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Performance Analysis of Turbo Coded WiMAX System over Different Communication Channels

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Abstract*—An ever crowed Radio spectrum system implies that future demands must be met using more data throughput wireless technologies. Since system bandwidth is limited and user demand continues to grow. This problem could be solved by WiMAX (Worldwide Interoperability for Microwave Access) technology based on the IEEE 802.16 specifications. Since it offers high level of services. In this paper the performance of Turbo Coded WiMAX system over different Channels like AWGN, Rayleigh & Rician has been analysed. And the performance of each channel is compared with the performance as was with convolution code (without Turbo) and performance at different iterations in Turbo code. Orthogonal Frequency Division Multiplexing have been used to achieve high data rate necessary for intensive application by maintaining FFT size 256. With result we could say that AWGN channel with more number of iterations shows better result. With Convolution code (without Turbo)performance was weak, it enhanced approx. 7db by the use of Turbo code.

Keywords*—OFDM,Convolution code, Additive White Gaussian Noise, Fading Channel, BPSK, Turbo code.

I. INTRODUTION

The IEEE 802.16 standard was firstly designed to address communications with direct visibility in the frequency band from 10 to 66 GHz. Due to the fact that non-line-of-sight transmissions are difficult when communicating at high frequencies, the amendment 802.16a was specified for working in a lower frequency band, between 2 and 11 GHz. The IEEE 802.16d specification is a variation of the fixed standard (IEEE 802.16a) with the main advantage of optimizing the power consumption of the mobile devices. The last revision of this specification is better known as IEEE 802.16-2004 [1].On the other hand, the IEEE 802.16e standard is an amendment to the 802.16-2004 base specification with the aim of targeting the mobile market by adding portability.

Conventional high speed broadband services are based on wired access technology, this type of solution is difficult to deploy in remote areas. Another point is that wired solution could not be used for Mobile services. Due these reasons there is huge demand of Wireless broadband solution. WiMAX technology offers good solution to overcome with these problems. It addresses the following needs.

1) The cost associated with the deployment is low.
2) It covers both Fixed and mobile networks.
3) It has flexible network architectures.

WiMAX is a technology based on the IEEE 802.16 specifications also known as IEEE wireless MAN air interface is an emerging standard for fixed portable and mobile BWA in MAN. The WiMAX offers data-transfer rates of up to 75 Mbit/s, which is superior to conventional cable-modem and DSL connections. WiMAX is IP based, wireless broadband access technology that provides performance similar to 802.11/Wi-Fi networks with the coverage and QOS (quality of service) of cellular networks. It intended for wireless "metropolitan area networks". WiMAX can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. The Paper which we choosen has analysed WiMAX physical layer using Soloman codes, But we studied that with Turbo code error reduces up to minimum level that is why we analysed WiMAX system by using Turbo code.So that WiMAX system could be simplified and can be made more useful.

Organisation of rest of paper is as follows. In section 2,Simulation model Fig.1 shows the Block diagram of WiMAX system & different blocks of WiMAX system are discussed like Randomization, FEC, interleaving, cyclic prefix addition, symbol mapping, encoding of Turbo code, AWGN channel, Rician fading channel, Rayleigh Channel etc. Fig.2, Fig.3 & Fig.4 shows Turbo code encoder, & Fig.5 shows Turbo code decoder. Fig.6 for distribution of White noise & in Fig.7 the Gaussian noise distribution shown. In Section 3 Results & Discussion, In Table.1 type of code, number of iterations taken in Turbo code rates at which we analyzed the performance, type of channel &modulation schemes is mentioned. Simulation results of different communication Channels like AWGN, Rician & Rayleigh channels are Fig.8, Fig.9 & Fig.10 Respectively.

II. SIMULATION MODEL

In Fig.1 Block diagram of WiMAX system is explained and details of each block are discussed below in brief.

2.1. Randomization

Randomizer uses a Linear Feedback shift register (LFSR) to scatter long data strings of zeros or ones.

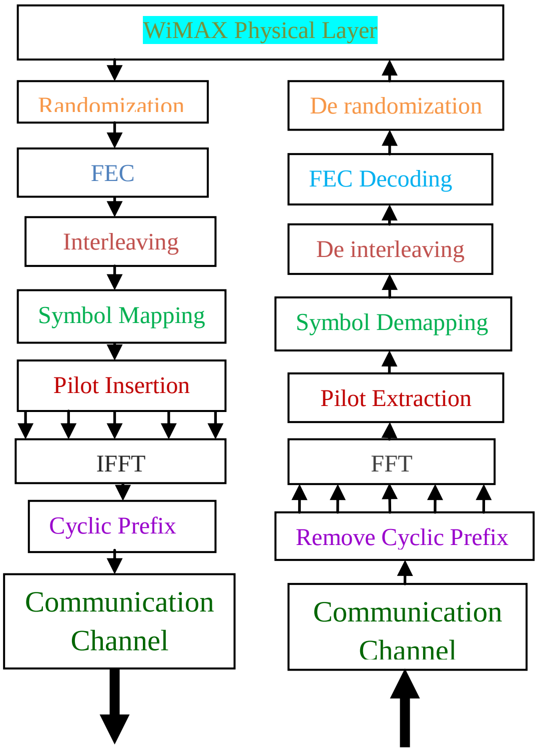

Fig 1: Block diagram of WiMAX system

2.2. FEC

Capable of correcting a certain number of errors, i.e. it should be capable of locating the positions where the errors occurred. In this paper convolution code is used.

2.2.1 Encoding of Turbo codes: In information theory, turbo codes (originally in French Turbo codes) are a class of high-performance forward error correction (FEC) codes developed in 1993, which were first practical codes to closely approach the channel capacity.The term ‘turbo code’ is something of misnomer as the word ‘turbo’ actually refers to the iterative decoding procedure, rather than to the codes themselves. Shannon demonstrated that it is possible to transmit information with arbitrarily few errors provided the capacity of the channel is not exceed, the capacity of the channel depending on bandwidth and SNR. The Shannon-Hartley channel capacity theorem states that the maximum rate of information transmission R_{max} , over a channel with bandwith B and signal-to-noise ratio S/N is given by:

$$R_{max} = B \log_2 \left(1 + \frac{S}{N}\right) \text{bits/s}$$

When bandwidth tends to infinity maximum channel capacity is $1.44\frac{S}{N}$.

2.2.2 Serially concatenated codes: Concatenated coding means method of combining two or more relatively simple codes to provide a much more powerful code, but with simpler decoding properties than a single larger code of comparable performance. The principle is simple. The output of the first encoder (the outer encoder) is fed into the input of the second encoder (the inner encoder).

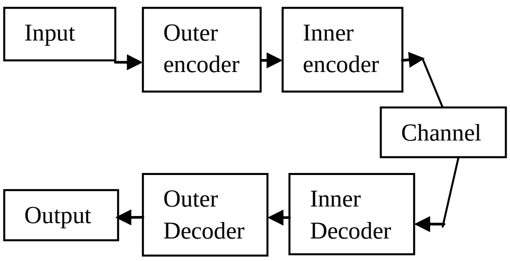

Fig 2: Serially Concatenated codes

2.2.3 Parallel-Concatenated recursive systematic convolution codes: In its most basic form of encoder of a turbo code comprises two systematic encoders joined together by an interleaver.

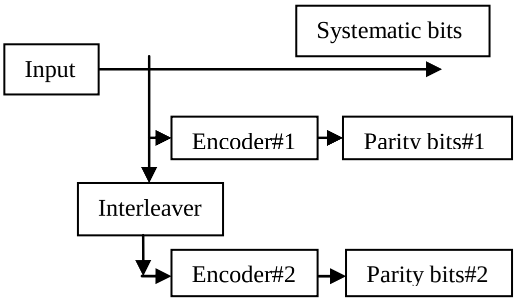

Fig 3: Parallel-Concatenated recursive systematic codes

Recursive systematic Convolutional (RSC) codes can be generated from non systematic codes (NSC) by connecting one of the outputs of the encoder directly to the input (here we should remember that convolution codes are non-systematic),whilst other weighted taps from the shift register stages are also fed back to the input.diagram is given below

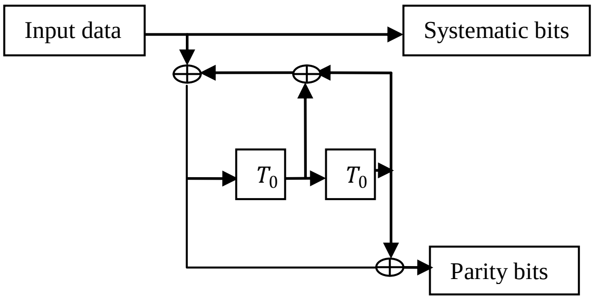

Fig 4: Turbo Encoder

Making the codes recursive means that the state of the encoder depends upon the past outputs as well as the past inputs.Thus the finite length sequence can generate an infinite lenth output sequence (unlike an NSC code) this affects the behavior of the error patterns (a single error in the original message bits producing an infinite number of parity errors) with the result that better overall performance is attained.operation of the turbo encoder is as follows:
The input data sequence is directy applied to encoder1 and interleaved version of the same input is applied to encoder2.
Systematic bits(i.e. the original message bits) and the two parity check bits are(generated by two encoders) are mutiplexed together to form output of the encoder.

2.2.4 Turbo Code interleavers: the interleaver ensures that two permutations of the same input data are encoded to produce two different parity sequences.The effect of interleaver is to tie together errors that are easily made in one half of the turbo encoder to errors that are exponentially unlikely to occur in the other half. This ensures robust performance in the event that the channel characterstics are not known and is the principle reason why turbo codes perform better than the traditional codes.

2.2.5 Turbo Decoding:In the decoding of turbo code soft information is applied to both decoders by de-interleaving the input signal and then applying this sequence to the input of second decoder. Using soft information from output of the first decoder and applying it to the input of the second decoder can make further improvements.A final improvement is to apply the output of the second decoder to the first; in effect iterating. When decoding a concatenated or product code, information from one decoder that is passed to the next is called extrinsic information. Only the extrinsic information is passed from decoder to decoder, as the intrinsic information is made directly available.

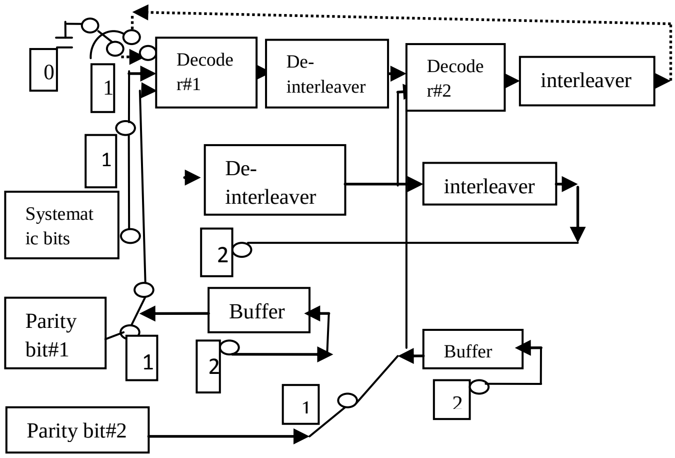

Fig 5: Turbo Decoding

2.3 Interleaving

By interleaving data is ordered in some other fashion so that errors do not accumulate at one place. Types of interleaves are as follows. Pilot Insertion-: Some pilot symbols are added to each frame. It is mainly is used to reduce ISI (inter symbol interference). Channel estimation is a major challenge for reliable wireless transmissions.

$$h_i^{LMMSE} = R_{hh} LsR_{hLS}^{-1} hLsh_i^{LS}$$

2.4 Cyclic Prefix

Cyclic prefix is actually a copy of the last portion of the data attached to the front of the symbol during the guard interval. Let us first define a new base function for transmission;

g_n (t) = $\exp\left[j2\pi n \frac{W}{N} t\right]$ for - $T_{cp} < t < Ts$

Where again W/N is the carrier spacing, andT_s =N/W. the symbol directionT_s is now $T_{s} =_{T_s}$ $+T_{cp}$. this definition of the base function means that for duration $0< t < T_s$ the "normal" OFDM symbol is transmitted. During time -$T_{cp} < t < 0$, a copy of the last part of the symbol is transmitted.

2.5 Symbol Mapping

Modulation by the use of PSK (phase shift keying)-:here in this project BPSK(Binary phase shift keying). BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180^0 and so can also be termed 2-PSK. The general form for BPSK follows the equation:

$$S_n(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi(1-n)), n = 0,1.$$

This yields two phases, 0 and π.

2.6 FFT

Fast Fourier transform is done. It is necessary for orthogonality of subcarriers.

$$x(n) = \frac{1}{N}\sum_{n=0}^{N-1} x(k)\, e^{j2\pi kn/N} \qquad for\ n = 0,1,2 \ldots \ldots . N-1$$

Where X(k) is the transmitted data symbol at the kth subcarrier of the OFDM symbo1, N is the fast Fourier transform(FFT) size.

2.6.1 OFDM (Orthogonal frequency division multiplexing)

Splits the information into N parallel streams, which are then transmitted by modulating N distinct carries (henceforth called subcarriers or tones) . symbol duration on each subcarriers thus become larger by a factor of N. in order for the receiver to be able to separate signal carried by different subcarriers , they have to be orthogonal

$$\int_{iT_s}^{(i+1)T_s} exp(j2\pi f_k t)\, exp(-j2\pi f_n t) dt \; = \delta_{nk}$$

2.7 AWGN Channel (Additive White Gaussian Noise)

The AWGN (Additive white Gaussian noise channel attenuates the transmit signal, causes phase rotation, and adds Gaussian distributed noise. The distribution of white noise is shown Fig.3 Attenuation and rotation is temporally constant, and is thus easily taken into account. Thus, the received signal (in complex baseband notation) is given by:

$r_{LP}(t) = \alpha s_{LP} + n_{LP}(t)$

Where ∝ is the (complex) attenuation and n(t) is a (complex) Gaussian noise process.

$$S_{n,,LP}(f) = \begin{cases} N_o & |f| \leq \frac{B}{2} \\ 0 & otherwise \end{cases}$$

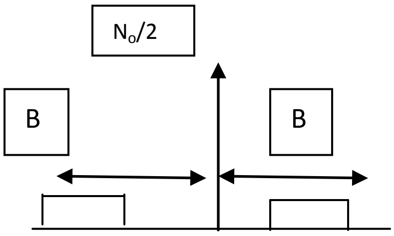

Fig.6 White Noise distribution

Note that $S_{n,LP}(f)$ is symmetric with respect to f i.e.$S_{n,LP}(f) = S_{n,LP}(-f)$

The Gaussian (also called normal) probability density function is defined as the mean and variance of this Gaussian density function the density has been adjusted to unity.Gaussian distribution curve is shown in Fig.4.

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

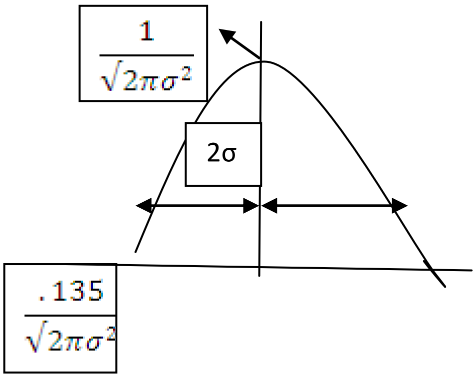

Fig.7 Gaussian probability density function

When x-m=±σ that is values of x separated from m by the standard deviation, The noise n(t) is assumed to be white Gaussian noise of power spectral density n/2.

2.8 Rician Fading Channel

The Rician Noise Generator block generates Rician distributed noise. The Rician probability density function is given by

$f(x) = \left\{\frac{x}{\sigma^2}\left(\frac{mx}{\sigma^2}\right) exp\left(-\frac{x^2+m^2}{2\sigma^2}\right)\right\} \quad x \geq 0$Where:

- σ is the standard deviation of the Gaussian distribution that underlies the Rician distribution noise
- $m^2 = m_I^2 + m_Q^2$, where m_I and m_Q are the mean values of two independent Gaussian components
- I_0 is the modified 0th-order Bessel function of the first kind given by

$$I_0(y) = \frac{1}{2\pi}\int_{-\pi}^{\pi} e^{ycost}\, dt$$

2.9 Rayleigh Fading Channel

The Rayleigh distribution is a good model for channel propagation, where there is no strong line of sight path from transmitter to the receiver. This can be used to represent the channel condition seen on a busy street in a city. Where the base station is hidden behind a building several blocks away and arriving signal is bouncing of many scattering objects in local area.

Doppler shift of each incident ray is given by

$\delta f_n = \frac{v}{\lambda} cos\alpha_n$ where v is the speed of the receiving antenna.

Maximum Doppler shift f_d occuurs for a wave coming from direction opposite to the direction the antenna is moving. It has a frequency shift with f_c being the carrier frequency and c the velocity of light,

$$f_d = \frac{v}{c} f_c$$

The max spread f_d is determined by the speed of the vehical and is only experienced by the spectral components arriving on paths directly in front of (max positive) or directly behind (max negative) the motion of the receiver. No shift is seen at 90 and 270 degrees relative to the mation. This is why we see the most spectral desity s(f) at the edges of the Doppler spread as given by

$$S(f)=\left[\frac{1}{f_d\sqrt{1-\left(\frac{f-f_c}{f_d}\right)^2}}\right] \quad where\ |f-f_c| < f_d$$

Which gives proportionate relationship correlating with the rays that are coming directly behind the motion of the antenna.

III. RESULTS & DISCUSSION

In Tabel.1 Modulation Schemes,Number of Turbo iterations (Without Turbo (Convolution Code),1-iteration,10-iterations) & type of Communication channel through analysis have been done are shown.

Modulation Scheme	No. of Iterations (Turbo Code)	Noise Channels
BPSK	Without Turbo(Convolution code),1-iteration, 10-iterations	AWGN Channel
BPSK	Without Turbo(Convolution code),1-iteration, 10-iterations	Rician Channel
BPSK	Without Turbo(Convolution code),1-iteration, 10-iterations	Rayleigh Channel

Table 1: Modulation Scheme, No. of Turbo Iterations & Noisy channels.

In the Fig.8 we have presented various BER v/s SNR graphs over AWGN(additive white Gaussian noise) channel.

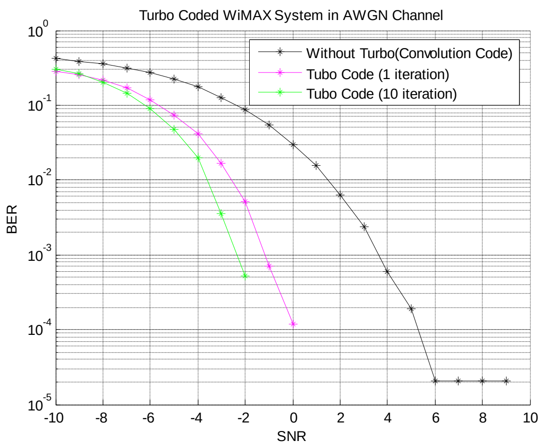

Fig.8 Plots of Turbo Coded WiMAX System over AWGN Channel.

The plots over AWGN (Additive White Gaussian Noise) Channel as follows:

a) First plot is plotted without Turbo Code (Convolution Code) shown by black color line.Convolution code
b) Second plot is plotted by taking Turbo Code (Iteration 1) shown by magenta color line.
c) Third plot is plotted by taking Turbo Code (Iteration 10) shown by green color line.

All plots are plotted by taking BPSK modulation Scheme. Plot with Turbo Code (iteration 1) is more tilted towards Y-axis as Compared to the Plot with plot without Turbo Code, thus by analyzing these two plots we could say that Turbo code gives much more better as compared to convolution code, there is shift of about 5dB in SNR value. The plot of Turbo Code (with iteration 10) shifts more towards Y-Axis as compared to plot of Turbo Code (with iteration 1) & plot without Turbo Code (Convolution Code) thus as number of iterations are increased performance enhances. The performance is enhanced about 6dB with Turbo code (with 10 -iteration) in comparison to performance by convolution code.

In the Fig.9 we have presented various BER v/s SNR graphs over Rician channel.

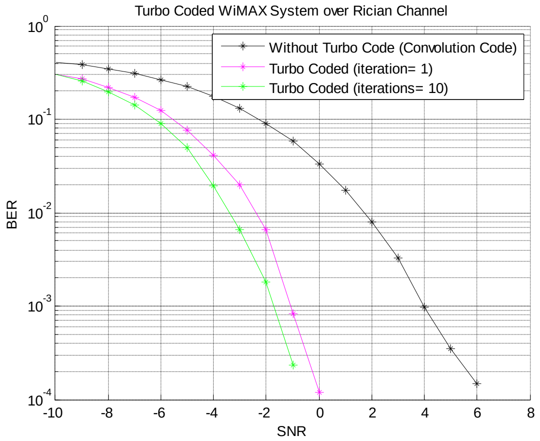

Fig.9 Plots of Turbo Coded WiMAX System over Rician Channel

These analysis are done at 5Hz Doppler frequency & Rician K-factor was kept 1.
The plots over Rician Channel as follows:

a) First plot is plotted without Turbo Code (Convolution Code) shown by black color line.Convolution code
b) Second plot is plotted by taking Turbo Code (Iteration 1) shown by magenta color line.
c) Third plot is plotted by taking Turbo Code (Iteration 10) shown by green color line.

All plots are plotted by taking BPSK modulation Scheme. Plot with Turbo Code (iteration 1) is more tilted towards Y-axis as Compared to the Plot with plot without Turbo Code, thus by analyzing these two plots we could say that Turbo code gives much more better as compared to convolution code, there is shift of about 5dB in SNR value. The plot of Turbo Code (with iteration 10) shifts more towards Y-Axis as compared to plot of Turbo Code (with iteration 1) & plot without Turbo Code (Convolution Code) thus as number of iterations are increased performance enhances. The performance is enhanced about 5.5dB with Turbo code (with 10 -iteration) in comparison to performance by convolution code.
In the Fig.10 we have presented various BER v/s SNR graphs over Rayleigh channel.

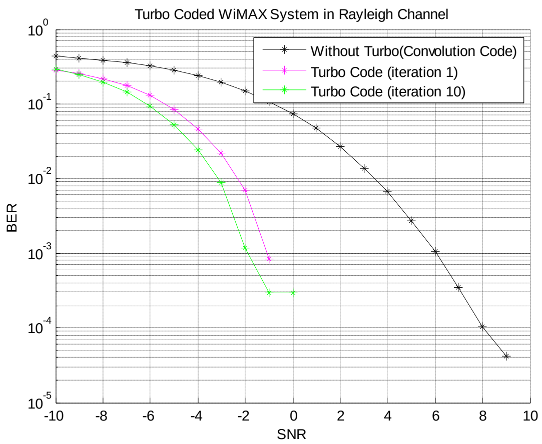

Fig.10 Plots of Turbo Coded WiMAX System over Rayleigh Channel

During analysis of Rayleigh Channel maximum Doppler Shift was taken 5Hz Doppler frequency.
The plots over Rayleigh Channel as follows:

a) First plot is plotted without Turbo Code (Convolution Code) shown by black color line.Convolution code
b) Second plot is plotted by taking Turbo Code (Iteration 1) shown by magenta color line.
c) Third plot is plotted by taking Turbo Code (Iteration 10) shown by green color line.

All plots are plotted by taking BPSK modulation Scheme. Plot with Turbo Code (iteration 1) is more tilted towards Y-axis as Compared to the Plot with plot without Turbo Code, thus by analyzing these two plots we could say that Turbo code gives much more better as compared to convolution code, there is shift of about 7dB in SNR value. The plot of Turbo Code (with iteration 10) shifts more towards Y-Axis as compared to plot of Turbo Code (with iteration 1) & plot without Turbo Code (Convolution Code) thus as number of iterations are increased performance enhances. The performance is enhanced about 8dB with Turbo code (with 10 -iteration) in comparison to performance by convolution code.

The results shown by AWGN channel are better as Rician & Rayleigh fading channel in each plots (i.e. Without Turbo (Convolution Code), Turbo code with iteration 1 & Turbo code with iteration 10). Plot of Rician fading channel shift 0.5dB more away from Y-axis as compared to plot of AWGN channel.Plot of Rayleigh fading channel shift 2.5dB more away from Y-axis as compared to plot of AWGN channel.Thus, Results of Rayleigh fading channel are worst as compared to Rician fading Channel &AWGN channel.

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