITS世界会議で発表論文の転載

inside the mirror unit. The prototype of the small antenna is illustrated in **Fig. 2**. This is a conventional inverted F-type antenna that is installed in the IRVM assembly. Since inverted F-type antenna is widely used in cellular phone, we think this antenna type would work well for limited space like IRVM.

The size of prototype is L55*W10*H15 [mm]. This is determined considering general IRVM size. We used the dielectric material to make small size. The radiation pattern is shown in **Fig 3**. This shows approx. 0dBi gain at front and rear. This seems there is no significant effect from mirror. Since the mirror is very close to the GND plane of inverted-F antenna, we think the metal material of mirror can be ignored [2) 3)].

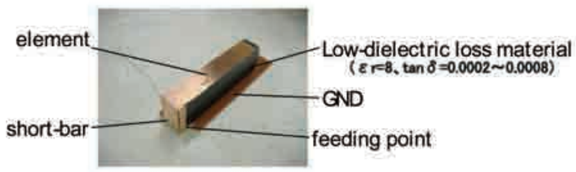

Fig. 2　Small Inverted-F Type Antenna

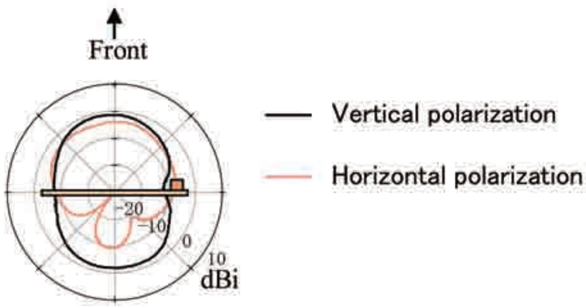

Fig. 3　Antenna Pattern of Small Antenna

1-2　EVALUATION

In order to confirm the practical antenna performance, we performed road tests on an actual street in Japan's Abashiri City. We had been granted to perform various tests under the MIC (Ministry of Internal Affairs and Communications) policy in this area. We used the test communication unit shown in **Table 1**. We, DENSO, developed this unit for wide study such as antenna, radio function and communication protocol. This uses the FPGA to comply with Japan's ITS Forum Test Guideline RC-006, which is prepared for the test of 700MHz ITS band.

The communications test unit was used to perform a non-line-of-sight (NLOS) conditions experiment. The test scenario was the same as used in the standardization activity of Japan (10^{-2} PER threshold).

Table 1　OFDM 700MHz Test Unit

Frequency	674MHz
Modulation	OFDM/QPSK
TX Power	20dBm
RX Sensitivity	-91dBm/10MHz
Packet Size	100Byte
Diversity Type	Maximum Ratio Combining

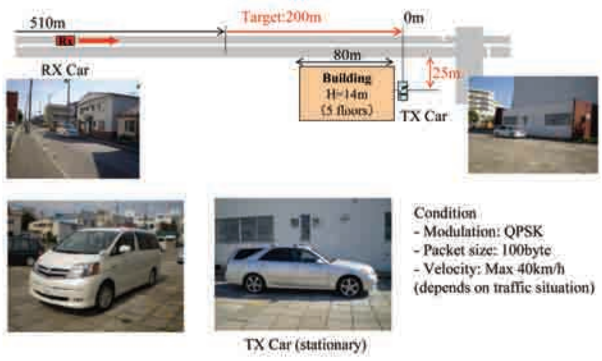

Fig. 4　Condition of Real Street Test

The test situation is shown in **Fig. 4**. The street we used for this test is located almost center of Abashiri city. There are many 2-3 floors houses and buildings. The car parked at side of big building (height=14m) was sending the periodic packet on 700MHz band. Then the receiving car that equipped DUT antenna started from the 510m far from the building. The receiving car recorded the packet error rate (PER). Our target was to get 200m communication range under 1% PER [1)].

As primary real street test, we compared the performance between the front direction of IRVM antenna and a mono pole installed on the vehicle roof. **Fig. 5** shows the experimental result and indicates that the single IRVM antenna has some performance degradation when compared to the roof mount antenna. The IRVM antenna was expected good radiation to front direction, but there still be a lack of communication range with IRVM antenna. To improve the performance of the IRVM antenna, we considered two types of solution. One corrective action is to use diversity and the other to establish antenna pattern control. Because we thought that the multipath caused some for this degradation. Diversity and beam forming may be good help.

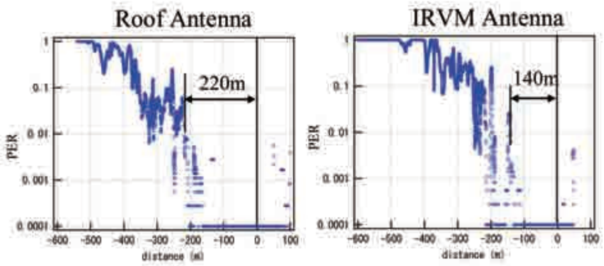

Fig. 5　Comparison with Roof Antenna

2. DIVERSITY ANTENNA

2-1 DESIGN

To evaluate the improvement when using the diversity approach, we made a prototype that included two inverted F-type antennas installed in the IRVM as shown in **Fig. 6** and **Fig. 7**. We made two different diversity samples. One incorporated two vertical polarized elements, and another is a combination of vertical and horizontal polarization. This allowed us to compare the effect of polarization diversity and space diversity using these two prototypes.

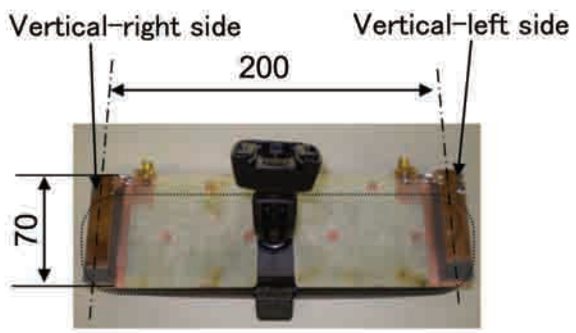

Fig. 6　Prototype IRVM Antenna (V-V)

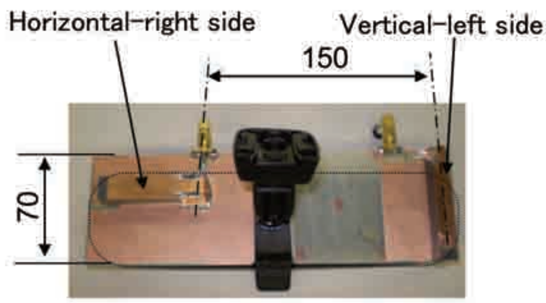

Fig. 7　Prototype IRVM Antenna (H-V)

2-2 EVALUATION

Again the experiment was conducted on the actual street under same condition mentioned above. The result is shown in **Fig. 8**. Here we see significant improvement from single inverted-F type antenna in the performance characteristic. But the polarization diversity does not provide any meaningful benefit, because a difference of polarization does not give remarkable performance difference.

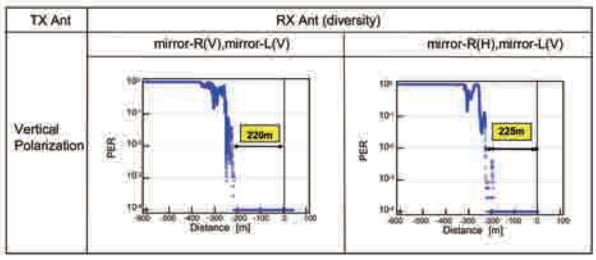

Fig. 8　Result of Diversity

3. ANTENNA PATTERN CONTROL

3-1 DESIGN

Since two inverted-F type antennas are installed with approximately 1/3 to 1/2 wave length spacing, we anticipated that the pattern might be controlled by using the antennas in an array. If antenna pattern can be controlled, it would greatly improve the communication range and also could be a help for interference to/from other station. Other benefit of this pattern controlled antenna is that it requires only one set of coax cable. In contrast, diversity antenna requires two set of coax cables. This means pattern controlled antenna has some advantage for cost, especially for expensive coax cable cost.

To evaluate this effect, we developed an antenna pattern control method diagramed in **Fig. 9**. We implemented the phase shifter and combiner on PCB as shown in **Fig. 10**. It enables to control the antenna pattern by changing the amount of phase shift.

Our assumption was that the antenna pattern can be guided to the suitable direction by radio. However, in our experience, we just performed the real road test with three types of antenna pattern. Then we can estimate the benefit of optimum antenna pattern control.

Fig. 11 shows the characteristics of pattern controlled antenna that is tuned the beam to front, right 40deg and left 40deg. This is the measurement result of installed condition into IRVM.

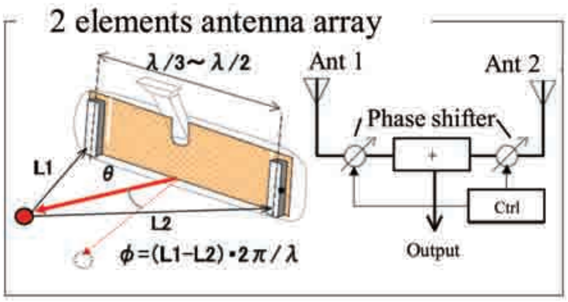

Fig. 9　Pattern Control Method

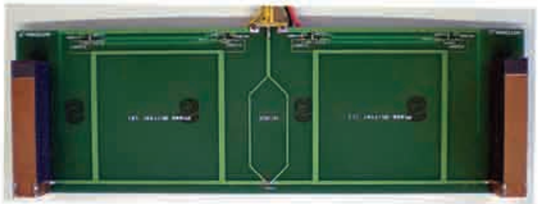

Fig. 10　Prototype of Pattern Controlled Antenna

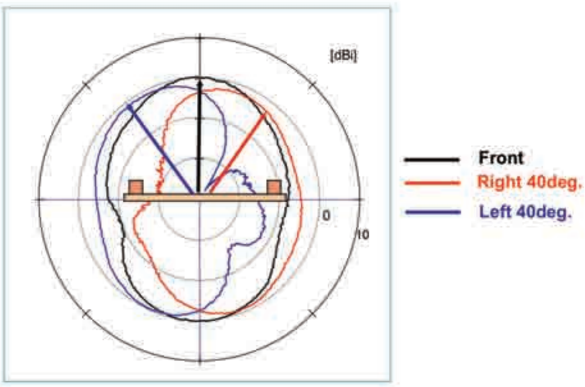

Fig. 11　Controlled Antenna Pattern of Prototype

3-2　EVALUATION

To see the benefit of antenna pattern control, we performed the real street test. The results shown in **Fig. 12** and **Fig. 13** tell different things, although they are the results from same real street test where the test condition is mentioned in previous section.

In **Fig. 12**, measured receiving signal by each antennas do not necessarily show significant differences among the antennas. But the **Fig. 13** shows each antenna gives different PER performance and tells potential improvement by antenna pattern control. To analyze these results, we executed a simulation of the propagation situation on real street where we performed the test.

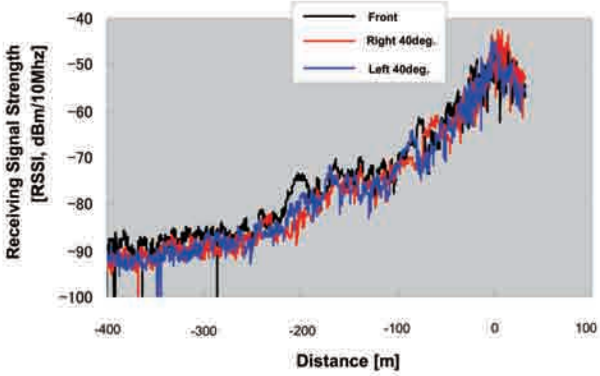

Fig. 12　RSSI Measurement of Pattern Controlled Antenna

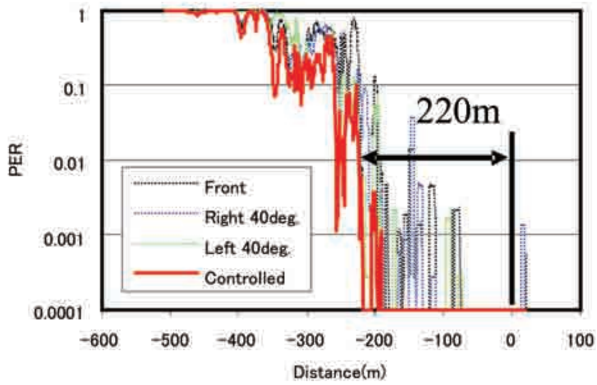

Fig. 13　PER Measurement of Pattern Controlled Antenna

3-3　ANALYSIS

We used ray tracing simulator RapLab (trademark of KOZO KEIKAKU ENGINEERING Inc.) to make sure the propagation situation on the street in Abashiri city. We made the street model illustrated in **Fig. 14** for this simulation [4]. This is based on actual street where we performed the test in Abashiri-city. The simulation condition is shown in **Table 2**. The parameter of antennas is based on the characteristics shown in **Fig. 11**. They were measured as IRVM installed antenna.

Table 2　Simulation Condition

Frequency	674MHz
Output Power	20dBm
Resolution of distance	1m
Antenna height	1.5m
Cable Loss	-2dB
Earth refletion	ON

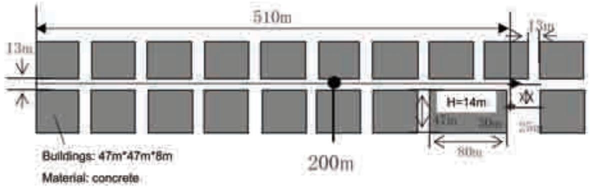

Fig. 14　Street Model for Simulation

The simulation result shown in **Fig. 15** and **Fig. 16** tell that the signals which are reflected by buildings and ground still come from almost same direction. It means the antenna pattern control do not necessarily work well. If so, what is the reason we saw the improvement with antenna pattern control?

After some studies, we paid attention to the antenna pattern on actual vehicle. We confirmed its characteristics by measurement using big radio anechoic chamber shown in **Fig. 17**. As the result, the antenna patterns of each have many dips for some directions as shown in **Fig. 18**. We think the pillars and other body material of vehicle cause these dips, since we did not see these in the antenna measurement shown in **Fig. 11**.

So, our antenna pattern control method controls not only front beam, but also such dip pattern. We guess this difference of dip pattern works to cancel influencing path signal. This improves the PER performance on real street, and was not simulated because we did not use onboard antenna pattern.

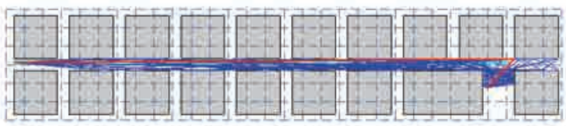

Fig. 15　Simulation Result of Propagation Paths

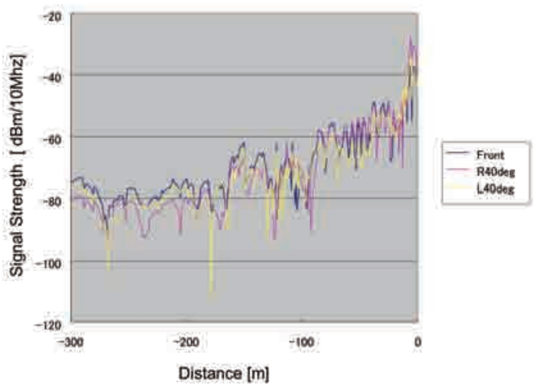

Fig. 16　Result of Propagation Simulation

Fig. 17　Vehicle Antenna Measurement in Radio Anechoic Chamber

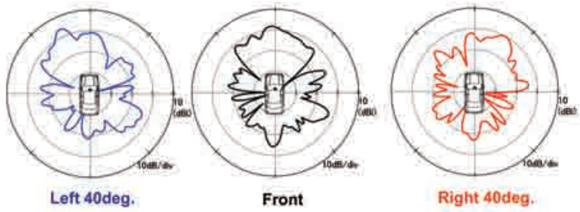

Fig. 18　Onboard Antenna Pattern

3-4　CONTROL METHOD

We expected to have optimum performance if we can guide the pattern to the direction that the radio needs. In this case, pattern control provided enhanced performance, however the issue of how to establish the optimum direction remains. We believe that the radio processing can generate necessary information from received signal. But, in this paper, we just point out that potential of the pattern control antenna. It will be necessary to consider the combination with OFDM modulator technology, in order to develop practical antenna control system.

SUMMARY

We considered an IRVM antenna assembly as a potential alternative to the roof mount element. Initially, the single IRVM antenna performed poorly, so we added diversity to improve the result. We showed how antenna pattern control using an array can also improve the performance but we still need to develop a method for optimizing the control system.

REFERENCES

1) Road Transport Bureau, ASV Suishin Keikaku Houkokusho [Summary of the Advance Safety Vehicle Project promotion planning], http://www. mlit. go. jp, Ministry of Land,

Infrastructure, Transport and Tourism, Japan, 2006
2) K. Fujimoto, A. Henderson, K. Hirasawa and J.R. James, "Small Antennas," Research studies press ltd., Letchworth, Hertfordshire, England, 1993
3) John D. Kraus, Ronald J. Marhefka, Antennas for All Applications, Third Edition , A Division of The McGraw-Hill Companies, 2002
4) Y. Hosoya, Radiowave Propagation Handbook, REALIZE INC., Japan, 1999

<著　者>

鈴木　忠男
（すずき　ただお）
技術開発センター　DP-V2X室
技術士（電気電子部門）
V2Xシステム製品の開発に従事

杉本　勇次
（すぎもと　ゆうじ）
（株）日本自動車部品総合研究所
車載用アンテナの研究，開発に従事

溝口　　幸
（みぞぐち　みゆき）
（株）日本自動車部品総合研究所
車両EMC解析技術の開発に従事