Spatial Modulation for V2V and V2I Communications in a Multiple Scattering Environment

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***Abstract*—In this paper, we investigate the performance of spatial modulation (SM) for vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications over a generalized multiple scattering channel. This channel model provides a realistic statistical description of an intervehicular communication environment and includes as special cases the Rician, Rayleigh, and double-Rayleigh channels. We derive an accurate closed form expression for the pairwise error probability of SM, which is used to obtain the error rate performances of SM over various propagation scenarios. The performance analysis reveals the impact of the number of receive antennas on the error rate performance of SM transmission over multiple scattering channels. Various numerically evaluated results are presented to demonstrate the correctness of the proposed analysis.**

***Index Terms*—Intervehicular communication, multiple scattering, spatial modulation.**

I. Introduction

Intelligent transportation systems (ITSs) have received growing attention by the scientific community and the industry over the past several years because they promise to advance transportation safety and efficiency through the dissemination of road and traffic information. The safety-related and information-related applications include messages regarding collisions, incidents, congestion, weather conditions, and coordination of vehicles at critical points such as blind crossings and highway entries. An integral part of ITSs are the so called intervehicular communication systems (IVCs) that include vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications. In a IVC system, vehicles form mobile adhoc networks and communicate with each other to get real time information, thus enable the driver to access information that is hard to acquire or measure by on-board sensors.

In order to provide an accurate analysis for the performance of IVCs, we need to use appropriate statistical models for the fading channel. It is noted that experimental results and theoretical analysis reveal that statistical models such as Rayleigh or Rician fading may not apply to IVCs where both the transmitter and the receiver are in motion. A physically motivated model for fading channels is the so called second order scattering (SOS) radio propagation channel [1]. This model actually represents a special case of the multiple scattering model that was initially proposed in [2], [3] and was statistically analyzed in [4]. The main idea of the SOS model is that depending upon the distance between the transmitter and the receiver, one or more groups of scatterers participate in the propagation [2]. Thus, as it is also noted in [2], it is more likely that a mixture of single Rayleigh, double Rayleigh and line of sight (LoS) components will exist at the receiver side. Moreover, the SOS distribution has been verified in experimental studies that collected measurements in various mobile-to-mobile communication environments [5], [6].

In order to enhance system reliability in IVC environments, multiple-input multiple-output (MIMO) systems have been proposed in the literature [7], despite the fact that current wireless transmission technologies for V2V communication systems (e.g. 802.11p, WAVE) employ single antennas at the transmitter and receiver side. MIMO systems can configure a multiple antenna array in multiple modes, depending on the interference intensity, surrounding propagation environment or the vehicular application of interest, in order to meet stringent user requirements. Furthermore, MIMO can best exploit the highly dynamic nature of the V2V channel to increase the link range, improve the reliability of communication, increase the throughput of the network, and manage multiuser interference. This versatility of MIMO systems renders it a key enabler for V2V communications.

However, despite the benefits that MIMO systems offer, they are also responsible for an increase on the system complexity and cost. In order to alleviate the negative aspects of MIMO systems, a new modulation concept has been recently proposed for a MIMO system, termed as spatial modulation (SM) [8], [9]. This scheme aims at reducing the complexity and/or cost of multiple-antenna transmission schemes without affecting the end-to-end system performance [10]–[12]. An important case of SM is the so-called space shift keying (SSK) modulation [13], [14], which employs multiple transmit antennas with only one transmitting at each time instant. According to SSK, the incoming bitstream is encoded into the index of the unique antenna which is switched on for transmission at each time instant while the others are switched off. SM can be considered as an ideal candidate for IVC systems, since it can improve system performance while minimizing transceiver complexity and cost. More specifically, SM entirely avoids inter-channel interference (ICI) and inter-antenna synchronization (IAS), and only requires a single radio frequency (RF) chain at the transmitter, which is of critical importance for the small-sized vehicle mounted transmission systems. Moreover, the receiver design is inherently simpler compared to other multiple antenna systems, e.g., V-BLAST, since complicated ICI cancelation algorithms are not required.

The performance of SM over fading channels has been addressed in several research works. For example, in [13], the performance of SSK in a Nakagami-m fading environment was addressed. In [14], the performance of SM in the presence of practical channel estimates was assessed. In [15], a framework for assessing the asymptotic performance of SM in a Nakagami-m fading environment was presented. [12] presents an approximate, yet accurate, framework for assessing the bit error rate performance of SM. In [16], the performance of SM over a three-dimensional V2V MIMO channel was investigated. The combination of SM with hierarchical modulation in a Ricean fading environment was addressed in [17] and [18]. In [19], differential SM for inter-vehicular communication is addressed. Finally, in [20], the combination of SM with orthogonal frequency division multiplexing with subcarrier index modulation for inter-vehicular communications is considered. However, to the best of the authors knowledge, SM transmission in a multiple scattering environment has not been considered with respect to IVC scenarios and thus motivates this work.

Technically speaking, the main contributions of the paper can be summarized as follows:

- New analytical expressions for the average bit error probability (ABEP) of SSK operating over multiple scattering conditions are derived. When the transmitter is equipped with two antennas the resulting analytical expressions are exact, whereas for an arbitrary number of transmit apertures tight upper bounds are obtained;
- An asymptotic ABEP analysis is carried out, which reveals useful insights on the impact of system parameters on the attained error rate performance;

The remainder of this paper is structured as follows. Section II outlines the system and channel models. In Section III, analytical expressions for the ABEP of SM in multiple scattering environments are presented. In Section IV various performance results and their interpretations are presented. Finally, concluding remarks are given in Section V.

Mathematical Notations: $\imath = \sqrt{-1}$, $|\cdot|$ is the magnitude of a complex number, $\Gamma(\cdot)$ is the gamma function [21, Eq. (8.310/1)], $\mathbb{E}\langle\cdot\rangle$ denotes expectation, $J_a(\cdot)$ is the Bessel function of the first kind and order a [21, Eq. (8.402)], $Q(x) = 1/\sqrt{2\pi}\int_x^\infty \exp(-t^2/2)\mathrm{d}t$ is the Gaussian Q-function, and $\mathrm{Ei}(\cdot)$ the exponential integral function [21, Eq. (8.21)]. The probability density function (PDF) of the random variable (RV) X is denoted as $f_X(\cdot)$ and its corresponding moment generating function (MGF) as $\mathcal{M}_X(\cdot)$.

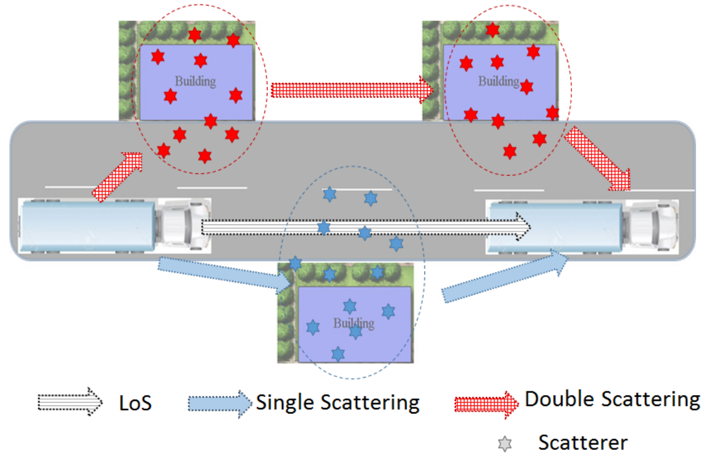

Fig. 1. Intervehicular communication scenario in SOS conditions.

II. System and Channel Model

A. System Model

We consider a generic IVC system, with both vehicles moving and their local scattering environments as shown in Figure 1. We assume that the source vehicle employs N_t transmit antennas and the destination vehicle has N_r receive antennas. According to [10], the transmitter encodes blocks of $\log_2(N_t)$ data bits into the index of a single transmit antenna, t_i, for $i = 1, \ldots, N_t$. Such a block of bits is hereafter referred to as "message". It is assumed that the N_t messages are transmitted by the encoder with equal probability. During each time slot, the t_i-th antenna is switched on for data transmission while all other antennas are kept silent, i.e., $N_t - 1$ antennas do not transmit. At the receiver, a N_t hypothesis detection problem is solved to retrieve the active transmit antenna index, which results in the estimation of the unique sequence of bits emitted by the transmitter.

B. Channel Model

Depending on the propagation characteristics around the communicating vehicles, a variety of vehicular environments are often distinguished in the literature, such as highways, rural roads, suburban and urban streets. This variety of environments will result in different propagation conditions, which can be modeled by a weighted combination of LoS, single scattering and double scattering fading. In this work, the SOS distribution is adopted to model signal fluctuations, because this distribution can accurately approximate small-scale fading statistics for a wide range of IVC scenarios. Specifically, depending upon the existence or not of a LoS component as well as the distance between the transmitter and the receiver several communication scenarios exist where SOS conditions may arise. In Fig. 1, an example of a communication scenario is depicted, where SOS conditions exist under the assumption of a LoS path. Hereafter, in contrast to recently published channel models for inter-vehicular communications, i.e. [22],

[23], it is also assumed that underlying channel is quasi-static, which is well justified for vehicular communication scenarios in rush-hour traffic. This is common assumption that has been widely adopted by many researchers in order to be able focus to analyze the system performance, e.g., [24].

The transmitted signal can be expressed as a linear combination of signal components with constant, Rayleigh and double-Rayleigh distributed amplitudes. This multiple scattering model yields as special cases the Rician, Rayleigh, and double-Rayleigh fading channels. The complex channel gains $\alpha_{i,\ell}$, $\forall i = 1, 2, \ldots, N_t$ and $\forall \ell = 1, 2, \ldots, N_r$ are defined as $\alpha_{i,\ell} = a_{i,\ell} \exp(\imath \phi_{i,\ell})$ where $a_{i,\ell}$ and $\phi_{i,\ell}$ are the envelopes and phases of the link from the i-th transmit antenna to the ℓ-th receive antenna, respectively.

Under the considered multiple scattering scenario, $\alpha_{i,\ell}$ can be expressed as [4]

$$\begin{aligned}\alpha_{i,\ell} &= w_{0,i,\ell} \exp(\imath \theta_{i,\ell}) + w_{1,i,\ell} H_{1,i,\ell} + w_{2,i,\ell} H_{2,i,\ell} H_{3,i,\ell} \\ &= \sum_{n=0}^{2} C_{n,i,\ell}\end{aligned} \tag{1}$$

where $C_{0,i,\ell} = w_{0,i,\ell} \exp(\imath \theta_{i,\ell})$ is the LoS component with constant magnitude and uniformly distributed phase over $[0, 2\pi]$, $C_{1,i,\ell} = w_{1,i,\ell} H_{1,i,\ell}$, $C_2 = w_{2,i,\ell} H_{1,i,\ell} H_{2,i,\ell}$ where $H_{n,i,\ell}$ are independent and identically distributed (i.i.d.) isotropic Gaussian processes having zero mean and unit variance, and $\{w_{n,i,\ell}\}_{n=0}^{2}$ are nonnegative real-valued constants that determine the mixture weights of the multiple scattering components.

III. Average Bit Error Probability of SM

A $N_t \times N_r$ MIMO system employing SM is considered, equipped with N_t transmit and N_r receive antennas, which can send digital information via M complex symbols, $\chi_j = |\chi_j| e^{\imath \theta_j}$, $j = 1, \ldots, M$. In the following and without loss of generality, two test cases are considered: *i*) A pure SSK system operating under independent and identically distributed (i.i.d) fading (*Case I*); and *ii*) A SM system operating under i.i.d fading with constant-modulus modulation i.e. $|\chi_j| = \kappa_0$, $\forall j = 1, \ldots, M$ (*Case II*).

1) Case I: Under the assumption of i.i.d fading, a tight upper bound for the ABEP of SSK can be obtained from [13, Eq. (35)], [15], as

$$\overline{P} \leq \frac{N_t}{2} \mathrm{PEP}_{\mathrm{SSK}}(t_1 \to t_2) \tag{2}$$

where $\mathrm{PEP}_{\mathrm{SSK}}(t_1 \to t_2)$ denotes the average pairwise error probability (PEP) related to the pair of transmit antennas t_1 and t_2, $\forall t_1, t_2 = 1, 2, \ldots, N_t$, defined as

$$\begin{aligned}\mathrm{PEP}_{\mathrm{SSK}}(t_1 \to t_2) &= \mathbb{E}\left\langle Q\left(\sqrt{\overline{\gamma} \sum_{\ell=1}^{N_r} Z_{\ell,t_1,t_2}}\right)\right\rangle \\ &= \frac{1}{\pi} \int_0^{\pi/2} \prod_{\ell=1}^{N_r} \mathcal{M}_{Z_{\ell,t_1,t_2}}\left(\frac{\overline{\gamma}}{2\sin^2\theta}\right) \mathrm{d}\theta\end{aligned} \tag{3}$$

where $\overline{\gamma} = E_m / 4N_0$ is the symbol-energy-to-noise-spectral-density ratio and $Z_{\ell,t_1,t_2} = |a_{t_2,\ell} \exp(\imath \phi_{t_2,\ell}) - a_{t_1,\ell} \exp(\imath \phi_{t_1,\ell})|^2$. When two transmit antennas are used, i.e. when $N_t = 2$, the ABEP of SSK is equal to $\mathrm{PEP}_{\mathrm{SSK}}(t_1 \to t_2)$.

Using the tight approximation for the Gaussian Q-function presented in [25, Eq. (14)] (i.e., $Q(x) \approx \frac{1}{12} e^{-x^2} + \frac{1}{4} e^{-\frac{2x^2}{3}}$) as well as the definition of the MGF of a random variable X (i.e. $\mathcal{M}_X(s) = \mathbb{E}\langle \exp(-s\,X)\rangle$), an expression accurately approximating (3) can be deduced as

$$\begin{aligned}\mathrm{PEP}_{\mathrm{SSK}}(t_1 \to t_2) \approx& \frac{1}{12} \prod_{\ell=1}^{N_r} \mathcal{M}_{Z_{\ell,t_1,t_2}}(\overline{\gamma}) \\ &+ \frac{1}{4} \prod_{\ell=1}^{N_r} \mathcal{M}_{Z_{\ell,t_1,t_2}}\left(\frac{2\overline{\gamma}}{3}\right).\end{aligned} \tag{4}$$

In the following analysis, analytical expressions for the MGF of Z_ℓ will be deduced. By employing [26, Eq. (9)], $\mathcal{M}_{Z_{\ell,t_1,t_2}}(s)$ can be expressed as

$$\mathcal{M}_{Z_{\ell,t_1,t_2}}(s) = \frac{1}{2s} \int_0^{\infty} R e^{-\frac{R^2}{4s}} \Phi_{\alpha_{t_2,\ell}}(R) \Phi_{\alpha_{t_1,\ell}}(R) \mathrm{d}R \tag{5}$$

where $\Phi_{\alpha_{t_2,\ell}}(R) \triangleq \int_0^{\infty} J_0(Rr) f_{\alpha_{t_i,\ell}}(r) \mathrm{d}r$ are the zeroth order Hankel transforms of $f_{\alpha_{t_i,\ell}}(r)/r$. Due to the independence of $C_{n,i,\ell}$, $\forall n \in \{0, 1, 2\}$, the Hankel transforms in (5) can be expressed as [4, Eq. (6)]

$$\Phi_{\alpha_{t_i,\ell}}(R) = \prod_{n=0}^{2} \Phi_{C_{n,t_i,\ell}}(R) \tag{6}$$

where $\Phi_{C_{n,t_i,\ell}}(R)$ are given as [4, Eqs. (8), (12), (13)]

$$\Phi_{C_{0,t_i,\ell}}(R) = J_0(w_{0,t_i,\ell} R) \tag{7a}$$

$$\Phi_{C_{1,t_i,\ell}}(R) = \exp\left(-w_{1,t_i,\ell}^2 R^2 / 4\right) \tag{7b}$$

$$\Phi_{C_{2,t_i,\ell}}(R) = \frac{4}{4 + w_{2,t_i,\ell}^2 R^2}. \tag{7c}$$

When a LoS component is present, i.e. $w_{0,t_i,\ell} \neq 0$, a closed form expression for $\mathcal{M}_{Z_{\ell,t_1,t_2}}(s)$ is very difficult - if not impossible - to be deduced and one has to resort to numerical integration. Assuming the absence of the LoS component, i.e. $w_{0,t_i,\ell} = 0$, it will be shown that $\mathcal{M}_{Z_{\ell,t_1,t_2}}(s)$ can be expressed in closed form. Such an assumption corresponds to a blind end propagation environment for V2I communications as shown in Fig. 2 [27]. For this scenario, a vehicle moving along a curved street communicates with a fixed road-side unit (RSU) deployed on the other side of the curved road. The RSU, which acts as a fixed receiver, provides the driver with information related to traffic and road conditions. Due to the curvature of the street, the driver is not able to see the road ahead and thus the LoS component can be ignored.

$$\mathcal{M}_{Z_{\ell,t_1,t_2}}(s) = \frac{-\exp\left(\frac{1+w_{1,t_1,\ell}^2 s+w_{2,t_1,\ell}^2 s}{w_{1,t_2,\ell}^2 s}\right)\mathrm{Ei}(-\frac{1+w_{1,t_1,\ell}^2 s+w_{2,t_1,\ell}^2 s}{w_{1,t_2,\ell}^2 s}) + \exp(\frac{1+w_{1,t_1,\ell}^2 s+w_{2,t_1,\ell}^2 s}{w_{2,t_2,\ell}^2 s})\mathrm{Ei}(-\frac{1+w_{1,t_1,\ell}^2 s+w_{2,t_1,\ell}^2 s}{w_{2,t_2,\ell}^2 s})}{s(w_{1,t_2,\ell}^2 - w_{2,t_2,\ell}^2)} \quad (9)$$

$$c_\ell = \frac{-\exp\left(\frac{w_{1,t_1,\ell}^2+w_{2,t_1,\ell}^2}{w_{1,t_2,\ell}^2}\right)\mathrm{Ei}(-\frac{w_{1,t_1,\ell}^2+w_{2,t_1,\ell}^2}{w_{1,t_2,\ell}^2}) + \exp(\frac{w_{1,t_1,\ell}^2+w_{1,t_2,\ell}^2}{w_{2,t_2,\ell}^2})\mathrm{Ei}(-\frac{w_{1,t_1,\ell}^2+w_{2,t_1,\ell}^2 s}{w_{2,t_2,\ell}^2})}{w_{1,t_2,\ell}^2 - w_{2,t_2,\ell}^2} \quad (12)$$

Fig. 2. A blind bend propagation scenario for V2I communications.

In this case, by substituting (7b) and (7c) into (5), $\mathcal{M}_{Z_{\ell,t_1,t_2}}(s)$ can be expressed as

$$\mathcal{M}_{Z_{\ell,t_1,t_2}}(s) = \frac{1}{2s}\int_0^\infty \frac{Re^{-\frac{(w_{1,t_1,\ell}^2+w_{1,t_2,\ell}^2+s^{-1})R^2}{4}}}{\left(1+\frac{R^2 w_{2,t_1,\ell}^2}{4}\right)\left(1+\frac{R^2 w_{2,t_2,\ell}^2}{4}\right)}\mathrm{d}R. \quad (8)$$

By performing the change of variables $R^2 = t$ along with a partial fraction decomposition and by employing [21, Eq. (3.354/4)], $\mathcal{M}_{Z_{\ell,t_1,t_2}}(s)$ can be deduced as (9) (shown at the top of the next page).

In order to provide further insight on the impact of system parameters to the error rate performance, an asymptotic analysis at high values of $\overline{\gamma}$ is carried out. The diversity gain of the considered SSK system can be obtained using the approach presented in [28]. In particular, a generic analytical expression, which becomes asymptotically tight at high SNR values, can be derived for the average PEP appearing in (3), as follows:

$$\mathrm{PEP}_{\mathrm{SSK}}(t_1 \to t_2) \overset{\overline{\gamma}\gg 1}{\approx} \frac{2^{N_r-1}\Gamma\left(N_r+\frac{1}{2}\right)}{\sqrt{\pi}\Gamma\left(N_r+1\right)}\left[\prod_{\ell=1}^{N_r} c_\ell\right]\overline{\gamma}^{-N_r} \quad (10)$$

where

$$c_\ell = \frac{1}{4}\int_0^\infty \prod_{i=1}^{2}\Phi_{\alpha_{t_i,\ell}}(\sqrt{y})\mathrm{d}y. \quad (11)$$

As it is evident, the diversity gain of SSK is equal to the number of receiving antennas, N_r. Assuming the absence of the LoS component, it can be shown that c_ℓ can be expressed in closed form. By performing a partial fraction decomposition and by employing [21, Eq. (3.354/4)], c_ℓ can be deduced as (12) (shown at the top of the page).

2) Case II: The ABEP of SM can be tightly upper bounded as [12, Eq. (6)]

$$\overline{P} \le \mathrm{ABEP}_{\mathrm{signal}} + \mathrm{ABEP}_{\mathrm{spatial}} + \mathrm{ABEP}_{\mathrm{joint}} \quad (12)$$

where $\mathrm{ABEP}_{\mathrm{signal}}$, $\mathrm{ABEP}_{\mathrm{spatial}}$ and $\mathrm{ABEP}_{\mathrm{joint}}$ show how the error performance of SM is affected by the signal constellation diagram, the spatial constellation diagram and the interaction of both signal and space constellation diagrams, respectively. Under generalized fading, the term $\mathrm{ABEP}_{\mathrm{signal}}$ when either M-ary phase shift keying (M-PSK) or M-ary quadrature amplitude modulation (M-QAM) are employed, can be readily evaluated using [12, Eqs. (7), (8)] and [12, Table I]. Assuming constant modulus modulation $\mathrm{ABEP}_{\mathrm{spatial}}$ and $\mathrm{ABEP}_{\mathrm{joint}}$ can be obtained from [12, Eq. (10)] and [12, Eq. (11)], respectively, as

$$\mathrm{ABEP}_{\mathrm{spatial}} = \frac{N_t \log_2(N_t)}{2\log_2(N_t M)}\mathrm{PEP}_{\mathrm{SM}}(t_1 \to t_2) \quad (13a)$$

$$\mathrm{ABEP}_{\mathrm{joint}} = \left[\frac{M(N_t-1)\log_2(M)+N_t(M-1)\log_2(N_t)}{2\log_2(N_t M)}\right] \times \mathrm{PEP}_{\mathrm{SM}}(t_1 \to t_2) \quad (13b)$$

where $\mathrm{PEP}_{\mathrm{SM}}(t_1 \to t_2)$ can be readily obtained from (4) by replacing $\overline{\gamma}$ with $\kappa_0\overline{\gamma}$.

IV. Numerical Results

In this section, we present various performance results obtained by numerically evaluating the mathematical expressions derived in Section III for SM systems, operating over multiple scattering environments. The IVC scenarios that were used to obtain the above performance graphs include a V2I scenario and a V2V scenario. In the V2I scenario, the source vehicle is equipped with $N_t = 2$ transmit antennas and moves in a curved road (no LoS component exists), whereas the RSU is equipped with $N_r \ge 1$ antennas. In the V2V scenario, the source vehicle is equipped with $N_t = 2$ transmit antennas whereas the destination vehicle has $N_r \ge 1$ receive antennas operating in a multiple scattering environment with a LoS component. Unless otherwise stated, for the V2V scenario, the weight coefficients are selected as $w_{0,t_1,\ell} = 1.5$, $w_{0,t_2,\ell} = 1$, $w_{1,t_1,\ell} = 1$, $w_{1,t_2,\ell} = \sqrt{2}$, $w_{2,t_1,\ell} = 1.2$, $w_{2,t_2,\ell} = 2\sqrt{2}$. As already mentioned, for the V2I scenario $w_{0,t_1,\ell} = w_{0,t_2,\ell} = 0$,

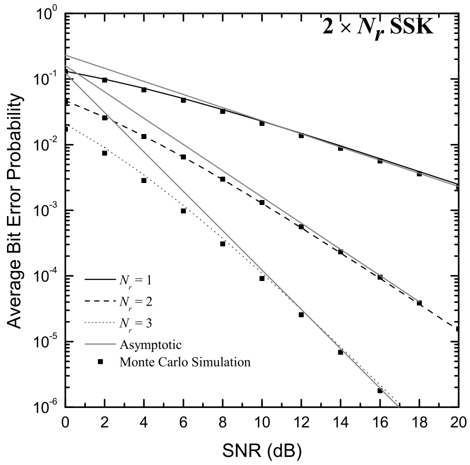

Fig. 3. ABEP of SSK in a V2I environment with curved road.

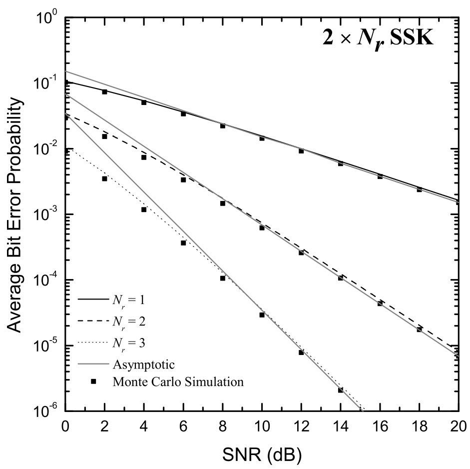

Fig. 4. ABEP of SSK in a V2V environment with LoS conditions.

whereas the remaining weights are the same. It is noted that for all considered cases, arbitrary values for the corresponding weights were considered in a similar fashion as in [27].

In Fig. 3, the derived ABEP approximation using (4) with (9) for the V2I scenario with non LoS component is illustrated as a function of $\overline{\gamma}$, using different values of N_r. The exact ABEP is also evaluated using Monte-Carlo simulations and it is included as a reference (illustrated by square patterns). It is observed from Fig. 3 that the derived ABEP provides a very tight approximation for the entire SNR region. For all cases considered, it is observed that the asymptotic analysis correctly predicts the diversity gain of the SSK transmission scheme and that the asymptotic ABEP coincides with the exact one in the high SNR regime.

In Fig. 4, the derived ABEP approximation for the V2V scenario is illustrated as a function of $\overline{\gamma}$, using different values of N_r. Since a closed-form expression for the ABEP in (4) cannot be derived in this case, all results have been evaluated using numerical integration of (5). This integration can be performed in an efficient and accurate manner by means of numerical integration techniques available in mathematical

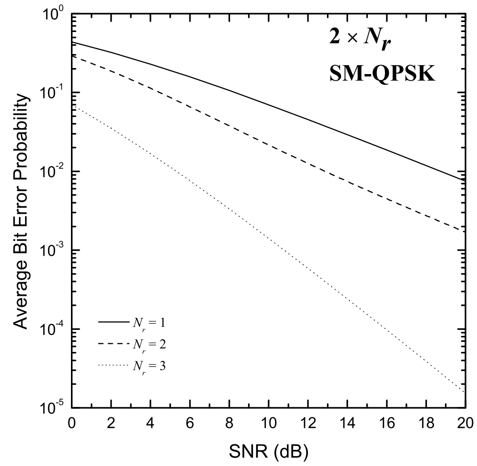

Fig. 5. ABEP of SM-QPSK in a V2I environment with nLoS conditions.

software packages such as Matlab or Mathematica [1]. As far as the accuracy of the exact and asymptotic analysis is concerned, we observe similar findings to those reported for the V2I case.

In Fig. 5, the ABEP of MIMO SM-QPSK $(M = 4)$, for the V2I scenario with non LoS component is illustrated as a function of $\overline{\gamma}$, using different values of N_r. It is observed from Fig. 5 that the derived ABEP improves as SNR or N_r increases.

V. Concluding Remarks

In this paper, we introduced SM transmission for IVC operating over a multiple scattering channel model, which can be used to model various propagation scenarios. Analytical expressions for the ABEP of SM over this fading model were derived for the first time. Our analytical expressions offer a simple and reliable method to estimate ABEP performance of SM systems in multiple scattering channel models without resorting to lengthy simulations. Therefore, they are useful for the development, design, and test of future V2V and V2I communication systems. Finally, of particular interest is the application of the proposed transmission scheme when time varying channel models are considered, which is left for future contribution.

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