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Realization of Multi Carrier Direct Sequence CDMA System for Multipath Faded Channels using Adaptive Viterbi Decoder

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Abstract: In this paper Multi Carrier-Direct Sequence Spread Spectrum CDMA technique has been consider for users to support multimedia service in wireless mobile communication systems. It is a one of the recent technology to provide higher data rates over conventional medium access techniques like Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). Recently, a new CDMA system that combines advantages of both Orthogonal Frequency Division Multiplexing (OFDM) and DS-CDMA which is term as "MC-DS-CDMA," system combined with the adaptive viterbi decoder algorithm. It is to be considering for bit error rate of system over multipath fading channels.

Keywords: MC-DS-CDMA, OFDM, Adaptive Viterbi Decoder, OSTBC

I. INTRODUCTION

In recent years with the rapid increase in wireless communication technology along with mobile internet and multimedia services, it demands for higherdata rate transmission capability. As we know wireless communication supports various multimedia services such as voice, data, video and much more. The reliable communication through wireless channel faces great challenges including fading, interference and multipath fading [7].

This paper, the technique combines the merit of both Multi Carrier (MC) modulation and Direct-Sequence CodeDivision Multiple Access (DS-CDMA).Multi Carrier-DS-CDMA has beensupported by both academia and industry for its robustness andflexibility in the future wireless network. In order to avoid theMultiple Access Interference (MAl) and select the attainablefrequency diversity .The major technique presented here is,convolution encoder with Adaptive Viterbi decoding (ADV) algorithm.

This is an optimum decoding algorithm for the convolution encoded data sequences and combined with multiple antenna system to achieve higher data rates with reduced multiple access interference. We have developed a faster, area efficient adaptive viterbi decoder for MC-DS-CDMA. By using this approach, we can effectively reduce the bit error rate of proposed system over multipath faded channels [5].

This paper is dividing into six subsections. Section first deals with introduction and a short summary about MC-DS-CDMA and decoding algorithm. Second Section gives a brief knowledge about Multiple Access Techniques and different fading environments that causes data losses in wireless communication. ThirdSection gives a brief idea of Multi Carrier-Direct Sequence Spread SpectrumCDMA system and it block diagram.

Fourth Section explains a new approach towards decoding of data for multi carrier system. Fifth section show simulation results and last section is about conclusion.

II. WIRELESS CHANNEL ACCESS TECHNIQUES

Various multiple access techniques allow users to access band-limited spectrum. Due to fixed bandwidth, spreading techniques play a vital role to enhance bandwidth utilization factor. Sharing of same bandwidth among multiple users enhances capacity of wireless channel.
MC-CDMA are three methods of sharing the available bandwidth over a same channel among multiple users in wireless communication system.

A. DS-CDMA

In direct sequence(DS) CDMA systems, the narrowband message signal ismultiplied by a very large-bandwidth signal called the spreading signal. On account of this operation a narrow band signal converts to wide band signal. All users in a DS CDMA system use the same carrier frequency at a same time and transmitsimultaneously. Each user has its own spreading signal, which is orthogonal to the other user spreading signals. The receiver performs a correlation operation to detect the message to a given user [1]. The sequences from other users appear as noise due to de-correlation.

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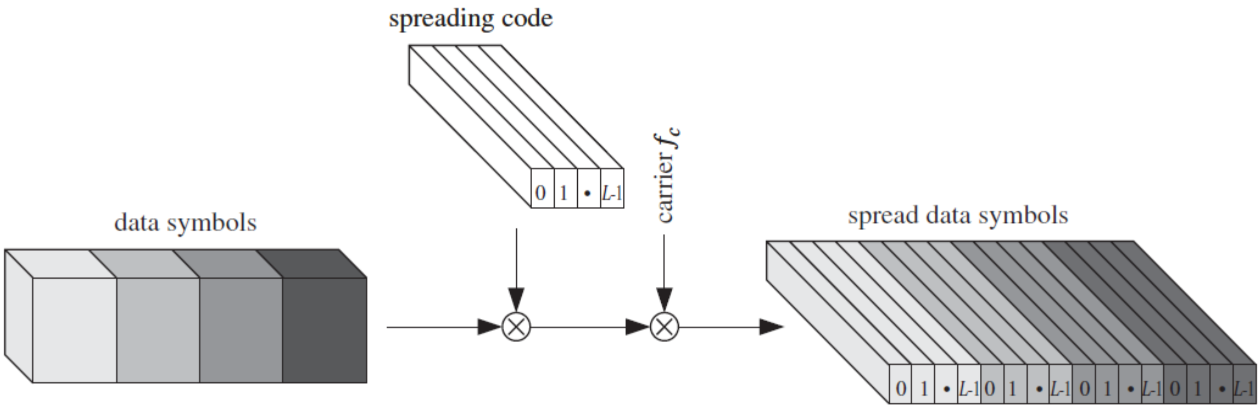

Figure 1: Direct Sequence Code Division Multiple Access for single user

B. MC-CDMA

MC-CDMAsystemtransmits data symbol of a user simultaneously on several narrowbandsub-channels [1]. These sub-channels are multiplied by each user spreading code [5]. MC-CDMA offers a flexible system design, since length of spreading code not have to same as no. of sub-carriers.From above figure1 which shows that MC-CDMA offer spreading in frequency direction. In a given figure L represent spreading code length with chip rate of $T_c$and symbol rate after spreading becomes T_s.

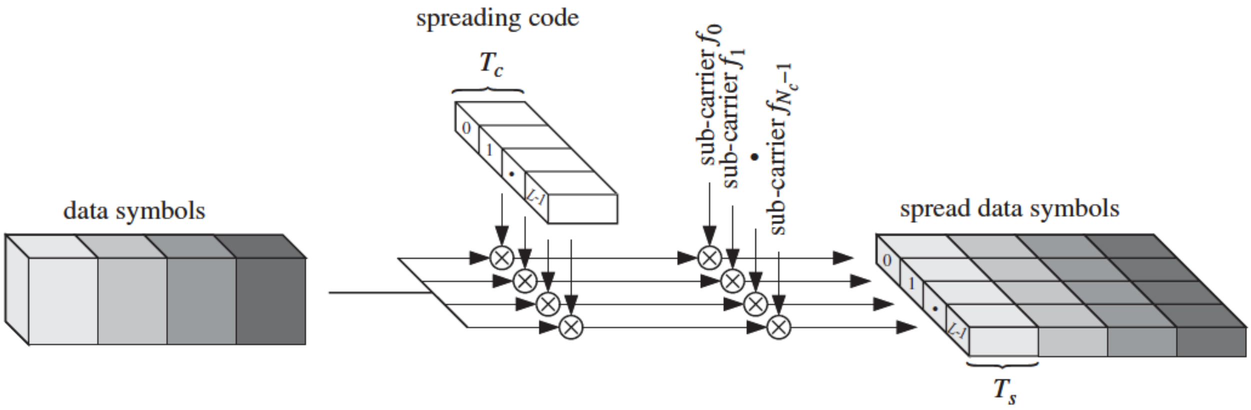

Figure 2: MC-CDMA signal generation for single user

III. MULTI CARRIER DIRECT SEQUENCE CDMA

A multi carrier direct sequence spread spectrum code division multiple accesses provides higher data rates over Time Division Multiple Access, Frequency Division Multiple Access and Direct Sequence Code Division Multiple Access. There is a little difference between MC-CDMA and MC-DS-CDMA. The previous system, data sequence multiplied by a spreading sequence which modulates M carriers. In later system, before applying to spreading data symbols first serial to parallel converted to make them high data rate to low parallel sub-stream [1].

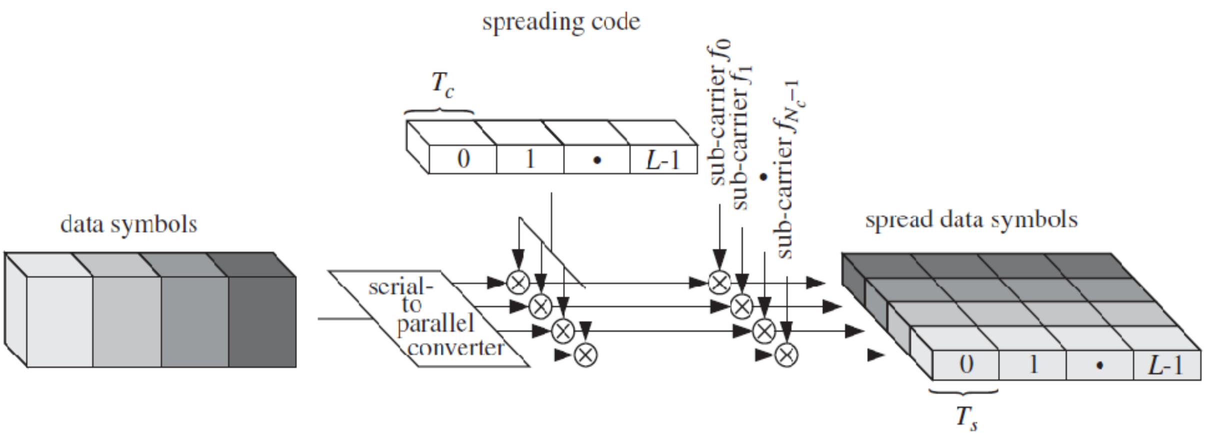

Figure 3: Multi Carrier DS-CDMA

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A Multi-carrier direct sequence spread spectrum signal in data symbol rate is 1/Td. A sequence of Nc complex-valued data symbols$d^{(k)}$n , n = 0, . . .,N_c− 1, of user k is serial-to-parallel converted into Nc sub-streams. Thedata symbol rate on each sub-stream becomes 1/ (NcTd). Within a single sub-stream, adata symbol is spread with the user-specific spreading code.

$$c^{(k)}(t) = \sum_{l=0}^{L-1} c_l^{(k)} P_{Tc}(t - lTs) \qquad (1.1)$$

Of length of length L. The pulse form of the chips is given by P_{Tc} (t) and chip periodof a chip within asub-stream is given as

$$Tc = Ts = \frac{N_c T_c}{L} \qquad (1.2)$$

With multi-carrier spread spectrum, each data symbol gets spread over Lmulti-carrier symbols, each symbol of duration of duration Ts . The complex value sequence obtained afterspreading is given by

$$x^{(k)}(t) = \sum_{n=0}^{N_c-1} d_n^{(k)} c^{(k)}(t) e^{j2\pi f_n t} \qquad 0 \le t \le lT_s \qquad (1.3)$$

For n^{th} sub-frequency which is given as-

$$f_n = \frac{(1+\alpha)n}{T_s} \qquad (1.4)$$

Where α varies for 0≤α≤1, choice of α depends upon the chosen chip from P_{Tc}(t) and is typically chosen such that the N_c parallel sub-channel are disjoint.

As soon as each sub-channel can be considered as narrowband, i.e. the sub-channelbandwidth is smaller than the coherence bandwidth $(\Delta f)_c$, the fading per sub-channel isfrequency nonselective and low complex detection techniques compared to broadband sub-channelscan be realized. Narrowband sub-channels are achieved by choosing a sufficientlylarge number of sub-carriers relative to the bandwidth B. A rough approximation for theminimum number of sub-carriers is given by

$$Nc \ge \tau_{max} B. \qquad (1.5)$$

The overall transmission bandwidth is given by B and τ_{max} is the maximum delay of themobile radio channel.

A. Simulation Model

Figure 3 shows a complete block diagram for a multi carrier direct sequence code division multiple access system.

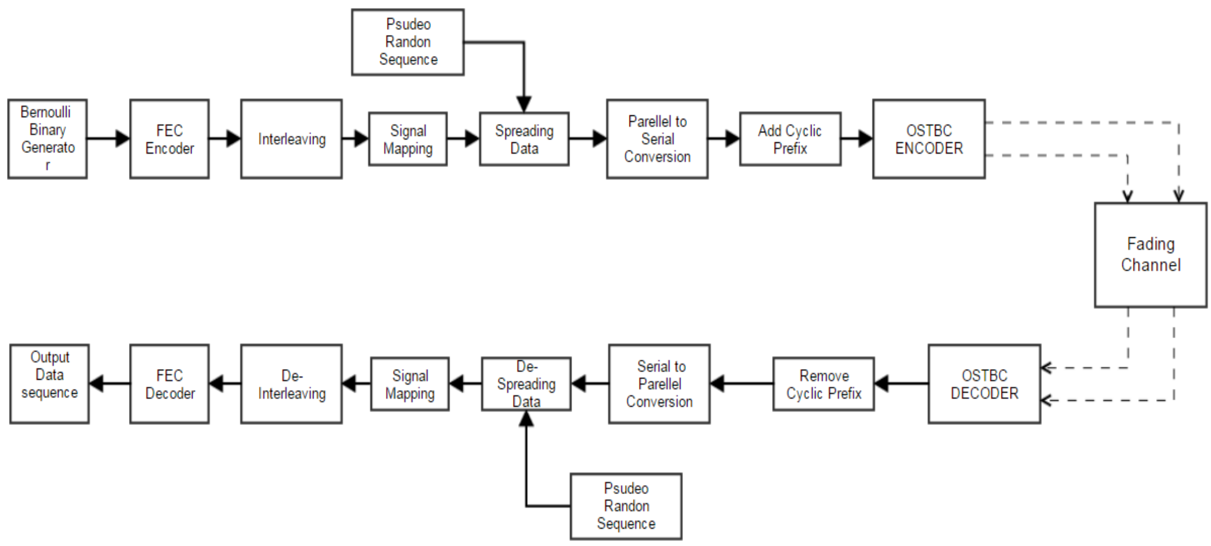

Figure 4: Multi Carrier Direct Sequence CDMA Transreceiver Model

The information sequence generated by the Bernoulli binarygenerator is encoded by one of the Forward error correcting cod, convolution encoder with the coding rate of ½.The single bit output codes is combined toproduce punctured codes with the rate other than ½ .Here, the rate ½ implementation is converted to ¾ code rate called as puncturing. The punctured code is then interleaved to make the forward error correction much more effective towards the burst errors.
The matrix interleave and general block interleave is used for interleave purpose. The code word is mapped by Quadrature Amplitude Modulation (QAM) modulation, 16-QAM modulations is used. The output is given to the spreader with spreads code word with a pseudorandom code. This spreading sequence is converted parallel too serially with N=64 subcarriers and a cyclic prefix of 16 is added resulting in the symbol.

These symbols are transmitted over the multiple antennas using orthogonal space time block coding technique (OSTBC) over the fading channel. At the receiver, the data is demodulated and decoded to recover the information sequence. The bit error rate is calculated using error rate calculation.

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B. Multi Path Fadingand AlamoutiSpace Time Block Codes(ASTBC)

As we know wireless channel highly suffer from addition of multi-path propagation and interferences. This attenuation makes receivers more difficult to receive signal unless a less attenuated replica of signal is not transmitted to receiver. This technique called diversity scheme which is important factor for reliable communication.

For our system model we are using multiple diversity scheme with half rate convolution ally encoded Alamouti space time block codes, also for reduce Inter Symbol Interference (ISI) [7].

A simple transmit diversity scheme for transmit antennas using STBCs wasintroducedby Alamouti and generalized to an arbitrary number of antennas byTarokh et al.

A simplest Alamouti code scheme in whichthe transmitted symbols $x_i$are mapped to the transmit antenna with the mapping given by a matrix below

$$A = \begin{bmatrix} x_0 & x_1 \\ -x_1^* & x_0^* \end{bmatrix} \quad (1.6)$$

Rows corresponding to matrix shows time index andcolumn corresponding to transmit antenna index.In the first symbol time interval x_0 is transmitted from antenna 0 and x_1 is transmitted fromantenna 1 simultaneously, while in the second symbol time interval antenna 0 transmitsx_1 andsimultaneously antenna 1 transmits x_0^*.

IV. VITERBI DECODER

This section discusses the different parts of the Viterbi decoder. It performs basically two operations, Synchronization and Quantization. It is mainly used for decoding convolution ally encoded data to overcome noise that added due to noisy and faded channels like Rayleigh, Additive white Gaussian noise and Rician channel.

This unit is dividing into two parts one is convolution encoder and second one is viterbi algorithm in which we have introduced a new adaptive viterbi decoder to enhance our system performance over multipath fading channels.

A.Convolution Encoder

It consists of one or more shift registers (generally D-FF) and multiple XOR gates. XOR gates are connected to some stage of the shift registers as well as to the current input [4].

Position of taps for XOring operation is given by polynomial The encoder has two modulo-2 adders which are Xor gates. (Y1 Y0)-output of encoder and x(n) message input to encoder.

The encoder in figure 2 produces two bits of encoded information for single bit of input information, so it is called a rate 1/2 encoder. A Convolution encoder is generally represented in (n, k, m) format with a rate of k/n, where n is number of outputs of the encoder, k is number of inputs of the encoder, m is number of flip-flops [4]. Sometimes instead of m, K is use.

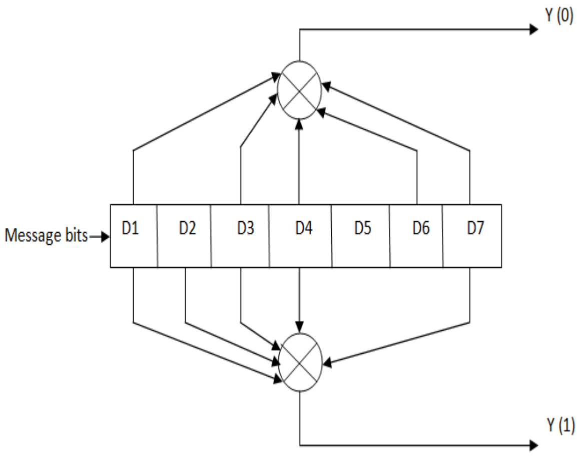

Figure 5: Convolution encoder for code rate 1/2 and constraint length K=7

B. Viterbi decoder algorithm

This section discusses the different parts of the Viterbi decoder. This decoding algorithm finds a shortest path in state matrix. In this paper we introduce a new approach for viterbidecoder that is area efficient as well as enhance system performance [3]. A hardwareimplementation of Viterbi decoder for basic code usually consists of the following major blocks:

(i)Branch metric unit (BMU)
(ii)Add compare select engine or unit or Path metric unit (PMU)
(iii)Trace back unit (TBU)

(i)Branch metric unit (BMU): It calculates the minimum distance b/w input and possible pairs. This minimum distance called Hamming distance in case of Hard Decoding andEuclidean distance when decoding is soft decoding.

(ii)Add compare select engine or unit or Path metric unit (PMU):This unit carries the bulk of arithmetic processing of the Viterbi decoder. The Path Metric Unit calculates new path metric values and decision values.
Because each state can be achieved from two past stage, so there are two possible path metrics coming to the current state.

(iii)Trace back unit (TBU):This unit stores only decision bit for survivor path metrics that comes from ACS unit. It chooses thebest of one from two paths.

C. Flow chart for Viterbi Decoder Algorithm: This figure shows process flow of viterbi decoder algorithm.

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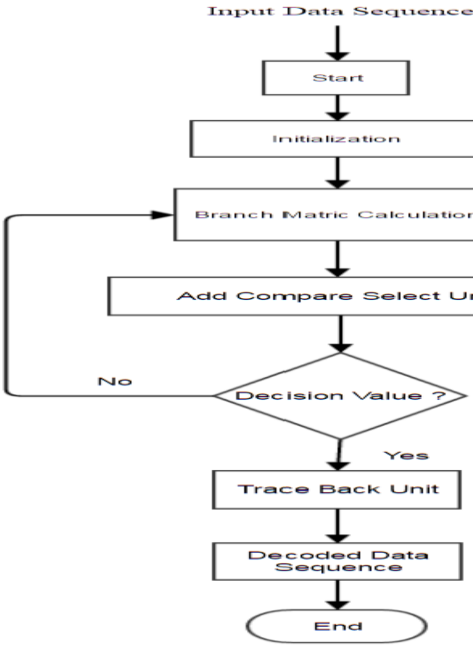

Figure 6: Flow chart for Viterbi Decoder

V. SIMULATION RESULT AND ANALYSIS

The MC-CDMA system described in section III is implemented using MATLAB R2014a with various simulation parameters enlisted in Table 1. The BER curves and spectral efficiency curves are obtained from the simulations

Table 1: Simulation model parameters

Parameters	**Values**
Coding rate	½
Constraint Length	K=7
Type of Modulation	16-QAM
Channel coding	½ rate convolution encoder with Alamouti STBC
Decoding Algorithm	Adaptive Viterbi Decoder(AVD)
Antenna Diversity scheme	2x1, 2x4
Channel	AWGN, Rayleigh & Rician

Table 1 shows parameters that consider during simulation process. Figure 7 shows Bit error rate graph for MC-DS-CDMA over Rayleigh channel.

BER calculated for different pairs of transmitter and receiver and shows significantly improvement in system performance.

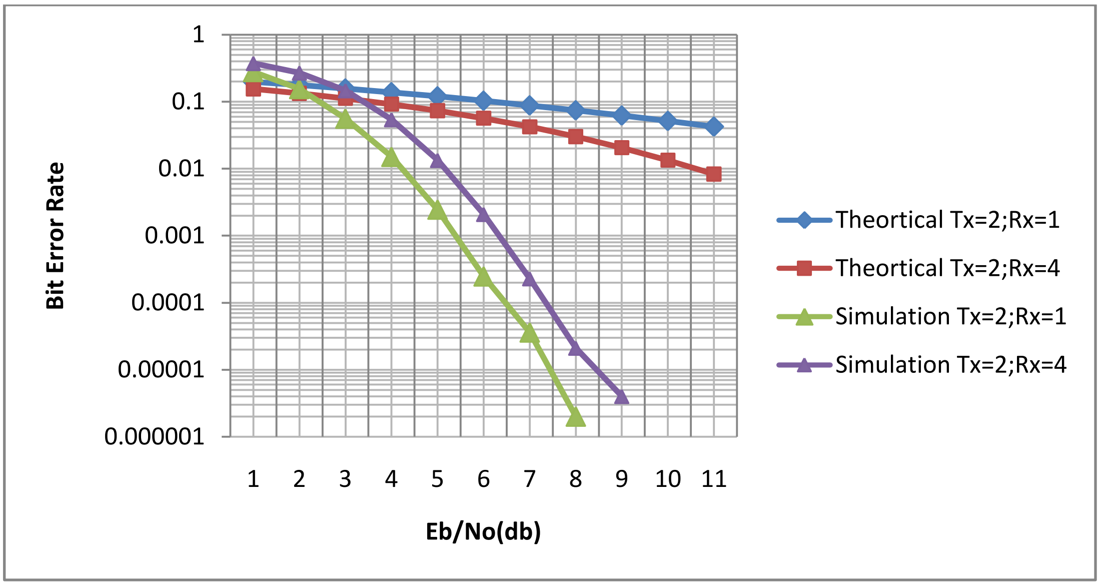

Figure 7: MC-DS-CDMA in Rayleigh Fading Channel forTX=2 and Rx=1, Rx= 4

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Figure 8 shows Bit error rate graph for MC-DS-CDMA over Rician channel. BER calculated for different pairs of transmitter and receiver and shows significantly improvement in system performance. For a Rician faded channel we consider line of sight factor(LOS) K=3.

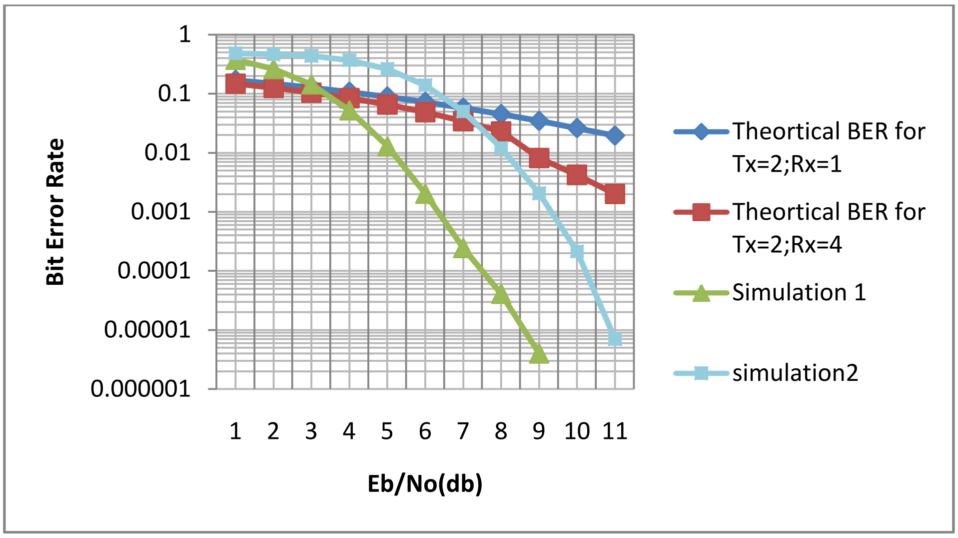

Figure 8: MC-DS-CDMA in Rician Fading Channel for TX=2 and Rx=1, Rx= 4

VI. CONCLUSION

From the comparison results, it is clear that MC-DS-CDMA with a new approach viterbi decoder schemes have better performance than the previous one. The BER performance of MC-DS-CDMA system under the viterbi decoder has been analyzed in the presence of multi-path Rayleigh fading channel. As previously define adaptive Viterbi decoder is an optimal decoding technique for MC-DS-CDMA system under faded channel. From simulation results we can conclude system performing better than previous one. For antenna diversity scheme we consider mainly 2x1 and 2x4 of transmitter and receiver pair. Multicarrier Direct Sequence CDMA leads for 4G terminals.

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