STUDY AND SIMULATION OF DVB-T2 IRD PERFORMANCE FOR DIFFERENT TYPES OF CHANNELS

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ABSTRACT

Digital video broadcasting is used for digital television transmission, which is based on moving pictures expert group (MPEG-2) video compression. The DVB standards are classified into three categories of traditional broadcast networks which are DVB – S for satellite network, DVB – C for cable network, DVB – T for terrestrial network. The digital terrestrial television supports two types of services which are DVB-T and DVB-T2. DVB-T2 is considered as the most advanced digital terrestrial television system. It supports high-definition television (HDTV) services using same frequency spectrum, and better performances in mobile environments. Furthermore, in June 2014, version-1 of DVB-T2 Integrated Receiver Decoder (IRD) technical specification for ASEAN countries was released with the objective of reaping the benefits of economies of scale for affordable DVB-T2 IRDs so as to facilitate the adoption of digital TV in ASEAN members' countries. However, one of the challenges of the DVB-T2 is the many options it provides in system mode and parameters which needs to be accurately selected to suit different applications. In view of this, this project studied and investigated through simulation the BER versus SNR performance for the IRD specification. This includes the different types of channels: Gaussian, Rician and Rayleigh. In addition simulations for different scenarios were carried out for cases of different guard interval, code rates, effect of constellation rotation in different modulation schemes. The common software platform (CSP) developed for simulation of the DVB-T2 and Matlab 2014 was used in carrying out the simulations. The result of simulation showed the different BER versus C/N performance of the IRD specification. From the results, it can be seen that the IRD can be used for different kinds of services and can support both fixed and portable devices based on selected scenario or system requirements.

ABSTRAK

Penyiaran video digital digunakan untuk penghantaran televisyen digital, yang berdasarkan kaedah mampatan Moving Picture Expert Group (MPEG-2). Piawaian DVB diklasifikasikan kepada tiga kategori rangkaian penyiaran tradisional iaitu DVB - S untuk rangkaian satelit, DVB - C untuk rangkaian kabel, DVB - T untuk rangkaian daratan. Televisyen terestrial digital menyokong dua jenis perkhidmatan iaitu DVB-T dan DVB-T2. DVB-T2 dianggap sebagai digital sistem televisyen terestrial yang paling terkini. Ia menyokong perkhidmatan televisyen definisi tinggi (HDTV) menggunakan spektrum frekuensi yang sama, dan prestasi yang lebih baik dalam persekitaran mudah alih. Tambahan pula, pada bulan Jun 2014, versi-1 daripada DVB-T2 spesifikasi teknikal Penerima Decoder Bersepadu (IRD) bagi negara-negara ASEAN telah dikeluarkan dengan tujuan meraih manfaat bagi skala ekonomi yang berpatutan IRDs DVB-T2 dan juga memudahkan penggunaan TV digital di negara-negara anggota ASEAN. Walau bagaimanapun, salah satu cabaran DVB-T2 adalah mod dan parameter sistem yang menyediakn banyak pilihan memerlukan pemilihan yang tepat untuk setiap aplikasi yang berbeza. Oleh itu, projek ini mengkaji dan meneliti melalui simulasi prestasi BER berbanding SNR bagi spesifikasi IRD. Ini termasuk pelbagai jenis saluran: Gaussian, Rician dan Rayleigh. Simulasi tambahan untuk senario yang berbeza telah dijalankan bagi kes-kes yang berbeza selang pengawal, kadar kod, kesan putaran buruj untuk skim modulasi berbeza. Platform perisian biasa (CSP) telah dibangunkan untuk simulasi DVB-T2 dan Matlab 2014 telah digunakan untuk menjalankan simulasi. Hasil simulasi menunjukkan terdapat perbezaan antara BER berbanding prestasi C / N untuk spesifikasi IRD. Daripada keputusan simulasi, ia menunjukkan bahawa IRD boleh digunakan untuk pelbagai jenis perkhidmatan dan boleh menyokong kedua-dua peranti tetap dan mudah alih berdasarkan senario atau keperluan system.

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LIST OF ABBREVIATION

AGWN	-	Additive White Gaussian Noise
BCH	-	Bose-Chaudhuri-Hocquengham
BER	-	Bit Error Ratio
BBFRAME	-	Base Band Frame
C/N	-	Carrier-to-Noise Ratio
C/R	-	Code Rate
CSP	-	Common Software Platform
DTT	-	Digital Terrestrial Television
DVB-C	-	Digital Video Broadcasting-Cable
DVB-H	-	Digital Video Broadcasting-Handheld
DVB-S	-	Digital Video Broadcasting-Satellite
DVB-T	-	Digital Video Broadcasting-Terrestrial
DVB-T2	-	DVB-2nd Generation Terrestrial
ETSI	-	European Telecommunications Standards Institute
FEC	-	Forward Error Correction
FECFRAME	-	Forward Error Correction Frame
FFT	-	Fast Fourier Transform
GI	-	Guard Interval
HDTV	-	High DTV
IFFT	-	Inverse Fast Fourier Transform
IRD	-	Integrated Receiver Decoder
LDPC	-	Low Density Parity Check
OFDM	-	Orthogonal Frequency Division Multiplexing
PLP	-	Physical Layer Pipes
PAPR	-	Peak to Average Power Ratio
QPSK	-	Quaternary Phase Shift Keying
SDTV	-	Standard Definition Television

SFN	-	Single Frequency Network
SNR	-	Signal to Noise Ratio
16-QAM	-	16-ary Quadrature Amplitude Modulation
64-QAM	-	64- ary Quadrature Amplitude Modulation
256-QAM	-	256-ary Quadrature Amplitude Modulation

LIST OF SYMBOLS

Δf	-	Shift in frequency
v	-	Speed of light
Φ	-	Angle of incidence of echo
R_s	-	Symbol rate
n	-	Number of bit per carrier
CR_1	-	Inner code rate
CR_{RS}	-	Reed Solomon code rate
T_U	-	Duration of useful symbol
T_S	-	Symbol duration
R_U	-	Useful net data rate
N_{ldpc}	-	Length if LDPC
t_c	-	twisting parameter

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years wireless networks have experienced massive advancement as a result of increased demand for mobile data, emergency of new services such as internet of things, machine-to-machine communication. Also the use of digital television in consumer's homes has led to a new kind of service known as "wireless video". Digital video broadcasting is used for digital television and is a transmission scheme based on moving pictures expert group (MPEG-2) video compression. The interesting features of DVB are the ability to deliver superior picture quality which can be viewed in standard format or wide screen (16:9) format along with mono, stereo and surround sound. The DVB standards are classified into three categories of traditional broadcast networks which are DVB – S for satellite network, DVB – C for cable network, DVB – T for terrestrial network. The digital terrestrial television supports two types of services which are DVB-T and DVB-T2. DVB-T2 is considered as the most advanced digital terrestrial television system. It supports either or any combination of SD, HD, UHD, and mobile TV. It offers more robustness, flexibility and is considered to be at least 50% more efficient than DVB-T. The DVB-T standard is based on the orthogonal division multiplexing (OFDM) multi carrier modulation scheme. The transmission data stream is distributed over a set of orthogonal subcarriers equally spaced in pre-assigned VHF and UHF channels. Each subcarrier is then digitally modulated according to a QPSK, 16-QAM or 64-QAM scheme. The number of carrier can be set according to two modes of operation: 2K mode and 8K mode. Just like the DVB-T, DVB-T2 uses OFDM modulation with a large number of sub-carriers. It uses low density parity check (LDPC) coding combined with Bose-Chaudhuri-Hocquengham (BCH) coding which offers a robust signal. In addition, it offers the ability to adjust the number of carriers, guard interval sizes and pilot signals which helps to optimise the overheads for any target transmission channel. The features of DVB-T and DVB-T2 are shown in Table 2.1. Features such as advanced and more flexible coding systems, constellation rotation, extended OFDM, various guard intervals and flexible pilot patterns makes DVB-T2 standard an ideal candidate for high definition television broadcasting (HDTV) networks [1].

Furthermore, several countries have taken steps to switch over from analogue to digital broadcasting based on the International Telecommunication Union (ITU) 2006 directive [2]. The ITU agreed on switchover from analogue to digital broadcasting by 2015 because it will open up new distribution networks and enlarge the opportunities for wireless innovation and services. To this ends, different countries have taken step to change to DVB-T2 although many are yet to implement due to technical challenges as indicated in [2]. Figure 1.1 shows the status of digital TV standard in the world and Table 1.1 shows the specified DVB-T2 standard adopted in different countries. In June 2014, version-1 of DVB-T2 Integrated Receiver Decoder (IRD) technical specification for ASEAN countries was released with the objective of reaping the benefits of economies of scale for affordable DVB-T2 IRDs so as to facilitate the adoption of digital TV in (Association of Southeast Asian Nations) ASEAN members' countries.

Hence in this project we intend to investigate the performance of the DVB-T2 system using different channel models and selected system parameters. The parameters are limited to the IRD specifications for ASEAN countries which was released in June 2014.

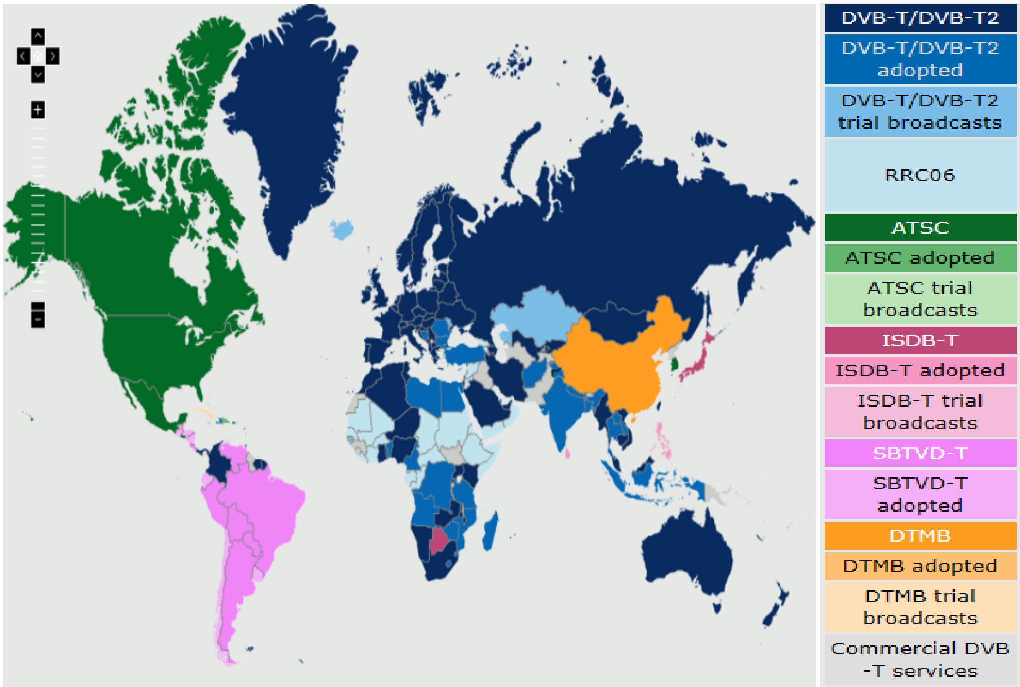

Figure 1.1 Digital TV Standard in the World (dtvstatus.com, 2013)

Table 1-1. Specific Standard of DVB-T2 across different countries [3]

Countries	Specific Standard of DVB-T2
New Zealand	GI 1/32 , 32K , CR 2/3 , 256-QAM , PP6
UAE	GI 1/32 , 8K , CR 4/5 , 64-QAM , PP7 GI 1/128 , 32K , CR 2/3 , 256-QAM , PP7
Vietnam	GI 19/256 , 32K , 64-QAM , 8 MHZ , SFN
UK	GI 1/128 , 32K , CR 3/5 , 256-QAM , MFN
Italian	GI 1/16 , 32K , CR 3/5 256-QAM SFN
Colombia	GI 1/8 , 16K , CR 2/3 , 64-QAM , PP3
Ghana	GI 1/16 , 32K , CR 3/5 , 64-QAM , PP4
Turkey	GI 19/256 , 32K , CR 2/3 , 64-QAM , PP4
Thailand	GI 19/128 , 16K , CR 3/5 , 64-QAM , PP2
Russia	GI 1/16 , 32K , CR 4/5 , 64-QAM , PP4

1.2 Problem Statement

To meet the requirement of the DVB-T2 standard, the communication channel plays a very important role. The communication channels are subject to different environmental factors such as multipath propagation and echoes from object which leads to delayed signal arrivals. The multipath propagation causes fading, a phenomena that alters the amplitude, phase of the transmitted wave at the receiver due to delay in transmitted signal. In addition, DVB-T2 supports a large number of options such as (Pilot Patterns, Guard Interval Fraction, Rotated Constellations, FFT sizes) that can be chosen to optimise system suitable for different uses, from low data rate mobile services, to HDTV program broadcasting in fixed reception.

Furthermore, in June 2014, version-1 of DVB-T2 Integrated Receiver Decoder technical specification for ASEAN was released with the objective of reaping the benefits of economies of scale for affordable DVB-T2 IRDs in ASEAN so as to facilitate the adoption of digital TV in ASEAN members' countries [4]. There is currently to paper published to investigate the performance of the DVB-T2 mode/parameters specified in the technical specification under the different channel models for the IRD. The performance in terms of bit error rate and carrier to noise ratio (C/N) under the different channels AWGN, Rician and Rayleigh needs to the simulated so as to ascertain what parameters give best performance in terms of BER and SNR.

1.3 Research objectives

The research objectives are as follows:

(1) To determine the best SNR for the IRD specification for the Gaussian, Rician and Rayleigh channel models through simulation.

(2) To simulate the communication system over the different channels AGWN, Rayleigh and Rician using the IRD system parameters specified in the technical code SKMM MTSFB TC T004:2013 for Malaysia [4].

(3) To compare and analyse the BER versus SNR performance from the simulated result using the different channel model and different parameters such as code rates, modulation type, guard interval and effect of rotation of modulation scheme as specified in Table 2.2

4) To compare and analyse the BER vs SNR for defined scenario and existing scenario from [5, 6].

1.4 Scope

The scope of this project is presented here. First the project work will cover study and understanding through literature the basic theory of channel models, DVB-T2 system and associated parameters. In addition the Common simulation platform (CSP) developed for DVB-T2 will be studied to know how to simulate and plot results. Thereafter, simulation of the DVB-T2 system using the parameters defined specified in Table 2.1 will be carried out. The simulation will be carried out using Matlab and CSP tool box developed for DVB-T2 standard. The results of the simulation will be presented, followed by analysis and discussion. The finding of the result will be presented in this project report.

1.5 Structure of project report

In **chapter 2** covers the literature review of this project. A comparison of the DVB-T and DVB-T2, basic principle of the DVB-T2 system and parameters was presented. Related works of the performance analysis from the literature was also presented. **Chapter 3** covers the methodology of this project. The operational frame work of the whole project was presented using a flow chart and different stages of the work were identified. The simulation were in two stages. First is the simulation for best SNR for all the different scenarios which include the all guard intervals and code rate under the three types of channels: Gaussian, Rician and Rayleigh. Second stage is the simulation for defined scenario using some parameters form IRD specification. The results of the defined scenario was also compared with scenario from reference literature. **Chapter 4** is the result and discussion. The result of from the two stages of simulation was presented in graphical forms and tabular forms were necessary. Analysis were made based on the BER and C/N performance. Finally **chapter 5** concluded this report and future works were suggested.

1.6 Summary

In this chapter, digital terrestrial television standards were identified with a focus on the DVB-T2. IRD and DVB-T2 standards were introduced. The problem statement, objectives, scope and outline of report was presented.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the background study for DVB-T and DVB-T2 is provided. The limitation of DVB-T and enhancement in DVB-T2 are highlighted. The system model of DVB-T2 and system parameters are presented. The use of OFDM technique in achieving high bit rates in DVB-T2 transmission is discussed. In addition, related works in literature is reviewed.

2.2 Background study

In this section, the basic theory of the DVB-T and DVB-T2 is provided. This includes the difference between DVB-T and DVB-T2, basic principles of DVB-T2 operations and selection of parameters.

2.2.1 DVB-T

Digital Video Broadcasting-Terrestrial (DVB-T) is the most widely deployed digital terrestrial television system worldwide with services on air in over thirty countries [7]. The DVB-T terrestrial digital video broadcasting standard (ETSI, 1997) has been used to replace many analogue systems around the world. The benefit of digital coding and transmission technique which it offers enabled perfect signal recovery in all the serviced areas. The digital data sequences, which contain MPEG video, audio and other information streams, are transmitted using coded orthogonal frequency division multiplexing (COFDM) modulation. The information bits are coded, interleaved, mapped to a quadrature amplitude modulation (QAM) constellation and grouped into blocks. All the symbols in a block are transmitted simultaneously at different frequency subcarriers using an inverse fast Fourier transform (IFFT) operation. The number of IFFT points, which can be either 2048 (2K) or 8192 (8K), determines the transmission mode and the number of the available subcarriers in the transmission bandwidth. Some of these subcarriers are not used to allow for guard frequency bands whereas others are reserved for pilot symbols, which are necessary to acquire the channel information required for signal recovery. DVB-T was seen to offer many benefits, however certain limitations were faced when compared with new wireless transmission techniques. The limitations include low bit rates and transmission channels, inability to support the broadcast of high-definition television (HDTV) services using same frequency spectrum. The DVB-T had a very bad performance in mobile or portable environments, so it could not be properly implemented in scenarios such as moving vehicles. Last but not least, the deployment of the DVB-T network has been and still is a true nightmare in single frequency networks (SFN) scenarios, where interferences between repeaters, which transmit the same information on the same frequency bands, may destroy the received signal avoiding its reception in areas with good reception levels. As a result of this limitations, and the advances in signal processing, modulation and coding, the DVB consortium published a draft standard named DVB-T2 aiming to extend the capabilities of the aforementioned DVB-T standard. The DVB-T2 Standard is discussed is the next section.

2.2.2 DVB-T2

As a result of the increased interest in digital television all around the world and in order to satisfy growing demands, DVB organization decided to design a new physical layer for digital terrestrial broadcast television. The main goals of the new standard were to achieve more bit-rate compared to the first generation DVB-T standard, targeting HDTV services, improve SFN, provide service specific robustness, and target services for fixed and portable receivers. As a result of the work carried inside the DVB organization the DVB-T2 specification was released in June 2008 [8]. The DVB-T2 was designed to allow for some mobility, with the same spectrum characteristics as DVB-T. Table 2.1 shows the comparison of DVB-T and DVB-T2 standard specification. The table shows the new improved options in DVB-T2.

Table 2-1: new improved options in DVB-T2

	DVB-T	**DVB-T2 (new/improved options in bold)**
FEC	Convolutional Coding+Reed Solomon 1/2, 2/3, 3/4, 5/6, 7/8	**LDPC + BCH** 1/2**, 3/5,** 2/3, 3/4**, 4/5,** 5/6
Modulation orders	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM**, 256QAM**
Guard Interval	1/4, 1/8, 1/16, 1/32	1/4**, 19/128,** 1/8**, 19/256,** 1/16**,** 1/32**, 1/128**
FFT Size	2k, 8k	**1k,** 2k**, 4k,** 8k**, 16k, 32k**
Scattered Pilots	8% of total	**1%, 2%, 4%,** 8% **of total**
Continual Pilots	2.0% of total	**0.4%-2.4% (0.4%-0.8% in 8K-32K)**
Bandwidth	6, 7, 8 MHz	**1.7, 5,** 6, 7, 8**, 10 MHz**
Typical data rate (UK)	24 Mbit/s	40 Mbit/s
Max. data rate **(@20 dB C/N)**	31.7 Mbit/s (using 8 MHz)	45.5 Mbit/s (using 8 MHz)
Required C/N ratio (@24 Mbit/s)	16.7 dB	10.8 dB

2.2.3 Implementation of DVB-T2

Several countries have adopted and implemented the DVB-T2 according to the ITU directive. Because DVB-T2 has a lot of options, different countries have specified standards. The summary of the standard are shown in Table

2.2.4 Overall DVB-T2 system model

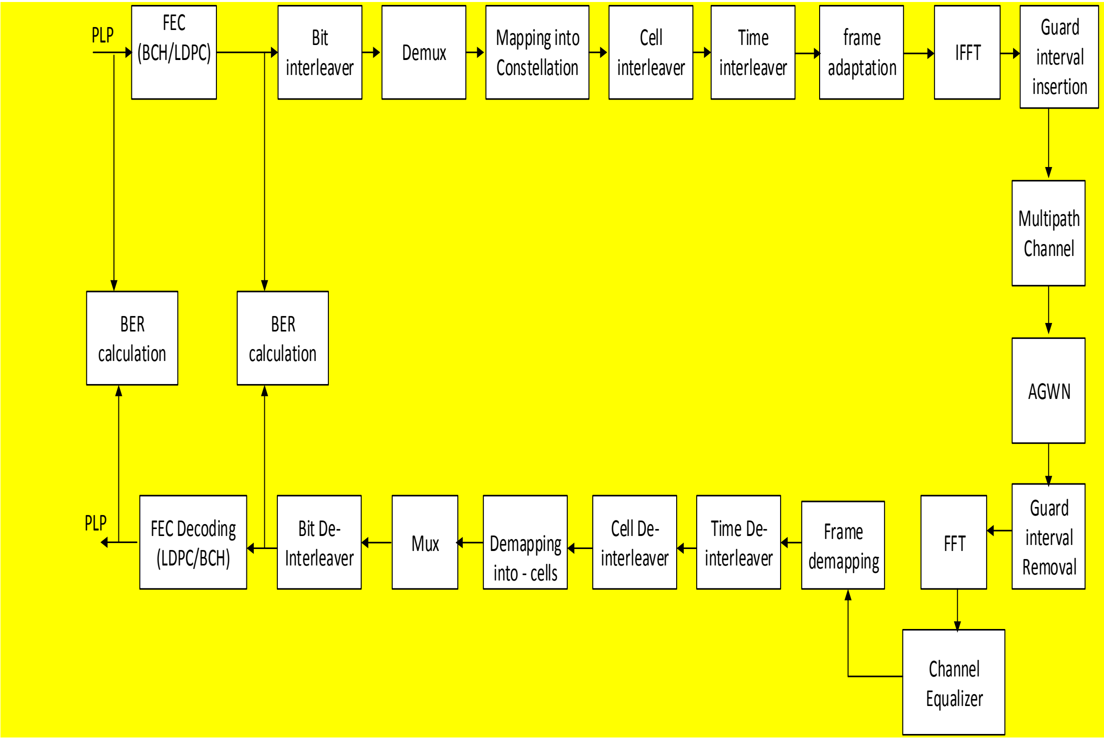

Figure 2.1: DVB-T2 simulated end-to-end system block diagram

The block diagram shown in Figure 2.1 shows the overall model of the DVB-T2. The FEC, bit interleaver, Demux, Mapping into constellation, cell interleaver, time interleaver are subsystem that are part of the Bit Interleaved Coding & Modulation. The description of each of the blocks are presented as follows.

2.2.4.1 FEC

The forward error correction takes as input base band (BBFRAME) and the output is a FECFRAME with length K_{bch} and N_{ldpc} bits respectively performs the following

- Outer Encoding (BCH) – in the outer encoder, Bose – Chaudhuri – Hocquenghem (BCH) is applied to the BBFRAME to generate an error protected packet.
- Inner Encoding (LDPC) – the Low Density Parity Check are applied in the inner encoder in DVB-T2 because of its high error correcting performance. The encoding process starts with appending the parity check bits (BCHFEC) of the BCH outer code after BBFRAME. Then the parity check bits (LDPCFEC) of the LDPC inner code is appended after the BCHFEC. As a result, Error correction coded FECFRAME is obtained output of the inner encoder. The BBFrame and FECFRAME are shown in Figure 2.2.

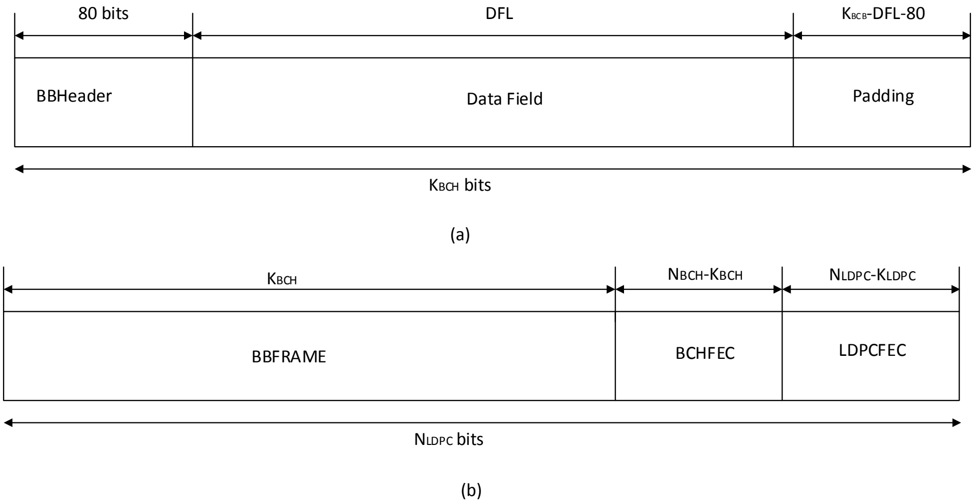

Figure 2.2: (a) BBFRAME format and (b) FECFRAME format [9]

The FECFRAME has two different length N_{ldpc} values which are normal FECFRAME = 64,800 and short FECFRAME = 16,200.

2.2.4.2 Bit Inter-leaver

Bit inter-leaving is used to disperse burst errors and uncorrelated the bits associated with given transmitted symbol. The bit interleaving is only applied to 16-QA modulation, 64-QAM modulation and 256-QAM modulation. The output pf the LPDC interleaving consist of parity interleaving followed by twist column interleaving. The interleaving process is described below:

First the parity interleaving is achieved by:

$$U_i = \lambda_i \quad for \quad 0 \le i \le K_{ldpc} \qquad (2.1)$$

$$U_{Kldpc+360t+s} = \lambda_{Kldpc+Qldpc.s+t} \qquad (2.2)$$

Where $Qldpc$ is defined in Table 2.2, λ is the output of LDPC and U is the output of the inter-leaver.

Secondly, the output of the parity inter-leaver is written into column-twist inter-leaver as column wise by using the twisting parameter t_c as the starting index of the column. After that, the data are read out row-wise as shown in Figure 2.3.

Table 2-2: Qldpc values

Code rate	Qldpc for normal FECFRAME	Qldpc for short FECFRAME
1/2	90	25
3/5	72	18
2/3	60	15
3/4	45	12
4/5	36	10
5/6	30	8

The column twist interleaving configuration for each modulation format is specified in Table 2.3

Table 2-3: Bit Interleaver structure

<table>
<tr><th rowspan="2">Modulation</th><th colspan="2">Rows Nr</th><th rowspan="2">Columns Nc</th></tr>
<tr><td>Nldpc = 64,800</td><td>Nldpc = 16,200</td></tr>
<tr><td>16-QAM</td><td>8100</td><td>2025</td><td>8</td></tr>
<tr><td>64-QAM</td><td>5400</td><td>1350</td><td>12</td></tr>
<tr><td rowspan="2">256-QAM</td><td>4500</td><td>--</td><td>16</td></tr>
<tr><td>--</td><td>2025</td><td>8</td></tr>
</table>

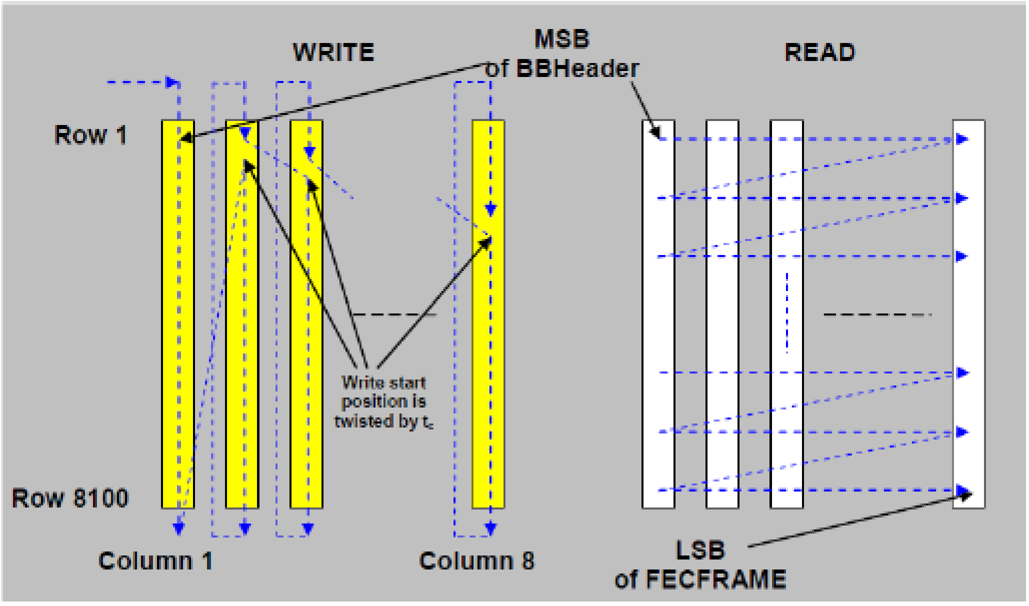

Figure 2.3: Bit interleaving scheme for normal FECFRAME length and 16QAM

2.2.4.3 Demux

The demultiplexer demultiplex the interleaved FECFRAME into parallel cell words which are then mapped into constellations. In the demux process, the output bit stream of the bit interleaving is demultiplexed into $N_{substreams}$ sub-streams as shown in Figure 2.4 and the values of $N_{substreams}$ is defined in table 3.15.

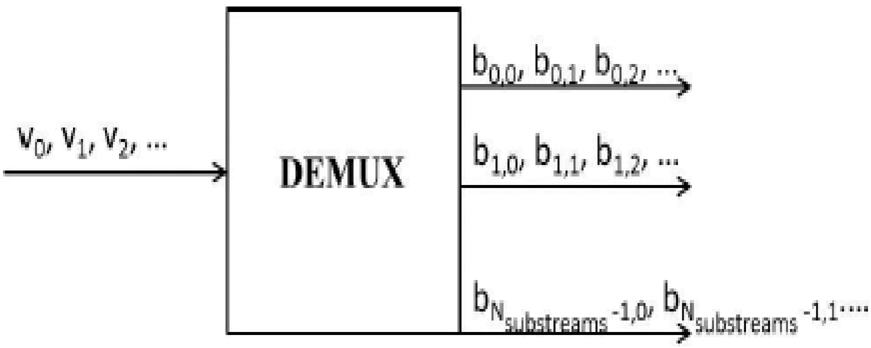

Figure 2.4: Demultiplexing of bits into sub-streams

Table 2-4: Values of parameter Nsubstreamsalues

Modulation	Nldpc	Nsubstreams
QPSK	Any	2
16-QAM	Any	8
64-QAM	Any	12
256-QAM	64,800	16
	16,200	8

2.2.4.4 Mapping into constellation

The parallel cell words from the demultiplexer are mapped into constellation values.

2.2.4.5 Cell inter-leaver

In the Cell inter-leaver, the cells in the FEC code word is spread uniformly. The main purpose of this process is to ensure an uncorrelated distribution of channel distortions and interference along the FEC code word at the receiver. The cell interleaver is defined as follows

2.2.4.6 Time inter-leaver

The time interleaver (TI) operates at the physical layer pipe level. The cell interleaved FEC block at the input of TI, is grouped in interleaving Frames which are mapped onto one or more T2-Frames. Each interleaving frame contains a dynamically variable whole number of FEC blocks. The maximum number of a FEC block is 1023.

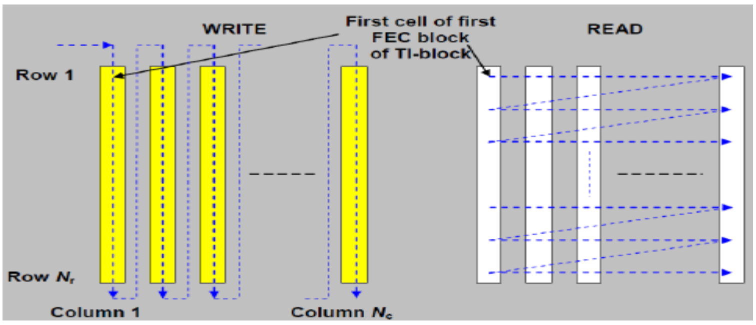

Figure 2.5: Time interleaving scheme for normal FECFRAME length and 16QAM

2.2.4.7 IFFT

In DVB-T2 systems there are six different transmission modes also known as FFT size. The transmission modes are 1K, 2K, 4K, 8K, 16K and 32K. A DVB-T2 transmitted signal is organized in frames. Each frame has duration of T_F and consists of OFDM symbols. N_{T2} frames constitute one super frame. Each symbol is constituted by a set of K_{total} carriers and has duration of T_S. A carrier is composed of two parts which are useful part with duration T_U and guard interval with duration Δ. Some important OFDM parameters are given in Table 2-5.

Table 2-5: OFDM parameters

Parameters	**1K**	**2K**	**4K**	**8K**	**16K**	**32K**
K_{total}	853	1705	3409	6817	13633	27265
$K_{\min}$	0	0	0	0	0	0
$K_{\max}$	852	1704	3408	6816	13632	27265
T_U (μs)	112	224	448	896	1792	3584
Carrier spacing $1/T_U$ **(Hz)**	8929	4464	2232	1116	558	279
Spacing between carriers (MHz) $K_{\min}$ **and** $K_{\max}$	7,61	7,61	7,61	7,61	7,61	7,61

2.2.4.8 Guard interval insertion

The Guard interval are inserted to avoid inter symbol interference. DVB-T2 systems have seven guard interval fractions. For each combination of FFT size and guard interval fractions, the absolute guard interval fractions are given in Table 2-7 expressed in multiples of the elementary period T which is also given in Table 2-6.

Table 2-6: Elementary period as a function of bandwidth

Bandwidth	**1,7Mhz**	**5MHz**	**6MHz**	**7MHz**	**8MHz**	**10MHz**
Elementary period T (μs)	71/131	7/40	7/48	1/8	7/64	7/80

Table 2-7: Duration of Guard Interval of elementary period T

FFT size	**Guard Interval fraction** (Δ / T_U)						
	1/128	1/32	1/16	19/256	1/8	19/128	1/4
32K	256T	1024T	2048T	2432T	4096T	4864T	NA
16K	128T	512T	1024T	1216T	2048T	2432T	4096T
8K	64T	256T	512T	608T	1024T	1216T	2048T
4K	NA	128T	256T	NA	512T	NA	1024T
2K	NA	64T	128T	NA	256T	NA	512T
1K	NA	NA	64T	NA	128T	NA	256T

2.2.4.9 Physical layer pipe

DVB-T2 uses the concept of physical layer pipe (PLP). The PLP allows for service-specific robustness. Every PLP can have its own modulation, FEC code rate and interleaving. All PLPs are broadcast over the same frequency so that it is considered as a single DVB-T2 channel. Figure 2.5 gives an illustration of PLP the concept.

Figure 2.6: PLP concept

Data to be transmitted are converted into DVB-T2 based-band frames (BBFRAMES) which is processed by the FEC coding subsystem. The low density parity check (LDPC) coding combined with Bose-Chaudhuri-Hocquengham (BCH) coding offers excellent performance resulting in a very robust signal reception. The output of the encoded data is bit interleaved. The bit interleaved data are then mapped to coded and modulated FEC blocks by the map bits onto constellation module. An optional module called the constellation rotation with cyclic Q-delay is used to resist the transmission channel with deep fading [10]. The cell inter-leaver spreads the cell words of a FEC block while the time inter-leaver cells of groups of FEC blocks makes up T1-blocks which are forms interleaving frames. The cell mapper assembles the modulated cells into arrays corresponding to OFDM symbols. The OFDM frame adaptation divide modulated stream, carrying useful data, into OFDM symbols and to add the pilots and signalling carriers. After that, the IFFT converts the signal from frequency to time domain and guard intervals are inserted. After carrier modulation, DVB-T2 signal is prepared and transmitted in the broadcasting network. A reverse process is carried out at the receiver.

2.2.5 DVB-T2 system parameters

The DVB-T system parameters are shown in Table 1.2. The forward error correction (FEC) techniques used in the LDPC which offers a significant improvement compared to convolution error correcting scheme used in DVB-T. The FFT size represents different modes which are symbol carriers. Higher value of FFT size 16k and 32k were introduced to increase the length of the guard interval without decreasing spectral efficiency. The modulation order are the constellation sizes. The DVB-T2 operating modes specified in [4] for IRD is shown below shown in Table 2.2.

Table 2-8: IRD DVB-T2 specification

Parameter	Required modes
Transmission mode	32K Normal & Extended
Constellation	QPSK, 16QAM, 64QAM, 256QAM
Constellation Rotation	Rotated and Non Rotated
Code Rate	1/2, 3/5, 2/3, 3/4, 4/5, 5/6
Guard Interval	19/128, 1/8, 19/256, 1/16, 1/32, 1/128
Pilot Pattern	PP1, PP2, PP3, PP4, PP5, PP6, PP7 and PP8
Antenna	SISO & MISO
PAPR	No PAPR & TR-PAPR
FEC Frame Length	16200 & 64800
Input Mode	Input Mode A & B (Single PLP, Multiple PLP)
Baseband Mode	Normal Mode, High Efficiency Mode

2.3 Selection of system parameters

2.3.1 Selection of guard interval (GI)

The GI consists of cyclic continuation of the useful symbol and is inserted before every useful symbol. This enables the reception of multiple signals at the receiver, therefore enabling frequency re-use via single frequency networks. The length of the GI determines the separation distance between adjacent transmission sites operating in SFN. Figure 2.3, illustrates the effect of GI in the DVB-T2 transmission. As the GI reduces, there is decrease in separation distance between transmission sites thereby leading to increase in capacity.

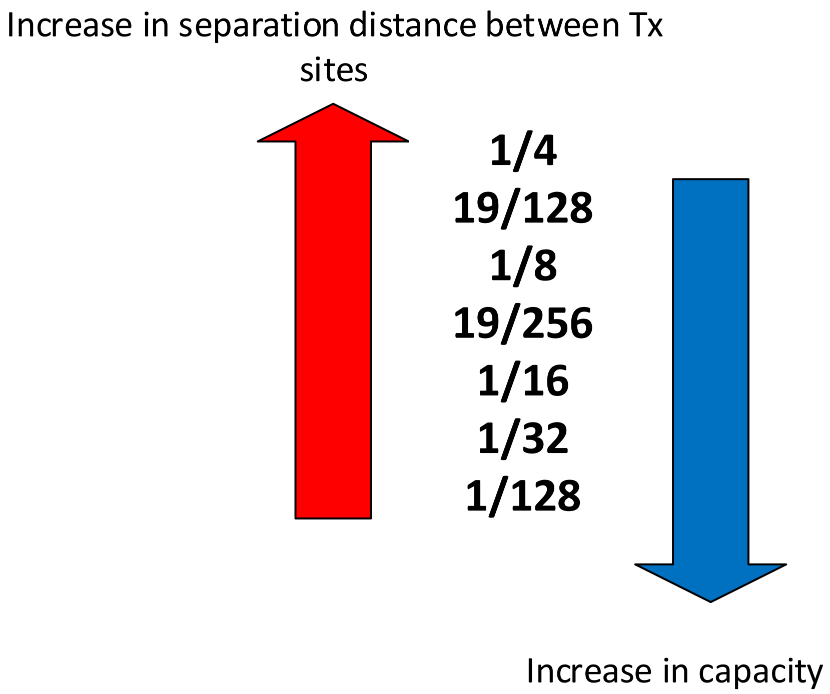

Figure 2.7: Effect of GI in DVBT-2

The distance between the transmitters can be computed using the formula as follows:

$$D = (GI * T_U) * \mathrm{c}$$

(2.3)

Example of computed distance between transmission sites is shown in Table 2.6. The maximum distance is obtainable at higher value of GI.

Table 2-9: Distance between Tx

Distance between the transmitters (D)	**Guard Interval (GI)**	**FFT Size**	
		8K	32K
Maximum Distance	1/4	76.200 Km	268.8 Km
Minimum distance	1/128	2.1 Km	8.4 Km

2.3.2 Selection of Fast Fourier Transform (FFT) Size

The FFT indicates the number of carriers modulated within the channel bandwidth as shown in Table 2.7.

Table 2-10: FTT size

FFT size	**Duration Time – Tu** (μs)	**Number of carriers in normal mode**
1k	112	853
2k	224	1705
4k	448	3409
8k	896	6817
16k	1792	13633
32k	3584	27265

The FFT size must be greater than the number of modulated carriers in order to make the analogue reconstruction filters realizable. Furthermore, the number of modulated carriers in a given bandwidth determines the inter-carrier spacing. The inter-carrier spacing impacts the mobile performance because of Doppler shift which causes inter carrier interference. For instance, mobile reception at high speed 2k FFT will be implemented. The SFN transmit separation distance increases as the FFT size increases however, there is a decrease in Doppler performance as shown in the Figure 2.7.

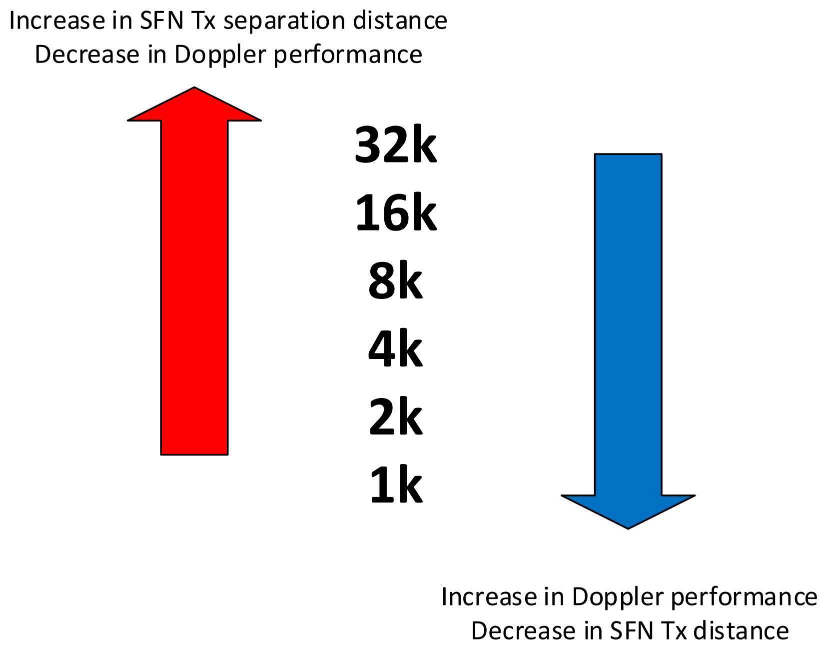

Figure 2.8: Effect of FFT size in DVB-T2

2.3.3 Selection of constellation and effects of rotation and non-rotation

Rotated constellation technique was included in DVB-T2 specification to achieve a better performance in difficult propagation scenarios. It increases the robustness of the receiver in propagation scenarios where there are deep fades and/or erasure events. The principle of the technique is explained as follows: In the non-rotated constellation, the receiver needs both the in-phase (I) and the quadrature (Q) components of one constellation point to identify what information was transmitted. But in the case of rotated constellation, a certain rotation angle is applied in the complex plane to a classical signal constellation such that I and Q components has enough information on its own to determine what symbol was transmitted. This is illustrated in Figure 2.8, where the rotated and classic constellation for QPSK and 16-QAM are plotted. After rotation, interleaving process is performed only over the Q components to allow for separate transmission of the I and Q constellation point in different carriers and time slots. Hence, if any of the components is affected by deep fading of the channel, the other component can be used to recover the transmitted symbol or information. The implementation of the rotated constellation in DVB-T2 is described in [1]. Table 2.8 shows the number of bits for each constellation in DVB-T2.

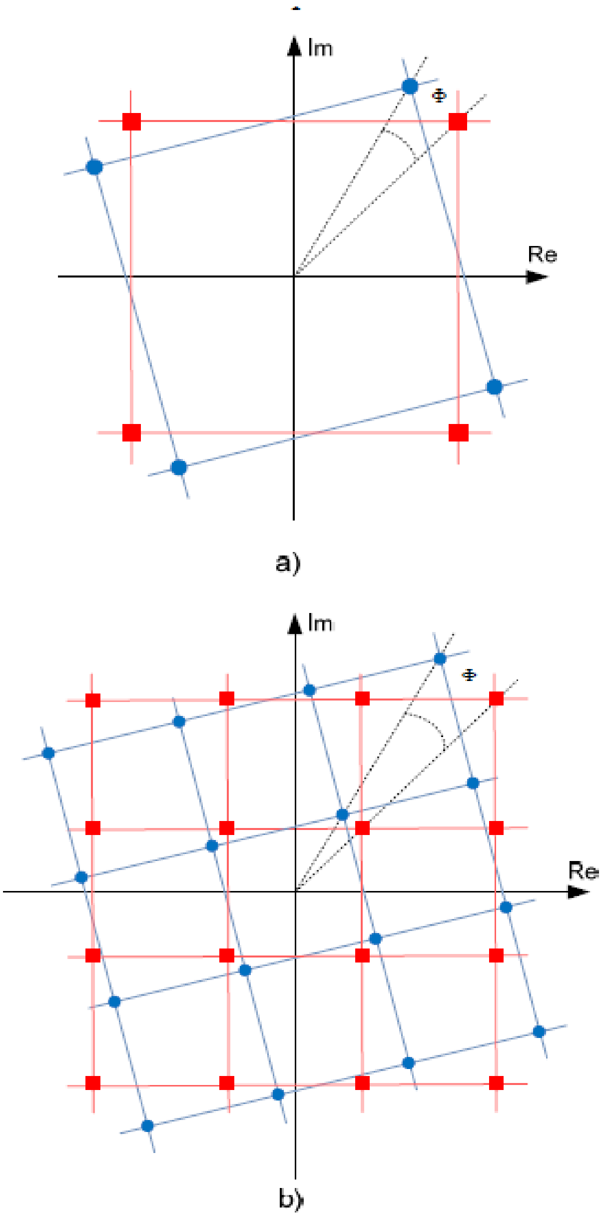

Figure 2.9: (a) Rotated and classic QPSK constellations (b) Rotated and classic 16-QAM constellations. The red square points and blue circles show the conventional and rotated constellation respectively [1].

Table 2-11: Total number of BIT for different constellations

DVB-T2 Constellations	Number of Bits (n)	Rotation angle (degrees)
QPSK	2	29.0
16-QAM	4	16.8
64-QAM	6	8.6
256-QAM	8	atan(1/16)

2.3.4 Selection of pilot pattern

In the coded OFDM system, a large number of closely orthogonal carriers are used to carry data on several parallel channels. Small number of the carriers are allocated to estimate pilot tones which are used to estimate the channel. The DVB-T2 supports eight different pilot patterns. The selection of pilot patterns depends on the selected system configuration and transmission mode: either SISO (Single input single output) or MISO (Multiple input single output).

Figure 2.9 shows the graphical representation of the pilot patterns structure, without continual pilots and reserved carriers. The patterns shows gradual decrease of the number of the scattered carriers (pilots) where theoretically the best operation is expected in PP2 and worst-case is PP8. Each of the patterns are more suited to particular channel types than others and this gives the network planner more freedom to match the transmission mode and pilot pattern to the intended transmission channel or payload requirement [11]. An overview of the eight different pilot patterns are shown in Table 2.9

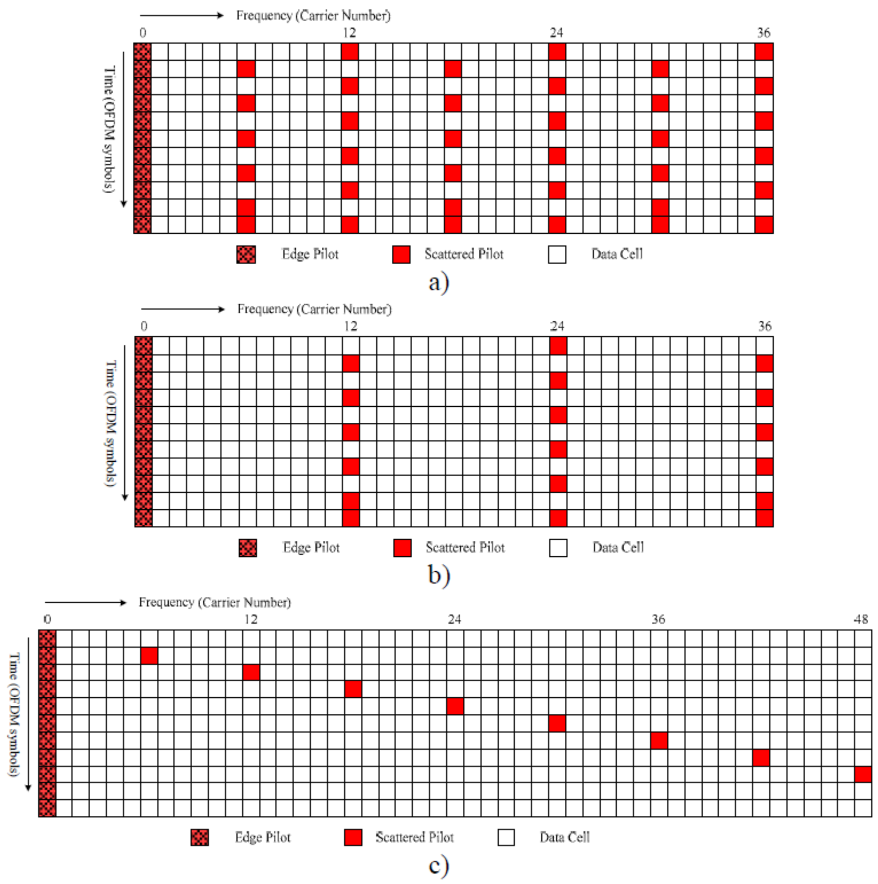

Figure 2.10: Structure of the SISO scattered pilot pattern a) PP2 b) PP4 and c) PP8 [5]

Table 2-12: Overview of different pilot patterns in DVB-T2

Pilot pattern	Separation of pilot bearing carriers (Dx)	No. of symbols forming one scattered pilot sequence (Dy)
PP1	3	4
PP2	6	2
PP3	6	4
PP4	12	2
PP5	12	4
PP6	24	2
PP7	24	4
PP8	6	16

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