Performance of Forward Error Correction Convolution Encoder & Viterbi Decoder

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ABSTRACT— *The crux of this research article is forward error correction encoder and viterbi decoder .The Viterbi algorithm estimate the maximum likelihood path through a trellis based on received symbols. Viterbi algorithm has lots of applications due to its error detection and correction character. Convolution encoding with Viterbi decoding is a authoritative method for forward error correction. It has been broadly deployed in many wireless communication systems to get better the limited capacity of the communication channels. The viterbi algorithm is implemented for detection and correction of single bit error.*

Keywords— Forward Error Correction (FEC), Maximum Likelihood, Convolution Encoder & Viterbi Decoder.

1, INTRODUCTION

In the world of digital communication system, error detection and error correction is an important for reliable communication. Error detection techniques are much simpler than the forward error correction (FEC). The main purpose of forward error correction (FEC) is to improve the capability of channel by adding some carefully designed unneeded information to the data is to be transmitted throughout the channel. The process of adding this unneeded (redundant) information is known by the name channel coding. Basically Convolution coding and block coding are two main forms of channel coding. Block codes operate on comparatively large message blocks. Convolution codes operate on serial data, may be on one or on few bits at a time. Generally used block codes are known as Hamming Codes, Reed Solomon Codes, Golay Codes and BCH Codes. Convolution coding with Viterbi decoding is a very famous FEC technique that is particularly suited to a channel in which transmitted signal is corrupted mainly via additive white Gaussian noise (AWGN). In most of real time applications like audio and video, the convolutional codes are useful for error correction [1] [2].

Since most physical channels make burst errors, is a serious problem. Therefore, the complexity increases as the number of memory registers increases in the encoder, and the increase of the memory causes the increase of calculation. To pay compensation these problems, a new solution may be useful to concatenation of a Reed-Solomon (RS) code and a convolutional code (CC) or RS-CC or CC-RS concatenated code[3][4].

During digital data transmission and storage operations, performance is commonly determined by BER which is the ratio of Number of error bits / Number of total bits. Noise

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in signal transmission medium disturbs the signal and causes data corruptions [5]. Relation between signal and noise is described with SNR (signal-to-noise ratio). Generally, SNR is given by signal power / noise power and is inversely proportional with BER. It means, a lesser amount of the BER results in higher the SNR and the improved communication quality [3].

FEC processing in a receiver may be applied to a digital bit stream or in the demodulation of a digitally modulated carrier. For the latter, FEC is an integral part of the initial analog-to-digital conversion in the receiver. The Viterbi decoder implements a soft-decision algorithm to demodulate digital data from an analog signal corrupted by noise. Many FEC coders can also generate a bit-error rate (BER) signal which can be used as feedback to fine-tune the analog receiving electronics. The maximum fractions of errors or of missing bits that can be corrected is determined by the design of the FEC code, so different forward error correcting codes are suitable for different conditions.

2, FORWARD ERROR CORRECTION

There are numerous ways of classifying the forward error correction codes as per different characteristics [4].

1.2 Linear Vs Nonlinear- Linear codes are those codes in which the sum of any two valid code words is also a valid code word. In case of nonlinear code this statement is not always true.

2.2 Cyclic Vs Non-Cyclic - Cyclic code word are those in which shifting of any valid code word is also a valid code word. In case of non-circular code word this statement is not always true.

2.3 Systematic Vs Nonsystematic- Systematic codes are those in which the actual information appears unchanged in the encoded data and redundant bits are further added for detection and correction of error. In non-systematic code the actual message does not come into view in its original form in the code rather there exist one mapping technique from the data word to code word and vice versa.

2.4 Block Vs convolutional -The block codes are those technique in which one block of message signal is transformed into on block of code. In this case no memory register is required. In case of convolutional code a sequence of message bits is converted into a sequence of code. Hence encoder requires memory or shift registers as present code is combination of present and past message.

2.5 Binary vs. Non binary -Binary codes are those in which error detection and correction is done on binary information i.e. on bits. Hence after the error is detected, correction means only flip the bit found in error. In Non-binary code error detection and corrections are done on symbols, symbols may be binary though. Hence both the error location and magnitude is required to correct the symbol in error.

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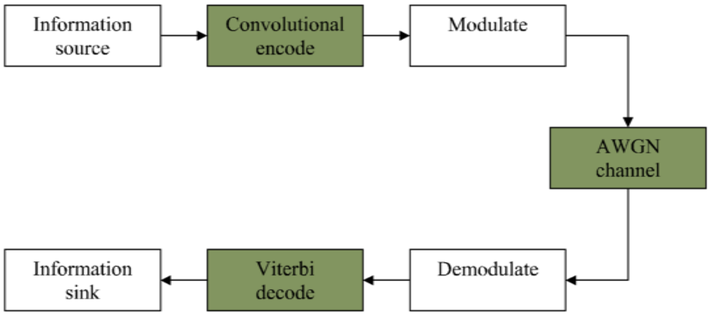
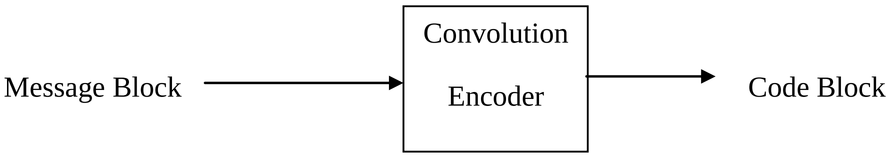


Figure 1: Error Correcting Communication link

As seen in Figure 1.4, [5] convolution encoding is one way of performing 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. 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 [5].

3, CONVOLUTION CODING

Convolutional encoder maps a continuous data into a continuous data of encoder output. Thus convolutional encoder is a finite state machine, which is having memory registers of past inputs and also having a finite number of diverse states. The number of output bit depends on the number of modulo 2-adders which is used with the shift registers.[23]



Convolutional coding is a bit-level encoding technique. Convolutional codes are used in applications that require good performance with low implementation cost. Using convolutional codes a continuous sequence of information bits is mapped into a continuous sequence of encoder output bits. The encoded bits depend not only on current input bits but also on past input bits. This mapping is highly systematic so that decoding is possible. As compared with the block codes, convolutional codes have a larger coding gain. [6]

3.1 Convolution Encoder Parameters

Convolutional codes are commonly specified by the three parameters (n, k, m), where
n = number of output bits
k = number of input bits and,
m = number of shift registers. [5]
Commonly k and n parameters range from 1 to 8, m from 2 to 10, and the code rate from 1/8 to 7/8 except for deep space applications where code rates as low as 1/100 or even longer can be employed.[4] The convolutional codes discussed here will be referred as (n, k, m) codes. [1]

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Passing the information sequence to be transmitted through a linear finite shift register generates a Convolutional code. The shift register consists of k bit stages and n linear algebraic function generators. The contents of shift register are multiplied by respective term in generator matrix and are then XORed together to generate respective generator Polynomials. [8]

4, VITERBI DECODER

Viterbi decoders work on Viterbi algorithm to decode the encoded data. The Viterbi decoding algorithm was discovered and analyzed by Viterbi in 1967. The Viterbi algorithm essentially performs maximum likelihood decoding; however, it reduces the computational load by taking advantage of the special structure in the code trellis [8].

4.1 Viterbi Decoding Technique

The Viterbi decoder examines an entire received sequence of a given length. The decoder computes a metric for each path and makes a decision based on this metric. All paths are followed until two paths converge on one node. When two paths enter the same state, the one having the best metric is chosen; this path is called the surviving path. The early rejection of the unlikely paths reduces the decoding Complexity [4][7][8]

4.2 SOFT DECISION VITERBI DECODING

Also referred to as the soft input Viterbi decoding technique, this uses a path metric called the Euclidean Distance metric, to determine the survivor paths as we move through the trellis. The soft decision Viterbi decoder discussed in this report uses a 3-bit quantizer to quantize the received channel data stream. A Viterbi decoder with soft decision data inputs quantized to three or four bits of precision can perform about 2 dB better than one working with hard decision inputs.

Trellis explanation

Based on the example considered, of the encoded 3-bit input stream [1 0 1] trellis are shown in the figures [1]. The corrupted, and quantized data bit stream at the input of the soft decision Viterbi decoder is assumed as [3-4 -43 33 -43 -4-4].

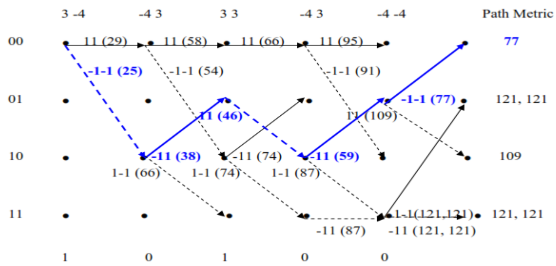

Figure 4.1: Decoded sequence 10100 for the noisy encoded bit stream 3-4 –43 33 –43 -4 -4.

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4.3 Soft decision decoding model

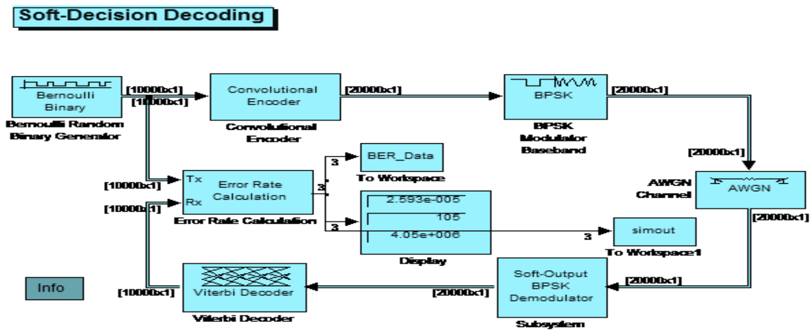

Figure 4.2: Soft decision viterbi decoding model [9]

5, RESULTS

We have calculated BER for Eb/No = 2 to 7 & found simulated result using MATLAB14a. We have taken 4 input bits 1000 & generator polynomials [1,0,0,1,1,1,1;1,1,0,1,1,0,1]. We took code rate of ½ & m=6. Figure 5.1: BER vs. Eb/No (SNR) for soft decision decoding for rate ½ & m=6. We calculated BER for the unbound result for viterbi decoding for SNR 1 to 12 & input bits 1000. Figure 5.2 shows the comparative performance of convolution and FEC.

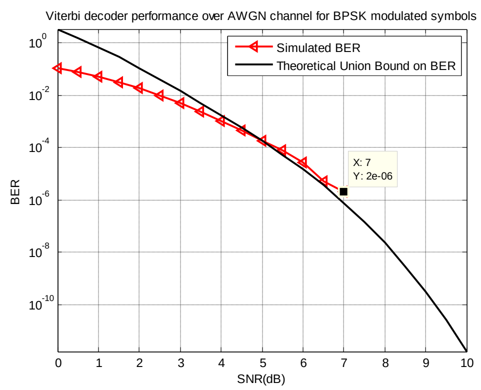

Figure 5.1 : BER vs Eb/No (SNR) for 4-bit input

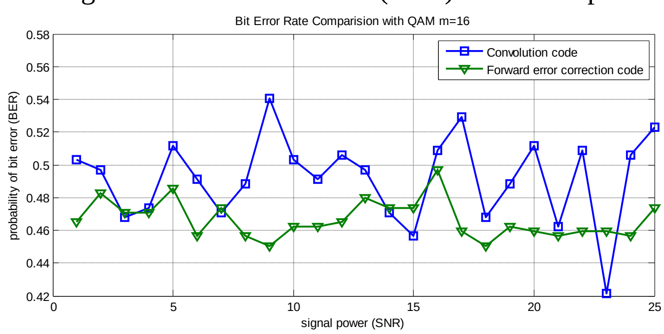

Figure 5.2: Comparative between convolution & FEC

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6, CONCLUSION

The design of a convolutional encoder with a Viterbi decoder that can encode a bit stream of digital information and outputs a code word that has a capability to be transmitted to the destination and then decoded .The encoder was designed with a rate 1/2.The Viterbi decoder design had been driven in such a way that it would calculate the decoding path with the minimum metric to be passed to the decoder output port. The comparative performance of convolution and FEC has been observed.

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