Simulink Modeling of Convolutional Encoders

* Ahiara Wilson C and ** Iroegbu Chbuisi,
*Department of Computer Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
**Department of Electrical/Electronics Engineering , Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

ABSTRACT
This paper presents the Simulink modeling of convolutional encoders. The configuration covered modeling of configurable rate convolutional encoder with Viterbi decoder from a mother code rate of ½ to1/3 and 2/3 with constraint length 7. The modeling is done by changing rates of convolutional encoder and error of binary symmetric channel using simulink blocks.
Keywords: *Encoders, Simulink, Channels, Convolutional, Viterbi Decoder*

I. INTRODUCTION

The main aim of a digital communication system is to transmit information reliably over a channel [1]. The channel can be coaxial cables, microwave links, space, fiber optics etc, and each of them is subject to various types of noise, distortion and interference that lead to errors. Shannon proves that there exist channel-encoding methods which enable information to be transmitted reliably when source information rate R is less than channel capacity C. It is possible to design a communication system for that channel and with the help of error-control coding such as convolutional coding, one can achieve a very small probability of output error for that channel. Some forms of error control encoding that are used to recover some corrupted information are available. Convolutional coding is one of the channels coding extensively used for real time error detection and correction.

Convolutional encoding with Viterbi decoding is a powerful Forward Error Correction technique that is particularly suited to a channel in which the transmitted signal is corrupted mainly by Additive White Gaussian Noise (AWGN). The purpose of forward error correction (FEC) is to improve the capacity of a channel by adding some carefully designed redundant information to the data being transmitted through the channel [2]. The Viterbi algorithm essentially performs maximum likelihood decoding to correct the errors in received data, which are caused by the channel noise. Hence, minimize the bit error rate (BER) to improve the performance. Viterbi decoding has the advantage that it has a fixed decoding time and it is well suited to hardware decoder implementation. The requirements for the Viterbi decoder, which is a processor that implements the Viterbi algorithm, depend on the application in which it is used. Viterbi algorithm is the most resource consuming, and efficient [3].

II. ERROR CORRECTION TECHNIQUES

Channel coding and modulation provide the means of mapping information into waveforms such that the receiver (with an appropriate demodulator and decoder) can recover the information in a reliable manner. A block diagram derived from Figure 1, which shows this part of the digital communication link, is shown below.

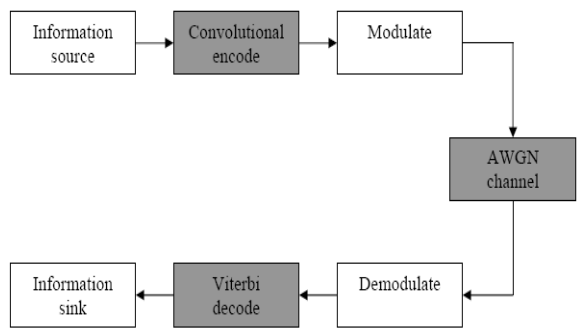

Figure 1: Basic digital communication link.

As seen in Figure 1, convolutional encoding is one way ofperforming channel coding. Another method uses block codes. In these methods, redundant bits are used to help determine the occurrence of an error due to noise present in the channel. In the receiver, Viterbi decoding is a way of performing channel decoding. Another method is turbo codes [4]. Turbo codes can be applied to the encoding process too. In these methods, errors can be "automatically" corrected (within specified limitations) to recover the original information. Error correction is a technique defined by the methods of encoding and decoding.One such technique, called the automatic repeat request (ARQ), simply recognizes the occurrence of an error and requests the sender retransmit the message. Another technique is known as the forward error correction (FEC) technique. This technique allows for "automatic" correction of errors [5].

2.1 Data Generation

Data generation is actually specifying and providing test input data that will be used to calculate the test output data. In matlab the data generator can generate this data (1…n) as required and specified in code. Since the model is for a 4G system and knowing that; that is a lot of data; the data generator was given the initial command randomgen=10000; which tells it the length of the data to generate.

The data generated will be transmitted through the channel by creating a matrix of random numbers of which ideally will constitute of both positive and negative numbers. The system is a digital one and the expected input data should be 0's and 1's is so saying that if else statement was used to achieve that by rounding off the numbers generated to either a one or zero. In the case matlab generates a number less than 0.5 it will automatically change that to zero and anything else would be 1. The idea behind converting the generated numbers to 0's and 1's is because the system is a digital one and as such we should be dealing with binary numbers of which the only existing numbers in the binary world are 0 and 1. The output of the data generator was called data and it is the input to the Convolutional encoder.

2.2 Convolution Encoder

Convolution encoder is a type of error-correction method in which each m-bit information input in will be encoded to n-bit information symbol at the output. M/n is the code rate, and the transformation is a function of the k information symbol, k is the constraint length of the encoder. In a typical a Convolution Encoder with rate of ½ and constraint length of k=7, there are six memories to hold the bits input, at the beginning all the memory hold the value of zero. There are two adders that combine the input data to product the output according to the arrangement of the designer.

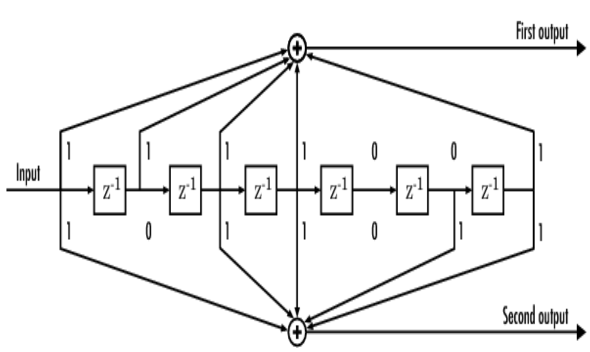

Figure 2: Example of Convolution Encoder constraint of 7

Convolution encoding can be done using the following methods

a. State diagram

b. Trellis diagram

a) State Diagram:

One way to represent simple encoders is with a state diagram. The state of an encoder is defined as its shift register contents. Each new input bit results in a new state. Therefore for one bit entering the encoder there are 2 possible branches for every state. To make easy for tracking the transition two different types of line are used. Solid line (-) represents the transition when the input bit is '1' and dotted line (------) represents the transition when the input bit is '0'. The diagram shown in Fig-3 illustrates all the state transitions that are possible for the encoder.

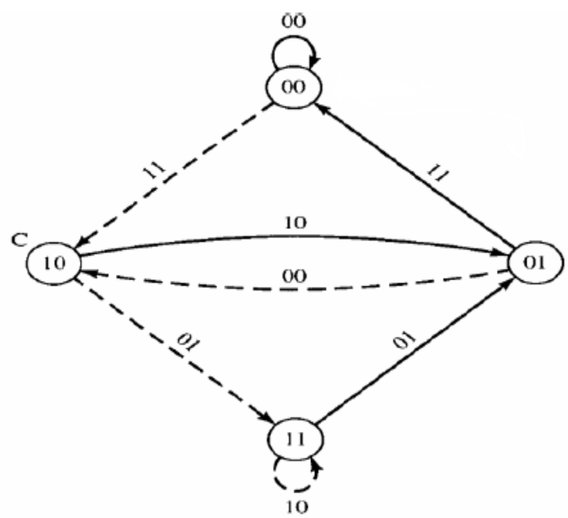

Figure 3: Encoder State Diagram

b) Trellis Diagram:

A trellis diagram is a kind of state diagram and mainly it can be used for decoding of convolutional codes. The detection of the original stream can be described as finding the most probable path through the trellis. In the trellis diagram, each node specifies an individual state at a given time and indicates a possible pattern of recently received data bits. Each branch indicates the transition to a new state at the next timing cycle. When two paths enter the same state, the one having the best metric is chosen: this path is called the surviving path. In the decoder the selection of surviving paths are performed by all the states. Based on the received coded bits we can choose the more likely path and ignore the least likely paths. The decoding complexity can reduce by ignoring the minimum likely paths.

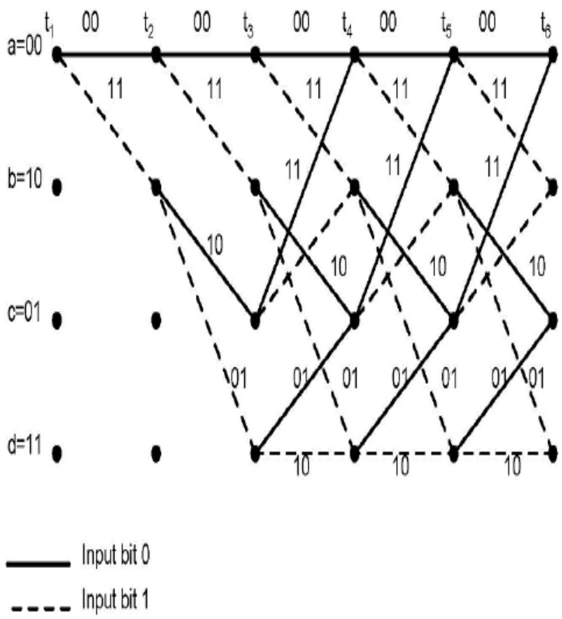

Figure 4: Encoder trellis structure for C=4 and r=1/2

2.3 Modulation

The modulation technique used is Binary phase shift keying (BPSK) to map the 0's and 1's to antipodal baseband signal. For the modelling it is important to modulate either using The BPSK or QPSK because the signal will be transmitted with at least 5dB less power than when transmitting without modulation.

```
l = length(Output_encd);
for i = 1 : l
if Output_encd(i) == 0
Mod_input (i) = -1;
else Mod_input(i) = 1;
end
end
```

2.4. AWGN Channel

Since it is known that AWGN channel embeds white noise to the signal that has been passed through it. The amount of noise in this channel is described by following quantities:

- Value of SNR for each sample. Value of SNR is the actual parameter of AWGN channel.
- Ratio of E_b/N_o and ratio of E_s/N_o.

We can define the relation between E_b/N_o and E_s/N_o by following equation:

$$E_s/N_o = E_b/N_o + 10\log_{10}(k/n)$$

Where bits per symbol are denoted by 'n'. This parameter may be influenced by the size of the modulation alphabet and code rate of the error control code.

2.5 De-Modulation

This is the stage to recover the original message that was mapped to -1 and +1 back to the 0 and 1.

2.6. VITERBI DECODER

In 1967 by Andrew Viterbi was proposed the Viterbi algorithm (VA) and is used to decoding a bit stream that has been encoded using FEC code [6]. Viterbi algorithm can be explained by a trellis diagram it requires which comprises of minimum path and minimum distance Calculation and retracing the path. Fig-7 shows the block diagram of the Viterbi decoder.

It consists of following blocks

a. Branch Metric Unit (BMU)
b. Path metric calculation
c. Add Compare and Select Unit (ACS)
d. Trace Back Unit (TBU)

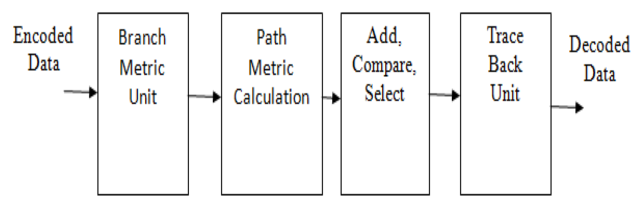

Figure 5: Block diagram of the Viterbi decoder

From the encoder output through the channel the BMU receives input data and computes a metric for each state and each input bit. There are two types of methods to calculate the metric. The metric which is used to calculate the Hard-decision encoded data is the Hamming distance and the metric is the Euclidian distance for Soft-decision encoded data. The metric is calculated for the entire path. The ACS unit is based on minimum distance calculations that are obtained from the previous row values. The Trace-back unit restore maximum likelihood path from the decisions made by BMU. This is the final stage of the Viterbi decoder where the input that was transmitted by using the convolution encoder is once again retrieved [7].

When the convolutional code bits encoded from input bits are modulated in to respective waveforms for transmission over a medium that introduces attenuation, distortion, interference, noise, etc .the received waveforms become uncertain" in their shapes. One of the frequently applied criteria is the maximum-likelihood decoding (MLD) rule under which the probability of code word estimate error is minimized subject to an equiprobable prior on the transmitted code words. The Viterbi decoding flow chart is given in Figure 6.

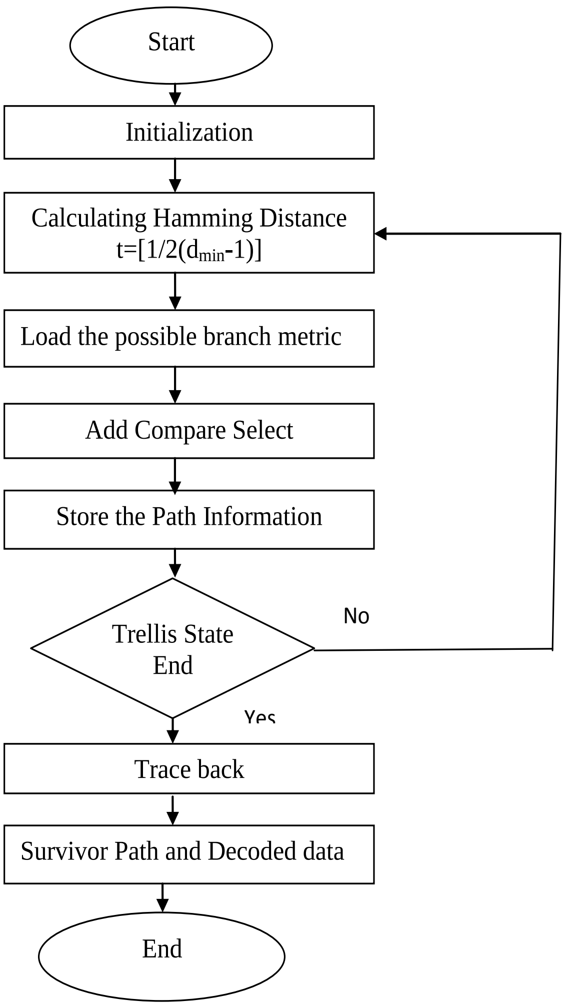

Figure 6: Flow chart of Viterbi Decoding

III. SIMULATION

The Simulink model simulation of convolutional encoders is shown in figure 7 below.

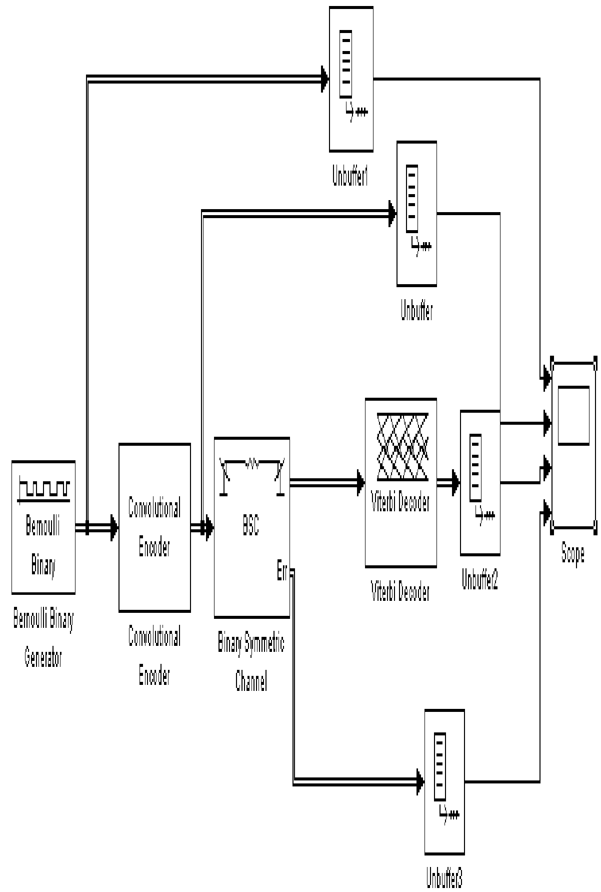

Figure 7: The Simulink model simulation of convolutional encoders

IV. RESULTS

The result of the simulations of convolutional encoders using simulink is shown in figures 8 and 9.

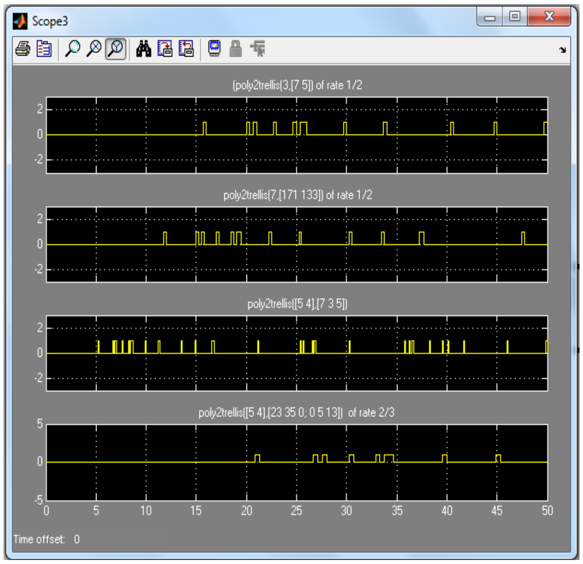

Figure 8: Simulation results by changing encoder with same BSC error

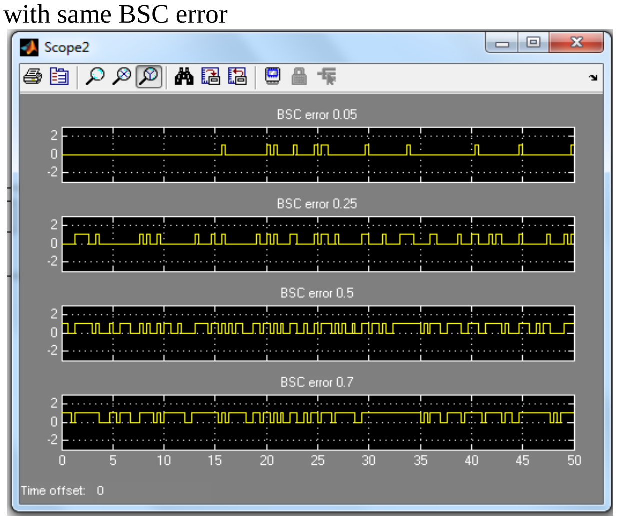

Figure 9: Simulation results by changing error of BSC with same encoder

V. CONCLUSIONS

Simulation has done by using MATLAB .When signal to noise ratio changes the change in the output of convolutional encoder occurs. From the above results, it can be seen that by keeping signal to noise ratio constant and by changing data rates of convolutional encoder, rate 2/3 gives better result than 1/2 and 1/3 and also, by keeping data rate 1/2 and changing signal to noise ratio it shows that with the minimum S/N ratio it gives better result.

REFERENCES

[1]. J. G. Proakis, *Digital Communication*, fourth Edition, McGraw Hill, 1998.

[2]. A. J. Viterbi, "*Error bounds for Convolutional Codes and an Asymptotically Optimum Decoding Algorithm*," IEEE Transaction on Information Theory, Vol. IT-13, 1967.

[3]. Yan Sun1, Zhizhong Ding2, " FPGA Design and Implementation of a Convolutional Encoder and a Viterbi Decoder Based on 802.11a for OFDM", Received March 5th, 2012; revised April 1st, 2012; accepted April 9th, 2012, doi:10.4236/wet.2012.33019.

[4]. JOHN WILEY, "ERROR CONTROL CODING", Peter Sweeney, University of Surrey, Guildford, UK

[5]. R. G. Gallager, Low-Density Parity-Check Codes. Cambridge, MA: MIT Press, 1962.

[6]. Zafar Iqbal, Saeid Nooshabadi, Heung-No Lee, "Analysis and Design of Coding and Interleaving in a MIMO-OFDM Communication System", Vol. 58, No. 3, August 2012.

[7]. J. G. Proakis, M. Salehi, G. Bauch, "Contemporary Communication Systems Using MATLAB® and Simulink®", Second Edition, Thomson, 2004

ABOUT THE AUTHORS

Ahiara Wilson C. holds a Bachelor of Engineering degree in Computer Engineering from Michael Okpara University of Agriculture Umudike (MOUAU) Abia State, Nigeria. He is a postgraduate student of the University of Uyo, Akwa Ibom State, and currently works as a System Engineer in the department of Computer Engineering, Michael Okpara University of Agriculture Umudike (MOUAU) Abia State, Nigeria. His research interests are in the areas of Eembedded systems, Microcontroller based systems, Network security, Expert systems, Electronics system designs and Wireless communication technology.

Iroegbu Chibuisi is a scholar in the department of Electrical and Electronics Engineering (Electronics and Communication option), Michael Okpara University of Agriculture, (MOUAU) Umudike, Abia State Nigeria. He holds a Bachelor degree (B.Eng) and Master's degree (M.Eng) in Electrical/Electronics Engineering (Electronics and Communication option). Iroegbu Chibuisi is also a member of International Association of Engineers. His research interests are in the fields of Radar systems, wireless sensor networks, Electronic and Communication Systems design and modeling, Security system design, Expert systems and Artificial Intelligence, Design of Microcontroller based systems, Channel coding, fading channels, interference management etc.