Design of Optimized BMU For QPSK Modulation Scheme For WI-MAX

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Abstract— Digital communication systems usually represent an increase in complexity over the equivalent analog system. Digital communication has become the most preferred option because of the increased scale of integration, sophistication and reliability of digital electronics for signal processing. In the proposed system the discrete data are EX-OR'ed with randomizer and Convolutionally encoded to transmit data securely. The data is rearranged in Block Interleaver and it is modulated by QPSK (Quadrature Phase Shift Keying) for increasing the signal strength by adding carrier signal and transmitted over to a AWGN (Additive White Gaussian Noise) channel. In the receiver side the received signal is demodulated using QPSK. The scrambled bits are rearranged by Block De-Interleaver and these bits are decoded by Viterbi Decoder. The extra bits decoded by Viterbi Decoder is removed by de-Randomizer which results in original discrete source data. The viterbi decoder increases the channel capacity by adding redundant bits to original bits, it performs Euclidean Distance approach to calculate the distance between the neighbouring signal points, so it performs complex operations. Efficient and secure data transmissions helps to achieve minimum computation.

Keywords: Randomizer, Convolution Encoder, Block Interleaver, QPSK, Modulation, Viterbi Decoder.

I. Introduction

In this fast development of the world in VLSI (Very Large Scale Integration) Technology, EDA tools development of communication (wired and wireless) standards/technologies are becoming flexible and also complex as increase in the data rate, because the transmission media (wired and Wireless) are effected by noise.

Therefore in such environment the probability of BER must be very less. Hence in order to compensate the data error rate, the information bits are convolutionally encoded and can transmit the data over noisy channel such as AWGN and other data degradation effects.

The most popular Channel Encoding method used in Digital Communication is convolution coding and it acts as a Forward Error Correction (FEC) which results in the low error rate, that is low Bit Error rate (BER). Initially the information source are first convoluted and then transmitted over a noisy channel (AWGN) by adding proper redundancy bits to the original information bits, which improves the data capacity of the channel.

Viterbi Decoder is the most popular decoder to decode the convolutionally encoded data. This viterbi decoder tracks the most likely state sequence of the convolutional encoder and decodes the original information (message) bits without the need for retransmission of the information bits. Almost every communication channel are affected by AWGN and hence the total of convolutional encoder and viterbi decoder using viterbi algorithm provides a correlation between modulated and demodulated information signal with low error rate.

Convolution encoder and Viterbi decoder is a powerful FEC technique which is well suited for the channel affected by AWGN. Viterbi decoder operates on the data stream and has memory that uses previous bits to encode. It is simple and performance is good with low implementation cost.

Andrew . J. Viterbi proposed Viterbi Algorithm (VA) in 1967 and is used for decoding a bit stream that has been encoded using FEC technique. There are two types of viterbi decoders namely Soft and Hard decision viterbi decoders. In this paper work, we implement Soft Decision Viterbi Decoder with using Absolute approach for distance calculation in BMU which is suitable to perform less computation.

II. LITERATURE SURVEY

As per paper [1], the probability of error in decoding an optimal convolutional code transmitted over a memoryless channel is bounded from above and below as a function of the constraint length of the code. For all but pathological channels the bounds are asymptotically (exponentially) tight for rates above &, the computational cut-off rate of sequential decoding. As a function of constraint length the performance of optimal convolutional codes is shown to be superior to that of block codes of the same length, the relative improvement

As per paper [2], The importance of convolutional codes is well established. They are widely used to encode digital data before transmission through noisy or error-prone communication channels to reduce occurrence of errors. This paper presents CC(2,1,3) encoder which belongs to the convolutional encoder's class. It also presents two different decoding techniques based on the Viterbi algorithm: the hard decision and the soft decision decoding techniques. Some simulated results obtained by using these two decoding techniques are presented as well.

As per paper [3], The emergence of WiMAX has attracted significant interests from all the fields of wireless communications. WiMAX has been tipped to bring a revolution in the way we use broadband services today. The WiMAX can also be considered to be the main technology in the implementation of other networks like wireless sensor networks. Developing and understanding of the WiMAX system can be best achieved by looking at a model of the WiMAX system. This paper discusses the model building of the WiMAX Physical layer using Simulink in Matlab. This model is a useful tool for performance evaluation of the WiMAX under different data rates, coding schemes and channel conditions besides serving as a helpful resource for the students and the researchers who want to base their studies and research on the fields related to the WiMAX. Standards from IEEE and ETSL have been used to develop this model. The model presented in this paper built with generic MAC PDU processed by the Physical Layer using Convolutional Encoding Rate of *5/6* with QPSK modulation and transmitted with 256 carrier OFDM symbols.

III. PROPOSED SYSTEM

The proposed system in figure 1 shows the system level block diagram which represents the physical layer of communication system. This system implements FEC channel encoder for 4G communication standard. In this the convolution encoder or the channel encoder adds proper redundant bits to the original information source bit stream, in which the errors are corrected at the end of the received data by viterbi decoder. The original information bits are mapped to a QPSK pattern constellation, in which the data rate is increased as increasing in the order of the QPSK constellation.

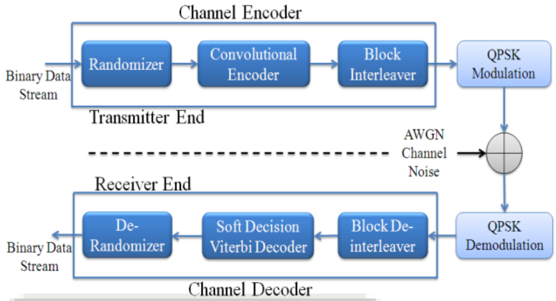

Fig. 1: System level block diagram

A. Randomizer:

As shown in figure 2, the randomization is the first process to be done in the physical layer after the information data bits are received from higher layers. Randomizer operates on a bit by bit basis and the purpose is to convert long sequences of 1's and 0's in to a random sequence to improve the coding performance.

The randomizer is constructed using the generator polynomial $GP=1+x^{14}+x^{15}$, and it is initially initialized to a sequence as [100101010000000] and the sequence of PRBS will repeat 2^{15}-1. The Randomizer we used [1][2] has the following specifications with reference from IEEE 802.16,2009.

Fig. 2: Randomizer

B. Convolution Encoder

Convolution encoder [1][2] is a forward error correction unit which adds proper redundancy bits to the original information bits in order to increase the channel capacity signal to noise ratio (SNR). Convolutional codes are processed on a bit-by-bit basis. They are particularly suitable for implementation in hardware, it consists of shift register. The figure 4 shows the Convolutional encoder specified by (m, k, n), for each clock cycle, with m-memory stages, takes one message symbol of k-bits and produces one code symbol of n bits. Convolutional codes are generated by the convolution of message sequence with set of generator polynomial sequences (G1, G2). Figure below shows convolution encoder of a (6, 1, 2) and g1 and g2 are 171o and 133o respectively

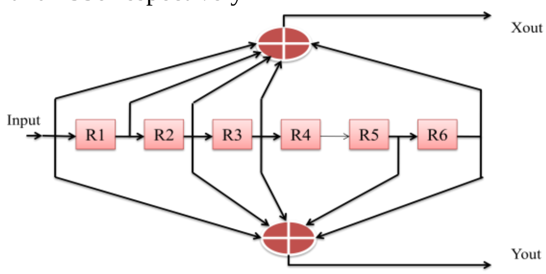

Fig. 3: Randomizer

$G1=1+x^1+x^2+x^3+x^6$; therefore Xout =1111001=171o;
$G2=1+x^2+x^3+x^5+x^6$; therefore Yout= 1011011=133o;

The code rate, r=k/n=1/2; expressed as a ratio of the number of input bits (k) to Convolutional encoder to the number output bits (n) of Convolutional encoder in an encoder cycle. The constraint length, L=7; denotes the 'Length' of the Convolutional encoder; i.e. how many k-bit stages are available to feed the combinational logic that produces the output symbols. Closely related to L is the parameter m, which indicates how many encoder cycles an input to the Convolutional encoder (m is the memory length of the encoder).

Convolutional encoder parameter

L = constraint length is 7 (combinational feedback)

m = # of memory stages is 6

n = # of output bits produce by encoder for one bit is 2

k = # of input bits to the Convolution encoder is 1

r = code rate is *k*/*n*=1/2.

Convolution encoder requires modulo-2 adders and a multiplexer in order to serialize the encoded outputs. The mod-2 adder is implemented by EXCLUSIVE-OR gate and linear addition is performed, hence the encoder is a linear feed forward shift register. Figure 5 shows the Matlab simulation result for the given inputs and outputs of the Convolution encoder.

C. Block Interleaver

Block Interleaver [1][2] Changes the position of the bits within the block as shown in figure 3. The purpose of Interleaving is to reduce the effect of burst errors. Using Block size=784 according to IEEE 802.16e block Interleaver is designed. Table 2 shows block interleaver of different modulation scheme

Modulation	Default	8 sub channels	4-sub channels	2-sub channels	1-sub channels
	N_{cbps}				
BPSK	192	96	48	24	12
QPSK	384	192	96	48	24
16-QAM	768	384	192	96	48
64-QAM	1152	576	288	144	72

Table. 1: Different block sizes of Block Interleaver

The first permutation is defined by Equation:

$m_k=(N_{cbps}/d) . k_{mod(d)} + floor (k/d)$

d=16, k=0, 1, 2, ... N_{cbps}-1

The second permutation is defined by Equation:

$j_k = s . floor (m_k/s) + (m_k + N_{cbps} - floor(d (m_k/N_{cbps}-1)))$

d=16, k=0, 1, 2, ... N_{cbps}-1

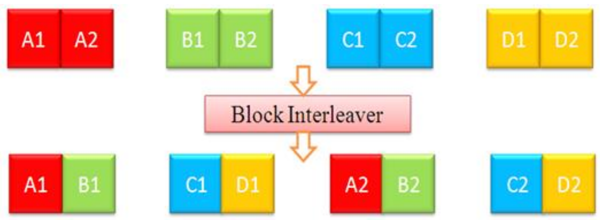

Fig. 3: Block Interleaver

D. Constellation Mapping-

The output of punctured block serially enters into the QPSK constellation Mapper, the amplitude of message bits can change by the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme.

As increasing in the order of QPSK constellation, it is possible to transmit more number of bits per symbol. Hence higher order QPSK can transmit more data than other digital modulation techniques. Thus increases the data rate.

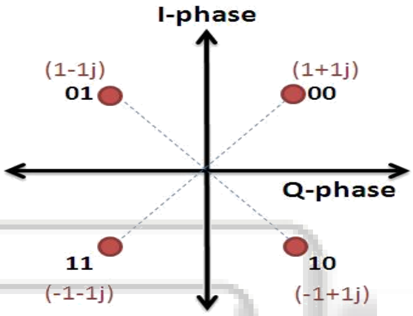

Fig. 4: QPSK Constellation

E. Channel

The most important digital communication channel is the AWGN (Additive White Gaussian Noise) channel as shown in figure 5 which passes the modulated signal X(t) and the White Gaussian Noise N(t) to the receiver as sum of modulated signal and noise signal Y(t).

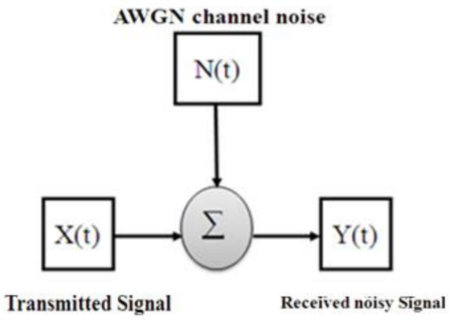

Fig. 5: Awgn Channel

The output of the channel is sum of input signal plus noise added signal hence the received signal will be noisy received signal. Figure 10 shows the effect of noise in the received signal, which is coloured as Green.

F. Quantization

Quantization is the process of the division of the range of values of a wave into a finite number of sub ranges, each of which is represented by an assigned or quantized value within the sub range. The Received signal is quantized using quantization process as shown below.

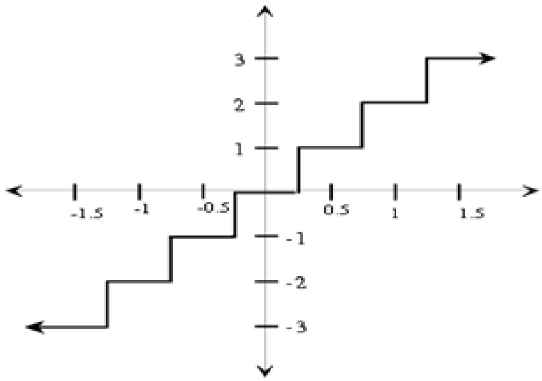

Fig. 6: Quantization Process

G. Block De-Interleaver

The De-Interleaver is done using the inverse of Interleaver permutation. De-Interleaver First Permutation:

m_j = s.floor (j/s) + (j + floor(d (j/N_{cbps}))) mod (s)

d=16, k=0, 1, 2, ... N_{cbps}-1

Where *j* is the index of the bit before permutation and *mj* is the index of the bit after first permutation.

Second Permutation:

k_j = d.mj - (N_{cbps}-1). floor (d.m_j/N_{cbps})

d=16, k=0, 1, 2, ... N_{cbps}-1

Where *kj* is the index of the bit after second permutation.

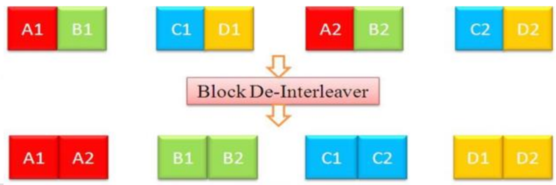

Fig. 7: Block De-Interleaver

H. Viterbi Decoder

Viterbi Decoders (VDs) are widely used as forward error correction (FEC) devices in digital communications and multimedia products, including mobile (cellular) phones, video and audio broadcasting receivers and modems.

VDs are implementations of the Viterbi Algorithm (VA) used for decoding Convolutional codes. Ideally, Viterbi algorithm reconstructs the maximum-likelihood path of encoded data bit sequence.

I. Soft Decision Viterbi Decoder

A Soft Decision Viterbi decoder consists of the following three major functional units:

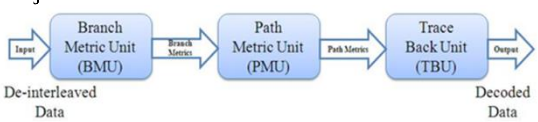

Figure 8. Soft Decision Viterbi Decoder

Branch metric unit – A BMU's function is to calculate branch metrics, which are norm (space) distance between every possible received symbol.

Path metric unit – for every encoder state, PMU summarizes branch metrics to get metrics of $2^{(k-1)}$ path, one of which eventually chosen as optimal path.

Trace back unit – Trace back unit restores a maximum likelihood path from the decision made by PMU.

1) Branch Metric Unit (BMU)

Soft decision decoding (also sometimes known as "soft input Viterbi decoding") builds on this observation. It does not digitize the incoming samples prior to decoding. Rather, it uses a continuous function of the analog sample as the input to the decoder. For example, if the expected parity bit is 0 and the received voltage is 0.3 V, we might use 0.3 (or 0.3^2, or some such function) as the value of the "bit" instead of digitizing it.

An attractive soft decision metric is the square of the difference between the received voltage and the expected one. If the Convolution code produces p parity bits, and the p corresponding analog samples are V = V1, V2 ...Vp one can construct a soft decision branch metric as follows

$$BMU\ [a,b] = \sum_i^p (ai - bi)^2 \text{- - - } equ\ (1)$$

$$BMU\ [r, i] = (r - r_0)^2 + (i - i_0)^2$$

$$BMU = [(r^2 - 2*r*r_0 + r_0^2) + (i^2 - 2*i*i_0 + i_0^2)]$$

2) Modified BMU

The above conventional method requires 4 multipliers and 2 summations unit; hence it performs more complex operation. The another absolute method is as followed below

BMU [a, b] = -ab; - - - equ (2)

BMU[r, i] = -(r*r0)-(i*i0)

By cancelling the square terms of *a* and *b*, then we get the shortest operation which requires only two multipliers, hence it performs less complex operation than conventional method as shown in equation 2. For example if the received signal is (2, 5), then the BMU calculates the distance as follows shown in figure 17 and distance values tabulated in table 4.

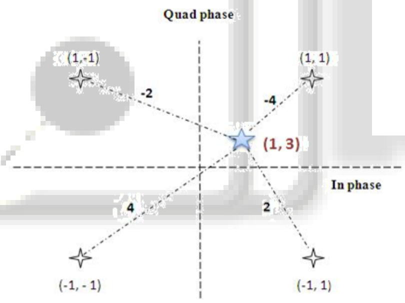

Fig. 9: Branch Metric Calculation using Euclidean Distance Approach

Received Symbol	Ideal symbol	Branch metric calculation	Branch metric value
1,3	(1,1)	$(1-1)^2+(3-1)^2$	4
	(1,-1)	$(1-1)^2+(3+1)^2$	16
	(-1,-1)	$(1+1)^2+(3+1)^2$	20
	(-1,1)	$(1+1)^2+(3-1)^2$	8

Table. 2: Calculated Values

3) Path Metric Unit (PMU)

A path metric unit summarizes the results of branch metric unit, to get metrics for 2^{k-1} paths, where k is the constraint length of the Convolutional encoder, one of which can eventually be chosen as The branch with the smaller value PM survives, and the other one is discarded. Every time it makes 2^{k-1} decisions, throwing off wittingly non-optimal paths. The results of these decisions are written to the memory of a trace back unit.

4) Trace Back Unit (TBU)

The TBU extracts the decoded bits, beginning from the state with the minimum distance of PMU. From this state and tracing backwards in time by following the survivor path, which originally contributed to the current PMU, identifies the unique path is decoded bits.

J. De-Randomizer

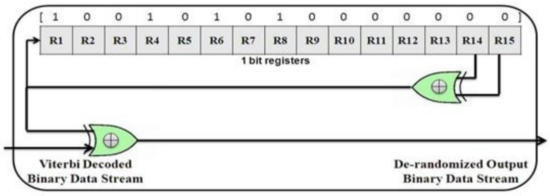

Fig. 10: De-Randomizer

De-Randomizer performs inverse operation of randomizer. Each decoded data bit are entering sequentially into the De-randomizer as shown in figure 18. The De-Randomizer parameters are same as Randomizer, which follows 802.16,2009 standards.

IV. Result and Analysis

Figure 11 shows the Matlab simulation result for the given inputs and outputs of the randomizer.

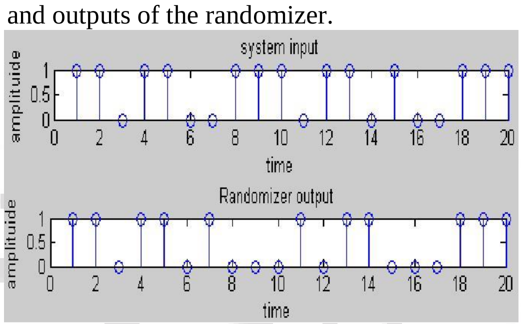

Fig. 11: Matlab simulated result of Randomizer

Figure 12 shows the Matlab simulation result for the given inputs and outputs of the Convolutional encoder.

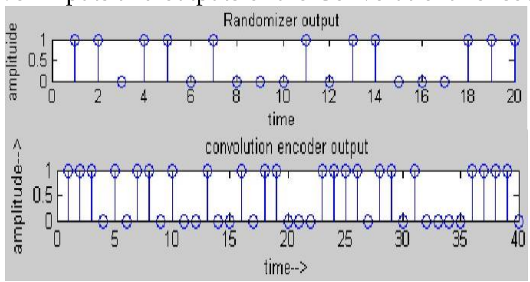

Fig. 12: Matlab Simulated Result Of Convolution Encoder

Figure 13 shows the ideal constellation map for QPSK modulation scheme.

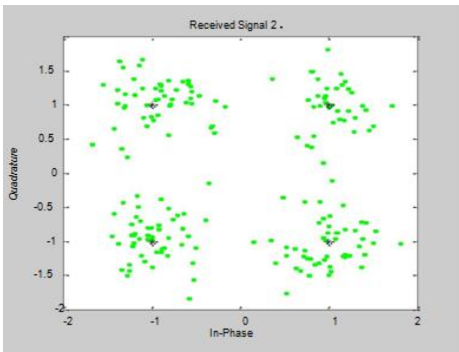

Fig. 13: Matlab Simulation Result For QPSK

Figure 14 shows the Matlab simulated result quantization process.

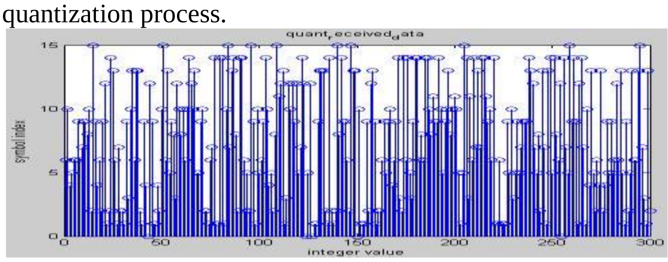

Fig. 14: Quantized Signal

Figure 15 and 16 shows the received signal (1, 3) for both real and imaginary parts of the signals and is calculated as shown in the below table 3 and 4.

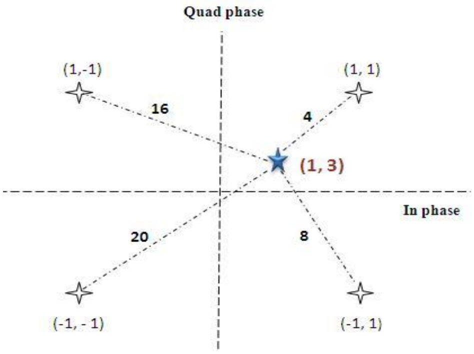

Figure 15. Distance Calculation Between Neighbour Points Using Conventional Method

Received Symbol	Ideal symbol	Branch metric calculation	Branch metric value
1,3	(1,1)	$(1-1)^2+(3-1)^2$	4
	(1,-1)	$(1-1)^2+(3+1)^2$	16
	(-1,-1)	$(1+1)^2+(3+1)^2$	20
	(-1,1)	$(1+1)^2+(3-1)^2$	8

Table. 3: Calculated Values

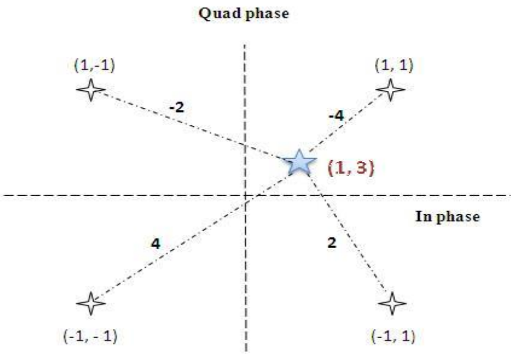

Figure 16. Distance Calculation Between Neighbour Points Using Absolute Method

Received Symbol	Ideal Symbol	Branch Metric Calculation	Branch Metric Value
(1,3)	(1,1)	-1-3	-4
	(1,-1)	-1+3	-2
	(-1,-1)	1+3	4
	(-1,1)	1-3	2

Table 4. calculated values

Figure 16 shows the implementation flow of Viterbi Decoder.

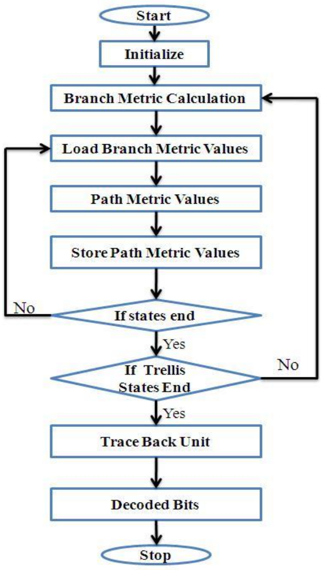

Fig. 16: Implementation Flow Of Viterbi Decoder

V. CONCLUSION

The presented paper describes about the channel encoding and decoding method. Convolutional encoder Viterbi decoder are the popular forward error correction(FEC) to improve the channel capacity by adding proper redundancy bits to the original information bits. Viterbi decoder is a maximum likelihood detection technique for Convolution encoded data, currently the package of Convolutional encoder and viterbi decoder are used in many cell phones broadband application.

Usually BMU's in viterbi decoder performs the Euclidean distance to calculate the distance between neighbour signal points so it performs complex operation. So with the modified BMU in the viterbi decoder, we attain minimum computation than with the conventional decoder. Figure.15 Distance calculation between neighbour points using Conventional method.

REFERENCES

[1] A.J. Viterbi, "Error bounds for Convolutional codes and an asymptotically optimum decoding algorithm," IEEE Trans Inform. Theory, vol. IT-13, pp. 260-269, Apr. 1967
[2] Dr. H. Meliani, A.Guellal.;"Comparison between Viterbi Algorithm Soft And Hard Decision Decoding" University of Blida, Algeria
[3] Khan, M.N.; Ghauri, S.;" The WiMAX 802.16e Physical Layer Model" Wireless, Mobile and Multimedia Networks, 2008 IET International Conference
[4] Ms.M.B.Mulik, Prof. U.L.Bombale, Prof. P.C.Bhaskar.;"Design of Viterbi Decoder for Noisy Channel on FPGA" International Journal of Scientific & Engineering Research Volume 2, Issue 6, June-2011
[5] Textbook of "Error Control Coding", second edition by Lin, Shu ; Costello, Daniel J, published by Pearson Education-2005
[6] IEEE 802.16 Part 16-2009.;"Air interface for Fixed and Broadband Wireless Access System"
[7] J. Hagenauer and P. Hoeher, "A Viterbi algorithm with soft-decision outputs and its applications," in Proc. IEEE Global Telecommunications Conference 1989