Performance Analysis of OFDM Based DVB-T over Diverse Wireless Communication Channels

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Abstract

Presently in communication areas Digital Video Broad casting in terrestrial (DVB-T) is playing an important role for the transmission of digital video worldwide. Orthogonal frequency division multiplexing (OFDM) is becoming a popular modulation scheme for wireless communication systems to achieve high throughput, high data capacity, spectral efficiency and resilience to multipath. In OFDM the data transmission is parallel by splitting high rate serial data into low rate sub-streams. Then each sub-stream is modulated on separate sub-carriers. By splitting the data into parallel streams the data rate is reduces, which results in an increase in the length of symbol duration. The robustness to channel impairments and high data rates make OFDM an efficient scheme for the DVB-T applications. In this paper we have investigated the bit error rate (BER) performance analysis of the OFDM based DVB-T 2k mode using different modulation schemes in different transmission channels.

Keywords: BER, DVB-T, OFDM, transmission channel, spectral efficiency.

1. Introduction

In the world of communication the main goal is to provide high quality of service to the end users and can be achieved by the high data rate information transmission along with high capacity and reliability. Due to the growth of the digital televisions and a huge demand for the mobile TV series in the market Digital Video Broadcasting (DVB-T) systems are became a popular standard for providing digital television and broadcasting digital data world-wide.

Terrestrial broadcasting means transmission of TV channels via transmitters which are usually done by high transmitting sites. Recently there was only analog broadcasting which means one transmitter operating on some frequency and transmitting only one TV channel. But Digital video broadcasting (DVB-T) means broadcasting a package of TV channels called multiplex. This kind of broadcasting has many advantages: efficient usage of radio frequency spectrum, better sound and picture quality, possibility of additional services, possibility of high-definition picture (HDTV) and wide screen picture format to mention just the most important properties.

So due to the recent advances in digital technology and efficient compression of audio and video signals the digital broadcasting has become feasible for the present broadcasting system. This altogether has brought to the conclusion that one radio frequency channel can be used to transmit more than one TV program. Digital video broadcasting (DVB-T) means broadcasting a multiplex, a package of various services.

The radiated signal power and spectrum utilization are the two important communication resources for the design of any communication system. Because of the low radiated power and efficient utilization of the spectrum DVB-T systems are the popular standards. But the measure problem that the wireless communication suffers is the multipath propagation delay, fading and Inter Symbol Interference (ISI) due to the frequency selectivity of the channel at the receiver side as a result of which the poor performance and high probability of errors degrades the efficiency of the system. So to overcome these limitations some advance techniques like channel coding and equalization are implemented in the system. But the equalization and different coding schemes introduces delays in the system and the cost of hardware is also very high so it is not feasible to the system as high data rate and the required reliability is very high.

For the above mentioned issues an effective scheme called as Orthogonal Frequency Division Multiplexing (OFDM) is implemented in the wireless communication systems where the high bit rate over the frequency selective channel is guaranteed to some extent. OFDM is a multi-carrier modulation technique where data symbols modulate a sub-carrier which is taken from orthogonally separated sub-carriers with a separation of fk within each sub-carrier. The spectra of sub-carrier are overlapped in case of OFDM and the sub-carriers are also orthogonal to each other so by which the bandwidth utilization is more efficient with comparing other modulation schemes. To avoid Inter Carrier Interference (ICI) and maintain the orthogonality, separation between the sub-carriers should be fk. OFDM can be used to convert a frequency selective channel into a parallel collection of frequency flat sub-channels by choosing the sub-carrier spacing properly in accordance with the channel coherence bandwidth. OFDM uses the discrete Fourier transform (DFT), fast Fourier transform (FFT) with a cyclic prefix that makes the system free from interference.

OFDM also allows single frequency networks (SFN, Single Frequency Networks), where different transmitters send the same signal simultaneously and two or more transmitters carrying the same data operating on the same frequency. In such cases the signals from each transmitter in the SFN needs to be accurately time-aligned, which is done by the information in the stream and timing at each transmitter. The length of the Guard Interval can be chosen between 1/4, 1/8, 1/16 and 1/32 of the of the symbol length. It is a tradeoff between data rate and SFN capability.

At receiver, the signals from different transmitters can be constructive combined to generate a diversity gain. The fact that bandwidth is subdivided in different sub channels, and all of them are modulated at low transmission velocity, makes symbol delay large enough to erase delay spread effects. The cyclic prefix (also denominated guard period) between consecutive OFDM symbols reduces a diversity gain. The fact that bandwidth is subdivided in different sub channels, and all of them are modulated at low transmission velocity, makes symbol delay large enough to erase delay spread effects. The cyclic prefix (also denominated guard period) between consecutive OFDM symbols reduces intersymbolic interference (ISI) effects.

OFDM also has some drawbacks. Because OFDM divides a given spectral allotment into many narrow subcarriers each with inherently small carrier spacing to preserve the orthogonality between subcarriers. OFDM systems also have a high peak-to-average power ratio or crest-factor, which may require a large amplifier power back- off and a large number of bits in the analog-to-digital (A/D) and digital-to-analog (D/A) designs.

In this paper a comparison is made by using the different M-QAM modulation schemes in Digital Video Broadcasting Terrestrial (DVB-T) standard specifications using 2K mode. Here we compare bit error rate (BER) for different SNR values and the corrupted signal is then manipulated in terms of different values of SNR (ranging from 0db to 16dB). The Performance of the OFDM systems with M-QAM constellations are derived for additive white Gaussian noise (AWGN) and Rayleigh channels and are analyzed to find the better modulation scheme.

Following this introduction the remaining part of the paper is organized as follows. Section II introduces the DVB-T system standard. Section III gives the details of the modeling and simulation of the system using MATLAB. Then, simulation results have been discussed in Section IV. Finally, Section V provides the conclusions.

2. **Digital Video Broadcasting**

Digital Video Broadcast- Terrestrial can be abbreviated as DVB-T is the DVB European-based consortium standard for the broadcast transmission of digital terrestrial television. In DVB three modes are present named as 2k, 4k and 8k. Each modes having different number of sub-carriers and different in symbol length. For the modeling of a DVB-T system OFDM is implemented by taking different value of parameters for different modes. A simplified block diagram of the European DVB-T standard is shown in the Figure 1 below.

Signals in the discrete form are generated by the matlab codes and these signals are mapped by the QAM technique. To translate the signal in time domain from the frequency domain IFFT is performed and the guard intervals are inserted in between them to avoid the interference. For the transmission the in phase and Quadrature phase information from IFFT is converted to analog form using Digital to Analog Converter. By passing data impulse through reconstruction filter it is achieved and is equivalent to the convolution of the data impulse with rectangular pulse of width equal to sampling period. The cutoff frequency of reconstruction filter is equal to one half of the sampling rate.

After passing the signal from filter an UP conversion is performed. For transmission, Analog signal after digital to analog conversion is up converted by multiplying it with the carrier frequency by which it is converted to a very high frequency. Then the signal after up conversion is transmitted to the channels (Additive white Gaussian Noise and Rayleigh) where the data is corrupted by the noise.

The inverse process is performed to retrieve the signal back to the original shape at the receiver side, thus down conversion, filtering, removal of guard interval, FFT and QAM slicing is performed respectively. The signal is down converted and passed through the low pass filter. After that the guard intervals that are removed and then by the fast Fourier transform the time domain signals are converted in to frequency domain and demodulated by the QAM slicing. The characteristics and the noise adding capability of the channels are different so by considering the issues this paper proposes a solution so that the problems can be eliminated in practical scenario of video broadcasting in order to perform optimized transmission and reception.
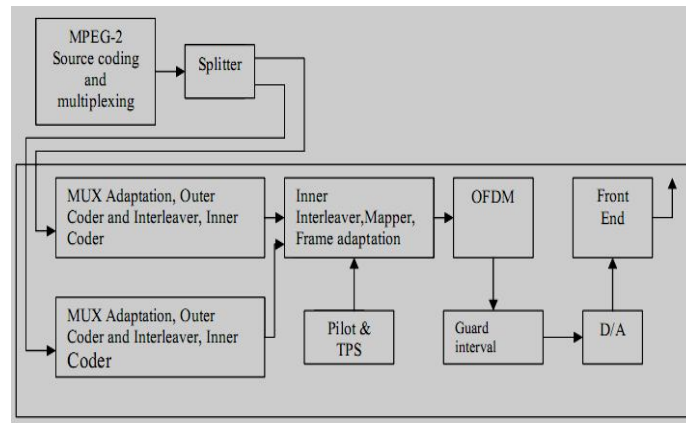

Figure 1: Block diagram of the DVB-T transmitter.

The parameters used for the 2k mode is presented in Table-I below. Total duration of the symbol consists of useful period and Guard interval given by (1) below:

$$T_t = T_u + T_g \tag{1}$$

Where T_t =Total symbol period, T_u=Useful period=224μsec (2k mode) and T_g = Guard interval

For the different modes the subcarriers and the symbol duration is different with guard intervals. The following Table-II shows the different parameters for the different modes for the DVB-T systems.

3. The Simulation Model

Figure 2 presents the complete block diagram of the DVB-T system which was modeled and simulated by us in MATLAB environment. The main objective of this simulation study is to evaluate the BER performance of the DVB-T system using different M-QAM modulation techniques. The simulation parameters are obtained from Table I and Table II for 2k mode. A frame based processing is used in this simulation model. The system model was exposed to AWGN channel and Rayleigh fading channel for performance analysis. Since DVB-T (2K mode) can support 1705 carriers simultaneously. Number of data bits that can be transmitted over these carriers depends on the order of Modulation scheme.

During the process of simulation and analysis of the DVB_T based OFDM systems some of the basic concepts should be taken care. The OFDM symbols transmitted, is first

4. DVB-T 2K Parameters

PARAMETER	2K mode			
Elementary period T	7/64µs			
Number of carriers K	1705			
Value of K_{min}	0			
Value of Kmax	1704			
Duration Tu	224 µs			
Carrier spacing 1/Tu	4464 Hz			
Spacing between kmin and Kmax(K-1)/Tu	7.61 MHz			
Allowed guard interval	¼	1/8	1/16	1/32
Duration of Tu	224µs			
Duration of guard interval	56µs	28 µs	14 µs	7 µs
Symbol Duration	280µs	252µs	238µs	231µs

5. Data Carriers

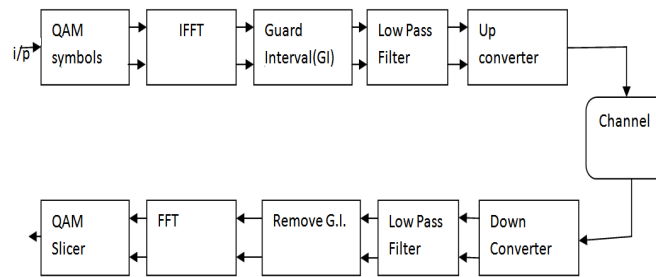| MODES	DATA SUB CARRIERS
1K	853
2K	1705
4K	3409
8K	6913
16K	13921
32K	27841

Figure 2: Block diagram of the simulated model.

Organized in frames which have the duration T_f. Four frames constitutes one super frame and 1 super frame can accommodate 272 symbols [i.e. 1 frame = 68 symbols]. Each symbol has a duration of TS [TS=GI + TU], where GI is guard interval and TU is useful symbol period. For different modes, number of IFFT/ FFT length for the DVB-T standards is kept as 4096 for 2k mode and 8192 for 8k mode.

5.1 QAM Modulation

Quadrature Amplitude Modulation (QAM) is a form of modulation that is widely used for the modulating data signals onto a carrier used for radio communications. QAM is a signal in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations.

Quadrature amplitude modulation, QAM, when used for digital transmission for radio communications applications is able to carry higher data rates than ordinary amplitude modulated schemes and phase modulated schemes. As compared with phase shift keying the number of points at which the signal can rest, i.e. the number of points on the constellation is indicated in the modulation format description, i.e. 16QAM uses a 16 point constellation. Again by using higher order modulation formats, i.e. more points on the constellation, it is possible to transmit more bits per symbol. But the points are closer together and they are therefore more susceptible to noise and data errors

5.2 IFFT

The IFFT in OFDM is used to convert the signal from frequency domain to time domain the idea in OFDM generation, the transmitter accepts a stream of data and converts them to symbols using modulation technique, for example QPSK or QAM. Then the S/P converter takes the output 4 symbols and mixes each one with one of the subcarrier 4 sine waves then adds the 4 sine. Then the S/P conversion stage the data represent as a function of frequency. After addition stage stage the data represent as a function of time. This conversion is actually a well-known computational technique called the inverse Fast Fourier transform.FFT is implemented in the transmitter and IFFT is in the receiver.

In OFDM, by the IFFT the data symbol-modulated spectrum on the transmitter end, gives a N-point time multi-carrier signal. This would imply that there is N

frequency in the spectrum. If the subcarrier spacing is Δf, then the subcarriers are 0, Δf, 2Δf ... (N-1).Δf.

5.3 Guard Interval
The purpose of the guard interval is to introduce immunity propagation delays, echoes and reflections. By dividing the input data stream in to Ns subcarriers, the symbol duration is made Ns times smaller, which also reduces the relative multipath delay spread, relative to symbol time, by the same factor. To eliminate inter symbol interference completely; a guard time is introduced for each OFDM symbol. The guard time is chosen larger than the expected delay spread, such that multipath components from one symbol cannot interfere with the next symbol.

This ensures that delayed replicas of the OFDM symbol always have an integer number of cycles within the FFT interval, as long as the delay is smaller than the guard time. As result, multipath signals with delays smaller than the guard time cannot cause ICI.

6. . Simulation Result and Analysis
The simulations performed by the using the M- QAM modulation techniques like 16QAM, 32QAM and 256QAM in the AWGN channel and Rayleigh channels where the SNR variation is observed. The Figure 3 through Figure 5 presented below shows the graphs of bit error rate vs. SNR for different M-QAM modulation schemes in AWGN channel.

From these figures it can be readily evaluated that as go towards higher modulation techniques we require a higher transmitted signal power to achieve the same performance.

The modulation scheme used in Figure 1 is 16 QAM, so the number of bits representing one symbol will be 4, in the 32QAM it is 5 and in 256QAM it is 8. From the above simulation results it is found that as the modulation scheme increases, the chances for the error is also increased because of the reason of decreasing period of symbol and high data rate. This leads to problems like ISI.
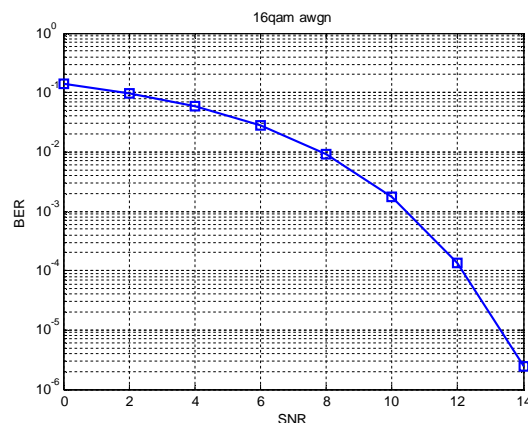

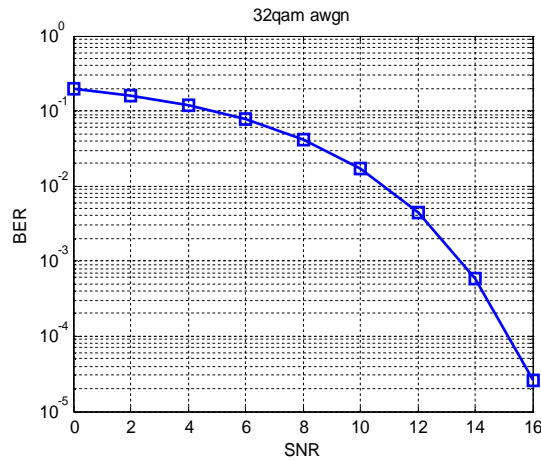**Figure 3**: BER curve for 16QAM over AWGN channel.

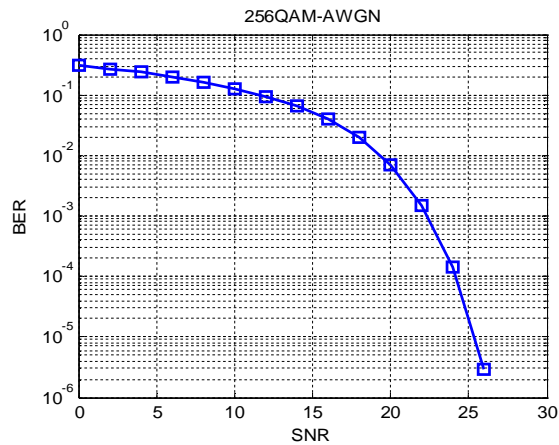**Figure 4:** BER curve for 32QAM over AWGN channel.

Figure 5: BER curve for 256QAM over AWGN channel.

It can be evaluated that for the same AWGN channel for a BER of 10^{-4} a SNR of 12 dB is required in case of a 16QAM modulation and the SNR for 32QAM is 15 dB and finally a SNR value of 23.5 dB is required if the modulation scheme is 256QAM.

After investigating the BER performance evaluation in the AWGN channel we now present the performance evaluation for the Rayleigh channel for the different MQAM modulation schemes. Furthermore in terms of bit error rate, the maximum path affected by the noise is again the Rayleigh due to the fact that been discussed that the Rayleigh path has high multipath fading by which the ratio of error was high in Rayleigh channel.

Figure 6 presented below shows the graphs of bit error rate vs. SNR for different BPSK, QPSK, and 16QAM over a Rayleigh fading channel.
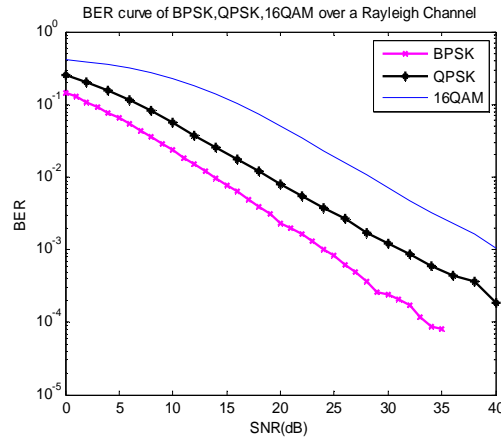
Figure 6: BER curves of BPSK, QPSK, and 16QAM over a Rayleigh channel.

For higher order modulation scheme more SNR is required to achieve same BER as possible with low SNR for small value of M. Figure 7 presented below shows the graphs of bit error rate vs. SNR for 16QAM,32QAM and 256QAM over a Rayleigh fading channel.

In the Rayleigh channel for 16QAM a SNR of 40 dB is required for BER of 10^{-3} and in case of 32QAM a SNR value of 47 dB is required .Then for the higher modulation scheme of 256QAM a SNR more than 60 dB is required. Depending upon the number of bits per symbol the data rate also different for the different modulation schemes.

Comparison of data rates over different modulation schemes is presented in Table-III below:
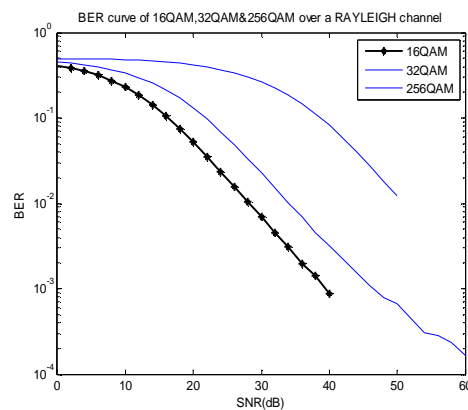

Figure 7: BER curve of 16QAM, 32QAM, 256QAM over a Rayleigh channel.

7. Data Rate of QAM Modulation

Comparison of 32QAM with 16QAM in terms of bandwidth efficiency vs. SNR shows that 32QAM is 25% more bandwidth efficient then 16QAM. This efficiency in bandwidth comes at a price of sending data at 7 dB more SNR.

Modulation	Bits/Symbol	Data Rate (Mbps)
4-QAM	2	40
16-QAM	4	80
32-QAM	5	100
64-QAM	6	120

7.1 Performance evaluation of 2K Mode

The simulation is done for the DVB-T for the 2k mode where the performance of the DVB-T system is analyzed by the standards provided by the European Telecommunication system. From the simulation we know that the 2k mode is having the less probability of noise .And with it also if we are adapting higher order modulation schemes then the error is increased that the performance of the system is less. So for the higher order modulation some error control coding must have to use to get batter performance over the noisy channels. By increasing the modulation scheme yields the high probability of error and produce undesirable signal as the receiver is unable to make the decision correctly.

We can see that 256-QAM is more bandwidth efficient schemes for video transmission but at the same time it is less power efficient as constellation points are close in 64-QAM so we need to transmit symbols with more power to achieve low BER. But however for low M-order modulation schemes like 4 QA M, 16QAM these are more power efficient schemes as compared with higher order modulation schemes (like 64-QAM) but at the same time these are bandwidth less efficient than 64-QAM and 32-QA 64-QAM and 32-QAM, as less number of bits can be packed per symbol.

Conclusion

For high data rate communication systems with high data capacity, high spectral efficiency, and robust to interference and multipath effects OFDM is ideal for the high data applications. In this paper a comparison of the performance of OFDM for Terrestrial Digital Video Broadcasting Systems for different order QAM schemes were analyzed. Due to the use of Fast Fourier Transform techniques to implement modulation and demodulation functions it is computationally efficient. The M-QAM modulation scheme is more bandwidth efficient schemes for video transmission but at the same time it is less power efficient as the constellation points are close in 64-QAM. To achieve low BER we need to transmit symbols with more power. But for low M-order modulation schemes like 4 QAM, 16QAM these are more power efficient schemes as compared with higher order modulation schemes but at the same time these are bandwidth less efficient than 64-QAM and 32-QAM, as less number of bits per symbol.

Depending upon the simulation results which were obtained verify that the Rayleigh channel is the worst channel and most affected multipath environment due to its non line of sight communication and delay characteristics.

Finally it is concluded that the schemes which have higher data rates are more prone to error than the schemes with lower data rates, the performance of different schemes can be made acceptable by increasing the SNR but only to a certain limited

extent. If we increase the data rate the bit error rate also increases even the SNR value failed to effect the reception at very high data rates like 64 QAM or 256 QAM. So the effective modulation scheme found for the DVB-T is 16 QAM for 2k mode.

This work can be successfully extended with effect of concatenated coding with Reed Solomon and Turbo coding.

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