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PERFORMANCE ANALYSIS OF A CONVOLUTIONAL ENCODER USING DIGITAL MODULATION TECHNIQUE

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Abstract

The challenges in 5G is to provide a tradeoff between Bit Error Rate (BER) and high data rate. Forward Error Correction is one of the prominent techniques to correct both random and burst errors. A Software-Defined Radio (SDR) is the device used in the area of radio communication system where the key parts of its functionality are performed by means of software. Such a design makes SDR to be used in ubiquitous network environments because of its flexibility and programmability. NI USRP 2954R provides an integrated hardware and software solution, operates at a frequency of 10MHz to 6GHz, and is used for rapidly prototyping high-performance wireless communication systems such as 5G technology. The software simulator of the SDR transceiver is designed using NI LabVIEW which is a graphical programming language developed by National instruments. In this paper, the performance of convolution encoder is simulated in NI LabVIEW and analysed for various modulation schemes such as Binary Phase Shift Keying (BPSK) and Quadrature Amplitude Modulation (QAM). The parameters of the convolution encoder such as constraint length and code rate are varied in BPSK modulation and corresponding variations in BER are analysed. From the result it is concluded that transmission with convolution coding provides better result than uncoded transmission and it is also concluded that BER decreases with increase in constraint length (3, 5, 6, 7) and it is observed that for lower code rate BER is better.

Keywords:

Software Defined Radio, BER, Binary Phase Shift Keying, Quadrature Amplitude Modulation, Signal-To-Noise Ratio

1. INTRODUCTION

Wireless communication is the term that includes all the procedures and forms of connection and communication related to the usage of wireless communication technologies and devices. Upcoming technologies like 5G aim at producing higher data rate in the range of gigahertz per second with minimal Bit Error Rate (BER). Error rate plays a vital role in determining the efficiency of the communication system [1]. Hence, error control coding is one of the most appropriate methods for error-free transmission of information to the receiver in a communication system [2].

There are two types of error correction methods, namely Automatic Repeat request (ARQ), and Forward Error Correction (FEC) technique. Among the two, FEC is the prominent technique as it is quicker and will not retransmit the bits when there is an error, but sends the redundant bit with the transmitted bits. Whereas, in the ARQ technique, error detection method is accompanied with acknowledgement which is time consuming. Forward Error Correction (FEC) is the suitable technique used for controlling errors in modern data transmission over noisy communication channels, as it has the capability to correct both random and burst errors [3].

One of the methods in forward error correction is Convolutional codes. A Convolution Encoder accepts an input stream of message and transmits the encoded bit stream generated in the process of encoding. The redundant symbols in output bit pattern make the transmitted data more immune to the noise in the channel. This is because redundant bits help to decide and rectify the errors in received pattern. Convolutional codes are basically used in the area of space communication or in very noisy channels [4]. Convolutional Encoder is applied with the significance that it belongs to the category of block code which can transmit the stream of bits rather than the fixed number of bits.

In a basic communication system, the transmitter-source will generate the input bits that will be encoded, modulated and passed over an AWGN channel and then the output waveform will be demodulated and decoded for error correction in the receiver's end. In this paper, the performance of convolution encoder is simulated in NI LabVIEW and analysed for various modulation schemes such as Binary Phase Shift Keying (BPSK) and Quadrature Amplitude Modulation (QAM). BPSK is the simplest digital modulation technique where only zeros and ones are involved. Quadrature Amplitude Modulation is the spectral efficient modulation technique where symbols are transmitted by the combination of both Amplitude modulation and phase modulation. The parameters of the convolution encoder such as constraint length and code rate are varied in BPSK modulation and the corresponding variation in BER is analysed in the NI LabVIEW software. The software simulator of the SDR transceiver is designed using NI LabVIEW which is a graphical programming language developed by National instruments. SDR is a combination of software and hardware. In SDR we can implement different modulation and demodulation techniques in any frequency that is available in the wide frequency spectrum. This is done with the help of reconfigurable hardware and software [5], thus enabling the SDR to reduce the spectrum scarcity [6]. Universal Software Radio peripheral is a SDR system wherein majority of the functions are performed by the software, LabVIEW [7]. USRP is used in prototyping many technologies such as Multiple Input Multiple Output (MIMO), LTE technology, 5G technology, etc. Produced by National Instruments, USRP is used for a wide range of Radio Frequency communication up to 6GHz.

The subsequent parts of this paper are organized as follows: section 2 details an algorithm of convolution encoder and Viterbi decoder, section 3 depicts the LabVIEW implementation, section 4 shows the simulation results, and section 5 affirms the results are concluding the paper.

2. ALGORITHM

2.1 CONVOLUTIONAL ENCODER

Convolutional coding technique is the bit level coding. Convolutional codes are used in applications where high performance with low implementation cost is required. It also has larger gain when compared with linear codes. Encoding of convolutional codes can be accomplished with the help of simple registers. The convolutional codes are denoted by (*n*, *k*, *K*, *L*), where *n* is number of output bits (coded), *k* is the number of input bits (uncoded), *K* is the code rate and *L* is the code memory depth, which represents the number of register stages [9]. The number of the registers used in the encoding process is called the constraint length and it is indicated as *C* in Eq.(1)

$$C = (L+1) \quad (1)$$

$$K = k/n \quad (2)$$

The Eq.(2) represents the code rate which is the ratio of input bit (*k*) to the output bit (*n*).

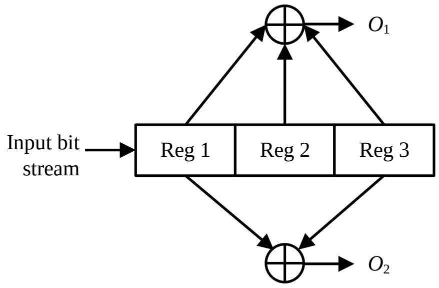

Fig.1. Convolutional encoder [10]

2.2 VITERBI DECODER

The Viterbi decoding algorithm is used to perform decoding in the memory-less noise channel [11]. The Viterbi Algorithm (VA) finds the most likelihood path transition sequence in a state diagram, when sequence of symbols is provided. The Viterbi decoder consist of Branch metric, path metric unit and trace back unit as shown in Fig.2. The path with minimum hamming distance is traced and symbols are retrieved.

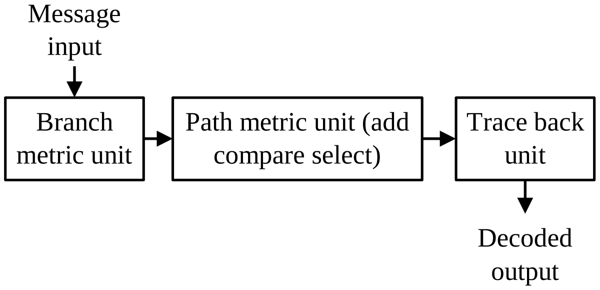

Fig.2. Viterbi decoder [12]

2.3 BER

The Bit Error Rate (BER) is the ratio of error bits to the total number of transferred bits during a studied time interval. BER is a unit-less quantity, mostly expressed in percentage.

BER = Number of errors in received bits/Total number of bits transmitted

3. LABVIEW IMPLEMENTATION

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a design platform and development environment used as a graphical language for SDR application. The concept mapping of the proposed approach is shown in the Fig.3.

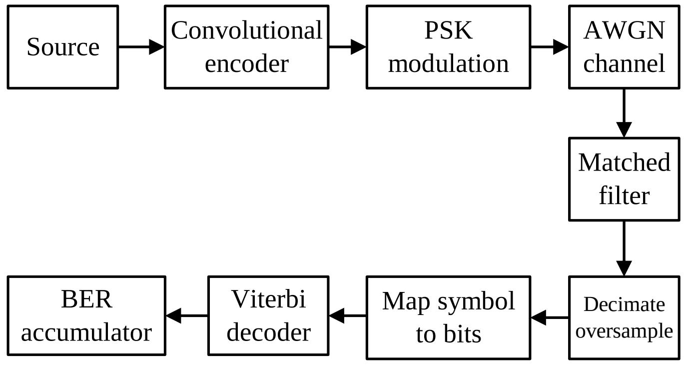

Fig.3. Proposed Method

In this paper, the BER is analysed for various constrains of the convolutional encoder. The LabVIEW block is designed based on the concept mapping provided in the Fig.3.

The transmission block consists of random bit sequence generator which act as source. The random bits are encoded using the convolutional encoder and then modulated using the digital modulation techniques such as BPSK and QAM. The output complex waveform is passed through the AWGN channel that is obtained from adding two Gaussian noises. The complex wave is demodulated and decoded using Viterbi decoder. The output of the decoder is compared with the bits of random bit generator to obtain the BER of the process.

3.1 CONVOLUTIONAL ENCODE VI

The convolution encoder is in the form of a finite state machine wherein the data is sent serially. Inputs as per the Fig.4 are code rate, constraint length, and input bit streams. The encoded bits are generated based on the code rate. The preconfigured generator matrix is used to vary the code rate accordingly [9].

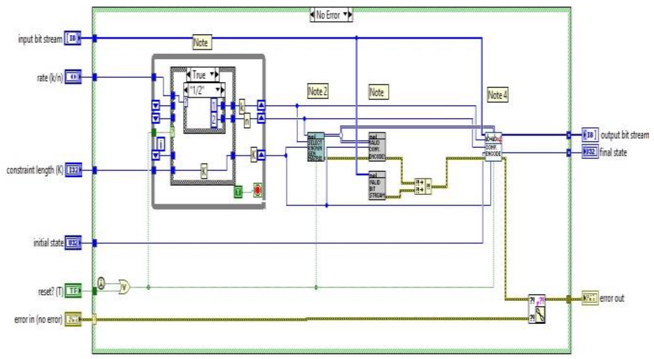

Fig.4. MT Convolutional Decode VI

3.2 CONVOLUTIONAL DECODE VI

The Viterbi decoder has the function of decoding a convolutional encoded bit stream, using a specified rate or generator matrix. The Modulation Toolkit implements the convolutional decoding algorithm as a polymorphic VI with polymorphic instances corresponding to different types of the Viterbi decoding algorithm (hard decision or unquantized or soft decision) and the type of specification (code rate/generator matrix). The Viterbi algorithm (VA) is the optimal solution to the issue of determining the state sequence of a discrete-time finite-state Markov process observed in memoryless noise [13].

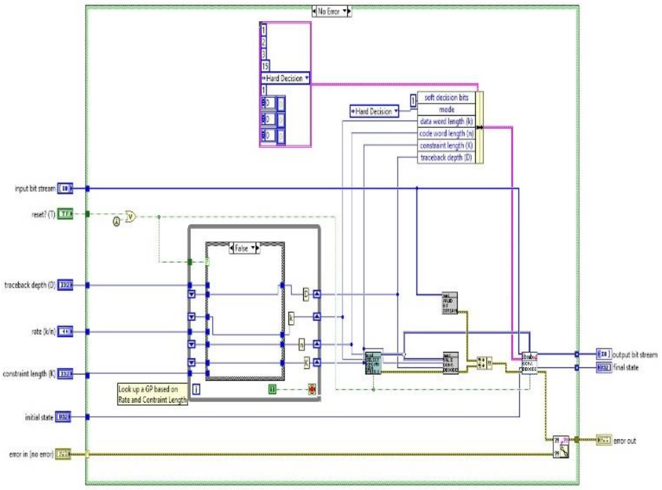

Fig.5. MT Convolutional Decode VI

3.3 AWGN VI

In the Additive White Gaussian Noise (AWGN), 'Additive' represents the adding to the intrinsic noise of the communication system, and 'White' refers to the distribution of uniform power across the frequency band. It is the basic noise model used in the communication system.

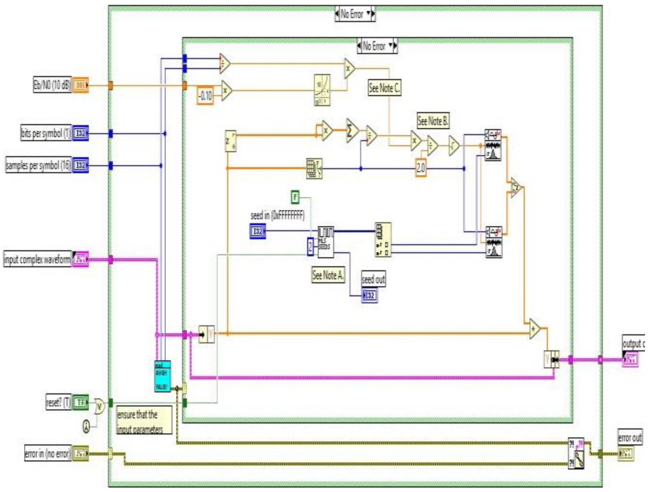

Fig.6. AWGN block

In Fig.6, the VI of AWGN, the complex waveform from the modulation is added up with the AWGN to generate specified E_b/N_0. This process is done by addition of two Gaussian noises that are been seeded separately. The noise can be varied by adjusting the seed value. The AWGN is widely used in deep space communication [14].

4. SIMULATION AND RESULTS

Table.1. Parameter used in simulation

Parameter	Value
Modulation type	QAM, BPSK
Encoder	Convolutional encoder
PN order	19
Seed in	-1
Code rate	1/2, 2/3, 1/3
Constraint length	3, 5, 6, 7

The Fig.7 and Fig.8 represent the BER of the uncoded and convolutional coded BPSK and QAM modulation respectively.

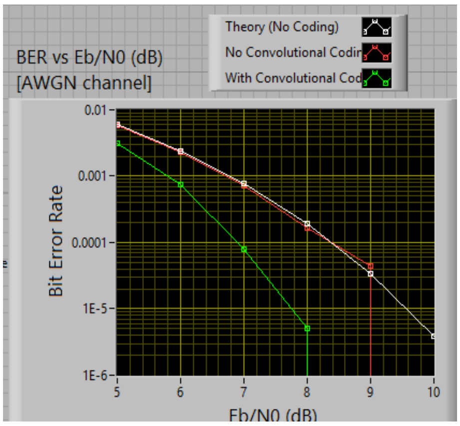

Fig.7. BER vs. E_b/N_0 of convolutional code in BPSK modulation

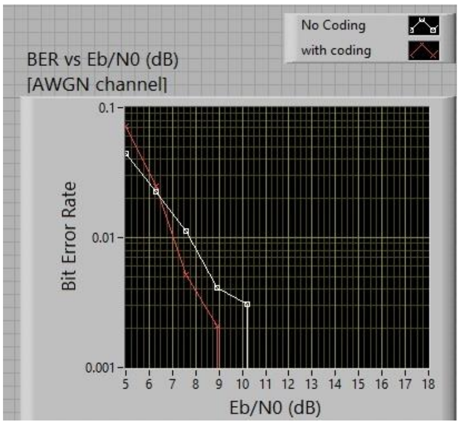

Fig.8. BER vs, E_b/N_0 of convolutional code in code QAM modulation

Table.2. Comparison of BER with and without convolution coding in QAM and BPSK modulation

E_b/N_0	BER of uncoded	BER (BPSK)	BER of uncoded	BER (QAM)
5	0.0086	0.0053	0.07	0.08
6	0.0032	0.00095	0.05	0.04
7	0.0009	0.000091	0.045	0.02
8	0.0002	0.0000008	0.0098	0.008
9	0.00007	0.0000001	0.007	0.003

From the Table.2, it is clearly seen that BER decreases more in the convolution coded BPSK and QAM modulation than in the modulation that is not coded. This happens because the Convolutional codes sender does not send the message bits, it sends only the parity bits, thus making the convolution-coded modulation to be more efficient than the uncoded modulation. It also shows that BER of BPSK modulation is low when compared with BER of QAM modulation.

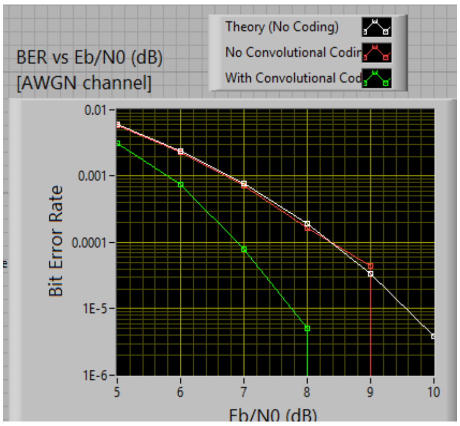

Fig.9(a). BER vs. E_b/N_0 of convolutional code in BPSK modulation of code rate 1/2

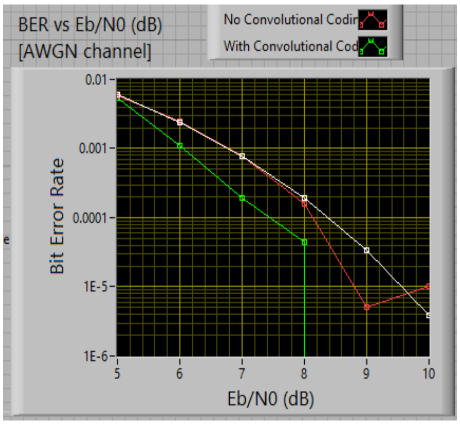

Fig.9(b). BER vs. E_b/N_0 of convolutional code in BPSK modulation of code rate 1/3

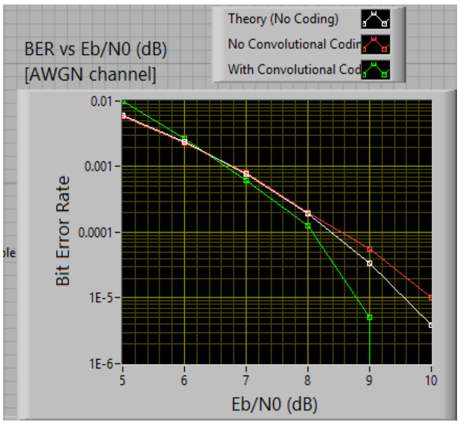

Fig.9(c). BER vs. E_b/N_0 of convolutional code in BPSK modulation of code rate 2/3

The Fig.9(a) - Fig.9(c) shows the BER vs. E_b/N_0 graph for the convolutional encoder of the constant constraint length 3 and the rate has been varied as 1/2, 1/3, 2/3 respectively and the corresponding changes in the BER graph has been obtained in the LabVIEW simulation software.

Table.3. Comparison of BER for the various code rate of the convolution encoder

E_b/N_0	BER (1/2)	BER (1/3)	BER (2/3)
5	0.0053	0.009	0.09
6	0.00095	0.001	0.005
7	0.000091	0.0002	0.0009

From the Table.3 it is seen that BER increases with increase in code rate. This is because the rate of a convolutional code that produces p parity bits per window and slides the window forward by one bit at a time is 1/*p*. The greater the value of *p*, the higher the resilience of bit errors, but the trade-off is that a proportionally higher amount of bandwidth is devoted to coding overhead [8].

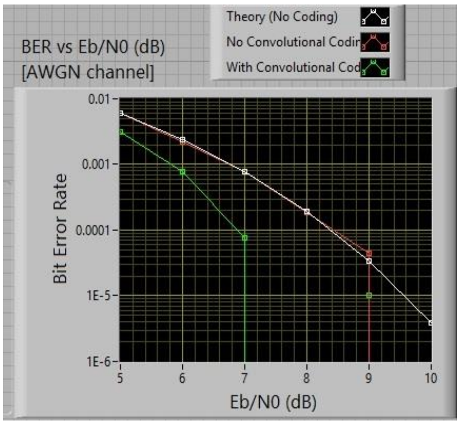

Fig.10(a). The BER vs. E_b/N_0 of convolutional encoder in BPSK modulation of constraint length 3

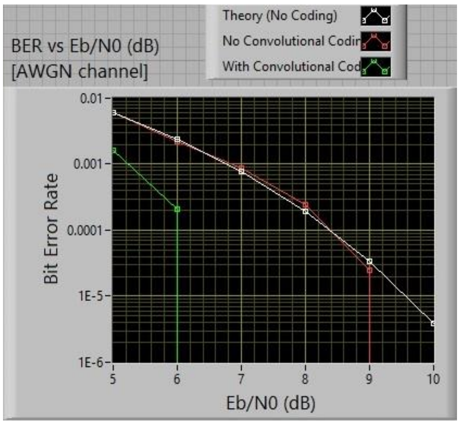

Fig.10(b). The BER vs. E_b/N_0 of convolutional encoder in BPSK modulation of constraint length 5

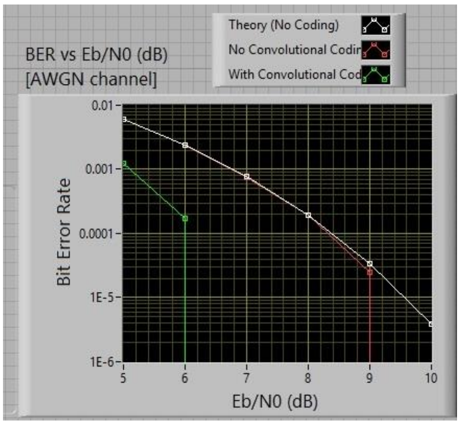

Fig.10(c). The BER vs. E_b/N_0 of convolutional encoder in BPSK modulation of constraint length 6

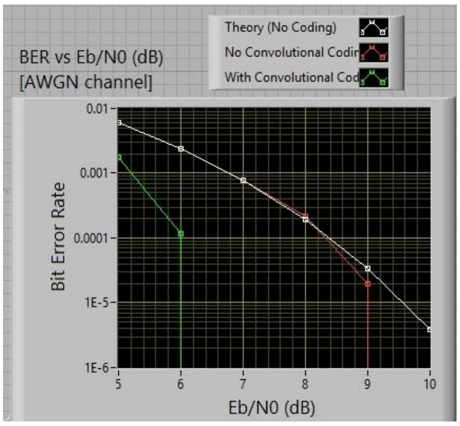

Fig.10(d). The BER vs. E_b/N_0 of convolutional encoder in BPSK modulation of constraint length 7

The Fig.10(a) - Fig.10(d) shows the BER of the convolutional encoder in the BPSK modulation technique with different constraint lengths, 3 - 7 respectively, where the code rate remains a constant at 0.5.

Table.4. Comparison of BER for various constraint length of the convolution encoder

E_b/N_0	BER (3)	BER (5)	BER (6)	BER (7)
5	0.0051	0.0044	0.0023	0.0023
6	0.00094	0.0005	0.0004	0.0001
7	0.00009	0.000005	0.0000002	0.0000001

From the Table.4 it is clear that BER decreases with increase in constraint length. As K is increased, the effect of input on the output is increased. Hence, the correlation between successive bits at output is increased. This leads to reduction in BER.

5. CONCLUSION

In this paper, we have used the graphical programming language LabVIEW for building, the BPSK and QAM transceiver block which consists of PN sequence order, convolution encoder, Viterbi decoder, AWGN channel, matched filter, QAM modulator, BPSK modulator, and Decimate Oversampler. With the help of LabVIEW, the communication system model is designed efficiently in a short period of time in comparison to the text based programming language. The performance efficiency of the convolutional encoder is analysed by simulation using NI LabVIEW. From the simulation results, it is concluded that the BER performance of convolutional coded system using Viterbi decoding algorithm provide much better results as compared to the uncoded system in different modulation techniques such as BPSK and QAM. This happens because of the transmission of parity bits that are computed from message bits. Unlike block codes, however, the sender does not send the message bits; it sends only the parity bits, so this makes the convolution coded modulation more efficient than the uncoded modulation.

From the Table.4 it is evident that the BER of the convolutional code system decreases as the constraint length increases. It is also concluded from the Table.3 that increase in code rate of the encoder increases the BER. The BER performance of the convolutional code system for the constraint length 7 is much better as compared to other lower values of the constraint length. Thus, we can conclude that the convolution coded modulation technique with code rate 1/2 and constraint length 7 has lesser error probability, which, in turn, increases the data rate.

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