THE IMPACT OF DOPPLER SHIFT ON THE OSTBC SYSTEM IN VEHICULAR CHANNEL CONDITION

HIBA ABDALLAH

Department of Electrical and Computer Engineering, Beirut Arab University, Beirut-Lebanon
E-mail: habdallah@bau.edu.lb

Abstract- In ITS communicating systems, the transmitter and receiver are moving at high speeds. This causes different fading statistics depending on the existence of a line-of-sight (LOS). Rician channel model can be considered as a suitable probabilistic channel model for the vehicular network in the highway scenario. On the other side, Rayleigh channel model can be considered as a suitable probabilistic channel model for the vehicular network in the traffic scenario. Multiple-input multiple-output antennas at the transmitter and receiver side enhanced the BER performance of wireless communication systems. MIMO channels between transmit and receive antennas are statistically independent identically distributed channels. In real life, the channels are correlated and the MIMO gains are not always be reachable. Hence, spatial correlation between a signal's spatial direction and the average received signal gain exists. In a vehicular scenario, transmit and receive antennas are mounted at heights of 1–3 meters. Vehicles and buildings are in close proximity which can be very close to one antenna but far from the others. Therefore, the channels are probably non-identically distributed. In this paper, we present a brief analysis on the effect of high mobility patterns on the bit error rate (BER) performance of Orthogonal Space Time Block Coding (OSTBC) and Trellis Code Modulation (TCM) in correlated fading channels. These channels are characterized by high speed wireless interaction which typically fit in Intelligent Transportation System (ITS) mobility models. Simulations show that the performance of the system is degraded in a manner proportional to the vehicle's velocity and channel correlation. It also demonstrates that Rician channels are less affected by higher mobility than Rayleigh channels.

Keywords- ITS Communication; MIMO; OSTBC; TCM; Rayleigh Channel; Rician Channel; Doppler Frequency, Correlation.

I. INTRODUCTION

Intelligent Transportation System (ITS) is witnessing a rapid proliferation supported by successful implementations from diverse car vendors. ITS communicating systems allow mobile vehicles to exchange informative and entertainment messages without relying on any fixed infrastructure or Road Side Units (RSUs). The great life and material losses incurred from car accidents is highly necessitating the presence of an intelligent transportation system that facilitates the interaction between wireless communication systems, remote sensing infrastructures and other IT schemes to improve the efficient and safe operation of traffic systems. The major problem faced by ITS systems is the severe deterioration of the BER performance resulting from the high mobility patterns of the communicating entities. The ITS system needs to sustain at least one wireless local area network technology, e.g., IEEE 802.11a/b/g to maintain non-safety applications. By making modifications to the IEEE 802.11a radio technology, IEEE 802.11a is derived to adapt to vehicular environments. It occupies 75 MHz of the licensed spectrum, from 5.85 to 5.925 GHz, as part of the intelligent transportation system for dedicated short range communications (DSRC) in the USA. Although the ITS communication technologies have many challenges, it must be tackled before deployment. ITS propagation channel has strong impact on the coverage, reliability, and real-time capabilities of Vehicle to vehicle networks. Wrong assumptions about fading lead to incorrect conclusions on the dependability of inter vehicle warning systems. It is crucial to use well characterized measurement based models of ITS communications channels. Therefore, much research attention has been attracted to ITS channel modeling and measurements. In ITS communicating systems, the transmitter and receiver are moving at high speeds. This causes different fading statistics depending on the existence of a line-of-sight (LOS). Rician channel model can be considered as a suitable probabilistic channel model for the vehicular network in the highway scenario. On the other side, Rayleigh channel model can be considered as a suitable probabilistic channel model for the vehicular network in the traffic scenario. Multiple-input multiple-output antennas at the transmitter and receiver side enhanced the BER performance of wireless communication systems.

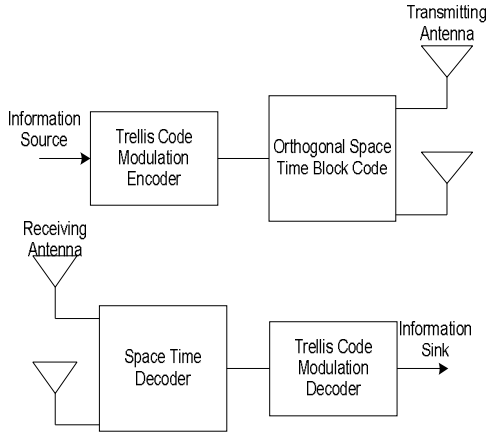


Fig.1. Block diagram of cascaded MIMO TCM-OSTBC

MIMO channels between transmit and receive antennas are statistically independent identically distributed channels. In real life, the channels are correlated and the MIMO gains are not always be reachable. Hence, spatial correlation between a signal's spatial direction and the average received signal gain exists. In a vehicular scenario, transmit and receive antennas are mounted at heights of 1–3 meters. Vehicles and buildings are in close proximity which can be very close to one antenna but far from the others. Therefore, the channels are probably non-identically distributed. In this paper, we present a brief analysis on the effect of high mobility patterns on the bit error rate (BER) performance of Orthogonal Space Time Block Coding (OSTBC) and Trellis Code Modulation (TCM) in correlated fading channels. These channels are characterized by high speed wireless interaction which typically fit in Intelligent Transportation System (ITS) mobility models. Simulations show that the performance of the system is degraded in a manner proportional to the vehicle's velocity and channel correlation. It also demonstrates that Rician channels are less affected by higher mobility than Rayleigh channels.

Recent researchers studied the BER performance of OSTBC under perfect and imperfect channel state information (CSI) at the receiver. These studies based on the assumption that the channels are independent and identically distributed (i.i.d.). This assumption is not likely to seize in vehicular scenarios. In a vehicular scenario, transmit and receive antennas are mounted at heights of 1–3 meters. Vehicles and buildings are in close proximity which can be very close to one antenna but far from the others. Therefore, the channels are probably non-identically distributed.

In this paper, an analysis on the effect of high mobility patterns on the bit error rate (BER) performance of Orthogonal Space Time Block Coding (OSTBC) and Trellis Code Modulation (TCM) in both correlated MIMO Rayleigh and correlated MIMO Rician probabilistic channel models is presented. These channels are characterized by high speed wireless interaction which typically fit in Intelligent Transportation System (ITS) mobility models. The system simulation demonstrates the effect of applying various mobility patterns on ITS communication systems.

The performance of the system is degraded in a manner proportional to the vehicle velocity. Simulations show that Rician channels are less affected by higher mobility than Rayleigh channels.

Section II focuses on the background of this work. A detailed literature survey on MIMO ITS channels is given in section III. Simulation works of different ITS mobility patterns with and without channel correlation are explained in section IV and finally the paper is concluded in section V.

II. RELATED WORK

Space time block coding (STBC) is a novel approach in wireless data communication that exploits a set of antennas for transmitting and receiving duplicate copies of network traffic for the purpose of enhancing the BER performance of the received data stream. Orthogonality is augmented to space-time coding schemes to achieve simpler designs with reduced implementation costs. OSTBC promises dramatic advantages in MIMO wireless systems and supports relatively high spatial diversity at the expense of constant coding gain. Trellis coded modulation (TCM) is a modulation scheme that incorporates coding together with modulation to support extremely efficient coding gains.

The operational carrier frequencies employed in ITS communication range mainly between 5.8-5.9 GHz. The high mobility patterns characterizing ITS systems and the concurrent movement of both the transmitting and receiving entities results in very high Doppler shifts compared to that witnessed in cellular communication systems which operate in the 700 – 2400 MHz range.

III. SYSTEM MODEL

The system model we followed is presented in Fig.1. Two transit and one receive antenna are used in this model. The binary input signal is encoded by M-symbols Phase shift Keying (Mary-PSK) trellis code modulation (TCM).

The input signal is convolutionally encoded and the result is mapped to an arbitrary signal constellation. The signal constellation parameter lists the signal constellation points in set-partitioned order. This parameter is a complex vector with a length (M) equal to the number of possible output symbols from the convolutional encoder. ($\log_2$ M= n for a rate k/n convolutional encoder). The OSTBC Encoder block encodes an input symbol sequence using orthogonal space-time block code (OSTBC). The block maps the input symbols block-wise and concatenates the output codeword matrices in the time domain. It combines the input signal (from all of the receive antennas) and the channel estimate signal to extract the soft information of the symbols encoded by an OSTBC. The input channel estimate may not be constant during each codeword block transmission and the combining algorithm uses only the estimate for the first symbol period per codeword block. A symbol demodulator or decoder would follow the Combiner block in a MIMO communications system. The block conducts the combining operation for each symbol independently

This system exploits several system objects to simulate a concatenated OSTBC with TCM over a 2x1 flat Rayleigh fading channel and Rician channel. An OSTBC system over 2x1 flat Rayleigh and Rician fading channels with TCM are investigated under the impact of spatial correlation.

System performance was measured using the BER curves. Simulations are carried out using the Rayleigh flat fading and the Rician channel models with 2 transmit and 1 receive antennas. The maximum Doppler frequency of the channel (1400 Hz) is utilized which is represented by the following equation:

$$v = \frac{f_d \times c}{f_c} \quad (1)$$

Where,
v is the velocity of the vehicle transceiver, f_c is the carrier frequency, f_d is the maximum Doppler frequency, and c is the speed of light in vacuum.

Since channel characteristics differ in diverse, three mobility patterns are employed and represented using the following notation:

ITS-L:
Low mobility vehicle communication such as in traffic scenario surrounded by high buildings.

ITS-M:
Moderate mobility vehicle communication as in narrow city roads, few buildings.

ITS-H:
High mobility vehicle communication as witnessed on highways, no high buildings.

Each mobility pattern is simulated using different combinations of OSTBC and TCM schemes. Adaptation among these mobility patterns is achieved based on the target BER performance in the ITS context. Table 1 demonstrates the different Doppler shifts representing the above mobility patterns.

TABLE 1 Maximum Doppler frequency vs. vehicle velocity at 6 GHz

Mobility Pattern	f_d(Hz)	v (Km/hr)
ITS-L	30	5.4
ITS-M	600	108
ITS-H	1400	250

IV. SIMULATION RESULTS

This section illustrates the MATLAB simulation results for the different mobility patterns using Mary-PSK TCM orthogonal space-time block codes. Monte Carlo Simulation has been used in plotting all the graphs. Bit error analysis shows the comparison between different mobility patterns for two transmit and one receive antennas. The operational carrier frequencies employed in ITS vehicle to vehicle communication range mainly between 5.8-5.9 GHz. In this system, the carrier frequency is taken to be 6 GHz.

The high mobility patterns characterizing ITS systems and the concurrent movement of both the transmitting and receiving entities results in very high Doppler shifts compared to that witnessed in cellular communication systems which operate in the 700 – 2400 MHz range.

Fig.2, shows the effect of mobility on the ITS mobility patterns where ITS-L surpass ITS -H by 1.8 dB at a target BER of 10^{-3}.

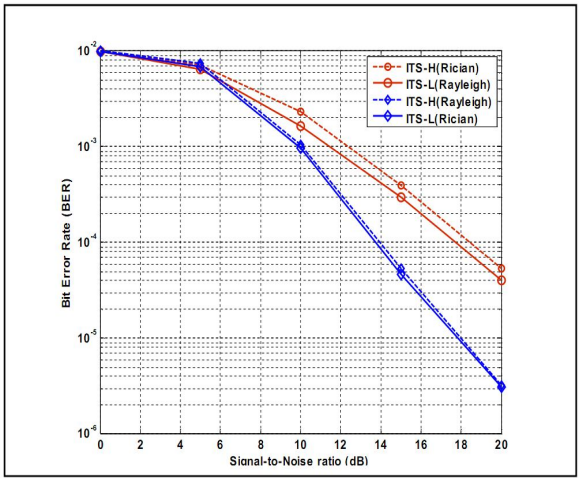


Fig.2. BER for ITS under different mobility patterns in Rayleigh channel using OSTBC with TCM

Fig.3, demonstrates that, in Rayleigh fading channel, ITS-H pattern needs 0.8 dB more than ITS-L to get a target BER=10^{-4}. While in Rician fading channels high mobility is less effective, it needs almost 0.2 dB more. Fig.4, and Fig.5, compare the BER of the different OSTBC, TCM combinations by varying the mobility levels from high, moderate to low. The same previous results are illustrated again. Rician channels is less affected by high mobility.

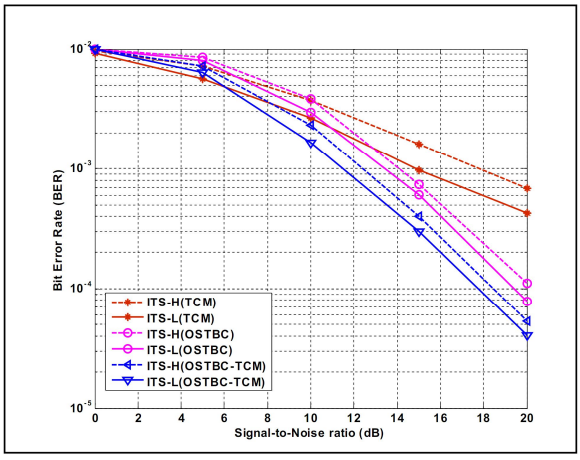


Fig.3. Comparison between ITS mobility patterns in both Rayleigh and Rician channel models using OSTBC with TCM.

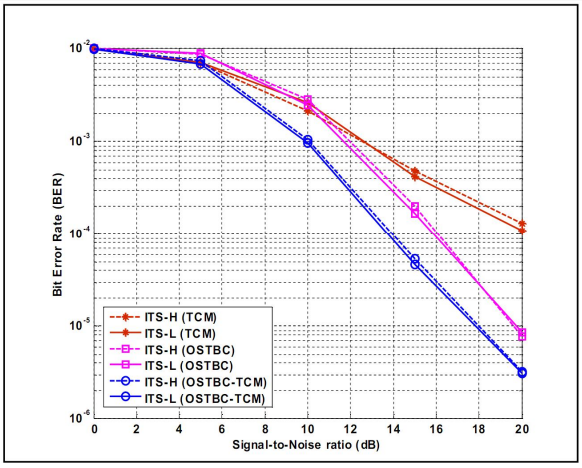


Fig.4. BER for ITS mobility patterns in Rayleigh channel model.

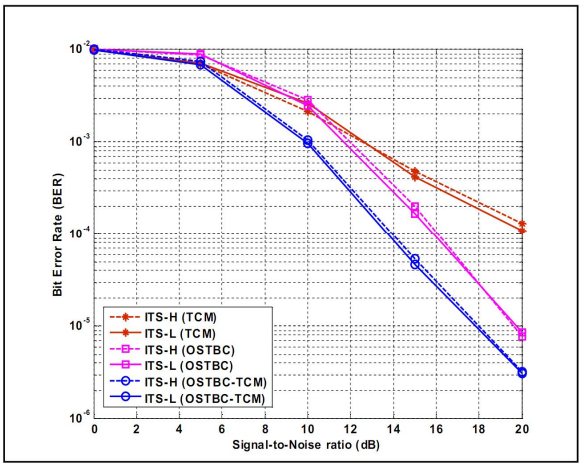


Fig.5. BER for ITS mobility patterns in Rician channel model.

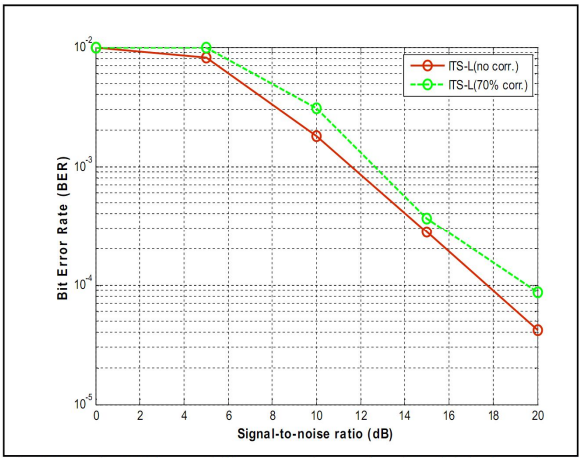


Fig.6. BER for ITS low mobility pattern in correlated Rayleigh channel model using OSTBC-TCM.

Fig.6, demonstrates the BER performance of low mobility OSTBC-TCM under different channel correlation scenarios. It shows that at target BER= 10^{-3}, 1.1 dB is needed for 70% channel correlation.

In Fig.7, the simulation results show that ITS-L OSTBC scheme achieves the same degradation as in the BER performance of ITS-L OSTBC-TCM due to the channel correlation. However, the performance of OSTBC is 1.4dB worse due to the fact that OSTBC-TCM has excess coding since it uses trellis coded modulation.

For 70% correlation and 1400 Hz Doppler shifts, the performance of ITS-OSTBC needs 3.3 dB more to get target BER=10^{-3} as shown in Fig.8.

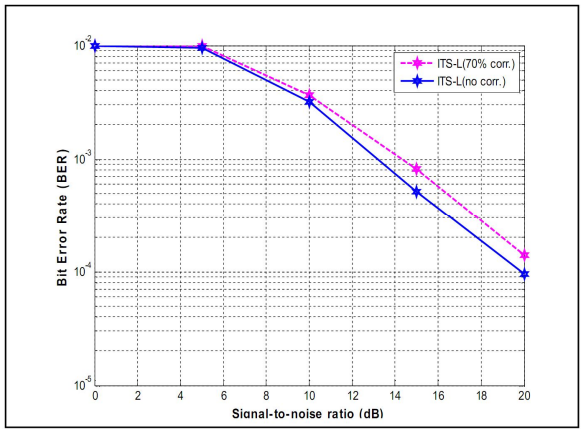


Fig.7. BER for ITS low mobility pattern in correlated Rayleigh channel model using OSTBC scheme.

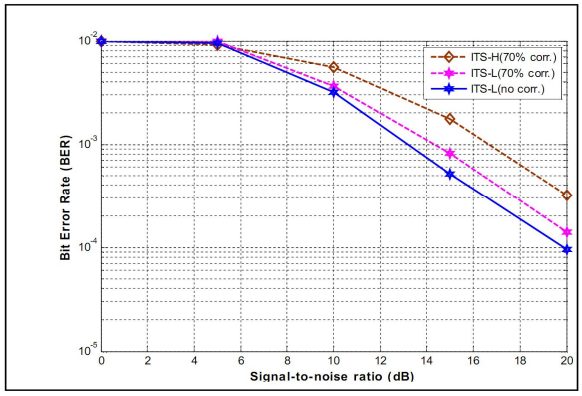


Fig.8. BER for ITS mobility pattern in correlated Rayleigh channel model using OSTBC scheme.

CONCLUSION

In this work, BER performances for different mobility scenarios are considered under the impact of channel correlation. Simulation shows that the performance of the system is degraded in a manner proportional to the vehicle's velocity and channel correlation. Simulations show that Rician channels are less affected by higher mobility than Rayleigh channels.

Hence, Rician channel model can be considered as a suitable probabilistic channel model for the vehicular network in the highway scenario. On the other side, Rayleigh channel model can be considered as a suitable probabilistic channel model for the vehicular network in the traffic scenario.

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