International Journal of Future Generation Communication and Networking
Vol. 13, No. 3, (2020), pp. 3002–3012

Analysis of Hard Decision and Soft Decision decoding mechanism using Viterbi Decoder in Presence of Different Adaptive Modulations

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ABSTRACT

This paper exhibits the performance of both the hard and soft decision method of decoding for analysis of different existing adaptive modulation techniques by using Viterbi decoder. In hard decision Viterbi decoding, the got code word is contrasted and all the conceivable code words and the code word which gives the base Hamming distance is chosen. While in soft decision decoding all the possible code words with the minimum Euclidean distance is selected in presence of Additive White Gaussian Noise (AWGN) channel. The MATLAB codes are executed for signal-to-noise ratio per bit (Eb/No) with respect to bit error rate (BER) using convolution encoder and optimized Viterbi decoding (HDVD) algorithm. Also the performance is compared for both the hard and soft decision decoding.

Keywords— *Adaptive modulation; Convolution encoding; Viterbi decoding; Signal to noise ratio; Trellis diagram; Hard decision decoding; Soft decision decoding;*

I. INTRODUCTION

Transmission of information over wireless systems are influenced by noise, intersession and distortion, this influences the recipient's capacity to get right data [1]. In correspondence framework the discovery and rectification of these deformations are essential. Various procedures exist to lessen the impacts of bit error rate (BER) with the goal that the mistake free form of the first message is received at the recipient end. The major error detection techniques used are Automatic Repeat Request (ARQ), Forward Error Correction (FEC) and hybrid forms of ARQ and FEC [2].

Forward error correction codes work by adding redundant data to the messages. This expansion of excess information improves the limit of the channel as it permits the recipient to identify and address mismatches without requesting re-transmission of information from the encoder. There are two significant kinds of error correcting codes: block code and convolution code. Convolution code is a type of FEC that is being used extensively nowadays in different forms of communications like wireless and satellite communication. Convolution codes are preferred over block codes as they are less complex when compared to block codes and are thus easy to use [2].

A decoder is a gadget or program that makes an interpretation of encoded information into its unique configuration for example it translates the information. Classical block codes are usually decoded using

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hard-decision algorithms, which implies that for each info and yield signal a hard decision is made whether it compares to a one or a zero binary digit. Interestingly, convolutional codes are commonly decoded utilizing soft-decision algorithms. There are four basic decoding techniques used to decode convolutional codes. They are: consecutive, limit, maximal-probability and Viterbi algorithm.

The Viterbi algorithm along with the convolutional coding is one of the more powerful error correction technique, also helps to develop CDMA standard. The Viterbi calculation is an ideal interpreting strategy. It is said so on the grounds that it brings about the base probability of error [3]. The Viterbi algorithm was devised by Andrew J. Viterbi [4]. The Viterbi decoder along with the convolution encoder provides optimal decoding of signals. The fixed decoding time of the Viterbi decoder makes it highly advantageous [5]. It is relatively less complex for small constraint lengths which make it the most suitable choice for decoding convolutional codes. The Viterbi calculation disentangles via looking through the base cost way in a trellis chart. Fast Viterbi decoders for convolutional codes are of incredible enthusiasm for high-information rate applications [6]. A Viterbi decoder is able to minimize the BER to a great extent making it suitable for wireless communications. Convolution coding alongside Viterbi unravelling is reasonable for channels in which the transmitted sign is adulterated for the most part because of added substance white Gaussian noise (AWGN).

In our work we are going to focus on both hard decision and soft decision method of decoding by using the Viterbi decoder on different adaptive modulation [7] schemes. In hard decision decoding the decoder takes a stream of bits from the threshold detector stage of a receiver, where each bits are considered 1 or 0 [8]. A hard choice Viterbi decoder gets a basic piece stream on its info, and a Hamming separation is utilized as a measurement. In hard decision Viterbi decoding, the received code word is compared with all the possible code words and the code word which gives the minimum Hamming distance is selected. While in soft decision decoding multi-bit quantization is used for the received bits. The Euclidean distance is utilized as a metric in soft decision disentangling. In soft decision Viterbi decoding, the got code word is contrasted and all the conceivable code words and the code word with the base Euclidean distance is chosen.

The Viterbi algorithm is a generally straight calculation to actualize in equipment. It is widely deployed in wireless communication systems like Wi-Max, WCDMA, CDMA, GSM and also in OFDM networks [9] [10]. With the need for high speed sophisticated wireless devices being high the demand for high speed Viterbi decoders is also increasing [2, 11]. For upgrading the cyclic prefix (CP) length, Nandi et al. [12] used modified flower pollination (MFP) calculation and BAT calculation to conquer the deficient cyclic prefix. For the equivalent MFP calculation to accomplish better throughput consider least CP length. To improve CP length, there calculation was introduced to achieve least BER and PAPR ratio [13] [14], in this manner boosting the spectrum range effectiveness. As an instance of remote communication, Nandi et al. additionally indicated time block coding method to transmit a few duplicates of data over the number of antennas and estimate the channel [13]. Convolution Encoder with Viterbi decoder discovers application in advanced telecom, satellite applications, computerized portable applications, profound space, CDMA and voice-band data communications [3].

This paper is sorted out as follows: Section 2 clarifies the framework model of both Convolution Encoder and Viterbi Decoder. The simulation results are appeared in segment 3. Segment 4 depicts the observation table. Finally, part 5 reaches the inferences of this paper.

II. SYSTEM MODEL

A. Convolution Encoder

An encoder works by including additional piece of data in the transmitted sign to decrease the likelihood of errors in the got signal which gets undermined because of noise. A convolution encoder works by adding redundant bits of data into the data stream by using linear shift registers [1]. It is a combination of modulo 2 adders and shift registers, where the output is obtained by the modulo 2 addition of selective contents from the shift register and the present input bits. Fig. 1 exhibits the functional diagram of M-QAM modulator using convolution encoder which is expound by the following properties:

i. A binary convolutional code is represented by a three-tuple (i, j, k).

ii. j output bits are generated whenever i input bits are received.

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iii. k is called the memory order of the convolutional code.

iv. The code rate is given by r, where r=i/j.

v. The imperative length k of a convolutional code is characterized as the quantity of movements over which a solitary message bit can impact the encoder yield.

A convolution encoder acknowledges an info message stream and produces encoded yield streams for transmission. During this procedure for one information bit the encoder creates more than one yield bit and the excess information in the yield bit stream makes the transmitted information increasingly resistant to noise. The redundant bit helps the process of detection and correction of errors [15]. The Soft Viterbi Algorithm Decoder upgraded with Non-Transmittable Codewords indicated a surprising improvement in remedying the damages in the storage media [16].

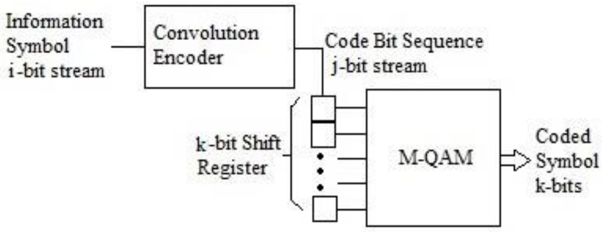

Fig. 1. Functional diagram of M-QAM modulator using Convolution Encoder

The code rate of the encoder shown in Fig. 2 is 1/2 and the constraint length = 3. Since the rate of the encoder is 1/2 it means that for every 1 bit entering the encoder there is 2 bits leaving the encoder. The constraint rate is 3 because there are 3 shift register stages.

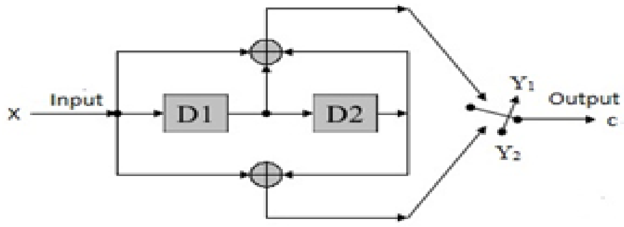

Fig. 2. A (2, 1, 2) Convolution Encoder

B. Representation of Encoder

The encoder is spoken to [10] in three distinctive graphical approaches to increase better comprehension of its activity. They are: State Diagram, Tree Diagram and Trellis Diagram.

C. State Diagram Representation

The state diagram for the (2, 1, 2) code is given in Fig. 3. Each state of the encoder is given by a circle. Each state speaks to the situation of the encoder. When there is an adjustment in the information 0 or 1, the advancement of present state to the accompanying state is given by the lines of arrows.

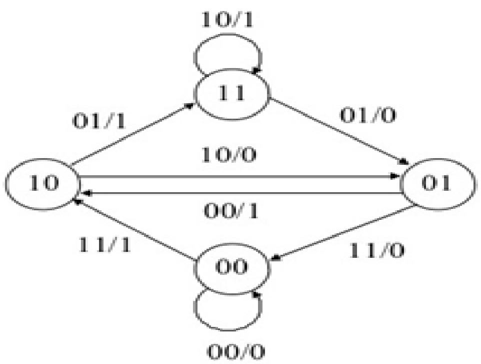

Fig. 3. State diagram of (2, 1, 2) convolution code

D. Tree Diagram Representation

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The tree outline is another portrayal of the encoder activity. For the sources of info 0 or 1, part of the tree is followed from its root esteem. The first branch indicates the arrival of initial input 0 or 1. The fundamental or starting state is continually thought to be 00. Exactly when input 0 is gotten the upper branch is followed and at whatever point input 1 is gotten the lower branch is escorted. The tree diagram of (2, 1, 2) code is represented in Fig. 4.

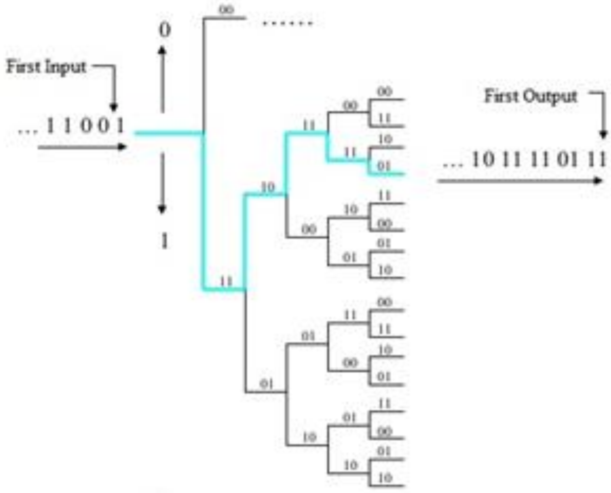

Fig. 4. Tree diagram of (2, 1, 2) convolution code

E. Trellis Representation

Trellis graphs are mind boggling in structure however commonly favoured over both the tree and the state diagrams, since they speak to direct time sequencing of events. The trellis chart for the encoder arrangement is spoken to in Fig. 5. The x-axis of the trellis speaks to the discrete time and every conceivable state are appeared on the y-axis. On the off chance that there is any progress, then it implies another binary digit has shown up.

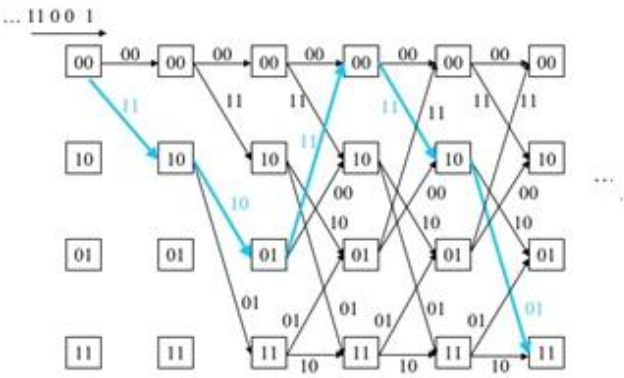

Fig. 5. Trellis diagram of (2, 1, 2) convolution code

F. Encoding of messages in a Convolution Encoder

To understand how the message gets coded let us consider a 3-bit code 110 which is given as the input to the encoder and the encoder adds redundant data sequences. The coding of the data bit is shown in Table. 1 for different instants of time. In the table I1 and I2 represents the present state of the shift register and F1 and F2 represents the output of the shift register i.e. the output code.

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Table. 1. Coding of data bits at different time instants

Time Instant	Input	Present Condition		Output	
		I_1	I_2	F_1	F_2
t = 1	1	0	0	1	1
t = 2	1	1	0	1	0
t = 3	0	1	1	1	0
t = 4	0	0	1	1	1

G. Decoding of convolution codes

The two classes to translate a convolutional code are the sequential decoding which utilizes the Fano algorithm and other one is the Maximum probability decoding which utilizes the Viterbi algorithm. From these codes, the Viterbi calculation is ordinarily utilized for decoding of convolutional codes, in view of its effortlessness in equipment execution and least events of errors in the communication channel.

H. Viterbi Decoder

A Viterbi decoder utilizes the Viterbi calculation for unravelling a bit stream that has been encoded utilizing convolutional code or trellis code. Viterbi algorithm was devised by Andrew J. Viterbi in 1967, for the process of decoding convolutional codes. For a given sequence of symbols, the Viterbi Algorithm (VA) finds the most-probability way transition sequence in a state diagram. An equipment of Viterbi decoder for fundamental code as a rule comprises of the accompanying significant blocks, appeared in Fig. 6. The Viterbi decoder is utilized in wireless sensor network (WSN) to accepting information that is transmitted by different nodes [17] The motivation behind growing low-complex Viterbi decoder for IoT applications is essential and the estimations of Viterbi decoder's boundaries, for example, trace back length (L), input information bit-width (D), and Log-Likelihood Ratio (LLR) shortened worth (E), influences to bit error rate (BER) and packet error rate (PER) of a communication framework. [18] [19].

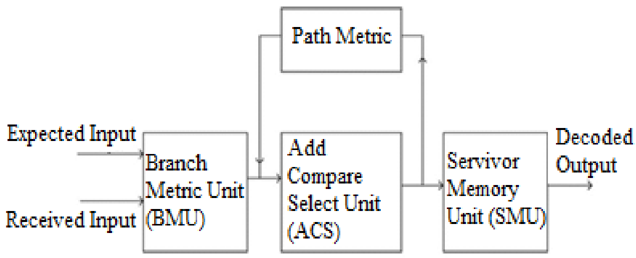

Fig. 6. Viterbi Decoder block diagram

i. Branch Metric Unit: It contrasts the got input and the normal information and tallies the quantity of varying information bits [12]. Both the Hamming distance for hard decision decoding and Euclidean distance for soft decision decoding represent the value of measured BMU.

ii. Path Metric Unit: The PMU computes way metric and decision values as each state can be reached from two distinctive past states [3]. The main element of the PMU is the Add Compare Select (ACS) Unit. The ACS unit compares the two path metrics and selects the smaller valued metric as the new path metric for that state.

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iii. Survivor Memory Unit: The SMU stores the information obtained from the ACS and uses them to compute decoded output. Two methods are mainly used in this unit, they are: trace back method and register exchange method. The trace back unit takes up less area than the register unit area [15] and hence is used in our work [21] - [24].

I. Viterbi Algorithm

The Viterbi algorithm is a maximum likelihood algorithm as it calculates the most likelihood path transition sequence [2]. It is also called an optimum algorithm as it minimizes the probability of error [3]. It is a popular algorithm for decoding convolution codes with constraint length lesser than 10. The basic steps of the algorithm are described below:

i. Calculate the Hamming distance.

ii. Calculate the branch metric from the hamming distance.

iii. The minimum branch metric is selected as the path metric.

iv. The shortest path estimated is and the survivor path is updated. The survivor path is the shortest path to each table.

v. The survivor path is then traced back in time and merged to form the decoded output.

J. Types of Viterbi decoding

i. Hard Decision Viterbi Decoding (HDVD): In HDVD the Hamming distance is taken as the computing metric i.e. the Hamming distance is used to fetch the path through the trellis. Hence the most optimum path is the one with the minimum Hamming distance. Hard decision decoding applies 1-bit quantization on the decoded bits [20].

ii. Soft Decision Viterbi Decoding (SDVD): In SDVD the Euclidean distance is taken as the computing metric i.e. the Euclidean distance is used to compute the path through the trellis [16]. Hence the path with the minimum Euclidean distance is the most optimum path. Soft decision decoding appeals multi-bit quantization on the decoded bits.

III. SIMULATION RESULT

In this work the simulated plots of different modulation schemes using binary convolution coding (BCC) and optimized hard decision Viterbi decoding (HDVD) in AWGN channel is evaluated using MATLAB tool. The result is obtained in the form of Eb/No vs BER by varying the SNR. Each simulation process going through several intermediate stages to obtain the result finally. The steps are given below in Fig. 7.

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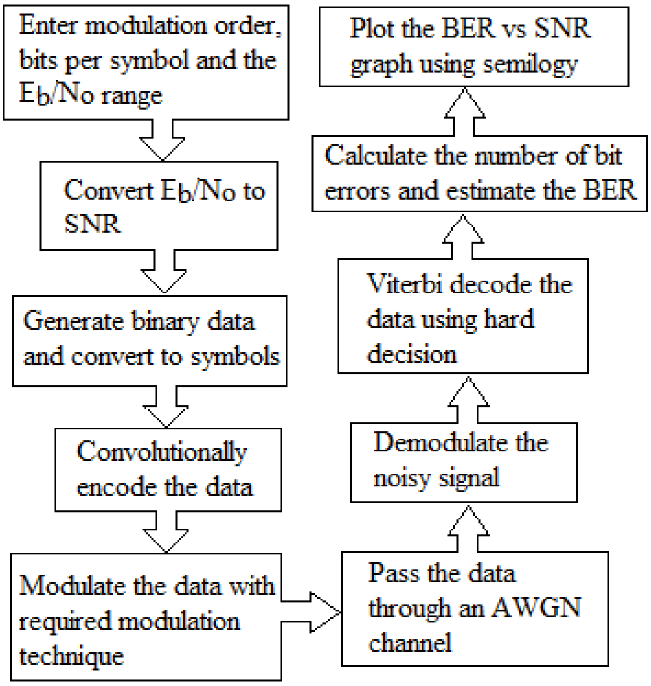

Fig. 7. Steps of the execution process

The simulation results of Signal to Noise Ratio (SNR) vs BER plot for BCC with Viterbi decoding for 16-QAM, 32-QAM, 64-QAM, BPSK, and QPSK in presence of AWGN channel is shown in the Fig. 8 to Fig. 12 respectively. The plots provide the nature of information on BER verses SNR for Hard decision, Soft decision and uncoded signal.

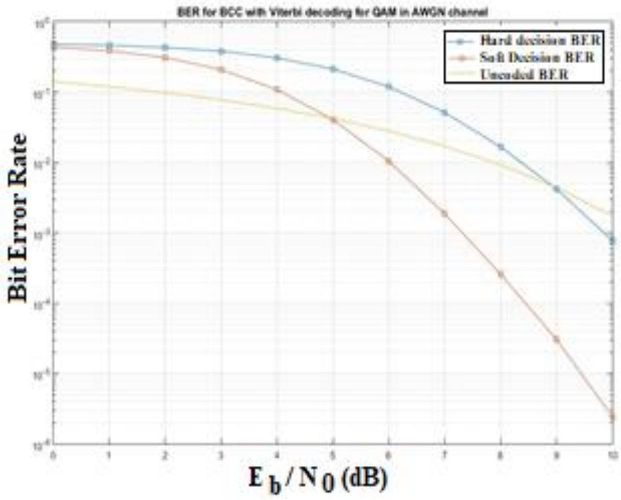

Fig. 8. BER for BCC with Viterbi decoding for 16-QAM in AWGN channel

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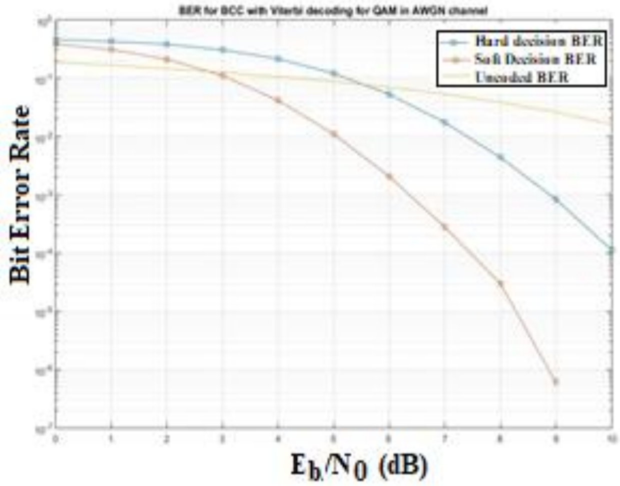

Fig. 9. BER for BCC with Viterbi decoding for 32-QAM in AWGN channel

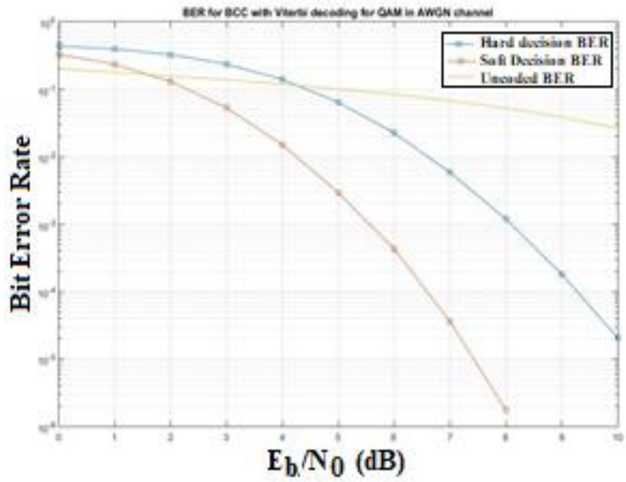

Fig. 10. BER for BCC with Viterbi decoding for 64-QAM in AWGN channel

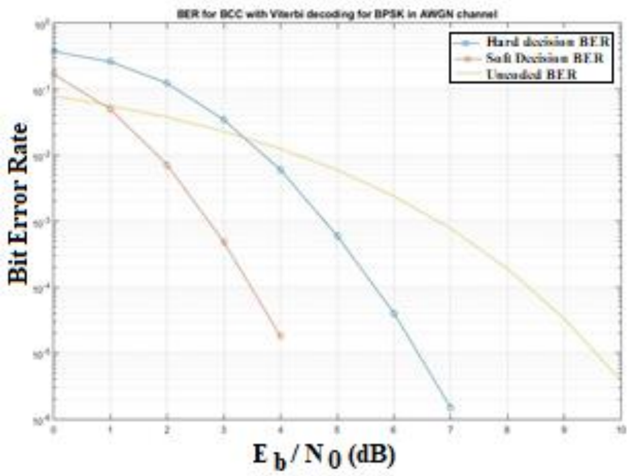

Fig. 11. BER for BCC with Viterbi decoding for BPSK in AWGN channel

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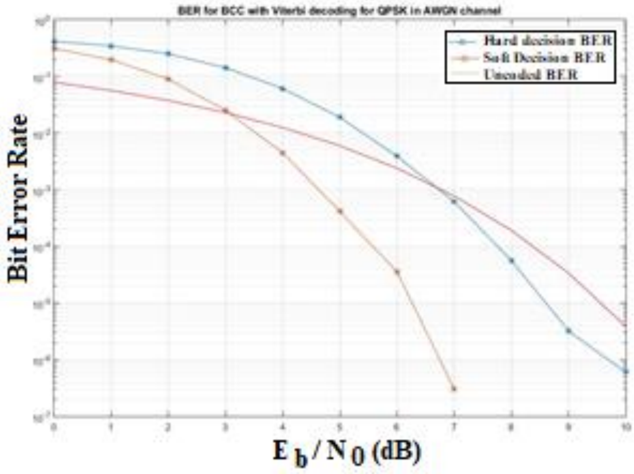

Fig. 12. BER for BCC with Viterbi decoding for QPSK in AWGN channel

IV. Observation Table

Table. 2 illustrated the BER values of different modulation schemes for Hard decision, Soft decision and uncoded signal, for a fixed value of E_b/N_0 of 4 dB.

Table. 2. BER of different modulation schemes for E_b/N_0 = 4 dB

Modulation Scheme	Uncoded BER	Hard decision BER	Soft decision BER
QPSK	0.0125	0.06104	0.00447
BPSK	0.0125	0.005973	0.000018
16-QAM	0.05862	0.3052	0.1082
32-QAM	0.1066	0.2153	0.04168
64-QAM	0.1185	0.1396	0.01498

V. Conclusion

The transmission of information at inflated data rates would make more impedance to different clients in the adaptive modulation environment. The convolution encoder with Viterbi decoder is utilized in the proposed simulation to highlight a comparative study with the hard decision and soft decision Viterbi decoding. Therefore, the results derived in this paper provide good performance outcome with lower implementation cost as it operates on data stream without depending on the static block. The values of BER obtained in Table. 2 shows that in uncoded signal formatting BPSK and QPSK both can provide lowest BER, while in hard decision and soft decision process the possible lowest BER is found in BPSK modulation scheme out of the remaining different adaptive modulation schemes. Thus we can conclude that BPSK modulation is the most effective modulation scheme for different communication purposes because of having low BER.

This work idea is definitely based on previously published work but this is innovative in a way that the result of simulation details which is unique and may help in the evolution of cost effective communication technology in the future communication purpose like 5G and beyond.

ISSN: 2005-4238 IJAST

ACKNOWLEDGEMENT

The authors deeply acknowledge the support from laboratory of Department of ECE, Bengal Institute of Technology (Techno India Group), Dr. B. C. Roy Engineering College, Durgapur and National Institute Technology, Silchar, India.

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