Performance Estimation of DVB-T under Co-Channel Interference for Deployment of DVB-T in National Border Regions

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ABSTRACT

In solving the frequency planning problem for Digital Video Broadcasting Terrestrial (DVB-T), it is assumed that all geographical neighboring services interfere with each other. The neighbors then have to agree on the terms of how to dissolve this situation and eliminate the frequency collisions by sacrificing for some of the frequencies. ITU is helping member countries to coordinate each other's Digital Video Broadcasting services in order to reduce the Co-Channel-Interference (CCI) but it can't be fully implemented in many parts of the world, especially in the conflict regions.

This thesis focuses on the bit error rate analysis for DVB-T systems subject to heavy co-channel interference. The tolerance of DVB-T system with Co-Channel-Interference (CCI) in AWGN and Rician fading channels has been investigated. The four scenarios presented in this thesis are as follow: 1-the evaluation of BER for DVB-T system consideration with AWGN channel and the DVB-T system with Rician channel. 2- The evaluation BER of DVB-T system after adding co-channel interference. 3- Comparing the BER with CCI and without CCI. 4- Determine tolerance of DVB-T system with different channels when the various levels of co-channel interference happen. The BER of the system has been checked in low, normal and high SNR by MATLAB simulation and it is expected that the system works properly in normal SNR but the CCI prevents this. The system worked properly while SNR is increased. The DVB-T system with AWGN channel has less BER than the system with Rician. One of the important parts of this thesis is related to tolerance of the system while encountering with the different levels of co-channel interference. As it is expected, the system with AWGN channel can tolerate the heavy CCI but the system with Rician can handle it when S/CCI=20dB (signal to co-channel interference). In this case increasing the SNR was not useful. As a result, the OFDM and AWGN and Rician channels are employed plus RS encoder for correcting the errors.

Keywords: Digital Video Broadcasting, OFDM, AWGN Channel, Rician Fading Channel, Co-Channel Interference

ÖZ

Karasal Dijital Video Yayını için, frekans planlanlama problemlerinin çözümünde, bütün coğrafik komşu servisler birbirleri ile girişim halinde oldukları kabul edilmiştir. Komşu servisler bu durumun nasıl çözüleceği konusunda hemfikir olmak zorundadır ve bazı frekansları feda ederek frekans çarpışmaları elimine edilmiştir. Yardımcı kanal girişimlerini azaltmak için, ITU üye ülkelererin, birbirleri ile Karasal Dijital Video Yayını konusunda koordine olmaları konusunda yardımcı olmaktadır. Fakat dünyanın bir çok kısmında uygulanamamaktadır. Özellikle engebeli bölgelerde.

Bu araştırmanın odak nokası Karasal Dijital Video Yayını sistemlerinde ağırlıklı olarak yardımcı kanal elde etmek için kullanılan BER ve SNR'dır.Karasal Dijital Video Yayını sistemlerinin töleransı ile AWGN ve Rician zayıflama kanallarındaki yardımcı kanal girişimleri araştırılmıştır. Bu tezde bulunan dört senaryo şu şekilde sıralanmıştır; 1-Karasal Dijital Video Yayın sistemi ile AWGN kanal ve Karasal Dijital Video Yayın sistemi ile Rician kanallarının BER değerlendirmeleri yapılmıştır. 2-Yardımcı kanal girişimlerini ekledikten sonraki sistemlerin BER'i değerlendirilmiştir. 3-Yardımcı kanal girişimli ve yardımcı kanal girişimsiz olarak BER'ler karşılaştırılmıştır. 4-çeşitli seviyelerdeki yardımcı kanalların girişim yaptıkları zaman, Karasal Dijital Video Yayın sistemlerindeki farklı kanalların tolerelerinin tanımlanması . BER sistemleri düşük, Normal ve yüksek SNR'ları matlab simulasyonları ile kontrol edildi ve sistemin SNRda düzenli bir şekilde çalışacağı beklenirdi fakat yardımcı kanal girişimi bunu korudu.SNR arttığı zaman sistem düzenli olarak çalışmştır.AWGN kanal ile çalışan Karasal Dijital Video Yayın sistemleri Rician ile çalışandan daha az BERe sahiptir. Bu tezdaki en önemli kısımlardan biri, farklı seviyelerdeki yardımcı kalan girişimlerinin birbirleri ile karşılaştıklarındaki toleranslardı.Beklenildiği gibi AWGN kanalı ağırlıklı yardımcı kanal girişiminde toleranslı olabilmektedir, fakat Rician ile olan sistemlerde sadece normal yardımcı kanal girişimi işlenmiştir.Bu durumda SNR'ı arttırmak faydalı olmayacaktır.Sonuç olarak OFDM, AWGN ve Rician kanalları ve buna ek olarak hataları düzeltmek için RS kodlayıcılar kullanıldı.

Anahtar Kelimeler: Dijital Video Yayını, OFDM, AWGN Kanal, Rician Solma Kanal, Co-Kanal Girişim

To my mom and dad for their love, support and encouragement which got me through

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$H_{L,K}$	Channel Frequency Response
f_d	Doppler Effect
K	Number of Active Carriers in OFDM Symbol
N_0	Single-Sided Noise Power Spectral Density (Watts/Hertz)
T_u	Symbol Duration
α	Constellation Ratio which Determines the QAM Constellation for the Modulation for Hierarchical
Δf	OFDM Carrier Spacing
AWGN	Additive White Gaussian Noise
BCH	Bose-Chaudhuri Hochquenghem Multiple Error Code
BER	Bit Error Rate
BSS	Broadcast Satellite Service
CATV	Community Antenna Television
CCI	Co-Channel Interference
COFDM	Coded Orthogonal Frequency Division Multiplexing
CP	Cycle Prefix
DFT	Discrete Fourier Transform
DTH	Direct to Home
DVB	Digital Video Broadcasting
DVB-C	Digital Video Broadcasting Cable
DVB-C2	Digital Video Broadcasting Cable Second Generation

DVB-H	Digital Video Broadcasting Handheld
DVB-S	Digital Video Broadcasting Satellite
DVB-S2	Digital Video Broadcasting Satellite Second Generation
DVB-T	Digital Video Broadcasting Terrestrial
DVB-T2	Digital Video Broadcasting Terrestrial Second Generation
Eb/No	Energy Per Bit to Noise Power Spectral Density Ratio
ELG	European Lunching Group
ES	European Standard
ETSI	European Telecommunication Standard Institute
FSS	Fixed Satellite Service
GI	Guard Interval
HP	High Priority
ICI	Inter Carrier Interference
IDFT	Inverse Discrete Fourier Transform
ISI	Inter Symbol Interference
LP	Low Priority
OFDM	Orthogonal Frequency Division Multiplexing
PDP	Power Delay Profile
QPSK	Quadrature Amplitude Modulation
RS	Reed-Solomon
S/CCI	Signal over Co-Channel Interference
SFN	Single Frequency Network
SMATV	Small Master Antenna Television
SNR	Signal to Noise Ratio

SPI	Synchronous Parallel Interface
STB	Set Top Box
TR	Technical Report
UHF	Ultra High Frequency
16APSK	16-ary Amplitude Phase Shift Keying
32APSK	32-ary Amplitude Phase Shift Keying
16QAM	16-ary Quadrature Amplitude Modulation
32QAM	32-ary Quadrature Amplitude Modulation
64QAM	64-ary Quadrature Amplitude Modulation

Chapter 1

INTRODUCTION

1.1 The Aim of Study

In solving the frequency planning problem in case of Digital Video Broadcasting Terrestrial (DVB-T), it is assumed that all services which located in the same geographical area interfere with each other. For solving these kinds of problem neighbors have to make a decision to dissolve this situation and eliminate the frequency collisions by sacrificing for some of the frequencies. For this reason countries decided to follow ITU directives which are helping member countries to coordinate each other's Digital Video Broadcasting services for reducing the Co-Channel-Interference (CCI). It should be mentioned that it can't be fully implemented in many parts of the world, especially in the conflict regions. The DVB-T system is one of the most important communication systems which are used by the vast number of the countries. Sometimes this system does not perform well enough and there are different reasons for this such as undesirably high level of Co-Channel-Interference (CCI). CCI reduces the efficiency of whole system significantly. CCI causes smaller problems for DVB-T over a multipath fading channel when there is a direct path or Line-Of-Sight (LOS), but these problems are more significant for DVB-T systems without a LOS. The main aim of this thesis is to investigate the effects of CCI on the tolerance of DVB-T over AWGN channel and Rician channel. The capacity and performance of MIMO with CCI have been investigated in [1]- [2]. Song, Y., & Blostein, S. D have been researched in treatment of capacity with different number of interferences by simulations [3]. Ye illustrated the unequal-power interference has better performance than equal-power interference [4]. The capacity optimum signaling with interference was studied by Blum [5]. The closed form expressions of the mean, variance, moment generating function were obtained by Kang [6, 7]. Laine studied the effects of CCI on multi carrier system such as OFDM [8]. The capacity subject of multipath antenna system has been investigated widely with the concentration on MIMO system without interference [9]. Under these circumstances, there are many difficulties such as selecting the proper value for the LOS relative to the multipath components (*K*-factor) in Rician fading channel for obtaining acceptable performance or even to realize the impact of Reed-Solomon encoder, convolution interleaver and convolution encoder on BER [10]. For this aim the basic OFDM system is designed and different position has been analyzed.

1.2 Background

DVB-T is a short form of Digital Video Broadcasting-Terrestrial. The DVB European based group for the broadcasting transmission of digital terrestrial television that issued for the first time in 1997 and firstly showed in UK in 1998 [11]. This certain system spreads compressed digital audio, digital video and another data in MPEG transport stream by using coded OFDM (orthogonal frequency division multiplexing) modulation. The ACTS digital television standard is used in USA which standardizes NTSC format transmission [11]. DVB standard is used in Europe which allows Normal PAL resolution with some audio formats [11]. DVB is applicable for different systems such as satellite, terrestrial and the follow cable TV [11]. Different types of DVB are used for distinction of data signal modulation, frequency bands and even error correction used. These kinds of DVB and options are used in countries all around the world and broadcasters.

The following steps have to be done for transmitting digital TV: analog audio/video, digitization-MPEG, compression-digital or multiplexing-ready for transmission-modulation to analog Carrier [11].

Two different steps have to be followed for converting digital to analog for receiving analog signal the first one is demodulation of analog carrier-Error and the second one is correction-de-multiplexing. In Euro-zone the signal requirement level is at least well below the analog requirements, so the spreading power is much less than on analog part. Co-Channel Interference can significantly disrupt the ability of communicates in the commercial communication and military system [11]. For detecting the aim signals the receiver must be able to recognize the interference. This interference produces different problems for estimating unknown parameters essentially for signal detection.

Frame timing or boundary is one of the important parameters which should be accurate before communication starts. The ideal receiver should perform the time estimation before phase estimation and carrier-frequency. Hence, during timing estimation, carrier-frequency, phase offsets between transmitters and the receiver are unknown [11]. On the other hand the Co-Channel Interference in cellular frequency-reuse scheme more impairs the timing estimation. The additional space degrees of freedom are used to mitigate unpleasant effect of CCI during data detection and timing estimation if compound antennas are employed at the receiver. In any case, a synchronization way which is strong to phase offsets and frequency and CCI is highly desirable.

1.3 Organization of Thesis

This thesis included five chapters. In the second chapter, current digital video broadcasting systems will be introduced, in the next chapter some digital video channel modeling which used for this study will be explained and finally different simulation results will be presented in the Chapter 4.in Chapter 5 the conclusion will be explained.

Chapter 2

DVB BROADCASTING AND OFDM SIGNALING

2.1 The DVB Project Team

The Digital Video Broadcasting (DVB) was created by approximately 300 companies for the aim of joining all digital media [12]. At the beginning of The 80s until 1990 the digital technology started to become recognizable for public, but it was too difficult to bring Digital Television Broadcasting to home because more capital have to be allocated for this aim and that level of investment was not adequate so the aim of having public DVB was not applicable [12]. During 1991 man companies such as broadcasters, equipment manufactures decided to unify efforts. The European Lunching Group (ELG) worked for this aim and tried to obtain the attention of European media grouped for both privet and public, and the consumer electronics companies. They establish the rules to take expand Digital TV. The ELG signed the Memorandum of Understanding (MOU) in 1993 showing an intended common line action [13]. At this moment the ELG was renamed as Digital Video Broadcasting by itself. The DVB project`s target were to developed terrestrial broadcasting, digital cable And satellite and improve and standardization of this. The first level was that the System may contain combination of image, audio and multimedia. This work turned out ETSI standards for the error correction, physical layer and transport for each distribution medium. The standards have been common for all companies and they do not allow changing something except they do not have any choice from this moment [14].

2.1.1 Important Standard of DVB-Project

The MPEG stream has been used by DVB project to improve standards and transport for all kind of systems. The standard are recognized with initials which identify the region such as DVB-S which is the requirement for the first generation form of Digital satellite system and DVB-S2 which is for the second generation satellite system.

At the beginning of 1990`s the European market decided to develop satellite and Cable standards before these standards for terrestrial and the reason behind of this decision was that they believe they could extend satellite and cable faster than terrestrial. Digital satellite broadcasting was developed in 1993. This system worked by using QPSK which presents channel coding and error protection. Channel Plus in France was the first company which used this system in 1995.

The DVB-C was set up in 1994 for digital cable which concentrate to use 64QAM. Extension of DVB-T (Digital Video Broadcasting) was a tough job and different reasons exist for that such as presence of noise in environment or requirement of bandwidth for this system as a result this system needs OFDM which works in two modes:

The first one is 2 carriers + QAM modulation: It is sufficient when the receiver is in movement (Doppler Effect).

The second one is 8 carriers + QAM modulation: For more multipath protection In 1998 Sweden and UK started to DVB broadcasts.

2.1.2 Execution of the Standards in Countries

Extending the DVB-Project was very successful in 1997. The DVB grew to be the mark of digital television all around the world. Different countries like Japan and USA used digital satellite and also used DVB-S. The DVB-T system was slower than of both DVB-C and DVB-S and it was too difficult to be used in more countries but it is predicted that more than 100 million receiver are used this system all around the world. 10 countries changed analogue to digital during 2009 to use DVB terrestrial.

The action of switching from analogue to digital for some countries in past decade is presented below [14]

In 2006: Luxemburg, Netherland

In 2007: Finland, Andorra, Sweden and Switzerland

In 2008: Belgium, Germany

In 2009: Denmark, Norway and United States

In 2010: Spain and Latvia will be switched off in June

In 2011: Japan, Canada

In 2012: United Kingdom

Or even this switching predicted for China in 2015.

Two million households were not ready for transition when in United State the swap occurred, for this reason some analogue TV signal stopped after original data.

In 2007: Brazil, in most cities in Brazil the switched was happened in the year.

In 2009: Indonesia, 90% of households use Digital TV

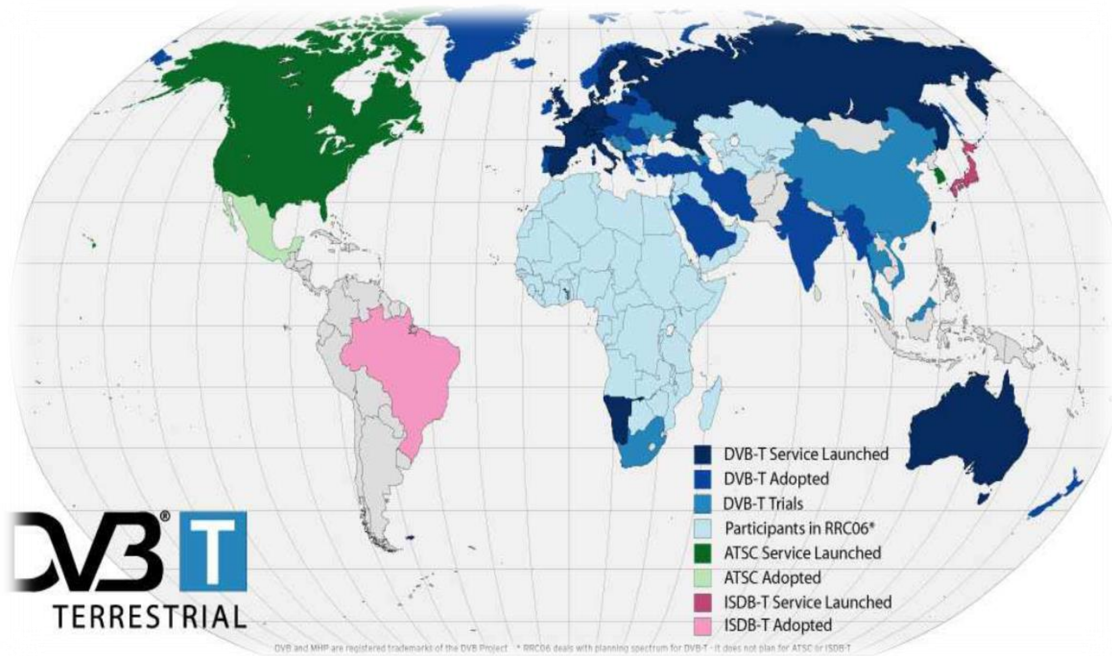

Figure 2.1: DVB-T Standard Adoption in the World [15]

2.1.3 Recent Research

In fact, all of the DVB system is recently developed like DVB-S2. This is going to use in all future European Digital satellite multiplexer. The receiver will be prepared with both systems: DVB-S and DVB-S2.

In case of digital TV on mobile devices, a terrestrial system was developed which named DVB-H. This system presents flexible and strong digital system hand-held terminals. Time slicing and 4K OFDM mode creates this certain system. Every digital broadcasting system is able to deliver multimedia also to television programs. The DVB scheme has extended a transport system for this kind of data.

2.2 ETSI DVB Standards

European Telecommunication Standard Institute (ETSI) generates worldwide applicable standards for information and communication technology (ICT) consists of fixed, mobile, radio, converged, broadcast and internet technologies. It should be mentioned that they are free organization and distinguished by European Union as European standards organization. 600 different companies from 60 countries across the 5 continents create ETSI. ETSI tries to develop the standards around the world which are useful for network telecommunication and other services. The ETSI gives the telecommunication`s standards for network around the world. Its specifications help the international cooperation in this area. The EU regulates and operates these standards with other organizations. All the specifications and technical information about the standards is collected in the following documents [16]:

1) ETSI Technical Specification (TS): This document contains the technical specification about the standards. The TS is agreed by the ETSI technical committee proposed in the document. This document is used in DVB-Project to Create specification of their specification.

2) Technical report (TR): All the guideline for developing the standards specifications are gathered in this document. ETSI technical committee approves this technical report.

3) ETSI Standard (ES): The whole ETSI group joined each and approved this certain document and this is not produced by only technical group. This certain document is more precise than TR and TS.

4) ETSI Guide

5) European Standard (European Norm (EN)): The largest number hierarchical publications agreed by the European organization standardization.

6) Special Report (SR).

7) DVD Bluebooks: Technical specification or commercial documents which are processes of standardization.

2.2.1 Basic Standards for Digital TV

Satellite, cable and terrestrial transmitters can transmit a digital TV. Specific standards have been introduced for them which make possible transmission and the reception depending of stage. Figure 2.2 shows how to use these systems.

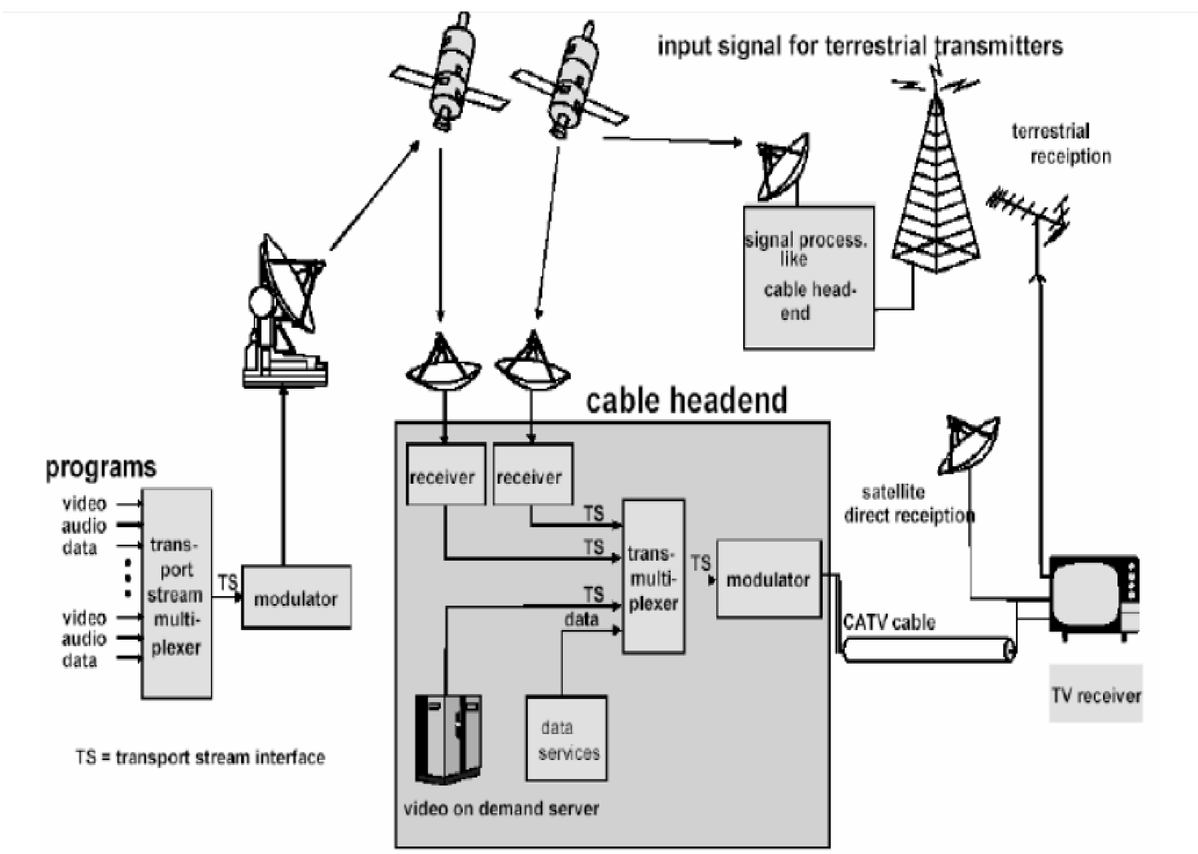

Figure 2.2: Scheme of Standard DVB-T, DVB-C, DVB-T [8]

2.3 Terrestrial Digital Video Broadcasting (DVB-T)

DVB-T (Digital Video Broadcasting terrestrial) also is called digital TV system, specified in ETSI standard (European Telecommunication Standard Institute) EN300 744. The DVB-T is designed to permit optimum use of available frequency Spectrum with a structure of broadcast enough data to provide numerous services: Multiplex of up to 8 video plan in 8MHZ bandwidth (the place that only one analogue program was broadcasting), multi-language stereo/surround, etc.

The DVB-T network is consisted of different part such as program coder, multiplexer, SFN network adaptor, COFDM (Coded Orthogonal Frequency Division Multiplexer) modulator, up convertor and transmitter. It identifies all the process to use terrestrial transmission Channels: Channel coding and modulation [17].

2.3.1 Block Scheme

The Figure 2.3 indicates the block diagram of DVB-T system. By looking more precise in this diagram it can be seen that after transmission signal the channel coding uses Forward Error Correction (FEC). Furthermore the Modulation scheme indicates the transmission type OFDM (Orthogonal frequency Division multiplex), combination of this with multi-carrier and error corrections the COFDM transmission type.

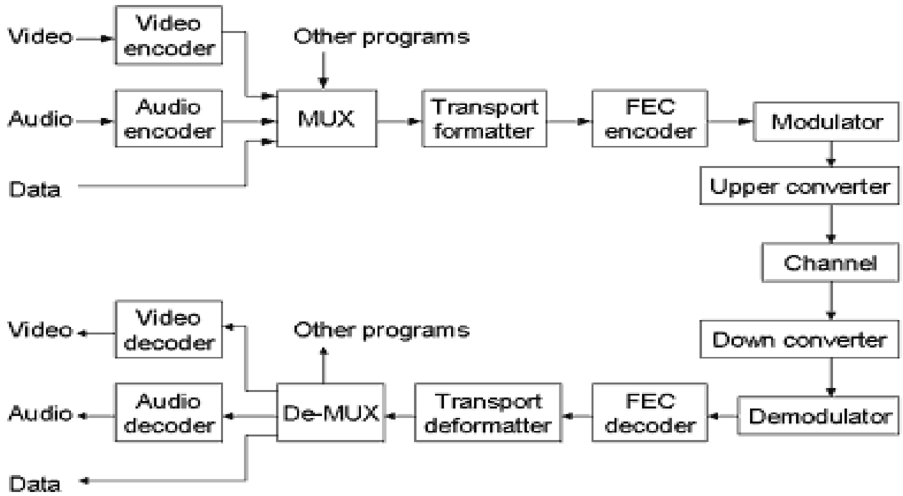

Figure 2.3: Block Diagram of DVB-T Standard [13]

The DVB-T system has diverse configurations which will be listed below:

1) Transmission modes
2) Modulation schemes
3) Codification rates
4) Guard interval
5) Channel modulation.

These options have restriction depend on the system.

2.3.2 Source Coding

The standard MPEG-2 Transport stream (TS) produces the input signal. This transport stream is created by an adaption of MPEG-2 by fallowing ISO/IEC 13818, which multiplexes different programs and the information service (IS) (ETD 300468).

The main reason for extension of the ISO/IEC 13818 was to give necessary reply to find codification of the images which are not fixed and show movement with associate sound for applications like television broadcasting, digital storage. Usage of this certain requirement means that video can be transmitted and can be used as bits and received over the existing and future networks, on the other hand the actual and coming broadcasting channel can distribute the video.

In this part of Chapter 2 for better understanding of the source coding a figure will be presented which shows the scheme of source coding. A program (program stream) multiplexes the compressed audio and video and data stream, which are joined In a transport multiplex to shape MPEG-2 transport stream. This stream is transmitted and received by Set Top Box (STB). In this will stay a certain number of television channels, radio and interactive services as programming schedule at the same time.

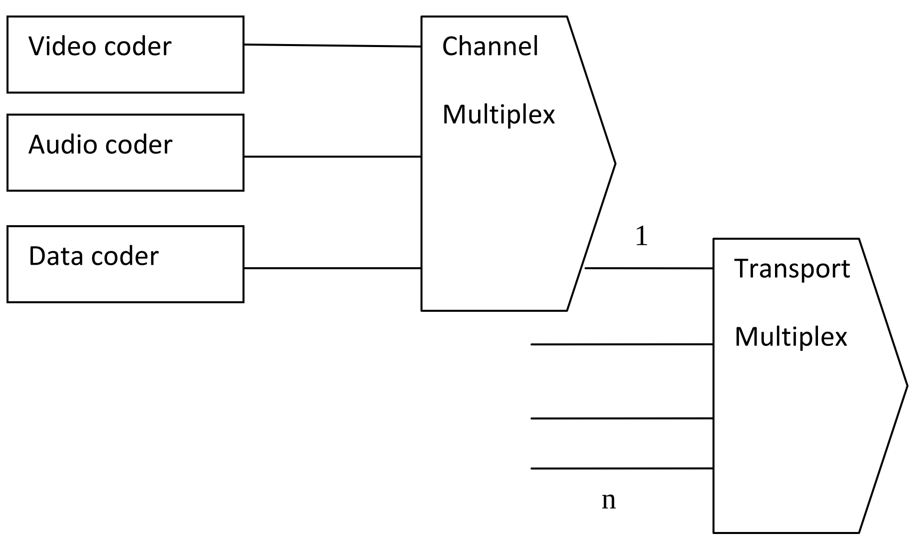

Figure 2.4: Source Coding [13]

2.3.3 Channel Coding

The codification of the signal adds enough redundancy and defense to allow the correction of errors and for making the signal stronger. After passing the signal through the channel, The Forward Error Correction (FEC) will be used. The main duty of codification is to allow recovering the transported information by sub carriers which are cancelled due to the selective fading of the radio channel.

The modulation scheme is described by channel coding which is used in transmission: A multi carrier modulation OFDM. There are two different kinds of codes to encrypt the radio channel: The first one is Block Codes: the block code contains vast number of error-correcting codes which totally gathered in a certain block. There are vast examples of block codes such as Reed Solomon, parity the second one is Convolution Codes: Sometimes codes depend not only on output but also depends on previous entries. The bitrates of the output signal normally is the double or triple of the input bitrates. Both block codes and convolution codes are useful in DVB-T system. Not only channel coding are used for keeping away from mistakes in existing blocks at the demodulator but also interleaving techniques is used for this exact aim.

The DVB-T system has different options which introduced it as a flexible system. These options can be listed below:

a) 2 Transmission modes: 2K (1705 carriers), 8K (6817 carriers).

b) 3 Modulation schemes: QPSK, 16QAM, 64QAM.

c) 5 Relations internal coding error protection: 1/2, 2/3, 3/4, 5/6, 7/8.

d) 4 Lengths for guard interval: 1/4, 1/8, 1/16, 1/32.

e) Non-hierarchical or hierarchical channel modulation with different values of Alpha parameters.

The OFDM techniques are permitted to work in both small and big areas with Single Frequency Networks (SFN). It means that this system can receive the signal when different programs from various operator transmitters are radiating in the same frequency. The DVB-T standard describes a physical layer and data link of a distribution system. The terminals work with physical layer through synchronies parallel interface (SPI) and Synchronous Serial Interface (SSI) or Asynchronous Serial Interface (ASI). The MPEG-2 transport stream transmits all the data with restriction giving by (DVB-MPEG).

2.4 Reed-Solomon Error Correction

A Reed-Solomon is a technique which allows the receiver to detect and correct the errors which generally occur in transmission. The errors can be the extra information which adds to the signal. There are different positions which Reed-Solomon can be used the most important of them is DVB-T system [13].

2.4.1 Classification of Reed-Solomon Code

There are lots of groups of error correcting codes. One of the important of these is block codes and convolution codes. A Reed-Solomon code is block code which means that a transmitted message is divided into the distinct blocks of data. Each block has balance protection information added to it to appearance a self-contained code word. In addition, as commonly used a systematic code which means that the encoding process does not change the message symbols and protection symbols are added as a separate section of block. The RS code can be explained as (N, K) code, the K is a number of information in the messages and the n is block length in symbols. In addition,

$$N \leq 2^m\text{-}1 \tag{2.1}$$

The number of bit in the symbol is m. when the up equation is not equal the shortened form will come [14].

$$\text{If (n-}k\text{) is even} \quad \Rightarrow \quad t = (n\text{-}k)/2 \tag{2.2}$$

$$\text{If (}n\text{-}k\text{) is odd} \quad \Rightarrow \quad t = (n\text{-}k\text{-}1)/2 \tag{2.3}$$

T symbols can correct the errors in the block.

2.4.2 The Code for DVB-T

A Reed-Solomon code (255,239, t=8) belongs to DVB-T system, shortened to form a (204,188, t=8) code, so that the 188 bits will extended with 16 bits for producing 204 symbols coded block length. The Galois field consists of 256 elements (m=8) the polynomial is represented [14]:

$$\alpha_7 x^7+\alpha_6 x^6+\alpha_5 x^5+\alpha_4 x^4+\alpha_3 x^3+\alpha_2 x^2+\alpha_1 x^1+\alpha_0 x^0 \tag{2.4}$$

2.5 Digital Video Broadcasting by Satellite (DVB-S)

The DVB-S system (Digital Video Broadcasting by Satellite) improves the transmission`s capacity for Digital TV programs by satellite with using compression video techniques which is based on the standard MPEG-2 for the multiplexer and source coding. There is only one different between this standard and the other one proposed by the DVB (Cable and terrestrial broadcast), which is in the kind of modulation and the channel code used. For transmissions by satellite the QPSK (Quadrature Phase Shift

Keying) code with a variable binary which fluctuate between 18.4 and48.4 Mbps will be taken [18].

2.5.1 Block of Transmission

The below figure show the DVB-S transmitters. It should be mentioned that the most important process in this certain transmission are:

a) Multiplex and framework (based on the multiplexed transport of the standard MPEG).

b) Randomization of the signal

c) Advanced security against errors (external and internal coders).

d) Process of interleave

e) Digital of modulation

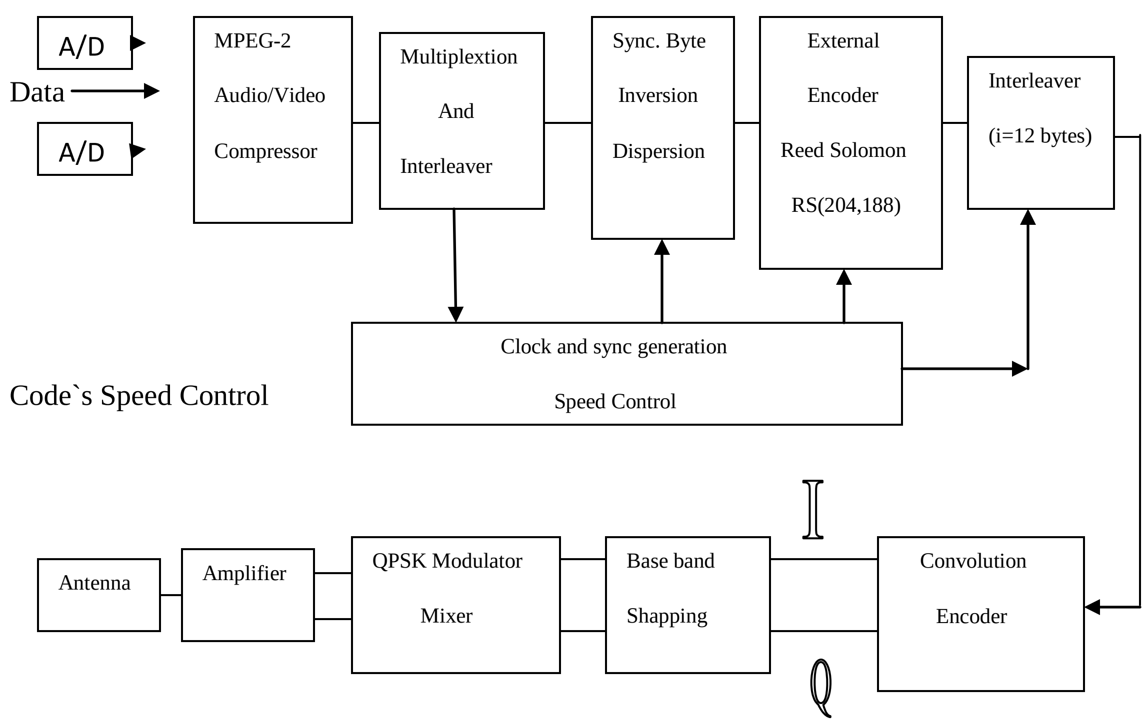

Figure 2.5: Block of DVB-S Standard Transmission [8]

2.5.2 Source Coding and Multiplex

The DVB-S is working based on the coding of sound and image by using MPEG-2. The frame's structure of the transport by MPEG (TS) includes packages with a fixed length, which permits to bring a vast number video services, data and audio in the same plot. The whole package has length of 188 bytes, 1 byte for synchronism, headline has 3 bytes and 184 bytes of data. Protection against errors will be added in later process.

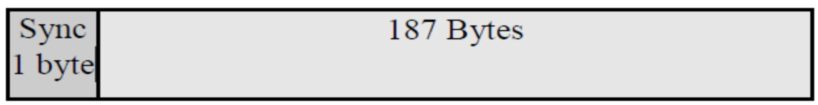

Figure 2.6: MPEG-2 Transport MUX Packet [13]

2.5.3 Channel Encoding and Modulation

The target of channel encoding and modulation is to adjust the signal in base band to the characteristics of the satellite channel. The DTH (Direct to Home) services affected by the power limitation so in such way, protection against the interference and noise is necessary duty, as well as effective use of the spectrum. Due to this uses, this system needs a modulation QPSK relevant to a strong correction block of errors based on the concatenation of convolution codes and the reed Solomon code.

After obtaining transport block, the bits will employ in accident way to facilitate the recovery of clock signal in the receiver. Later the Reed-Solomon`s code RS(204,188), codes the packages, which adds 16 bytes of redundancy to each package, providing a size of correction of 8 random errors.

The convolution interleaving is used for increasing the capacity of correction based on approach of Forny. Convoluted flexible codes used for coding again which depend on the requirements of the service.

2.5.4 Block of Reception

Fundamentally, the major function of digital receiver (IRD-Integrated Receiver Decoder) is to decompress the signal of Digital audio and video received in MPEG-2 format. While these signals have been demodulated and possible errors have been eliminated these signals will be capable to be visualized in a receiver of standard TV. The satellite sends a Radio Frequency (RF) signal which picked up in the center of the satellite dish, the signal has to be stronger through an amplifier of low noise and finally should be moved to the first intermediate frequency. The RF band frequency carrier has to take the value between 10.7 and 12.5 GHz (Ku-Band) for the broad cast of digital satellite. When the band of the first resulting is between 950 and 2150 MHz, another external stage which named LNB (Low Noise Block) will happen. Two possible widths exist for each channel [2]: The first one is FSS Band (Fixed Satellite Service):26 MHz and 22 M symbols/s and the second one is BSS Band (Broadcast Satellite Service): 36 MHz and 26Msymbols/s. The tuner takes the signal from the LNB and brings it to IF (Intermediate Frequency) of 479.5 MHz, in this time the signal is ready for demodulated. In such way, the signal which is obtained again from audio, video and data compressed and multiplexed in the emitter can be chosen up in base band for backing to their process, which includes in the inverse operations performing in the transmitter and the correction of possible errors.

All of these techniques provide an output data especially without errors with rates of error in the bit (BER) upper to 10^{-10}, and the BER approximately 7×10^{-4}Or better in presence in burst errors.

2.5.5 The Evolution of DVB-S and DVB-S2

When the DVB-S standard developed, the new standard will introduce which is named DVB-S2 (DVB-S2 version2). It is famous as a powerful error correction by using of two cascade encoders, the low density parity check and BCH code which supplies a capacity near to the fixed by Shannon's limit.

For improving the flexibility of system and to permit different binary speeds this system uses:

1) Different modulation schemes such as QPSK, 8PSK, 16APSK and 32APSK

2) Roll of taxes: 0.2, 0.25, 0.35

3) Flexible inflow.

The system is able to change the parameters of the physical layer based on the channel conditions applying an adaptive coding and modulation (ACM). By using the new standard named DVB-S2 the capacity of the system increased by approximately 30% in compare to the last version is named DVB-S standard.

2.6. Digital Video Broadcasting by Cable (DVB-C)

DVB-C is created based on European Standard ETS 300 429 (Digital Broadcasting system for TV, sound and data services, Framing structure, Channel coding and modulation for cable system). This system is applicable for any cable network which describes the modulation of the packages by MPEG-2 by cable. The most important features of this certain standard are having suitable signal to noise ratio and the little space available in frequencies which can be used and even the rebounds and non-lineal distortion. This certain standard deals with various kind of modulation such as 16-QAM, 32-QAM,…, 256-QAM.

2.6.1 Characteristics

By looking more precisely on the presented figure it can be understand that the transmitter block is shaped by different parts:

1) Random process: Three is an input signal on the base band, according to the transport layer MPEG-2. Later, this one is submitted to random process, in order to form spectrum to spread this one uniformly. In this way the spectrum was not centering in spectral periodic stripes that would emphasize the interference between symbols. The random process is type of set-reset.

2) Codification: After applying random process, for detection of error in the receiver Reed-Solomon codification will be used. The Reed-Solomon which used in standard ETS 300 429 can detect 8 incorrect symbols.

3) Interleaver: The interleave convolution is applied when the packages are codified in order to segment and to spread the long blasts errors, to assist in later process the detection and change in reception. The mixture of the Reed-Solomon codification and the convoluted interleave permit the detection of 96 incorrect symbols (768bits).

4) Conversion Byte-Symbol: When the signal on the band base is prepared for transmission, this one goes into the conversion block from byte to symbol. The total

number of bits which are in one symbol depends on the number of symbols in the constellation.

5) Differential codification: A discrepancy codification is applied to the 2 bits of more weight, with the aim of capturing a constellation QAM invariant in rotation of π/2. By consideration of differential codification, by the change of two more important bits, the points of first quadrant of the constellation QAM cannot change those of the second, third or fourth quadrant.

6) Filtered: Before the modulation QAM, the signal I (In phase) and Q (Quadrant) are filtered for reducing the interference between symbols.

7) Modulation: After filtering the signal, it is modulated and sent it, the used constellation can be 16, 32, 64, 128, 256 symbols. The receiver does the reciprocal processes to obtain the signal MPEG-2 sent [1].

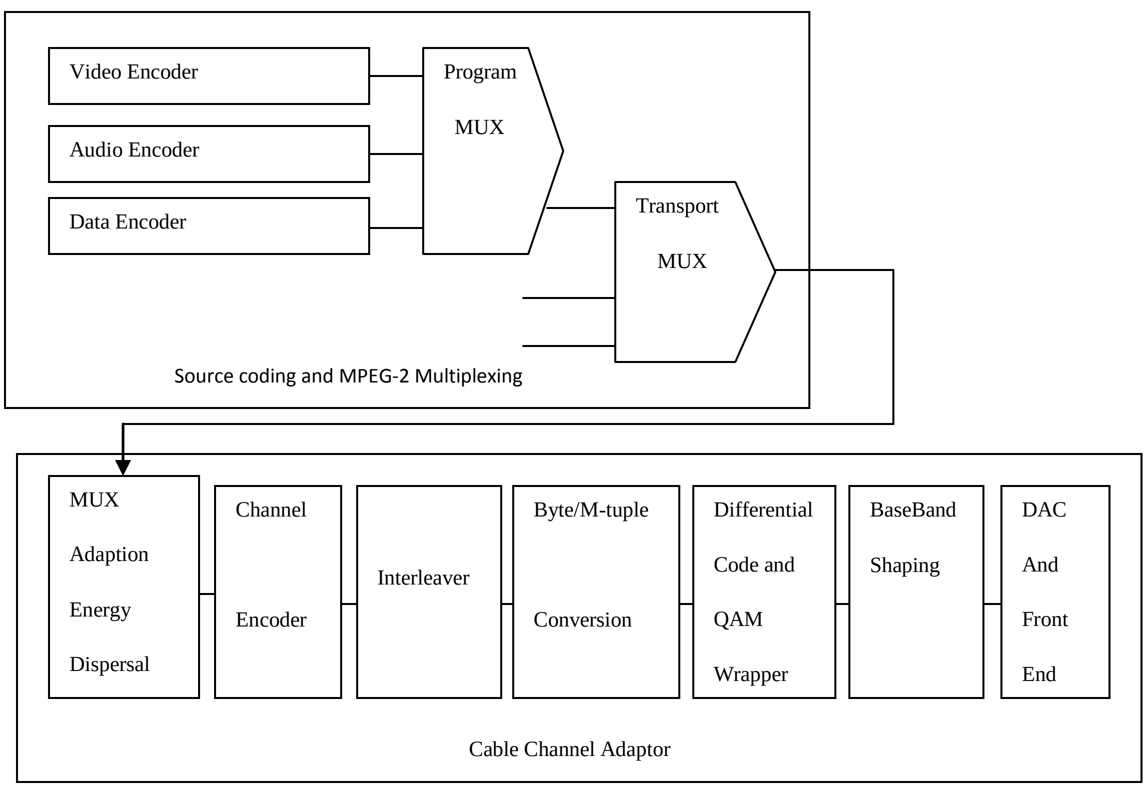

Figure 2.7: Blocks Diagram of DVB-C Transmission [19]

2.6.2 The Evolution of DVB-C and DVB-C2

The DVB-C2 standard is derivation between DVB-C and DVB-S. This standard is introduced as a standard which is used for Collective Antenna System (CATV) and TV network by cable. It can be used inside a building or even between various close buildings. The satellite can capture different signals and after this, the combination action will join signals and terrestrial TV. The SMATV system introduces the possibility to distribute the same resources for terrestrial reception or by satellite. In addition, it permits the adaption of the satellite signals to the specifications of the channel.

2.7 Concept of OFDM

The OFDM tries to divide bandwidth in to the some sub-channels. It can cause these certain narrow sub-channels can have flat fading. The characteristic of orthogonal sub-channels causes the OFDM has high spectral efficiency. Cyclic extension avoids Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) and makes the transmitter periodic, in addition the cycle extension is the forward part or copy of last part of each OFDM symbols [20].

2.7.1 Mathematical Descriptions of OFDM

By considering the data X_k(t) is modulated by a series of orthogonal sub-carriers. Considering it have Nsc sub-carriers.

$$S_n(t) = \sum_{k=0}^{N_{sc}} X_k\,(t) e^{j2\pi k \Delta f t} \tag{2.5}$$

Where: The sample frequency is 1/τ. T_u Is duration of one symbol Due to the equation (2.2) the N_{sc}samples are generated

$$T_u = N_{sc}.\tau \quad (2.6)$$

The wave form of data $X_k(t)$ can be rewritten as $X(k)$ if $X_k(t)$ is fixed value over symbol period the result can be shown by equation (2.3) which presented below

$$S_n(n\tau)=\sum_{k=0}^{N_{sc}} X_k\,(t)e^{j2\pi k\Delta f n t} \quad (2.7)$$

Equation (2.8) shows the normal form of inverse Fourier transform. By comparing it with equation (2.6) it can be mentioned that if equation (2.9) is true then equation (2.6) and equation (2.8) will be equivalent. Therefore, IDFT can be used to fulfillment the modulation of an OFDM system.

$$Y(n\tau) = \frac{1}{N_{sc}}\sum_{k=0}^{N_{sc}} Y(k)e^{j2\pi nk/N_{sc}} \quad (2.8)$$

Where

$$\Delta f = \frac{1}{N_{sc}\tau} \quad (2.9)$$

2.7.2 Guard Interval and Cyclic Extension

ISI and ICI are presented by transmission channel distortion make problem on the orthogonality of sub carrier in OFDM. It can be solved by adding an empty guard interval (GI) between two repeated symbols. The two consecutive symbols do not have interference to each other, if the length of GI is longer than spread channel response. But it can be harmful because the GI can destroy the orthogonality and presents ICI if the symbol boundary estimation does not accurately place the symbol. To avoid this problem, a mechanism is suggested to copy the last part of an OFDM symbol into the empty GI, which is named Cycle Prefix (CP) as illustrated in Figure 2.8. Cycle Prefix causes the sub-carrier signal has integral period, in addition it can keep orthogonality. In addition, adding CP to each OFDM symbol causes line convolution has the same value as circular convolution [21]

The l^{th}received OFDM symbol $r_{l,n}$ and its DFT $R_{l,k}$ are explained as:

$$R_{l,k}\text{=DFT }\{r_{l,n}\}\text{= DFT = }\{\text{IDFT}\{D_{l,k}\}\otimes h_{l,n}$$

$$\text{=DFT}\{\text{IDFT}\{D_{l,k}\}\}\text{.DFT}\{h_{l,n}\}\text{=}D_{l,k}.H_{l,k} \quad (2.10)$$

Because of the theory of circular convolution, the estimation of response channel can recover transmitted data$D_{l,k}$.

$$\widehat{D_{l,k}}\text{=}\frac{R_{l,k}}{\widehat{H_{l,k}}} \quad (2.11)$$

Where *n* is the simple index in a time domain, $h_{l,n}$ is the channel impulse response, *k* sub carrier index and $H_{l,k}$ is the channel frequency response.

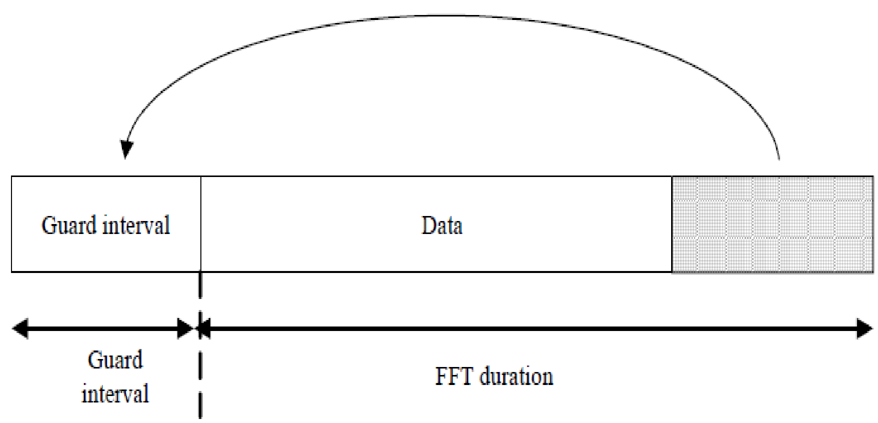

Figure 2.8: Illustration of Cycle Prefix [21]

2.7.3 OFDM Technique

The Orthogonal Frequency Division Multiplexing (OFDM) can reduce the effects owing to the radio channel. This certain technique includes in a multi carrier modulation where the signal is divided in N-flows of low speed which modules some sub-carriers.

The period of the low speed symbols are chosen in a way that goes over spreading time including the last echo. Each sub-carrier which is modulated has zero in a spectrum at the frequency of the following sub-carrier. In this way, they are orthogonal. To get this, the frequency of each sub carrier should be separated the same value just like an inverse of the low speed period [22]. If it selected a great number of OFDM sub carriers, the echo delay is smaller than the symbol`s time of each modulated signal and each one will be affected by flat fading. By consideration of this fact [21], with the orthogonality of the carriers, permits individual demodulation with quality. The echo problem decreased and become interference between symbols (ISI) that is limited. On the other hand, if the total number of OFDM sub-carriers are limited, the echo delay higher and the signal is influenced by selective fading and is not easy job to modulate because of high interference which are in, even the signal has high level of amplitude. The data output of the serial-parallel convertor modulates each sub carrier [23].

In the DVB-T standard three possible modulations are described: The first one is QPSK: 2 bits per symbol. The Figure 2.9 presents this certain modulation

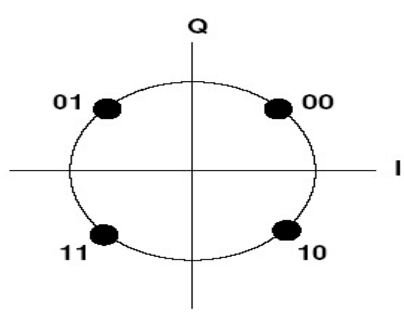

Figure 2.9: QPSK Constellation [14].

The second one is 16QAM: 4 bits per symbol which is presented by below diagram

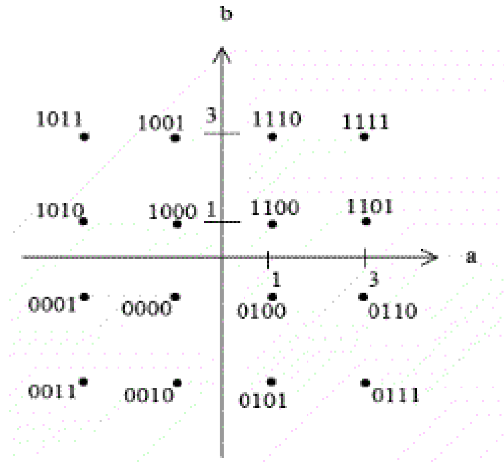

Figure 2.10: 16-QAM Constellation [13].

and finally the last one is 64QAM: 6 bits per symbol which is given by Figure 2.11.

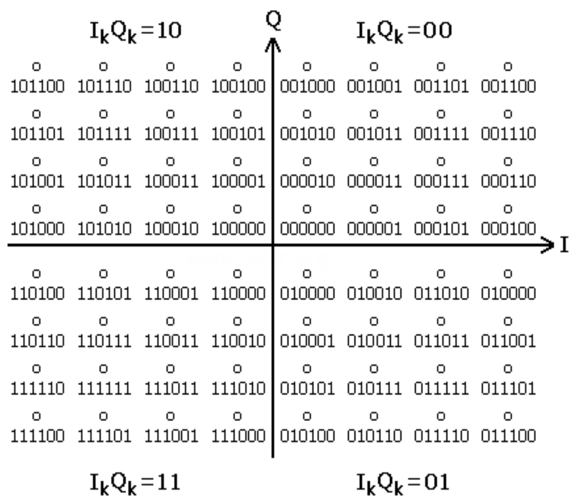

Figure 2.11: 64-QAM Constellation [13].

The DVB-T permits two possible values to the number of sub carriers. The first one is 2K mode: 1705 sub-carriers separate 4,464 kHz, 2048 theoretical carriers and the next one is 8K mode: 6817 sub-carriers separate 1,116 kHz, 8192 theoretical carriers.

2.7.4 Hierarchical and non-Hierarchical Modulation

There are two different types of modulation: Hierarchical and non-hierarchical modulation. All the multiple transport TS-MPEG-2 bits are processed in the same way which can transmit multiple programs at the same time, but all of them have same characteristics of robustness of radio channel. In the reception time with the reducing of SNR, the demodulation of signal changes from acceptable to loss service suddenly (cliff effect). For this reason, there is different technique which called hierarchical modulation and includes two different methods for the information. One method works with lower bit rate and has robust encryption and modulation another one works differently. It works with high bit rate but robustness. Hierarchical modulation prevents the cliff effect and permits a gradual degradation of the demodulated signal. Data after transmitting will divided in two streams (splitter) and each one will processed in different methods. The data flow with High Priority (HP) has low bit-rate and high defense against errors and it is against the low priority (LP) which has high bit-rate and low error protection. The HP data may be received in place where be far from the transmitter as a result the signal to noise ratio will be lower, in the other hand in the case of LP, the data is not in the far area from the transmitter and as a result the signal to noise ratio will be higher [24].

To accomplish this exact effect the shape of formation of the constellation map should be done in special way. HP flow describes the quadrant of the constellation (QPSK modulation) but LP flow describes the place of each point in the constellation in the quadrant (16QAM or 64QAM).Only some errors which involve a change of quadrant can have effect on HP flow, which include only a small portion of the total errors. The DVB-T has three hierarchical modulations by parameter "α" which describes the relation between the spaces of the neighboring points in the same quadrant. There different values introduced for α: 1, 2 and 4.When the value of α is 1 it will be named uniform modulation. The non-uniform modulation provides more protection for the HP flow but makes the loss to the reception to the second flow due to the fact that for a constant power received, inside the quadrant the symbol is closer. There are two possible emissions in hierarchical modulation: The first one is Simulcast: In fact simulcast is dividing one program into the one version with high bit rate and robustness and the other version with the opposite characteristic, in this way two different flows (HP and LP) emit this program. The second one is Multicast: In fact multicast can be introduced as two various programs with different robustness. The receiver will pick up sufficient LP or HP. The receiver does not have two diverse ways for each flow but it should be able to read each channel. In adverse condition receiver tries to decrease quality but maintaining the service.

Chapter 3

DIGITAL VIDEO CHANNEL MODELLING

3.1 Communication Channel

Communication channel is used between receiver and transmitter. In the other hand any devices which connect transmitter to receiver can be named channel. Channel can be “wired” transporting electrical signal and it can be used in telephone wire, TV cable or even in Ethernet cable. A wire channel can carry some special signal such as optical fiber. Wireless channel can be useful in different places like underwater ocean for sea prospecting wireless channel can transport acoustic waves. With the advent of digital communication some scenario has been changed because the communication need more speed.

3.1.1 Radio Channel

Nowadays a demand for indoor wireless increased significantly and as a result of this new demand, needs for efficiency raised. For designing an indoor wireless, the Pico cell antennas have to be located in a building in a way that obtaining the best coverage in whole area being possible. Different scenarios exist for the indoor wireless system such as communication between two fixed antennas or even produce ways for communication between moving antennas. Two different scenarios can be introduced for indoor wireless spread. The first one is a situation when there are 2 different antennas which the first one of them is located inside the building and the other one is located outside. The second scenario is related to the situation when both antennas are located inside the building.

Researchers have tried to verify a radio coverage that forecast a proper antenna spanning for different buildings with different features. These researchers tried too much in recent years for developing new models for the aim of describing the propagation of certain signal in space [25]. It should be mentioned that predicting the behavior of signals is a crucial job. On the other hand, analyzing and understanding these different models can be useful for designing a suitable indoor communication networks. Many features can be presented for indoor radio propagation or even by considering the application of indoor communication system various constructions can be presented for them.

Presence of various physical blocks and materials make serious problem for accurate forecasting the loss of signal energy. Different ranges of barriers like walls, stuff or even ceiling make difficulties for transmitting signals and as a result the signal will spread into the open area. In most of the cases non-line of sight (NLOS) will exist for transmitted signal but in some cases a line-of sight (LOS) will exist. For developing the performance of whole system users should be aware of these difficulties and tries to find a way for solving them. When there are huge number of reflectors and scatters in an indoor channel, multipath dispersion will be happened. It can be mentioned that the indoor channel has higher path losses and more significant changes in the mean signal level when it compares with the mobile channel [25].

There are two main different between indoor wireless channel and outdoor wireless channel. The first one is that the environment is more changeable relative to the path length in indoor channel and the second different is that the coverage size is smaller for indoor one. In reality multipath arises when more than a one path are available for propagation of signals. Different phenomena such as reflection, diffraction or even scattering can be presented as a reason for additional radio propagation paths to the direct LOS path among senders and receivers. Various reasons can be presented for losses of signals but partitions are among the main important of them. For both outdoor and indoor spread channels there is no united theoretical model for path loss and forecasting of fading results.

3.1.2 AWGN Channel

The Additive White Gaussian Noise (AWGN) is the easiest and omnipresent. The model does not include nonlinearity, frequency selective, interference and fading. The figure 3.1 shows the continues model of AWGN channel where *S(t)* is signal transmitter and *X(t)* is the signal receiver waveform.

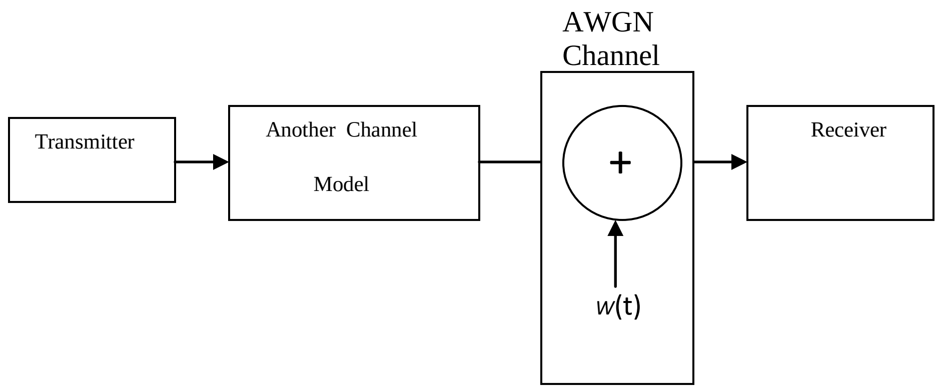

Figure 3.1: Communication System Model with AWGN and Another Channel [26]

Generally the *W(t)* is known as thermal noise. Random motion of electrons in electrical device causes to generate the thermal noise. Another name of AWGN channel is Memory less, which means that the influence of AWGN channel in transmitted symbols is independent of its impression of past symbols.

The thermal noise always exists in any communication system except the environment where the temperature is absolute zero of 0 Kelvin (k). The Power Spectral Density (PSD) of thermal noise is given by:

$$S_{w(f)}=\frac{N_0}{2} \text{ W/Hz} \qquad -\infty \leq f \leq \infty \tag{3.1}$$

Where N_0=k T_e, is the noise PSD generated by the front-end communication receiver circuit exhibit equivalent noise temperature. K=1.38047×10^{-27} Joule/Kelvin (J/K) is the Boltzmann constant and the N is normal distribution function. Assume the following model for a real-valued discrete-time channel:

$$Y=X+Z \qquad Z \sim N\,(0,\sigma^2) \tag{3.2}$$

Where the X is power-constrained input, E[X^2] ≤ E_s where E_s is average energy per symbol, in addition the spectral efficiency is given by:

$$r=\frac{C_c}{w} \tag{3.3}$$

In 3.3 C_c= 2wC_d denotes the capacity of the continues-time channel and $C_c = w2C_d$.

Therefore, The SNR will be presented by below formula:

$$\text{SNR}=\frac{E_s}{\sigma^2}= 2C_d\,\frac{E_b}{N_0}=\text{r}\,\frac{E_b}{N_0} \tag{3.4}$$

3.1.3 Flat Fading Channel

There are different reflectors in the area around transmitters and receivers which produce different paths for traverse a certain signal. By choosing each one of these unlike pathways, a certain signal can experience special delay, attenuation or even different phase shift. In wireless communication system, fading is known as a divergence of the attenuation which has different effects on a certain signal over publication media. Different range of factors like earthly situation, time or even radio frequency can have effect on this phenomenon. Fading can reduce efficiency of a communication system. When fading happen some signal power loss but at the same time nothing happened for the power of the noise that means losing some signal power is not joined with reducing the power of noise and in consequence of this event efficiency will decrease. The effects of fading can compensate by adopting diversity to spread the signal over multiple channels [27].

A fading channel can be introduced as a communication channel which included fading. Two different reasons can be the reason of fading. The first one is multipath induced fading and the other is shadow fading. The first one happened because of multipath propagation and the next one happened as a consequence of shadowing from difficulties disturbing the wave propagation [28].

For modeling different effects of electromagnetic spread of statistics over the air in cellular network, fading channel model will be used. Another application of this model is for modeling underwater when acoustic communication happened because of water. In a definition of flat fading or frequency nonselective fading channel it should be noted that the coherence bandwidth of certain channel is greater than the bandwidth of the signal but in the other hand in the definition of frequency-selected fading the bandwidth of coherence is narrower than the bandwidth of the signal. It should be mentioned that a flat fading channel can contain multipath effect.

3.1.4 Rician Fading Channel

There are different situation for receive signal, in one of these situations when considerable line of sight path and multiple fading path joined each other among receivers and transmitter a Rician fading channel happened. The line of sight path is the most powerful which moves directly from the transmitter to receiver. The effect of Rician fading on transmitted signal is less than this effect on Rayleigh fading because of the line of sight path.

The below formula is used as a Rician probability density function [29]

$$p(r_0) = \frac{r_0}{\sigma^2} \exp\left[-\frac{(r_0{}^2+A^2)}{2\sigma^2}\right] I_0\left(\frac{r_0 A}{\sigma^2}\right) \quad r \geq 0 \; A \geq 0 \qquad (3.5)$$

I_0 is equal to modified Bessel function of zero order and A is the peak magnitude of the line of sight signal component [4]. There are different factors in Rician fading channel, one of these inputs is K which explains as the proportion of power of line of sight component in the multipath components.

$$K=\frac{A^2}{2\sigma^2} \qquad (3.6)$$

When the value of K is equal to zero the Rician fading channel becomes Rayleigh fading channel. By rising K, a Gaussian distribution which has mean value equal to A will be predicted by Rician fading channel. The next Figure presents the Rician probability density function. For better understanding three different values is selected for K [26].

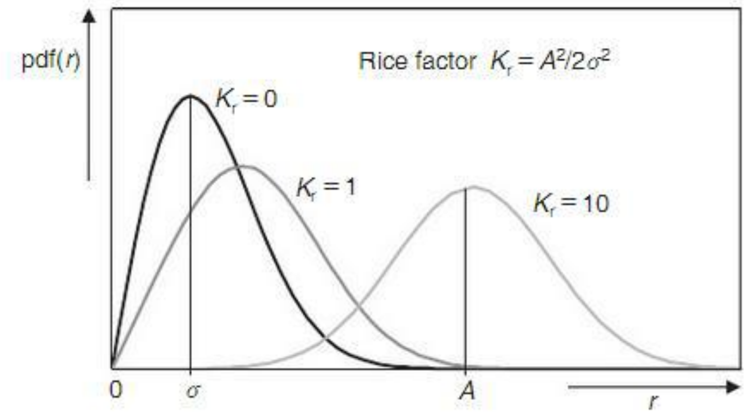

Figure.3.2: Different *K* Factor [29]

The Equation 3.7 which is given below is used as the probability density function of the immediate signal to noise ratio

$$\text{pd}f_{yb}(y_b)=\frac{1+K}{\overline{y_b}}\exp\left(-\frac{y_{b(1+K)+K\bar{y}_b}}{\overline{y_b}}\right)I_0\left(\sqrt{\frac{4(1+k)ky_b}{\bar{y}_b}}\right) \quad (3.7)$$

Another formula which is presenting the BER for non-ideal coherent detection of BPSK is:

$$p_b=\frac{1}{2}[1-Q_1\left(\sqrt{b},\sqrt{a}\right)+Q_1\left(\sqrt{a},\sqrt{b}\right)-\frac{A}{2}\exp\left(-\frac{a+b}{2}\right)I_0\left(\sqrt{ab}\right) \quad (3.8)$$

$$\text{Where } \left\{\begin{matrix} a \\ b \end{matrix}\right\}=\frac{1}{2}\left(\sqrt{\frac{\frac{K}{1+K}G\bar{y}}{1+\frac{1}{1+K}G\bar{y}}}\pm\sqrt{\frac{\frac{K}{K+1}\bar{y}}{1+\frac{1}{1+K}\bar{y}}}\right)^2 \quad (3.9)$$

$$\text{And} \quad A=\frac{\frac{\sqrt{G}}{1+K}\bar{y}}{\sqrt{\left(\frac{G}{1+K}\bar{y}+1\right)\left(\frac{1}{1+K}\bar{y}+1\right)}} \quad (3.10)$$

G is non-ideal coherent factor. Using formula for calculating Rician fading channel is a difficult job because of this problem Bertool will be used in MATLAB for calculating the theoretical amount of probability of bit error rate for Rician fading.

3.1.5 Power Delay Profile (PDP)

Another name of power delay profile ($A_c\,(\tau)$) is multi path intensity profile, is described as autocorrelation Equation (3.11) with Δt=0: $A_c\,(\tau) \triangleq A_c\,(\tau,\, 0)$ the power delay profile demonstrates the average power dependence with a given multipath delay. It can be measured experimentally. The average and spread delay can be defined base on the power delay profile $A_c\,(\tau)$.

$$E[c^*(\tau_1,\tau_2;\Delta t) = E[c^*(\tau_1;t)c(\tau_2;t+\Delta t)] \quad (3.11)$$

$$\mu_{T_m} = \frac{\int_0^\infty \tau A_c\,(\tau)\mathrm{d}\tau}{\int_0^\infty A_c\,(\tau)\mathrm{d}\tau} \quad (3.12)$$

$$\sigma_{T_m} = \sqrt{\frac{\int_0^\infty (\tau - \mu_{T_m})^{2A_c(\tau)d\tau}}{\int_0^\infty A_c(\tau)d\tau}} \quad (3.13)$$

The $A_c\,(\tau) \geq 0$ and the distribution of P_{T_m} can be defined as:

$$P_{T_m} = \frac{A_c\,(\tau)}{\int_0^\infty A_c\,(\tau)d\tau} \quad (3.14)$$

The μ_{T_m} is the mean and the σ_{T_m} is RMS value. The weak multipath parts helpless to delay spread than vigorous one. In particularly, multipath parts cannot considerably affect these delay spread characterization if they are located under noise floor. The measurement of the power delay profile of the channel specified the expected degree of dispersion. For calculating the power delay profile for the certain channel the spatial average of $|h(t)|^2$ over a local area should be calculated. By using power delay profile many parameters of multipath channel can be derived. The certain form is used for presenting power delay profile which can be described as plots of the captured power as a function of a surplus delay with respect to a fixed time delay reference. The signal will be captured by a certain delay after transmitting. Different parameters can be specified by a signal power delay profile, the most important of them are excess delay, RMS delay spread and excess delay spread. The below figure indicates PDP when the *K*=10dB.

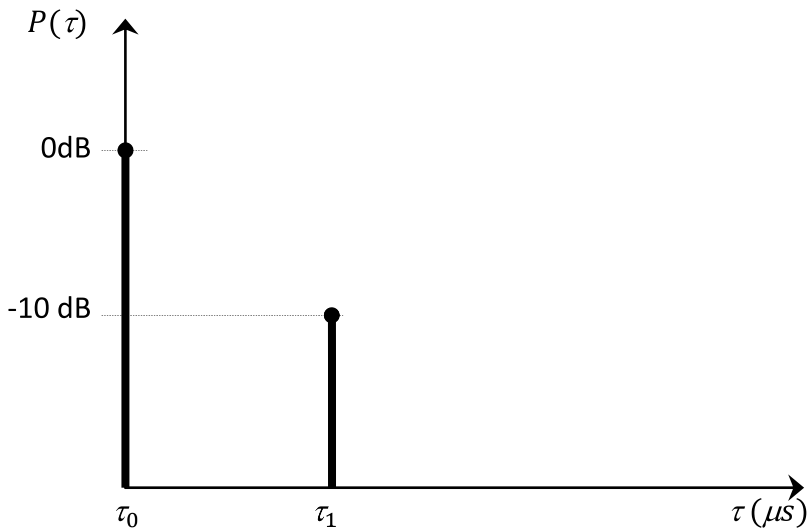

Figure.3.3: 2-Ray Power Delay Profile (PDP)

3.1.6 Rayleigh Fading Channel

Rayleigh fading is the name of fading which is useful for environments with large number of reflectors and can be introduced as a statistical model [30]. The main assumption about this model is that the enlargement of the signal which has send and passed through a communication channels will change randomly by following a Rayleigh distribution. This introduced fading is more useful and applicable in the certain cases when there is not any prevailing propagation during a line of sight between sender and receiver. In fact Rayleigh fading can be a proper model for cities which severely built-up and as a results of existence of buildings there is no line of sight for transmitting signals. In these cities, crowded architecture produce different serious problem for transmitting signals by attenuate, reflect and diffract the transmitted signals. It should be mentioned that Rayleigh fading is a tiny-scale effect, but on the other hand there will be properties like loss of pass or even shadowing which the fading can deal with them. This model will be applicable in a situation when many items exist in the environment which disperses the transmitted signal before its reception by the receiver [30].

3.1.7 Interleaving

A system can have an error because of non-stationary channel noise. On the other hand, another reason can be introduced for existence of noise which is wrong decision of an inner first decoder. In fact for scattering these kind of errors interleaving can be used. Interleaving is applicable for improving the action of error correction. In fact interleaving meliorates this certain problem by shuffling source symbols across many codes words.

3.1.8 Co-Channel Interference

Co-channel interference (CCI) can be explained as an interference between two various transmitters which sharing the similar frequency channel. Spectrum is very rare resource in wireless communication. Nowadays a massive and increasing demand for the spectrum can be seen and the reason behind this demand is the fast growing of wireless services. There are different reasons for CCI such as:

1) Cellular Mobile Networks

2) Adverse weather condition

3) Poor frequency planning

4) Overly-crowded radio spectrum

5) Daytime vs. Nighttime

6) Cancellation of signal.

One of them is reusing of frequency in cellular networks. Reusing frequency contribute to increase spectrum, Therefore, characterization of CCI, performance analysis [26]–[31], and estimation of the receiver parameters [31]on fading channels in the attendance of CCI are of significant interest. CCI happened among two access points which are using same frequency channel; in fact CCI can have effect on the performance of wireless LAN. By expanding the wireless LAN for producing more support for voice, CCI will produce more problems.

3.1.9 Doppler Effect

The various sounds will be produced by the fast cars depending to the speed relative to the observer. If they move towards the observer the high frequency sound will be produced. If they move the observer the opposite direct of observer the low frequency of sound will be produced. When the observer and source move the Doppler Effect (frequency shift) will be occurred. The physicist Christian Doppler first published the Doppler Effect in 1842 for light waves in monograph [25]. After that Austrian mathematician Christoph Buys-Ballot proved it scientifically [25]. Generally the Doppler Effect exists in light waves, electromagnetic waves and sound waves. The Doppler Effect is widely used in world for instance in medicine to understand the speed and direct of blood. In addition, the famous radar speed checks use the Doppler Effect.

The Equation 3.14 illustrates the Doppler frequency shift:

$$\Delta f = V \times (\frac{f}{c}) \times \cos\theta \qquad (3.14)$$

Δf is frequency shift, V= velocity of observer, f is carrier frequency of transmitter, C is speed of light and θ is the angle between signal and motion direction. As result the frequency signal will become bigger if the receiver travels toward the transmitter. And if the receiver move in opposite direct from transmitter the frequency signal will be compressed.

If the angel between transmitter and receiver becomes 90° the Doppler Effect will be zero it seems that the receiver does not move. Considering the human who are walking and talking with 5km/h speed and the range of frequency is between 600-700 MHz and the angel between transmitter and receiver is 0° consequently. $\Delta f = 1.38 \times \frac{(650 \times 10^6)}{300 \times 10^6} \times 1$ $\Rightarrow \Delta f = 3$Hz So the Doppler Effect in Rician fading channel is 3Hz in this thesis.

Chapter 4

SIMULATION RESULTS

4.1 Simulation Result

This chapter tries to illustrate the BER analysis in DVB-T system over AWGN and Rician channels in different conditions. Firstly the simulation is carried out on the basic OFDM over AWGN and Rician channels. After adding the RS encoder and convolution interleaver the system will be completed and ready for evaluation BER vs. SNR. Finally the co-channel interference will be added to determine the tolerance of the system.

4.2 Simulation System Design

The system which will be used for simulation is DVB-T with AWGN and Rician channels. The DVB-T system consists of Reed-Solomon encoder, convolution interleaver, convolution encoder, Viterbi, DVB inner interleaver, 64-QAM and OFDM. The rate of Forward Error correction is 3/4 and the guard interval is 1/4. The RS encoder works with shortened form (204,188). The Rows of shift register in convolution interleaver is 12 and the register length step is 17. The convolution encoder uses [1 1 0 1 1 0] as puncture code this code indicates the rate of FEC is 3/4. Next step belongs to 64-QAM, it uses DVB-T constellation and it will be used it for high quality. The 2k OFDM plays an important role in the system it will be used for carrying sub carriers and finally 3 different channels will be used: 1-AWGN has the best performance during simulation tries to use various SNR in AWGN and test it, 2-Rician with different levels of *K* will be tested. Desirable *K* will be used for final simulation during the simulation the Doppler Effect is 3Hz which corresponds to a pedestrian speed of 5km/hr 3-Rayleigh has the worst performance but it will be used to show which *K* in Rician channel is sufficient for acceptable performance. In the next section we shall study the performance of OFDM in AWGN and Rician fading channels. Figure 4.1 indicates the DVB-T block diagram the specification of each block is explained in this part.

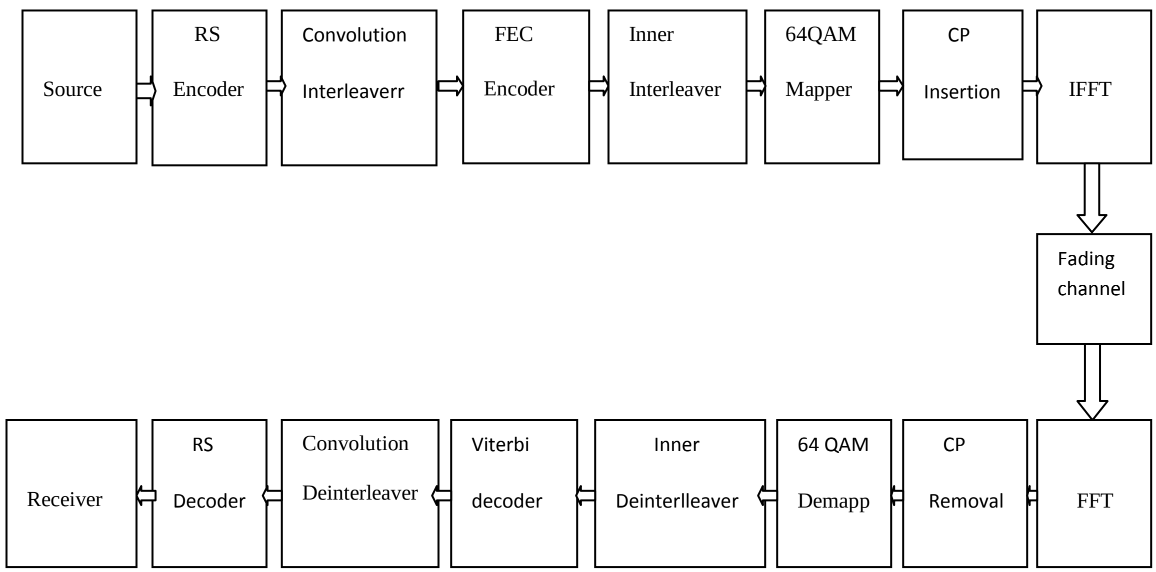

Figure 4.1: DVB-T Block Diagram [23]

4.3 Basic OFDM

The main aim of this simulation is how the DVB-T works without RS encoder and convolution interleaver and convolution encoder for this the Rician channel and the AWGN channel is employed. The system is made of 2K mode OFDM, 64-QAM, AWGN channel and Rician channel with 3Hz Doppler Effect and channel is flat fading. In this part the basic OFDM with AWGN and Rician channels will be evaluated. As the

Figure 4.13 indicates both diagram has the equal BER at the beginning. By observing more SNR, different conditions will be produced for both AWGN and Rician channels. Both systems have the same BER after 10dB but this certain level of SNR the AWGN decreased sharply and touched its lowest amount in 25dB which is equal to 0.00005. On the other hand, the Rician did not change too much and increasing the SNR does not have any significant effect on its BER. Finally the convolution and RS encoder in low SNR has undesirable affect but in high SNR they play an important role and they are very useful. They are able to decrease BER in high SNR sharply. In the next part we shall study the performance of OFDM with Convolution encoder over AWGN channel and Rician fading channel. In Figure 4.2 demonstrates the basic OFDM as can be seen there are not any RS encoder and convolution in this block diagram.

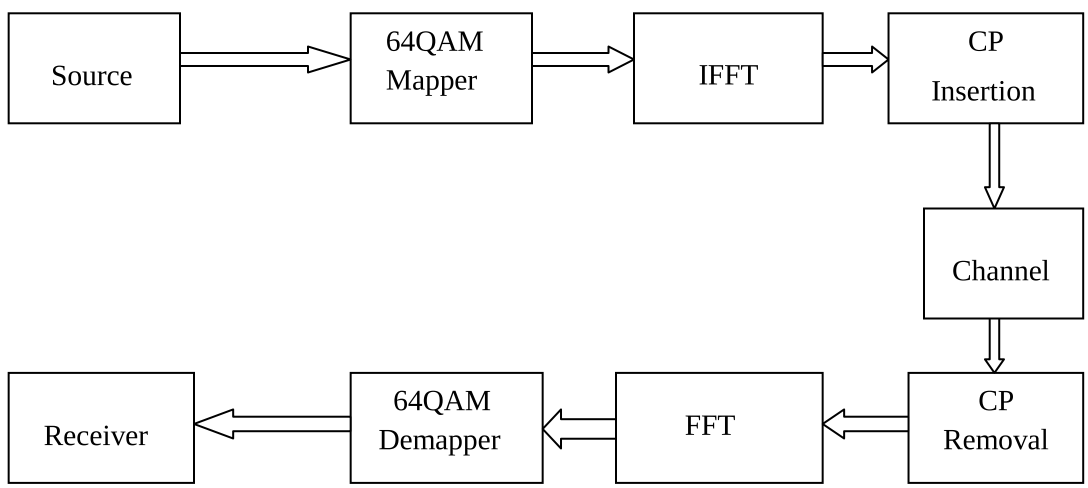

Figure 4.2: Basic OFDM Block Diagram

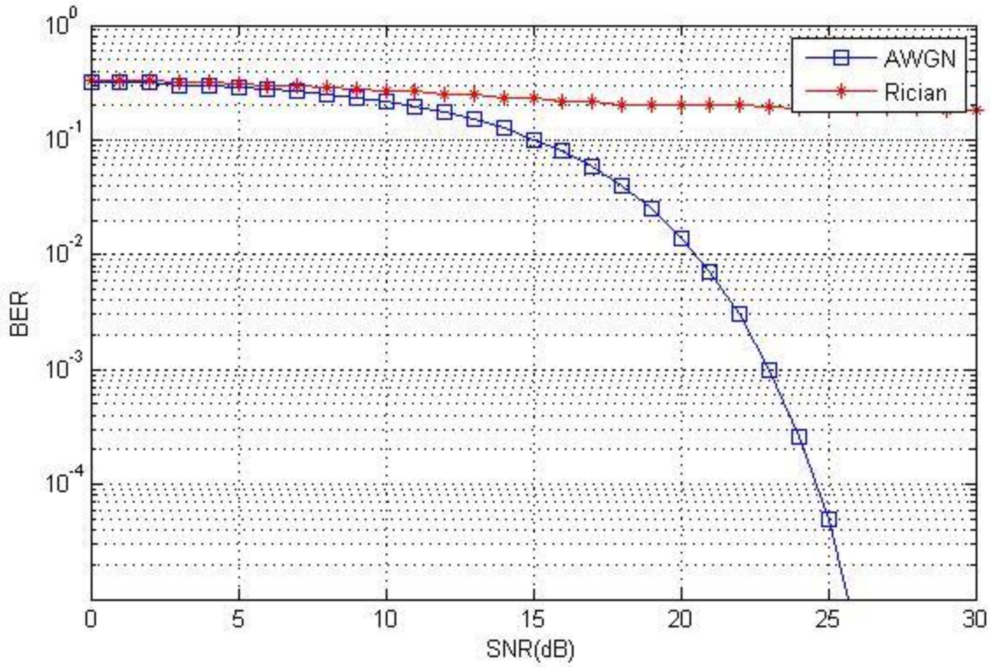

Figure 4.3: BER Simulation in Basic OFDM Over Rician Channel (K=10dB f_d=3Hz)

4.4 Basic OFDM with Convolution Encoder and DVB Inner Interleaver

The main purpose of this part is how the system works after adding convolution encoder and DVB inner interleaver. The system consists of convolution encoder (the puncture code is [1 1 0 1 1 0]), DVB inner interleaver, 2K mode OFDM, 64-QAM, AWGN channel and Rician channel with Doppler Effect 3Hz and flat fading channel. At starting point both graph have the same BER (0.5). This situation will be continuing till the SNR is 12dB. After that with increasing the SNR the BER will be decreased sharply in system with AWGN channel but the Rician channel does not tend to decrease. After SNR=20dB the BER in system with AWGN channel has little BER but the system with Rician the BER is still high. As result It should be mentioned that after adding viterbi and DVB-T inner inter leaver the system with AWGN channel has the better performance comparing to the basic OFDM but the system with Rician channel has high BER and the could not handle it. In next part the different levels of K in Rician fading channel will be simulated.

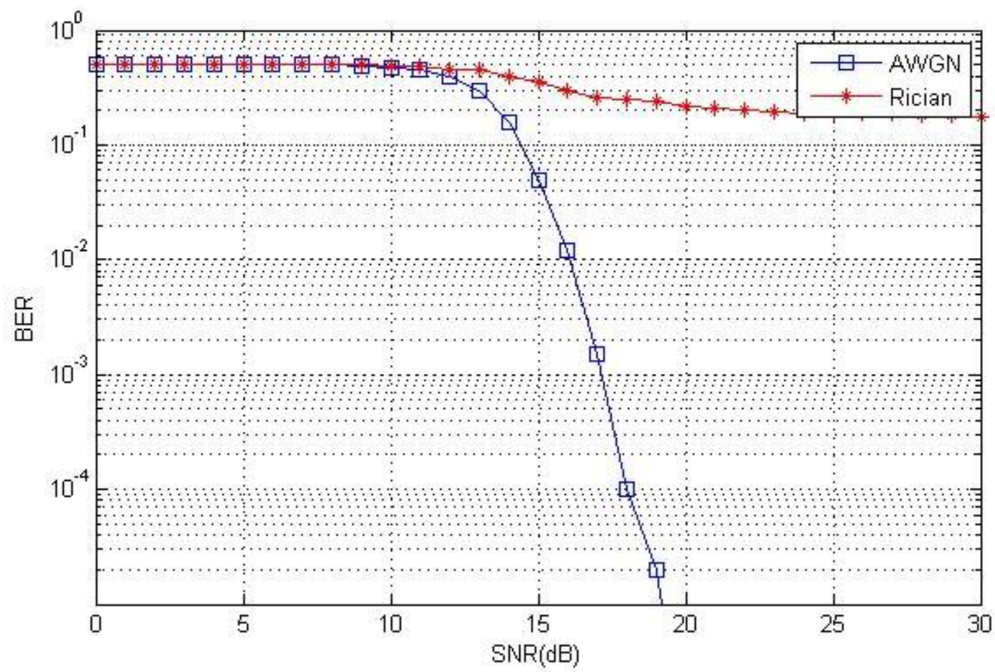

Figure 4.4: BER Simulation in Basic OFDM After Adding Convolution Encoder and DVB Inner Interleaver Over Rician Fading Channel (K=10dB, f_d=3Hz)

4.5 Different Levels of *K* in DVB-T in Rician Channel

The goal of this part is to determine the BER of different levels of K in Rician channel for comparing to the system with AWGN channel and the system with Rayleigh channel. All of the DVB-T sections will be used in this part. the system is made of RS encoder (204,188), convolution interleave, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM and Rician channel with 3Hz Doppler effect and flat fading channel. The rate of Forward Error correction is 3/4 and the guard interval is 1/4. The RS encoder works with shortened form (204,188). The Rows of shift register in convolution interleaver is 12 and the register length step is 17. The convolution encoder

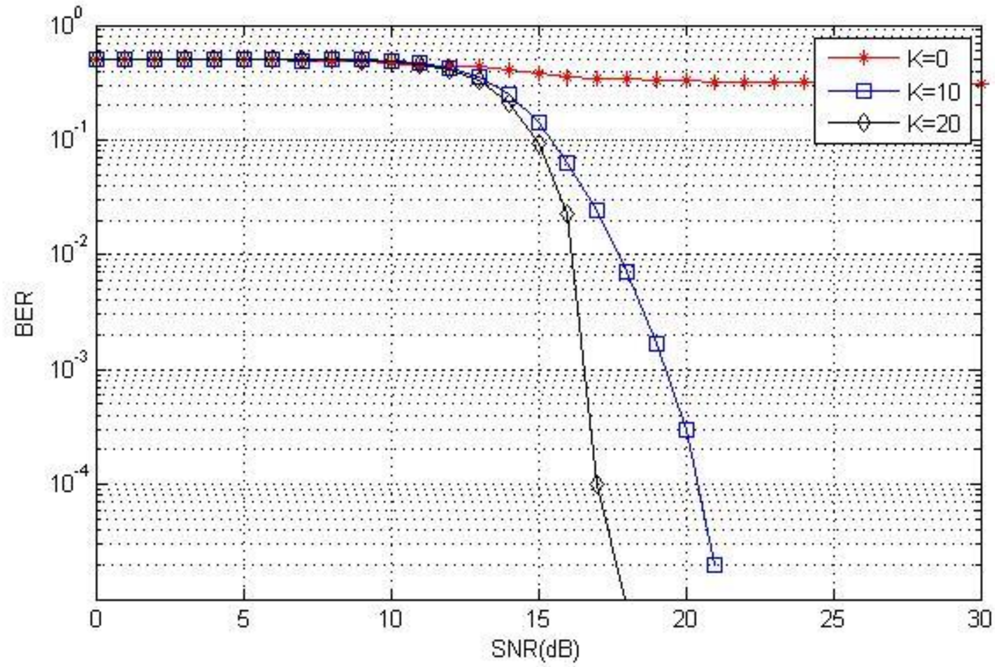

Figure 4.5: BER Simulation in DVB-T Over Rician Fading Channel with Levels of *K* (*K*=10dB, 0dB, 20dB f_a=3Hz)

Uses [1 1 0 1 1 0] as puncture code this code indicates the rate of FEC is ¾. As Figure 4.5 illustrates the different levels of K in Rician channel is simulated. It is expected that the system with K=20dB has best performance and the system which works with K=0dB has the worst BER. In next section the below figure will be compare to the system with AWGN channel and the system with Rayleigh channel for determining which K is suitable for simulation.

4.6 DVB-T AWGN Over Rayleigh and Rician Channel with Different levels of K

The main purpose of this part is comparing different levels of *K* in Rician channel with the system with AWGN channel and Rayleigh channel this part is very important because the below figure specify which K is proper for simulation. The system is made of RS encoder (204,188), convolution interleave, convolution encoder with rate 3/4,

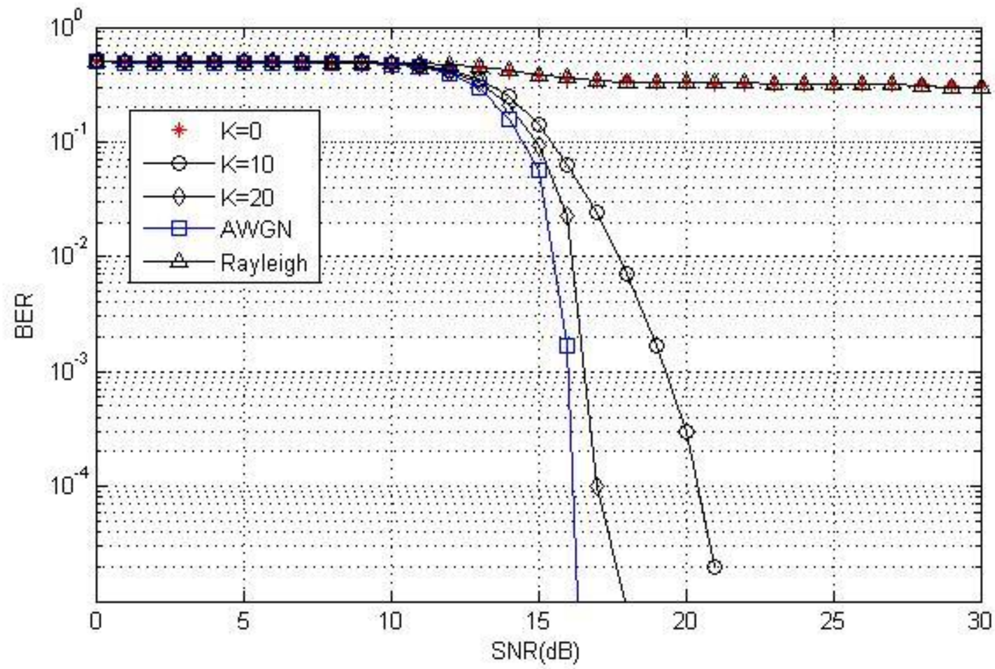

Figure 4.6: BER Simulationfor Comparing DVB-T Over AWGN vs. DVB-T Over Rayleigh vs. DVB-T Over Rician Fading Channel (K=0dB, 10dB, 20dB f_d=3Hz)

DVB inner interleaver, 64-QAM, 2K mode OFDM and Rician channel with 3Hz Doppler effect and flat fading channel and Rayleigh channel. As can be observed the system with K=20dB has the close BER with the system with AWGN channel and the system with K=20dB has similar BER with the system with Rayleigh channel. The section indicates that the performance of Rician channel with K=0dB is near the system which works with Rayleigh channel and in case K=0dB the system with Rician works like a system with AWGN channel so the Rician with K=10dB is suitable for simulation because it has its own characteristics. In next section the DVB-T in AWGN channel will compare with DVB-T in Rician fading channel.

4.7 DVB-T AWGN vs. DVB-T AWGN-Rician

The main target of this section is comparing DVB-T AWGN vs. DVB-T AWGN and Rician fading channel. The system which will be employed made of RS encoder (204,188), convolution interleave, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM, AWGN channel and Rician channel with 3Hz Doppler effect and flat fading channel. As can be seen in Figure 4.7, the line with square presents DVB-T AWGN and the line with stars show DVB-T AWGN with Rician. From SNR=0dB till to SNR=12dB, both system has the same BER but after SNR=13dB it can be seen that the BER in DVB-T AWGN obtains different value from DVB-T AWGN with Rician channel. In SNR=17dB the BER in DVB-T is equal to zero but DVB-T AWGN with Rician channel has little BER and after SNR=21dB the BER in DVB-T AWGN with Rician is zero. It is normal that the Rician has more BER than AWGN. There are different reasons for this event but the main one can be presented as the Rician is used for multipath. Using different paths causes to see more BER, but AWGN channel is used for direct path and using one certain path produce less BER. In next section some information about co-channel interference will be explained.

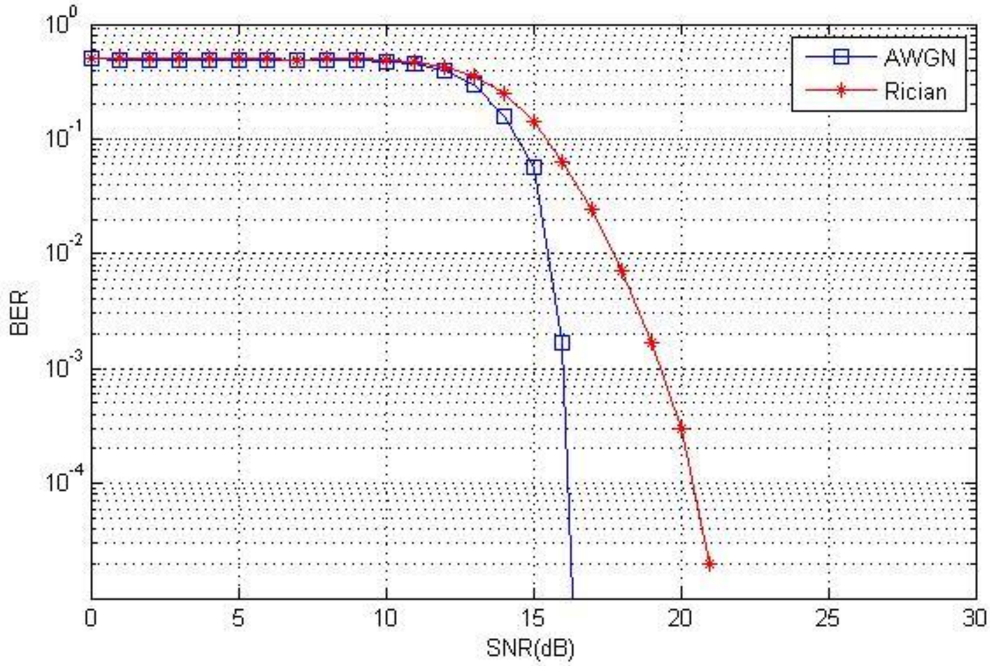

Figure 4.7: BER Simulation in DVB-T AWGN vs. DVB-T Over Rician Channel (K=10dB, f_d=3Hz)

4.8 DVB-T AWGN with Different Co-Channel Interference

The main goal of this part is to determine the BER in different levels of co-channel interference. Figure 4.8 shows the DVB-T with co-channel interference block diagram. The system is made of RS encoder (204,188), convolution interleave The Rows of shift register in convolution interleaver is 12 and the register length step is 17, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM and AWGN channel. This section of this thesis is so important because it contains the analysis of tolerance of DVB-T with AWGN channel when the different levels of co-channel interference happen. The figure 4.9 illustrates that the best performance of system occurs when the S/CCI is equal to 20dB. But sometimes the high level of CCI has bad effect on system and system could not work properly. As can be seen the line with square presents S/CCI when its value is equal to 15dB. In this condition the system cannot endure this level of CCI. By increasing the SNR the system don't show a downward trend and the BER will not decrease on the other hand, when S/CCI is equal to 16dB (the Star line) the BER decrease by increasing the SNR and it can be shown that this system can tolerate the CCI till S/CCI=16dB and it has acceptable performance against this distortion. In the next part the DVB-T in AWGN channel will compare with the different levels of co-channel interference. The Figure 4.8 presents the DVB-T over multipath fading with co-channel interference.

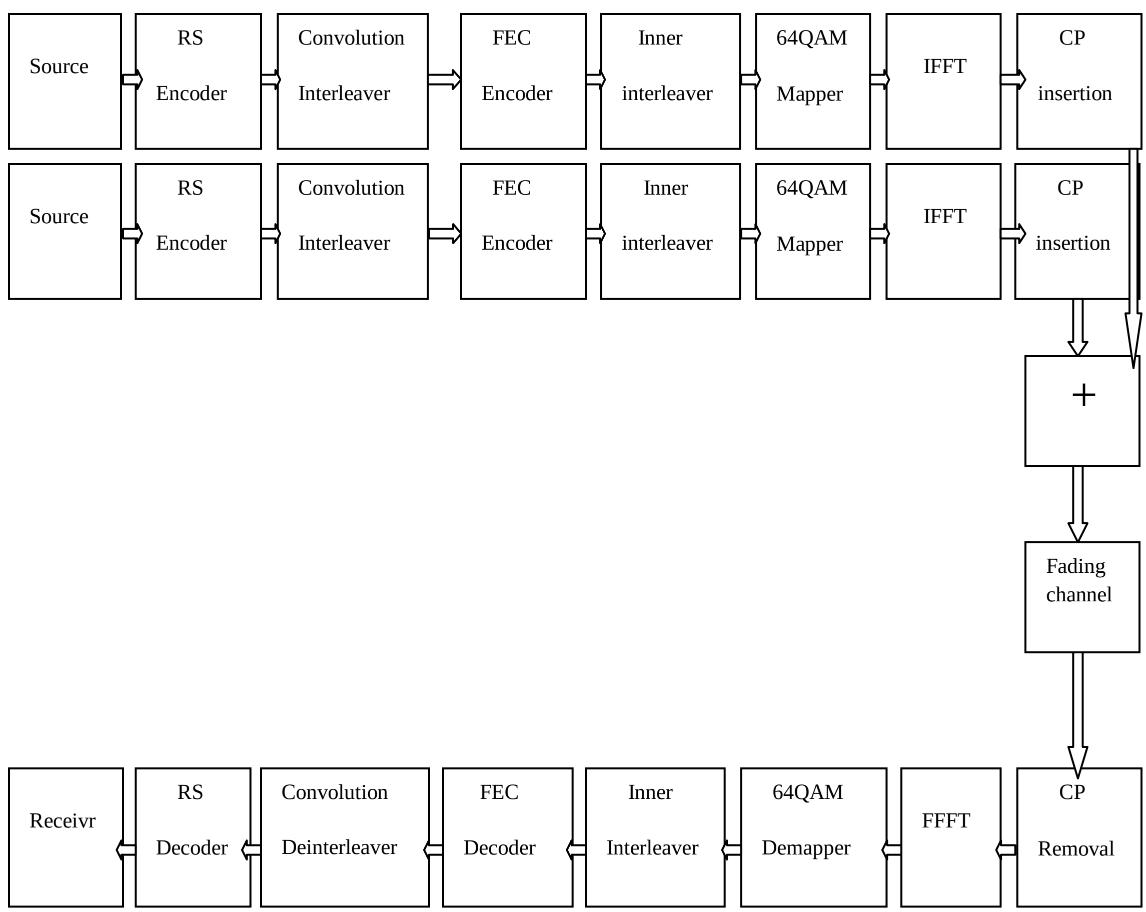

Figure 4.8: DVB-T Over Rician Channel with Co-Channel Interference Block Diagram

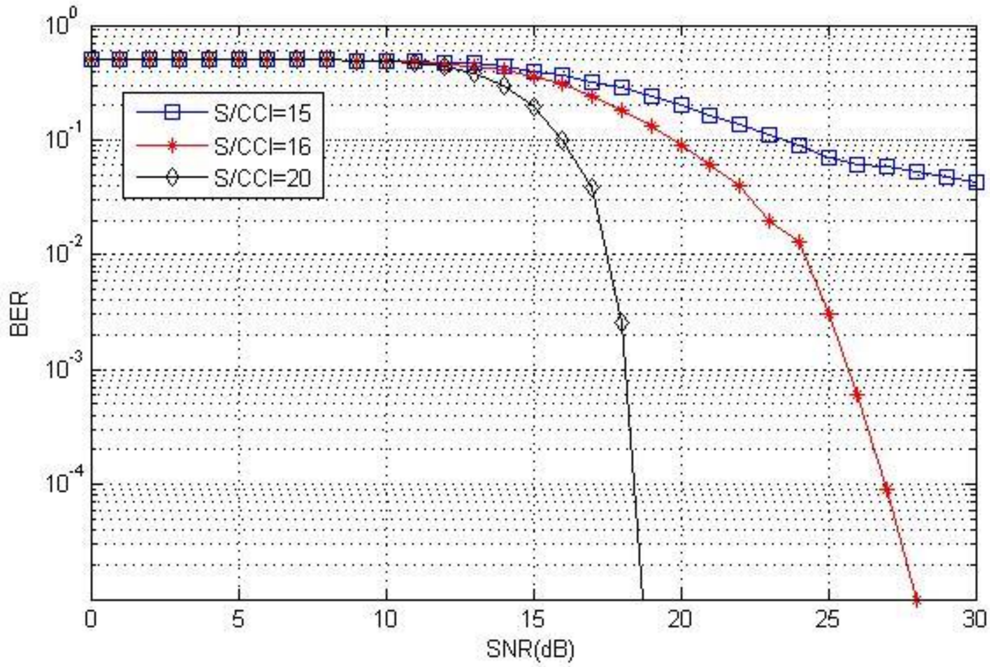

Figure 4.9: BER Simulation in DVB-T Over AWGN in Different Levels of Co-Channel Interference (S/CCI=20dB, 15dB, 16dB)

4.9 DVB-T AWGN vs. DVB-T AWGN with Co-Channel Interference

The main aim of this part is comparing the system with AWGN channel in normal condition with the system with CCI and detects which levels of CCI system can tolerate. The system is made of RS encoder (204,188), convolution interleave, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM and AWGN channel. In this part the CCI will be added to whole system and Figure 4.10 shows the undesirable effect of CCI in BER. Figure 4.10 indicates different levels of CCIs in DVB-T AWGN and the line which contains square, shows the DVB-T AWGN. All lines have the same BER from SNR=0dB till SNR=12dB, but in SNR=13dB the BER in DVB-T AWGN has less error than DVB-T AWGN CCI. By passing SNR=13dBthe variation between DVB-T AWGN and another systems will be more significant in comparison

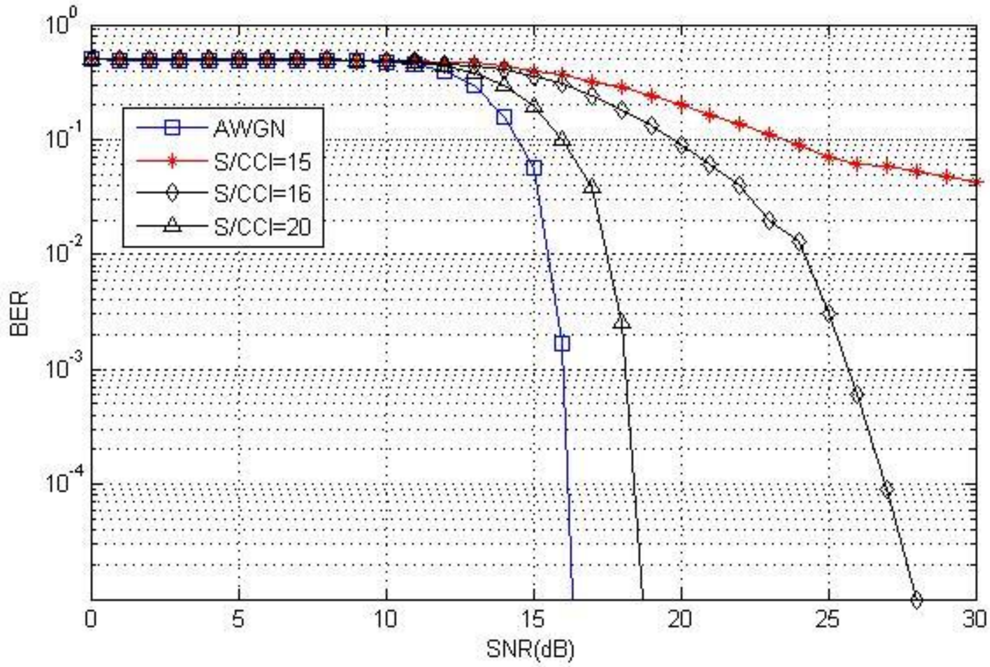

Figure 4.10: BER Simulation in DVB-T Over AWGN vs. DVB-T with Different Levels of Co-Channel Interference (S/CCI=20dB, 16dB, 15dB)

Before crossing SNR=13dB. In SNR=17dB the BER in DVB-T AWGN will obtain zero amount, but there is significant BER in DVB-T AWGN with various levels of CCI and the triangle line is similar to DVB-T AWGN because it has low level of CCI. As result the DVB-T system with AWGN channel can tolerate the CCI when the S/CCI=16dB. Next section the different types of CCI in DVB-T in Rician channel will be evaluated.

4.10 Different levels of DVB-T CCI Rician

The aim of this part is to determine the different levels of CCI in the system with Rician channel. The system is made of RS encoder(204,188), convolution interleave, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM and Rician channel with 3Hz Doppler effect and flat fading channel. As the figure

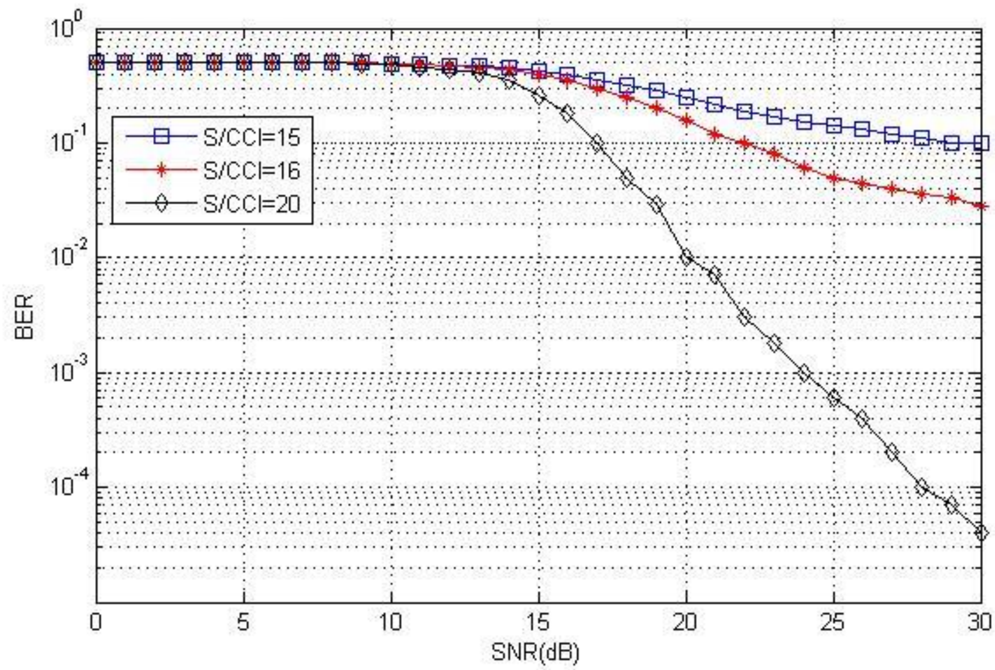

Figure 4.11: BER Simulation in DVB-T Over Rician Channel (K=10dB, f_d=3Hz) with Different Levels of Co-Channel Interference(S/CCI=20dB, 16dB, 15dB)

Indicates the S/CCI=15dB (the square line) has the worst condition. Using high level of SNR cannot decrease significantly BER, so the system will not be able to endure this level of CCI. The star line (S/CCI=16dB) has the same situation. By raising the SNR the BER does not show a downward trend. On the other hand, when S/CCI is equal to 20dB which specifies with diamond line, the condition will be better. When SNR is equal to 24dB the line with diamonds decrease sharply and in this moment it will be suitable for using. It should be mention the system works better in lower levels of CCI but most tries of this thesis is to predict the maximum tolerance of system. In next part the DVB-T over Rician fading channel will be compared with different levels of CCI in DVB-T over Rician fading channels.

4.11 DVB-T Rician vs. DVB-T CCI Rician

The main aim of this part is to detect which levels of CCI, system can tolerate. The system is made of RS encoder (204,188), convolution interleave, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM and Rician channel with 3Hz Doppler effect and flat fading channel. This part illustrates the compression between DVB-T Rician and DVB-T Rician with different levels of CCI. By looking more precisely at the below figure it can be said that the DVB-T Rician without different level of CCI will show better performance. But the system will experience worse situation by happening CCI and this condition depends on the types of CCI. When the S/CCI is equal to 20dB, the system has similar position to the normal system. The BER of them are the same while the SNR is 11dB. Moving to the more SNR causes that the BER of normal system decreases sharply but another systems decrease slightly. As result the DVB-T system with Rician channel can tolerate the CCI when the S/CCI=20dB.

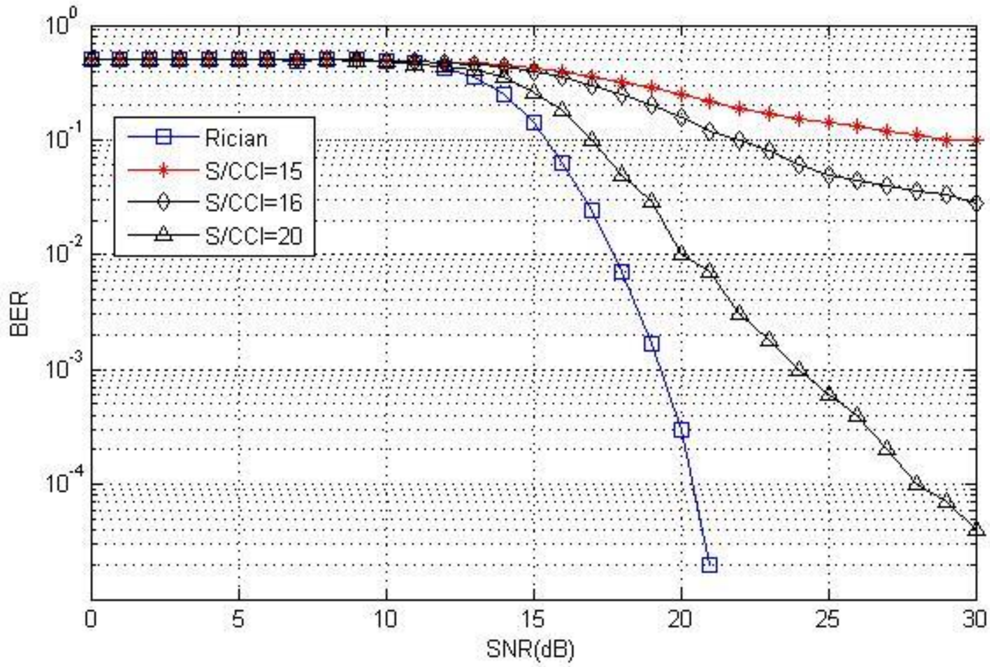

Figure 4.12: BER Simulation in DVB-T Over Rician Fading Channel (K=10dB f_d=3Hz) vs. DVB-T Over Rician (K=10dB f_d=3Hz) with Different Levels of Co-Channel Interference (S/CCI=20dB, 16dB, 15dB)

4.12 DVB-T Rayleigh vs. Rician and AWGN

In this chapter the Rayleigh channel will be added and the BER of system will be checked when the system works with AWGN and Rician and Rayleigh channels. The system is made of RS encoder (204,188), convolution interleave, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K mode OFDM and Rician channel with 3Hz Doppler effect and flat fading channel. As can be seen in Figure 4.13 the system with Rayleigh (a line with diamonds) does not work desirable. With increasing the SNR the BER will not decrease significantly (from 0.5 till 0.3), on the other hand in DVB-T with AWGN and Rician the BER is going to become zero.

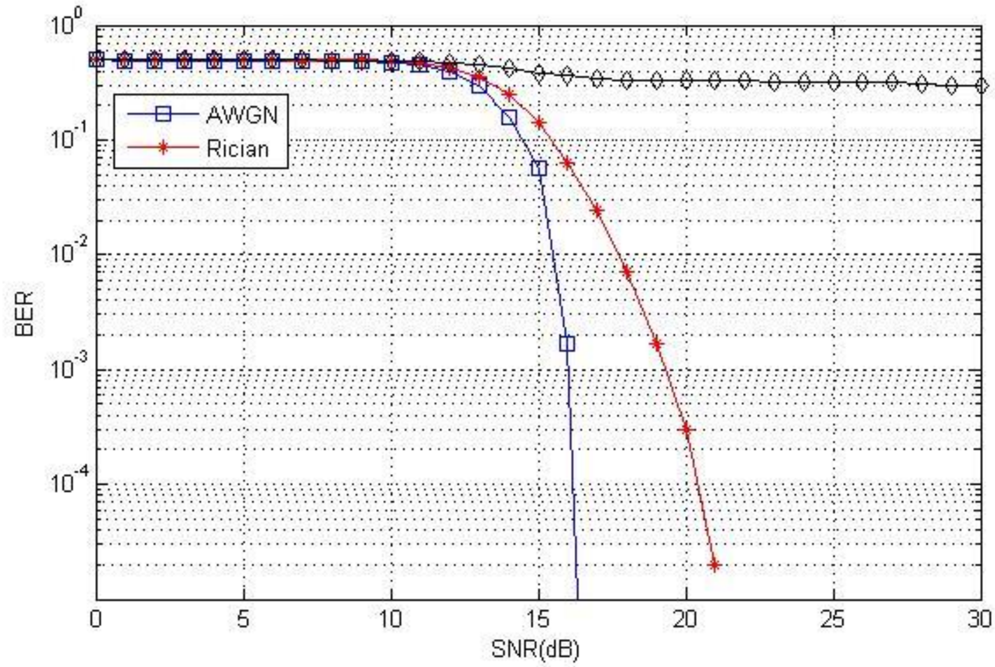

Figure 4.13: BER Simulation for Comparing DVB-T Over AWGN vs. DVB-T Over Rician Channel (K=10dB, f_d=3Hz) vs. DVB-T Over Rayleigh Fading Channel

4.13 Frequency Planning

The main goal of this part is to understand what the toleration of DVB-T CCI Rician is when there is not any movement. System which will be employed consists of RS encoder (204,188), convolution interleaver, convolution encoder with rate 3/4, DVB inner interleaver, 64-QAM, 2K OFDM, AWGN and Rician channel. There is not any movement so the Doppler Effect becomes zero. In this simulation the standard SNR is used (18.3dB). As the Figure 4.14 illustrates when S/CCI=0dB the BER is 0.5 by increasing the S/CCI when S/CCI=15dB the BER started to decrease significantly and in S/CCI the BER becomes 0.001 in SNR=18dB and it means that the performance of the system is acceptable. As result the DVB-T CCI Rician without any movement in SNR=18.3 can tolerate the CCI when S/CCI=24dB or more than it.

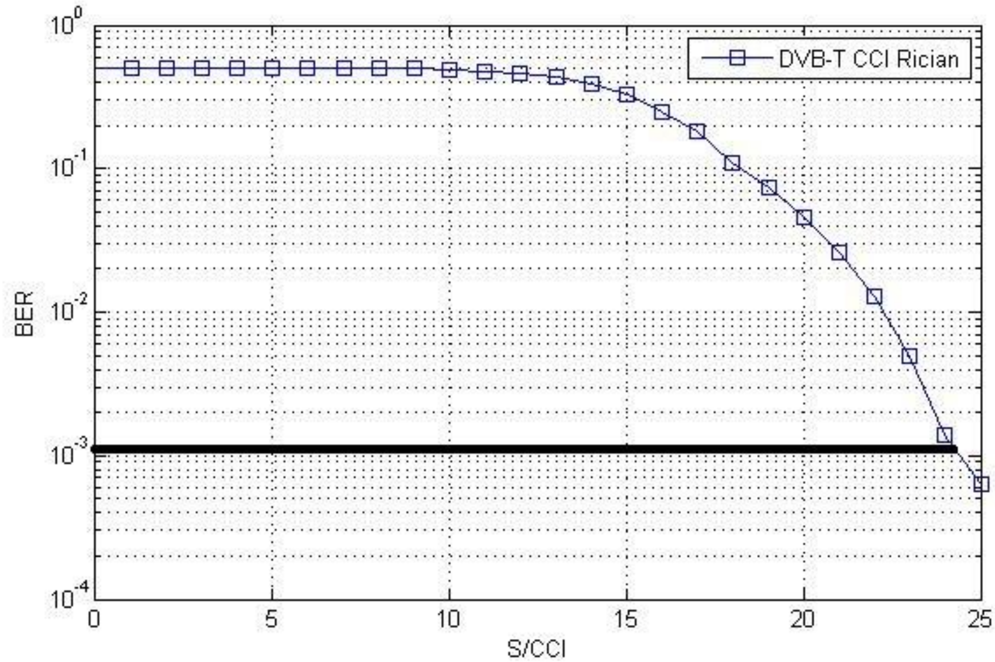

Figure 4.14: BER Simulation in DVB-T Over Rician in Standard SNR (SNR=18.3dB K=10dB f_d=3Hz)

In realistic as the Figure 4.15 shows there is one receiver between to transmitter which send the same frequency. So one of them is undesirable and the performance of the system becomes worst. In the figure there are both direct and reflected signal and it means that it related to Rician channel.

4.14 Mathematical Calculation for Receiver between 2 Transmitters

For better understanding frequency planning in real world, it is assumed that the receiver is located between two base stations. Both of them have same characteristics. But one of them sends desirable signal and another sends the undesirable signal as the Figure 4.15 illustrates.

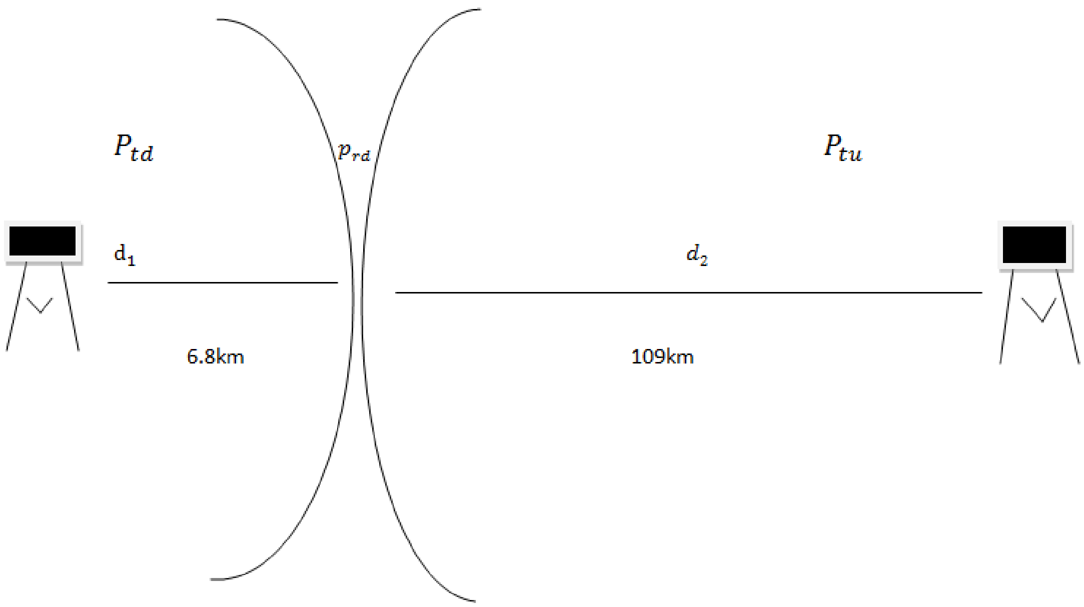

Figure 4.15: The Receiver Location

Since in DVB-T the standard SNR is around 18.3 dB, the P_{ds} is the power of desired signal can be calculated by 4.1

$$18.3 = 10\log_{10}\frac{P_{ds}}{P_N} \Rightarrow P_{ds} = 540.8\times10^{-8} = -52\,dBw \tag{4.1}$$

$$P_{rd} = \frac{P_{td}\times G_{td}\times G_r\times\lambda^2}{(4\pi)^2\times d_1^2} \Rightarrow d_1 = 6.8 \text{ Km} \tag{4.2}$$

The G_{td} is the gain of transmitter, G_r is the gain of receiver, λ is the wavelength of signal and P_{td} is the power of transmitter. After calculating λ will be 0.46. Assume that G_{td}=G_r=14 and P_{td}=1000W, According to the equation 4.2 d_1 is equal to 6800m=6.8Km. So if the distance between receiver and transmitter (which sent desirable signal) is 6.8Km or less than 6.8Km the noise could not distort the system, in the next step the P_{ru} will be calculated.

$$\frac{P_{rd}}{P_{ru}} \geq 24\text{dB} \Rightarrow 24 = 10\log_{10}\frac{540.8\times10^{-8}}{P_{ru}} \Rightarrow \quad P_{ru} \geq 2.15\times10^{-8}\text{W} \tag{4.3}$$

So the d_2=109km it means that if the distance of receiver and another base station(which sends undesirable signal) is 109km or more the co-channel interference could not effect on the system.

Chapter 5

CONCLUSION

5.1 Conclusion

The main motivation of this thesis was to investigate the tolerance of Digital Video Broadcasting terrestrial system to AWGN and Rician fading channels together with CCI. At the first step, the basic OFDM with AWGN and Rician channels was simulated and the following result obtained: The Reed-Solomon encoder, convolution interleaver and convolution encoder has low performance in low SNR condition but they play an important role in high SNR in the basic OFDM with AWGN channel but not for basic OFDM in Rician fading channel. For instance the BER in basic OFDM with AWGN channel is 0.33 when SNR=0dB. By adding the DVB inner interleaver and convolution encoder the BER will become approximately 0.5 when the SNR=0dB. But in high SNR this condition is not true, the BER in basic OFDM in AWGN channel is 0.014 when SNR=20dB. After adding DVB inner interleaver and convolution encoder the BER is 0.0000005 when SNR=20dB.

At the second step the BER performance of DVB-T over Rician fading channel with different levels of K was checked. The aim of that was to understand which k is sufficient for acceptable performance. For final simulation and the following results obtained:

1. When K=0dB, the channel works like Rayleigh channel.

2. When K=20dB the channel works like AWGN channel.

3. When K=10dB the channel has a unique characteristic. So in final simulation the channel with K=10dB was used.

At the third step the DVB-T over AWGN and Rician channel was simulated by Matlab for comparing to the DVB-T system when co-channel interference happened at the forth step the system with CCI was checked in different levels of S/CCI and in the fifth step all the simulations in step three and step four were compared and the following results were obtained:

1. DVB-T system with AWGN channel can tolerate the co-channel interference when S/CCI=16dB.

2. DVB-T with Rician channel cannot tolerate the co-channel interference when the S/CCI=16dB. The reason was there is slow motion in Rician channel so the performance of this channel is worse than AWGN channel. The DVB-T with Rician channel could tolerate the CCI when the S/CCI=20dB.

In case of frequency planning the toleration of DVB-T over AWGN and Rician fading channels have been determined and the following result obtained: The DVB-T system over Rician channel can tolerate the CCI in SNR=18.3dB when the S/CCI=24dB. It should be mention that in this case there is not any movement. Such a system can successfully perform if the desired transmitter is closer to the receivers than the undesired transmitters by a factor of 16.02.

5.2 Future Work

One way of solving the above problem is to consider the received composite signal made up of desired and undesired signal components. Therefore, rather than seeing the undesired signal as an unknown source of interference plus noise, the desired and undesired signals will be detected cooperatively so that from the composite signal at the receiver, the undesired signal will be suppressed, leaving the received signal free from CCI.

REFRENCES

[1] Farrokhi, F., Foschini, G., Lozano, A. and Valenzuela, A., "Link optimal Space-time processing with multiple transmit and receive antennas," *IEEE Communications Letter*, pp. 85-87, 2001.

[2] Alfano, G., Lozano, A., Tulino, A. and Verdu, S., "Eigenvalue statistics of Finite dimensional random matrices for MIMO Wireless Communications," in *IEEE International conference on communication*, Istanbul, pp. 19-22, 2006.

[3] Song, Y. and Blostein, S. D., "MIMO channel capacity in co-channel Interference.," in *Proceding of 21st biennial symposium on communications*, pp. 53-56 2004.

[4] Ye, S. and Blum, R.S., "Some properties of the capacity of MIMO systems With co Channel interference," in *In proceeding of IEEE international Conference on Acoustics, speech, and signal processing*, pp. 41-45, 2005.

[5] Blum, R. S., "Analysis of MIMO capacity with interference," in *IEEE international conference*, pp. 71-74, 2003.

[6] Kang, M. and Yang, L. and Alouini, "M.S. Performance analysis of MIMO Channels in presence of co-channel interference and additive Gaussian noise," in *in Proceeding of the 35th annual conference on information sciences and systems*, pp. 64-67, 2005.

[7] Kang, M., Yang, L.and Alouini, M.S., Capacity of MIMO channels in the Presence of co-channel interference,Wireless Communications and Mobile Computing, 2007,

pp. 113-125.

[8] Laine, J., "Interference estimation in a multi-cellular OFDMA environment," Royal Institute of Technology, Gothenberg, 2004.

[9] Telatar, I.E., "Capacity of multi-antenna Gaussian channels," *European Transactions on Telecommunications,* pp. 585-596, 1999.

[10] Kiessling, M., "Unifying analysis of ergodic MIMO capacity in correlated Rayleigh fading environments," *European Transactions on Telecommunications,* pp. 17-35, 2005.

[11] ETSI TR 101, 154 V1.4.1., "Digital Video Broadcasting (DVB);Implementation guidelines for the use of MPEG-2 system, Video and Audioin Satellite, Cable and terrestrial broadcasting applications," 2000-2007.

[12] Benoit, H., "Satellite Television: Techniques of analogue and digital Television," New York, Arnold, 1999.

[13] ETSI EN 300 744, V.1.1.2., "Digital Video Broadcasting (DVB); Channel Coding and modulation for Digital terrestrial television," 1997-08.

[14] [Online]. Available: http://www.dvb.org/. [Accessed June 2013].

[15] [Online]. Available: En.wikipedia.org/wiki/DVB-C. [Accessed June 2013].

[16] Reamers, U., "DVB- The family of international standard of Digital Video Broadcasting," Berlin, Springer Verlag Berlin Heidelberg, 2005.

[17] ETSI, TS 101191 V1.4.1., "Digital Video Broadcasting (DVB); “DVB Mega-Frame for Single Frequency Network (SFN) synchronization," 2004.

[18] [Online]. Available: Schools-wikipedia.org/images/85/8525.png.htm. [Accessed

June 2013].

[19] [Online]. Available: wikimedia.org/wiki/file:tx_DVB-S.jpg. [Accessed June 2013].

[20] ETSI, TS 102 591 V1.1.1., "Digital Video Broadcasting; IP Data cast over DVB-H Content delivery protocols implementation guidelines," 2007.

[21] Terry, J. and Heiskala, J., OFDM Wireless Lans: A Theoretical and Practical Guide .USA, 2002.

[22] Jorswieck, E. and Boche, H., "Optimal transmission strategies and impact of Correlation in multi-antenna systems with different types of channel state Information," *IEEE Transactions on Signal Processing*, pp. 20-34, 2004.

[23] Han, D.S., Seo, J.D. and Kim, J.J., "Fast carrier frequency offset compensation in OFDM system," *IEEE Trans. Consumer Electronics*, vol. 47, pp. 364-369, August 2001.

[24] ETSI, EN 300 468 v.1.3.1., "Digital Video Broadcasting (DVB) Specification for Service information (SI) in DVB system," 1998-2002.

[25] [Online]. Available: http://de.wikipedia.org/wiki/Doppler-Effekt. [Accessed June 2013].

[26] Madhow, U., in *Fundamental Digital Communication*, New York, Cambridge Universiy Press, 2008.

[27] Alex, H. and Wong, C., "Antenna Selection and Deployment Strategies for Indoo Wireless Communication System," The University of Auckland, Auckland, 2007.

[28] Alfano, G and Lozano, A., "Accuarate Performance Analysis of Diversity System," in *14th IEEE intl Symp. Pres. Indoor Mobile Communication*, 2000.

[29] Ahlin, L. and Zander, J., in *Principles of Wireless Communications*, 1998, pp. 126-130.

[30] John, G. Prokis., "Digital Communications," Singapor, McGraw-Hill Book Co, 2005, pp. 765-768.

[31] Ziqiang, X., Akansu, A.N. and Tekinay, L., "Co Channel Interference Computation and and asymptotic performance analysis in TDMA/FDMA systems WithInterference adaptive dynamic channel allocation," *IEEE Trans. Veh. Technol*, vol. 49, pp. 711-723, 2000.