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MIMO STBC Data Transmission Scheme for Inter-Vehicle Communication at 60 GHz in ITS

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1. Introduction

In order to reduce congestion and accident rates for cars, Intelligent Transport System (ITS) has been interested as a countermeasure. To realize safety driving systems in ITS, there are two fields of researches one is RVC (Road-to-Vehicle-Communication) and the other is IVC (Inter-Vehicle Communication). For IVC, which will be treated in this paper, multipath fading, caused by road surface reflection, is one of the most severe problems. Signal reduction improvement by means of space time diversity at receiving site seems very effective [1]. In order to enhance the space diversity effects, MIMO (Multiple Input Multiple Output) data transmission scheme with STBC (Space Time Block Coding) [2] is examined and evaluated.

2. Propagation Channel Model of IVC

This section shows propagation channel model of IVC system. The system we considered here has two transmit antennas and four receive antennas as shown in Fig.1. The channel characteristic H (Channel State Information: CSI) considering of the direct wave and ground reflected wave is given by

$$H = \begin{bmatrix} h_{11} \cdots h_{1M} \\ \vdots \quad \ddots \\ h_{N1} \cdots h_{NM} \end{bmatrix} \qquad N = 4, M = 2 \tag{1-a}$$

$$h_{nm}(L) = \alpha \times \left(\frac{1}{L_{nm}^{direct}} \times \exp(-j\frac{2\pi}{\lambda} L_{nm}^{direct}) + \gamma \frac{1}{L_{nm}^{reflected}} \times \exp(-j\frac{2\pi}{\lambda} L_{nm}^{reflected}) \right) \tag{1-b}$$

where L_{nm}^{direct} and $L_{nm}^{reflected}$ represent the direct path length and reflected path length for transmit

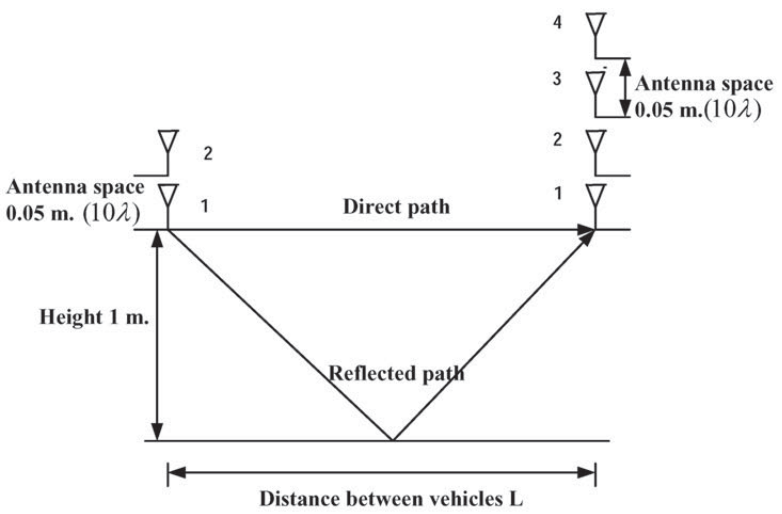

Figure1. Channel Model of IVC where there is the direct wave and ground reflected wave

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antenna m to receive antenna n. α is a path amplitude factor which is given by L (distance between vehicles) for the purpose of normalization to keep signal-to-noise ratio constant irrespective of distance L. γ is reflection coefficient of road surface and assumed to be -1 in this paper [1]. Since the vehicular distances L changes with time(t) in terms of vt (v: the difference of speed between two vehicles), CSI also changes with time.

3. Space Time Block Coding (STBC) data transmission scheme

In space time diversity which is based on Alamouti's scheme known as space time block coding (STBC), two signals are transmitted from the two transmit antennas. The transmitted signal from antenna 1 in the first symbol period is assumed by s_0 and from antenna 2 by s_1. In the next symbol period, signal $-s_1^*$ is transmitted from antenna 1, and signal s_0^* from antenna 2 where * is the complex conjugate operation. This sequence is shown in table 1 and Fig.2.

Table 1 Sequence of transmitted signal

	tx antenna 1	tx antenna 2
time	s_0	s_1
time $t+T_s$	$-s_1^*$	s_0^*

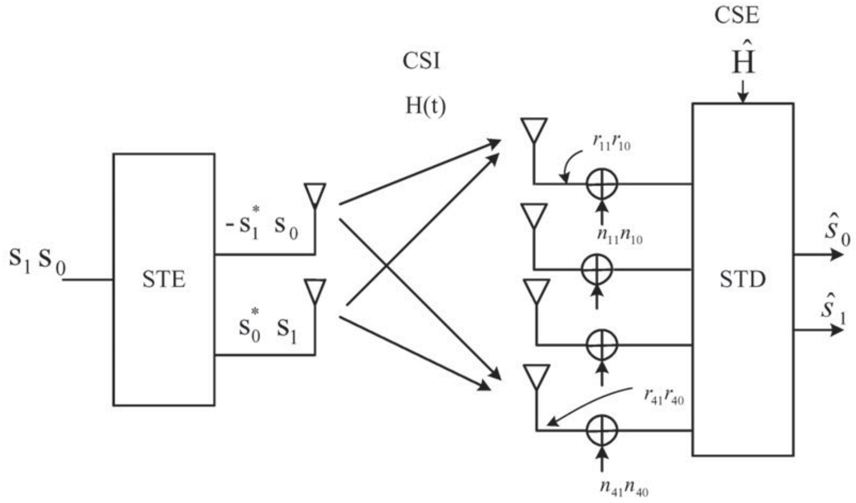


Figure2. Alamouti's STBC scheme (STE: space time encoding, STD: space time decoding)

At the signal direction stage in the case of Alamouti's scheme, estimated channel information (CSE) is necessary to separate s_1 and s_2 from the received signal r_{n0} and r_{n1} (n=1-4). In order to have CSE and to transmit data, a signal transmission sequence shown in Fig.3 is adopted. One sequence has two subsequences, one is training subsequence to have CSE and the other is data transmission subsequence. By transmitting a pair of pilot symbols which consist of Walsh codes, CSE given by $\hat{H}(i)$ can be obtained from pilot (i). For data transmission, we consider two methods. The first method (method 1), estimates CSI at the receiver by information given in Eq (2-a) while method 2 by Eq (2-b).

$$CSE = \hat{H}(i) \qquad \text{for Data (i) detection} \qquad \text{(2-a)}$$

$$CSE = \frac{1}{2}(\hat{H}(i) + \hat{H}(i+1)) \qquad \text{for Data (i) detection} \qquad \text{(2-b)}$$

In the latter case (namely, method2) data accumulation at least one sequence must be necessary. Since channel condition changes with time very rapidly because of 60 GHz signal, we can expect that

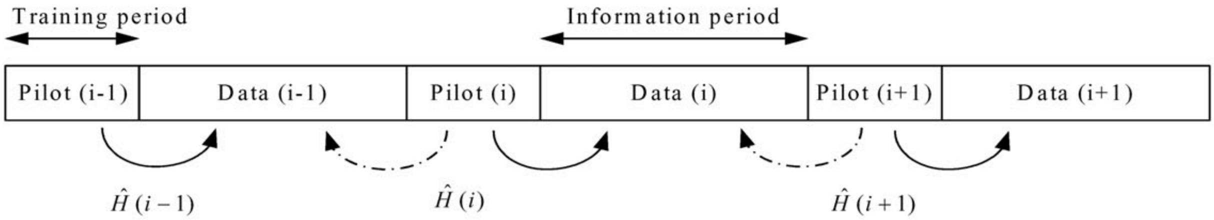


Figure 3. Data transmission sequence scheme

method 2 gives better performance.

4. Simulation Conditions

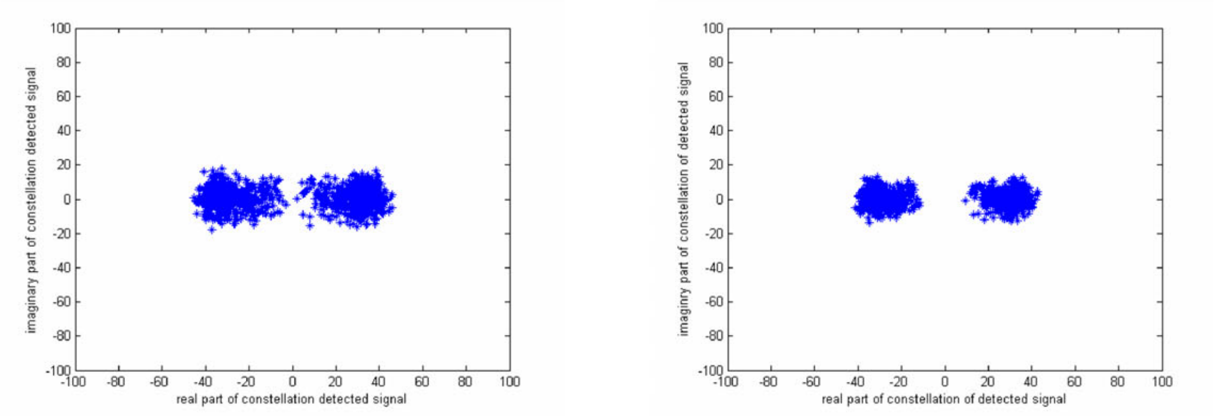
For the preliminary evaluation, the distance between two vehicles is equal to 50 meters at time $t = 0$, the frequency considered here is 60 GHz so that element antenna spacing of 0.05 m corresponds to 10 wavelengths . The speed difference v between two vehicles is assumed to be 0-40 m/s. The simulation condition is given in Table 2.

Table 2 Simulation conditions

Frequency (wavelength)	60GHz (5mm)
Antenna height	1 m.
SNR	20 dB
velocity difference	0-40m/s
modulation	BPSK
bit rate	1Mbps
Training bits (period)	8 bits (8μsec)
Information bits (period)	50 bits (50μsec)

5. Results

Constellation of detected signal results is presented in Fig 4. It is evaluated by computer simulation at the speed of vehicle equal to 15 m/s. In Fig 4 the constellation signals of method 1 are more dispersed than that of method 2. Namely, the constellation signals from method 2 are detected clearer than from method 1 so that bit error rate in method 2 is expected to be smaller than in method 1. The bit error rate of both methods is shown in Fig 5. In the case of lower speed, both schemes have no errors. When the vehicle speed up to 13 m/s bit error rate exceeds 10^{-5} and increases with the velocity in method 1 but in method 2 it appears at the speed of 18 m/s and also increase with the velocity. However, in method 1 give more bit error rate than in method 2 as shown in Fig 5.



(a) method 1

(b) method 2

Figure 4. Constellation of detected signal at $v = 15$ m/s with $L \cong 50$ m

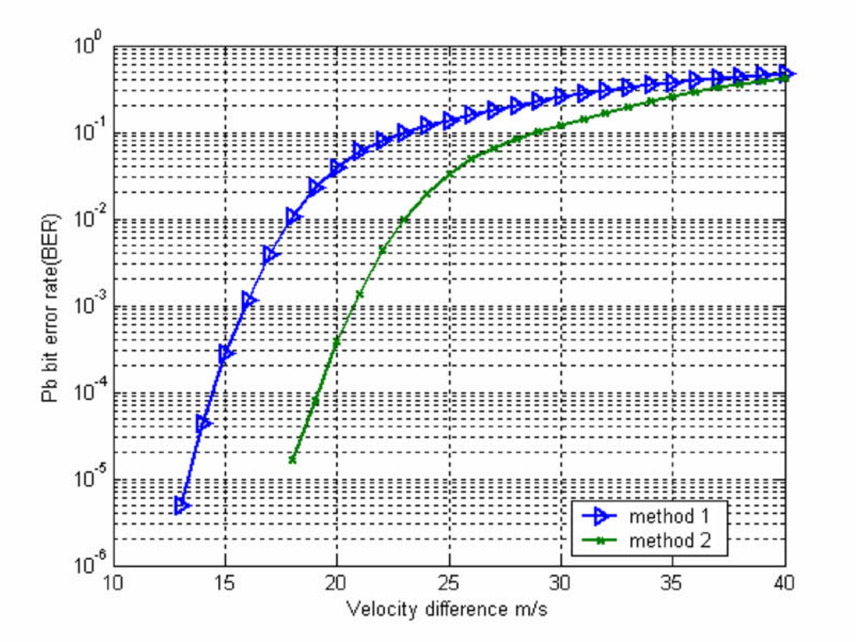


Figure 5. The BER as a function of velocity difference for two methods

6. Conclusions

The data transmission schemes for Inter-Vehicle Communication (IVC) have been presented. It is shown that, using space time diversity (space time block coding) with two transmit antennas and four receive antennas can suppress multipath fading. Since carrier frequency assumed here is 60 GHz so that phase change is very rapid, the BER performance decreases with increasing the velocity difference. By using channel state information obtained from method 2 can have better performance than method 1.

Reference

[1] Y.Karasawa, "*Multipath Fading Due to Road Surface Reflection and Fading Reduction by Means of Space Diversity in ITS Vehicle-to-Vehicle Communications at 60 GHz*", Electronics and Communications in Japan, Part 1, vol.85, no.1,pp.35-41, 2002.

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