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Comparison of BER for various Constraint Lengths of Convolution Coding in OFDM System

Jaipreet Kaur, Sukhdeep Kaur, Manjit Sandhu

Abstract— **In this paper, simulation model of OFDM system has been developed using convolutional codes with various constraint lengths3, 5 ,7 and 9of code rate ½ using simulation in Matrix laboratory language (MATLAB). The bit error rate performance of OFDM system has been carried out for different modulation techniques like BPSK, 16 QAM and 64 QAM.The OFDM signal was transmitted over the AWGN channel for various signal-to-noise ratio (SNR) values. The impact of convolution codes with varying constraint length is considered.**

Index Terms— **BER, Convolution Coding, Constraint Length, OFDM, SNR.**

I. Introduction

Convolutional codes are one of the powerful and widely used class of error correcting codes.Convolutional codes are introduced in 1955 by Elias.Then, Wozencraft proposed sequential decoding as anefficient decoding scheme for convolutional codes. In 1963, Massey proposed a less efficient but simpler toimplementdecoding method called threshold decoding.Then in 1967, Viterbi proposed a maximum likelihood decodingscheme that was relatively easy to implement for codes with smallmemory orders.
Convolutional codes are used as inner codes withburst error correcting block codes as outer codes toform concatenated codes.The burst error correctingcapability of the outer code is used to recover fromsuch burst error patterns in the decoding of the innercode. Convolutional codes are easy to implement than other error correcting codes.

II. OFDM System

OFDM is a combination of modulation and multiplexing. In OFDM, multiplexing is applied to the independent signals but these independent signals are a subset of the one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then multiplexed to create the OFDM carrier. OFDM is a special case of Frequency Division Multiplexing (FDM) [2,3].

To implement the OFDM transmission scheme, the whole design is divided into three sections –Transmitter, Channel and Receiver as shown in fig. 1.In the transmitter, binary input data sequence is taken. Forward Error-Correction Coding (FEC) and interleaving is done to provide frequency diversity. The information is typically FEC encoded and interleaved prior to modulation. The sequence is encoded by a convolutional encoder. Then Interleaving is applied to randomize the occurrence of bit errors prior to increase performance. The symbol is modulated onto subcarriers by applying the Inverse Fast Fourier Transform (IFFT). The output is converted to serial and a cyclic extension is added to make the system robust to multipath propagation. In channel, additive white Gaussian noise characteristics are taken. The receiver performs the reverse operations of the transmitter. After removing the cyclic extension, the signal can be applied to a Fast Fourier Transform to recover the modulated values of all subcarriers. The modulated values are then demapped into binary values, and finally deinterleaving and Viterbi decoder decodes the information bits

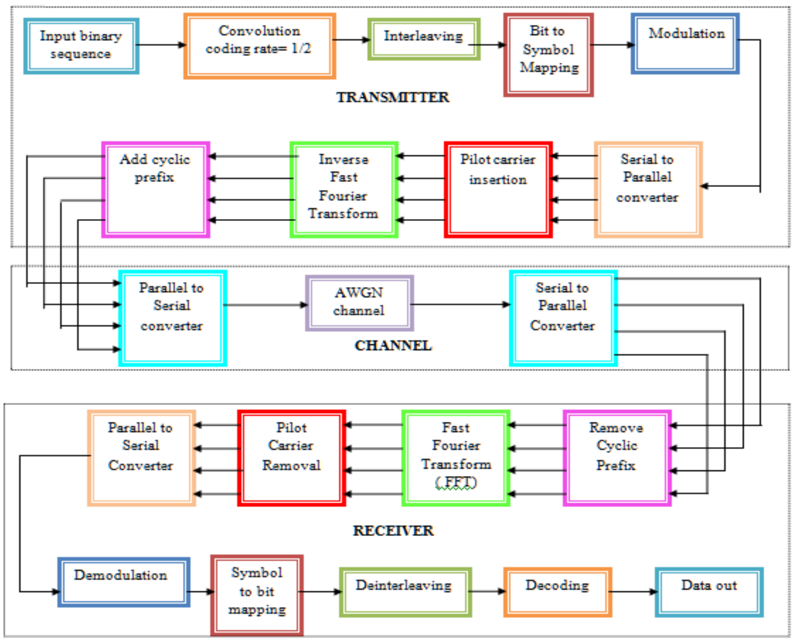

Fig. 1: Block Diagram of OFDM system

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III. Convolution Coding

Convolutional codes are extensively used for real time error correction. Convolutional coding is done by combining the fixed number of input bits. The input bits are stored in fixed length shift register and they are combined with the help of mod-2 adders. An input sequence and contents of shift registers perform modulo-two addition after information sequence is sent to shift registers, so that an output sequence is obtained. This operation is equivalent to binary convolution and hence it is called convolutional coding.

The convolutionalencoder computes each *n*-bit symbol ($n > k$) of theoutput sequence from linear operations on the currentinput *k*-bit symbol and the contents of the shiftregister(s). Thus, a rate *k/n* convolutional encoderprocesses a *k*-bit input symbol and computes an *n*-bitoutput symbol with every shift register update.

Convolutional codes are commonly specified bythree parameters (n, k, K).

- *n* = number of output bits or length of the code word
- *k* = number of input bits
- *K*= constraint length

The quantity *k/n* is called as code rate. It is a measureof the efficiency of the code [1]. The constraint length K, defines the past number of input bits in the memory register that affect the output code word. The constraint length K represents the number of bitsin the encoder memory that affect the generation ofthe *n* output bitsThe R=k/n is the rate of convolution code, which defined as the ratio of number of output bits to the number of input bits and is denoted by R. In general, k data bits may be shifted into the register at once, and n code bitsare generated. In practice, it is often the case that k=1 and n=2, giving rise to a rate 1/2 code. Convolution encoder with K=7, R=1/2.

There are three major families of decodingalgorithms for convolutional codes: sequential,Viterbi, and maximum a posteriori (MAP). Viterbioriginally described the decoding algorithm as maximum-likelihood in the sensethat it selects the sequence that makes the receivedsequence most likely. MAP decoding explicitly minimizes bit (rather than sequence) errorrate. Compared with Viterbi, MAP provides anegligibly smaller bit error rate. These small performancedifferences require roughly twice the complexity ofViterbi, making MAP unattractive for practicaldecoding of convolutional codes [5]. However, MAPdecoding is crucial to the decoding of Turbo codes.When convolutional codes are used in the traditionalway they arealmost always decoded using some form of theViterbi algorithm. The goal of the Viterbi algorithm isto find the transmitted sequence (or codeword) that isclosest to the received sequence. As long as thedistortion is not too severe, this will be the correct sequence.

A. Constraint Length 3,[6 7]

The 3,[6 7] convolution code is shown in Fig. 2 has a constraint length of 3. The last registerhold bit and the first register holds the incoming bit. This code outputs 2 bits for every 1 input bit. It is a rate ½ code. This convolutional encoder uses the industry standard generator polynomials, $G_1 = 6$ and $G_2 = 7$ of rate R = ½.

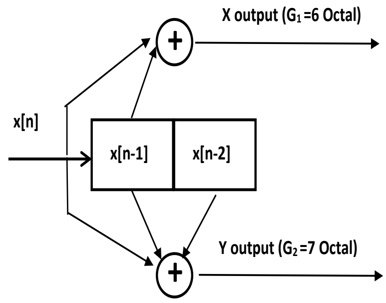

Fig. 2: Convolution Encoder of 3,[6 7]

B. Constraint Length 5,[37 33]

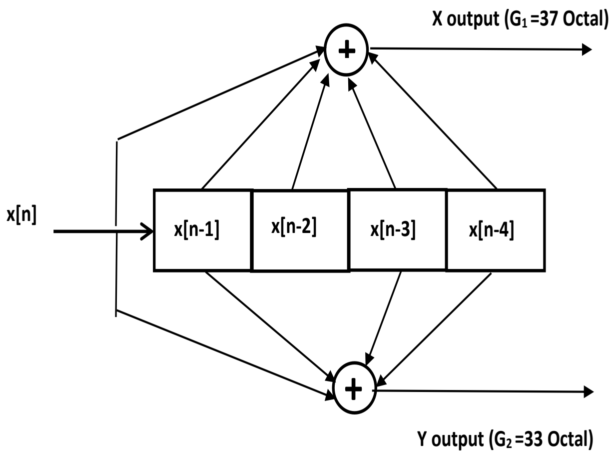

Fig. 3: Convolution Encoder of 5,[37 33]

The 5,[3733] convolution code is shown in Fig. 3 has a constraint length of 5. This code outputs 2 bits for every 1 input bit. It is a rate ½ code.This convolutional encoder uses the industrystandard generator polynomials, $G_1 = 37$ and $G_2 = 33$ of rate R = ½

C. Constraint Length 7,[171 133]

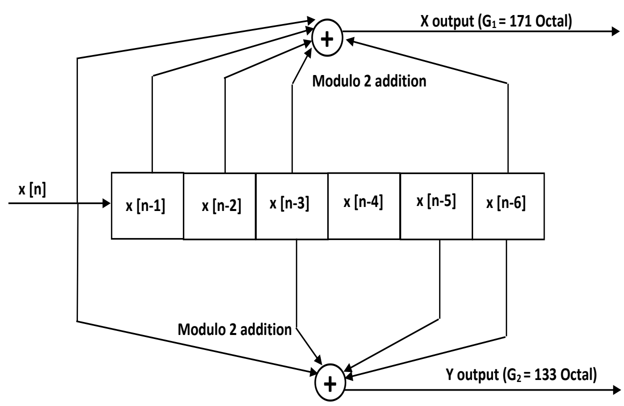

Fig. 4: Convolution Encoder of 7,[171133]

The 7,[171 133] convolution code is shown in Fig. 4 has a constraint length of 7. This convolutional encoder uses the

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industry-standard generator polynomials, G_1 = 171 and G_2 = 133 of rate R = ½.

D. Constraint Length 9,[561 753]

The 9,[561753] convolution code is shown in Fig. 5 has a constraint length of 9. This convolutional encoder uses the industry-standard generator polynomials, G_1 = 171 and G_2 = 133 of rate R = ½.

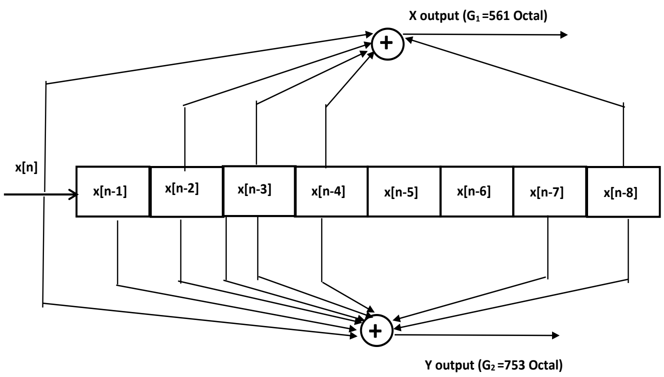

Fig. 5: Convolution Encoder of 9,[561 753]

IV. . SIMULATION RESULTS

The simulations are performed on following standardparameters as shown in table I.

Table I: Parameters consider in simulation

Parameters	Values
Number of OFDM symbols	10000
Total data	260000
Number of bits per OFDM symbol	26
Number of data sub-carriers	26
Number of data sub-carriers after coding	52
Number of FFT points	64
Cyclic prefix	16 (1/4)
OFDM symbol	80 (64 +16)
Modulation scheme	BPSK, QPSK, 8QAM, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM
Coding	Convolutional coding with code rate ½ having constraint lengths: 3,[6 7] 5,[37 33] 7, [171 133] 9,[561 753]

A. Bit error rate curve for BPSK in OFDMwith differentconstraint lengths of convolution codes

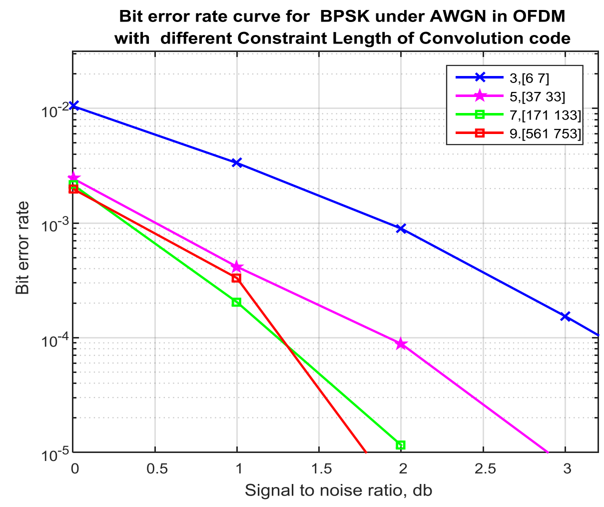

Fig. 6: Demonstrates plot of Bit error rate against Signal to noise ratio for BPSK with different Constraint lengths.

The simulated plot between BER and SNR for BPSK in OFDM system is shown in Fig.6.From the fig. 6, it is observed that for BPSK, on fixing BER10^{-5} the simulated SNR (dB) is 1.7 for 9, [561 753] and 2 for 7, [171 133] which indicates the BER for 9, [561 753] is better than other considered constraint lengths for noisy channel. So, for BPSK scheme, the convolution code having constraint length 9, [561 753] would be preferred.

B.Bit error rate curve for 16 QAM in OFDMwith differentconstraint lengths of convolution codes

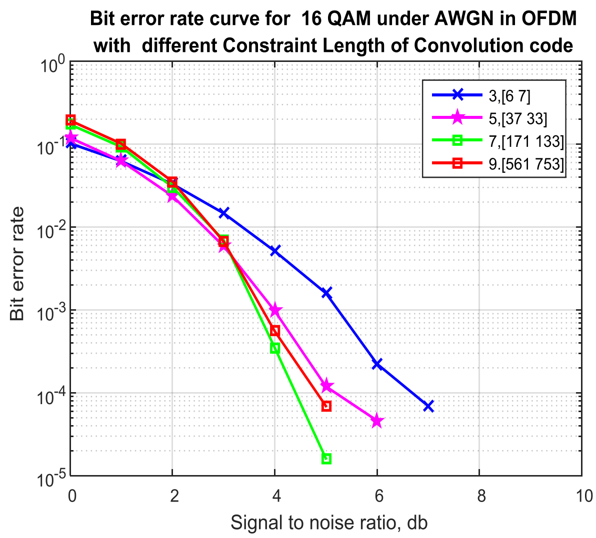

Fig. 7: Demonstrates plot of Bit error rate against Signal to noise ratio for 16 QAM with different Constraint lengths.

The simulated plot between BER and SNR for 16 QAM in OFDM system is shown in Fig. 7. From the fig. 7, it is observed that for 16 QAM, on fixing BER 10^{-4} the simulated SNR (dB) is 5 for 9, [561 753] and 4.5for 7, [171 133] which indicates the BER for 7, [171 133] is better than other considered constraint lengths for noisy channel. So, for 16 QAM scheme, the convolution code having constraint length

7, [171 133] would be preferred. The convolution code having constraint length 7, [171 133] for 16 QAM modulation is adopted in IEEE 802.16 and 802.11 standards.

C.Bit error rate curve for 64 QAM in OFDM with different constraint lengths of convolution codes

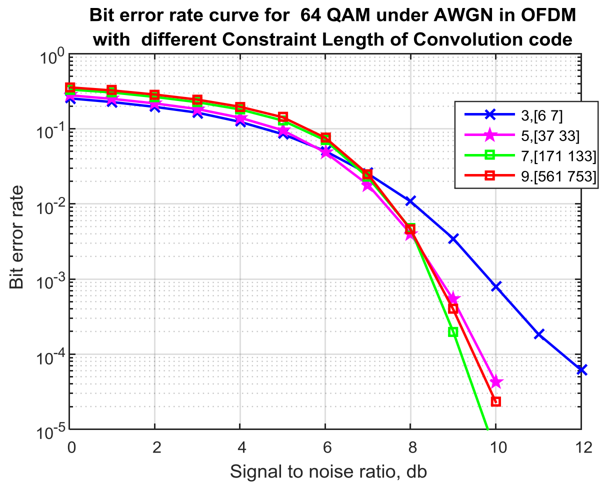

Fig. 8: Demonstrates plot of Bit error rate against Signal to noise ratio for 64 QAM with different Constraint lengths.

The simulated plot between BER and SNR for 64 QAM in OFDM system is shown in Fig. 8. From the fig. 8, it is observed that for 64 QAM, on fixing BER 10^{-4} the simulated SNR (dB) is 9.5 for 9, [561 753] and 9for 7, [171 133] which indicates the BER for 7, [171 133] is better than other considered constraint lengths for noisy channel. So, for 64 QAM scheme, the convolution code having constraint length 7, [171 133] would be preferred. The convolution code having constraint length 7, [171 133] for 64 QAM modulation is adopted in IEEE 802.16 and 802.11 standards.

V. CONCLUSION

The design of convolutional codes is very important for extremely lowerror probabilities used at high data rates in wirelesscommunication system. The basic design ofthe codes can bedeveloped based on code rate andconstraint length. As the constraint length isincreasing the parallel implementationhas to be usedfor feasibility at high data rates.The simulation results of Bit Error Rate (BER) displays that the implementation of 9, [561 753] convolution code technique gives less error with BPSK modulation which is generally employed at worst channel conditions as compared to other considered convolution codes of different constraint lengths. With 16 QAM and 64 QAM modulation scheme, the implementation of 7, [171 133] convolution code technique gives less erroras compared to other considered convolution codes of different constraint lengths. Under good channel conditions QAM with higher mode value i.e. 16 QAM (4 b/s/Hz) and 64 QAM (6 b/s/Hz) is considered as they providebetter spectral efficiency. From these figures, we can conclude that on fixing BER and under good channel conditions QAM with higher mode is used with 7, [171 133] convolution codeand under worst channel conditions, we can use BPSK with 9, [561 753]convolution code. Thus, we have to use adaptive modulation and coding depending upon channel conditions.

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Jaipreet Kaur received M.Tech. degree in Communication Systems from Guru Nanak Dev University, Amritsar, India. She is serving as Assistant Professor at Guru Nanak Dev University Regional Campus, Sathiala, Amritsar, India. Her main research interests are in wireless communication systems includes WiMax and MIMO.

Sukhdeep Kaurreceived M.Tech. degree in Communication Systems from Guru Nanak Dev University, Amritsar, India. She is serving as Assistant Professor at Guru Nanak Dev University Regional Campus, Sathiala, Amritsar, India. Her main research interests are in wireless communication systems and materials science.

Manjit SandhureceivedM.E. degree from Punjab University, Chandigarh, India. She is serving as Assistant Professor at Guru Nanak Dev University Regional Campus, Sathiala, Amritsar, India. Her main research interest isbiomedical instrumentation.