# Bipolar Chaotic Communication System Based On Turbo Code in Wireless Communication

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***Abstract:*** **In the wireless communication technology, error propagation is one of the issues presented in the recent year. To overcome the error propagation, system BCPPM is proposed. Using BCPPM system two-bit information is transmitted to the receiver in each channel. So this scheme improves the communication efficiency. The turbo code is used for parallel communication that focused to mitigate the effect of noise. The proposed system is secure, insensitive to the channel distortion and convenient for multiple access communication. The simulation result shows that the BCPPM system has lower bit error rate (BER) compared with CPPM and chaotic pulse on-off-keying (CPOOK). In hardware, using turbo codes the bit error rate (BER) performance is evaluated and implemented on the FPGA kit.**

## I. INTRODUCTION

In recent years, Interest has been growing in the use of chaos for secure communications. In today‘s scenario there is growing need to transmit information wirelessly, quickly and accurately, So communication engineers have combined various technologies suitable for high data rate transmission. In order to further improve the efficiency of communication, a bipolar chaotic pulse position modulation (BCPPM) communication system is proposed. It sends two-bit data in each pulse. Chaotic communication offers high security and a low probability of intercept. Since the chaotic synchronization is very sensitive to the signal distortion, filtering and channel noise, utilizing the chaotic communication systems encounters many difficulties in practical applications. In the CPPM system, the intervals between pulses are chaotically changed based on the chaotic map. This communication scheme protects information from interception. The status information of the chaotic system is completely contained in the time intervals of the pulses with the same shape.

The distortion caused by filter and channel will only destroy the shape of pulses and will not affect the intervals between them. In this case, the CPPM system is insensitive to the multipath channel distortion. Turbo codes stands to combat the interference of the fading channel [3] .This makes the chaotic pulse signal much easier to be reused and achieve multiple access communication than continuous chaotic signal. CPPM has many advantages; it induces additional delay into the chaotic map that not only causes the chaotic map to diverge easily, but also leads to error propagation. A method was proposed as the chaotic pulse on-off keying (CPOOK), which does not have any feedback loop in its structure. Therefore, it has lower bit error rate (BER) than the CPPM system in the case of non-ideal timing. But each bit signal needs to transmit extra synchronization pulse in this scheme, which reduces the efficiency of the transmitter.

Turbo codes were first presented at the International Conference on Communications in 1993. Until then, it was widely believed that to achieve near Shannon‘s bound performance, one would need to implement a decoder with infinite complexity or close Parallel concatenated codes can be implemented by using either block codes (PCBC) or convolutional codes (PCCC). The combination of three ideas that were known to all in the coding community:

- Transform commonly used non-systematic convolutional codes into systematic convolutional codes.
- Use of soft input soft output decoding. Here, the decoder uses the probabilities of the received data to generate soft output which contain information about the degree of certainty of the output bits.

➢ This is achieved by using an interleaver. Encoders and decoders working on permuted versions of the same information.

The encoder for a turbo code is a parallel concatenated convolutional code. The input to this turbo decoder is a sequence of received code values from the demodulator.

The bit error rate performance for differential chaos shift keying chaotic communication was evaluated by using the non-central F distribution of the decision variable in the reference[1].

## II. BCPPM SYSTEM

### A. BCPPM Modulation

In BCPPM, every two-bit data are set as a group. The first bit and the discrete chaotic map determine the position of sent pulse, while the second bit determines the polarity of sent pulse. Each pulse in the channel contains two-bit information, so this scheme improves the communication efficiency. BCPPM is based on the CPRG. When the system initialization is complete, CPRG unit starts working: The nonlinear function outputs the delay time value Tn; the timer starts timing; the comparator compares its two inputs constantly. Chaotic synchronization was used in discrete-time systems connected by band limited channels [2]. When CPRG outputs the enable signal, the system reads the first bit data to decide whether to add the Td before entering later modules. After that, it reads the second bit data to choose the polarity of the narrow pulse for output. The sent data are grouped in every two bit. In each round, the first bit data and the chaotic map determine the position of pulse and the second bit determines its polarity. The delay module is moved outside of the feedback loop compared with that of CPPM. It makes the signal intervals of CPRG only relevant to the states of nonlinear function which is inside the CPRG. They are independent of the information sequence. Now get Tn = F (Tn − 1). In this way, it avoids the possible adverse effects of information sequence to the chaotic map and keeps the no regularity of output pulse intervals sequence of CPRG. It eliminates the possibility of divergence. In each transmission period, the BCPPM modulator outputs a bipolar pulse, which contains two-bit information under the same conditions with CPPM. So, the BCPPM scheme doubles the information rate.

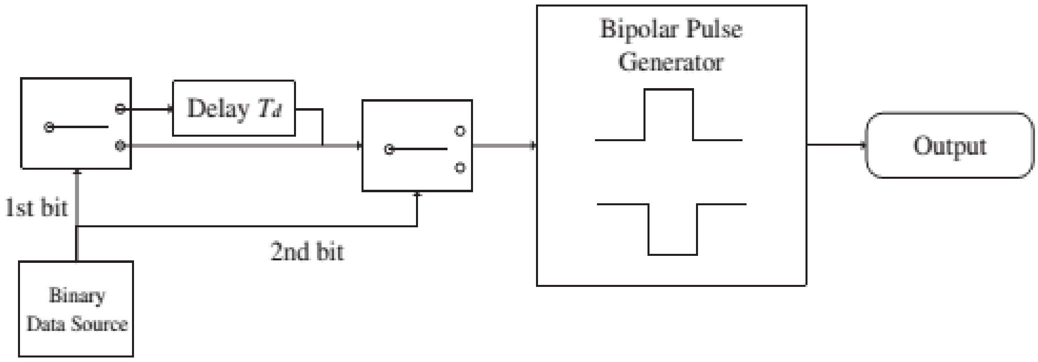



**Fig.1 BCPPM Modulation**

### B. BCPPM Demodulation

Pulse sequence with delay and polarity modulation becomes the signal to be transmitted in the channel. If an unauthorized receiver does not know the interval information of pulse sequence, it is impossible to judge whether a received pulse was delayed. Therefore, it cannot judge whether ‘0’ or ‘1’ is transmitted at this moment. If there is an ideal synchronization between the transmitter's CPRG and the receiver's CPRG, it will output the same signal with the sent signal in channel except some of the pulses delayed due to the data modulation. By estimating the received signal and the time, when CPRG outputted the corresponding pulse, the first bit data can be restored. According to the polarity information of pulse, the second bit data can be judged. While the CPRGs of both sides of the transceiver are not enough to match, it will generate a large number of errors. Therefore, the initial parameters of CPRG act like a private key & play a decisive role in the transmission. That allows the output of the receiver to be kept locked before the appearance of excepted pulses. During this period, other users can transmit their information pulses. In BCPPM, there are two time windows in the receiver. Based on the synchronization of the transmitter and the receiver, the CPRG of the receiver enables the sampler near the time when the pulse is expected to appear. It will create a time window which contains the expected pulse, then divide the window into two parts based on the time Td, time window '0' and time window '1', respectively. The signal in time window '0' and time window '1' are transferred to a two-peak detector, and then it figures out the two bits of information.

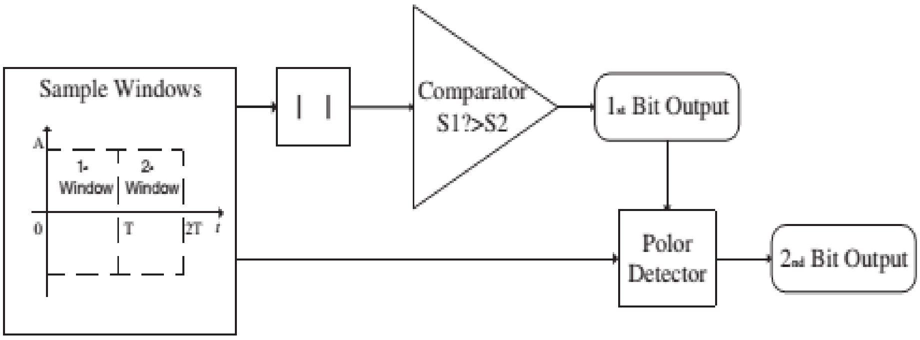



**Fig.2 BCPPM Demodulation**

The detailed demodulation process can be described as follows: While demodulating the two-bit data, priority should be given to the first bit, then the second one. The first bit, delay information, can be judged from the sampling value in which window it has the larger peak. If the peak is in window '0', the first bit is '0'. Otherwise, it is '1'. On this basis, the detector detecting the polarity of pulse in the above time window, if it is positive, the second bit information is '0'. Otherwise, it is '1'. So, there are a total of four cases for the two-bit data.

### C. CYCLIC Redundancy Check (CRC)

A cyclic redundancy check (CRC) is an error-detecting code or an error checking code used to detect accidental changes to raw data. Blocks of data entering these systems get a short check value attached, based on the remainder of a polynomial division of their contents; on retrieval the calculation is repeated, and corrective action can be taken against presumed data corruption if the check values do not match.

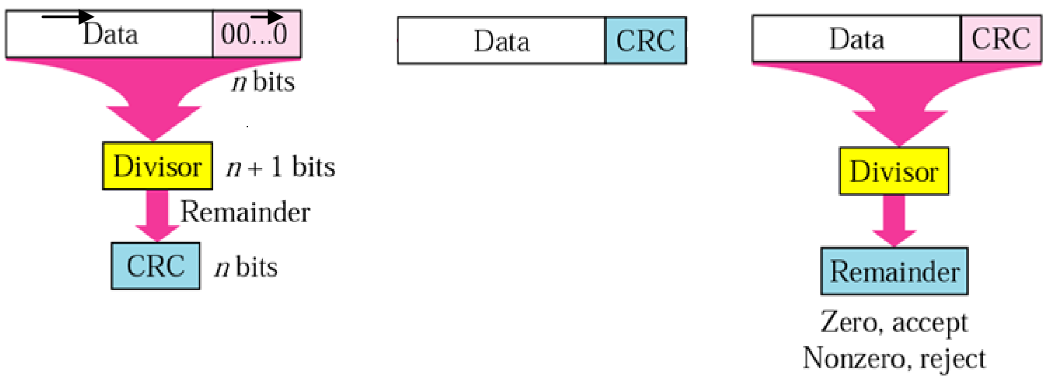



**Fig.3 CRC analysis structure**

This algorithm is based on Turbo codes. In the present product code, the row code consists of a cyclic redundancy code (CRC) combined with a systematic turbo code [2]. CRCs are popular because they are simple to implement in binary hardware, easy to analyze mathematically, and particularly good at detecting common errors caused by noise in transmission channels. The check value has a fixed length; the function that generates it is occasionally used as a hash function.

## III. TURBO CODES

Turbo codes were first presented at the International Conference on Communications in 1993. Until then, it was widely believed that to achieve near Shannon‘s bound performance, one would need to implement a decoder with infinite complexity or close. Parallel concatenated codes can be implemented by using either block codes (PCBC) or convolutional codes (PCCC). In the moderate-to-high SNRs where an interleaver gain is observed, the outer encoder should simply possess a good distance spectrum, i.e., highest minimum distance and low weight of the associated error-sequence combination not just for the minimum-distance term [6].

### A. Encoders For Turbo Codes

The encoder for a turbo code is a parallel concatenated convolutional code. Berrou gave the model for turbo encoders [10] Here, the binary input data sequence is represented by dk = (d1….dN). This input sequence is passed into the input of a convolutional encoder ENC1 and a coded bit stream xk1p is generated..

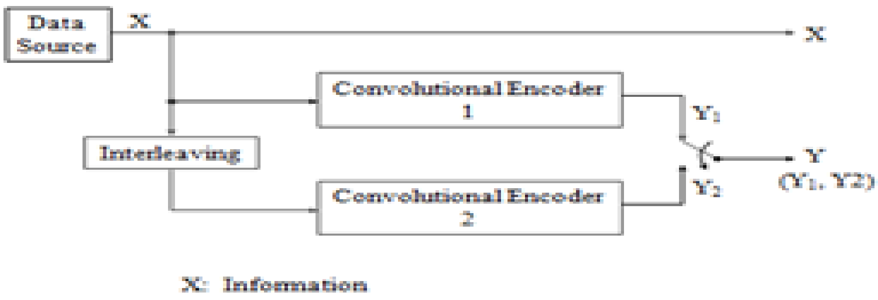



**Fig.4 Turbo Encoder**

Then the data sequence is interleaved. This means, the data bits are loaded into a matrix and read out in a way so that the positions of the input bits are spreader. The bits are often read out in a pseudo-random manner. Then the interleaved date sequence is passed to the second convolutional encoder ENC2, and a second coded bit stream xk2p is generated. The code sequence that is passed to the modulator for transmission is a multiplexed (and possibly) stream consisting of systematic code bits xks and parity bits from both the first encoder xk1p and the second encoder xk2. Improving the performances of database systems exist, the most efficient one consists in implementing an effective data indexing mechanism. This must ensure the balance between the processor, memory and storage resources of the database server accordingly to the type, structure, the physical organization and the cardinality of data, the type of queries and the number of competing transactions [10].

### B. Decoder for Turbo Codes

An iterative decoding is proposed. The modification is necessary due to the recursive nature of the encoders. The difference in this algorithm from the Viterbi algorithm is that while the former produces hard outputs, this one produces soft outputs. Thus instead of outputting only 0 or 1, the output range is continuous and is a measure of the log-likelihood ratio of every bit estimate. The iterative feedback scheme is shown in Fig. 2.

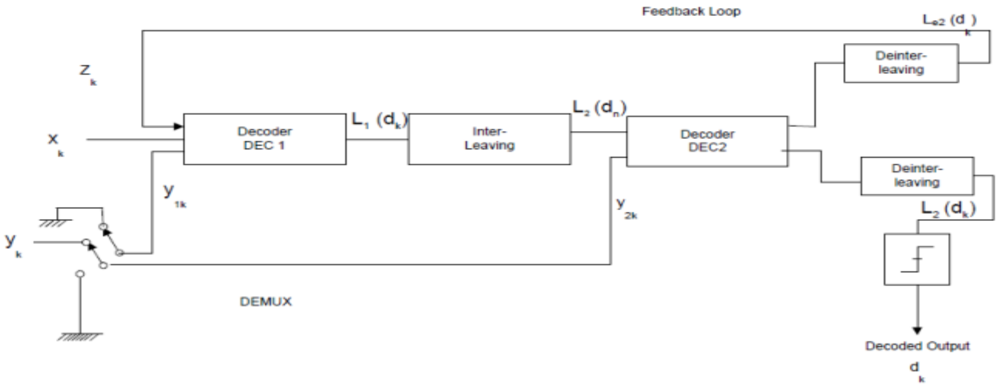



**Fig.5 Turbo Decoder**

The input to the decoder *xk* and *YK* are the punctured encoder outputs *Xk* and *YK* corrupted by two independent noises with the same variance. The demultiplexer selects *y*1*k* when the transmitted sequence is *Y*1*k* and selects *y*2*k* when the transmitted sequence is *Y*2*k* and sets it to zero for no transmission. The output of DEC1 (known as extrinsic information of the decoder) is used by DEC2 to modify the confidence levels and thus obtain a more accurate estimate of the transmitted message. The purpose of the interleaver is same as before i.e., to de–correlate the error bursts. These feedback schemes are based on a modification of the extrinsic information passed between the constituent maximum a posteriori probability (MAP) decoders in a Turbo decoder [5]. The output of DEC2 is fed back to DEC1 and the process is repeated several times depending on the BER rate required for the application. Turbo decoding can be thought of as the accumulation of a large number of effects giving some justification to modeling the LLRs as stable [7]. Errors in data communication and memory can be corrected through interleaving, the overall performance of the processor and system increases. Energy per bit to noise power spectral density ratio is calculated by using the formula:

**Eb/N0 = C/N0-[10*log (data rate)]**

Where,

C/N0 is the carrier to noise ratio.

### C. Channel Bandwidth Analysis

Channel Capacity is the maximum information rate that a channel is able to transmit/receive. The channel capacity and the bandwidth of a channel are related according to Shannon's theorem. The combination of parallel concatenation and recursive decoding allows this coding to achieve the performance near Shannon‘s limit [9]. To select the required bit rate, channel bandwidth calculation is needed. So the calculation is done by using the Nyquist formula,

$$C = 2B \log2 M$$

The log2 M part of the formula gives the number of bits coded by one signal level. For a bandwidth B the maximum bit rate is 2B. Every channel has some sort of noise, which can be thought of as a random signal that contends with the information signal. If the noise is too great, it can obscure the signal. Shannon's theorem was showing how noise affects the signal capacity of a channel. In particular, Shannon derived the following formula. Maximum Data Rate is calculated by using the formula:

$$\mathbf{C = B \log_2 (1 + {}^{S}/_{N})} \textbf{ bits per second}$$

Where,

B is the bandwidth of the channel, and the quantity ${}^{S}/_{N}$ is the signal-to-noise ratio, which is often given in decibels (dB). Channel bandwidth is the difference between the upper and lower cutoff frequencies. The bit rate is the number of bits that pass a given point in a telecommunication network in a given amount of time, usually a second (Kbps). Bit Error Rate is calculated by using this formula:

$$BER = \frac{\text{number of error}}{\text{Total no of bits sent}}$$

Channel capacity is the tightest upper bound on the rate of information that can be reliably transmitted over a communications channel.

## IV. BIT ERROR RATE

The performance of turbo codes is evaluated in terms of BER. These simulations are conducted in the presence of AWGN channel and the modulation scheme used is BPSK. The BER plots for coded and un-coded data, Convolutional codes Vs. Turbo codes are shown in this section. Similarly, performance of turbo codes in the presence of inter-leaver and without inter-leaver and for various lengths of inter-leaver.

### *A. AWGN Channel*:

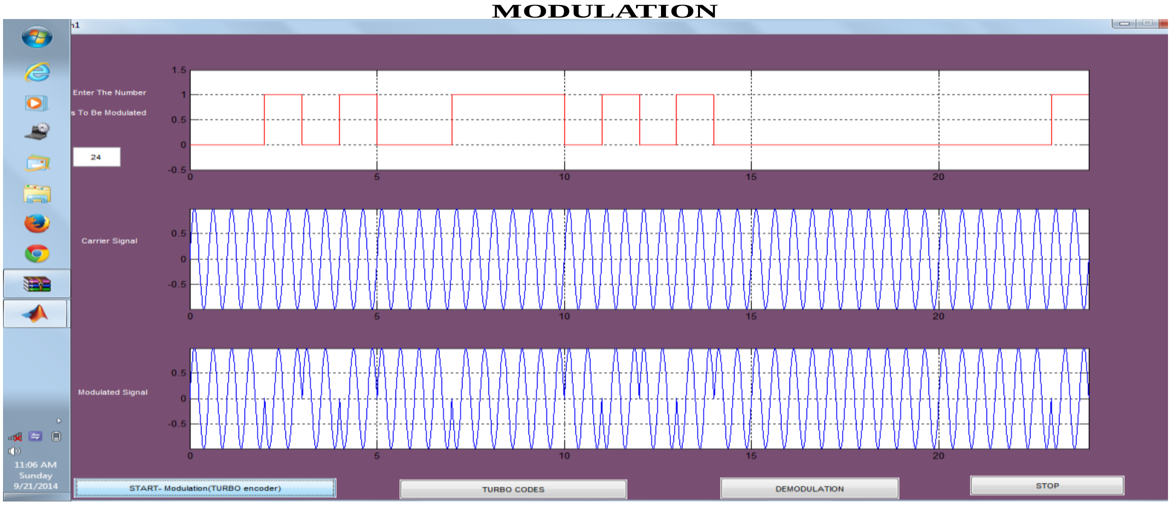
For this channel, output from demodulator is a continuous alphabet. We cannot describe these alphabets as correct or incorrect. It is seen that maximizing the is equal to maximizing the correlation between the codeword □□ and the value received from channel z given below:

So decoder will select a code-word that provides closest Euclidean distance to z. in order to apply the above equation, decoder needs to be able to handle analog values. But this is impractical because decoders are implemented in digital domain, so we need to quantize our data. This quantized Gaussian channel referred to as soft decision channel [12]. Designing a channel code is always a tradeoff between energy efficiency and bandwidth efficiency. Codes with lower rate (i.e. bigger redundancy) can usually correct more errors [13]. If more errors can be corrected, the communication system can operate with a lower transmit power, transmit over longer distances, tolerate more interference, use smaller antennas and transmit at a higher data rate. The MAP algorithm is optimal in terms of minimizing the decoded bit error rate , it explores every possible path through the trellis and provides the estimated bit sequence, and also a probability for each bit stating the likelihood that the bit has been decoded correctly [14] The Maximum A-Posteriori (MAP) Algorithm is an algorithm suitable to decode convolutional codes that operates with soft bits.

## V. SIMULATION RESULTS

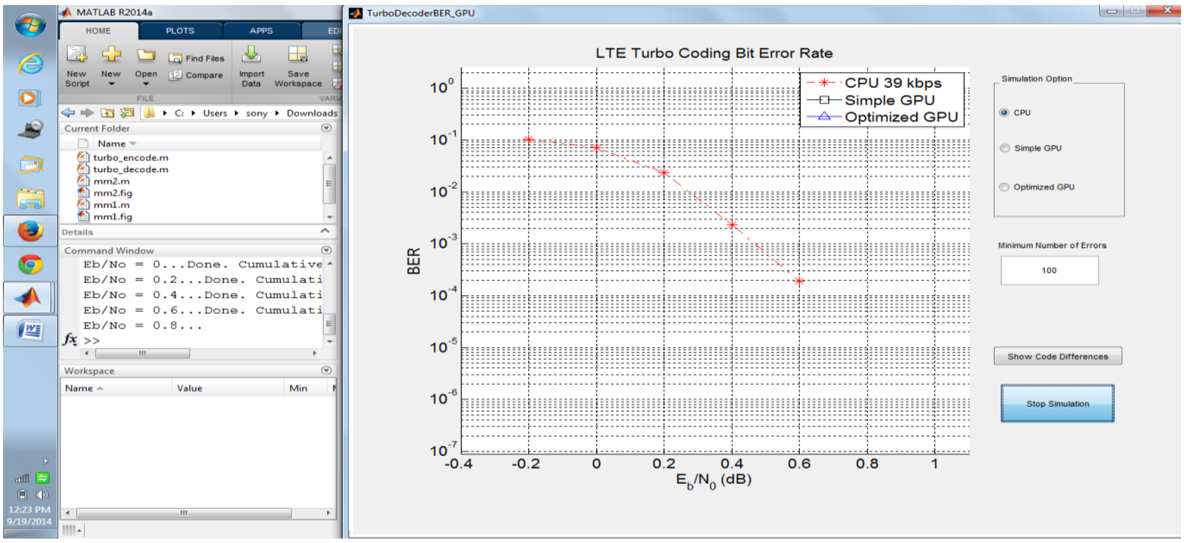
The simulations are done to achieve a desired BER using Turbo codes to lower the bit error rate as 0.8 Eb/N0, then the received signal is merged. The Bit Error Rate curve does not exhibit any flattering effect down to $10^{-9}$ [8]. turbo codes provide better error performance and sufficient coding gain as compared with other schemes. It is also deduced that presence of interleaver is much important in order to improve the error performance.

**MODULATION**

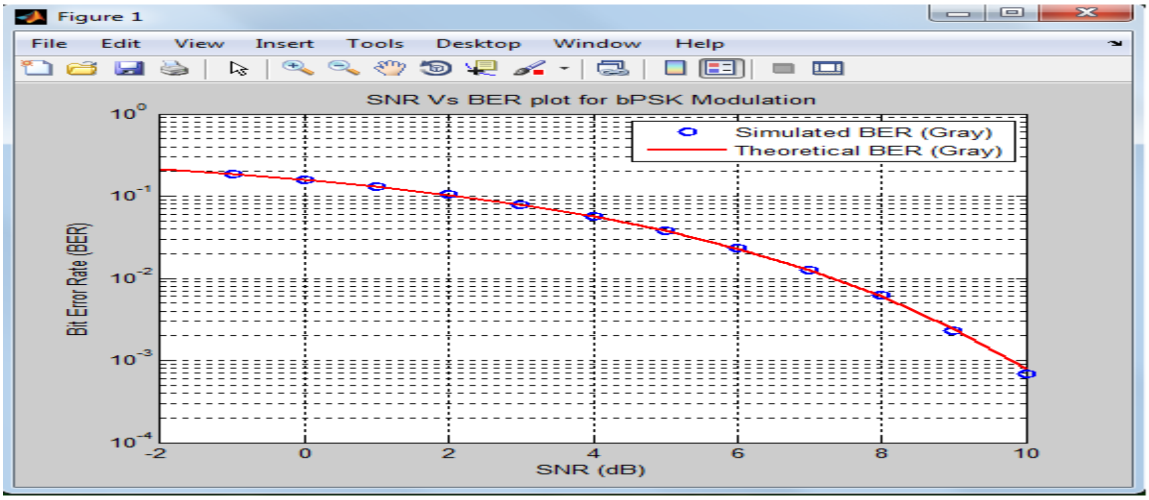



Channel bandwidth analysis was completed and produces the demodulated signal i.e. output signal. Finally Bipolar chaotic pulse position modulation communication produces speed, efficiency, lower bit error rate and more secure communication.

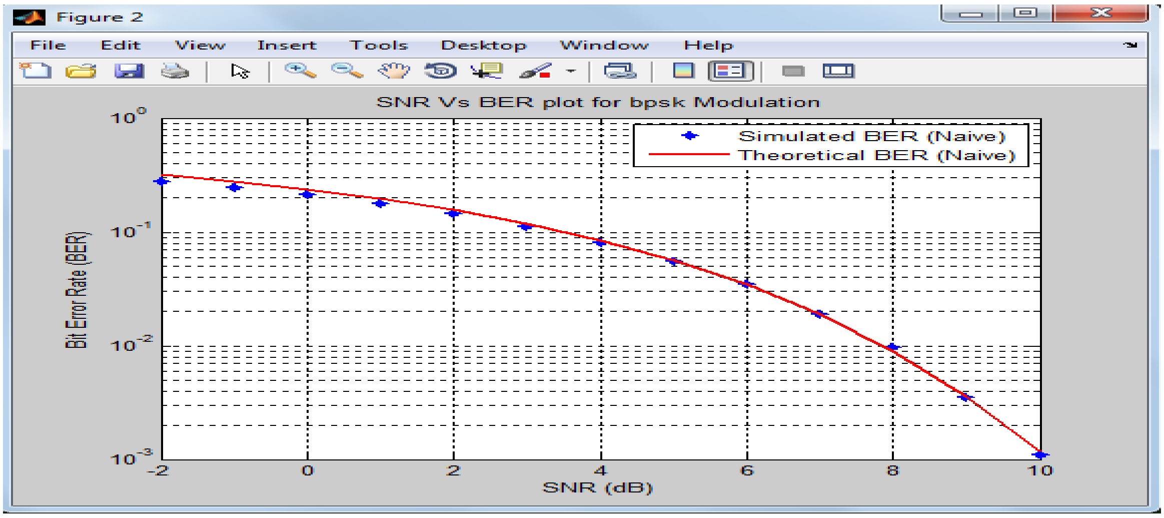
**BIT ERROR RATE**



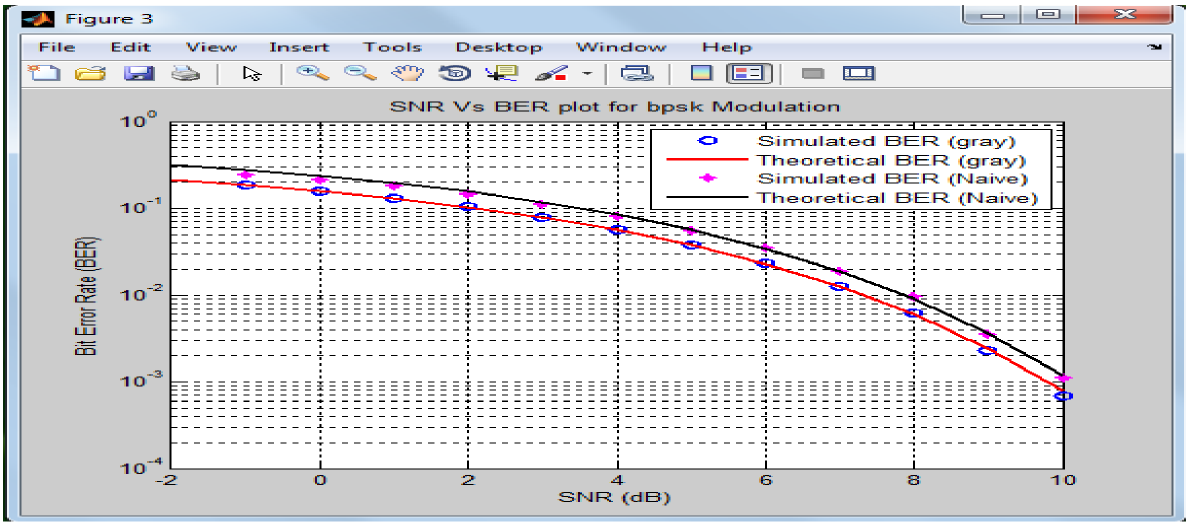
**SNR Vs BER IN GRAY TECHNIQUE**



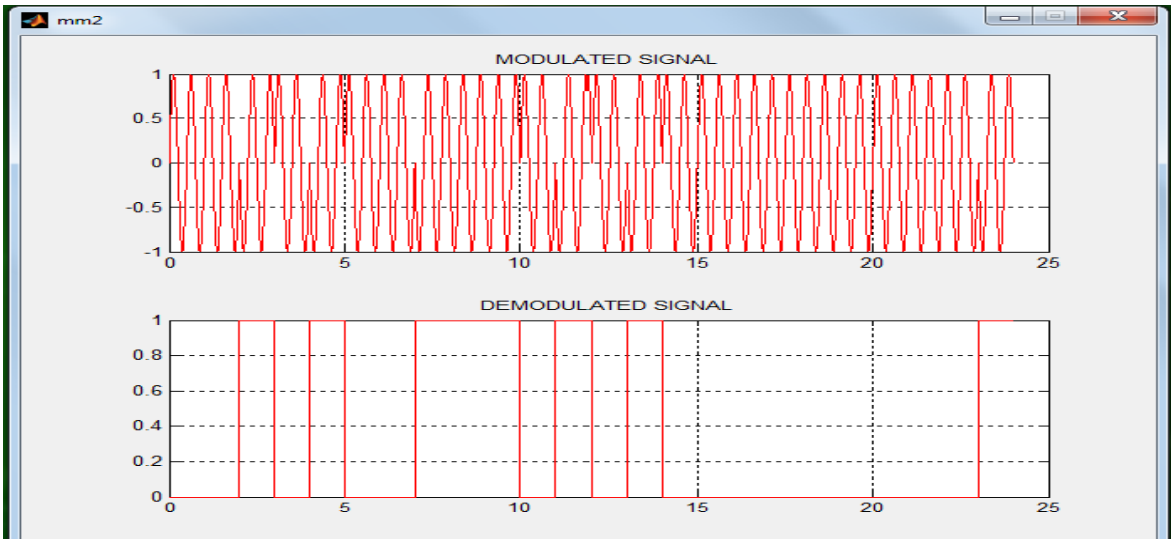

**SNR Vs BER IN NAIVE TECHNIQUE**




The direct implementation of MAP is computationally intensive and hence not feasible for real-time applications. In order to minimize the decoding complexity, the logarithms of the state metrics are taken. This converts the multiplication operation to additions (Log-MAP algorithm). [11].



**COMPARISON OF GRAY & NAIVE**




**Demodulation**

Through Matlab simulation, the bit error rate was reduced as 0.001 and the bipolar chaotic communication system efficiency was improved for phase I. bipolar chaotic communication system will implement on SPARTON FPGA kit for phase II.

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