

UNEQUAL ERROR PROTECTION EMPLOYING TRELIS CODED MODULATION FOR H.264/AVC VIDEO OVER WIRELESS CHANNELS

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ABSTRACT

With the advent of communication technologies, we have more and more multi-media services available. Therefore, the main focus is to transmit video at high quality, and this concept tends to continue in the years to come. In this work, a Trellis Coded Modulation (TCM) system is used in order to achieve high video quality. The aim is to reduce the effect of transmission errors on the transmitted H.264 AVC by using the concept of Unequal Error Protection (UEP). UEP gives higher priority to the most important bits and vice-versa. The performance of the TCM system is investigated by varying the Doppler shift (Hz) and the E_b/N_0 values which will reflect on the quality of the received signal. The signal is transmitted through the Rayleigh channel, followed by the Additive White Gaussian Noise channel (AWGN). The output of this system is to prove that the relation between Energy of Bit to Noise Ratio (E_b/N_0) and Bit Error Rate (BER) is as expected in theory. The design, implementation and simulation are carried out using the MATLAB R2008b. The performance of the system can be illustrated using graphical and analytical representation of BER with respect to the applied Doppler shift.

KEYWORDS: H.264/AVC, Error Control Coding, Convolutional Codes, Trellis-Coded Modulation, Wireless Channels

INTRODUCTION

The aim of this project is to design a novel unequal error protection (UEP) scheme employing trellis coded modulation (TCM) for H.264 video transmission. The video quality, expressed in terms of Peak-Signal-to-Noise Ratio (PSNR), has to be enhanced [1-7]. In other words, the effects of transmission errors have to be reduced in order to provide the best video quality which can be achieved by the error-control coding [8,9].

Unequal error protection (UEP) gives higher protection to the most important bits, that is, the more important video data. Likewise, at the physical layer (at the modulation side), after mapping, each symbol corresponds to the Most Significant Bit (MSB) or the Least Significant Bit (LSB) accordingly, resulting in the unequal error protection [10, 11].

Communication engineers and coding theorists used the work done by Hamming, which was published in 1950, (was already known by Shannon in 1948), to develop many more applications' schemes in order to achieve the best performance (to what was promised by Shannon) [8].

Shannon proved that channel noise limits the transmission rate, and not the error probability. Hence, the transmission channels to be used are Rayleigh Fading channels and Additive White Gaussian Noise (AWGN). The effect of Doppler shift on the quality of the processed signal has to be examined. The graphical representation of BER with respect to the applied Doppler shift, of the signal quality, is obtained.

In this work, Trellis-Coded Modulation (TCM) is used which combines convolution codes and Mary PSK modulation in a single process while the signal is transmitted. Likewise, at the receiver side, both the demodulation and the decoding will be performed in a single process.

H.264 ADVANCED VIDEO CODING (AVC)

The H.264 is a coding standard for video compression, that is, the process of converting digital video into a format that contains fewer bits for better storage and transmission of the video [10,11]. The H.264 standard was first issued in 2003. The Joint Video Team (JVT) of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC JTC Moving Picture Experts Group (MPEG) worked on the H.264 standard to develop it. It is based on the concept of MPEG-2 and MPEG-4 Visual and gives higher efficiency in the compression of videos, that is, better quality compressed video and greater flexibility in compressing, transmitting and storing video [11].

An H.264 video encoder consists of three processes, that is, the prediction, the transform and the encoding processes in order to produce a compressed H.264 bit stream. On the contrary, an H.264 video decoder consists of the opposite processes, that is, the decoding, the inverse transforms and the reconstruction to generate a video sequence as shown in Fig.1 [11-13].

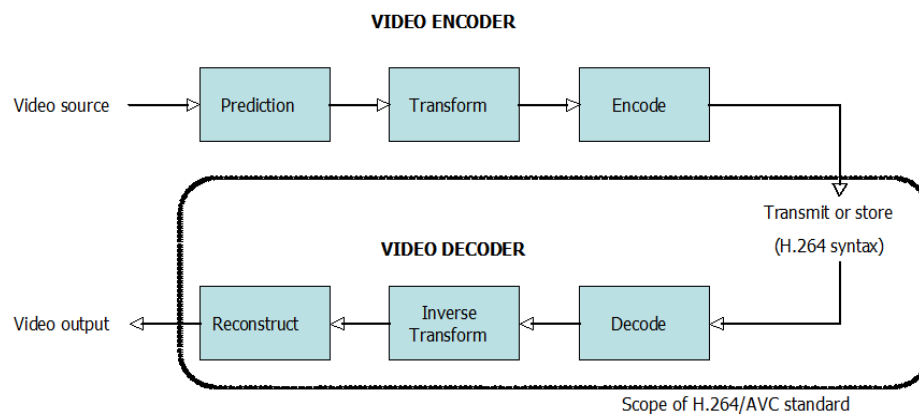


Figure 1: The H.264 Video Coding and Decoding Process

The H.264/AVC standard [10, 11] is composed of two layers, namely the Video Coding Layer (VCL) for video compression and Network Abstraction Layer (NAL) for transport of compressed video data over networks [11]. NAL works in two kinds of mode: Single Slice mode and Data Partitioning (DP) mode. When using the DP mode, H.264 puts all variable length codes with the same data type together in each frame as described below.

The H.264/AVC compressed video data can be organized in packets of varying importance, depending on the frame type and DP type. In this paper, we classify the H.264/AVC bit stream into three priorities as shown below. Here priority 1 represents the most important data, while priority 3 represents the least important data.

- Priority 1: IDR frame, DPA of my frame and DPB of my frame.
- Priority 2: DPA of P frame, DPA of B frame and DPB of P frame.
- Priority 3 Queue: DPC of P frame, DPB of B frame and DPC of B frame

CONVOLUTIONAL CODES AND TRELIS CODED MODULATION

In a conventional code, knits are shifted into a shift register circuit and at each clock cycle n bits are output. A convolutional code is normally defined as (n, k, m) [15, 16] where n : the number of output bits per unit time, k : the number of input bits per unit time and m : the number of memory registers. The conventional code can also be defined as by the parameters (n, k, L) which are often specified by the manufacturers. The parameter L is the constraint length of the code and is defined as the Constraint length, $L = k(m-1)$. Fig. 2 shows a communication system, employing a convolutional code with parameters $n=2, k=1, m=3$ and having a code rate of $1/2$. An encoder circuit of the $(2, 1, 3)$ convolutional encoder is shown in Fig. 3 below [15].

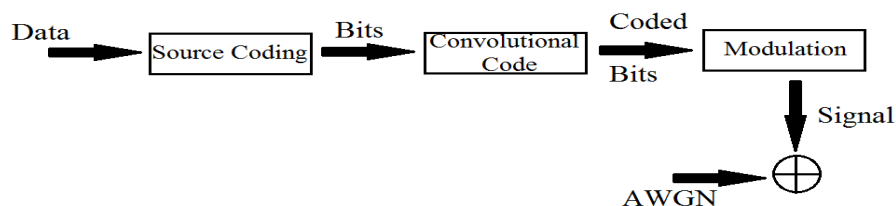


Figure. 2: Communication System with (2, 1, 3) Convolutional Code

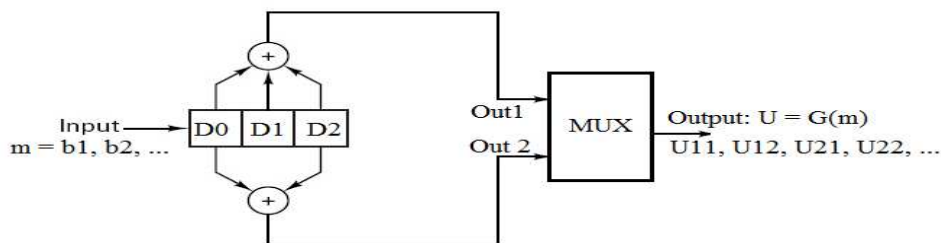


Figure. 3: First Representation of the Encoder (2, 1, 3)

In order to decode a convolutional code a trellis structure is used. A trellis is a time stretched graphical representation of the state diagram that helps to see the changes of the encoder with time together with the input and output bits. The trellis diagram of the $(2, 1, 3)$ code is illustrated below [8].

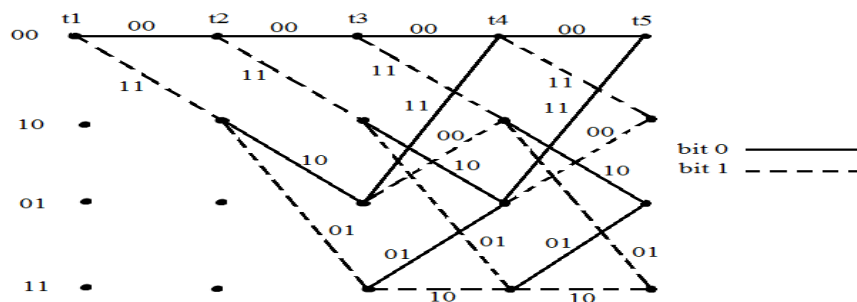


Figure. 4: Trellis Diagram of the (2, 1, 3) code

Trellis-coded modulation (TCM) is an efficient coding scheme for the transmission of information over band-limited communication systems. The functions coding is a digital function and modulation is an analog function. In many coding scheme these two functions are done individually. However, in Trellis Coded Modulation (TCM), it is not the case. The two are combined in one function which is the key idea of improving coding gain while a digital data is being

transmitted, keeping the transmitted power or the required bandwidth [8]. As a result, Trellis Coded Modulation (TCM) is perfect for channels which are both power and bandwidth limited.

With the innovation aspect of TCM on the concept that convolution encoding and modulation are treated as one operation, the loss from the expansion of the signal set is easily overcome and significantly coding gain is achieved with relatively simple chords. Likewise, at the receiver side, instead of the signal to be first demodulated and then decoded, there is the process of demodulation and decoding which is treated as one operation.

This is based on a soft decision rather than a hard decision since the parameters used for the performance of the transmission system is from the Euclidean distance between the transmitted signal sequences and not from the Hamming distance of the convolutional code. Hamming distance between two symbols of the same length is the number of positions at which they differ [18, 19].

Euclidean distance between two symbols is the length of the path connecting them. Similarly, TCM is a means of achieving a coding gain on bandwidth-constraint channels by using bandwidth-efficient multilevel modulation schemes such as Mary QAM [8]. Coding gains of TCM are expressed as

$$G = 10 \log_{10} \left[\left(\frac{\delta^2_{\text{free}}}{\delta^2_{\text{free, u}}} \right) \times \left(\frac{E_s}{E_s, u} \right) \right] \quad (1)$$

Where δ^2_{free} : the squared free distances of the Trellis Coded Modulation

$\delta^2_{\text{free, u}}$: the squared free distances of the uncoded schemes.

E_s : the average energies of the signal of the Trellis Coded Modulation

$E_{s, u}$: the average energies of the signal of the uncoded systems.

Ungerboeck [18] proposed the set partitioning, which is better than gray code mapping. It creates efficient coded modulation schemes for band-limited channels. The reason for proposing this mapping is that for the correct decision to be made during demodulation and decoding, the symbols must be at the largest possible distance apart to increase the Euclidean distance between the symbols in the set, and in contrast, gray code mapping may fail to accomplish this goal with some codes and usually leads to low coding gain.

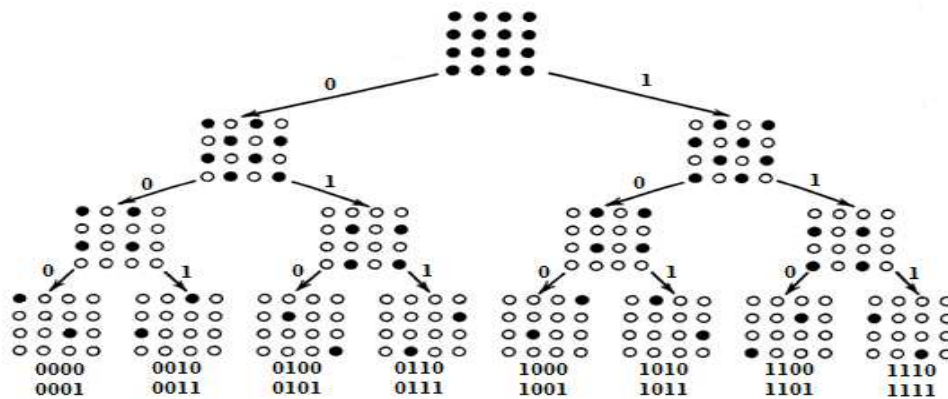


Figure 5: Ungerboeck set Partitioning of the 16-QAM Constellation [18]

From Fig. 5 above, which is based on the partitioning of a 16-QAM rectangular constellation, the partitioning is done successively in subsets of 2, 4, 8 ... with size of $16/2$, $16/4$, $16/8$... respectively. Hence, as the number of subsets increases, the distance between the individual points also increases. Therefore, as a result, the Euclidean distances amongst the constellation points are extended as well. In each step, the constellation, that is signal set, is partitioned into two equal subsets representing either a bit '1' or a bit '0'.

DESIGN AND IMPLEMENTATION OF ROBUST H.264/AVC TRELLIS CODED MODULATION SYSTEM

The hardware implementation of the system is complex and hence a virtual system is implemented in Simulink instead. Simulink is a platform which is used for multi-domain simulation, analysis and model-based design using block diagrams. Simulink is fully integrated with MATLAB[®] which is very easy and fast to learn. This is an interactive graphical environment and it provides a comprehensive set of block libraries that helps to design, simulate, implement, and test. However, before implementing it in MATLAB[®], a flowchart shown in Fig. 6 of the system is designed in order to have an overview of what is expected.

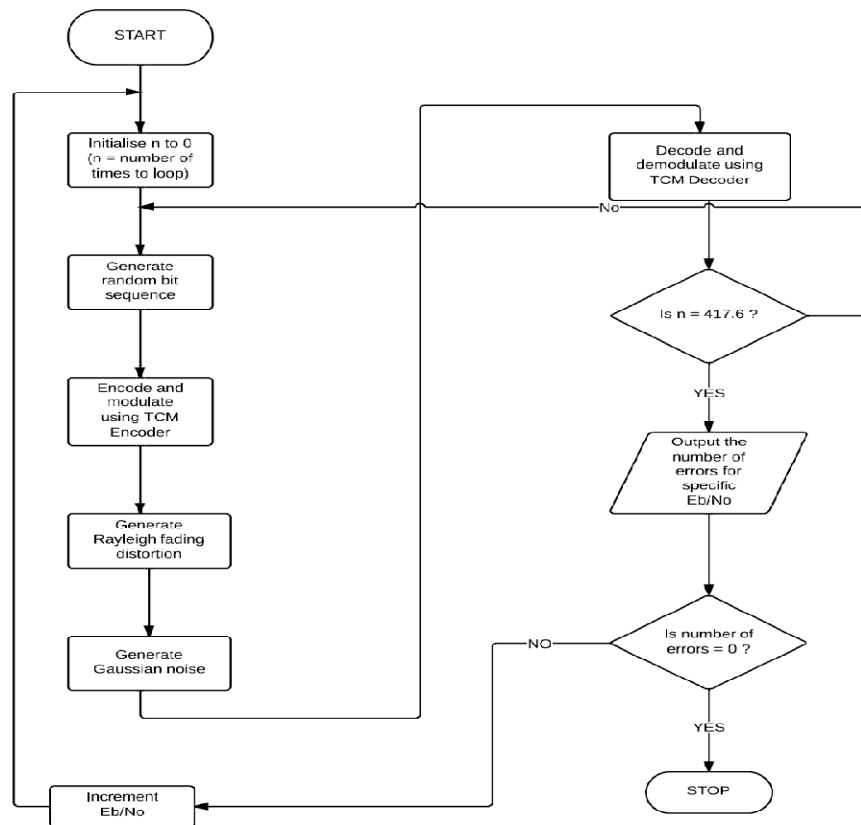


Figure 6: Flowchart of the System

The block diagram of the H.264/AVC TCM simulation system used in this research work is designed in MATLAB SIMULINK and shown in the Fig. 7 below.

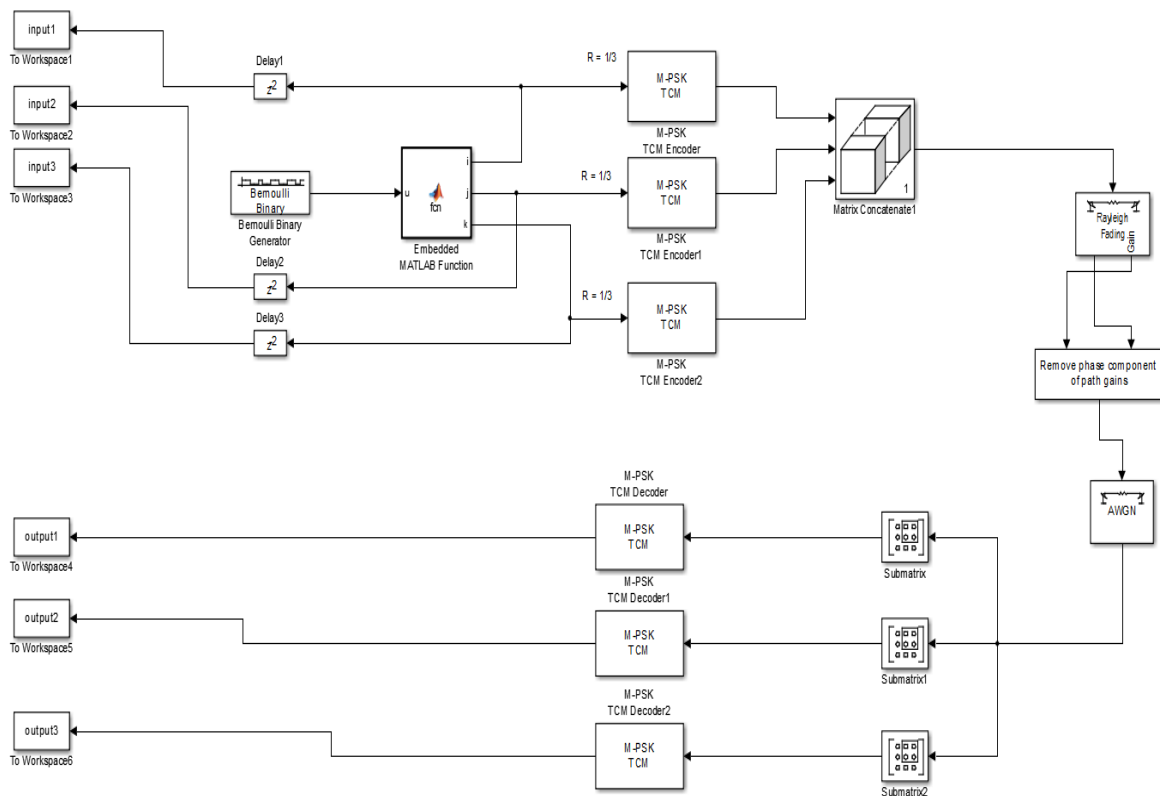


Figure 7: Block Diagram of the H.264/AVC TCM Simulation System

The block diagram of Fig. 7 shows the Bernoulli Binary Generator, generating bits, which are passed into an embedded MATLAB function to generate equal number of bits in the three Trellis-Coded Modulation (TCM) encoders which enable to connect to the H.264/AVC three priority inputs as explained in Section 2. These are then followed by a functional block, a matrix concatenate, which concatenates the signals from the encoders to a single concatenated array. The output then passes through the channels, which are Rayleigh Fading Channel and Additive White Gaussian Noise (AWGN) channel. Finally, before the decoding process, sub-matrices are used to separate the output signal accordingly to the required size and then these are passed through the respective Trellis-Coded Modulation (TCM) decoders.

SIMULATION RESULTS AND DISCUSSIONS

The proposed Trellis-Coded Modulation (TCM) model of Fig. 7 is simulated in MATLAB[®] by varying the E_b/N_0 (Signal-to-noise ratio) for different values of the Maximum Doppler shifts in the frequency of the signal. The Bit Error Rate (BER) is calculated by comparing input1 with output1, input2 with output2, and input3 with output3 for the respective E_b/N_0 (dB) used. The performance of the system is illustrated using graphs of $\log(\text{BER})$ versus E_b/N_0 . The values of the AWGN (E_b/N_0) are varied from -2 dB to 30 dB in steps of 2dB. The results obtained are shown in Fig. 8 below for the respective E_b/N_0 (dB) used. **BER1** is the bit error rate with the highest priority. **BER2** is the bit error rate with the medium priority. **BER3** is the bit error rate with the lowest priority.

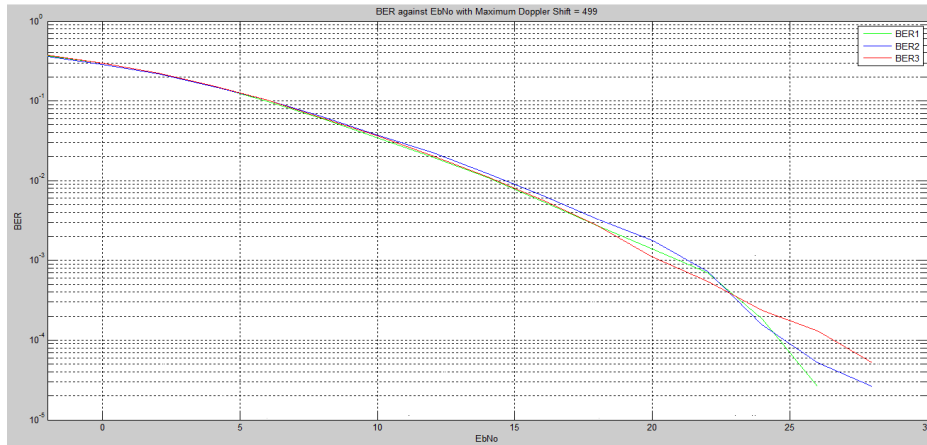


Figure 8: Graph of BER against Eb/No Maximum Doppler shift of 499 Hz

The input bits from the Bernoulli binary generator are recorded in a text file (sent.txt) and its output bits are recorded in another text file (received.txt) by the use of software called CYGWIN. Cygwin is a set of powerful tools which can be used on Microsoft windows. It is a Unix-like environment operating on windows. With Cygwin, it is possible to run applications on disparate platforms. For instance, windows applications can be run using Cygwin. In this way, scripts are launched on the Cygwin environment to create the necessary files in order to produce H.264 files and hence YUV files. The YUV files are then processed through a YUVviewer. YUVviewer is a user friendly interface for playback of uncompressed YUV video files. The YUVviewer allows to play the yuv video files in different resolutions, pixels formats and frame rates. Below shows the frames obtained, using the YUVviewer, for the different Maximum Doppler shifts (Hz) used with respect to the range of Eb/No (dB), that is, how the transmitted video is affected with variable noise level.



Figure 9: Error Free PSNR for bus (CIF) Sequence is 28.2 dB.

Maximum Doppler shift = 300 Hz, Frame Number =200

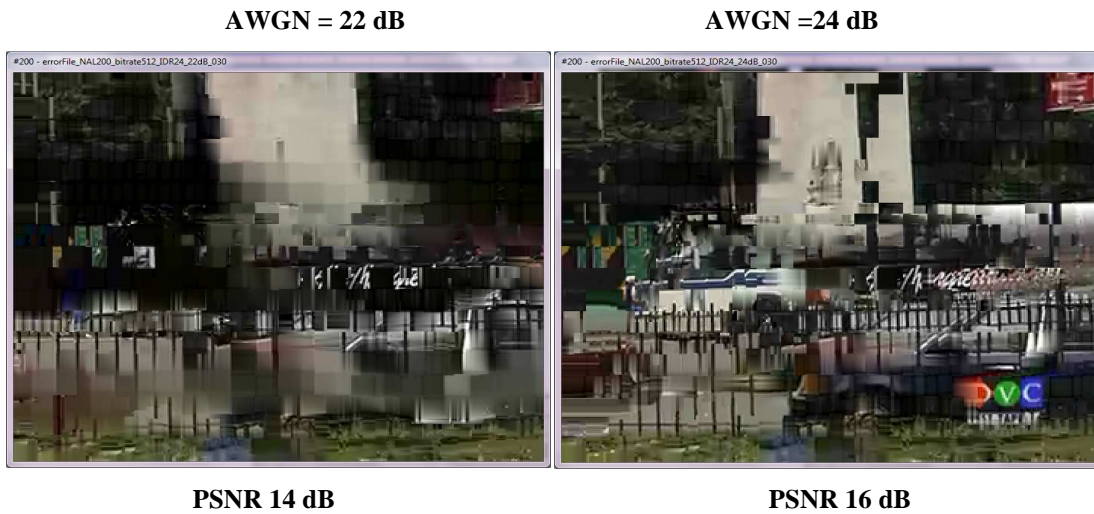


Figure 10



Figure 11

AWGN = 30 dB



Figure 12

Maximum Doppler shift = 500 Hz, Frame Number = 200

AWGN = 22 dB



PSNR 16 dB

AWGN = 24 dB



PSNR 18 dB

Figure 13

AWGN = 26 dB



PSNR 23 dB

AWGN = 28 dB



PSNR 25 dB

Figure 14

AWGN = 30 dB



PSNR 28 dB

Figure 15

From all of the video frames, it can be observed that on increasing the value of Maximum Doppler Shift, the coded system improves from severe performance degradation. In addition, it can be noticed that on increasing the value of Eb/No to the signal, the video quality increases, hence achieving the objective of this research work.

CONCLUSIONS

The performance of the proposed scheme, employing Trellis-Coded Modulation (TCM) for H.264 videos has been investigated and compared with the original video, that is, before compression. The system was designed in order to reduce the effects of transmission errors on the video quality (for video compression) so as to provide the best video quality. As expected, good video quality occurs at high PSNR and AWGN values. For instance, the video quality of Eb/No = 22 is lower than that of Eb/No = 30 for the same Doppler shift. Hence, implying better video quality. However, when comparing the Eb/No value for each Doppler shift used, the PSNR value varies.

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