EMITTER International Journal of Engineering Technology
Vol. 4, No. 2, December 2016
ISSN: 2443-1168

Performance Analysis of Video Transmission Using Sequential Distortion Minimization Method for Digital Video Broadcasting Terrestrial

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Abstract

This paper presents about the transmission of Digital Video Broadcasting system with streaming video resolution 640x480 on different IQ rate and modulation. In the video transmission, distortion often occurs, so the received video has bad quality. Key frames selection algorithm is flexibel on a change of video, but on these methods, the temporal information of a video sequence is omitted. To minimize distortion between the original video and received video, we aimed at adding methodology using sequential distortion minimization algorithm. Its aim was to create a new video, better than original video without significant loss of content between the original video and received video, fixed sequentially. The reliability of video transmission was observed based on a constellation diagram, with the best result on IQ rate 2 Mhz and modulation 8 QAM. The best video transmission was also investigated using SEDIM (Sequential Distortion Minimization Method) and without SEDIM. The experimental result showed that the PSNR (Peak Signal to Noise Ratio) average of video transmission using SEDIM was an increase from 19,855 dB to 48,386 dB and SSIM (Structural Similarity) average increase 10,49%. The experimental results and comparison of proposed method obtained a good performance. USRP board was used as RF front-end on 2,2 GHz.

Keywords : DVB-T, OFDM, SEDIM, USRP, Convolutional Code

1. INTRODUCTION

Increasingly, an important part of consumer multimedia services are video broadcasting. Digital video broadcasting (DVB) is a common standard that is accepted internationally for video broadcasting. DVB systems distribute data using a variety of approaches, satellite (DVB-S), cable (DVB-C), terrestrial (DVB-T) and digital terrestrial for hand held (DVB-H). Moving from analog to digital transmission enables better picture quality and also new types of services that could be transmitted using digital video broadcasting terrestrial (DVB-T)standard.

Digital Video Broadcasting Terrestrial (DVB-T) is a digital transmission system that delivers a series of data at the symbol rate. DVB-T using Orthogonal Frequency Division Multiplexing (OFDM) in order to help the receiver to counter the effect of multipath environment. As demand for bandwidth is increasing, OFDM is introduced as one of the solutions to enable bandwidth efficiency and robustness due to intersymbol interference (ISI) in the consequence of multipath fading environment [1]. Dividing high rate data stream into parallel low rate data streams using Fast Fourier Transform is the main principle of OFDM [2].

DVB standard uses MPEG-2 compression standard as a data container. With the conception of the transmission of digital information can be done flexibly without needed to impose limits what type of information will be stored in the container the data. The MPEG2 transport streams packets of constant length that have been optimized for DVB-T. Length MPEG-2 TS packet is 188 bytes,consisting of 4 byte header and an 184 byte payload. The payload consists of video, audio or data in general, while the header is composed of various essential items for packet transmission. Protocol and format of TS to DVB-T are compatible parts in the MPEG-2 specification defined in ISO / IEC 13818-1. This format is based on the approach to the transport stream packet length which is fixed and has been optimized for DVB-T.

In the video transmission, distortion often occurs. Key frames selection algorithm is flexibe on an change of video but on these method the temporal information of a video sequence is omitted. To minimizes distortion between the original video and received video, we purpose to add methodology using sequential distortion minimization algorithm. Its aim is to create a new video, better than original video without significant loss of content between the original video and received video, fixed sequentially. The ratio between the temporal duration of the original video and received video is equal to $\alpha \in [0,1]$. The number frames of original video denote as N, so the number frame of received video consists of $\alpha.N$ as representative key frames. The real speed of the new video has been increased by the factor of $1/\alpha$ on average.

To transmit DVB-T system signal based on OFDM using Universal Software Radio Peripheral (USRP). USRP is RF front end which can be used for good performance in wireless implementation.

This paper is organized as follows. In Section I we present introduction. Related work of this research is described in Section II. Then, in Section III, we explain our proposed method. In section IV, we explain about the DVB-T system, shot detection, sequential distortion minimization method, OFDM system, Convolutional code and USRP system. Then, system implementation is described in Section V. In Section VI, we discuss the experimental result. Finally, our conclusion is presented in Section VII.

2. RELATED WORKS

Video distortion often occurs on video transmission. The selection of key frames is usually done to minimize video distortion. The most of key frames selection techniques assume that the video has been segmented into shots and then extracted within each shot a small number of representative key frames. A shot can be defined as a sequence of frames that are (or appear to be) continuously captured from the same camera. Key frames can be defined as a subset of a video sequence that can represent the video visual content as close as possible, with a limiting number of frames [7]. Key frames selection approaches can be classified into: cluster-based methods, energy minimization-based methods and sequential methods. The clustering techniques take all the frames of a shot together and classify them according to their content similarity. Then, the key frames are determined as the representative frame of a cluster. The disadvantage of these approaches is that they ignore the temporal information of a video sequence.

Costas Panagiotakis, Nelly Ovsepian, and Elena Michael proposed video synopsis based on a sequential distortion minimization method. The main goal is to select from a video the most significant frames in order to broadcast so that the visual content distortion between the initial video and the synoptic video is minimized[4]. The proposed method sequentially minimizes this distortion, resulting high performance in any value of the parameter α that controls the number of frames of video synopsis. Furthermore, the method can be used in any video content description.

P. Goudarzi, M.Hosseinpour use distortion minimization for transmitted video sequence in Mobile Ad hoc Network. Intrinsic high levels of packet error probability in Mobile Ad hoc Network (MANETs) can cause high levels of distortion based on the position of packet loss in transmitted frames. Hence, exact modeling of the impact of packet loss on video quality and the resulting distortion is an important task. Many conventional distortion modeling techniques simply consider a linear relationship between the packet loss and distortion, which is inaccurate. The main contributions of the current work are twofold. At first, an accurate model has been developed, which can capture the exact effect of network packet loss on video quality performance (and hence on the QoE) with Group Of Picture (GOP)-level granularity. Then, based on this model, an optimal bandwidth allocation strategy is developed in MANETs, with which, based on some network-specific constraints, the loss-induced distortion associated with a video source is minimized, using some cross-layer design techniques. Finally, the resulting optimal rates can be used as rate-feedbacks for on-line rate adaptation of an appropriate video encoder, such as H.264/AVC.

In this research, we purposed performance analysis of video transmission using sequential distortion minimization method for digital video broadcasting terrestrial and implemented into USRP as RF front end.

3. ORIGINALITY

This paper presents performance analysis of video transmission using sequential distortion minimization method for digital video broadcasting terrestrial with good performance on IQ rate and modulation. DVB standard uses MPEG-2 compression standard as a data container so the transmission data can be done flexibly. In addition, method using sequential distortion minimization algorithm resulted a new video according to a given parameter α for the best performance on digital video broadcasting terrestrial system. The method is divided into several steps. The first is estimated Color Layout Descriptor (CLD). Then, shot detection uses lightness histogram of each frame with next one. Sequential Distortion Minimization algorithm for the new video is select the number of frames for the shots so that the distortion between the original video and new video is sequentially minimized. Digital video broadcasting constructed using Labview platform and implemented in real condition using NI USRP-2920 on 2,2 GHz carrier frequency.

4.SYSTEM DESIGN

4.1 DVB-T System Overview

DVB-T is stands for " Digital Video Broadcasting — Terrestrial " it is the DVB European-based consortium standard for the broadcast transmission of digital terrestrial television that was first published in 1997 and first broadcasted in the UK in 1998. This system transmits compressed digital audio, digital video and other data in a MPEG transport stream, using coded orthogonal frequency-division multiplexing (COFDM or OFDM) modulation.

In the DVB standard using MPEG-2 compression standard as a data container. With the conception of the transmission of digital information can be done flexibly without needed to impose limits what type of information will be stored in the container the data. The MPEG2 transport streams packets of constant length that have been optimized for DVB-T. Length MPEG-2 TS packet is 188 bytes, consisting of 4 byte header and a 184 byte payload. The payload consists of video, audio or data in general, while the header is composed of various essential items for packet transmission.

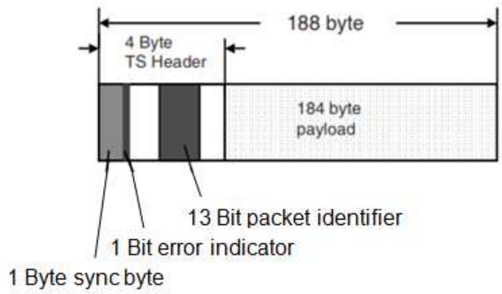


Figure 1. MPEG2 Transport Stream Packets

In **Figure 1** can be explained some of the functions parts of the header. The first header byte is the length of the packet sync byte with 8 bits. Sync byte is used for synchronization or the initial identification of a transport stream packet, while transport error indicator is used to identify the error bit in the TS packet. A packet identifier (PID) has a length of 13 bits package, serving to identify the TS packets carrying data of the same elementary stream. Protocol and format of TS to DVB-T are compatible parts in the MPEG-2 specification defined in ISO / IEC 13818-1. This format is based on the approach to the transport stream packet length which is fixed and has been optimized for DVB-T.

4.2 Shot Detection

The aim of shot detection is to find out the percentage of the frames of each shot that are capable enough to represent the whole shot. The equation can be written as follows :

$$L_k = \sum_{i \in SHk} d(i, i+1) \quad (1)$$

where :
L*k* is the sum of sequential visual changes of shot *k*
SH*k* denotes the set of frames of shot *k*

4.3 Sequential Distortion Minimization

To minimize the distortion between the original video and new video is select b_k frames for the *k* shot. Initially, we set CAN_k = SH*k* and $S_k = Ø$ denoting as the frames of new video of shot *k.* For each shot *k* we iteratively select the frame *f* from CAN_k so that if we include it in set S_k the new video distortion is minimized. Then remove it from set CAN_k and we add it to set S_k :

$$f = argmin_{u \in CAN_k} \sum_{i \in SH_k} D(SH_k, S_k \cup u) \quad (2)$$

$$CAN_k = CAN_k - \{ f \}, \qquad S_k = S_k \cup f$$

CAN_k becomes empty when shot *k* becomes b_k. The process continues until the number of key frames of video synopsis becomes α.N. Scheme of video sequential distortion minimization can be seen in Figure 2.

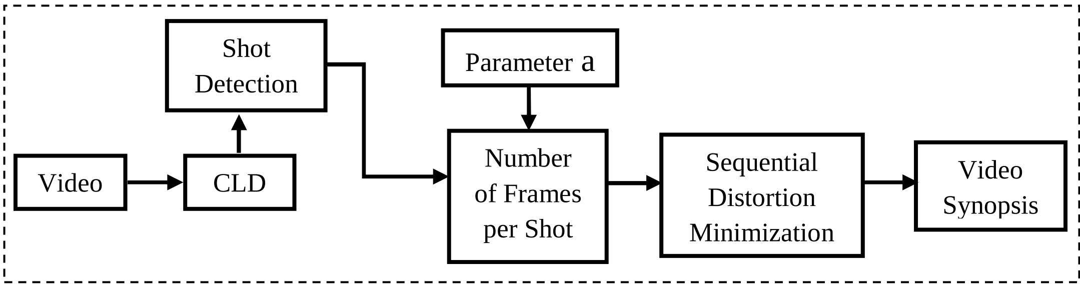


Figure 2. Scheme of video sequential distortion minimization[4]

4.4 Orthogonal Frequency Division Multiplex (OFDM)

OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier transmission technique, where inter subcarrier one another mutually orthogonal. Due to the nature of this orthogonality between adjacent subcarriers can be made without causing overlapping intercarrier interference (ICI). This would make OFDM has higher spectral efficiency.

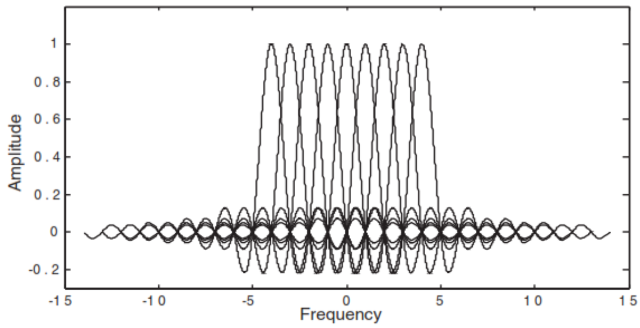


Figure 3. OFDM Signal spectrum

OFDM is a modulation technique that is used for DVB-T standard. With OFDM modulated data are transmitted in parallel via subcarriers.The concept of OFDM is to divide the data rate wideband information signal into parallel rows of data with a data rate that is lower than parallel data is modulated with mutually orthogonal subcarriers. This is one of the advantages of OFDM since the original channel is frequency selective fading will be perceived as flat fading by each subcarrier, so the signal distortion due to multipath fading canal treatment is reduced. To shorten the computing time can be implemented algorithm fast Fourier transform (FFT).

The disadvantage of OFDM is the peak average power ratio, this is because the power of the transmitted signal is the sum of the power of the subcarrier so the impact on the power amplifier. The expression for one OFDM symbol starting at t = ts as follows:

$$s(t) = Re\left\{\sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i+N_s/2} \exp\left(j2\left(f_c - \frac{i+0.5}{T}\right)(t-t_s)\right)\right\}, t_s \leq t \leq t_s + T \quad (3)$$

$s(t) = 0, t < t_s$
$t > t_s + T$

Where :
d_i = complex modulation symbol
N_s = number of subcarriers
T = symbol duration
f_c = frequency carrier

IFFT and FFT process is key in OFDM. IFFT serves as a symbol of manufacture (modulator) OFDM and FFT as decomposers of OFDM symbols (demodulator) [6]. FFT and IFFT equation can be written as follows.
FFT :

$$x(k) = \sum_{n=0}^{N-1} x(n) \sin\left(\frac{2\pi kn}{N}\right) + j\sum_{n=0}^{N-1} x(n) \cos\left(\frac{2\pi kn}{N}\right) \quad (4)$$

IFFT :

$$x(k) = \sum_{n=0}^{N-1} x(n) \sin\left(\frac{2\pi kn}{N}\right) - j\sum_{n=0}^{N-1} x(n) \cos\left(\frac{2\pi kn}{N}\right) \quad (5)$$

Where :
x(k) = number of FFT/IFFT
N + number of subcarriers

4.5 Convolutional Code

The Convolutional code sequence is generated by passing the information to be sent via a shift register in the form of FlipFlop. In general, the shift register consists of K (k-bit) stage and n function of linear algebraic generators. Input data to the encoder in the form of binary numbers, shifted into and along the k-bit shift register at that time. The number of output bits for every k-bit input sequence is n bits. K parameter called length limit of convolutional codes. In the convolutional encoder circuit, there are two basic components, namely the shift register FF and ex-or gate, where the ex-or gate is a component adder. **Figure 4** is an example of a form of convolutional encoder circuit generator that consists of 2 pieces of shift registers.

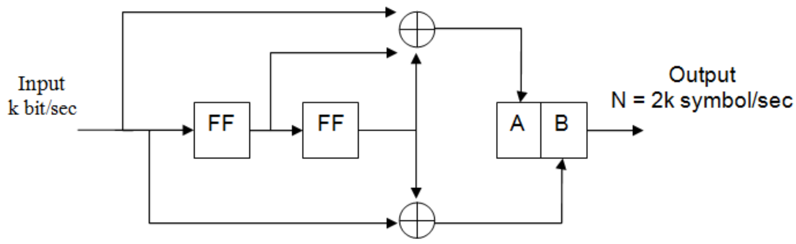


Figure 4. Convolutional code circuit generator

The output of the convolutional encoder and then through the process of modulation and transmitted through the channel, on the receiver side through the demodulation process and then go on the convolutional decoder. In this part encoder must begin and end at a known state so that the decoder can be obtained by a sequence of bits are correct.

4.6 Universal Software Radio Peripheral (USRP)

USRP is a flexible radio that turns a standard PC into prototyping platform. Manufactured by National Instrument (NI), USRP 2920 paired with NI LabVIEW software.Tuneable center frequency from 50 MHz to 2,2 GHz covering FM radio, GPS, GSM, radar and ISM bands, NI USRP 2920 transceivers provide relevant, laboratory learning in RF and communications experimentation in multiple frequency bands.

5. IMPLEMENTATION

This research analyzes the performance of video transmission using sequential distortion minimization method for digital video broadcasting terrestrial, furthermore implements the DVB-T system using USRP. The transceiver uses NI-USRP 2920 and LabVIEW platform. The process begins with connect the USRP transceiver to PC and continue with setting USRP IP address on transmitter and receiver side. After that on the transmitter side,configure the signal such as Tx IQ Sampling Rate, Tx Gain and Tx Antenna, also on the receiver side. The next step is open file video that we would like to transmit. After video compress based on standard compression DVB, MPEG2, Shot detection process is then performed. The parameter α given as a number of frames per shot to the new video. Shot detection is for sharp shot change only, using the chi-squared distance between of the lightness histogram of each frame with the next one. Then produce several of frames shot that capable to representing the whole shot. Next step is minimized distortion between new video and original video with select b_k frames for the k shot. After distortion has minimized, video entering OFDM system and then encoding the file source.Bits of data are encoded using the convolutional code with 1/2 rate and constraint length 3. The OFDM symbols are constructed with a number of FFT 2048 and using modulation 8 QAM. Zero padding is added 232 zeroes as start symbol and 231 zeroes as stop symbol with 1 zero at DC carrier.Then cyclic prefix is inserted 504 bits from duplicating the last OFDM symbols to beginning OFDM symbols. Then the digital signal is converted to analog signals with carrier frequency 2,2 GHz and transmit using USRP as RF front end.

The signals are received and converted to digital signals. USRP initialize with open Rx session and signal configure. On receivers side processing symbol OFDM becomes to beginning the process on the transmitter. The transmission process can be seen in Figure 5 and Figure 6.

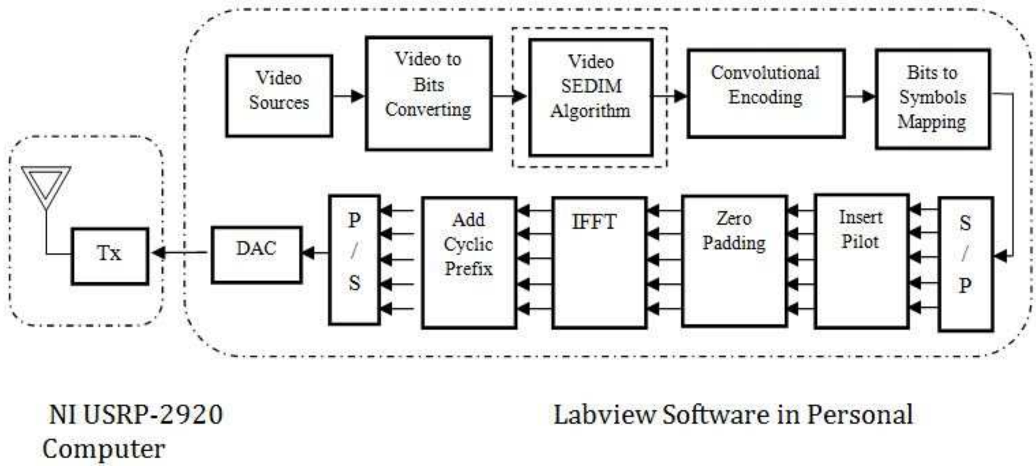


Figure 5. Transmitter process

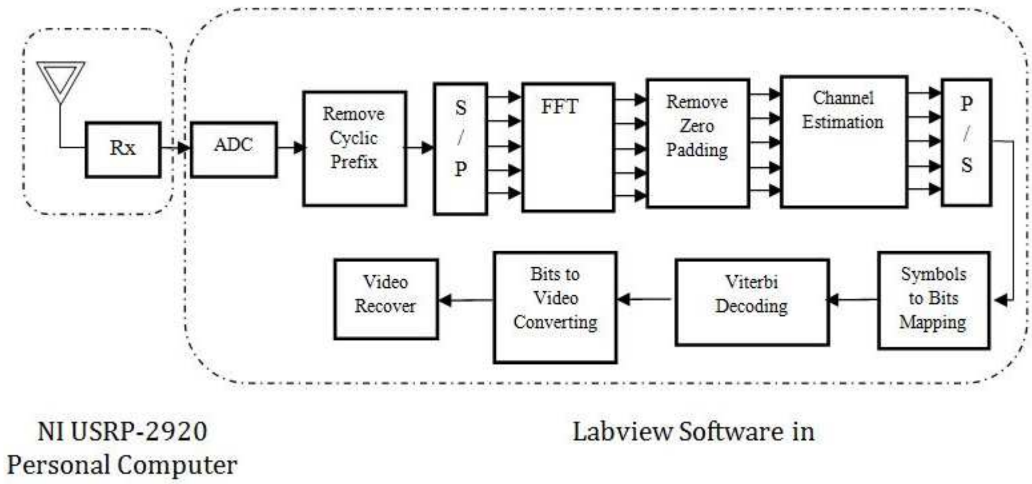


Figure 6. Receiver process

Table 1. Parameter of OFDM System

Parameter	Value
FFT size	2048
Guard Intervals	464
Cyclic Prefix Ratio	¼
Number of subcarriers	2048
Carrier Frequency	915 MHz
Modulation	8 QAM

The OFDM parameters given in accordance with the parameters of DVB-T system[1],which is can be seen on Table 1.

6. EXPERIMENT AND ANALYSIS

This experiment uses two PCs and two USRP 2920 as transmitter and receiver.The practical measurement includes the reliability of streaming video transmission on different IQ rate and modulation investigated by constellation diagram.Then the performance of Sequential Distortion Minimization method on the DVB-T system with α = 0,1 observes based on PSNR (Peak Signal to Noise Ratio) and SSIM (Structural Similarity).

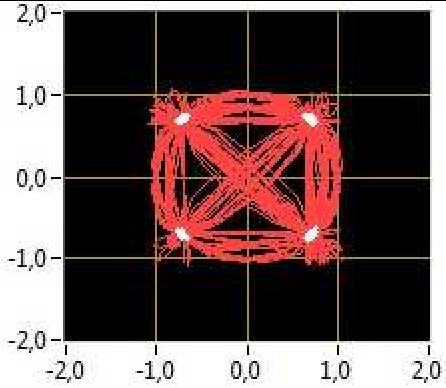
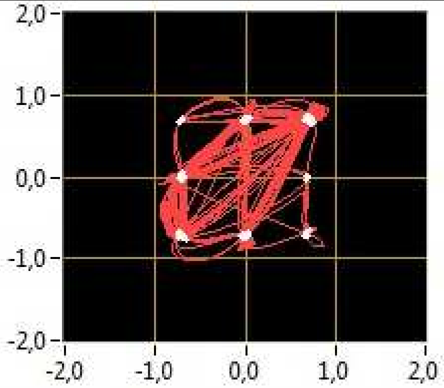
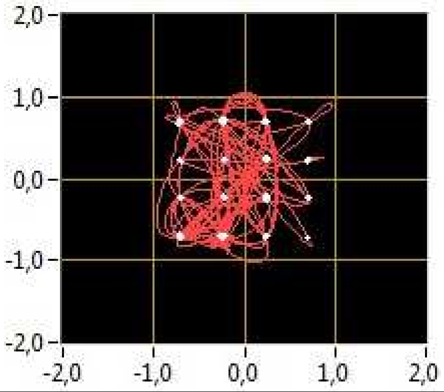
6.1 The reliability of video transmission measurement.

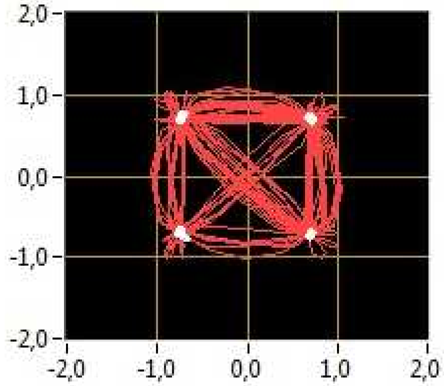
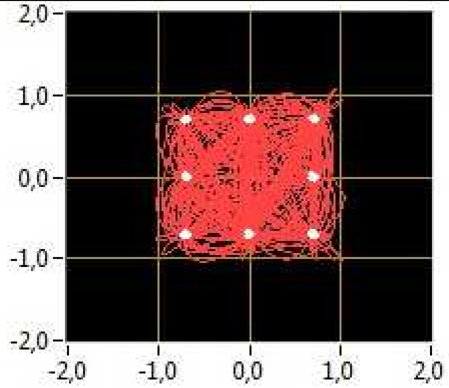
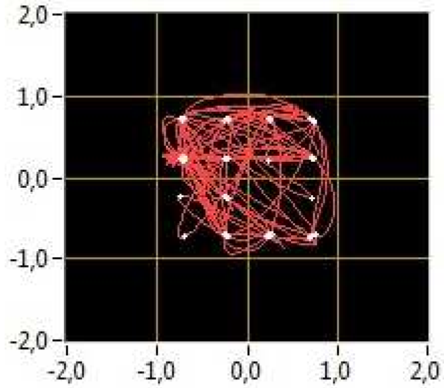
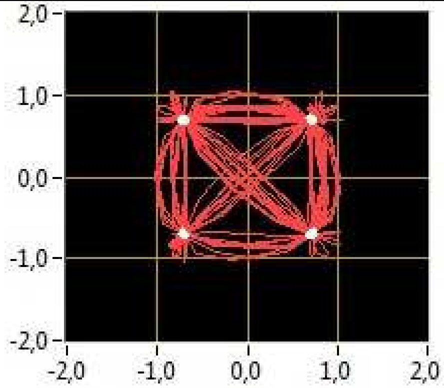
The purpose of this experiment is to observe the reliability of the DVB-T system. The video sent using USRP 2920 with frequency 2,2GHz, indoor environment. The experiment is used different IQ rate and modulation. If the IQ rate is increased, spectrum bandwidth will go up too and computation of computer host is increasing too[9]. Table 2 shows constellation diagram on different IQ rate and modulation. The reliability system is achieved when IQ rate under 2Mhz and modulation under 8 QAM. When IQ rate is more than 5MHz and modulation is more than 16 QAM, the video transmission is an error. Video transmission encountered an error while the higher-order modulation. The higher-order modulation, the more susceptible to noise resulting in error. The computing process on USRP tool also higher so USRP tool specification does not compatible.USRP is not support for condition 5MHz and 10MHz at 16 modulation scheme.

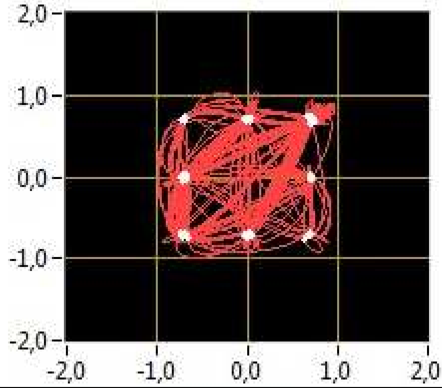
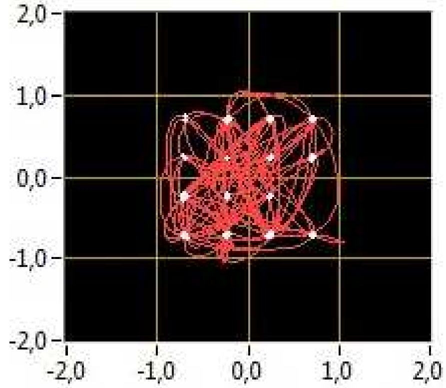
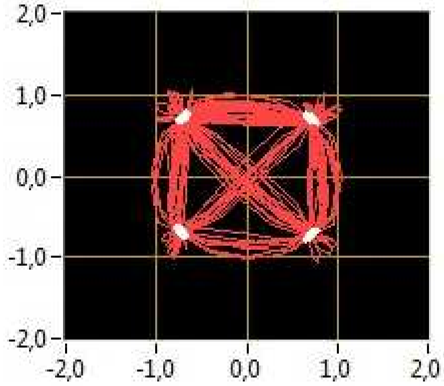
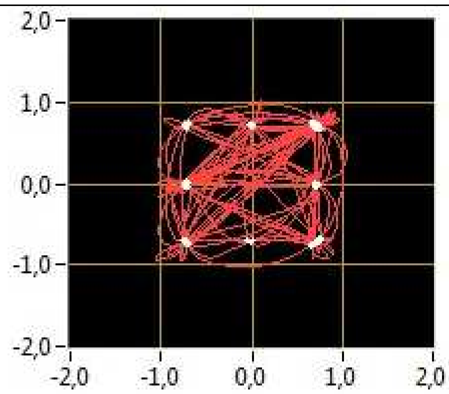
6.2 The performance of Sequential Distortion Minimization Method.

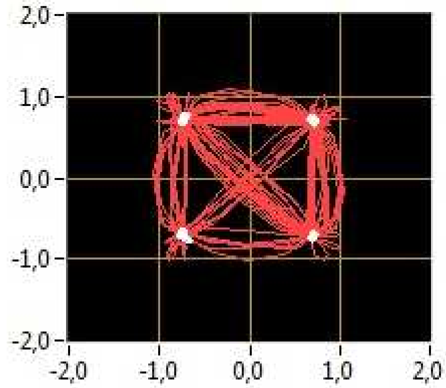
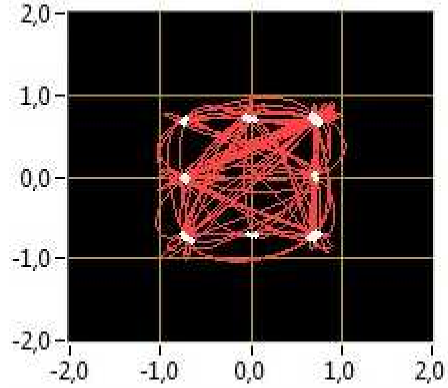
Sequential Distortion Minimization Method (SEDIM) is to minimize distortion between video transmit and video received **.**This experiment is to observe PSNR (Peak Signal to Noise Ratio) and SSIM (Structural Similarity) on video transmission using DVB-T system and video transmission using DVB-T system with sequential distortion minimization method with α = 0,1 .

Table 2. Comparison the reliability of the system on different IQ rate and Modulation

IQ rate	Modulation	Constellation
500kHz	4 QAM	
	8 QAM	
	16 QAM	

1MHz	4 QAM	
	8 QAM	
	16 QAM	
2MHz	4 QAM	

	8 QAM	
	16 QAM	
5MHz	4 QAM	
	8 QAM	
	16 QAM	Error

10MHz	4 QAM	
	8 QAM	
	16 QAM	Error

Specification IQ rate and modulation based on the best performance on investigation earlier, which is IQ rate 2 MHz and modulation 8 QAM.

PSNR compares the maximum possible signal energy, i.e, the maximum value of the luminance component of the frame, to the noise energy, that is the mean square error (MSE) computed pixel by pixel between the source frame and the received frame[5]. The PSNR in dB can express as :

$$PSNR(x,y) = 20log\frac{V_{peak}}{\sqrt{MSE(x,y)}} \tag{6}$$

x denote as source frame and *y* as received frame. $MSE(x,y)$ denotes the mean square error between *x* and *y*. $V_{peak} = 2^k - 1$, where *k* is the number of bits per pixel.

SSIM metric is closer to human vision system than PSNR. SSIM is a measure of structural information change can,therefore be used to assess perceived image distortion based on luminance, contrast and structure of an object in the shot. The SSIM index can be expressed as :

$$SSIM\ (x,y) = \frac{(2\mu_x\mu_y + C_1)\ (2\boldsymbol{\sigma}_{xy} + C_2)}{} \quad (7)$$

$$(\mu_x^2 + \mu_y^2 + C_1)(\boldsymbol{\sigma}_x^2 + \boldsymbol{\sigma}_y^2 + C_2)$$

Where $\boldsymbol{\sigma}_{xy}$ is the covariance of x and y. C_1, C_2 are small constant included to avoid instability when the other terms of the denominators are very close to 0. μ_x, μ_y is the mean intensity and $\boldsymbol{\sigma}_x$,$\boldsymbol{\sigma}_y$ is the standard deviation of a signal x and y.

According to this experiment, video transmission using DVB-T system without SEDIM produce PSNR average 19,855 dB. Video transmission using the DVB-T system with SEDIM produce PSNR average 48,386 dB. The result show the value of PSNR with SEDIM is better than without SEDIM.The graph shown in Figure 7.

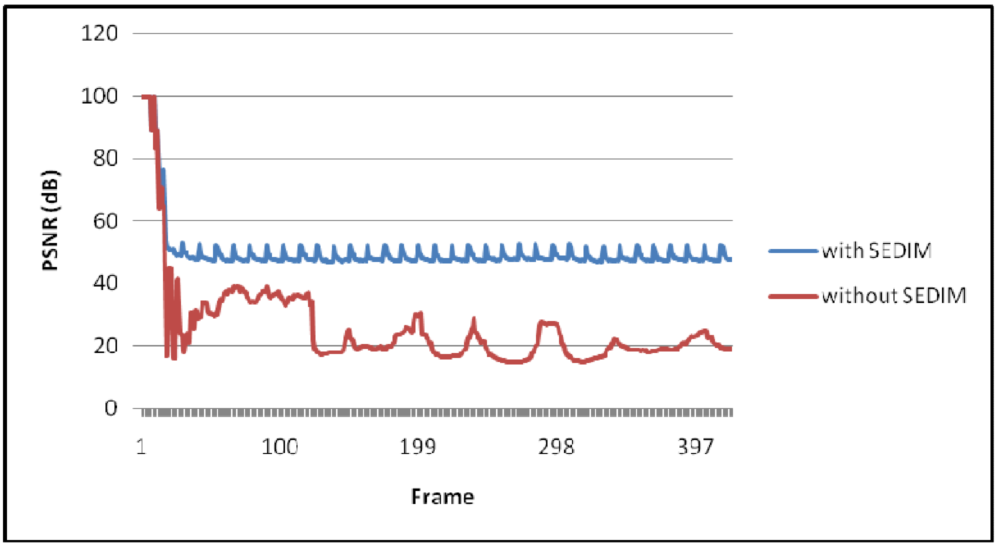


Figure 7. PSNR comparison results without SEDIM and with SEDIM

SSIM result shows on a system without SEDIM has SSIM average 0,896 and with SEDIM 0,99. The comparison video transmission based on SSIM using SEDIM is better than without SEDIM. The graph shown in Figure 8.

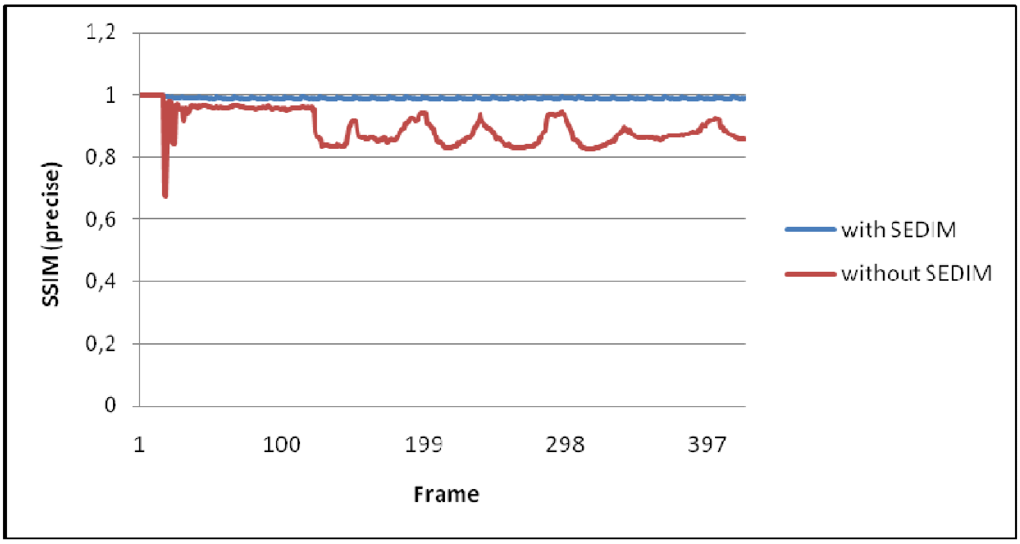


Figure 8. SSIM comparison results without SEDIM and with SEDIM

7. CONCLUSION

In this paper, we have presented some experimental studies video transmission using sequential distortion minimization method for Digital Video Broadcasting Terrestrial and then implemented to USRP. We have studied the reliable system based on IQ rate and modulation. Good performance achieved in IQ rate 2 MHz and 8 QAM. PSNR average was increased more than twice by using SEDIM from 19,855 dB to 48,386 dB. The proposed method also increased 10,49% from 0,896 to 0,99 in SSIM average. Moreover, we intend to study higher video resolution due to future works.

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