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A Comparative Study of BER Performance in Deep Space Communication Based on Coding Techniques

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ABSTRACT: Deep space data transmission is the most challenging mission in satellite communication. The main difficulties faced in this mission are the transmission delay, weak signal to noise ratio, disrupted communication links etc. Channel coding technique can be used efficiently to recover data at low signal to noise ratio (SNR). This paper provides a survey on various coding techniques used in deep space image transmission for reducing bit error rate (BER). The objective of the survey is to compare the bit error rate performance of convolution code, turbo code, Low Density Parity Check (LDPC) code, concatenated turbo-LDPC codes and raptor codes.

KEYWORDS: BER, convolution code, LDPC code, turbo code, raptor code.

I. INTRODUCTION

Wireless communication has attained a tremendous advancement in the last few decades. These developments led to another phase of communication – Deep Space Communication. Error control coding, modulation of data to be transmitted etc. are the key technologies used to overcome the challenges in deep space communication system. The main characteristics of deep space communication are large delay, limited storage capacity processing capability of space craft low signal to noise ratio.

In this paper we are focusing on the BER performance of deep space data transmission using different coding schemes. The main concern is given to reduce the bit error rate, as the non-reliability of data received lead to wrong conclusions in scientific missions. Advancement in error control coding technique leads to the development of new channel coding schemes which can be used to reduce the bit error rate.

The paper is organized as follows: Section II Literature Survey, Section III Proposed scheme and Section IV Conclusion.

II. LITERATURE SURVEY

A. *Deep Space Channel*

Deep space is an additive white Gaussian channel (AWGN) with constant power spectral density. This channel is free from fading, frequency selectivity, interference, non-linearity or dispersion. Considering X(t) as the input, n(t) as the white Gaussian noise Y(t) as the received signal,the deep space channel can be represented as :

$$Y(t) = X(t) + n(t) \qquad \text{eq. (1)}$$

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B. *Coding Techniques*

Reliability of data transmitted can be improved by use of coding techniques. Source coding and channel coding are two separate coding methods used for this purpose. Source coding is the compression of data or removal of redundancy of the data to be transmitted so that available bandwidth can be efficiently utilized and storage capacity can be increased. Channel coding enables us to retrieve the compressed data with minimum error. Various channel coding techniques are developed to improve the image reconstruction capability of the retrieved data. Joint source-channel coding was introduced to achieve a good bit error rate and image reconstruction quality.

In the early times coding techniques used in deep space communication were linear block codes.If the channel is noisy, the performance of convolutional codes out-performs that of linear block codes. More over the convolutional codes can be used for continuous data as well. Thus linear block codes are replaced by convolutional codes[2]. The advancement in error control coding lead to the development more efficient coding techniques like concatenated convolutional codes, LDPC codes,turbo codes,concatenated turbo-LDPC code etc.

Convolutional codes can be concatenated mainly in two ways.

1. SerialConcatenated Convolutional Codes (SCCC)
2. Parallel Concatenated Convolutional Codes (PCCC or Turbo Codes)

In serial concatenated convolutional code the output of one convolutional encoder is interleaved and given as the input of next convolutional encoder. Interleaving is used to eliminate burst errors.The overall rate of the transmitted message is the product rate of inner and outer coder.In parallel concatenated code two convolutional coders are used in parallel. First encoder input is the original message and the second encoder input is an interleaved version of the original message. The overall code rate of PCCC is less than that of individual convolutional encoders. Comparing the performance of SCCC and PCCC the performance of PCCC is better than that of SCCC at low SNR and at high SNR SCCC performance is better [1].

Table 1 : SCCC and PCCC performance comparison[1]

TYPE	Coding gain at 10^{-5} dB	Coding gain at 10^{-8} dB
SCCC	7.6	9.2
PCCC	8	8.4

In deep space communication better performance at low SNR is required so PCCC or turbo code is used for deep space image transmission. In all the above cases the modulation scheme used is BPSK.

Low Density Parity Check Code (LDPC) is a coding technique in which the generator matrix is low density (less number of ones are present in the parity matrix). In LDPC coding the code word is generated by multiplying the message with the low density generator matrix. LDPC code in concatenation with turbo can be used for deep space image transmission. In concatenated turbo-LDPC code turbo is used as the inner code and LDPC is used as the outer code. The encoding section is designed in such a way that both the coding technique can be decoded with the same algorithm. When this method is used for deep space transmission using BPSK modulation scheme BER of 10^{-5} is attained at an SNR of nearly 0.36 dB [3].

Raptor code is a form of rate less codes.LT-codes, introduced by Luby for the scalable and fault-tolerant distribution of data over computer networks. A raptor code is an extension of LT-codes which have linear time encoding and decoding. They exhibited a class of universal Raptor codes for an integer p and any real $\varepsilon>0$, Raptor codes produce an infinite stream of symbols such that any subset of symbols of size $p(1+\varepsilon)$ is sufficient to recover the original symbols

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with high probability[5]. Each output symbol is generated using O(log(1/ ε)) operations, and the original symbols are recovered from the collected ones with O (p log(1/ ε)) operations.

Table 2: BER comparison

Coding Scheme	BER	Rate	Modulation	SNR
Concatenated Turbo-LDPC	10^{-5}	Turbo-1/4 LDPC- 5/6	QPSK	.36 dB
	10^{-5}	Turbo-1/3 LDPC- 3/4	QPSK	.45 dB
	10^{-5}	Turbo-1/3 LDPC- 5/6	QPSK	.60 dB
Turbo	10^{-5}	1/4	BPSK	.7 dB
Convolution	10^{-5}	1/2	BPSK	2.7 dB
SCCC	.013	3/4	BPSK	3 dB
No coding	10^{-5}	-	BPSK	9.6 dB

In deep space communication channel characteristics is varying abruptly. So if a coding technique which can vary the transmission rate depending upon the channel conditions it will be an added advantage. The development of raptor codes(rate less codes) was a bench mark in deep space transmission. Raptor code is concatenated LDPC-Luby transform code. The rate flexibility is obtained by the use of luby transform. In this coding technique, the code rate of data transmission is changed considering the entropy of image to be transmitted as well as the channel conditions. If the channel is very noisy low code rate is preferred and vice versa. In [4] image was transmitted through deep space using QPSK modulation and raptor coding. Image reconstruction quality was very good even at an SNR of 1 dB

III. PROPOSED METHOD

Improvement in bit error rate performance is a major concern in deep space communication. The system with QPSK modulation shows acceptable BER performance. Using high data rate modulation techniques like OFDM gives better error rate. Therefore better performance can be obtained by proposing a deep space communication system with OFDM modulation and raptor coding .Block diagram of the proposed method is shown below.

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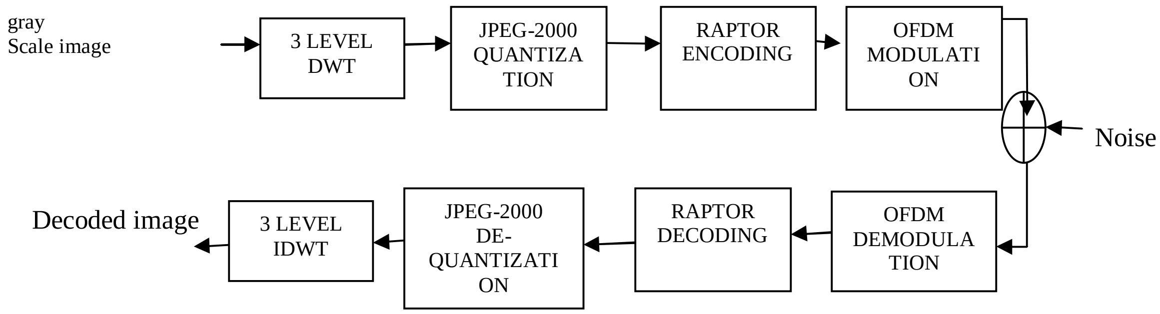

Fig.1.Block diagram of proposed method

IV. CONCLUSION

In this paper various coding techniques used in deep space communication was discussed. The survey revealed that use of raptor code is more advantageous as rate flexibility is possible depending upon the channel condition. This paper also suggest a new scheme for deep space communication with OFDM-QPSK modulation. As the bit error rate performance of OFDM system is much better than other modulation schemes better performance is expected in the proposed method.

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BIOGRAPHY

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