Abstract: This research article represents the literature review on study of coded convolution codes like trellis coded modulation (TCM) and bit interleaved coded modulation (BICM) for robust error correction of codes. In wireless communication error correction codes and interleaving have an important application due to fading. Reviewed research papers have TCM and BICM with different techniques and methods used in it. Papers show different modulation schemes used with TCM for various applications. Different algorithms are used with BICM for improving bit error rate and improving bandwidth efficiency in reviewed papers. Different techniques like Iterative decoding and Constellation mapping are used with BICM and TCM to improve Bit error rate (BER) and signal to noise ratio (SNR).

Keywords: TCM, BICM, BER, SNR.

1. INTRODUCTION

In wireless communication, signal is transmitted wirelessly (without wires) from source to destination. But the signal at the receiver end, we get, is distorted due to different obstacles in non line of sight that is called fading. To overcome fading error detection and correction codes are used. Error detection is the recognition of error due to noise or other deterioration during transmission. Error correction is the recognition of errors and reformation of the original data with no error. Error detection and correction can be done by simply adding some extra bits to a message which receiver can use to check compactness of the delivered message. Error correction codes are differentiated as convolution codes and block codes. Block codes are processed on a segment basis and convolution codes on symbol basis. Convolution codes are the error correcting codes in which parity symbols are generated by sliding application (convolution of encoder over data) of a Boolean polynomial function to a data steam. Convolution codes are used to attain reliable data transfer in fields like mobile communication, satellite communication etc. So in today’s wireless communication convolution codes can be used in different schemes like in trellis coded modulation.

A. Trellis coded modulation (TCM)

Trellis coded modulation is the composition of coding which is done digital and modulation which is done in analog as a single function. ‘Trellis’ stands for the use of trellis (also called convolution code). It has non linear nature of performance and its performance is measured by coding gain over an uncoded signal. By the use of convolutional coding TCM is bandwidth efficient modulation. The trellis coded modulation function contains a Trellis code and a Constellation Mapper. The function of Convolution coder of rate R = N/N+1 and a M-ary signal mapper that maps M = 2^N input points into bigger constellation of M = 2^{N+1} constellation points are combined in TCM.

B. INTERLEAVING:

Interleaving is a process of making system more efficient, fast and reliable by reorganising a group of symbols. Interleaving can be used in arranging storage in RAM, error correction in data and in multidimensional data structure.

C. BIT INTERLEAVING:

In bit interleaving the data is shuffled so that the burst errors are converted into random error. Time division multiplexing (TDM), telecommunication and computer memory uses bit interleaving.

D. BIT INTERLEAVED CODED MODULATION:

Bit interleaved coded modulation is considered as the powerful strategy to achieve high data rates with general signal constellation. It uses powerful family of binary codes with any modulation format.
Comparative study results show the superiority of bit fading channel like AWGN and Rayleigh fading. The focus is on evaluating its performance on different ways it is better than trellis-coded modulation. Paper is about Bit interleaving coded modulation (BICM), and in [6], G. Caire, G. Taricco, and E. Biglieri give a brief idea about robust performance in the presence of fading. Multiplexing together for coherent detection to provide TCMP trellis-coded data and pilot sequences are needed for coherent detection to achieve full optimization. In [5], Michel L. Moher and John H. Lodge describe a technique called TCMP (trellis-coded modulation with pilot sequences) to overcome the drawback of TCM that is TCM need coherent detection for achieving full optimization. In TCMP, the trellis-coded data and pilot sequences are multiplexed together for coherent detection to provide robust performance in presence of fading.

G. Caire, G. Taricco, and E. Biglieri in [6] give a brief idea about Bit interleaving coded modulation (BICM) and in what ways it is better than trellis-coded modulation. Paper is focussed on evaluation of its performance on different fading channel like AWGN and Rayleigh fading. Comparative study results show the superiority of bit interleaved codes over Viterbi’s orthogonal Convolutional codes (OCC). BICM specifications involve minimum Hamming distance, minimum Euclidean distance, and number of nearest neighbors which indicates the performance of BICM.

Vincent K. N. Lau [7] proposed an error correcting method, Adaptive Bit interleaved coded modulation for bandwidth efficiency in wireless systems. Bit interleaving is preferred over TCM due to bit by bit interleaving instead of symbols. In ABICM according to channel conditions, code rates and modulation levels are varied. By less sufficiency feedback link – in good channel state modulation level and code rate are increased and vice versa in bad channel state to maintain targeted error level. ABICM focused on multilevel puncturing and interleaving. In terms of signal to noise ratio and output significant performance improvement is obtained.

Author of [8] proposed a bandwidth efficient method over fading channels that is BICM- ID. Compared to trellis modulation, soft decision iterative decoding has a large diversity with small Euclidean distance. According to results Performance efficiency of BCIM- ID depends on error free feedback.

Naghi H. Tran and Ha H. Nguyen [9] investigated different mapping techniques for 8-ary constellation in BICM – ID. Main is put on Euclidean distance and Mutual information for mapping techniques. Free squared Euclidean distance (FED) distance parameters are also discussed in this paper. After comparing different mapping schemes, Io Maximised mapping scheme was found to be the most suitable for 8-ary constellation BICM – ID system. Results show that BER (bit error rate) at high SNR for an uncoded system own an additive white Gaussian noise channel (AWGN) is minimized by Io mapping in 8-ary constellation.

In [10], hierarchical constellations are used to protect a data stream from channel impairments. BER performance of single data stream is improved by using Constellation. Multiplexer and interleaver are also used for Nakagami-m fading channels. Bit interleaved coded modulation with iterative decoding in two-way relaying communication (TWRC) is proposed in [11]. For multiple access (MA) phase iterative decoding is adopted, relaying on quaternary code representation. Bit error probability is successfully deducted in this paper with the use of iterative decoding and XOR based network coding at the relay.

### Table I. Literature survey table

| Year | Authors          | Title                          | Contribution               | Result                      |
|------|-----------------|--------------------------------|-----------------------------|-----------------------------|
| 1987 | Lee–Fang–Wei[2] | Trellis coded modulation with   | Multidimensional TCM scheme like four, | Better tolerance to phase ambiguities |

![Fig.2. Block diagram of transmission with bit interleaved coded modulation. Where \( \pi \) denotes interleaving at the bit level.](image)
| Year | Authors | Description | Bit Error Rate Analysis |
|------|---------|-------------|------------------------|
| 1987 | Dariush Divsalar and Marvin K. Simon | TCM for transmission (4800-9600 bps) over a fading mobile satellite channel | Bit error rate is analysed to increase gain |
| 1988 | Dariush Divsalar and Marvin K. Simon | Multiple trellis coded modulation (MTCM) | 3db gain is obtained compared to conventional TCM |
| 1989 | Michel L. Moher and John H. Lodge | TCMP- A modulation and coding strategy for Racian Fading Channels | Robust performance in presence of fading |
| 1997 | G. Caire, G. Taricco and E. Biglieri | Bit interleaved coded modulation (BICM) | BICM performance analysis over several fading channel |
| 1999 | Vincent K.N. Lau | Performance of variable bit interleaved coding for high bandwidth efficiency | Gain in terms of SNR and Throughput |
| 2002 | Xiaodong Li, Aik Chindapol, James A. Ritscey | BICM with iterative decoding and 8 PSK signalling | Bandwidth efficiency |
| 2006 | Naghi H Tran and Ha H. Nguyen | 8-ary constellation signal mapping for bit interleaved code modulation with iterative decoding | Minimize bit error rate at high signal to noise ratio |
| 2011 | Md. Jahangir Hossian, Alex Alvarado, Laszek Szczecinski | Interleaver and constellation design for bit interleaved coded modulation | Bit error rate for single data stream is improved |
| 2016 | Hongzhong Yan and Ha H. Nguyen | BICM-ID in two way transmitting communication | Bit error rate diminished by using iterative decoding and XOR based network coding |

3. CONCLUSION

This paper reviews the performance comparison of two coded modulation techniques – trellis coded modulation and Bit interleaved coded modulation. TCM offers more coding gain without compressing bandwidth by maximizing the free Euclidean distance among coded signal while BICM uses hamming distance to increase diversity order and with increased diversity order bit error rate diminishes. Unlike in TCM, BICM consider coding and modulation as two distinct operations which lead to provide more flexibility in design and implementation.

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