ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 2, Issue 2, February 2013

Simulation and evaluation of convolution encoder for different noisy channel over wireless communication network in CDMA environment

[1] Jai Kumar, [2] Anita Suman

***Abstract*— In this paper we simulate and evaluate the performance of physical layer of wireless communication system of CDMA-2000 specification using radio configuration-3 under forward fundamental channel 1x in terms of bit error rate (BER) by using convolution code. We modeled and evaluated convolution encoder at different rates ½,1/3,1/4 using constraint length k of 3,4,5,6,7,8,9,10 values, under different noise channels (AWGN, BSC, Rayleigh. Rician, combination of AWGN and Rayleigh, combination of AWGN and Rician channel). On the basis of better simulated results of convolution encoder at rate ¼ and higher constraint length in all noise channel, we simulated rate ¼ convolution encoder with constraint length (k) 9 and structure [775 631 413 471] in CDMA-2000 physical layer. With these parameter of convolution encoder we simulated CDMA-2000 system under AWGN (at different Eb/No and trace back depth) and Rayleigh channel (at different Doppler shift) and Rician channel (at comparable results of Rayleigh channel). We had shown the BER performance of CDMA-2000 physical layer performance at higher rate of convolution encoder in AWGN channel and advantage of Rayleigh channel over Rician channel. This also gives an idea of contribution of trace back depth of viterbi decoder in BER performance.**

***Index Terms*— AWGN, BSC, BER, CDMA-2000 standard, Convolution code, Doppler shift, Multipath fading channel, Radio configuration-3, Trace-back depth.**

I. INTRODUCTION

Forward error Correction (FEC) technique is mainly used to improve the capacity of channel and minimize the corruption of data on communication process. Noise channels and channel coding also play important role in communication process between transmitter and receiver. Block coding and convolution coding are two major methods of channel coding. Convolution coding maps the information to code bits where as block code takes information in block. Convolution operation encodes some redundant information in the data transmitted and thus improves the channel capacity and viterbi decoder uses maximum likelihood theorem to minimize the corruption of data.

Additive white Gaussian noise (AWGN) channel accounts only for white noise and does not accounts for fading, frequency selectivity, interference and dispersion. BSC channel corrupt a binary signal by reversing each bit by a fixed probability p. Multipath fading channel (Rayleigh and rician) include multipath scattering effects, time dispersion, and Doppler shifts that arise from relative motion between the transmitter and receiver.

CDMA-2000 is a terrestrial radio interface of 3G wireless communication and specifications developed by 3GPP2. It is basically developed within the specification of IMT-2000 of international telecommunication union (ITU) and is backward compatible and well suited for global roaming. CDMA-2000 physical layer includes several mode of operations as per the requirement of user and local conditions. 1xRTT of CDMA-2000 uses 1 time radio transmission technology. Radio configuration-3 utilizes 1.25 MHz full duplex bandwidth (referred as 1x spreading rate) within a band of operation [1]. Performance of CDMA-2000 physical layer model at spreading rate 1x under radio configuration-3 for forward fundamental channel is evaluated for AWGN and multipath fading channel for different environmental conditions for better communication between transmitter and receiver with minimizing BER.

II. SYSTEM MODEL

A. Channel coding

When error introduced by the information channel is unacceptable then channel coding is needed. The use of channel coder with source coder provides the efficient and reliable transmission in the presence of noise. Efficient channel coding increases channel capacity very near to Shannon limit. Block codes and convolution codes are used for channel coding where block codes takes the information in terms of block and convolution code takes input of continuous data stream.

Shannon limit for channel capacity is C= W log (1+SNR) where W is bandwidth is capacity of channel and SNR is signal to noise ratio,

Convolution codes are commonly specified by three parameters: (n,k,K), where n is the number of encoder output bits, k is the number of input bits, and K is constraint length. The constraint length represents the number of bits in the encoder memory that affect the generation of the n output bits. The quantity k/n, called the code rate, is a measure of the efficiency of the code. The encoder introduces redundant bits into the data stream through the use of linear shift registers.

Manuscript received Feb, 2013.
Jai Kumar, ECE, BCET Gurdaspur, Punjab, India, Mobile No.9592513669.
***Anita Suman**, ECE, BCET Gurdaspur, Punjab, India, Mobile No, 9464068400.*

The information bits are input into shift registers and the output bits are obtained by modulo-2 addition of the input information bits and the contents of the shift registers. The encoder can be represented in several different but equivalent ways.

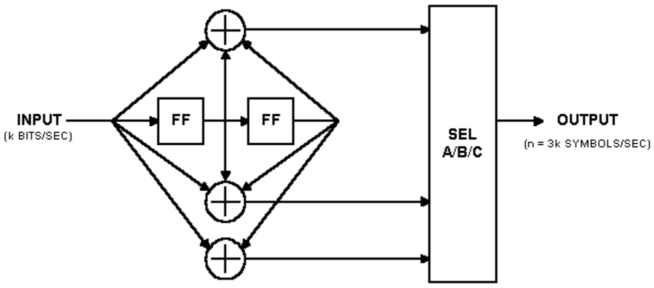

Fig.1 Convolution encoder at rate 1/3 constraint length K=3.

Convolution encoder works in conjunction with a decoder. Normally viterbi decoder used with Convolution encoder which works in the principle of maximum likelihood theorem. Trellis structure is used for viterbi decoding algorithm.

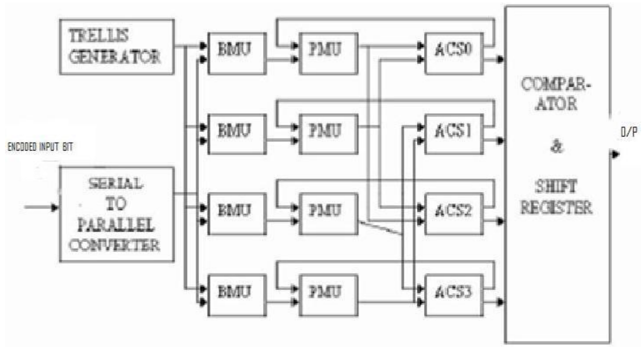

Fig.2 Viterbi decoder Model

We referred different rates 1/2, 1/3, 1/4 of convolution encoder at different constraint length from 3 to 10 and also at different structure. On decoder side we have taken different trace back depth for better results.

B. Noise channel

In between source to destination information data passes through different channel. These channels introduce different types of noises in the data and data said to be corrupted. We modeled convolution encoder intern CDMA-2000 physical layer for in AWGN, BSC and Rayleigh and Rician noise channel. General model of convolution encoder with viterbi decoder looks like-

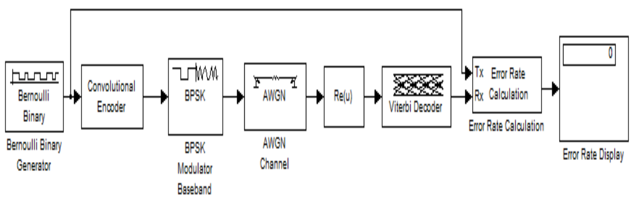

Fig.3. Noise channel (AWGN) in convolution encoder

As Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. Gaussian distribution is sometimes informally called the bell curve**.** This model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. Channel capacity C for the AWGN channel is given by- $C = \frac{1}{2}\log\left(1+\frac{P}{n}\right)$ Where P is maximum channel power and n is variance of noise .Probability density function of AWGN is given by equation below, where parameter σ is its standard deviation; its variance is therefore σ^{2} [2].

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise),shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun.

Binary symmetric channel (BSC) is a common communications channel model used in. In this model, a transmitter wishes to send a bit (a zero or a one), and the receiver receives a bit. It is assumed that the bit is usually transmitted correctly, but that it will be "flipped" with a small probability (the "crossover probability"). This channel is used frequently in information theory because it is one of the simplest channels to analyze.

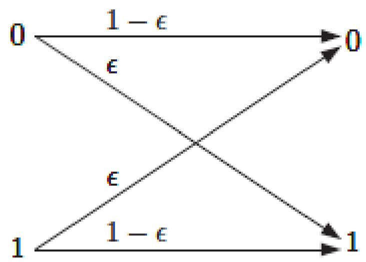

Fig.4 Binary Symmetric Channel

Capacity of the BSC channel is 1 − H(p), where H(p) is the binary entropy function *[3]*. Binary entropy function, denoted H(P) or Hb(P), is defined as the entropy of a Bernoulli process with probability of success *p*.If $\Pr(X=1)=p,$ then $\Pr(X=0)=1-p$ and the entropy of *X* is $H(X)=H_{\mathrm{b}}(p)=-p\log_2 p-(1-p)\log_2(1-p).$

A fading channel is a communication channel comprising fading which is deviation of the attenuation affecting a signal over certain propagation media. Fading may either be due to multipath propagation and categorized in slow and fast fading. The coherence time (Tc) of the channel is related to a quantity known as the Doppler spread (Ds) of the channel and are inversely related to each other. Rayleigh fading and Rician fading channel are mainly considered here in evaluation of Convolution encoder.

Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade, according to a Rayleigh distribution. Doppler power spectral density

$S(\nu) = \dfrac{1}{\pi f_d \sqrt{1 - \left(\frac{\nu}{f_d}\right)^2}}$ is where ν the frequency shifts relative to the carrier frequency [4]. This equation is valid only for values of ν between $\pm f_d$; the spectrum is zero outside this range. The 'bowl shape' or 'bathtub shape' is the classic form of this Doppler spectrum. Rayleigh fading is viewed as a reasonable model for troposphere and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable.

Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution. A Rician fading channel can be described by two parameters: K and Ω. K is the ratio between the power in the direct path and the power in the other, scattered, paths. Ω is the total power from both paths ($\Omega = \nu^2 + 2\sigma^2$), and acts as a scaling factor to the distribution. PDF then is-

$$f(r) = \frac{r}{\sigma^2} exp\left(-\frac{r^2 + k_d^2}{2\sigma^2}\right) I_0\left(\frac{r k_d}{\sigma^2}\right) \qquad r \geq 0$$

Where (Io(.)) is the 0th order modified Bessel functions of the first kind [5]. We varied the channel in convolution encoder as well as in CDMA-2000 model and evaluated the performance.

C. CDMA-2000 physical layer 1xRTT

The CDMA-2000 Physical Layer model is a part of the downlink physical layer of a wireless communication system according to the cdma2000 specification. In particular, the model focuses on Radio Configuration 3 of a forward fundamental channel of a 1x (spreading rate 1) forward link between a base station and a mobile station.

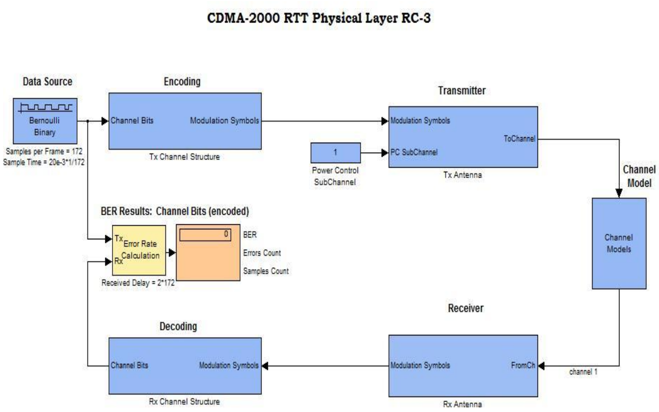

Fig.5. CDMA-2000 physical layer Model

We used encoder, transmitter, channel, receiver, decoder and BER calculator along with data source and display indicator. Encoder uses convolution coding with puncturing and interleaving data steam. Interleaving is used to eliminate the effects of selective fading. It offsets any deep fades that occur in the wireless channel by spreading the data bits over the sub-carrier channels. Transmitter utilizes scrambler, modulator and sequence generator. Channel constitutes in variable options i.e. AWGN, Rayleigh or Rician. Receiver part have rack receiver, descrambler and filters. Decoder utilizes viterbi decoder, depuncture and deinterleaver [6].

Full model of simulation is build with the help of MATLAB where data source is Bernoulli binary generator and error calculator is called function of MATLAB.

III. SIMULATION RESULTS

A. Convolution encoder simulation-

Simulation of convolution encoder model as in fig.3 carried out under fallowing parameters-

Table-1 Convolution code parameters

Parameters	Values	Remarks
Probability of zero	0.5	Gen. source
Constraint length(K)	3,4,5,6,7,8,9,10	Encoder
Rate	½,1/3,1/4	Encoder
Modulation	BPSK	Modulator
Noise channel	AWGN,BSC,Fad ing	Channel
Decoder	Viterbi	Decoder
Eb/No	1 db	Channel
Power	1 w	channel

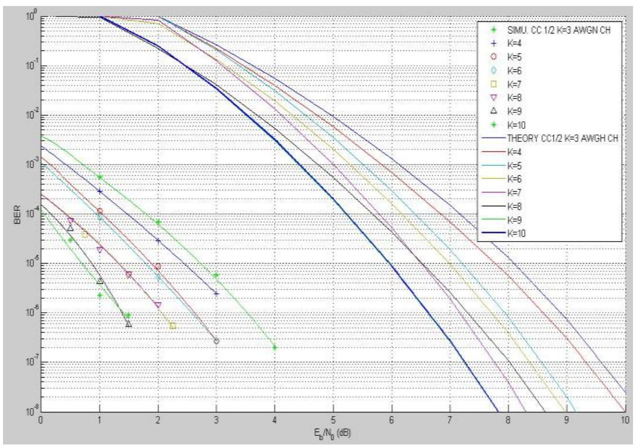

Fig.**6.CC rate ½ performance under k=3, 4….10 in AWGN**

Here improved performance of CC on same rate at higher values of constraint length (k) is observed in terms of lower BER values in theoretical as well as in simulated results. With higher values of constraint length, CC performance improves on decrease in rate as shown in table.2 and fig.7.

Table.2 CC Performance under different parameter

Encoder rate	BER at K=3 (Eb/No=1db)	BER at K=5 (Eb/No=1db)	BER at K=7 (Eb/No=1db)	BER at K=7
1/2	$6.179*10^{-4}$	$1.000*10^{-4}$	$1.798*10^{-5}$	$1.7*10^{-4}$ (0db SNR)
1/3	$2.175*10^{-3}$	$2.279*10^{-4}$	$1.247*10^{-5}$	$4.0*10^{-4}$ (-2db SNR)
1/4	$2.496*10^{-3}$	$3.000*10^{-4}$	$9.500*10^{-6}$	$3.8*10^{-4}$ (-4db SNR)

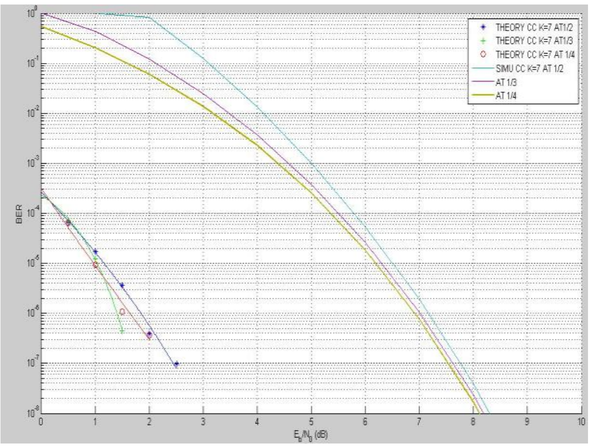

Fig.7.CC performance under rate ½, 1/3, 1/4 at k=7 at AWGN noise channel.

This performance of CC indicates that more value of k at decreased rate results in BER improvement in the terms of 10-6 at 0.5db Eb/No similar to theoretical results. Now this CC model simulated in different noisy channel on almost similar parameters and performance are-

Table.3.Noise channel performance

Encoder rate	BER (AWGN)	BER (BSC)	BER (Rayleigh)	BER (Rician)	AWGN +Rician	AWGN +Rayleigh
1/2	$1.000*10^{-4}$	$4.183*10^{-3}$	$9.560*10^{-2}$	$2.481*10^{-1}$	$1.898*10^{-1}$	$2.898*10^{-1}$
1/3	$2.279*10^{-4}$	$4.133*10^{-4}$	$3.876*10^{-1}$	$2.756*10^{-2}$	$2.427*10^{-1}$	$2.695*10^{-1}$
1/4	$3.000*10^{-4}$	$2.816*10^{-5}$	$6.211*10^{-1}$	$2.488*10^{-1}$	$2.387*10^{-1}$	$2.531*10^{-1}$

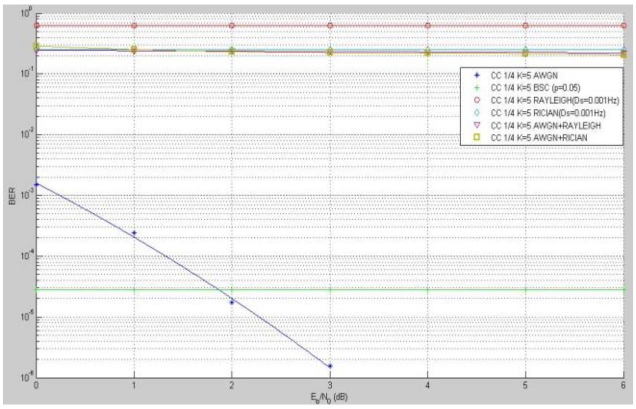

Fig.8 CC performance at rate ¼, k=5 in AWGN, BSC (p=0.05), Rayleigh (Ds=0.001 Hz), Rician (Ds=0.001, k=1), AWGN+Rayleigh (Eb/No=1, Ds=0.01 Hz), AWGN+Rician (Ds=0.01 Hz) noise channel.

Here we found that performance of CC is better in AWGN channel in all rate except rate ¼ than BSC channel and in Rayleigh chanel at increased rate ½ than Rician channel. However at lower rate 1/3, 1/4 rician channel is better than Rayleigh channel with lower BER.

B. CDMA-2000 physical layer 1xRTT simulation-

As we seen above that higher values of constraint length at higher rate of convolution provide better results in CC model at all channel so we chosen set of higher value parameter of convolution code and noise channel for simulation over CDMA-2000 physical layer.

Table.4 CDMA-2000physical layer parameters

Parameter	Values	Specification
Sample time	20e-3*1/172	generator
Coding	Convolution	Encoder
Encoder structure	(9, [775 631 413 471])	Encoder
Puncture vector	[1]	Encoder
Forward traffic channel walse code length	64	Tx
Tx rate	¼	Tx
Tx diversity mode	Non-TD	Tx
Channel	AWGN(Eb/No=45db&1w) Rayleigh(Ds=3270hz) Rician(Ds=3270/2670hz)	Channel
Rx	Rack receiver	Rx
Decoder	Viterbi	Decoder
Radio configuration	RC-3	CDMA
Traceback depth	30/60/90	Decoder

We simulated the CDMA -2000 model under CC str (9, [775 631 413 471]) in three channel and results in fig.9.

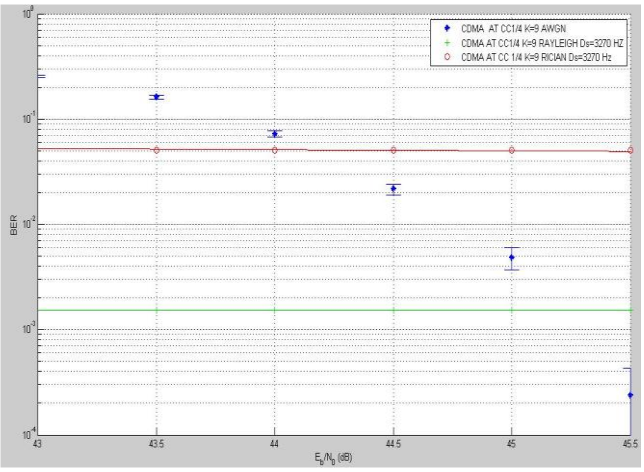

Fig.9 cdma-2000 physical layer 1xRTT performance under AWGN (1w), Rayleigh (Ds=3270 Hz) and Rician (Ds=3270 Hz) Channel.

Table.5 CDMA-2000 performance in Different channel

CHANNEL	(Eb/N0)/D.SHIFT	BER
AWGN	45 db	$5.339*10^{-3}$
RAYLEIGH	3270 Hz	$1.542*10^{-3}$
RICIAN	3270 Hz	$5.055*10^{-2}$
RICIAN	2670 Hz	$1.542*10^{-3}$

Here we have better performance of CDMA-2000 in 3270 Hz Doppler shift in Rayleigh channel. Now we also simulated the CDMA-2000 in AWGN channel for different Trace back depth of viterbi decoder and results are-

Table.6 tackback depth results of decoder in CDMA-2000

Eb/N0	Depth	power	BER
43	30	1w	0.2468
43	60	1w	0.2547
43	90	1w	0.2569
44	30	1w	$8.246*10^{-2}$
44	60	1w	$7.214*10^{-2}$
44	90	1w	$7.202*10^{-2}$
45	30	1w	$8.424*10^{-3}$
45	60	1w	$4.865*10^{-3}$
45	90	1w	$8.393*10^{-3}$
45	60	0.85w	$2.237*10^{-4}$

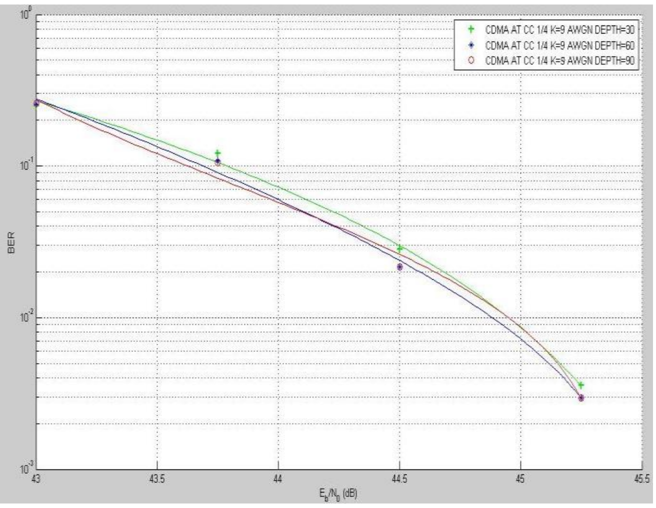

Fig.10 CDMA-2000 performance under AWGN channel at different traceback depth of decoder.

Above shown result indicate that on increase of traceback depth of viterbi decoder, performance of CDMA-2000 improves slightly.

IV. EVALUATION

Evaluation of CC model and CDMA-2000 physical layer model is based on BER results. Lower value of BER indicates better performance of system. At the same time every system have some constraint limit/trade-off and beyond those limits it may not perform so good as it perform under these limits.SNR(Eb/No) and BER are inverse to each other and while we simulate the system we find that an increase in Eb/No results in lower values of BER[7]. Similarly when increase Convolution Constraint length from K=3 to K=10at ½ rate CC then we find a marked improvement of 2.25 db gain in10^{-6} BER fig.1 *[8]* and 4.5 db gain on rate ¼ CC from K=3 to K=7 as shown in table.2.But at the same time higher value of K involve large number of electronic components thus bulky model.

Another factor is rate of convolution, on lowering of rate of CC we results in 4db (at ¼ rate) gain(in SNR) than in rate ½ CC for comparable BER of degree 10^{-3} as shown in table.2.But on decreased rate we requires more number of outputs and number of gates thus increases the complexity of system.

Performance of CC in different noise channel is listed in table.3 and we can determine that at lower rate, performance of CC is better in Rayleigh channel and at higher rate performance is better in rician channel however mixed performance in AWGN and BSC channel *[9]*. On adding two noise channels simultaneously the performance decreases gradually. So it is recommended that for mixed noisy environment we require much care for design encoder.

CDMA-2000physical layer perform better in Rayleigh channel up to 3270 Hz Doppler shift while rician channel performance is limited to 2670 Hz only for similar 10^{-3}BER .Rician channel degrade the performance of CDMA on Ds=3270 Hz as shown in Fig.9[5]. Similarly CDMA-2000 evaluated for AWGN channel for traceback depth parameter of viterbi decoder as in table.6 and fig.10 and indicates that on increment of traceback depth, performance of CDMA improves at all Eb/No values *[10]*.

V. CONCLUSION

This paper evaluated the performance of convolution code in AWGN, BSC and Fading channels and results that consideration of AWGN provides better performance. Multipath fading and idea of multi channel existence in environment is also taken in account and found that performance of CC is reduced gradually.

On the basis of simulated result of Convolution Encoder under AWGN channel we find 2db (SNR) gain in rate 1/3 CC and 4db (SNR) gain in rate ¼ CC in comparison of rate ½ CC at k=7 for similar results of 10^{-4}BER. Similarly rate ½ CC provide 2.25 db Gain at K=10 in comparison to rate ½ CC at k=3.At lower rate we result in gain of 4.5 db in K=7 in comparison to K=3 in rate 1/4 CC.

While CDMA-2000 physical layer 1xRTT forward traffic channel model performed better under consideration of Rayleigh channel and performed similar for more Doppler spread of 600 Hz than rician channel for 10^{-3} BER which is satisfactory. On similar model it results in better performance in AWGN channel for similar Eb/No and gives some degree improvement in traceback depth of 60 in compare to traceback depth of 30.

In order to analyze the performances of the model experimentally and theoretically, convolution coding is used here. CDMA-2000 physical layer model employed RC-3 configuration at 1x rate. We can further analyze the model at different channel coding scheme like turbo code, LDPC code etc. and different radio configuration RC-1/RC-2 with higher spreading rate 2x/3x.

References

[1] H. Gharavi, F. Chin and R.Wyatt-Millington, "A Link-Level Simulator of the cdma2000 Reverse-Link Physical Layer", Journal of Research of the National Institute of Standards and Technology. Volume 108, Number 4, July-August 2003.

[2] Shu Lin, Denial J. Castallo, "Error Control Coding", prentice hall series in computer application and electrical engineering.

[3] Po-Ning Chen, Professor," Digital communication Ch-4", Institute of communication Engineering Tiwan.

[4] R. H. Clarke,"A Statistical Theory of Mobile Radio Reception". Bell Systems Technical Journal 47 (6): 957–1000 (July–August 1968).

[5] Dilip Mandloi, Prateek Paliwal,Deepali Yadav, "Performance Evaluation of ½ Rate Convolution Coding with Different Modulation Techniques for DS-CDMA System over Rician Channel", International Journal of Computer Applications (0975 – 8887) Volume 55– No.12, October 2012.

[6] Serge Willenegger, "cdma2000 Physical Layer: An Overview", 1229-2370/00/$10.00 c2000 KICS.

[7] Ragini Gupta, Sanjeev Kumar "Performance Comparison of Different Forward Error Correction Coding Techniques for Wireless Communication Systems", IJCST Vol. 2, Issue 3, September 2011.

[8] Wei Chen Dept. of Computer Engineering at Linköpings universitet on paper "RTL implementation of Viterbi decoder"June 02, 2006. http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-3886

[9] Md. Golam Rashed, Sheikh Enayet Ullah, "Transmission of Voice Signal: BER Performance Analysis of Different FEC Schemes Based OFDM System over Various Channels", International Journal of Advanced Science and Technology Vol. 34, September, 2011.

[10] Jittra Jootar, John G. Proakis," Performance of Convolutional Codes with Finite-Depth Interleaving and Noisy Channel Estimates", IEEE transactions on communications, vol. 54, no. 10, october 2006.

Er. Jai Kumar received his B.Tech. (ECE) from IEI (I) Kolkata in 2009 and M.Tech. from Beant College of Engineering and Technology, Gurdaspur Punjab, India. His field of interest includes Wireless communication and satellite communication.

Mrs. Anita Suman is working as assistant professor (ECE) in BCET Gurdaspur, Punjab and has 10 years of teaching experience. She completed her ME and has interest in field of 'information theory and wireless communication'. She publishes a number of international papers and also attended conference at national level.