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Performance Evaluation of Convolutional Coding for the Reduction of AWGN in a Communication Channel for Digital Video Broadcasting Terrestrial

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Abstract : *Common channel impairments such as noise, interference and fading are known to degrade data transmission in a telecommunication channel. Channel coding seeks to achieve the transformation of signals to improve communication performance through the alteration of data sequence characteristics. Thus the converted sequence contains structured redundancy which enables the transmitter or receiver to decide how to process the data to correct the channel impairments. In this study, a Simulink model was used to describe the use of convolutional encoder and Viterbi decoder blocks to improve transmission in the AWGN channel. The study utilized IEEE and ETSI standards in developing the model. The use of encoding and decoding techniques on Digital Video Broadcasting Terrestrial (DVB-T) standard was demonstrated. Simplified transmitter and receiver were used to demonstrate the use of different code rates and their impact on Bit Error Rates (BER). By varying AWGN parameters, the signal to noise ratio (SNR) and BER were observed. The relationship between the rates was plotted as constellation diagrams which established that as the SNR increased the BER also improved. The BER was observed and measured under various SNR. It was shown that the BER at 15 dB was within the acceptable BER of* 10^{-3}.

Keywords: *AWGN,BER,DVB-T, modulation, punctured convolution coding, SNR.*

I. Introduction

Telecommunication technology growth has led to a high demand for high speed data transmission with less error rate. In other to meet up with this demand, channel coding techniques are commonly used [1] to transform the signal sent in such a way that it will have increased robustness against common channel impairments such as noise, interference and fading. Channel coding is the transformation of signals to improve communication performance through the alteration of data sequence characteristics, in such a way that the converted sequence contains structured redundancy [2] which enables the transmitter or receiver to decide how to process this data. The transformed data have a level of error correction code embedded in it. This method has been found to be less susceptible to errors [3]. Convolutional coding is commonly used today in various application such as digital video, radio communication, mobile communication and satellite communication. Convolution is a mathematical way of combining two signal to form a third signal [3]. The channel coding technique used in this model is punctured convolutional coding system. Convolutional encoding involves adding redundancy to the input signal *s*, and the encoded output *x* symbols are transmitted over a noisy channel. The input of the convolutional decoder, which is the input for the Viterbi decoder *r* is the encoded symbols contaminated by noise. Then the decoder tries to extract the original information from the received sequence and generates an estimate *y* [4]. This is as illustrated in Fig. 1.

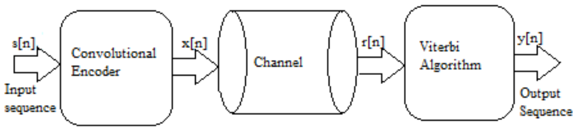

Fig. 1: Encoding / decoding convolutional code [4]

In the aforementioned communication systems, the success of efficient transmission of data at high speed heavily depends on the development of efficient data transmission schemes by the use of channel coding high speed communication within acceptable bit error rate [5]. Researchers have employed various methods to improve the data transmission integrity in a communication channel. Such methods include the use of turbo codes [6], convolution coding [7], [8], RCPC codes [9], etc. This study employed simulation (*Simulink*) to examine the use of convolutional coding in practical application on Digital Video Broadcasting Terrestrial (DVB-T).

II. Simulation Description

2.1 Convolutional Encoder

Convolution encoding is a type of forward error correction process where coding is carried out in such a way as to correct errors in data transmission by altering the characteristic of the sequences of the data so that it now contains a structured redundancy which will enable a receiver or transmitter decide how to process the received data.The convolution encoder as illustrated in Fig. 2, is made up of six memory registers. It has only one input. The present input is 1 bit making the total of bit stored seven. The first element in the matrix determines which input contributes to the first output and the second element indicates which input value contributes to the second output. The encoder is scalar for it contains only one input. When in operation, the encoder is specified by *m, n, k* in which each m-bit information to be encoded is transformed into n-bit symbol and *m/n* used to specify the code rate, and the transformation obtained is a function of last information denoted as *k* which is the constraint length [3].When data are to be encoded, the encoder starts with *k* memory registers, each storing 1 input bit. This encoder has two binary adder as shown in Fig. 2. Let A=1111001 (octal, 171) and B=1011011 (octal, 133) as shown in Fig. 2, then the output of the convolutional encoder is then punctured to remove the additional bits from the encoded stream of data. The number of bit removed is a function of the code rate used.

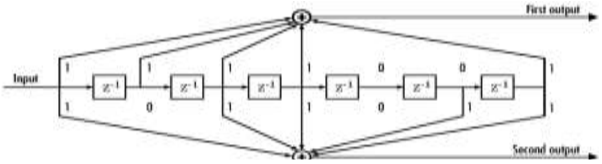

Fig. 2: A rate 1/2 code feed-forward convolution encoder [3]

The foregoing model was simulated using Simulink. The graphs of simulated bit error rate (BER) and theoretical BER were plotted against signal to noise ratio (SNR). Also included is a best fit curve for simulated BER as shown in Fig. 3. Table 1 gives the obtained BER values (theoretical and simulated).

2.2 Punctured Encoder

In the *punctured convolution encoder* (Fig. 4) a Bernoulli binary generator generates the binary bit stream to be encoded. The stream is then applied to the convolution encoder to be encoded and modulated by means of the BPSK modulator and subsequently transmitted over the additive white Gaussian noise (AWGN) channel block. This effectively simulates the transmission over a noisy channel. The demodulation is carried out by the Viterbi decoder block and then *depunctured*.

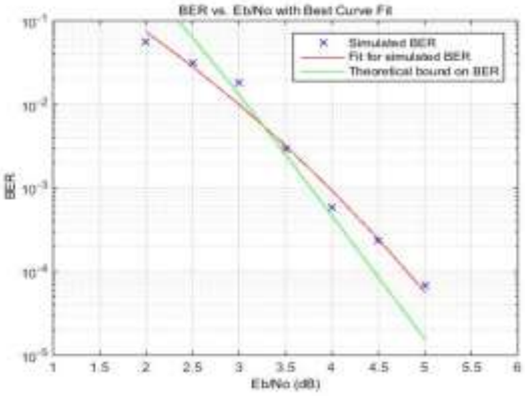

Fig. 3: BER versus SNR with best curve fit

Table 1: Table of Theoretical and Simulated BER

SNR (Eb/No.) dB.	BER (Theoretical)	BER (simulated)
2	10^{-1}	10^{-1}
2.5	10^{-1}	10^{-1}
3	10^{-1}	10^{-2}
3.46	10^{-2}	10^{-3}
4	10^{-3}	10^{-3}
4.5	10^{-5}	10^{-4}
5	10^{-5}	10^{-5}

2.3 Viterbi decoder

The Viterbi decoder is set to the same rate 1/2 code specified in the encoder block. The error rate block compares the decoded bits with its original source bits and the information contained in the error calculation block are the bit error rate (BER), the number of errors observed and number of bits processed. Table 2 itemizes the parameter used. To confirm the validity of the results, it is compared to an established performance error code rate *r*given in eqn. (1):

$$r = \frac{n-1}{n} \qquad (1)$$

where r = the code rate and
n= number of bits

The punctured code is bounded above by the expression given in eqn. (2):

$$P_b \le \frac{1}{2(n-1)} \sum_{d=d_{free}}^{\infty} \omega_d \, erfc\left(\sqrt{rd(E_b/N_0)}\right) \text{ [10];} \qquad (2)$$

whereerfc denotes the complementary error function,
r is the code rate,
d is the minimum free distance of the punctured code, and
both*dfree* and ω_d are code-dependent.

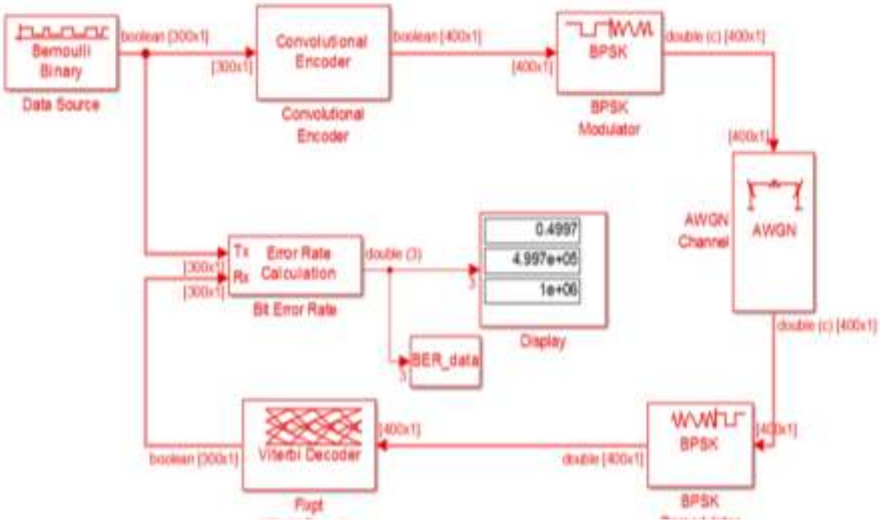

Fig. 4: Simulink model for the punctured convolutional coding [5]

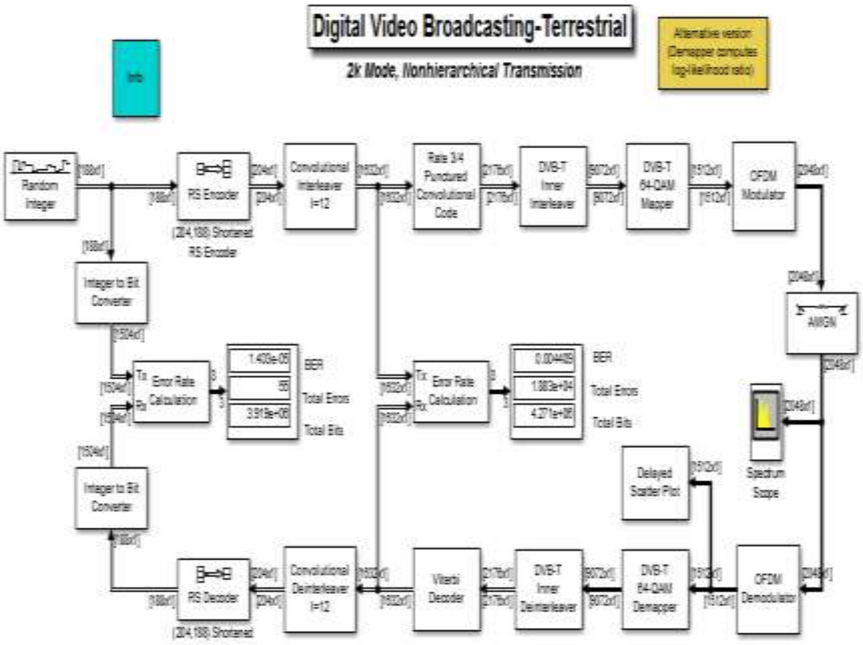

Fig. 6: DVB-T: digital video broadcasting terrestrial

Table 2: Simulation Parameters for the Viterbi Decoder

Attribute	Units
Convolution encoder	Poly2trellis (7, [171 133] and puncture vector [1 1 0 1 1 0]
BPSK demodulator	Hard decisions
Viterbi decoder	Poly2trellis (7, [171 133] and puncture vector [1 1 0 1 1 0], trace back depth = 96, decision type= hard decision
Error rate calculation block	Receiver delay=96

2.4Dvb-T Model

The DVB-T model (shown in Fig. 6) is a European telecommunications Standards Institute (ETSI) standard [11]. Included in it is the Bernoulli Binary Generator block to produce binary stream as a source to the AWGN channel block to simulate the noise. The error rate calculation block is used to display the BER and the amount of processed bits [3]. The RS encoder block provided extra protection to the system by adding redundancy codes that can be used during error correction. The punctured convolutional code block is used to convolve the bit stream at the input. The DVB-T 64 QAM mapper maps the data stream from the interleaver into the constellation. The orthogonal frequency division multiplexing (OFDM) modulates the constellation map after which the data are then encoded by the Reed Solomon encoder (RS encoding) [2, 12, 13, 14]. This adds redundancy to the data stream which help to correct data error, and the interleaver block works on the position of the bit stream by spreading the code in time before transmission. The randomizer converts the long sequence of bit stream in a random sequence to improve the coding performance.

At the receiver end of the model, a Viterbi block decoder, a convolutional deinterleaver, and RS decoder decode the transmitted signal. This model employed OFDM with 64 QAM modulation. It displays the transmitter side coding and modulation for the 3/4 code rate mode with a corresponding AWGN [2], [15] and ideal receiver chain. Using this model the performance of convolutional coding on the communication system was investigated by measuring the bit error rate (BER) and the SNR (Eb/No) [3], [16]. The effect of increasing the SNR was observed on both the frequency spectrum and constellation diagram. Table 3 gives the parameters used for the DVB-T model.

Table 3: Simulation Parameters for the DVB-T Model

Attribute	Unit
Rate 3/4 Punctured convolution code block	Trellis structure poly2trellis(7, [171 133]), Punctured code=[1 1 0 1 1 0]'
AWGN	Initial seed=54321, SNR=18.5dB, input signal power =1/2048
Signal constellations and mapping	Normalize
Modulation techniques (OFDM)	OFDM transmitter and receiver

III. Simulation Results

As obtained in Fig. 4 and Table 2, as the value of SNR increased, the bit error rate also improved. For instance, at SNR value of 5dB a bit error rate of 10^{-5} was obtained. That is, at this value, 1 bit received in error for 100000 bit sent. This was far better than when the SNR was 2dB with a bit error rate of 10^{-1}. That is, 1 bit received in error when 10 bits were sent. The results of convolution code application (Simulated BER) are as shown in Table 2. For the theoretical BER the SNR ranges of 2dB, 2.5dB and 3dB had a bit error rate of 10^{-1} while in the simulated BER the SNR was observed to be of the range 2dB, 2.5dB and had the same value of BER of 10^{-1} whereas the SNR of 3dB of the simulated BER had an improved BER of 10^{-2}.This was as a result of the convolution coding introduced.Another characteristic was obtained by considering the trend of the theoretical and simulated value obtained as in Fig. 5.

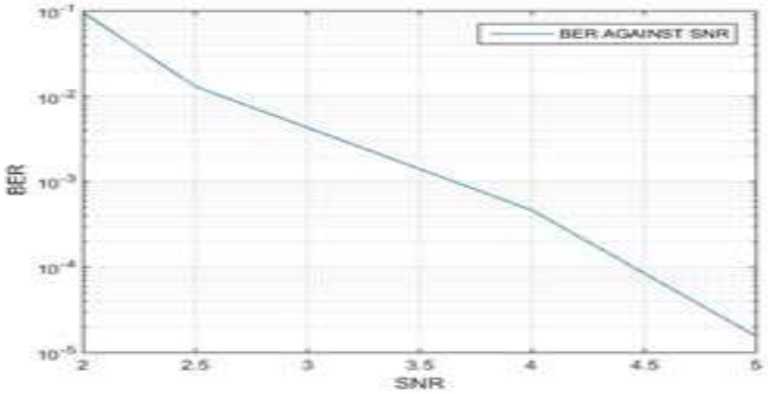

Fig. 5: BER versus SNR.

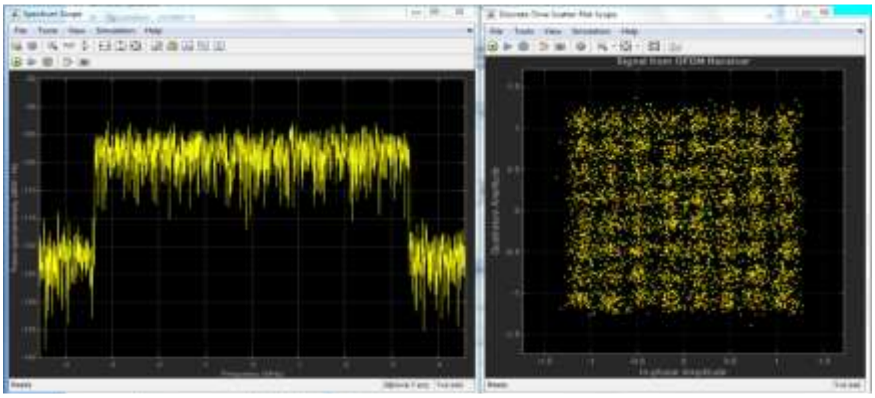

Fig. 7: Frequency spectrum of receiver and constellation diagram at 18.5dB SNR default

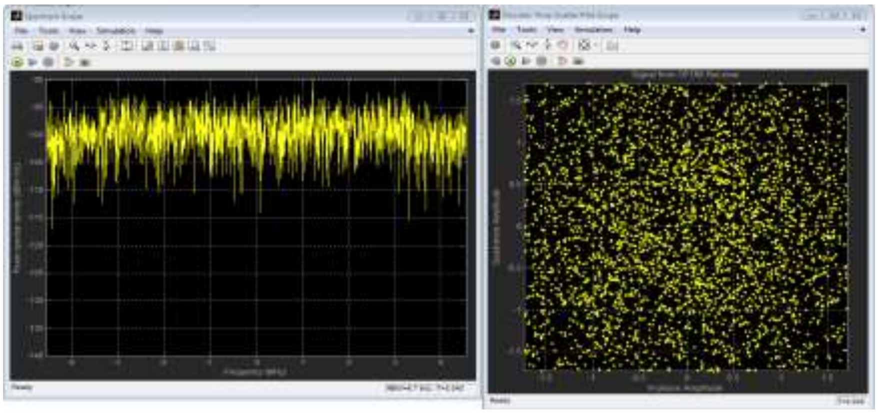

Fig. 8: Frequency spectrum of receiver and constellation at -3db SNR

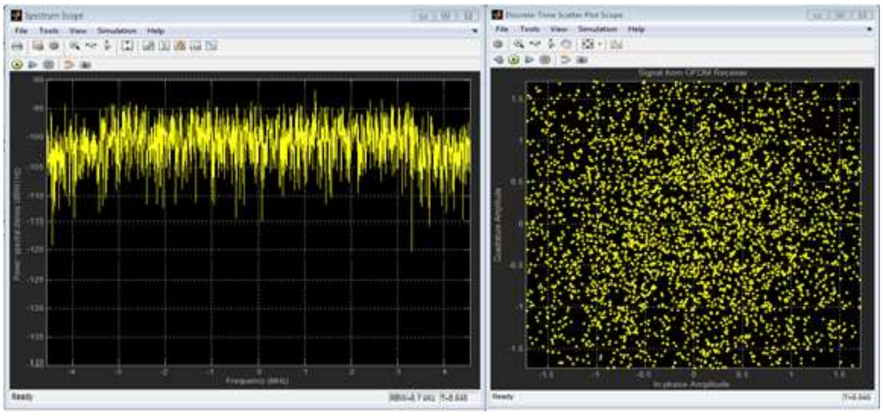

Fig. 9: Frequency spectrum of receiver and constellation at -1dB SNR

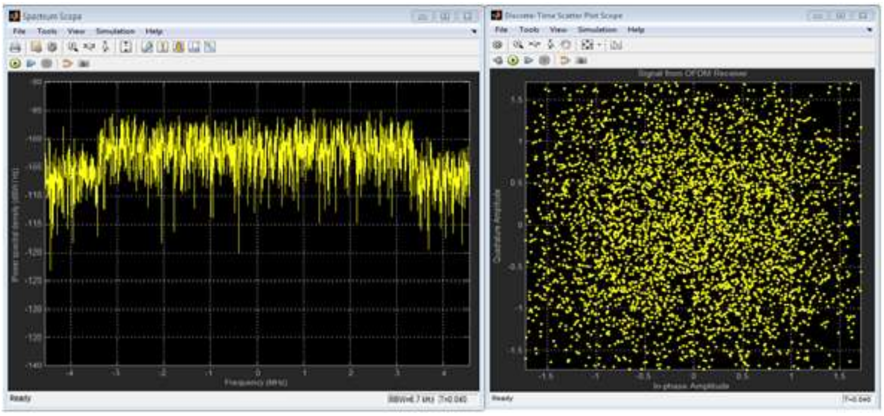

Fig. 10: Frequency spectrum of receiver and constellation at 3dB SNR

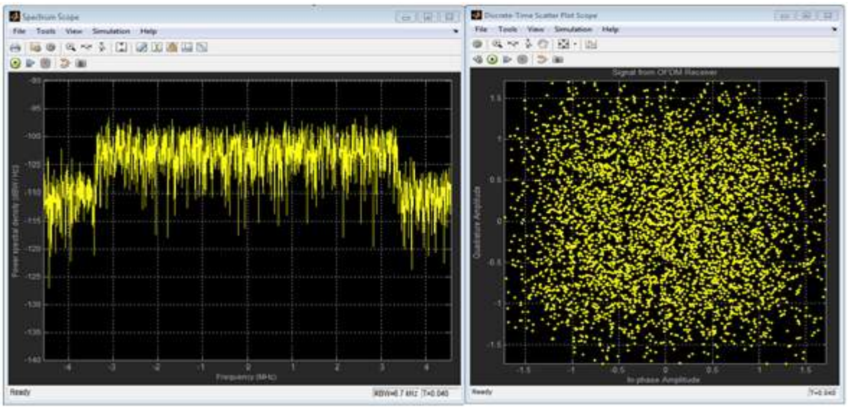

Fig. 11: Frequency spectrum of receiver and constellation at 7dB SNR

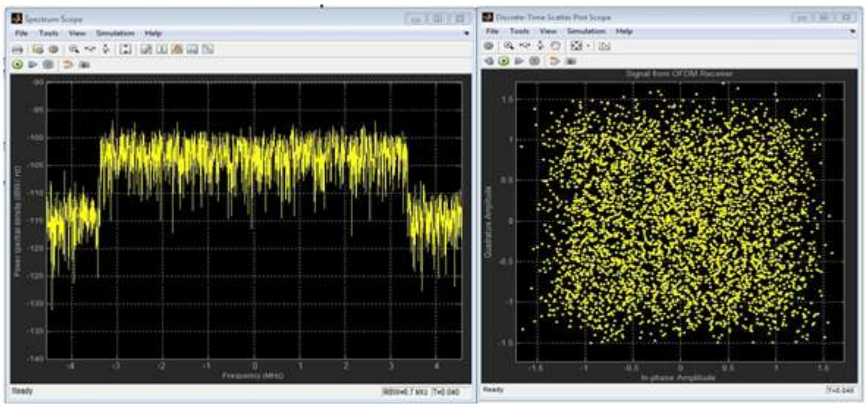

Fig. 12: Frequency spectrum of receiver and constellation at 11dB SNR

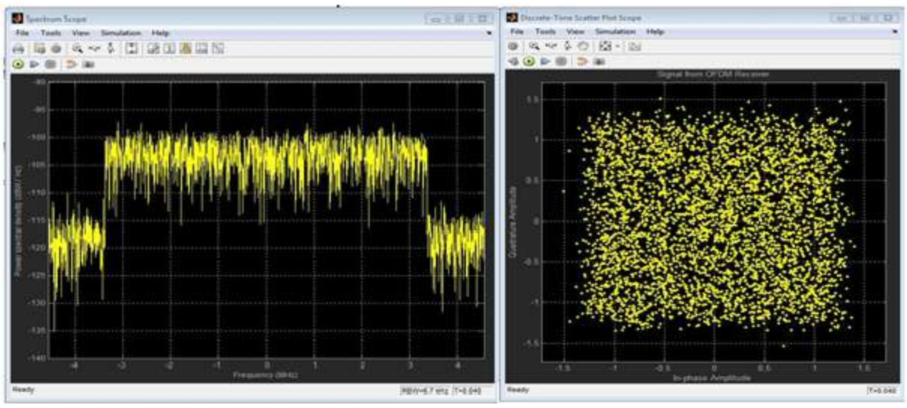

Fig. 13: Frequency spectrum of receiver and constellation at 15dB SNR

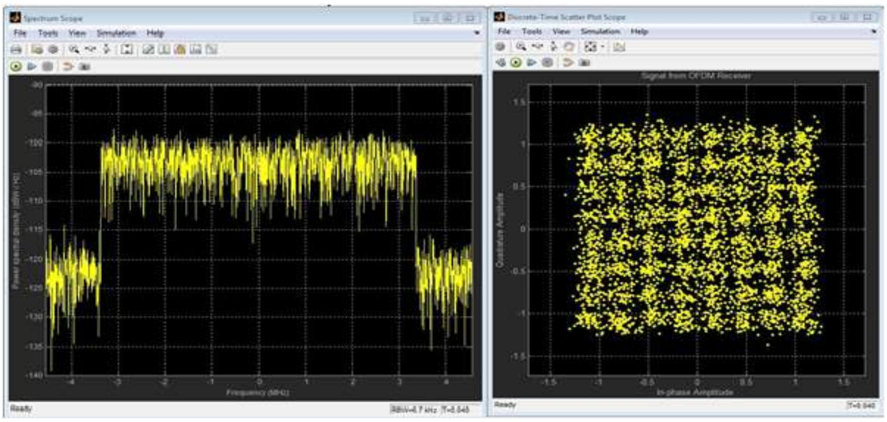

Fig. 14: Frequency spectrum of receiver and constellation at 19dB SNR.

The DVB-T model was simulated and the receiver frequency spectrum and accompany constellation diagram in Figs. 7 to 14 obtained. The simulation model was further carried out for SNR in the range of -3 to 35 dB for 64 QAM as modulation technique and the results are shown in Table 4. Fromthe table it is observed that a better BER performance of 10^{-3} is achievable at 15dB of the SNR. The plot obtained showed that this model worked well on SNR above 15dB. For the value of BER measured after the convolution deinterleaver decoder at the receiver, the set of BER shown in Table 5 was obtained.

IV. Results Discussion

The constellation diagrams represent the time scatter plot demonstrating the scattering of the transmitted and received signal at different values of SNRs. It is observed that at very low SNRs the symbols were very difficult to recognize (low resolution) but as the value of SNR increased, the symbols became clearer (higher resolution). At low value of SNR (-3dB to -1dB), the modulated signal and side frequencies were indistinguishable (that is, they overlap), but as the SNR increased (from 3db to 19dB) the modulated signal was separated from the noise (side band frequencies) as depicted in Figs. 7 through to 14. The higher the SNR, the more distinct the carrier signal from the noise at the receiver (the higher the resolution).

Table 4: Measured BER after Viterbi Block Decoding

No.	SNR (dB)	BER
1	-3	10^{-1}
2	-1	10^{-1}
3	3	10^{-1}
4	7	10^{-1}
5	11	10^{-1}
6	15	10^{-3}
7	19	10^{-6}
8	23	0
9	27	0
10	31	0
11	35	0

Table 5:SNR and Measured BER after Convolution Deinterleaver

No.	SNR (dB)	BER
1	-3	10^{-1}
2	-1	10^{-1}
3	3	10^{-1}
4	7	10^{-1}
5	11	10^{-1}
6	15	10^{-3}
7	19	0
8	23	0
9	27	0
10	31	0
11	35	0

The results shown in Table 5 indicate that at a 15 dB SNR, a BER of 10^{-3} was obtained. By comparing Tables 4 and 5, it is observed that at an SNR of 19 dB, the BER was 0. That is, there was no error. This implies that when convolution decoding was employed the bit error rate BER was improved and by extension, it can be seen that above 15 dB SNR the model worked well.When a 16 QAM was used in place of 64 QAM, a better BER value was obtained because the 16 QAM required a less SNR but a lower bandwidth hence cannot transmit data at a larger bandwidth. That is, the 16 QAM can transmit 4 bit per symbol [17, 18] while the 64 QAM transmits 16-bit per symbol [19] and hence requires higher SNR to achieve the same BER. For instance in Table 4, as the acceptable BER of 10^{-3} was obtained at 15 dB SNR, same result could be obtained with less SNR value if 16QAM was used.

V. Conclusion

The simulation results in this study has demonstrated how channel coding using convolutional code can improve the efficiency of data transmission. The DVB-T model described how encoding using punctured convolution can improve error correction and improve bit error rate. The AWGN was used as the channel. The SNR and BER deduced showed that the convolution coding worked within acceptable BER value of 10^{-3}.

The study showed that convolutional punctured coding will improve the reliability of data transmission over a channel. Two conclusions can be made based on the result obtained namely:

1. convolution coding improves the reliability of data by enhancing error correction at the receiver and hence

by extension improve data transmission over a channel

2. Secondly, depending on application performance requirement, a 16QAM can be used in place of the 64QAM in the model for improvements in the BER.

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