Reduction of white noise in a communication channel

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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 channel. The study utilized IEEE and ETSI standards in developing the model. 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 parameter, the signal to noise ratio (SNR) and BER were observed and a relationship between the rates plotted, which established that as the SNR increased the BER also improved when convolutional coding was employed. The use of encoding and decoding techniques on Digital Video Broadcasting Terrestrial (DVB-T) standard was demonstrated. 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}.

Key words: Channel, Convolution Coding, modulation, SNR, BER.

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 (Semenov & Krouk, 2011), to transform the signal sent in such a way that it will have increased robustness against common channel impairments, like 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 contain structured redundancy which enable the transmitter or receiver to decide how to process this data. The transform data has a level of error correction code embedded in it. This method has been found to be less susceptible to errors (Semenov & Krouk, 2011). Convolutional coding are 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 (Mathworks, 2016). The channel coding technique used in this model is punctured convolutional coding system. A convolutional encoder can be employed to convol the input stream with the encoder impulse response to obtain a convolutional code, in the aforementioned communication systems, the success of efficient transmission of data at high speed heavily depend on the development of efficient data transmission schemes by the use of channel coding high speed communication within acceptable bit error rate can be achieved (Mathworks, 2015). This report by extension also examine the use of convolutional coding in practical application on digital video Broadcasting Terrestrial (DVB-T).

This paper is organized into the following sections, in section II., the convolution model is describe and building block used was defined, in the third section (section III) convolution Simulation and result using feed forward encoder. Section IV described the DVB-T model, Section V describe simulation and result as convolution coding is applied to a standard DVB-T system and the result and analysis of the bit error rate(BER) and signal to noise ratio SNR. Section VI describes the Conclusion.

II. CONVOLUTION ENCODING PRINCIPLE AND MODELS

convolution encoding codes 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 contain structured redundancy which will enable a receiver or transmitter decide how to process the received data.

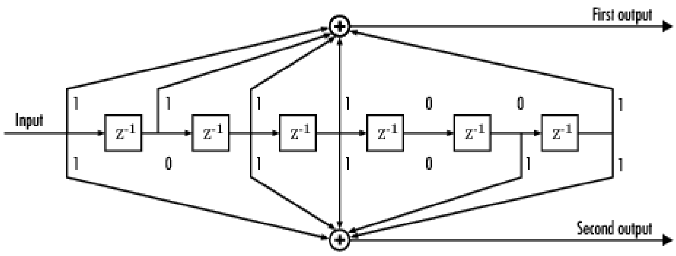

Figure 1: A rate 1/2 code Feed-Forward Convolution Encoder (Source:.mathworks.co.uk)

The encoder is made up of six memory registers, considering figure 1. the encoder has only one input the current input is 1 bit making a total of seven bit stores this number of bits stored in the shift register is called the constraint length, encoder has one input as seen in figure 1 and two output, the code generator is a 1 by-2 matrix of octal number, The first element in the matrix determine which input contribute to the first output and the second element indicate which input value contribute to the second output. it is also observe that the encoder is scalar for it contain only one input. (Mathworks, 2015). when in operation the encoder is specified by m, n, k. (Semenov & Krouk, 2011) in which each m-bit information to be encoded is transformed in to n-bit symbol and m/n is used to specifies the code rate, and the transformation obtain is a function of last information symbol k and k is the constraint length(Semenov & Krouk, 2011) . when data is to be encoded it start with k memory registers, each storing 1 input bit this encoder has two binary adder as shown in figure 1. let A=1111001 which in octal is 171 and B=1011011 which in octal is 133 as shown in figure 1 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.

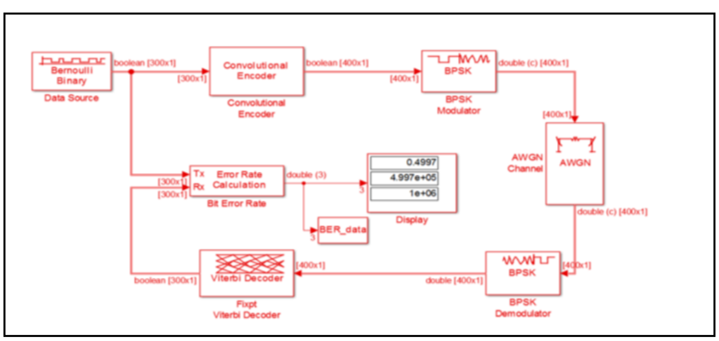

Figure 2: Punctured convolutional coding simulink model (Source: mathworks.co.uk.)

Operation:

The Bernoulli Binary generator generate the binary bit stream to be encoded, which is then applied to the convolution encoder the binary stream are then encoded and by the use of the BPSK modulator it is then modulated and transmitted over the AWGN channel block to simulate transmission over a noisy channel. demodulating is done by the viterbi decoder block and then depuntured. 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 to its original source bits. and the information contain in the error calculation block are the bit error rate (BER), the number errors observed and number of bits processed(Mathworks, 2015). the table of parameter shows the parameter used.

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

Table 1: Table of parameters

the theoretical bit error rate(BER) is also calculated using

Theoretical bit error rate r = (n-1)/n

$$P_b \le \frac{1}{2(n-1)} \sum_{d=d_{free}}^{\infty} \omega_d erfc(\sqrt{rd(E_b / N_0)}) \quad (1)$$

"In this expression equation (1), erfc denotes the complementary error function, r is the code rate, and both dfree and wd are dependent on the particular code. For the rate 3/4 code of this example, dfree = 5, w5 = 42, w6 = 201, w7 = 1492, and so on"(Mathworks, 2015). The expression is used to calculate the theoretical bit error rate (BER).

III. CONVOLUTION MODEL

Using MATLAB simulink the model was simulated and the graph of simulated bit error rate (BER) and theoretical BER was plotted against signal to noise ratio, also included is a best fit curve for simulated BER

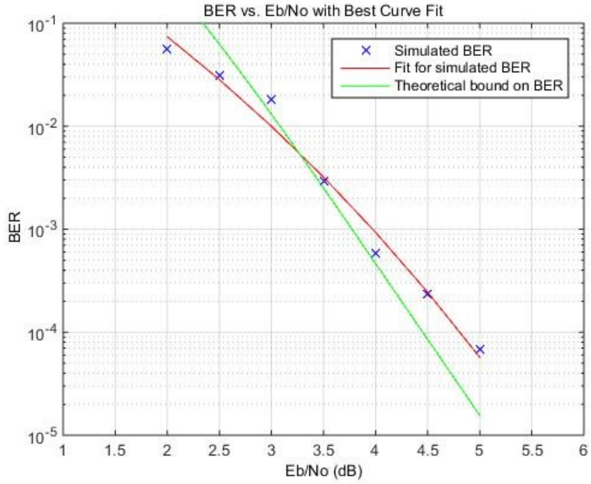

Figure 3: BER versus SNR with best curve fit

Table 2: 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}

It can be deduced from Figure 3 and Table 2 of the simulated value and theoretical value calculated, that as the value of signal to noise ratio SNR increases, the bit error rate also improves for instance it can be observed that the signal to noise ratio of SNR value of 5dB in table 2 has a bit error rate of 10^{-5} that is at this value, 1 bit received in error for 100000 bit sent. this is far better than when the signal to noise ratio is 2dB that is with bit error rate of 10^{-1} that 1 bit received in error when 10 bits are sent. When convolution code is used (Simulated BER) the value obtained for the simulated BER and theoretical BER. shown is in table 2, in the theoretical BER the signal to noise ratio range 2dB, 2.5dB, 3dB are having a bit error rate of 10^{-1} while in the simulated BER the signal to noise ratio is observe to be of the range 2dB, 2.5dB are having same value of BER 10^{-1} where Eb/No. of 3dB of the simulated BER is having an improved BER of 10^{-2} this is due to the convolution coding introduce, in comparism to the theoretical value obtain, another graph can be obtain by considering the trend of the theoretical and simulated value obtained in figure 3, which will show the plot of signal to noise ratio SNR to the bit error rate (BER)

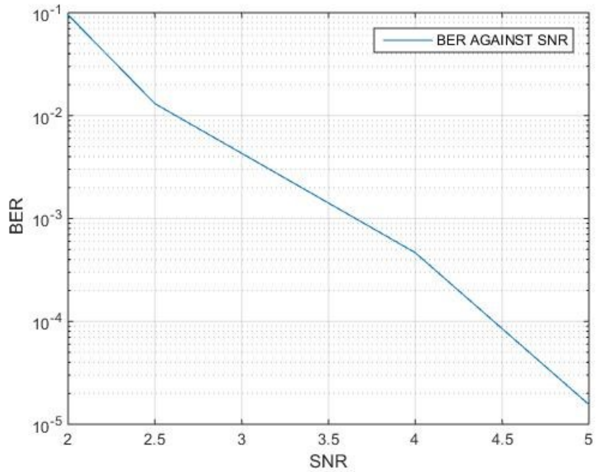

Figure 4: BER Versus SNR.

Considering Figure 4, which is the plot of SNR to BER base on the trend of both the simulated and theoretical BER. This graph infers that the ideal BER versus SNR graph will exhibit this trend. Hence has the signal to noise ratio increases the bit error rate also improves from 10^{-1} to 10^{-5}. it can be observe that the graph obtain from this trend is almost linear hence convolutional coding improves the bit error rate.

IV. DVB-T MODEL

The experiment uses DVB-T model which is a standard from the European telecommunications Standards Institute(ETSI)(Begin, Haccoun & Paquin, 1990).

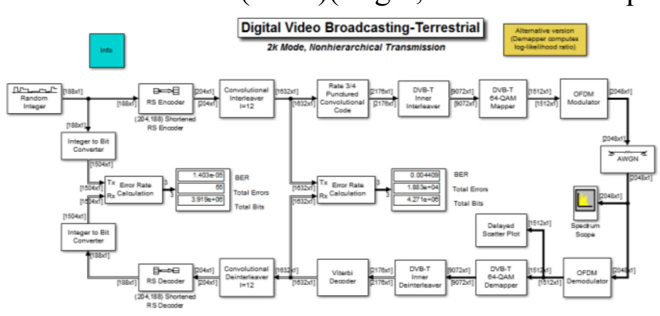

Figure 5: DVB-T: digital video broadcasting Terrestial (ETSI, 2016).

This model also include the Bernoulli Binary Generator block to produce binary stream as a source the AWGN channel block to simulate the noise and the error rate calculation block to display the BER, error, and amount of processed bit(Mathworks, 2016). The RS encoder block provide extra protection to the system by adding redundancy code that can be used during error correction, Punctured convolutional code block to convol the bit stream at the input. DVB-T 64 QAM mapper to map the data stream from the interleaver to unto constellation, OFDM modulator to modulate the constellation map, data is then modulated, Reed Solomon encoding (RS encoding)(Blahut, 1983) this add redundancy to the data stream which help to correct data error, and the interleaving block works on the position of the bit stream by spreading the code in time before transmission, The randomizer convert long sequence of bit stream in a random sequence to improve the coding performance (Mathworks, 2016).

At the receiver end of the model a viterbi block decoder, Convolutional deinter leaver, and RS decoder decode the transmitted signal. This model uses orthogonal frequency division multiplexing (OFDM) with 64 QAM modulation. It display the transmitter side coding and modulation for the 3/4 code rate mode with a corresponding AWGN (Begin, Haccoun & Paquin, 1990) and ideal receiver chain. Using this model the performance of convolutional coding on the communication system will be investigated by measuring the bit error rate (BER) and the signal to noise ratio SNR (Eb/No)(Mathworks, 2016). The effect of increasing the SNR is observe on both the frequency spectrum and constellation diagram, table 3 shows the parameters used for this model

Table 3: Table of parameters

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

V. SIMULATION AND RESULT OF DVB-T MODEL

When model is simulated it display the receiver frequency spectrum and constellation diagram consider figure 5 to 11.

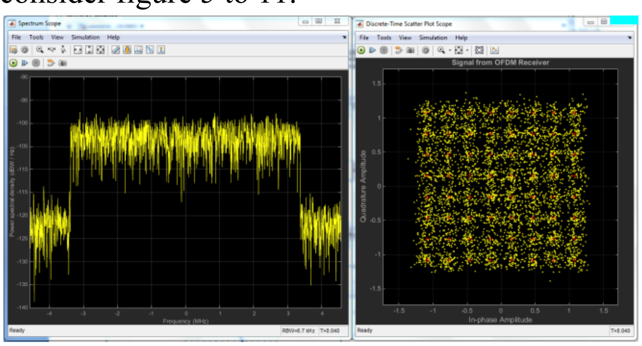

Figure 5: Frequency spectrum of receiver and constellation diagram. at 18.5dB SNR default

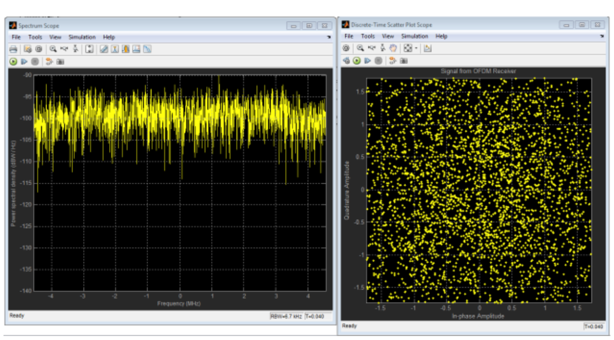

Figure 6: Frequency spectrum of receiver and constellation at -3db SNR

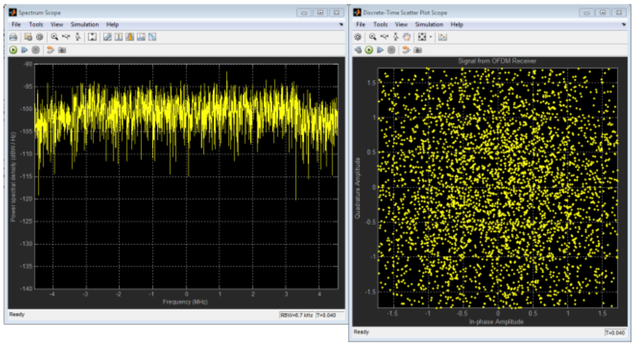

Figure 7: Frequency spectrum of receiver and constellation at -1db SNR

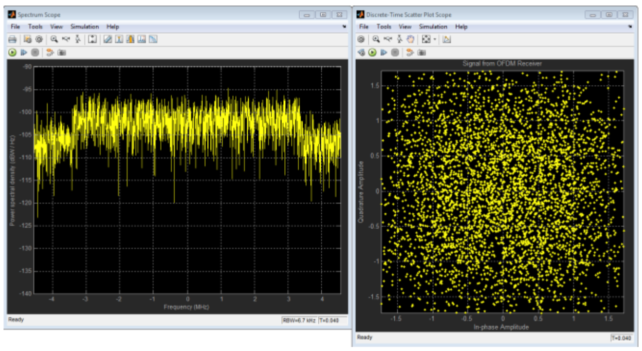

Figure 7: Frequency spectrum of receiver and constellation at 3dB SNR

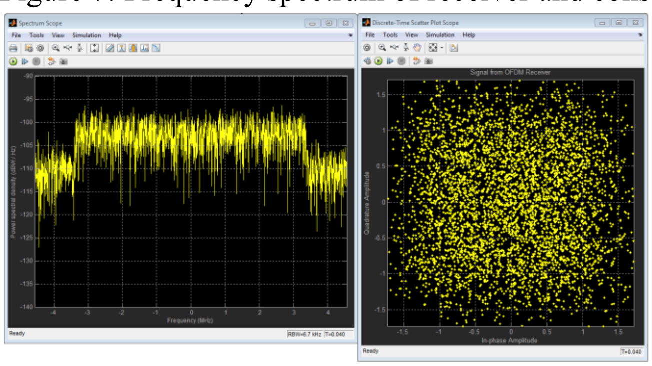

Figure 8: Frequency spectrum of receiver and constellation at 7dB SNR

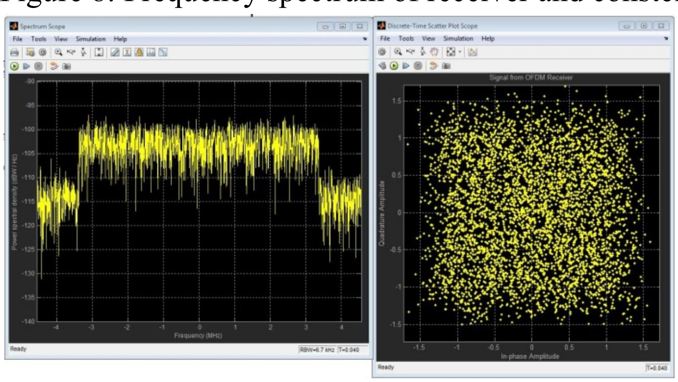

Figure 9: Frequency spectrum of receiver and constellation at 11dB SNR

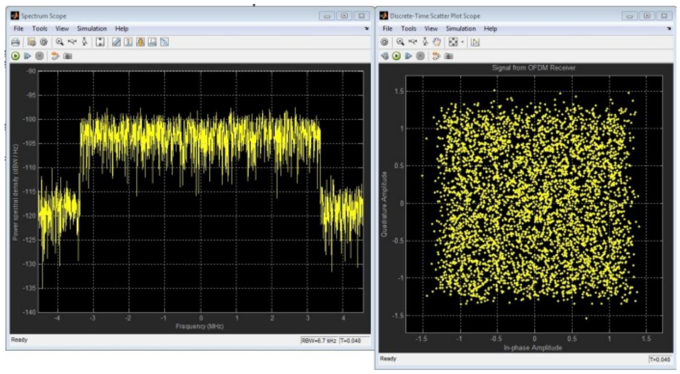

Figure 10: Frequency spectrum of receiver and constellation at 15dB SNR

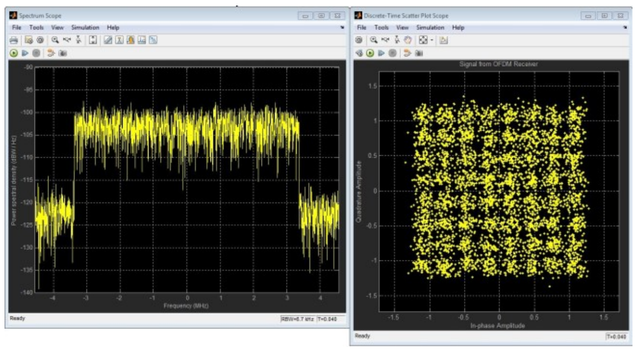

Figure 11: Frequency spectrum of receiver and constellation at 19dB SNR.

The constellation diagram is the time scatter plot demonstrating the scattering of the transmitted and received signal at different values of signal to noise ratios. it will be observe that at very low signal to noise ratio SNR the symbols are very difficult to recognize(low resolution) but as the value of SNR increases the symbols becomes clearer(higher resolution) on the frequency spectrum at low value of SNR -3dB to -1dB the modulated signal and side frequencies are indistinguishable that is overlap on each other but as the signal to noise ration SNR increases (from 3db to 19dB) the modulated signal is separated from the noise(side band frequencies) as depicted in figure 7 through to 11. As the SNR increases the more distinct the carrier signal from the noise at the receiver.

Further using simulation model shown in figure 4 simulation is carried out for signal to noise ratio in the range of -3 to 35 for 64 QAM as modulation technique and the result obtain is shown in table 4.

Table 4: BER measured after Viterbi block decoder

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

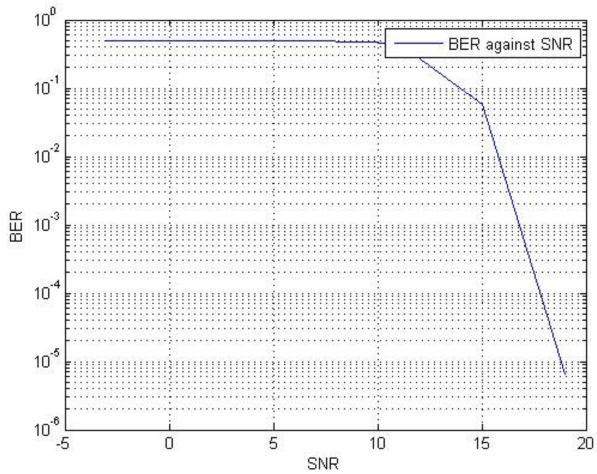

Figure 12: The plot of BER Versus SNR

considering figure 12 it is observe that the performance 10^{-3} is achievable at 15dB of the SNR, the plot obtain shows that this model works well on SNR above 15dB. Considering the value of BER measured after the convolution deinterleaver decoder at the receiver the following BER is observed as shown in table 5.

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

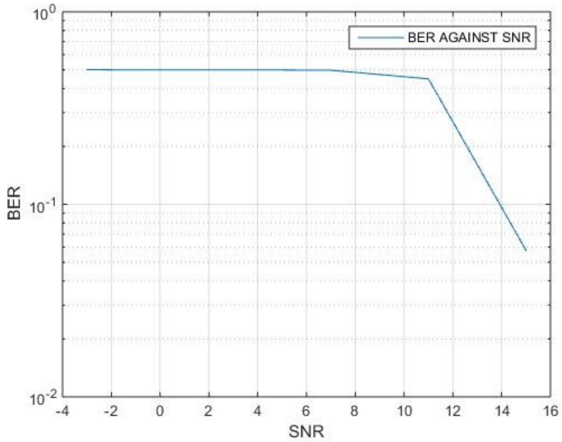

Figure 13: BER versus SNR

Table 5 and figure 13 infers that at 15dB SNR a BER
of 10^{-3} is obtained. but comparing table 4 and 5, it is observe that at 19dB SNR the BER is 0 that is there is no error, this implies that when convolution decoding was done the bit error rate BER was improved and by extension it can be seen that at above 15dB SNR the model works well.

When a 16 QAM is used in place of 64 QAM it will have a better BER value because the 16 QAM requires a less signal to noise ratio but 16 QAM has a lower bandwidth hence cannot transmit data at a larger bandwidth higher than that is 4 bit per symbol (Van Lint, 1982) while the 64 QAM will have a greater bandwidth that is 6-bit per symbol and hence require higher signal to noise ratio SNR to achieve the same BER. for instance in table 4. When the acceptable BER of 10^{-3} was obtained at 15dB SNR it will be obtain in less SNR value if 16QAM is used.

VI. CONCLUSION

The model used in this paper demonstrate how channel coding using convolutional code can improve the efficiency of data transmission, the DVB-T model describe how encoding using punctured convolution can improve error correction and improve bit error rate. The AWGN was used as the channel. The signal to noise ratio SNR and bit error rate (BER) deduce shows that the convolution coding works within acceptable BER value of 10^{-3}. The Paper shows that convolutional punctured coding will improve the reliability of data transmission over a channel. There are two conclusion that can be made base on the result obtain above. First, Convolution coding improves the reliability of data by enhancing error correction at the receiver and hence by extension improve data transmission over a channel. Secondly, depending on application performance requirement instead of using 64 QAM, a 16 QAM can be used in the model to improve the BER.

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