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Performance Evaluation and Computer Simulation of ATSC Digital Television

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Abstract: This paper addresses the evaluation of the performance of Advanced Television Systems Committee digital television. The evaluation is carried out through a simulated digital television system using matlab with simulink .The ATSC digital television standard accommodate a system designed to transmit high-quality video and audio, and ancillary data within a single 6-MHz terrestrial television broadcast channel. The main purpose of this work is to model the primary portions of a Main Service 8-VSB transmitter with MPEG-2 Transport Packet data as inputs, also model the primary portions of a possible Main Service 8-VSB receiver design. The evaluation of the system is realized by generating error statistics including number of corrected bytes, number of defective packets and byte error rate.

Keywords—Advanced Television Systems Committee (ATSC), digital television, interactive television and MPEG-2

I. INTRODUCTION

The high definition television standards defined by the ATSC produce wide screen 16:9 images is designed to accommodate up to 1920×1080 pixels in size which is more than six times the display resolution of the earlier standard. However, many different image sizes are also supported. The reduced bandwidth requirements of lower-resolution images allow up to six standard-definition "subchannels" to be broadcast on a single 6 MHz TV channel.[3]. ATSC standards are marked A/x (x is the standard number) and can be downloaded for free from the ATSC's website at ATSC.org. ATSC Standard A/53, which implemented the system developed by the Grand Alliance, was published in 1995; the standard was adopted by the Federal Communications Commission in the United States in 1996, and It was revised in 2009. ATSC Standard A/72 was approved in 2008 and introduces H.264/AVC video coding to the ATSC system. ATSC supports 5.1-channel surround sound using the Dolby Digital AC-3 format. Numerous auxiliary data casting services can also be provided. Many aspects of ATSC are patented, including elements of the MPEG video coding, the AC-3 audio coding, and the 8VSB modulation. The cost of patent licensing, estimated at up to $50 per digital TV receiver, has prompted complaints by manufacturers [7]. As with other systems, ATSC depends on numerous interwoven standards, e.g. the EIA-708 standard for digital closed captioning, leading to variations in implementation.

II. STRUCTURE OF THE ATSC

A. *Digital switchover*

Broadcasters who use ATSC and want to retain an analog signal must broadcast on two separate channels, as the ATSC system requires the use of an entire channel. Virtual channels allow channel numbers to be remapped from their physical RF channel to any other number 1 to 99, so that ATSC stations can either be associated with the related NTSC channel numbers, or all stations on a network can use the same number. There is also a standard for distributed transmission systems (DTx), a form of single-frequency network which allows for the synchronised operation of multiple on-channel booster stations[6]

B. *MPEG-2*

There are three basic display sizes for ATSC. Basic and enhanced NTSC and PAL image sizes are at the bottom level at 480 or 576 lines. Medium-sized HDTV images have 720 scan lines and are 1280 pixels wide. The top tier has 1080 lines 1920 pixels wide. 1080-line video is actually encoded with 1920×1088 pixel frames, but the last eight lines are discarded prior to display. This is due to a restriction of the MPEG-2 video format, which requires the number of coded luma samples (i.e. pixels) to be divisible by 16. The different resolutions can operate in progressive scan or interlaced mode, although the highest 1080-line system cannot display progressive images at the rate of 50, 59.94 or 60 frames per second, because such technology was seen as too advanced at the time and the image quality was deemed to be too poor considering the amount of data that needs to be transmitted.[6] A terrestrial (over-the-air) transmission carries 19.39 megabits of data per second (a fluctuating bandwidth of about 18.3 Mbit/s left after overhead such as error correction, program guide, closed captioning, etc.), compared to a maximum possible MPEG-2 bit rate of 10.08 Mbit/s (7 Mbit/s typical) allowed in the DVD standard and 48 Mbit/s (36 Mbit/s typical) allowed in the Blu-ray disc standard. Although the ATSC A/53 standard limits MPEG-2 transmission to the formats listed below (with integer frame rates paired with 1000/1001-rate versions), the U.S. Federal Communications Commission declined to mandate that television stations obey this part of the ATSC's standard.

C. *Transport stream (TS)*

MPEG transport stream. The file extension ".TS" stands for "transport stream", which is a media container format. It may contain a number of streams of audio or video content multiplexed within the transport stream. Transport streams are designed with synchronization and recovery in mind for potentially lossy distribution (such as over-the-air ATSC broadcast) in order to continue a media stream with minimal interruption in the face of data loss in transmission. [4] .When an over-the-air ATSC signal is captured to a file via hardware/software the resulting file is often in a .TS file format. [2]

D. *Modulation and transmission*

ATSC signals are designed to use the same 6 MHz bandwidth as analog NTSC television channels (the interference requirements of A/53 DTV standards with adjacent NTSC or other DTV channels are very strict). Once the digital video and audio signals have been compressed and multiplexed, the transport stream can be modulated in different ways depending on the method of transmission [3].Terrestrial (local) broadcasters use 8VSB modulation that can transfer at a maximum rate of 19.39 Mbit/s, sufficient to carry several video and audio programs and metadata. Cable television stations can generally operate at a higher signal-to-noise ratio and can use either the 16VSB as defined in ATSC or the 256-QAM defined in SCTE, to achieve a throughput of 38.78 Mbit/s, using the same 6 MHz channel.[5]

III. APLICATION

A. *ATSC 2.0*

ATSC 2.0 is a major new revision of the standard, which will be backward compatible with ATSC 1.0. The standard will allow interactive and hybrid television technologies by connecting the TV with the Internet services and allowing interactive elements into the broadcast stream. Other features include advanced video compression, audience measurement, targeted advertising, enhanced programming guides, video on demand services, and the ability to store information on new receivers, including Non-real time (NRT) content.[6]

B. *ATSC 3.0*

ATSC 3.0 will provide even more services to the viewer and increased bandwidth efficiency and compression performance, which requires breaking backwards compatibility with the current version. ATSC 3.0 is expected to emerge within the next decade[6][2].

IV. PRACTICAL WORK (SIMULATION)

A computer simulation using Matlab program is built to obtain the circuit of Advanced Television Systems ,Committee (ATSC). The structure of the ATSC circuit is shown in figure (1). The Simulink system is divided to two main segments. As shown in part 1 in figure(1) the first segment is the MPEG-2 Transport Packet generation part. The first function of this part is to Generate random uniformly distributed integers in the range [0, M-1], where M is the M-ary number. Another item in this part is the transmitter baseband processing to Generate pseudo random byte sequence for randomization and derandomization, this item also Encode the message in the input vector using an (N,K) Reed-Solomon encoder with the narrow-sense generator polynomial.

This block accepts a column vector input signal with an integer multiple of K elements. Each group of K input elements represents one message word to be encoded. Each symbol must have ceil(log2(N+1)) bits. A convolutional interleaver consists of N shift registers. The *i*th register has a delay (i-1)*B where B is a specified register length step. With each new input symbol, a commutator switches to a new register and the new symbol is shifted while the oldest symbol in that register is shifted out. When the commutator reaches the Nth register, upon the next new input, it returns to the first register.

The next stage of part (1) is the 8-VSB Trellis Interleaver, this except the symbol mapping part that is implemented by the following 8-PAM modulator block, the 8-PAM modulate the input signal using the pulse amplitude modulation method. This block accepts a scalar or column vector input signal. The input signal can be either bits or integers. When you set the 'Input type' parameter to 'Bit', the input width must be an integer multiple of the number of bits per symbol. Also AWGN Channel Add white Gaussian noise to the input signal. The input signal can be real or complex. This block supports multichannel processing. When using the variance modes with complex inputs, the variance values are equally divided among the real and imaginary components of the input signal.

The second main part of the simulation is shown in part 2 in figure(1). This part consist of receiver baseband processing, where 8-PAM demodulate the input signal using the pulse amplitude modulation method. This block accepts a scalar or column vector input signal. The output signal can be either bits or integers. When you set the 'Output type' parameter to 'Bit', the output width is an integer multiple of the number of bits per symbol. 8-VSB Trellis deinterleaver converts groups of 48 2-bit nibbles to 207 byte packets. A convolutional deinterleaver consists of N shift registers. The *i*th register has delay (N-i)*B where B is a specified register length step. With each new input symbol, a commutator switches to a new register and the new symbol is shifted in while the oldest symbol in that register is shifted out. When the commutator reaches the Nth register, upon the next new input, it returns to the first register. RS decoder and derandomize attempt to decode the input received signal using an (N,K) Reed-Solomon decoder with the narrow-sense generator polynomial. This block accepts a column vector input signal with an integer multiple of N elements. Each group of N input elements represents one received word to be decoded. Each symbol must have ceil(log2(N+1)) bits. Also shown in figure(1) the location of error rate calculation, spectrum and constellation diagram.

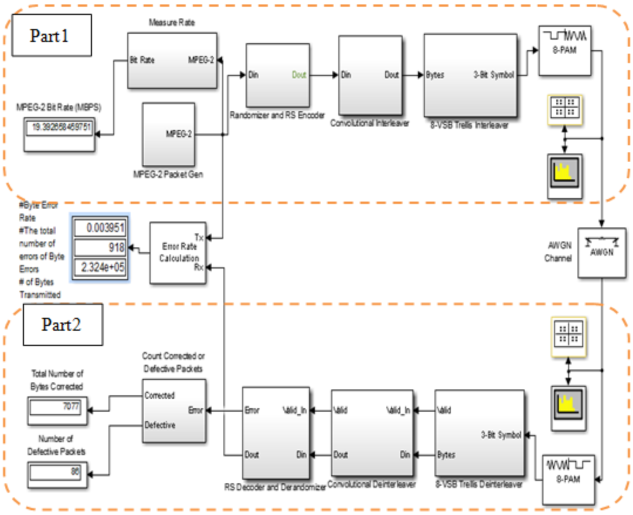

Figure1: ATSC digital television

V. RESULT AND DISSECTION

The experiments in this work are carried out by operating the circuit of ATSC TV in figure(1), and studying the power spectrum density in two main locations. First location is before AWGN channel, the second location is after AWGN channel as shown in figure(1).

Figure(2) displays this signal in the first location witch is the output of 8-PAM modulator baseband and before AWGN channel. The second location that is studied is the after AWGN channel, as shown in figure(4). The displayed signals in both figures (2),figure(4) show the relationship between the magnitude squared (dBw) and the frequency (MHz). when comparing these signals it is clear that the deference between the signals is caused by the white Gaussian noise in AWGN channel.

The second part of this work is to look in to constellation diagrams in the two locations, before and after the AWGN channel. By examining figure(3) and figure(5) the diagrams show the relationship between the quadrature amplitude and in phase amplitude. There is a clear difference between the results in these figures because of the presence of the white Gaussian noise in the channel.

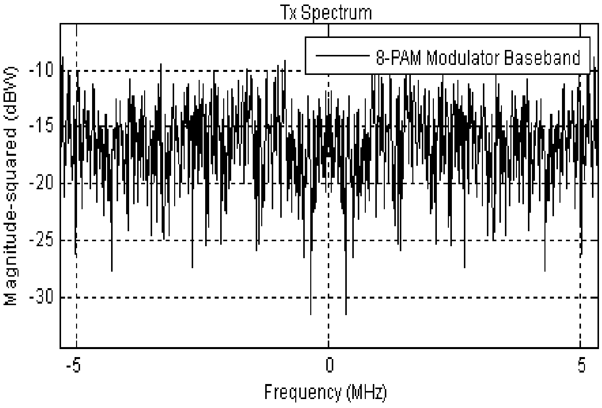

Figure2:Power spectrum density before AWGN channel.

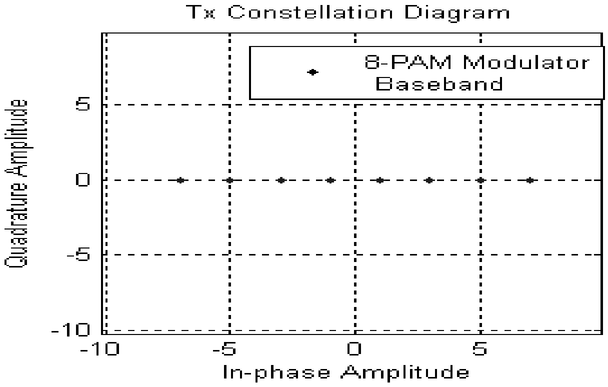

Figure3: Quadrature amplitude and in phase amplitude before AWGN channel.

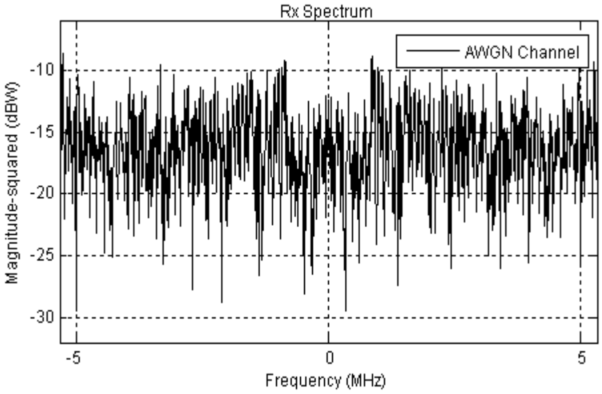

Figure4:power spectrum density after AWGN channel.

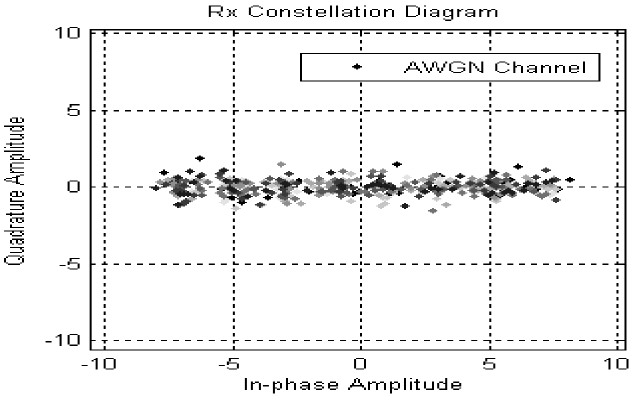

Figure5: The relationship between quadrature amplitude and in phase amplitude before AWGN channel.

The final stage of this work is shown is figure (6), where the relative between the in byte error rate and Eb/No (dB) is shown. This relation is found in AWGN channel by varring the Eb/No in the block AWGN channel and measure the byte error rate for each value. The main observation is that the decries in byte error rate results in a clear reduction of Eb/No (dB).

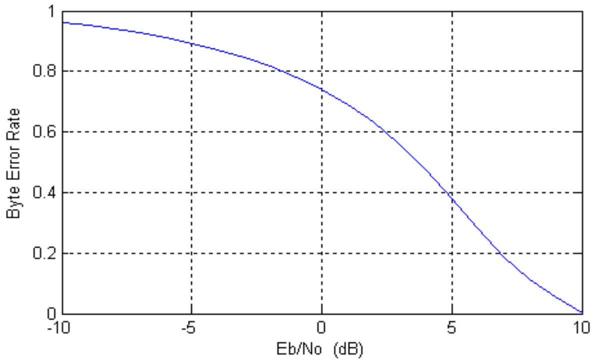

Figure 6: Byte Error Rate and Eb/No (dB) in AWGN channel.

VI. CONCLUSION

This paper studied the receiver spectrum display power spectrum density before and after AWGN channel. The relationship between magnitude squared (dBw) with frequency (MHz) is studied, and the effect of noise on the power spectrum density is noticed. The receiver 8-PAM constellation diagram display are also studied to show the relationship between quadrature amplitude and in phase amplitude before and after AWGN channel. It is very clear that the diagram is worse than before the channel due to the effect of the channel, this is due to the presence of noise in AWGN channel . The main conclusion of this work is the study of the relative between in byte error rate and Eb/No (dB) in AWGN channel, where it is clear that any decries in the byte error rate result in reduce of Eb/No (dB).

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