A Survey on Reed Muller block coded system for Bit error rate improvement

Miss. Mase P. B.[1]**, Prof. Mane A.P.**[2]**, Prof. Shinde S.G.**[3]

[1]ME Scholar, [2]Assistant Professor, [3]Head of Department
Department of E&TC
TPCT's College of Engineering, Osmanabad, India.

***Abstract*: Digital communication can perform unreliably and inaccurately in the presence of noise and interference along a channel. Error control coding techniques have been developed not only to detect these inaccuracies, but also correct them when decoded. Here we are implementing a block coded system consisting of Reed Muller (RM)code for error detection and correction.RM codes are a oldest family of linear error correcting codes used in communication and codes to construct. Useful iteration belief propagation (BP) algorithm is used for detecting purpose. The performance of iterative decoder for LBC is significantly depends on parity check matrix. Here new method implemented, which will adapt parity check matrix based on unreliably of bits in every iteration. The performance of static and adaptive parity check matrix is compared and validated under Additive White Gaussian Noise channel. A MATLAB simulation results were tested to achieve BER of 10-5 to 10-6.In simulation code rate used in 0.5 with 10 iterations. In this process, we did a proper research review analysis BER performance of adaptive method shows improvement over static method.**

***Keywords*: Block Codes, Reed Muller Code, Log Domain Belief propagation Algorithm, Bit Error Rate**

I. INTRODUCTION

I.I Problem Formulation

The basic communication problem, which is given in Fig.1.1, consists of three elements, the source with information to send to the sink, the sink to receive the information sent by the source, and the noisy channel which disrupts the information sent. The intended solution of this problem is transmission of data from source to the sink in an efficient and reliable way.

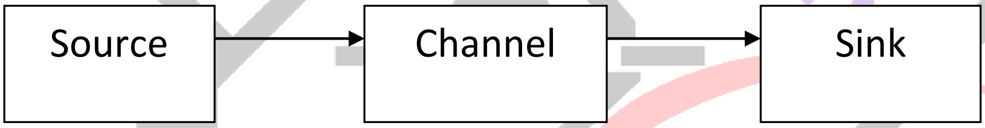

Fig.1.1: Basic communication Model

The basic communication problem introduced above has been formalized by Shannon in two separate parts; the first part deals with the information theoretical aspects of the data to be sent by the source, and the second part deals with the reliable transmission of this data through the noisy channel. The structure is given in Fig. 1.2.

There are four new blocks that have two different functions as stated before; the source encoder/decoder and the channel coder/decoder. Source encoder removes the redundancy of the source information, while the source decoder retrieves the full source information from the encoded data. On the other hand, channel encoder introduces redundancy for reliable transmission of the data through the noisy channel (or storage medium), and the channel decoder retrieves of course depending on the capabilities of the channel encoding/decoding blocks and the noise the source coded data from the received data. in the channel coding perspective the source and the source coding can be thought as a single large block. These blocks are shown in Fig. 1.2 by the big dashed rectangles.

Using the channel coding perspective described in the previous paragraph, the transmitter part is reduced to a source that generates arbitrary number information symbols from an alphabet, and a channel encoder encodes K of these symbols and produces an output of length N, where N-K is the redundancy of the channel encoder. In the channel some of these N encoded symbols are corrupted due to noise which might cause errors.

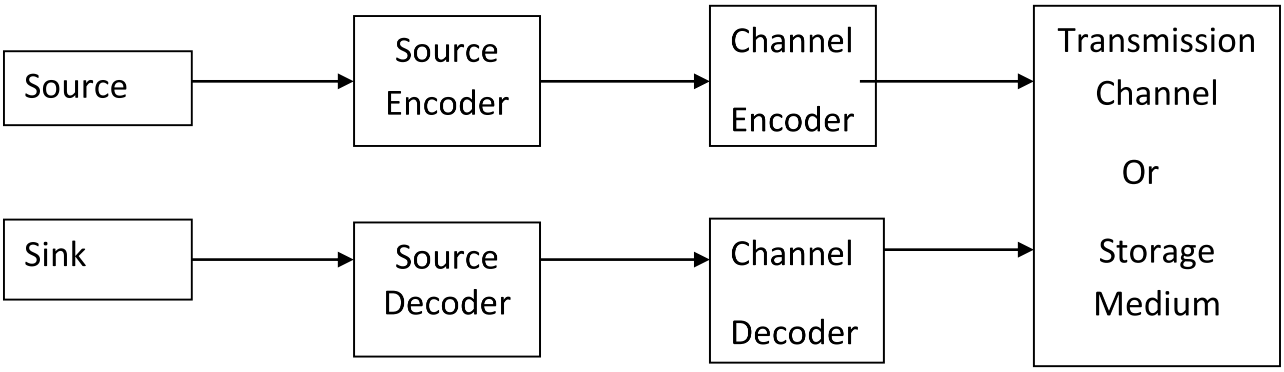

Fig 1.2: Basic communication Model Revised by Shannon

A symbol is called erroneous if its value is changed through the channel, and erased if no value or an erasure flag is received for that symbol. In the receiver, the received symbol sequence, which has length N is decoded to the K symbols that is closest to the received sequence. The term 'closes' might be in the sense of maximum likelihood, Hamming distance, etc. depending on the type of the decoder.

There are two main types of channel coding techniques. The first type is called Automatic Repeat Request (ARQ), in which the receiver requests retransmission of unreliable data frames. A data frame can be declared unreliable if an erasure or an error is detected in that frame. The second type is forward error correction Forward Error Correction (FEC) where the channel decoder estimates a code word from the received code word. Forward error correction methods will be the focus of this thesis. An error correction/detection scheme can be evaluated by three important properties; the reliability of the scheme, the complexity of the scheme, and the efficiency of the scheme. The reliability of the scheme stands for the reliability of the decoded words in the receiver, which can be measured by Bit Error Rate (BER) or Frame Error Rate (FER). The complexity of the scheme is measured by the number of operations that is required by the system and the complexity of these operations. efficiency of the scheme is measured by the ratio of the information sent for error correction/detection and the information sent from the source. The main trade-off in the error correction/detection technique is between these three properties.

It is easy to realize if channel coding has not been used, errors and erasures cannot be corrected. Therefore, for a more reliable transmission through a noisy channel, channel coding techniques are indispensable. Of course, the aforementioned advantages of error correcting codes comes with a price; usage of the error correcting codes requires more symbols to be transmitted, which is costly in terms of bandwidth, power, or time depending on the communication system. However, the benefits have outweighed the aforementioned costs and the calculations for the encoding/decoding; and channel coding is widely used in communications and storage systems.

Many different types of error-correcting codes have been developed in the almost 60 years since Shannon's original work such as the repetition code shown in the example above. In this work, we focus on Reed Muller (RM) codes, which are binary linear block codes based on linear transformations denoted by binary matrices. They have the dual advantage of both being very simple and very effective. In fact, they are some of the best error correcting codes known today.

Main application areas of error detecting/correcting codes can be given as;

- Wireless and Mobile Communications:
- Deep Space Communications
- Satellite Communications
- Military Communication
- Data Storage

II. LITERATURE SURVEY:

Reed–Muller codes are a family of linear error correcting codes used in communications. Reed-Muller (RM) codes were introduced in 1954, first by Muller [1] and shortly after by Reed [2], who also provided a decoding algorithm. They are among the oldest and simplest codes to construct; the code words are the evaluation vectors of all multivariate polynomials of a given degree bound. Reed-Muller codes have been extremely influential in the theory of computation, playing a central role in some important developments in several areas. In cryptography, they have been used e.g. in secret sharing schemes, instance hiding constructions and private information retrieval.

Moreover, despite being extremely old, new interest in it resurged a few years ago with advent of polar codes. Erdal Arikan in 2009 proposed a method of channel polarization to form a class of channel capacity achieving codes known as polar code. [3]

Arikan showed that the polar codes are the subset of RM code and derived from the same kernel matrix from which RM code is obtained. A performance comparison is carried out which shows at smaller block length RM code coincide with polar code thus achieving channel capacity. [4]

The conjecture that RM codes achieve capacity has been experimentally confirmed in simulations by M. Mondelli and etall. It showed that at practical block length RM code perform better than polar code. [5]

B. Li, H. Shen and D. Tse, has proposed the method for hybrid RM code which combines the distance parameter and Bhattacharyya parameter to obtain a hybrid code having better performance. But no concrete results were presented. [6]

The stopping redundancy of the code is an important parameter which arises from analyzing the performance of a linear code under iterative decoding on a binary erasure channel. Tuvi Etzion, show that the stopping redundancy of the simplex code is equal to its redundancy. An upper bound on the stopping redundancy of the first-order RM code is given. The stopping redundancy of related codes, such as codes with minimum distance and codes whose stopping redundancies is equal to their redundancies, was also discussed. [7]

Moshe Schwartz and Alexander Vardy introduce a new parameter, termed the stopping redundancy of C. It is now well known that the performance of a linear code C under iterative decoding on a additive gaussian noise channel (AWGN) and other channels is determined by the size of the smallest stopping set in the Tanner graph for C. Size of the smallest stopping set in the Tanner graph for C depends on the corresponding choice of a parity-check matrix. They are studied the effect of these constructions on the stopping redundancy. Specifically, for the family of binary Reed-Muller codes (of all orders), we prove that their stopping redundancy is at most a constant times their conventional redundancy.[8]

By G. David Forne, RM codes can be regarded as codes on graphs, and, hence, decoded by Belief Propagation (BP) decoders. He shown, on a cycle-free graph, there exists a well-defined minimal canonical realization, and the sum-product algorithm is exact. He presented an efficient cyclic and cycle-free realization of RM. [9]

The basic ideas were all present in Tanner’s work “A recursive approach to low complexity codes”. [10]

Frank R. Kschischang et.all introduce factor graphs and to describe a generic message-passing algorithm, called the sum-product algorithm, which operates in a factor graph and attempts to compute various marginal functions associated with the global function. [11]

In iterative decoding, a critical trade-off between complexity and performance is required. Based on these two issues, algorithms may be classified as optimal, sub-optimal or quasi-optimal. The optimal iterative decoding is performed by the Sum- Product algorithm at the price of an increased complexity, computation instability, and dependence on thermal noise estimation errors. [12]

The log likelihood ratio sum-product algorithms (LLR-SPA), developed by Mackay and Neal, are proven to achieve excellent capacity performance, by approaching to Shannon bound. However, one drawback for the LLR-SPA is the high complexity that implies large decoding delay that may be critical for some delay sensitive applications such as DVB. So, many modified approximations of LLR-SPA are developed to reduce its high complexity. [13]

The Min-Sum algorithm performs a suboptimal iterative decoding, less complex than the Sum-Product decoding. The sub-optimality of the Min Sum decoding comes from the overestimation of check-node messages, which leads to performance loss with respect to the Sum-Product decoding. [14]

Several correction methods were proposed in the literatures in order to recover the performance loss of the Min-Sum decoding with respect to the Sum-Product decoding which are called quasi-optimal algorithms. An example is Normalized min-sum algorithm proposed by Chen and Fossorier. [15-18]

Table on Literature Survey

Contributors	Parameter	Significance
Muller and Reed	RM code	A family of linear error correcting code
B.Li,H.Shen and D.Tse	Hybrid RM Code	Code is generated by combining distance parameter and Bhattacharyya parameter
	Stopping Redundancy	For first order RM code stopping redundancy is equal to its minimum hamming distance
Moshe Schwartz and Alexander Vardy	Parity Check Matrix	Performance of linear code depends on choice of parity check matrix
G.David Forne	Factor Graph	RM code can be regarded as code on graph so can be decoded by belief propagation algorithm
Frank R.Kschischang	Sum Product Algorithm	Iterative Decoding algorithm by passing the message between check node and bit node

N.Widerg	Sum Product Algorithm	SPA gives better performance at the price of an increased computational complexity
Mackay and Neal	LLR-SPA	Reduced implementation complexity but large decoding delay
	Min-Sum	Reduced decoding delay by considering minimum value among extrinsic information from the variable nodes
Han,Wei,Huang,Jianguo,Fan gfei Wu	Modified Min-Sum	The modified factor is obtained program and only one extra multiplication is needed in one cycle
Chen	Normalized Min Sum	Sub-minimum value among extrinsic information from the variable nodes into consideration, we make the correction factor varies with different iterations

Ⅲ. FUTURE SCOPE

In the future work, the little complexity added in the proposed method because of Gaussian elimination can be reduced by using a technique of spread parity check matrix. This method can be a substitute to obtain a sparse sub matrix at unreliable bit position by spreading parity check matrix.

Ⅳ. CONCLUSION

The Reed Muller code, a linear error correcting code can be treated as code on graph. RM code can be generated by various simple techniques like recursive generation, plotkin generation. RM code can be decoded by iterative belief propagation algorithm. Here we used a sum product algorithm to decode the RM code. With static parity check matrix we obtain a good coding gain over encoded system. Around 4db gain is achieved at 10-4 BER at 0.343 code rate.

Here a new method for iterative decoding with little increase in complexity based on the observation that, for linear code parity check matrix is not unique. As well the performance of iterative decoding algorithm is dependent on selection of parity check matrix. The new method adapt the parity check matrix for every iterations based on the reliabilities of LLR of bits. From simulation it is observed that we can achieve a very good coding gain of around 1.8dB as compared to static parity check matrix. The complexity can be neutralizes by using one of the low complexity variant of belief propagation algorithm like min sum algorithm or others.

REFERENCES

[1] D. E. Muller “Application of Boolean algebra to switching circuit design and to error Detection”.

Electronic Computers, Transactions of the I.R.E. Professional Group on, Vol. EC-3, Issue: 3, Sept. 1954.

[2] Reed, I. S. (1954), “A Class of Multiple-Error-Correcting Codes and the Decoding Scheme”, Information Theory, Transactions of the IRE Professional Group on, Vol.4, Issue: 4, September 1954.

[3] E. Arikan, “Channel polarization: A Method for Constructing Capacity Achieving Codes for Symmetric Binary Input Memory less Channels”, Information Theory, IEEE Transactions on, Vol. 55, Issue: 7, July 2009.

[4] E. Arikan, “A Performance Comparison of Polar Codes and Reed-Muller Codes”, Communications Letters, IEEE, Vol. 12, and Issue: 6, June 2008.

[5] M. Mondelli, S. H. Hassani, and R. L. Urbanke, “From Polar to Reed-Muller Codes: A Technique to Improve the Finite-Length Performance”, Communications, IEEE Transactions on, Vol. 62, Issue: 9, 01 August 2014.

[6] B. Li, H. Shen and D. Tse, “A RM-Polar Codes”, 2014 [Online]

[7] Tuvi Etzion, “On the Stopping Redundancy of Reed–Muller Codes”, On Information Theory, IEEE Transactions, Vol. 52, and Issue: 11, November 2006

[8] Moshe Schwartz, Alexander Vardy, “On the Stopping Distance and the Stopping Redundancy of Codes”, Information Theory, IEEE Transactions On, Vol. 52, Issue: 3, March 16, 2005

[9] G. David Forney, “Codes on Graphs: Normal Realizations”, Information Theory, IEEE Transaction On, Vol. 47, Issue: 2, February 2001

[10] R. M. Tanner, “A recursive approach to low complexity codes”, Inform. Theory, IEEE Transaction On, Vol. 27, Issue : 5, Sept. 1981.

[11] Frank R. Kschischang, Brendan J. Frey, Hans-Andrea Loel, “Factor Graphs and the Sum-Product Algorithm”, Information Theory, IEEE Transactions On, Vol. 47, Issue: 2, February 2001.

[12] N.Wiberg, “Codes and decoding on general graphs,” Ph.D. Dissertation, Dept. Elec. Engg. Linköping Univ., Linköping, Sweden, 1996.

[13] D. MacKay “Good error-correcting codes based on very sparse matrices,” Information. Theory, IEEE Transaction On, Vol. 45, Issue: 2, Mar. 1999.

[14] M.P.C.Fossorier, M. Mihaljevic, and H.lmai, “Reduced Complexity Iterative Decoding of Low-Density Parity Check Codes Based on Belief Propagation”, Communication, IEEE Transaction On, Vol. 47, Isuue: 5, May 1999.

[15] Han, Wei, Huang, Jianguo, Fangfei Wu, “A Modified Min-Sum Algorithm for Low-Density Parity-Check Codes”, Wireless Communications, Networking and Information Security (WCNIS), 2010 IEEE International Conference on , 25-27 June 2010.

[16] Xiaofu Wu, Yue Song, Long Cui, Ming Jiang, Chunming Zhao, “Adaptive-normalized min-sum algorithm”, Future Computer and Communication (ICFCC), 2010 2nd International Conference on , 21-24 May 2010

[17] Savin V., "Self-Corrected Min-Sum Decoding of LDPC codes”, Information Theory, 2008. ISI 2008. IEEE International Symposium on, July 2008.