Performance Analysis/Study of OFDM Based DVB-T System under AWGN, Rayleigh and Rician Channels

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Abstract— Digital video broadcast-terrestrial (DVB-T) is the most widely used standard for terrestrial digital television. In this paper, we report the performance of orthogonal frequency division multiplexing (OFDM) based DVB-T system for 2k mode under different channels viz. additive white Gaussian noise (AWGN), Rayleigh and Rician with various inputs like Image, audio and video. The transmitted signal is corrupted and is interpreted in terms of different values of Signal-to-Noise ratio (SNR ranging from 0db to 40dB). A 4 quadrature amplitude modulation (4-QAM) scheme is used for the simulation. The results show that the AWGN channel has the lowest bit error rate (BER) under QAM modulation schemes and outperforms marginally over Rayleigh and Rician channels. This can be attributed to the improvement in fading due to multiple reflections received at the receiver. This performance analysis gives the possible scope for improvement in design of advanced version of DVB-T system to support high performance bandwidth efficient multimedia services.

Key words: AWGN, DVB-T, OFDM, PAPR, QAM, Rayleigh, Rician, SNR

I. INTRODUCTION

The growth of the digital televisions and a huge demand for the mobile television (TV) series in the market Digital Video Broadcast-Terrestrial (DVB-T) systems are became a DVB European standard for providing digital television and broadcasting digital data world-wide. DVB-T system uses orthogonal frequency division multiplexing (OFDM) as modulation scheme for achieving the high data capacity and spectral efficiency requirements for wireless communication systems [1]. In DVB-T system one radio frequency channel can be used to transmit more than one TV program.

A. Orthogonal Frequency Division Multiplexing

OFDM [2] is an optimum version of the multicarrier transmission scheme in which high rate data stream is divided into multiple lower rate data streams and are transmitted over a lower bandwidth orthogonal subcarriers (sub-channels) in parallel. In OFDM systems [3], the spectrum of individual subcarrier is overlapped with minimum frequency spacing, which is carefully designed so that each subcarrier is orthogonal to the other subcarriers. Orthogonality of carriers means each carrier has an integer number of cycles over a symbol period. Because of orthogonality of subcarriers, the frequency spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This eliminates need of equalizer at the receiver side due to very small Inter Symbol Interference (ISI). The ISI may completely vanish if the guard interval is longer than the multipath delay between interference between the carriers, even though their spectra overlap. In OFDM Modulation and demodulation can be achieved by fast Fourier transform (FFT) and inverse fast Fourier transform (IFFT) which increases the computational efficiency of OFDM system.

B. Digital Video Broadcast-Terrestrial

DVB-T is the DVB European-based consortium standard for the broadcast transmission of digital terrestrial television [4] [5]. The DVB-T system shown in Fig.1 is implemented as a working system since March 1997. It uses coded orthogonal frequency division multiplexing (COFDM) as modulation scheme.

In DVB-T three modes are present and are named as 2k, 4k and 8k. Each mode is having different number of sub-carriers and is different in symbol length. The terrestrial network operator can choose one of the two modes of operation [4][5]:

- 2k mode: suitable for single transmitter operations and small single frequency networks (SFN) with limited transmitter distances. It employs 1705 carriers.
- 8k mode: suitable for both single transmitter operations and small and large SFN. It employs 6817 carriers.

Existing DVB-T modes produce a transport capacity of 5 to 15 Mbps (1-3 Television programs) suitable for mobile receivers.

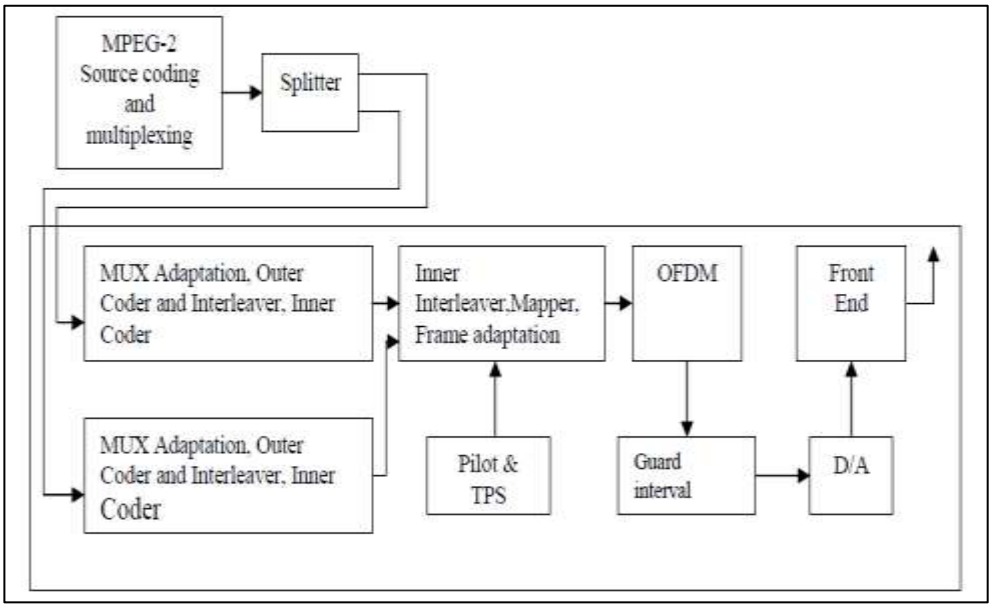

Fig. 1: Terrestrial Digital Video Broadcasting system [4]

C. Channel Models

The profile of received signal can be obtained from that of the transmitted signal if we have a channel model. The estimation of the channel is done using the following three channel models namely AWGN, Rayleigh and Rician.

1) Additive White Gaussian Noise Channel

In AWGN channel [6] transmitted signal gets disturbed by a simple additive white Gaussian noise process. An AWGN channel is typically described by quantities such as SNR per sample and this is the actual input parameter to the AWGN function. This model does not account for fading, frequency selectivity, interference, non-linearity or dispersion. The mathematical expression in received signal that passed through the AWGN channel is

$$\mathrm{r(t)} = s(t) + n(t) \qquad (1)$$

Where r(t) is the baseband received signal, s(t) is transmitted signal and n(t) is background noise.

2) Raleigh Channel

Rayleigh channel [7] is used when there is no direct path between transmitter and receiver. If there is no line of site then the constructive and destructive nature of multipath signal in flat fading can be approximated by Rayleigh Distribution. The channel is time variant due to the motion of the mobile terminal, but we will assume that the channel impulse response is constant during one OFDM symbol. The frequency non-selective and slow Rayleigh fading channel can be approximated into a multiplicative factor of the transmitted signal. Therefore, with the noise, the received signal can be expressed as

$$\mathrm{r(t)} = s(t)c(t) + n(t) \qquad (2)$$

where r(t) is the baseband received signal, c(t) denotes the multiplicative fading distortion and its envelope has a Rayleigh distribution, s(t) is the transmitted baseband signal and n(t) is the noise.

3) Rician Channel

Rician Fading [6] occurs when there is a line of sight (LOS) as well as the non-LOS path in between the transmitter and receiver. Rician channel model is a stochastic model (non-deterministic model) for radio propagation anomaly caused by partial cancellation of a radio signal by itself the signal arrives at the receiver by several different paths multipath interference and at least one of the paths is changing. Rician Fading channel can be defined using two parameters: *K a*nd Ω, and mathematical expression are given in (3) and (4) where *K* is called the Rice Factor [7]. Rice factor, *K* is the ratio between the power in the direct path to the power in the other, scattered, paths and Ω is the total power from both paths and acts as a scaling factor to the distribution. The received signal amplitude not considering the power R is then Rice distributed with parameters:

$$v^2 = \frac{\mathrm{K}}{1+\mathrm{K}^2}\Omega \qquad (3)$$

$$\sigma^2 = \frac{\Omega}{2(1+\mathrm{K})} \qquad (4)$$

II. PROPOSED WORK

In this work we have proposed performance analysis of OFDM based DVB-T system in terms of various parameters over AWGN, Rayleigh and Rician environments [8][9][10]. This work is based on the 2k mode of the DVB-T standard [4][5] intended for mobile reception of digital Television.

A. OFDM Simulation Model

The simulation of OFDM based DVB-T system using AWGN, Rayleigh and Rician channels with input image, audio and/or video is carried out for 2k mode of the DVB-T standard.

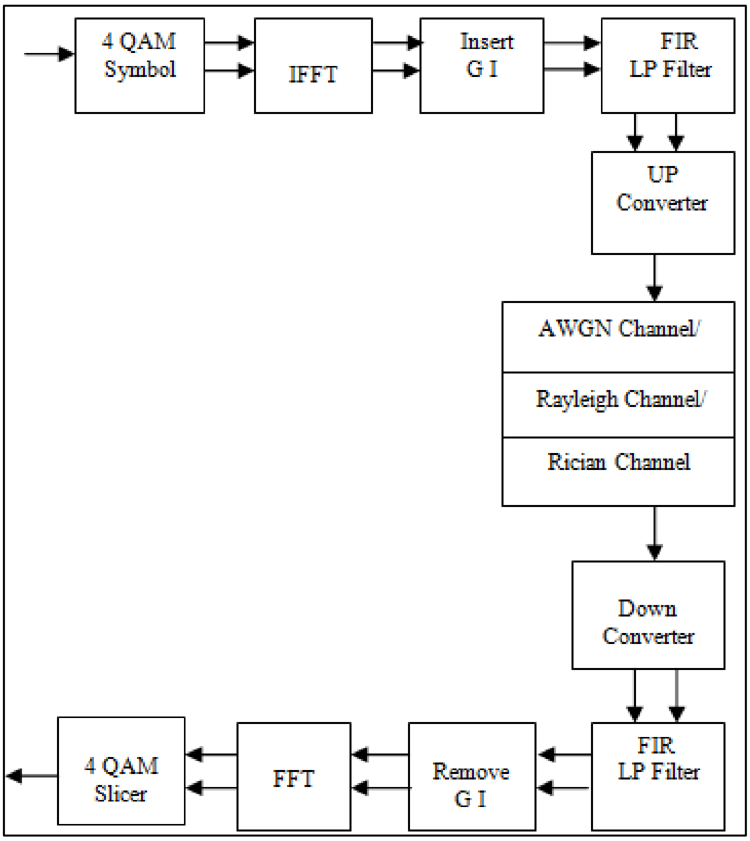

Fig. 2: Block diagram of the simulation model

DVB-T 2K mode carriers are transmitted over AWGN, Rician and Rayleigh channel, and the received signal is thus corrupted. The corrupted signal is then manipulated in terms of different values of SNR (ranging from 0dB to 40dB) and 4 QAM modulation scheme is selected to assess the performance of the designed OFDM system by finding their Bit Error rate for different values of SNR. The basic block diagram of OFDM transmitter and receiver used for MATLAB (Matrix lab) simulation is shown Fig.2. The parameters of the system viz. channel, input data, and channel type are varied and tested. Four main criteria are used for channel modeling to assess the performance of the OFDM system, they are: tolerance to multipath delay spread, peak power clipping, channel noise and time synchronization errors. The parameters varied in the simulations are given below.

1) Input: image, audio and video inputs are used to simulate.
2) The SNR of input is varied from 0 dB to 40 dB in steps of 5dB.

The inputs are collected from different sources. Images used in the simulation are the standard images which are popular with the image processing community. In case of audio transmission, one of the authors recorded five speeches of different durations. The wave format of recoding is used to obtain audio data. In order to have variable bit rate five video files are collected from different resources.

The steps involved in the generation and reception of an OFDM signal, more precisely the signal used in the 2k mode of the DVB-T standard, will concentrate only on the blocks labeled in OFDM generation and reception block diagram as shown in Fig.3 and Fig.4. The output of each of the block is indicated in rectangular boxes with appropriate names**.** In the Section III the observed outputs for a particular simulation are shown graphically.

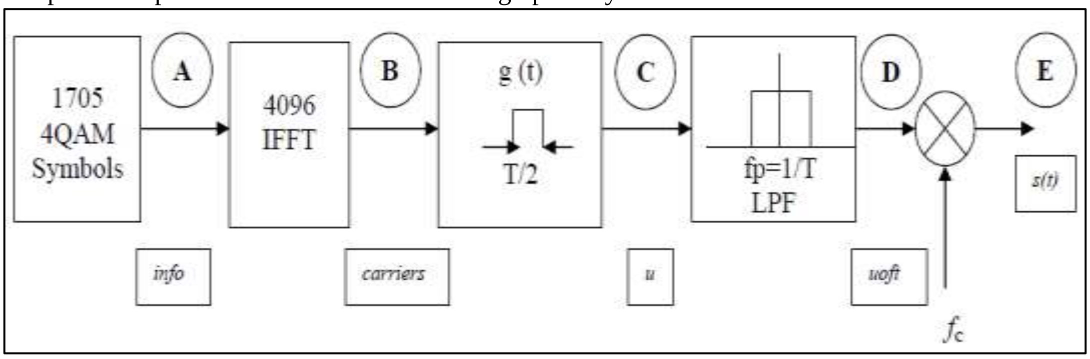

Fig. 3: OFDM symbol generation block diagram [8]

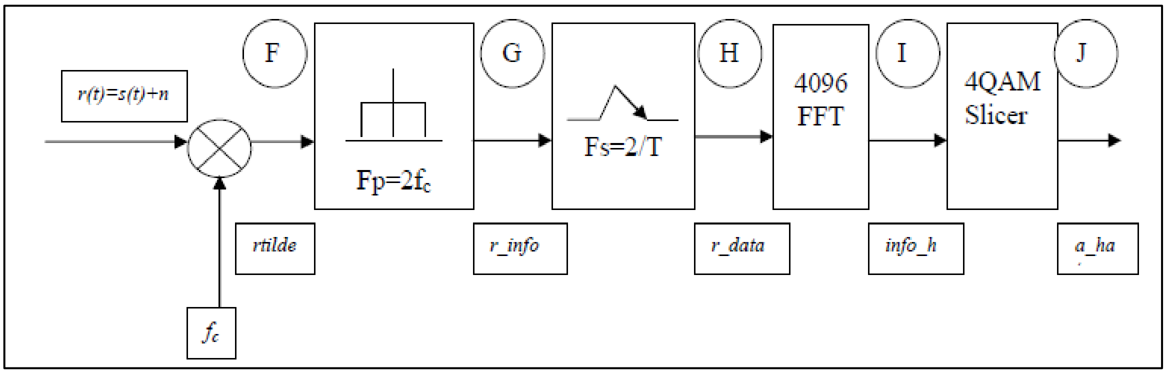

Fig. 4: an OFDM receiver [8]

Since the OFDM simulation pertains to DVB-T 2k mode, the detailed specifications are shown in Table 1. This standard uses 1705 carriers with an OFDM symbol period of 224 µs. The OFDM is implemented using IFFT/FFT algorithms. Then subsequent up-conversion gives the real signal s (t) centered on the radio frequency transmit carrier frequency f_c.

B. FFT Implementation

The OFDM spectrum is centered on carrier $f_{c.}$ Since the DVB-T has a range of 7.61 MHz, the sub-carrier 1 is located at a frequency of 7.61/2 MHz to the left of the carrier and sub-carrier 1705 is located 7.61/2 MHz to the right of the carrier.

The centering can achieve by using a 2N-IFFT with an elementary period of T/2. The OFDM symbol duration T_u is specified considering a 2048-IFFT (N=2048); thus we will use a 4096-IFFT. In order to efficiently compute IFFT/FFT, a 4096 point IFFT/FFT vector is used. A maximum of 4096 subcarriers can be used in the system. In our case, the DVB-T has a length of 1705 and hence OFDM needs only 1705 subcarriers. Therefore, we add 4096-1705 = 2391 zeros to the QAM modulated signal to achieve over-sampling.

Parameters	2K mode
Elementary period T	7/64µs
Number of carriers K	1705
Value of carrier number	K_{min} = 0 K_{max} = 1704
useful OFDM symbol period T_u	224 µs
Spacing between carriers K_{min} and K_{max} (K-1)/T_u	7.61MHz
FFT/FFT length	F_S = 4096
Simulation period	Rs = $4f_c$
Carrier frequency	f_c=q/T
Carrier spacing 1/T_u	4464Hz
Allowed guard interval (G I) Δ/T_u	1/4 1/8 1/16 1/32
Duration of symbol part T_u	2048xT 224µs
Duration of guard interval Δ	512xT 256xT 56 µs 28µs 128xT 64xT 14 µs 7 µs
Total OFDM symbol period (duration) T_s= Δ+T_u	2560xT 2304xT 280 µs 252µs 2176xT 2112xT 238µs 231µs

Table 1: DVB-T 2k mode specifications [4]

III. RESULTS AND DISCUSSIONS

Here, we represent the performance of OFDM based DVB-T system for 2k mode (Table 1) in terms SNR, and BER under AWGN, Rayleigh and Rician with input image, audio and/or video. Five samples each for image, speech and video are used in the simulation to account the variations present due to compression techniques used and averages out the simulation limitation to a larger extent. Fig.6 through to Fig.9 shows the relevant outputs obtained for different inputs and their average performances.

A. Simulation of Images

Standard images with tagged image file format (TIFF) compression are used to obtain the performance of the DVB-T under different channels. The received constellation of QAM for five different images viz Lena, Barbara, baboon, cameraman and house images are shown in Fig.6. Fig.7 shows the average BER performance of the DVB-T for Lena, Barbara, baboon, cameraman and house image transmission.

Fig. 5: Lena Image as input

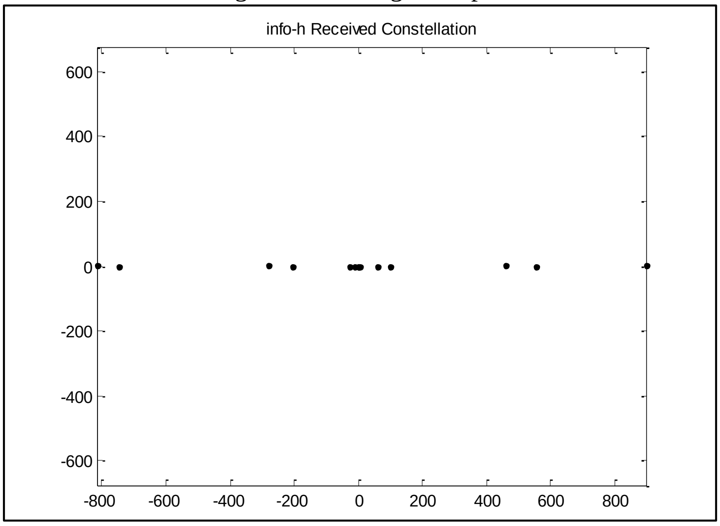

Fig. 6: Received constellation

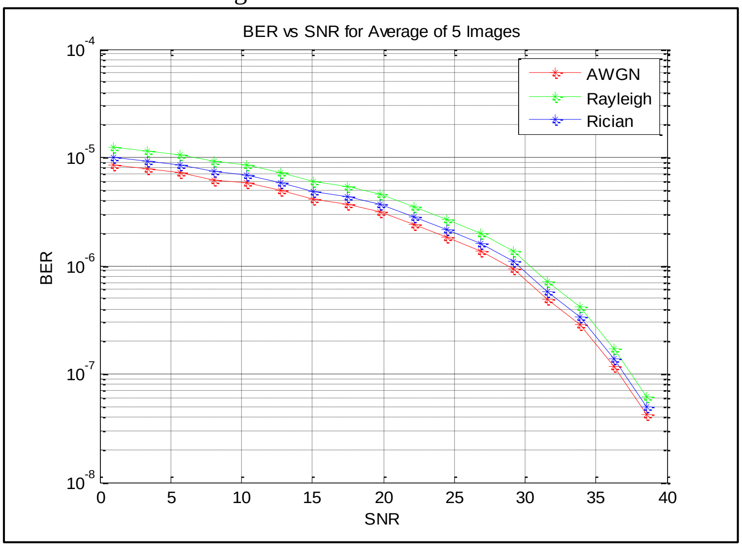

Fig.7: Average BER versus SNR performance for lena, barbara, baboon, cameraman and house image

B. Simulation of Audio signals

In this simulation the five different audio signals such as 'aaj','chaal','chal','chamak' and 'chouk' are used to obtain the performance of the DVB-T under different channel models. Fig.8 shows the average BER performance of the DVB-T for `Aaj', 'chaal', 'chal', 'chamak' and 'chouk' audios transmission.

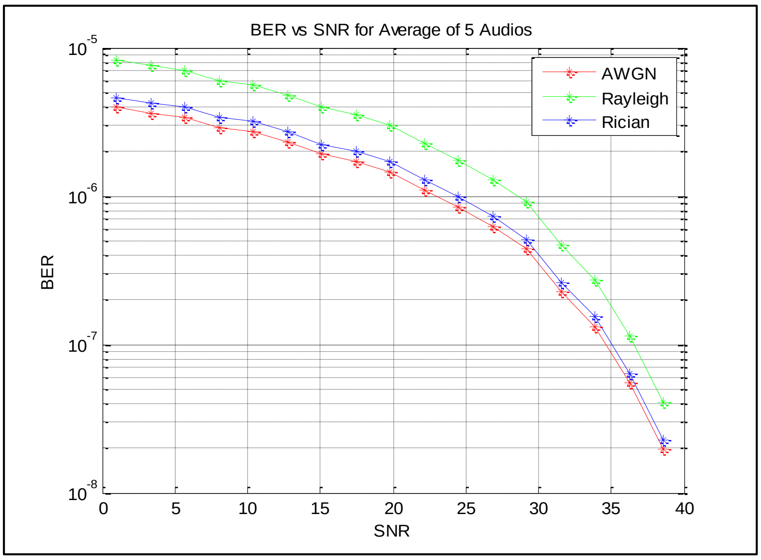

Fig. 8: Average of BER versus SNR performance for 'Aaj', 'chaal''chal', 'chamak' and 'chouk' audios.

C. Simulation of Video Signals

In this simulation cat video, scenevideoclip, vipcolorsegmentation video, vipfly video and viplane video signals are used to obtain the performance of the DVB-T under different channel models. Typical values of the SNR for AWGN channel are between 5 and 30. When the value is closer to zero this produces a high BER on the other hand, if the value of SNR increases we will get better BER. The relationship between SNR and BER is inversely proportional. An enhanced SNR indicates reduced error rate and an improved performance. Fig.9 shows the average BER performance of the DVB-T for cat video, scenevideoclip, vipcolorsegmentation video, vipfly video and viplane video transmission.

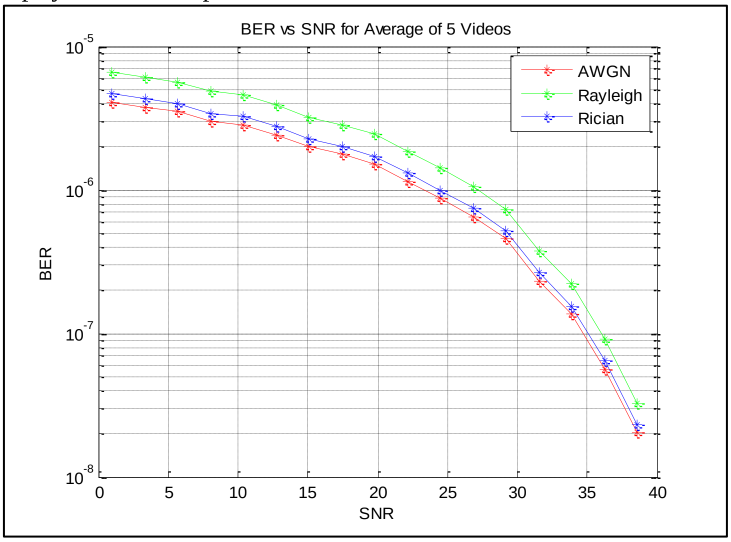

Fig. 9: Average BER versus SNR performance for cat video, scenevideoclip, vipcolorsegmentation video, vipfly video and viplane video

The Fig.7, Fig.8 and Fig.9 validate the above point in terms of different channels. It can be observed that there is clear difference in comparison between three channels in terms of BER and SNR comparison for same modulation technique. The type of channel also influences the performance of OFDM. The overall performance of each of the channels, as expected, improves with SNR. The type of channel also influences the performance of OFDM. The Fig.7, Fig.8 and Fig.9 presents a comparative plot between Rayleigh, Rician and AWGN channels for QAM type modulation.

D. Comments on the Channels Performance

From simulation results, we see that the BER performance evaluation of OFDM based DVB-T system over AWGN channel and Rayleigh & Rician channels. The AWGN channel out performs marginally over Rayleigh and Rician which can be attributed to the improvement in fading due to multiple reflection received at the receiver.

1) The performance of AWGN channel is the best of all channels as it has the lowest BER under QAM modulation scheme. The amount of noise occurs in the BER of this channel is quite slighter than fading channels.
2) The performance of Rayleigh fading channel is the worst of all channels as BER of this channel has been much affected by noise under QAM. It may be due to further fading of the signals due to multiple reflections.

3) The performance of Rician fading channel is worse than that of AWGN channel and better than that of Rayleigh fading channel. Because Rician fading channel has higher BER then AWGN channel and lower than Rayleigh fading channel.

IV. CONCLUSION AND FUTURE WORK

In this research work, it has been studied the performance of an OFDM based DVB-T system. A range of system performance results highlight the impact of AWGN and Rayleigh & Rician channels under QAM modulation techniques. The performance of AWGN channel is the best of all channels as it has the lowest BER under QAM. The amount of noise occurs in the BER of this channel is quite slighter than fading channels.

Peak Average Power Ratio (PAPR) performance of DVB-T is proposed to be evaluated and suggest a scheme to improve performance. We propose to incorporate adaptability of PAPR to the channel needs to improve reception. The techniques like clipping and coding are popularly used by the researchers. We propose techniques like PTS (partial transmit sequence) and SLM (selected mapping) to be used to develop the DVB-T 2k mode.

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