Turbo Code with Hybrid Interleaver in the Presence of Impulsive Noise

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Abstract—In this paper, a numerical density function of Impulsive symmetric α-stable (ISAS) noise was presented and simulated in the turbo coding environment. The ISAS noise has no closed-form expression, making it difficult to realize. The ISAS noise can be used to approximate many kinds of noise sources. In this paper, one of the parameters is used to set it as the Cauchy distribution. In addition, an improved interleaver structure is presented where the multiple interleavers of smaller capacity replace a single epic interleaver. Simulation results show that the hybrid interleaver outperforms the other interleavers presented in this paper.

Index Terms— turbo codes, interleaver, bit error rate, Cauchy distribution, stable distribution.

1 Introduction

The impulsive noise can be removed and by the use of impulsive noise filter the noisy signals can be enhanced. This type of impulsive noise has its importance in industrial automation applications, control system applications, and pattern recognition. The impulsive noise filters are used because the results of the median filter are not satisfactory. Generally, the median filters are only used but because of the above stated reason it is replaced by impulsive filters. The original signal and the properties of noise are taken into consideration while designing the impulsive noise filters. The different features like signal, noise, channel characterization and model of the signal generation results in less impulsive noise.

An interleaver is a signal processing method applied in various communication systems. It is a hardware device that takes symbols as a fixed alphabet at the input and produces the same symbols at the output. Generally, errors are formed at the transmission side and to minimize the burst errors the interleavers are used.

The main drawback for this interleaver is the usage of lookup tables for the implementation of interleaver. To overcome this drawback a pseudo interleaver is algorithmically implemented so that the reduction of lookup tables is reduced and the complexity in the hardware is also reduced. The deterministic interleaver the input message is ordered in a continues sequence of bytes. The input is accepted in the form of blocks and identical blocks are performed on those blocks before transmitting them. As the bit sequence is changed during the process, the data rate remains same.

In the present days, the use for mobile communication systems have been increasing. It is used to transmit the data, voice and images. While this wireless communication channel put forward the various drawbacks like channel width and transmission reliability without errors. the complexity of the system must be simple and the cost also should be effective.

2 Types of Noise

In electronic science, the noise is defined as the unwanted part of an electrical signal. The noise generally can be defined by different effects produced by different electronic devices. In communication system the noise is termed as an error. The useful data of a signal is affected by a random undesired disturbance can also be termed as noise. Normally it can be defined as signal to noise ratio.

Thermal noise happens with regardless of voltage carriers, inside the electrical conductors, there is a motion of charge carriers and it gives rise to the thermal noise. Shot noise is also an unavoidable fluctuation in the current. When the electron flows through the diode there is a gap between the flows of electrons and hence it is called as shot noise. It is similar to that of the rain drops falling discretely. When the current flows through an electronic device the current is partitioned into two or more paths then the fluctuations occur during the division it is called partition noise.

The noise which occurs externally at the communication is known as external noise. The noise which occurs due to environmental calamities like thunderstorms, lighting is called atmospheric noise. It is also called as static noise. The disturbances that occur due to switching gear, aircraft and auto mobiles is called as industrial noise.

It is caused mainly by high voltage wires. The discharge present in the operations is main cause for industrial noise. The data communication errors are mainly caused by line noise and distortion. Impulse noise is the primary noise in data communication system, one of the main sources of impulse noise is fluorescent lights, poor connection in circuits, voltage changes in adjacent lines. There are many ways to reduce errors are cross talk, intermodulation noise. They are occurred due to improper multiplexing. There are many causes for noise like poor connection, splices in cables, poorly maintained equipment. One can overcome this drawback by redo the connections and also to tune the transmission equipment.

3 Error Detection and Correction Codes

3.1 Block Codes

These codes can be implemented by using Boolean polynomials. Block coder is a memory less device. When the operator, by using a block code one can transmit very long data stream, since it can send all the data at a time, it can be divided into fixed pieces with some size. These pieces are called messages. Each message is encoded into a codeword, these can also be expressed in block codes. Then the operator can resend the data by using decoding technique and can retain the same information. The performance of the block code depends on the channel and block code parameters.

3.2 Convolutional Codes

The name itself suggests that the convolution of an encoder is called convolutional codes. These coding techniques are a continuous process. It can have random block length. These fixed block lengths are fixed by the algebraic properties.

It can be used to transfer data like videos, satellite communications, mobile communications and radio. These are most efficient. Here in the convolutional codes encoding and decoding process takes place. The encoder applied here is a finite state machine. If the input of the encoder has n-bits, then the states used are 2^n. The process of trellis diagram is explained by the following procedure:

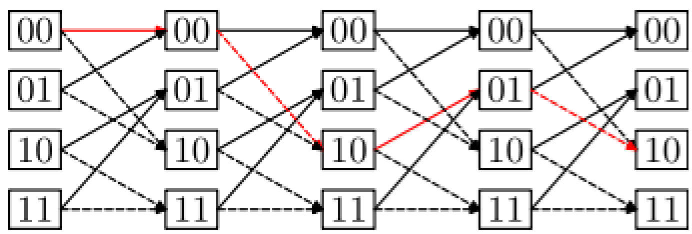

Fig.1 Trellis diagram of encoder.

A decoder cannot convert from 10 state to 00 or even stay in 10 state. Here in the trellis diagram 10 state can be defined when the 1 in one side and other side is 0.

4 Symmetric Alpha Stable Noise

The properties of impulsive noise can only be revealed with the analysis of stable distributions. Stable distribution is defined as follows.

"If a linear combination of two independent random variables with this distribution has the same distribution, up to location and scale parameters" [1]-[2]. The density function is shown in Fig. 2 to 5.

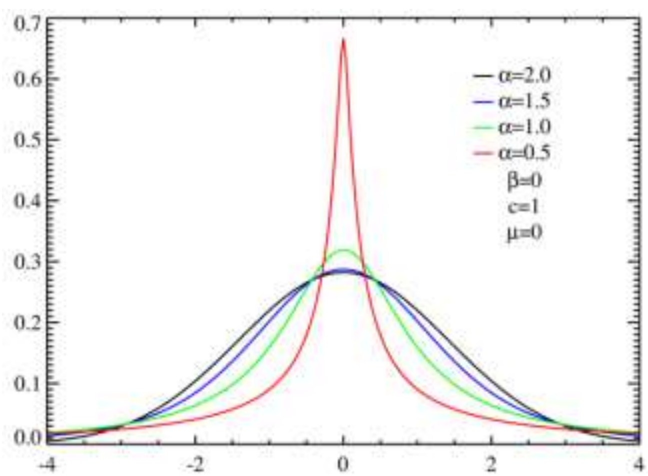

Fig. 2 Density of stable random variable with β=0, c=1 and μ=0

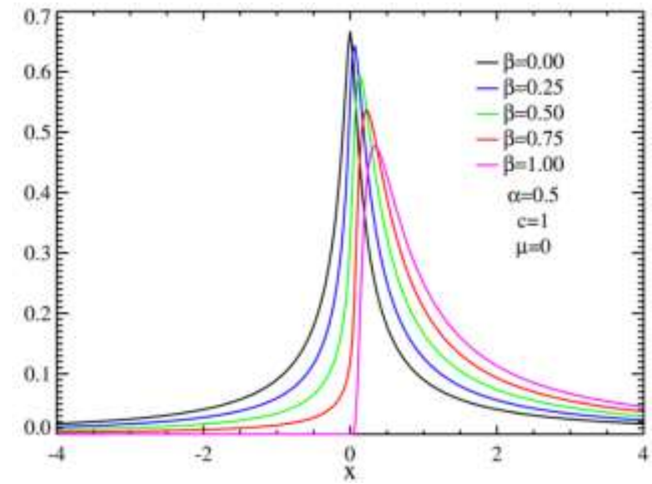

Fig. 3 Density of stable random variable with α=0.5, c=1 and μ=0

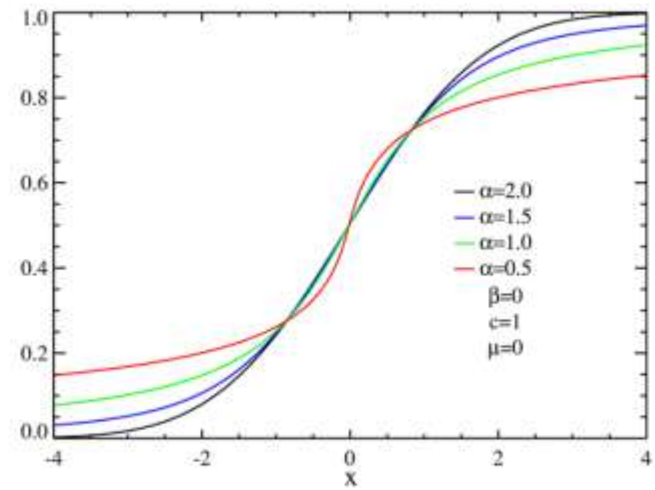

Fig. 4 Density of stable random variable with β=0, c=1 and μ=0

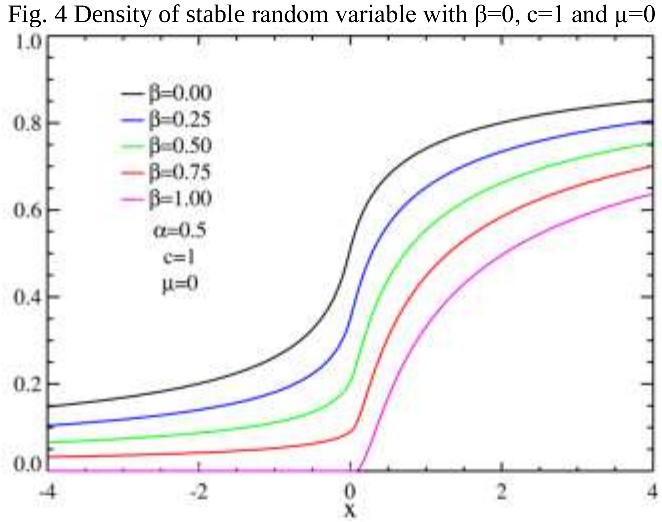

Fig. 5 Density of stable random variable with α=0.5, c=1 and μ=0

When the same condition is satisfied with $d=0$, then the distribution is said to be *strictly stable* [3]-[8].

5 INTERLEAVER DESIGN

Here, the SαS noise effect is handled by turbo codes. The practical implementation of SαS is a difficult task. Here by following the three cases an attempt had been made to reduce the SαS noise effect. These three cases are implemented in the turbo coding environment. Here the main important thing is the novel architecture of the interleaver. An attempt is made with no interleaver, combination of interleaver with the smaller dimension and block interleaver in [9] [10].

Design of channel code need to be done by considering both efficiency of energy and bandwidth constraints. The bandwidth requirements of channel code depend on the total number of bits transmitted per unit time. The number sample generated out of sampling is the double with respect to virtual samples present in an analog signal. When the discrete samples are generated using quantization, the total number of bits needed to represent each quantization level will be fixed. Hence, this decides the complete rate of communication and indirectly demands constraints on the bandwidth requirements of the channel [11] [12].

The energy efficiency is linked with E_b/N_o and in turn the feasible error rate. The error rate is linked with the error correction code employed. In that, the feature of error correcting code which controls the error rate need to be explored [13][14]. The turbo code is divided into two parts, they are encoding and decoding. The encoder part of turbo code is shown in Fig. 6.

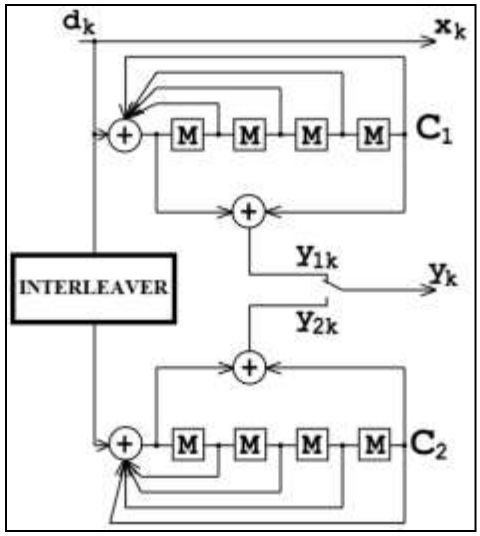

Fig. 6 Internal structure of Encoder section of Turbo coding system

The encoder of a turbo coding system consists of two parallel connected convolutional encoders. The input to the first encoder is the data stream from the input source, and to the second convolutional encoder is the interleaved input stream. The outputs of these convolutional encoders will be transmitted over a channel.

In addition to the outputs from these two convolutional encoders, a systematic output is also appended at the beginning of these bits. Hence, in total for a single bit at input, there are three bits at the output. There is a concept called puncturing where some or all of these bits can be multiplexed so that the rate of transmission can be increased from 1/3 to ½ or even 1. It is general practice to multiplex output bits of two convolutional encoders which is the case of Fig. 6. The remaining part of Fig. 7 is interleaver. In other words, specific length of input is given and at the other order the same bits are received. Here the order is evenly arranged. It can be clearly seen that the order is pseudorandom. Mainly the interleaving is done to combine the bits in a pseudorandom way, so that the stream of bits is changed. There are two main uses of interleavers. First, a stream of bits with less weight can be converted into a stream with more weight. The stream with more weight will ease the task of decoding. Hence the decoder design will be simpler. Second, burst errors can be converted into simpler errors. The transformation of burst errors into simpler errors is shown in Fig. 7.

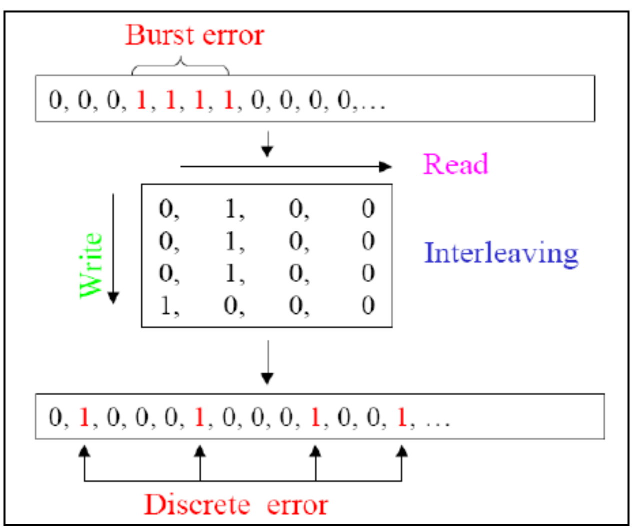

Fig 7. Operation of interleaver

Generally, an error detection code checks the error rate so the received data frame has to be transmitted again. Due to this the time delay to send the data packets over the network creates a drawback in the present day applications.so the use of error correcting codes has been into light. Error detection schemes are simpler when compared with the error correcting codes because of the limitation of distance is tight. To continue with the same correction capacity, the rate of coding will be low but the parity bits number added are high. Because of the complexity of the forward error feature the sender need not retransmit the data again. The benefits of the interleaver are the error correction and detection capability will have the less quantity of error. In this case, let us assume the bits in red color are 0s and the lightening are received as 1s. The turbo codes are not practically used, but the block codes are used for description.

Here, a hybrid interleaver is used and it is applied on SαS noise.it is proposed in [9]. The below figure number 7 represents the block diagram of hybrid interleaver. The main benefits in hybrid interleaver over single interleaver is that the order of the bits changes more in the hybrid interleaver. Since the frame length is high so it is effective. In the below Fig. 8 the total frame consists of 16 bits and it is divided into 4 frames. Each frame of 16 bits is applied to the block interleavers and the process is shown in the figure logically.

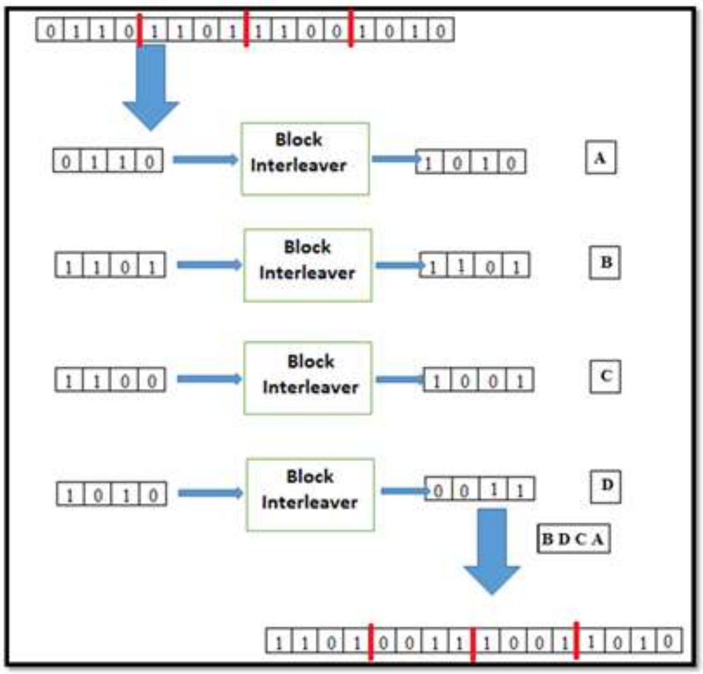

Fig. 8 Block diagram of Hybrid interleaver [9]

6 SIMULATION RESULTS

Here the simulation results tried in the turbo code environment were provided. Here Cauchy noise was introduced using sαs distribution. In the earlier section it is proved that any arbitrary noise distribution is minimized using sαs distribution. But here it is proved that sαs distribution can be applied to minimize the random noise distribution. Here 3 cases are considered. In the first one, no interleaver is applied hence the error rate is high and also resulted in poor combination of bit stream. In the second one a block interleaver is applied and the interleaver is taken as row wise read operation and column wise write operation. In the third case, the hybrid interleaver is applied and it uses a block interleaver with smaller size in dimension. Various frame lengths are used here and the length of each frame ranges from 2 to 16384. Here in the simulation results section, the results of the 3 sizes are shown. The 3 sizes are 1024,4096, and 16384.comparisions of the three cases are done with the different frame length sizes. The turbo coding is a continuous process. One can set the termination by two options either when reached to the point of minimum error rate or when the number of iterations reached to maximum. Here when the maximum number of iterations is reached then it gets terminated. A maximum of 8 iterations are processed. In the Fig. 9, it is shown that the error rate performance of turbo code in various cases.

Table 1. Bit error rate with no interleaver on 1024 in Cauchy noise environment

E_b/N_0 (dB)	02	03	04	05	06	07	08	09	010
Uncoded	0.079	0.080	0.076	0.069	0.068	0.065	0.061	0.054	0.053
Iteration - 01	0.090	0.074	0.074	0.061	0.051	0.044	0.041	0.034	0.032
Iteration - 02	0.092	0.071	0.070	0.058	0.052	0.044	0.038	0.032	0.028
Iteration - 04	0.094	0.069	0.069	0.055	0.050	0.042	0.040	0.030	0.028
Iteration - 08	0.093	0.069	0.068	0.053	0.047	0.042	0.039	0.028	0.027

Table 2. Bit error rate with hybrid interleaver on 1024 in Cauchy noise environment

E_b/N_0 (dB)	02	03	04	05	06	07	08	09	010
Uncoded	0.0814	0.0739	0.0748	0.0716	0.0701	0.0651	0.0655	0.0537	0.0536
Iteration - 01	0.0805	0.0694	0.0552	0.0492	0.0409	0.0350	0.0270	0.0188	0.0100
Iteration - 02	0.0795	0.0630	0.0520	0.0386	0.0215	0.0192	0.0069	0.0053	0.0025
Iteration - 04	0.0770	0.0598	0.0497	0.0328	0.0130	0.0066	0.0038	0.0017	0.0013
Iteration - 08	0.0777	0.0615	0.0438	0.0244	0.0106	0.0050	0.0045	0.0010	0.0013

Table 3. Bit error rate with block interleaver on 1024 in Cauchy noise environment

E_b/N_0 (dB)	02	03	04	05	06	07	08	09	010
Uncoded	0.0788	0.0766	0.0734	0.0692	0.0656	0.0599	0.0577	0.0571	0.0545
Iteration - 01	0.0870	0.0736	0.0618	0.0446	0.0360	0.0326	0.0289	0.0137	0.0135
Iteration - 02	0.0922	0.0669	0.0511	0.0312	0.0165	0.0164	0.0091	0.0020	0.0015
Iteration - 04	0.0909	0.0590	0.0446	0.0260	0.0082	0.0045	0.0018	0	0
Iteration - 08	0.0926	0.0605	0.0448	0.0237	0.0017	0.0042	0	0	0

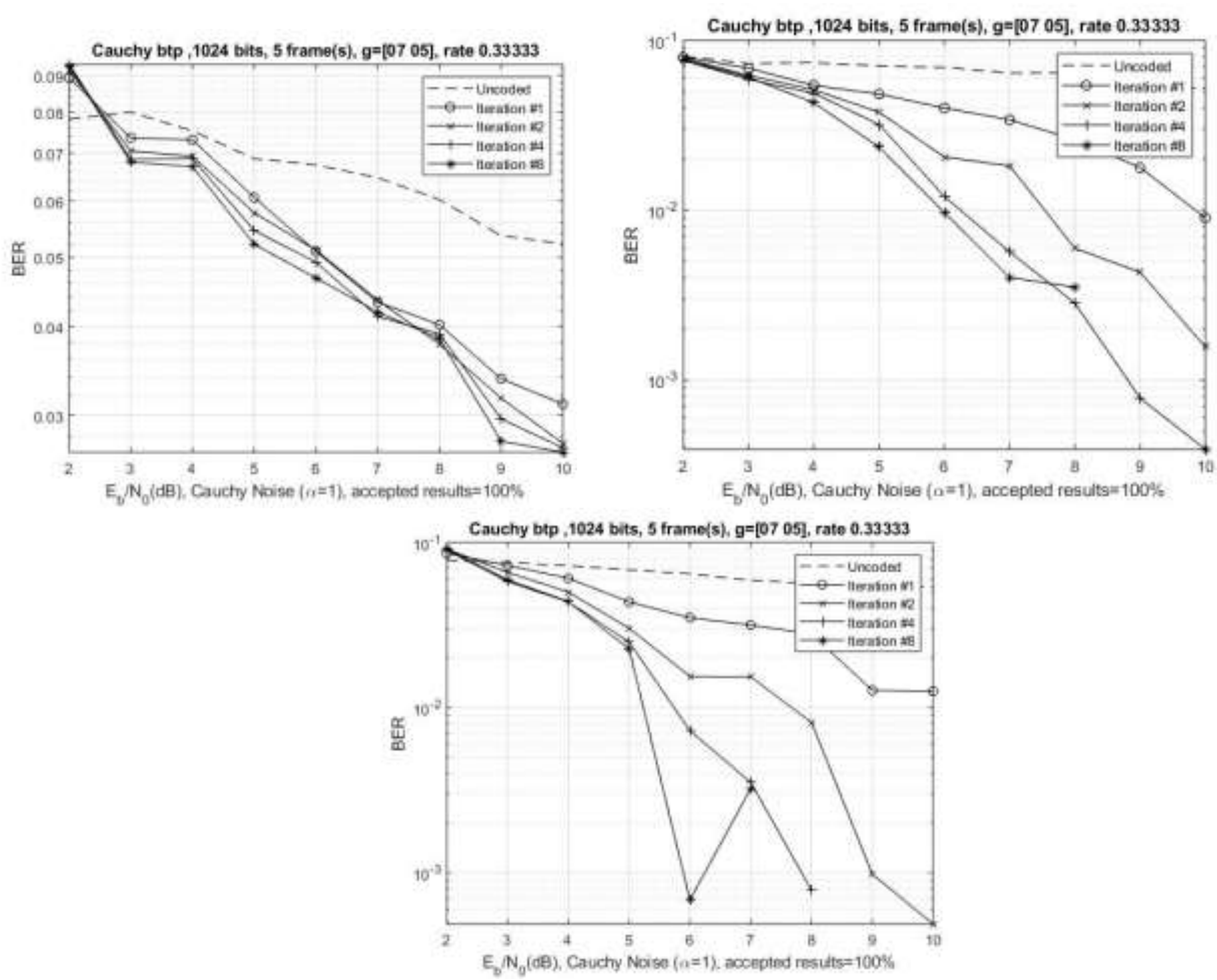

Fig. 9 Error rate performance of turbo code with no interleaver case, block and hybrid interleaver

From Fig. 9, it is evident that when interleaver is not used, the randomness of input bit stream is less and correspondingly, the weights will not be maintained to the required level. This degrades the error rate performance. When block interleaver is employed, in 8th iteration, a bit error rate of 10^{-3} is achieved at an E_b/N_0 of 9dB. But, with hybrid interleaver the same error rate is achieved with an E_b/N_0 of 6dB itself.

7 CONCLUSIONS

One of the fundamental limitations of Wireless communication is power consumption. Noise is the other fundamental limitation. When there exists error of more length, it is obvious to use an error correcting code capable of correcting that many bits. The codes capable of correcting more errors consume more power, hence the presence of burst errors concerns the designers of wireless system. Turbo codes is one solution, where the burst errors are converted into simple errors thereby reducing the overall power consumption. In this paper, a hybrid interleaver structure is proposed to tackle the speed concerns. In addition, Cauchy distribution is approximated using stable distribution.

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