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Performance Evaluation of Cooperative Communication with Relayselection

KEYWORDS Cooperative relaying, OSTBC, Nakagami Fading channel, EGC, ZF, MMSE.

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ABSTRACT *Cooperative communication is considered as one of the efficient technique to overcome fading in wireless network since it can achieve spatial diversity. Multiple relays provide increase in capacity without need for additional spectrum but transferring data though all relays increases the complexity and power consumption. OSTBC is used to overcome this. Zero Forcing detection is simple and effective technique for receiving multiple transmitted data streams at the receiver , however the detection requires knowledge of the channel state information and in practice accurate CSI may not be available. In this paper we used least square estimation (LSE) to estimate the channel. Simulation results shows the comparison of ZF and MMSE equalizers. We assumed that both the channels from source to relay and relay to destination are under the Nakagami fading channel.*

INTRODUCTION

In recent year multi hop communication has become an active and vital area of research in wireless communication .in a cellular network relaying scheme provide promising technology to transmit at higher data rate to destinations farther away[1] . The concept of cooperative transmission was introduced by [2],show how two users communicate each other to share the resource to increase the system capacity .The millimeter zero-forcing relay scheme has proposed in[5]with multiple source and destination node each relay node is equipped with signal antenna. The relays may amplify-forward (AF) or decode Forward (DF) where AF relay amplify and forwards the data destination in which even notice get amplified .where as in DF relay data get demonstrates first decodes and re encodes and forwards to the destination. DF relay do not cause any noise amplification. Considering all relays increases the power consumption and complexity. Several algorithms are introduced to select one relay or more than one relay. Selecting L out of M relays by highest signal to noise ratio [1] consumes less power compared to selecting all relays. In [2] relay selection algorithm is based on end to end performance. Relay selection based on pre defined threshold level is proposed in [3], this algorithm compares SNR of source to relay (γ_{SR}) and relay to destination (γ_{RD}) with predetermined threshold SNR (γ_T). If γ_{SR}, γ_{RD} are greater than or equal to $\gamma_{T,}$ then choose the relay for transmitting data from source to destination. In this paper we used relay selection based on Log Likelihood Ratio(LLR) [3],defined as $\left|\Delta\right| = \frac{4\sqrt{E_s}}{\sigma^2}\left|\mathrm{Re}\{\,\mathrm{r}_{\mathrm{s,r_i}}\mathrm{h}^*_{\mathrm{sr_i}}\,\}\right|$, where $\sqrt{E_s}$ is energy symbol by BPSK, σ^2 is the AWGN variance, $\mathrm{r}_{\mathrm{s,r_i}}$ received symbol at relay and $\mathrm{h}^*_{\mathrm{sr_i}}$ is complex conjugate of channel coefficient from source to ith relay. To compensate ISI introduced by multipath zero forcing and Minimum Mean Square Error Equalizers are used. The rest of the paper is organized as follows. Section II presents system model. Simulation results are discussed in section III. Finally, the conclusion is given in section IV.

SYSTEM MODEL:

The system model is depicted in fig1. In this wireless two hop system, source node X communicates to destination node Y through relay R. Let the source node X and destination node Y equipped with single antenna. Where there are four relays, each relay equipped with a single antenna in source side and destination side. For source to relay link, relay is acting as receiver with single input and multiple outputs. In relay to destination link, relay acts as transmitter with multiple outputs and single input can obtained by equal gain combiner. We consider slow flat fading nakagami channel from source to relay and relay to destination. We assume that relay have channel state information of X-R link. The channel of R-Y link will be estimated by Least Square Estimation (LSE).

Nakagami –m Fading Environment

For the considered Nakagami-m model, for a fixed value of the fading depth parameter m. Nakagami-m distribution is described by the pdf [14, 15]

$$p_z(z,\Omega)=\frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m z^{2m-1}\exp\left(-\frac{m}{\Omega}z^2\right),$$

$$z>0, m\geq\frac{1}{2} \quad (1)$$

Where z is the received signal level, Γ (.) is the gamma function; m is the parameter of fading depth (Fading Figure), defined as:

$$m=\frac{E^2[z]}{Var[z^2]} \quad (2)$$

While Ω is average signal power:

$$\Omega=E[z^2] \quad (3)$$

If fading figure is one i.e. m=1, the Nakagami fading as same as Rayleigh distribution [1]. It reduced to Gauss distribution for m=0.5.The case m→ ∞, describes the channel without fading. With certain restrictions the Nakagami-m distribution can approximate the Rice distribution [4]. The Nakagami-m channel model is simpler than Rice's, in which the Bessel function is used, so that using the above approximation calculation of statistical characteristics is significantly simplified. We choose to Nakagami-m channel model for reasons of generality and simplicity.

Relay Selection

A LLR algorithm selects M out of L relays which gives the largest log-likelihood ratio (LLR) magnitude for transferring data from transmitter to destination. LLR based relay selection gives less error rate and more reliable compared to [6],[7],[8]. At the first time slot the source broadcasts the BPSK signal to the relays and to the destination, at the second time slot, the relays receive the transmitted signal from the source, the log-likelihood ratio (LLR) is calculated for each relay and it is given by:

$$\Delta=\ln\frac{P(r_{s,ri}\mid \square_{sri},s=+\sqrt{E_s})}{P(r_{s,ri}\mid \square_{sri},s=-\sqrt{E_s})} \quad (4)$$

the LLR in its simplest form is given by

$$\Delta=|\mathrm{r}_{\mathrm{s,ri}}|^2+2\sqrt{\mathrm{E_s}}\,Re\{r_{s,ri}h^*_{s,ri}\}+|\mathrm{h}_{\mathrm{s,ri}}\sqrt{E_s}|^2-|\mathrm{r}_{\mathrm{s,ri}}|^2+2\sqrt{\mathrm{E_s}}\,Re\{r_{s,ri}h^*_{s,ri}\}-|\mathrm{h}_{\mathrm{s,ri}}\sqrt{E_s}|^2 \quad (5)$$

Then, the magnitude $|\Delta|$ of LLR in its simplest form can by written as

$$|\Delta|=\frac{4\sqrt{E_s}}{\sigma^2}\,|\mathrm{Re}\{r_{s,ri}h^*_{sri}\}| \quad (6)$$

the proposed relay selection algorithm is described. In this algorithm first we calculate the magnitude of the LLR for each relay. Then arrange the LLR values in descending order in which we select the first M relays out of L having largest magnitude of the LLR (the first M values). The M relays are used to send signal to the destination.

Relay protocol

In cooperative communications, the transmitting users not only broadcast their own message but they also relay some data, on behalf of each other, to the destination. The way, by which they relay this information to destination, is called as protocol. Various protocols have been introduced so far.

Amplify and Forward

A basic cooperative signaling is the amplify-and-forward method. Each and every user in this system gets a noisy form of the signal transmitted by its accomplice. As the name infers, the user then can amplify and re-transmits this noisy form. The base station joins the data sent by the user and associate, and settles on an ending choice on the transmitted bit (Figure 2). Despite the fact that noise is amplified by cooperation, the base station gets 2 autonomously faded variants of the signal and can settle on better choices on the location of data.

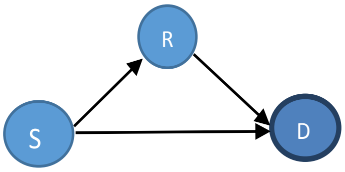


Figure 2.2: Amplify and Forward

This technique was suggested and analyzed by Laneman et al. [9]. The author demonstrates that for the two-user case, the technique accomplishes 2nd order diversity, which is the best conceivable result at high Sound to Noise Ratio. In amplify-and-forward it is expected that the base station identifies the inter-user channel coefficients to do ideal decoding, so any component of trading or evaluating this data must be fused into any usage. One more significant test is that amplifying, sampling, and re-transmitting analog values is technically uncertain. However, amplify-and-forward is an uncomplicated strategy that fits examination, and in this manner has been truly valuable in advancing our comprehension of cooperative communication systems.

Decode and Forward

This scheme is maybe nearest to the thought of a customary relay. In this strategy a user needs to recognize the accomplice's bits and after that retransmits the identified bits (Figure 3). The accomplices may be allocated commonly by the base station, or through some other system. Consider two users collaborating with each other, yet in practical the main vital issue is that every user has an accomplice that gives an additional (diversity) data path. The simplest strategy to envision this is by means of pairs, yet it is conceivable to accomplish the same impact through other association topologies that evacuate the strict limitation of pairing.

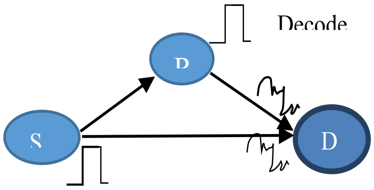
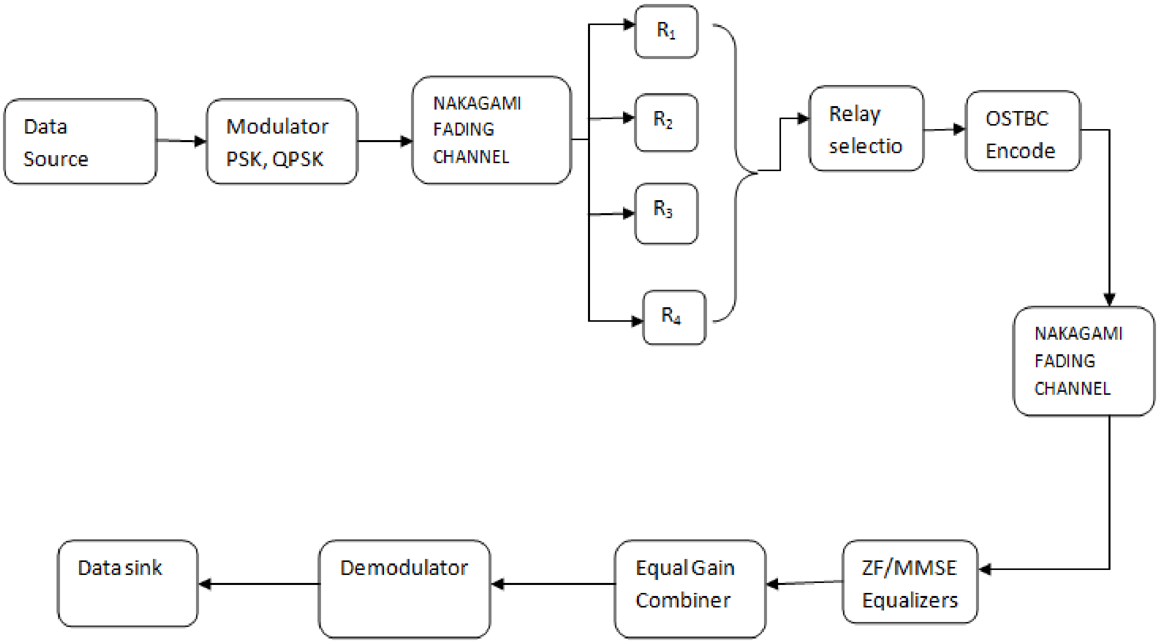


Figure 2.3: Decode and Forward

Compared to an AF relay, the complexity of a DF one is significantly higher due to its full processing capability. The DF protocol gives better performance than AF at the cost high complexity.



Fi.2.1: Block Diagram

2.4 OSTBC Encoder

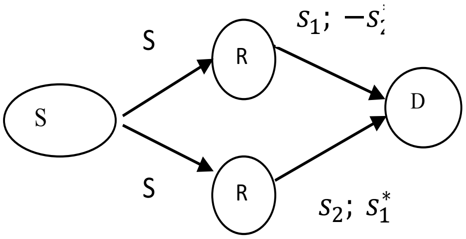
In this system we consider 2×1 encoder that is, Two transmit and one receiver antennas, basically called as Alamouti Encoder. Let S be a complex-valued M-point constellation data obtained from MPSK or MQAM modulation scheme of length $1 \times N$, where N is frame length. The transmission of data stream S to the destination is performed in two decoupled phases. In Phase I, the source sequentially transmits S to the relays r_1, r_2; hence, the data received in the K-th relay, $K \in \{8,92\}$, can be written as

$$y_{sr_1} = h_{s,r_1} * s + n_{sr_1} \tag{7}$$

$$y_{sr_2} = h_{s,r_2} * s + n_{sr_2} \tag{8}$$

Where y_{sr_1}, y_{sr_2} represent the $1 \times N$ received data vector, h_{s,r_1}, h_{s,r_2} denotes the channel gain of the link between the source and the relay-1, relay-2 respectively. n_{sr_1}, n_{sr_2} are the summation of $1 \times N$ complex valued additive white Gaussian noise vector with each element having zero mean and N_0 variance [10, 11]. It is assumed that the channels h_{s,r_1}, h_{s,r_2} are complex Gaussian random variables with zero mean and σ_m^2 variance, and remains constant over transmission of S. In second phase of transmission i.e. relaying phase each relay encodes its data into the form of 2×2 OSTBC with the code matrix given as [34]

$$x = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \tag{9}$$



Figur2.4: Alamouti Encoder

Where x being Alamouti OSTBC encoded data of length $2 \times N$. The Relaying phase starts with transmitting signals s_1, s_2 during first symbol period followed by transmission of signals $-s_2^*$ and s_1^* from relay1, 2 respectively as shown in Figure 3.2. Assuming channel coherence time to be greater than symbol period, the received signals at the destination terminal from relays 1, 2 are given by:

$$\mathrm{r}_{\mathrm{r}_1\mathrm{D}} = \mathrm{h}_{\mathrm{r}_1\mathrm{D}}\mathrm{s}_1 + \mathrm{h}_{\mathrm{r}_2\mathrm{D}}\mathrm{s}_2 + \mathrm{n}_{\mathrm{r}_1\mathrm{D}},\ \mathrm{r}_{\mathrm{r}_2\mathrm{D}} = -\mathrm{h}_{\mathrm{r}_1\mathrm{D}}\mathrm{s}_2^* + \mathrm{h}_{\mathrm{r}_2\mathrm{D}}\,\mathrm{s}_1^* + \mathrm{n}_{\mathrm{r}_2\mathrm{D}} \qquad (10)$$

Where n_{r_1D} and n_{r_2D} are the summation of AWGN noise present between Relay1 and destination and Relay2 and destination respectively.

2.5 Equalizers

Zero Forcing Equalizer

Zero Forcing Equalizer is a linear equalization algorithm used in communication systems; it inverts the frequency response of the channel. The name Zero forcing corresponds to bringing down the Inter Symbol Interference (ISI) to zero in a noise free case. This will be useful when ISI is more predominant when comparing to the noise.

ZF can be implemented by using the inverse of the channel matrix H to produce the estimate of transmitted vector x̃.

$$\tilde{\mathrm{x}} = \mathrm{H}^{\dagger}\mathrm{r} = \mathrm{H}^{\dagger}(\mathrm{Hx}) = \mathrm{x} \qquad (11)$$

Where $(.)^{\dagger}$ denotes the pseudo-inverse. However when the noise term is taken into account, the post-processing signal is given as fallow:

$$\tilde{\mathrm{x}} = \mathrm{H}^{\dagger}\mathrm{R} = \mathrm{H}^{\dagger}(\mathrm{Hx+n}) = \mathrm{x} + \mathrm{H}^{\dagger}\mathrm{n} \qquad (12)$$

With the addition of the noise vector, ZF estimate, that is x̃ consists of the decoded vector x plus a combination of the inverted channel matrix and the unknown noise vector. As the pseudo-inverse of the channel matrix may have high power when the channel matrix is ill-conditioned, the noise variance is accordingly improved and the performance is corrupted. To alleviate for the noise improvement introduced by the ZF detector, the MMSE detector was proposed, where the noise variance is taken into account in the construction of the filtering matrix G.

Minimum Mean Square Error Equalizer

Minimum Mean Square Error (MMSE) approach alleviates the noise enhancement problem by taking into consideration the noise power when constructing the filtering matrix using the MMSE performance-based criterion. The vector estimates produced by an MMSE filtering matrix becomes,

$$\tilde{\mathrm{x}} = [[(\mathrm{H}^{\mathrm{H}}\mathrm{H} + (\sigma^2\mathrm{I}))^{-1}]\,\mathrm{H}^{\mathrm{H}}]\,\mathrm{r} \qquad (13)$$

Where σ^2 is the noise variance. The added term ($1/\mathrm{SNR} = \sigma^2$, in case of unit transmit power) offers a trade-off between the residual interference and the noise enhancement. Specifically, as the SNR raises large, the MMSE detector converges to the ZF detector, but at low SNR it prevents the worst Eigen values from being inverted. At low SNR, MMSE becomes Matched Filter,

$$[(\mathrm{H}^{\mathrm{H}}\mathrm{H} + (\sigma^2\mathrm{I}))^{-1}]\,\mathrm{H}^{\mathrm{H}} \approx \sigma^2\,\mathrm{H}^{\mathrm{H}} \qquad (14)$$

At high SNR, MMSE becomes ZF:

$$(\mathrm{H}^{\mathrm{H}}\mathrm{H} + (\sigma^2\mathrm{I}))^{-1}]\,\mathrm{H}^{\mathrm{H}} \approx (\mathrm{H}^{\mathrm{H}}\mathrm{H})^{-1}\,\mathrm{H}^{\mathrm{H}} \qquad (15)$$

2.6 Equal Gain Combiner

There are three types of diversity combining (or diversity reception) are three common techniques: Selection Combining, Maximal Ratio Combining (MRC) and Equal Gain Combining (EGC). For all three, the goal is to find a set of weights w. The structure is similar to what we used in developing interference cancellation. Here, however, the weights are chosen to minimize the impact of fading for a single user. The three techniques differ in how this eight vector is chosen. In all three cases we assume that the receiver has the required knowledge of the channel fading vector h. In this system developed the combiner that is optimal in the sense of SNR. However, the technique requires the weights to vary with the fading signals, the magnitude of which may fluctuate over several 10s of dB. The equal gain combiner sidesteps this problem by setting unit gain at each element. In the equal gain combiner

$$\mathrm{w}_{\mathrm{n}} = \pi r^2 e^{\angle j h_n}$$

$$w_n^* h_n = |\,h_n\,|$$

$$w^H h = \sum_{n=0}^{N-1} |\,\mathrm{h}_{\mathrm{n}}\ | \qquad (16)$$

Also, the noise and instantaneous SNR are given by

$$\mathrm{P}_{\mathrm{n}} = \mathrm{w}^{\mathrm{H}}\,\mathrm{w}\,\sigma^2 = \mathrm{N}\,\sigma^2$$

$$\gamma = \frac{\left[\sum_{n=0}^{N-1} |\,\mathrm{h}_{\mathrm{n}}\,|\right]^2}{\mathrm{N}\,\sigma 2} = \pi r^2 \qquad (17)$$

The point of this analysis is to show that, despite being significantly simpler to implement, he equal gain combiner results in an improvement in SNR that is comparable to that of the optimal maximal ratio combiner. The SNR of both combiners increases linearly with N. The BER for general N for BPSK is

$$P_e = \frac{1}{2}\left[1 - \frac{\sqrt{\Gamma(\Gamma+2)}}{\Gamma+1}\right] \quad , N=2 \qquad (18)$$

III. Simulation Results

This research work is focused towards the development of dual hop cooperative diversity scheme based on the fusion of regenerative and non-regenerative cooperative schemes with orthogonal space-time block codes. Simulation of proposed scheme is carried out over Rayleigh, Rician and Nakagami fading environments under the influence of AWGN. To evaluate the performance test scenarios has been used based on varying modulation scheme, equalization techniques and combining techniques. Simulation parameters and obtained results are given as follows

Table 4.1: Simulation Parameter

Size of modulation constellation M	2
Number of bits per symbol K=log2(M)	1
Energy per symbol-to-noise power-spectral-density ratioEs/N0	0:2:30
Noise Power Sigma_z	1
Message Length	256 bit
STBC architecture	Alamouti's
Number of diversity branches	2
Combining Technique	EGC
Fading Environment	Nakagami
Shape Parameter m	3
Controlling spread sigma	1
Frame Length	256 bits
Modulation	BPSK,QPSK,QAM
Equalizer	ZF,MMSE
Channel	Nakagami
Relaying Technique	DF,AF

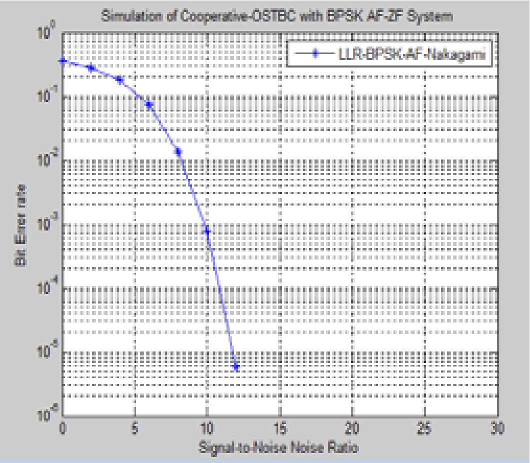


Fig4.1 Simulation result of BPSK Dual hop Relay of AF under Nakagami fading channel with Zero Forcing Equalizer of LLR relay selection

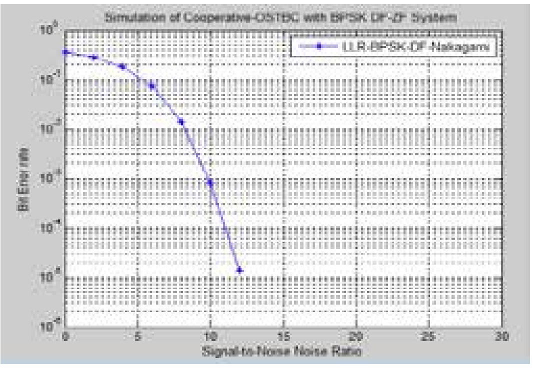
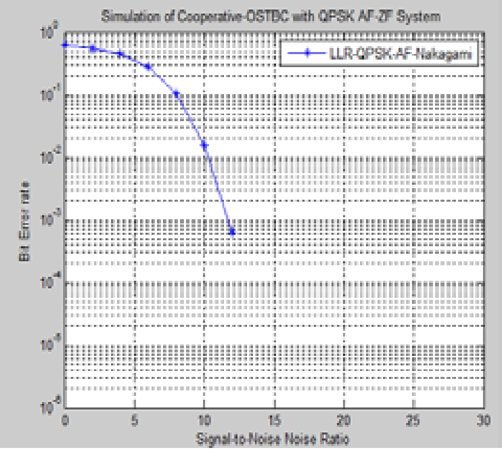


Fig4.2 Simulation result of BPSK Dual hop Relay of DF under Nakagami fading channel with Zero Forcing Equalizer of LLR relay selection



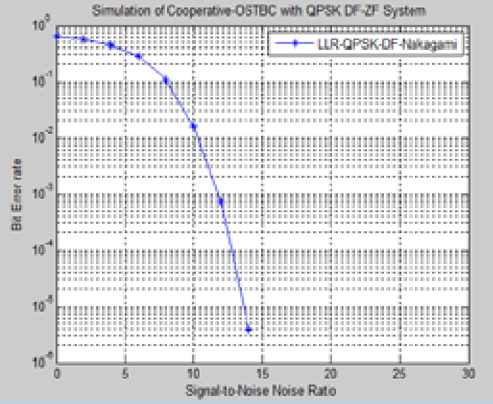


Fig4.4 Simulation result of QPSK Dual hop Relay of DF under Nakagami fading channel with Zero Forcing Equalizer of LLR relay selection

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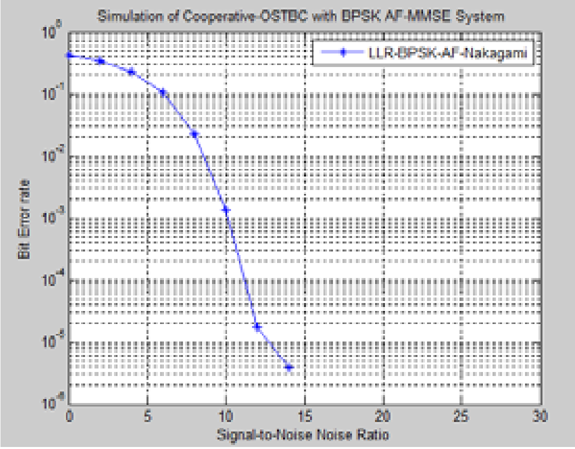

Fig4.5 Simulation result of BPSK Dual hop Relay of AF under Nakagami fading channel with MMSE Equalizer of LLR relay selection

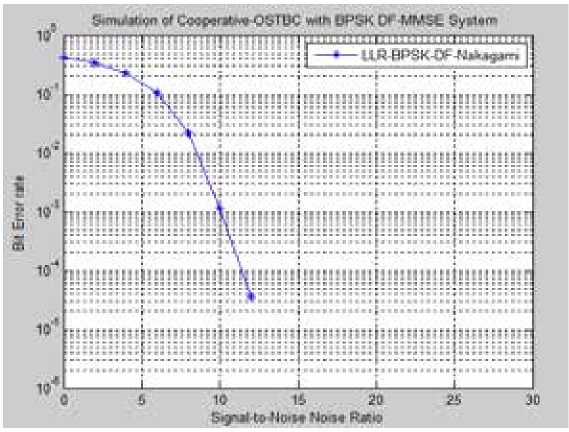

Fig4.6 Simulation result of BPSK Dual hop Relay of DF under Nakagami fading channel with MMSE Equalizer of LLR relay selection

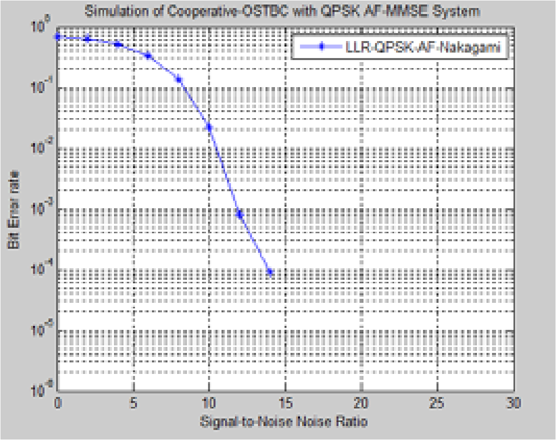

Fig4.7 Simulation result of QPSK Dual hop Relay of AF under Nakagami fading channel with MMSE Equalizer of LLR relay selection

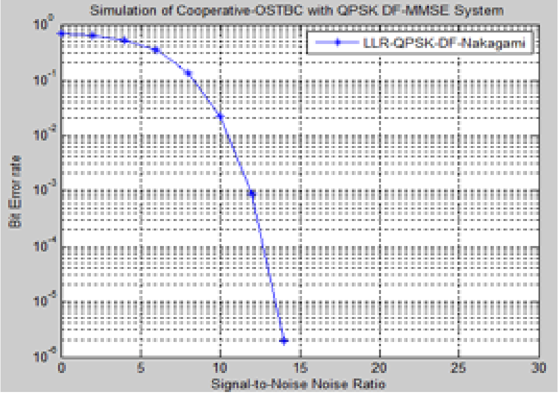

Fig4.8 Simulation result of QPSK Dual hop Relay of DF under Nakagami fading channel with MMSE Equalizer of LLR relay selection

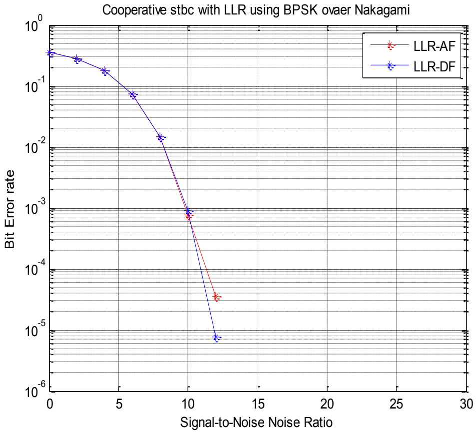

Figure-4.9: Comparison between Regenerative and Non-regenerative relaying for LLR based cooperative STBC system

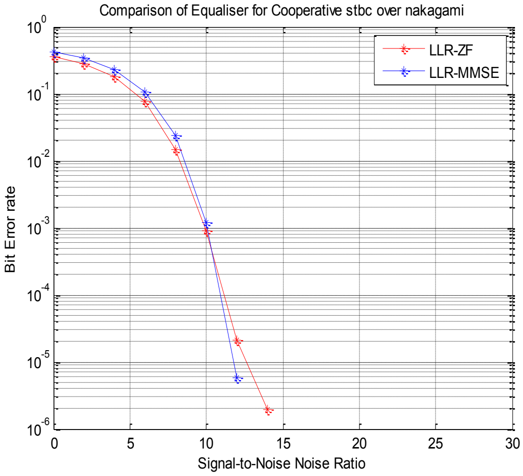

Figure-4.10: Comparison between equalization techniques for cooperative STBC system

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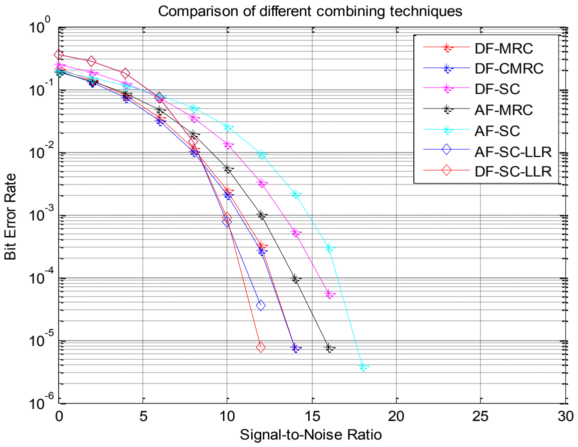

Figure-11: Comparison between combining techniques for cooperative STBC system

CONCLUSION:

In this research Dual Hop Cooperative STBC system is developed for regenerative (decode and forward) and non-regenerative (amplify and forward scheme). The proposed scheme utilizes the benefits of cooperative communication and space time coding to provide array gain and diversity gain in single antenna communication system. The proposed system architecture enhance bit error rate performance while keeping same spectral efficiency. Literature shows that spectral efficiency and bit error rate are inversely proportional to each other and there is a trade-off present between them. The proposed work uses LLR based multiple relay selection scheme. Simulation has been carried out on MATLAB-2010a and performance evaluation is done on the basis of Bit Error Rate vs. Signal to Noise Ratio. Simulation results for comparison between AF & DF relaying, comparison between ZF and MMSE equalisers and comparison between relaying techniques has been given. It is observed that the performance of LLR based cooperative stbc scheme is 6dB better than harmonic mean based relay selection

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