ENHANCING FUTURE WIRELESS SYSTEMS THROUGH ADVANCED PHYSICAL LAYER MECHANISMS

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Abstract: - In recent years, the rapid growth of new-generation wireless networks has spurred a research thrust in cooperative communication and it is a powerful physical layer technique to combat fading in wireless relaying scenario. Recently, chaos based communication with its excellent features has been proved to be an appropriate choice for the emerging wireless networks. Different chaos based modulation schemes has been analysed with immense literature, of which the Code Shifted-Quadrature Chaos shift Keying (CS-QCSK) modulation technique with its code domain approach provides better BER performance and spectral efficiency. In the coding scenario, Reduced Golden Ratio-Golden codes (RGR-GC) has been proved to exhibit better Bit Error Rate (BER) performance with less complexity than any other space time block codes in [29]. The forementioned coding scheme (RGR-GC) and the modulation scheme (CS-QCSK) are concatenated to obtain a suitable combination approach (RGR-GC_CS-QCSK) which enhances the performance significantly has been discussed in [30]. This paper aims to test the suitability of proposed technique in a cooperative relaying scenario. The single relay cooperative scenario consisting of source, relay and destination are considered with the Decode and forward (DF) protocol. The simulation results have validated the effectiveness of the proposed scheme by offering better BER performance, minimum outage probability and increased spectral efficiency compared to the non cooperative transmission method.

Key-Words: - Code Shifted-Quadrature Chaos shift Keying (CS-QCSK), Reduced Golden Ratio-Golden codes (RGR-GC), modified golden codes, Decode and forward (DF) protocol, single physical layer entity, cooperative communication.

1 Introduction

The ever-growing demand for high speed wireless multimedia services has put forth a compelling need to protect the data over hostile mobile radio channels. This challenge remains as an important bottleneck to find a suitable bandwidth efficient modulation and channel coding scheme. In the recent years, coding combined modulation seems to be a powerful technique for achieving high reliability, large coding gain and high spectral efficiency. In addition to this, cooperative communication is an interesting research topic in wireless communication because it achieves distributed spatial diversity, wider coverage, low transmit power and reduced interference. Recently, thrust for a new technique which exploits the advantages of aforementioned schemes (i.e, combining coding / modulation in cooperative relaying system) attracts a widespread attention in the literature. The relay based cooperative communication design for 4G systems using the coding combined modulation scheme is expected to be used in future generation wireless networks in order to provide reliable transmissions at higher data rates. Consequently, this paper aims at combining a superior chaotic modulation discussed in [27] with modified golden codes discussed in [29] and testing out its combined performance in a cooperative relaying scenario. In [1], the authors discuss the application of adaptive modulation concept to the performance of cooperative techniques with amplify and forward protocol and to improve the spectral efficiency of the system. The signal designs such as space time coding / modulation to achieve full cooperative diversity and an overview of the efforts on combating the time and frequency asynchronism of the cooperative communication network has been discussed in [2]. The measured bit error rate performance of a three node cooperative communication system operating with a maximum ratio combining technique and two cooperative coded schemes using hard and soft decision decoding has been discussed in [3]. The decode-remodulate-and-forward (D-ReM-F) cooperative modulation scheme with higher signal constellations and the capacity analysis for different protocol under different fading condition has been discussed in [4]. In [5], the authors explain about the cooperative relaying schemes like symmetric and asymmetric downlink communications which employs hierarchical modulation schemes. In [6], the modulation scheme supported with the knowledge of SNRs of all links in a simple DF cooperative communication system and proposed with the two rules, namely the exact rule and the approximate rules has been presented. A novel combiner capable of collecting full diversity with DF for any coherent modulation termed *cooperative* MRC (CMRC) which offers a high-performance demodulation with less-complexity has been discussed in [7].

A system combining DCSK / FM- DCSK with cooperative communication strategy can effectively enhance the system performance over multipath fading channels has been discussed in [8].The DF-based differential cooperative system utilizing complex-valued unitary and non-unitary constellations and uncoded transmissions for ML (Maximum Likelihood) decoder and PL (piecewise linear) decoder has been discussed in [9]. The demodulators with PL combination and the nonlinear ML detectors for coherent and noncoherent decode and forward (DF) protocol has been presented in [10]. Quadrature CSK (QCSK) is a multilevel version of DCSK, based on the generation of an orthogonal of chaotic functions. It allows an increase in data rate occupying same bandwidth with respect to DCSK has been discussed in [11]. CS-DCSK uses code domain approach where the reference and the information bearing signals are transmitted at the same time slots, it offers better BER performance and bandwidth efficiency, has been detailed in [12].The space time block coded spatial modulation (STBC-SM) which combines the spatial modulation with STBC and the performance comparison of simple SM (Spatial multiplexing) over V-BLAST (Vertical-Bell Lab Layered Space-Time) has been presented in [13].

In [14], the authors discuss about the space time block codes for a half-duplex multiple input multiple output (MIMO) and non-orthogonal amplify and forward (NAF) cooperative diversity scheme with multiple relays. The design of space time codes that are capable of achieving the full diversity and by illustrating how cooperation among nodes with different numbers of antennas can be accomplished and how the quality of interuser link can be affected has been portrayed in [15]. The alamouti coded form constructed at the destination node and each relay node performs either time-reversal or conjugation operation (i.e) the modified operations at the relay nodes which overcomes the influence of the frequency selective fading channels has been discussed in [16]. In [17] the authors explain the Distributed space time trellis codes (DSTTC) design criteria formulation with perfect and imperfect decoding at the relay and the derivation of the upper bounds of pair wise error probability (PEP) for different channel condition. For a 2x2 MIMO system, golden code has been discussed as a full rate and full diversity code with Non-vanishing minimum determinant (NVD) in [18]. In [19], the design of low complex Maximum likelihood (ML) decoder for Space Time Block Codes (STBC) and embedded orthogonal STBC with symmetric and asymmetric coding conditions has been discussed. Multigroup maximum-likelihood (ML) decoding for collocated and distributed space-time block codes (DSTBCs) and the orthogonal frequency-division multiplexing (OFDM)-based Alamouti space-time coded scheme application in synchronous wireless relay networks has been detailed in [20].

In [21], the Cooperative Bit-Interleaved Coded Modulation describes the power allocation with Decode-Remap-and-Forward Relaying (DRF) and different power allocation method to minimize the bit error rates. In [22], the authors discuss the variable rate adaptive Bit interleaved coded modulation (ABICM), where the code rate and modulation level are varied according to the current channel state and improves the system performance using different operation modes. The coded modulation based on blockwise concatenation and the comparison of serial and parallel turbo codes under block fading channels has been detailed in [23]. The family of signal constellations having the capacity close to the AWGN channel and the scheme based on the binary error- correcting codes which was decoded in sequential fashion has been portrayed in [24]. In [25], A Turbo Trellis-Coded Modulation (TTCM) aided superposition modulation scheme conceived for a Decode-and-Forward (DAF) in cooperative communication system has been discussed. The coherent versus non-coherent coded modulation and the investigation of the adaptive coded modulation (ACM) for cooperative communications under different channel conditions has been presented in [26].

In [27], a novel chaos based modulation scheme CS-QCSK which is the blend of CS-DCSK and QCSK modulation schemes has been proposed and the analytical BER expressions for single user scenario has been derived and discussed. The analysis of multiuser performance of a novel CS-QCSK modulation scheme has been discussed in [28].In this paper, a modified version of golden code called RGR-GC scheme, discussed in [29] has been used. Following the work quoted in the references [27&28], an attempt is made to propose a concatenation of chaotic modulation (CS-QCSK) approach with the most efficient code namely "Golden Code". Golden codes has been exhaustively investigated and reported by researchers as the best coding approach unlike alamouti and silver codes, etc in [29]. Golden codes with reduced golden ratio seem to be very attractive in terms of BER performance, as reported in [29]. Intuitively, from the above discussions, significant improvement in cellular system performance could be achieved even in a highly hostile environment by the mere concatenation of CS-QCSK and reduced golden ratio-golden code (RGR-GC) and the same has been proved through simulation analysis in [30]. The major highlight of this paper is that considerable performance improvement in a cooperative relaying system is certainly possible through the usage of both CS-QCSK and modified golden codes in the cooperative relaying nodes, which were originally suggested by us in [27-30]. The readers are advised to refer the references for detailed analytical modelling of them. Therefore, the so called proposed scheme namely concatenation of both approaches in a cooperative relaying system is truly novel and unique of its kind.

The remaining part of the paper is organized as follows: In section 2, the system model of the proposed cooperative relaying scheme is elaborated. In section 3, the proposed logic such as code shifted quadrature chaos shift keying scheme, modified golden code and its combinational effect are discussed briefly. Simulation results are discussed in Section 4. Section 5, deals with the conclusion of the paper.

2 System Model of the Proposed Cooperative Relaying Scheme

Consider a cooperative communication network consisting of three nodes, the source (S) node, relay (R) node and destination (D) node with each having two antennas. Let '$h_{s,r}$' be the fading channel matrix between the S and R, '$h_{s,d}$' be the fading channel matrix between S and D, and '$h_{r,d}$' be the fading channel matrix between R and D. Since the assumption is two antennas, all the fading channel matrices are 2 x 2 matrices whose entries are independent complex Gaussian random variables with zero mean and unit variance. The terms $h_{s,r}^{i,j}$, $h_{r,d}^{i,j}$ and $h_{s,d}^{i,j}$ for i, j = 1, 2 are the fading coefficients from the i^{th} transmit antenna to the j^{th} receive antenna for the corresponding channels. Assumptions carried out in the work are:

(i) Rayleigh fading channels is considered
(ii) The perfect channel state information is assumed to be known at the receiver.
(iii) A Cellular mobile environment enabling half-duplex communication has been treated for analysis.

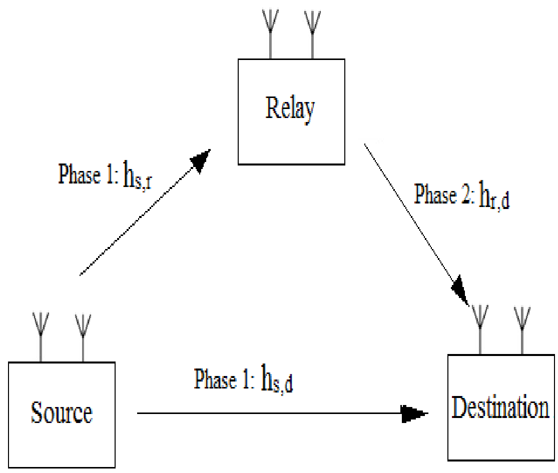

Fig.1 Cooperative Communication for single relay with the implementation of the proposed coding combined modulation scheme in the nodes

The internal structures of the source node, relay node and destination node which are shown in Fig. (a), Fig. (b) and Fig. (c).

Referring to the Fig. (a), the source node consists of two blocks namely CS-QCSK modulator block and RGR_GC encoder block. The operation at the source node is, the input bit streams are given as input to the CS-QCSK modulator and in the modulator bits are mapped according to the constellation and further encoded with RGR_GC encoder. Then, the encoded signal is launched over the two transmitting antennas.

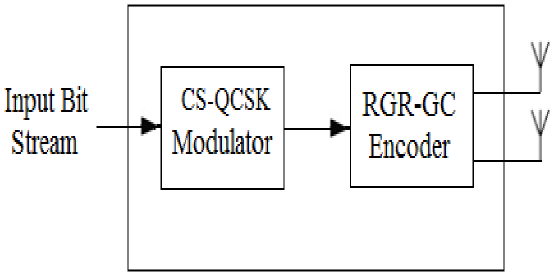

Fig. (a). Source node

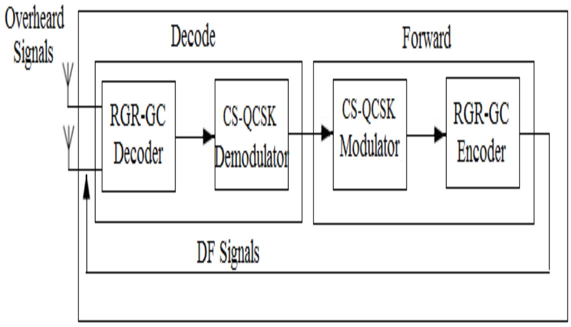

Fig. (b). Relay node

Referring to the Fig. (b), the relay node consists of two blocks (i.e) the decoder block and forward block. The decoder block in turn has two blocks namely RGR_GC decoder and CS-QCSK demodulator. The forward block in turn has two blocks namely CS-QCSK modulator and RGR_GC encoder. The process involved is, the relay receives the overheard signals and it is given to the decoder block. In decoder block, the signal is decoded and demodulated. Then the decoder output is given as input to the forward block. The forward block re-encodes the input signal according to CS-QCSK constellation and generates the Decode and Forward (DF) signals. Further, the DF signal is launched over the two transmitting antennas.

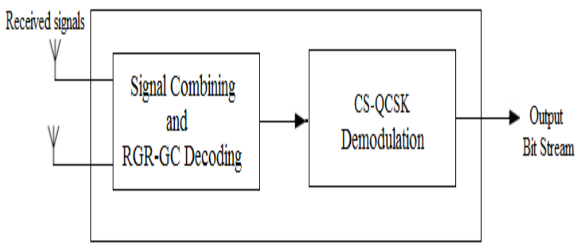

Fig. (c). Destination node

Referring to the Fig. (c), the destination node consists of two blocks namely signal combining with RGR_GC decoding block and CS-QCSK demodulation block. The process involved is, the signals are received and combined using maximum ratio combiner and decoded using RGR_GC decoder. The decoder output is given as input to the CS-QCSK demodulator and finally the output bit streams are obtained. The next section deals with the proposed CS-QCSK modulator and demodulator block in detail.

The cooperation strategy is modelled with two orthogonal phases to avoid the interferences. In phase1, source broadcasts information to the destination and a copy of information is received by the relay at the same time. In phase 2, the relay helps the source by forwarding or retransmitting the information to the destination. The received signals at the destination and the relay are obtained as,

$$y_{s,d} = \sqrt{P}\, h_{s,d}\, x + n_{s,d} \tag{1}$$

$$y_{s,r} = \sqrt{P}\, h_{s,r}\, x + n_{s,r} \tag{2}$$

Where, ‘P’ is the total transmit power at the source, ‘x’ is the transmitted information symbol, ‘$n_{s,d}$’, ‘$n_{s,r}$’ and ‘$n_{r,d}$’ are the additive noises, ‘$h_{s,d}$’, ‘$h_{s,r}$’ and ‘$h_{r,d}$’ are the channel coefficient from source to destination, source to relay and relay to destination respectively. They are modelled as zero-mean, complex Gaussian random variables with variances $\sigma^2_{s,d}$, $\sigma^2_{s,r}$ and $\sigma^2_{r,d}$ respectively. With the variance ‘N_o’ the noise terms ‘$n_{s,d}$’, ‘$n_{s,r}$’ and ‘$n_{r,d}$’ are modelled as zero-mean, complex Gaussian random variables.In phase 2, the relay forwards a processed version of the source’s signal to the destination and this is obtained as,

$$y_{r,d} = h_{r,d}\, q(y_{s,r}) + n_{r,d} \tag{3}$$

the function q (.) depends on which processing is implemented at the relay node.The mutual information in terms of channel fades for decode and forward transmission is given by,

$$I_{DF} = \frac{1}{2}\min\left\{\log\left(1+\Gamma\left|h_{s,r}\right|^2\right), \log\left(1+\Gamma\left|h_{s,d}\right|^2+\Gamma\left|h_{r,d}\right|^2\right)\right\} \tag{4}$$

Considering rayleigh fading channel, the outage probability can be written as,

$$\Pr\left[I_{DF} < R\right] = \Pr\left\{\left|h_{s,r}\right|^2 < \frac{2^{2R}-1}{\Gamma}\right\} + \Pr\left\{\left|h_{s,r}\right|^2 > \frac{2^{2R}-1}{\Gamma}\right\}\Pr\left\{\left|h_{s,d}\right|^2 + \left|h_{r,d}\right|^2 < \frac{2^{2R}-1}{\Gamma}\right\} \quad (5)$$

Averaging over the channel conditions, the outage probability for decode and forward is given by,

$$\Pr\left[I_{DF} < R\right] \simeq \frac{1}{\sigma^2_{s,r}} \frac{2^{2R}-1}{\Gamma} \quad (6)$$

Where, $\Gamma = P/N_0$ and 'R' is the transmission rate. The next section deals with the proposed logic used in this work such as modulation scheme, coding scheme and its combinational effect.

3 Proposed Concept

In order to explain the proposed logic, a brief introduction to CS-QCSK, modified golden codes and CS-QCSK combined with modified golden code scheme are essential and the details are given in this section.

3.1 Code Shifted - Quadrature Chaos Shift Keying (CS-QCSK)

In CS-QCSK, both reference signal and information signal (symbol 'S') is transmitted in same time slot. However they are separated using walsh codes. The CS-QCSK transmitted signal is given by,

$$S_b(t) = \sum_{k=0}^{N-1} W_{R,k+1} C_x(t-kT_c) + a_1 \sum_{k=0}^{N-1} W_{I1,k+1} C_x(t-kT_c) + a_2 \sum_{k=0}^{N-1} W_{I2,k+1} C_y(t-kT_c) \quad T_S = NT_C \quad (7)$$

Where $a_1 \in \{-1, 1\}$, $a_2 \in \{-1, 1\}$ is mapped from $b \in \{0,1\}$ which is the information bit to be transmitted. This scheme uses different Walsh code for the reference and information signal, where $W_{R,k+1}$ represent the Walsh code for reference signal and $W_{I1,k+1}$, $W_{I2,k+1}$ represent the Walsh code for information signal, C(t) is the chaotic signal with duration of T_c. Both the reference and the information signal are transmitted in the same time slot as given in equation (7). The orthogonality of the signal is assured by walsh code sequences, therefore the reference and the information signal are independent of the chaotic carrier. The description about chaotic modulator / demodulator discussed under this section can be referred in earlier paper [27].The error rates associated with CS-QCSK under AWGN and Rayleigh environment is given below.

The Bit error rates under AWGN channel is given as,

$$BER_{CS-QCSK} = \frac{1}{2} erfc\left(\frac{3(E_b/N_0)}{\sqrt{\frac{3}{4}K + \frac{1}{2}K + 2(E_b/N_0)}}\right) \quad (8)$$

The Bit error rates under Rayleigh fading is given as,

$$BER_{CS-QCSK} = \frac{1}{2} erfc\left(\frac{3(\gamma_b)}{\sqrt{\frac{3}{4}K + \frac{1}{2}K + 2(\gamma_b)}}\right) \quad (9)$$

Where 'E_b' is the bit energy, 'N_o' is the noise power spectral density, 'K' is the spread factor, 'γ_b'is the product of (E_b/N_o) and the gain of the propagation path. The next section highlights the concepts of the reduced golden ratio-golden code (RGR-GC) with less complex sphere decoder.

3.2 Reduced Golden Ratio –Golden Code (RGR- GC)

In this section, the modified golden code and its codeword form achievement is explained. An effective mathematical tool called Cyclic division Algebra (CDA) which has excellent properties is used in modified golden codes. The RGR-GC is a scaled version of golden code which is used to normalize the energy and in turn, yields the performance improvement in the system. A reduced golden ratio-golden code (RGR-GC) is obtained by choosing a minimum polynomial equation in such a way that, it obtains the reduced golden ratio without losing golden codes key properties. The minimum polynomial equation considered to obtain the reduced golden ratio is X^2-0.5x-0.5=0. The reduced golden ratio 'θ' is given by,

$$\theta = \frac{1+\sqrt{2}}{2},$$

Having defined the polynomial and RGR, the next attempt is to focus onto shaping up the process to yield lossless property. A codeword from this algebra, before shaping is of the form,

$$\begin{bmatrix} a+b\theta & c+d\theta \\ i\left(c+d\sigma(\theta)\right) & a+b\sigma(\theta) \end{bmatrix} \quad (10)$$

where, the information symbols a,b,c,d €Z[i]. The codeword 'X' belonging to the RGR-GC has the form,

$$X = \frac{1}{\sqrt{2}}\begin{bmatrix} \alpha(a+b\theta) & \alpha(c+d\theta) \\ i\sigma(\alpha)\left(c+d\sigma(\theta)\right) & \sigma(\alpha)\left(a+b\sigma(\theta)\right) \end{bmatrix} \quad (11)$$

Where a, b, c, d are QAM symbols and it takes any value in Z[i]. In an infinite code C_∞, a, b, c, d can take any value in Z[i] that is the finite signal constellations are carved from infinite lattices. The modified golden code and the reduced golden ratio-golden code (RGR-GC) are one and the same is used throughout this paper. For the modified golden codes, a low complex sphere decoder is designed which is the crucial task.

3.2.1 Low Complexity Sphere Decoder

In this section, a new low complexity decoder for the Reduced Golden Ratio- golden codes (RGR-GC) is described. To reduce the decoding complexity, many methods have been analyzed. In [19], the low complexity decoding for the space time block codes and the key properties for reducing the decoding complexity has been discussed in broad sense. One of the properties considered in the proposed method is, the real and imaginary parts of the symbol are decoded separately. Moreover, the channel matrix H=QR, was decomposed using QR decomposition method, where, 'Q' is a unitary matrix and 'R' is an upper triangular matrix. The 'R' matrix with zero entries and the real elements in it potentially reduce the decoding complexity. In this method, the real and imaginary parts of the symbol are decoded separately using sphere decoder with tree search algorithm, in a single symbol manner for Reduced Golden ratio Golden codes (RGR_GC). The steps involved in the receiver side and algorithm used is explained further. At the receiver, the received vector of samples $y=\left[y_1[1], y_2[2], y_3[3], y_4[4]\right]^T$ with two antennas at two time instances can be obtained as,

$$y=Hx+n \tag{12}$$

where, 'x' is the transmitted symbol vector, 'n ' is the noise vector and 'H' is the effective channel matrix represented as, $X=[x_1, x_2, x_3, x_4]^T$, $n=\left[n_1[1], ...n_2[2]\right]^T$ and

$$H=\begin{bmatrix} h_{11}[1] & 0 & \phi h_{21}[1] & 0 \\ 0 & h_{21}[2] & 0 & \phi h_{11}[2] \\ h_{12}[1] & 0 & \phi h_{22}[1] & 0 \\ 0 & \phi h_{22}[2] & 0 & \phi h_{12}[2] \end{bmatrix}\begin{bmatrix} \alpha & \beta & 0 & 0 \\ -\beta & \alpha & 0 & 0 \\ 0 & 0 & \alpha & \beta \\ 0 & 0 & -\beta & \alpha \end{bmatrix} \tag{13}$$

respectively.where,

$$\phi = e^{j\frac{\pi}{4}},\ \alpha=\cos(\theta),\ \beta=\sin(\theta)$$

In the equation (13), H=QR is an orthogonal-triangular decomposition of the effective channel matrix where, 'Q' is unitary and 'R' is upper triangular. The Gram-Schmidt orthonormalization is followed for the decomposition approach, Where this procedure is applied to the columns of H, then the entry of R in row i and column j will be the inner product between the i th column of Q and j th column of H. Therefore, $r_{i,j}=q_i{*}h_j$. In direct computation of R, the elements $r_{1,2}$ and $r_{3,4}$ are real, through the diagonal elements and the other elements are complex by nature. From the effective channel matrix, the diagonal elements and nondiagonal elements are computed. The total cost metric P(x) is given by,

$$P(x)=\|y-Hx\|^2 \tag{14}$$

$$=\|z-Rx\|^2$$

$$=\|z-R_1x_1-R_2x_2-R_3x_3-R_4x_4\|^2$$

The decoded symbol vector 'x' will be the minimum of the overall cost metric P(x). The minimum of overall cost metric P(x) is obtained using the tree search algorithm. A sphere decoder with four level tree, for the reduced golden ratio-golden codes (RGR-GC) associated with different x_i (i=1,..4) at each level has been discussed. It is proposed with a four level tree that associates $d^R=x_4^R$ and $d^I=x_4^I$ in the first level, $c^R=x_3^R$ and $c^I=x_3^I$ in the second level, $b^R=x_2^R$ and $b^I=x_2^I$ in the third level and $a^R=x_1^R$ and $a^I=x_1^I$ in the fourth level. Rewriting the cost metric function as,

$$P(X)=\|V^I-Aa^I\|^2+\|V^I-Ab^I\|^2+\|V^R-Aa^R\|^2+\|V^R-Ab^R\|^2 + \|Z_3{}^I-Dc^I\|^2+\|Z_4{}^I-Dd^I\|^2+\|Z_3{}^R-Dc^R\|^2+\|Z_4{}^R-Dd^R\|^2 \tag{15}$$

The number of combinations of each symbol (x_1) (x_2) (x_3) (x_4) is denoted by q. The decoding complexity of $\sqrt{q}$, comes from the fact that the symbols (x_1^R) and (x_1^I) are separately decodable. Therefore, it has the decoding complexity of O($q^{1.5}$). The reduced golden ratio golden code property satisfaction, complexity analysis of the sphere decoder and the performance analysis reduced golden ratio golden code with low complex sphere decoder has been discussed in [29]. For detailed explanation the readers are requested to refer the reference [29].

3.3 Combined coding and modulation

In general, coding combined with modulation is an effective technique to mitigate the fading effects in error-prone mobile environment. The coding combined modulation scheme has improved performance in many aspects compared to its individual performance. To justify this, a novel modulation technique discussed in [27] and a coding technique discussed in [29] is used in a combined fashion and it is presented in [30]. In this work, combined coding / modulation technique is used in the nodes of cooperative relaying system. On discussing with combined coding / modulation setup, it has the transmitter block which consist of CS-QCSK modulator and modified golden code encoder. The receiver block consists of modified golden code decoder and CS-QCSK demodulator. The process involved in the transmitter and receiver block is, initially the input bit sequence is given to the CS-QCSK modulator. The CS-QCSK modulator maps the bit sequence accordingly and this information is given to the modified golden code encoder. The encoder is of 2x2 MIMO type and the encoded signals are launched through the transmitting antennas. In the receiver, the corrupted signals are received through the receiving antennas and is decoded using the modified golden code decoder and fed to the CS-QCSK demodulator. Finally, the original bit streams are obtained. Further, the detailed explanation about this scheme and its performance analysis validated through the simulation has been reported in [30]. The next section deals with the simulation analysis of the proposed scheme with various validating factors.

4 Simulation Analysis

The simulation analysis for the proposed method is performed with the following parameters and it is tested in MATLAB 7.10 software. This section discusses the simulation analysis of the proposed scheme using the parameters mentioned in Table 1. The performance analysis of the proposed scheme in cooperative relaying scenario is analyzed initially and further the complexity analysis of the proposed scheme is tested.

Table 1. Simulation Parameters

PARAMETERS	VALUES / TYPES
Number of transmitted bits	$2x10^4$
Type of antenna system	MIMO (2x2)
Modulation scheme	CS-QCSK, QAM
Code rate	1,1/2
Decoder Type	ML, RGR-GC sphere
Coding Types	Alamouti , Golden, silver, RGR-GC
Number of Transmitter	1
Number of receiver	1
Number of relay	1
Power allocation	Ps=Pr=(1/2)P=0.5
Relay location	Dsr=Dsd=(1/2)Dsd=0.5
Path loss exponent	2
Doppler frequency	0.01
Channel Type	Rayleigh fading

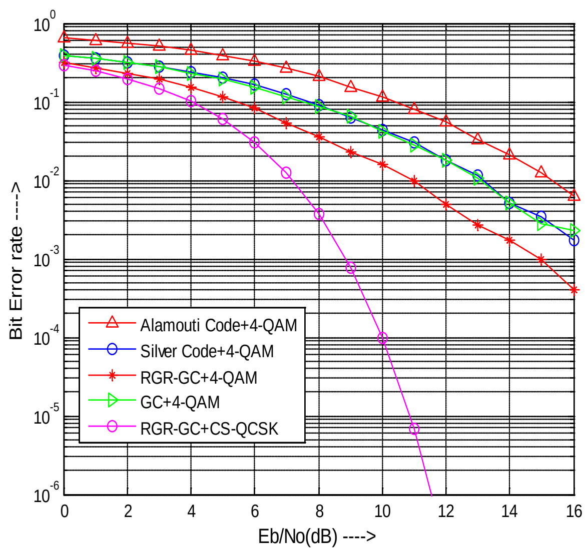

Fig. 2 BER performance comparison of the proposed Coding / modulation logic with 4-QAM

It is inferred from the Fig. 2 that the proposed (RGR-GC_CS-QCSK) Coding / modulation scheme offers better BER performance compared to the other conventional coding / modulation schemes. For the BER of 10^{-3} the conventional coding / modulation schemes (Alamouti code+4-QAM),(GC+4-QAM), (Silver code+4-QAM) and (RGR-GC+4-QAM) requires approximately18dB,16dB,16dB and 15dB (approx) respectively. But the proposed Coding/modulation scheme requires approximately 9dB. As discussed in the literature, combining a superior coding and modulation scheme exhibits significant performance improvement in the system. The improved coding gain achieved by the proposed scheme is due to the combination of efficient coding / modulation approach.

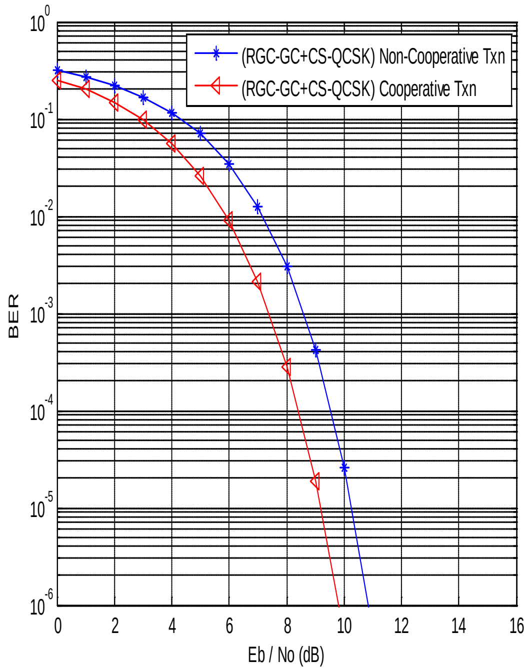

Fig. 3 BER performance analysis of the proposed scheme in Cooperative relaying scenario

From Fig. 3, the BER performance analysis graphs for the proposed scheme in cooperative relaying transmission and non-cooperative transmissions were plotted. It is inferred that, for a fixed BER of 10^{-3} the cooperative transmission method and non-cooperative transmission scheme requires approximately 7.3 dB and 8.3 dB respectively. The BER performance of the proposed coding / modulation scheme in cooperative transmission has better performance compared to the Non-cooperative transmission. It is due to the fact that, in a cooperative transmission mode the relay is located between the source and destination which helps in forwarding the information to the destination node. The system has better diversity to choose the best signal, whereby the reliability is ensured.

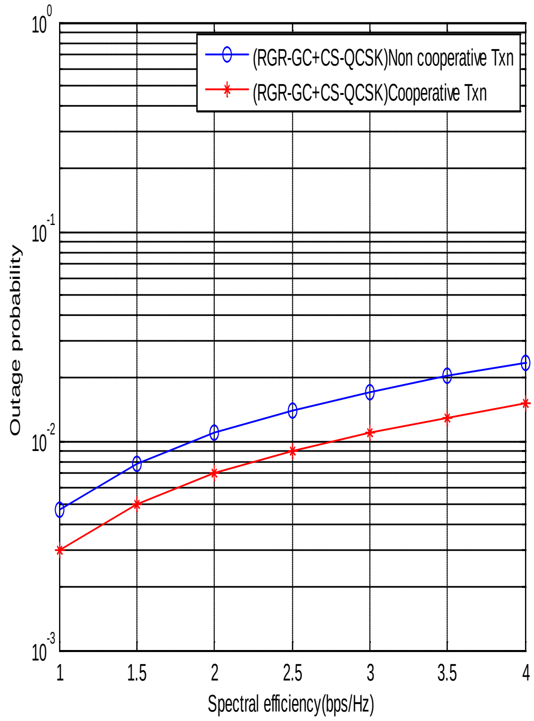

Fig.4 Outage Probability Versus Spectral Efficiency of proposed scheme in Cooperative relaying scenario

The next attempt was to check out for another critical 'QoS' parameter namely outage probability and its relation with spectral efficiency. From Fig. 4, it is inferred that for a fixed spectral efficiency of 2bps/Hz the proposed coding / modulation scheme in cooperative transmission method and non-cooperative transmission method has the outage probability of approximately 0.0076 and 0.01respectively. For fixed outage probability of 10^{-2}, the spectral efficiency for cooperative transmission method and non-cooperative transmission is 2.75 bps/Hz and 2 bps/Hz respectively. The proposed coding / modulation scheme in cooperative transmission has minimum outage probability and increased spectral efficiency compared to the Non-cooperative transmission method. According to the system capacity condition, as the spectral efficiency increases the outage probability also gets increased. It is obvious from the Fig. 4 that tradeoffs always exist between outage probability and spectral efficiency.

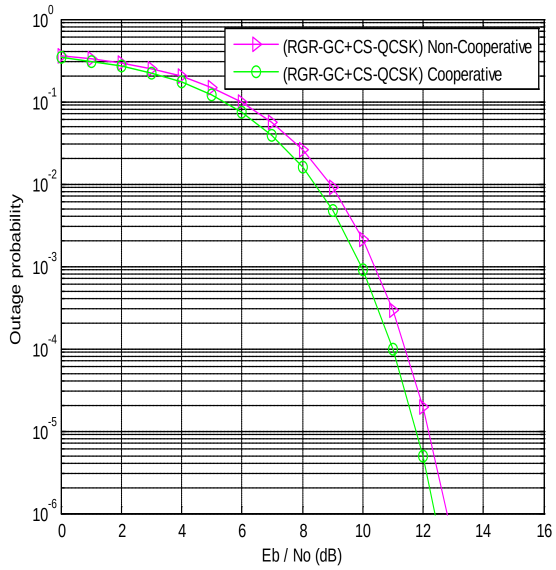

Fig. 5 Outage Probability Versus Eb / No of proposed scheme in Cooperative relaying scenario

The outage probability analysis for the CS-QCSK scheme in cooperative relaying transmission and non-cooperative transmission is plotted. From Fig. 5, it is inferred that, for a fixed Eb/No of 10 dB the proposed coding / modulation scheme in cooperative transmission method and non-cooperative transmission method has the outage probability of approximately $1x10^{-3}$ and $1.40x10^{-4}$ respectively. The proposed scheme in cooperative transmission has minimum outage probability compared to the non-cooperative transmission method. This proves the effectiveness of the cooperative mode of transmission.

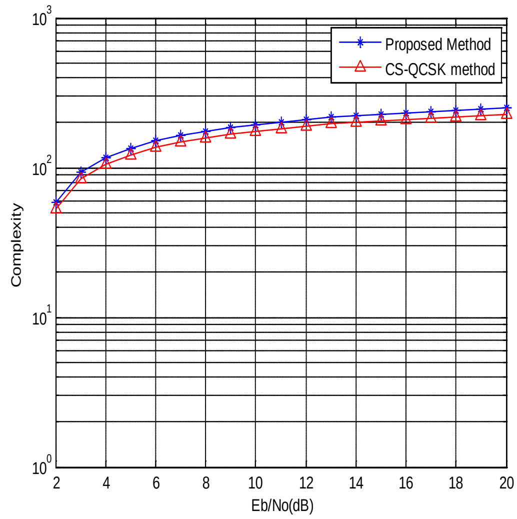

Fig. 6 Complexity analysis for the proposed coding combined modulation scheme and CS-QCSK scheme

Finally, the complexity analysis graphs were plotted for the proposed coding combined modulation scheme and CS-QCSK scheme. From Fig. 6, it is inferred from the graph that, for a fixed E_b/N_o of 4 dB the number of operations performed by the proposed scheme is 110 (approx) and for the CS-QCSK scheme the number of operations required is approximately 100. The complexity analysis expression is derived for the proposed scheme and the analysis is done through it. Though the proposed scheme has more computational complexity compared to the CS-QCSK scheme, it offers other benefits like improved BER performance, spectral efficiency and higher data rate.

5 Conclusion

A Challenging problem in wireless communication is to offer high speed data service by protecting the data over the error-prone fading channel in an effective way. In this paper, a chaos based coding / modulation which is a combination of a good coding scheme (RGR-GC) and modulation scheme (CS-QCSK) as a single entity called (RGR-GC_CS-QCSK) has been discussed and it is implemented in the nodes of the cooperative relaying system. The proposed coding combined modulation scheme in cooperative relaying scenario has a significant improvement in the performance. Simulation analysis is carried out and the results shows that the proposed scheme under cooperative transmission achieves better BER performance, minimum outage probability and increased spectral efficiency compared to the non-cooperative transmission, which is the need of the hour for wireless communication. The same work can also be extended to a multi-relay node scenario, which would certainly yield a satisfactory performance with an exception in the complexity involved.

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