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A Comparative analysis of orthogonal space time block code with trellis coded modulation over Rayleigh and Rician fading channel

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Abstract:- **For signal transmission in wireless communication, combining coding, modulation, transmit and receive diversity, and validly increases the antinoise performance in fading channels. We document the performance comparison of orthogonal space time block code (OSTBC) with trellis coded modulation (TCM) over Rayleigh fading channel and Rician fading channel. Orthogonal space time block code is a new channel coding technology for MIMO wireless communication. They exploit full spatial diversity order and enjoy symbol-wise maximum likelihood (ML) decoding. While the trellis coded modulation is a bandwidth efficient scheme that integrates coding and modulation to provide a large coding gain. In this paper, we are using MIMO alamouti's orthogonal space time block code for 2 Tx and 1 Rx antenna with M-ary psk trellis coded modulated signal to evaluate the frame error rate (FER) for M-ary PSK signal over Rayleigh fading channel and Rician fading channel to without line of sight (LOS) faded channel and direct line of sight (LOS) faded channel respectively. The results are used to examine definitively the FER and gain for OSTBC with TCM and to compare their performances over Rayleigh fading channel and Rician fading channel.**

Index terms:- **trellis-coded modulation, Multiple Input and Multiple Output , Orthogonal space time block code, Rayleigh fading channel ,Rician fading channel , frame error rate.**

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I. INTRODUCTION

In mobile radio communication, Performance analysis for diversity combining techniques commonly assumes identically distributed diversity branches, due to its analytical tractability. In practice, the environmental scattering on the propagation paths observed by different branches may be different. This may incur shadowing effects and, consequently, unequal path loss on different branches. When the transmitted signal waves are coming from the transmitter through the different paths are interacting with one another received by receiver then sometimes, the signals are in phase and sometimes they are in out-of-phase. These effects are caused to make the received signal amplitude and power increases and decreases respectively. And make a caused to the fluctuation with time. In wireless fading channel, the Rayleigh fading distribution is commonly used to describe the statistical time varying nature of the received fading signal. But this Rayleigh fading distribution does not considered for direct line of sight (LOS) component for received fading signal. However, Rayleigh fading models are not sufficient to describe many channels found in the real world. It is important to consider other models and investigate their performance as well.[1] Rician fading is one such model, which is applicable when the wireless link between the transmitter and the receiver has a direct path[2]. In fading channel, the Space diversity creates different independent propagation paths from transmitter to receiver and results the chances of deep fading over all paths. Orthogonal Space-Time Block Code (OSTBC) uses space diversity and time periods to transmit data. And the trellis-coded modulation (TCM) provides efficient bandwidth and large coding gain with direct line of sight component with factor K over rician fading channel . and without LOS component over Rayleigh fading channel.

II. MULTIPATH FADING CHANNEL MODEL

Multipath fading is due to the constructive and destructive combination of randomly delayed, reflected, scattered, and diffracted signal components. This type of fading is relatively fast and is therefore responsible for the short-term signal variations. Depending on the nature of the radio propagation environment, there are different models describing the statistical behavior of the multipath fading envelope[3]. Here we are studying the Rayleigh fading channel and Rician fading channel model. the propagation environment for any wireless channel in either indoor or outdoor may be subject to LOS (Line-of-Sight) or NLOS (Non Line-of-Sight). We know that a probability density function of the signal received in the LOS environment follows the Rician distribution, while that in the NLOS environment follows the Rayleigh distribution[4]. Here figure 1 shows the non line of sight propagation environments for Rayleigh fading channel and figure 2 shows line of sight propagation environments for Rician fading channel.

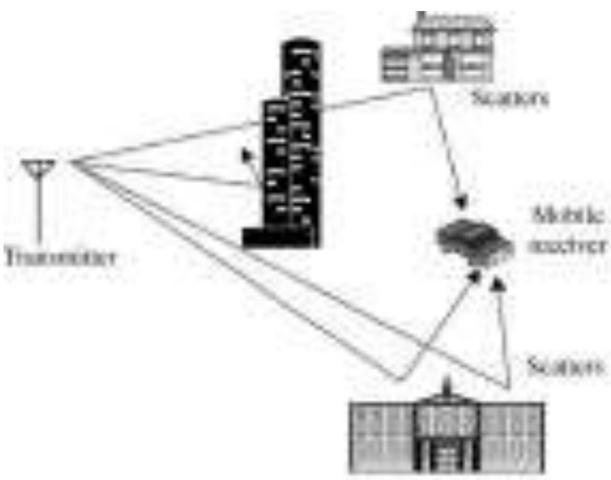

Figure 1:- Non LOS propagation environments.

The probability density function (PDF) of the Rayleigh fading channel is defined [5]as

$$f_x(X) = \frac{1}{\Omega} exp\left(\frac{-X}{\Omega}\right) \ , \ where\ \Omega = E[X].$$

And the moment generating function is defined as for Rayleigh fading channel is $\phi_x(s) = \frac{1}{1+s\Omega}$. Note that the Rayleigh fading channel does not consider direct line of sight path. Now for the Rician fading channel, the probability density function (PDF) is defined [6]as

$$f_x(X) = \frac{1+K}{\Omega} exp\left(-K - \frac{(1+K)\,X}{\Omega}\right) I_0\left(2\sqrt{\frac{K\,(K+1)X}{\Omega}}\right)$$

$where\ (\ K \geq 0)$, K is the Rician factor which is defined as the a ratio of the specular component power and scattering component power. And the moment generating function for Rician fading channel is defined as

$$\phi_x(s) = \frac{1+K}{1+K+s\Omega} exp\left(\frac{-Ks\Omega}{1+K+s\Omega}\right)$$

.

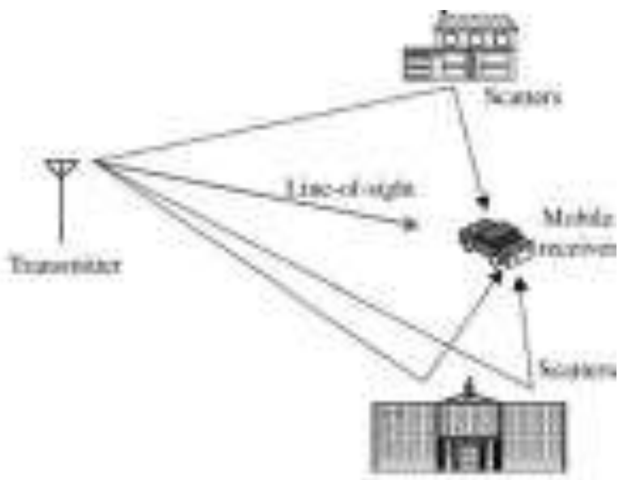

Figure 2:- LOS propagation environments.

III. TRELLIS-CODED MODULATION (TCM)

In communication field, the trellis coded modulation is a modulation scheme which allows highly efficient transmission of information over band-limited channels. it allows the achievement of significant coding gains over conventional uncoded multilevel modulation without compromising bandwidth efficiency. The TCM schemes [7] employ redundant nonbinary modulation in combination with a finite state encoder which governs the selection of modulation signals to generate coded signal sequence. In the receiver, the noisy signals are decoded by a soft-decision maximum-likelihood sequence decoder.[8] Simple four-state TCM schemes can improve the robustness of digital transmission against additive noise by 3 dB, compared to conventional uncoded modulation. With more complex TCM schemes, the coding gain can reach 6 dB or more. These gains are obtained without bandwidth expansion or reduction of the effective information rate as required by traditional error-correction schemes. A multiple trellis encoder has m binary input bits and u binary output bits which are mapped into *k* M-ary symbols in each transmission symbol. A multiple Trellis Encoded M PSK

Transmitter block diagram shown in figure 3. In Such a system has throughput *m/k bits/s/Hz* which has the same bandwidth with *2m/k* - point signal constellation. In the considered system the partition is carried out as follows: u binary encoder output bits are partitioned into k group of *m* = log2 M bits each. Each of these groups results in an MPSK output symbol. Clearly, to achieve this result the parameters *u, k, M* have to be chosen so that *u* = *k* . log2 M (here m1=m2=… =mk).

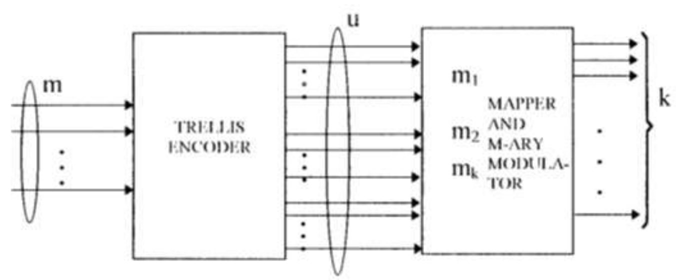

Figure 3:- Multiple Trellis Encoded M PSK Transmitter.

Let the samples be $r_n = a_n + w_n$ (real or complex valued, for one or two dimensional modulation, respectively), where the a_n are the discrete signals sent by the modulator and the w_n represent samples of an additive white Gaussian noise process. The decision rule of the optimum sequence decoder is to determine, among the set C of all coded signal sequences which a cascaded encoder and modulator can produce the sequence $\{\hat{a}_n\}$ with minimum squared Euclidean distance (sum of squared errors) from $\{r_n\}$, that is, the sequence $\{\hat{a}_n\}$ which satisfies

$$|r_n - \hat{a}_n|^2 = \min_{\{\hat{a}_n\}\in C} \sum |r_n - a_n|^2$$

. And the minimum squared such distance[8,9] is called the squared "free distance."

$$d_{free}^2 = \min_{\{a_n\}\neq\{b_n\}} \sum |a_n - b_n| \;; \{a_n\},\{b_n\}\epsilon\, C.$$

Where a_n and b_n are the signal sequence. In Trellis Coded Modulation the error can be determine by the error-event probability. At high signal-to-noise ratio, the error-event probability is generally well approximated by $P_r(e) \cong N_{free} \cdot Q[\,d_{free}/(2\sigma)]$, where Q(.) represents the Gaussian error integral $Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^{\infty} \exp(-y^2/2)\,dy$, and N_{free} denotes the (average) number of nearest neighbor signal sequences with distance d_{free} that diverge at any state from a transmitted signal sequence, and remerge with it after one to more transitions.

IV. ORTHOGONAL SPACE TIME BLOCK CODE (OSTBC)

A new channel coding technology –STBC[10] (space time block codes) has been presented in recent years. It combines coding, modulation, transmit and receive diversity, and validly increases the anti-noise performance in fading channels. the anti-noise performance in fading channels. Alamouti recently discovered a remarkable scheme for transmission using two transmit antennas and one receive antenna, and this scheme can achieve the same diversity advantage[11] as the scheme using one transmit antenna and two receive antennas. In this paper we are using Alamouti STBC scheme which uses two transmit antennas and N_r receive antennas and can accomplish a maximum diversity order of 2 N_r [11]. Moreover, the Alamouti scheme has full rate (i.e. a rate of 1) since it transmits 2 symbols every 2 time intervals. Take the STBC system of two antennas presented by Almouti as example, the orthogonal matrix with p=2, N_t= 2 is

$$X_2 = \begin{pmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{pmatrix}$$

The receive signal of jth antenna is

$$\begin{bmatrix} r_1^j \\ r_2^j \end{bmatrix} = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}\begin{bmatrix} h_{j1} \\ h_{j2} \end{bmatrix} + \begin{bmatrix} n_1^j \\ n_2^j \end{bmatrix}$$

$(j = 1,2,\ldots, N_r)$. Where n_i^j is the noise adding to the receive signal of j^{th} antenna from i^{th}(i=1,2) transmit antenna, the variance is $N_0/2$. In case of 1 receive antenna, the reception and decoding of the signal depends on the number of receive antennas available. Assuming that each symbol has duration T, then at time t + T, the symbols $-x_2^*$ and x_1^*, where $(.)^*$denotes the complex conjugate, For the case of one receive antenna, the receive signals are [7]:

$$r_1^{(1)} = r_t(t) = h_{1,1}x_1 + h_{1,2}x_2 + n_1^{(1)}$$
$$r_1^{(2)} = r_t(t+T) = -h_{1,1}x_2^* + h_{1,2}x_1^* + n_1^{(2)}$$

Assume that each transmit symbol source has the same symbol energy, that is $E_s = E[|x_1|^2] = E[|x_2|^2] = \ldots = E[|x_k|^2]$, where , $E[\bullet]$ is the statistic mean. Applying the decoding theory of Almouti's scheme into OSTBC system, for coding matrix as $N_t \times P$, with N_T transmit antennas, N_R receive antennas[12], the receiver can be equivalent to independent output at p moments, and each output has the receive SNR $R_{SNR} = \sum_{j=1}^{n_R}\sum_{i=1}^{n_T}|h_{j,i}|^2\, E_s/N_0$.

V. SIMULATION RESULT AND ANALYSIS

In this paper, our main aim is analysis the performance of OSTBC with TCM over the Rayleigh fading channel and Rician fading channel and compare their results using FER v/s SNR plots. So here we have proposed a simulation model using orthogonal space time block coding and trellis code modulation technique over Rayleigh fading channel and Rician fading channel to achieve full diversity of orthogonal space time block coding and coding gain of trellis code modulation. A Simulink model of OSTBC and TCM shows in figure 4. In this Simulink model, firstly we use a baseband transmission multiple antenna system with M transmit and N receive antenna over Rayleigh fading channel. Again same processes is apply over the Rician fading channel for the simulation. Here we are using 2 transmitter and 1 receiver antenna for our simulation results. Here in this simulation model, the Bernoulli binary generator block produces the information source for the simulation. And for trellis-coded modulation (TCM) we are using M-PSK TCM Encoder block, which modulates the message data from the Bernoulli binary generator to a PSK constellation that has unit average energy. Here we are using 8-PSK constellation with 8 trellis states [7]. In M-PSK TCM decoder block, the Viterbi algorithm is uses for TCM to decode the signals from the OSTBC combiner.

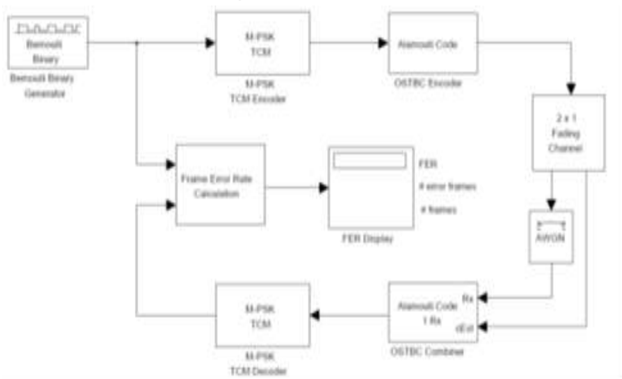

Figure 4 Simulink model for OSTBC with TCM.

In this paper, Matlab tools has been used for simulations to calculating the frame error rate(FER) performance of the OSTBC with TCM over Rayleigh fading channel and Rician fading channel. Here first we have simulate our model for Rayleigh fading channel and then we simulate the model for Rician fading channel for different line of sight (LOS) rician factor K. and then compare their FER performance through FER v/s SNR plots. Here first a random bit stream is generated through Bernoulli binary generator. Then signal power level is defined and the encoding scheme is used to generate the symbols that are supposed to be transmitted through multipath faded channel. Here 2×1 fading channel subsystem-based implementation has to be provided that we first uses the multipath Rayleigh fading channel then we use for the Rician fading channel with Rician factor K. Then estimation of the symbols at the receiver is done by using maximum likelihood detection. Then AWGN is added in the system which is generated using normally distributed and generated as N(0,1), where N stands for normally distributed RV with 0 mean and variance 1. After this process, the performance of the system is calculated at different values of SNR. Then the FER Vs SNR curves are plotted under Rayleigh and Rician fading environment. First we see the simulation plot of orthogonal space time block (OSTBC) for MPSK signal over Rayleigh fading channel and rician fading channel shown in figure 5.

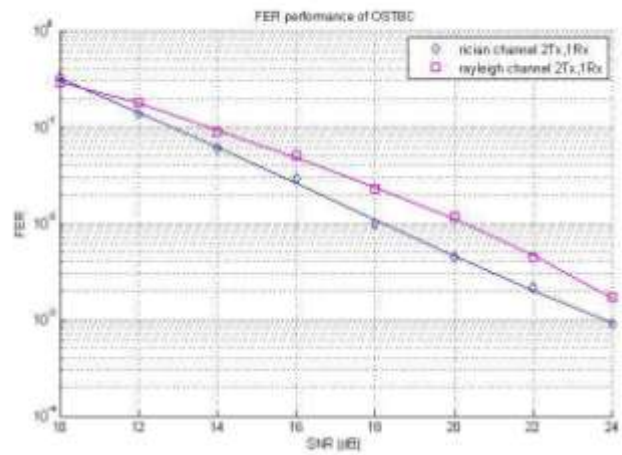

Figure 5:- FER for M-PSK modulation with OSTBC.

From figure 5, it has been shown that the FER of the Space time block code gives the better performance over the Rician fading channel for Rician factor K=1 then the Rayleigh fading channel. Initially at lower SNR value the FER for Rician and Rayleigh fading has minimum difference while the as increasing of SNR value, the difference of FER has to be increases approximately 2dB. Now we have seen the FER v/s SNR curves of OSTBC with TCM with 2 transmitter and 1 receiver antenna for M-PSK modulation over Rayleigh and Rician fading channel in figure 6 and figure 7 respectively.

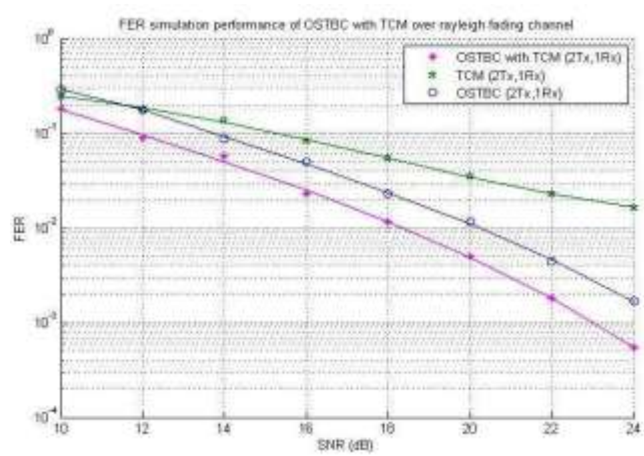

Figure 6:- OSTBC with TCM over Rayleigh fading channel.

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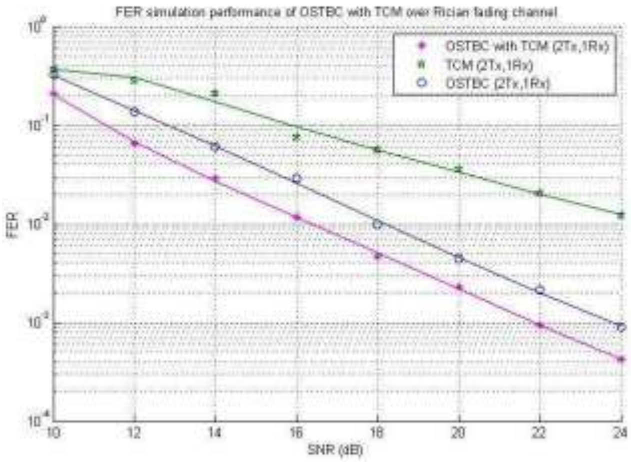

Figure 7:- OSTBC with TCM over Rician fading channel.

The simulation result from figure 6 and 7, it has been observed that the proposed scheme is known as OSTBC with TCM result in lowest FER. We are also compare the trellis code modulation and orthogonal space time block code for both Rayleigh and Rician fading channel shows that for a given value of SNR. From the above simulation results, it has been observed that orthogonal space time block coding performs better than trellis code modulation in terms of frame error rate. Now we have to compare the simulation results of FER performance for OSTBC with TCM over both Rayleigh fading channel and Rician fading channel from figure 8.

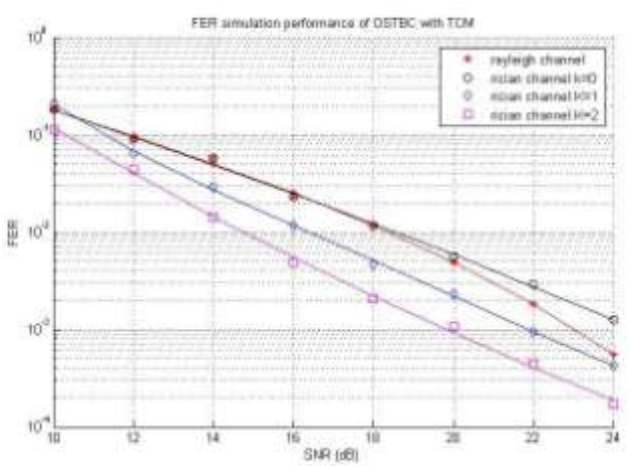

Figure 8:- FER simulation results for OSTBC with TCM.

Here form figure 8, we have to compare the performance of the OSTBC with TCM for Rayleigh fading channel and Rician fading channel with different Rician factor K. From this simulation results, it has been observed that the OSTBC with TCM gives the better performance over the Rician fading channel for direct line of sight (LOS) Rician factor K =1and K=2. While for the Rician factor K=0, no line of sight (NLOS), in this case the OSTBC with TCM performance decreases as compare to the Rayleigh fading channel where this channel does not considered no line of sight path.

VI. CANCLUSION

the orthogonal space time coding block coding is very useful technique for MIMO systems and produces full diversity on the other hand, Trellis code modulation is a band efficient scheme which provides large coding gain, thus to achieve full diversity of orthogonal space time block coding and large coding gain of trellis code modulation a new technique called orthogonal space time block coding combined with trellis code modulation has been proposed. And compare the performance of this technique over the Rayleigh fading channel and Rician fading channel. Where this scheme provides a significant diversity gain over the TCM scheme and about 2 dB coding gain over the Alamouti code. And this proposed technique for OSTBC with TCM shows the better performance around 3 dB over Rician fading channel when the line of sight (LOS) path is considered. While with no line of sight (NLOS) path is considered, this technique gives better result of about 1dB over Rayleigh fading channel as compare to the Rician fading channel.

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