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Development of a Reed-Solomon Error Detection and Correction System

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ABSTRACT

This project scopes into the Reed-Solomon (RS) Code as one of the optimal error detection and correction schemes. RS codes are codes in which adding unnecessary bits to a data in order for it to be reliably recovered even though the presence of errors in transferal, cache, and retrieval, is executed. The encoder for this specific code differs from a binary encoder in that it operates on the multiple bits rather than individual bits giving it the ability to precisely detect and correct error compared to other error and correction schemes. Its unique algorithm may be used in any analog or digital communication system because of it having the highest efficient use of redundancy, ability to adjust block length has a wide range of code rate and is an efficient coding technique perfect for accurate and precise code error detection. Storage devices, wireless communication, satellite communication, digital television, and high-speed modems are constructs of Reed-Solomon.

Key words: Reed-Solomon, Encoder, Error and Correction Schemes, Redundancy, Communication System.

1. INTRODUCTION

Based on the type of signals transmitted, communication electronics can be classified as an Analog or Digital, nevertheless, communications, in general, requires the relay of information from the information source to be processed in a way that its quality is to be as perspicuous as the quality the receiver obtains. The collection of certain individual networks is what makes up a communications system in which signals will pass through those given networks and then be relayed to the receiver which will further be used as the users' information. A diagram of which is shown below.

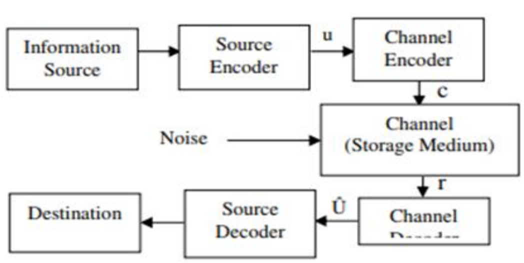

Figure 1: Block diagram of a data transmission

The information source serves as to where the message signal, in forms of audio, video, images, data, and etc, are from. The signal is then relayed to the source encoder which utilizes the bandwidth effectively and executes data compression. In the case of an analog being a signal, certain techniques like the Adaptive Data Modulation (ADM), Data Modulation (DM), and Pulse Code Modulation (PCM) [1]. For digital, the utilization of data compression is applied. A channel encoder is then met by the signal, it is used to provide noise immunity. The channel decoder sets the errors right and transforms it into an estimated sequence which will then be transformed by the source decoder to the approximate source output and sends the approximate to the point of end. One important component of a communications system is the channel (storage medium). A channel is a medium on which the signal is transmitted from one point to another. Each of the given channels has its own specific capacity known as the channel capacity. This certain capacity must be larger than that of the signal which will be transmitted through it. A minimal error of the data transmitted may be yielded if a certain parameter is applied. These certain errors may be corrected with the utilization of the two types of forwarding Error Correction or FEC coding techniques: linear block coding and convolution coding. The most powerful and optimal error detection and correction technique at present are the Reed-Solomon or RS codes are codes which fall under the linear block coding technique and were created by Irving S. Reed and Gustave Solomon [2]. They were able to generate a methodical process of creating codes that could identify and straighten a cluster of data errors. They are a subclass of non-binary Bose Chaudhuri Hocquenghem or BCH codes. The encoder for an RS code differs from a binary encoder in that it operates with multiple bits rather than individual bits giving it an advantage of detecting and correcting error codes more precisely than other error detecting and correction schemes.

2. BACKGROUND OF THE STUDY

When a signal of any kind in any form is sent from one point to another, whether that point is a device, a person or similar, a major inevitable problem that will be encountered manifests in the form of disturbances and obstacles, and the most famous of these disturbances is noise which is in turn classified into much more. The quality of the received signal as it reaches its specified destination is negatively affected due to these disturbances. The places in the message signal where the received form is different from the original transmitted form may be referred to as errors. In digital communications, there are methods and procedures that may be carried out so that systems that are concerned with the reception of signals may be able to either detect these errors, correct these errors or do both so that the outcome signal may show to be as identical as what was transmitted, even though it will never be as seen from a practical rather than an ideal perspective. Digital communications systems see message signals in the form of binary bits. Therefore, errors are identified and corrected based on which bits are different from what it appears in the original signal. Detection is done by simply systematically checking the binary bits in a frame for some possible redundancies when compared to a bit frame from a piece of actual data. For error correction, it is a little more complicated. There are, however, a couple of ways of performing this procedure, and they are the forward and then the backward error correction. For the forward, it involves the digital system directly correcting the bits that are detected to be wrong. Back correction involves sending the data back to the transmitter so that the message signal message may be sent again.

3. STATEMENT OF THE PROBLEM

In data transmission, digital integrity is a valuable thing, it requires tons and lots of protocols. The accuracy and quality of data and signal transmitted is a must for every processing that is being done. Ensuring minimal errors and discrepancies are optimal for a communication system to execute exchanges between a source and a receiver clearly but code and data transmission errors are inevitable due to channels being vulnerable to noise [3,4]. As it stands, signal quality deficiency and error have been more or less experienced by the majority of subjects carrying out any type of communication, however, due to the various selection of error detection and correction schemes, executing and thinking of what technique to use may be confusing. This research will provide the optimal coding technique hand in hand with error detection and correction which is the Reed-Solomon code. RS codes in present, are widely used in almost everything we see that involves data and signal transfer. Considering it as one of the most powerful techniques in error and correction, the codes are executed in telephony, broadcasting, wireless communication networks, hard drives, memory cards, compact discs, DVD's, and etc.

4. SIGNIFICANCE OF THE STUDY

With the vast and diverse reaches of technology at this specific point in time, message transferring may be done digitally. Almost everything we see, hear, and touch maybe, in some sort an adaptation of digital communication. It is inevitable, during the process of message, signal, and data transfer, to have certain errors and data corruption. The research findings of this paper will contribute to the ease and convenience of digital communication users and usage through error detection and code correction. The Reed-Solomon code is what will be utilized as the primary error detection and code correction. Known for its usage of finite fields to execute data and belong to the family of BCH codes, one of the most powerful linear cyclic codes, it brings no wonder why it is used in the majority of the communication systems we have today. Obtaining the knowledge of the most powerful error detecting and code correcting technique to ensure efficiency and sustainability of a digital communications system is necessary [5, 6, 7]. For the researchers, the research may help them unravel and dig deeper into coding. This may help them for future studies and which also may lead to new knowledge and discoveries, thus, helping them through the course of electronics.

5. DESCRIPTION OF THE SYSTEM

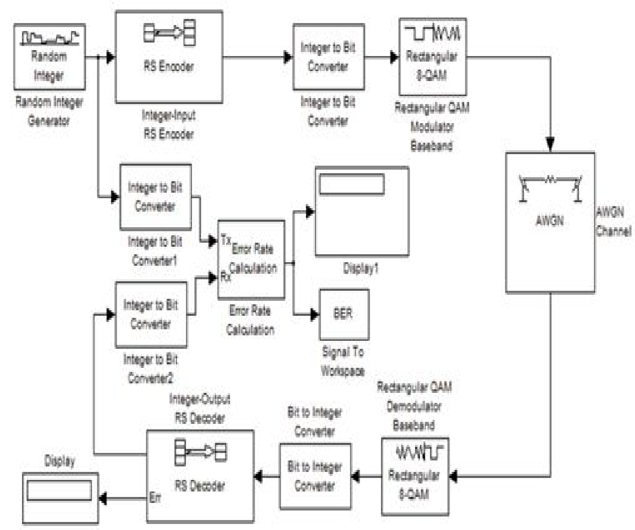

Figure 2: Block diagram of the Reed-Solomon

The design of the system is mainly composed of input, encoder, and decoder, from what the group has understood [8,9]. The first block of the design was the input, whether it be an integer or a certain kind of message. This message most likely were fields of 1 and 0, that can mean a lot like number or letters. The block that was used as the random integer generator. This block creates a uniformly constantly distributed random integer in the range [0, M-1], where M is the Set size parameter. The next block is the integer input RS Encoder [10]. It is a block that uses and represents the Reed-Solomon codes. This part is the encoder part where the symbols for the code that the Reed-Solomon reads is in k data symbol and also it is a code in an integer between 0 and 2M-1 and these elements are of the finite field GF(2M).

The input and output are integer value signals that make messages representing codewords or vice versa or even both or one of them. An (N, K) Reed-Solomon code can justify and correct up to floor((N-K)/2) symbol errors (not bit errors) in every message or codeword or etc just like said a while ago. The general idea of an encoder is to make a constructive polynomial that can be read or be converted when unreadable. the generator polynomial created will be exactly a data over /parity polynomial, which will be the coefficient that will produce the symbol that is needed. The last important block is just like before, but a decoder, which is an integer input RS Decoder. This is a block that decodes or recover or reclaims the messages representing codewords or vice versa or even both or one of them of Reed-Solomon code words. The block can make use of output shortened codewords if the shortened message length, S is given and that is specified as well. Just like encoder, the decoder also uses symbols for the code that the Reed-Solomon reads are in k data symbol and also it is a code in an integer between 0 and 2M-1 and these elements are of the finite field GF (2M) [11, 12]. Also like encoder, the decoder has the input and output are integer-valued signals that represent codewords and messages, respectively or messages representing codewords or vice versa or even both or one of them. The decoder is like checker and corrector. The decoder will seek to make the right thing right, not in an error which is commonly happening during the transmission progress [13]. As the message is interpreting the polynomial is by the default RS generator polynomial. As such if the remainder is zero, then there was no error during the transmission [14]. However, if it has, then it will start the “syndrome decoding”. It has 5 steps, first is to calculate the syndrome, second is to use the located syndrome to determine the error locator polynomial, third is to find the roots of the error locator polynomial, which the inverses of these roots give the locations of errors, fourth is when all three syndromes, roots, and error locator polynomial has been found and so what to find next is determine the error magnitudes, and last, but not the least is to use the information about error location and magnitude to actually correct the errors made during the transmission.

6. METHODOLOGY

The method here used basically the use of MATLAB and in the design, the main component needed is the RS encoder and decoder [15]. The idea was to implement by using the Simulink in order to make it better and faster to implement, because when you use reed Solomon codes it will take a while and will consume a lot of data unlike, if its Simulink the idea is just to place block that represents the reed Solomon and it understood in that in that block of reed Solomon encoder or decoder, the Reed Solomon code is already embedded inside the block. In this project, the group was also able to make use of idea where the input is an integer then will just convert it to a bit later using the block “integer to bit converter” block and vice versa is the bit to integer converter. As both meant as to convert the data of bit to an integer into a bit or integer, so that it can be readable with the RS encoder and decoder, then made use of rectangular QAM baseband for the amplitude modulation or demodulation of the signal.

The group also made use of the AWGN channel to make the blockage of additional white Gaussian noise, so that the input is real, that it will filter out the white Gaussian noise so that what will remain is the real data needed to be received or transmitted. Another block that the group made use of was the error rate calculation. That block as said a while ago have embedded codes in it, which was made user-friendly to users and the group just has to connect it to block that display value and displays the BER or in the workspace.

The (a.) spatial imaging couldn’t be applied in this project; however, rough set theory, electronic sensor, logic scoring of preference, artificial neural network, database monitoring, and data/ information transfer.

(b.) Rough Set Theory is one of the method used. Mainly, this theory most is at a block of error rate calculation and rectangular QAM baseband, because of its calculation and etc of arithmetic calculation is done.

(c.) Electronic Sensor is used by means of AWGN channel where it senses, if the data input is real, then all needed input is allowed, except the white Gaussian noise is being blocked or filtered off the input set.

(d.) Logic Scoring of Preference is used in by the rectangular QAM baseband. It has soft computing and having easy decision making in where to put data than after compiling.

(e.) Artificial Neural Network is commonly used in almost everywhere, so the process of input to processing data then to producing output.

(f.) Data/information Transfer is used in AWGN channel, whereas said a while ago, if the data input is real, then all needed input is allowed, except the white Gaussian noise is being blocked or filtered off the input set. The data transfer here is the if data is real or not.

7. REVIEW OF RELATED LITERATURE

There are several kinds of literature in the outside world that have as their main topic something about or related to Reed Solomon codes, such as error detection and correction as well as about the RS (n,k) codes themselves. Several of the types of literature that have decent insight are journals. One of them involves using these codes to assist in matters regarding power consumption which is clearly a critical issue particularly in the world people live in at present highly dependent on battery power. Low power applications are needed in these situations, and under this topic, forward error correction schemes are used, the assessment of which can be done through analysis of the tradeoff between performance gain and power consumption overhead [16, 17, 18]. Reed Solomon codes are a highly efficient type of forwarding correction method and effect the complexity of their related computations. Through these, bunches of code parameters may by smoothly deduced in order to have global power consumption lessened. A separate journal which is related to Reed Solomon codes that exist is concerned more with the analysis of the operational performance of a decoder device [19, 20]. Specifically, being talked about in it are the higher bounds of the decoder error probability for the derivation of Reed Solomon codes. According to this paper, it defines decoder error as a phenomenon where a codeword is produced that is different from what was transmitted. It also cites that there is such a thing as decoder failure, which pertains to the disability of a decoder to find any codeword at all [21]. There are other kinds of literature that had been found whose core topic is just error correction or detection in a general perspective - not specifically pertaining to Reed Solomon coding. Cited in this next piece of writing are thoughts of the author or authors about the academic topic of digital error detection and correction is regarded as a topic for advanced courses or courses for higher levels of learning, therefore academic information on it is less covered in textbooks of digital communications [22]. But, it is extremely essential information for students of the related course to know or not since signal error protection is a key essential feature of digital systems as it complements the work of the instruments which are concerned with the actual transmission and reception of carrier signals modulated by message signals. The journal provides readers with a template in the form of a spreadsheet. This, according to the authors or author, would assist students as it would allow them to visualize error correction. In another piece of writing that had been found, being talked about is a very basic discussion regarding errors in systems of signal communications, what causes them, and the things that engineers have developed in order to overcome ideally all, or at least most of those errors [23]. The writing sites that imperfections in a signal transmission medium can come in particle forms such as dirt film on, for instance, a disk or even microorganisms like bacteria. Due to these imperfections, portions of the transmitted data are compromised, and these portions are taken as bits in the scope of a digital system. Sometimes even words (16-bit binary phrases) are lost. One other journal mentions something called the Residue Number System. It inherits the benefits of modularity and parallelism. These result in property of fault tolerance in the system. This system results in more error protection rather than just detection or correction. This is due to the fact that limited to each hardware unit is the propagation of a carrier signal. The number system has the potential to be quick in its operation and has good reliability which both makes it good as a digital encoder in the system which is largely frequent to produce noise and, therefore, errors. Finally, one last academic document that talks about error detection is one that cites one of its procedures, the Cyclical Redundancy Check. It preps readers up by going through what main characteristics define demodulating message signals [24]. The two that are mentioned are that the message is sent to a bit stuffing procedure and that the signal is modulated due to the intervention of a modulation technique called Gaussian minimum shift keying. The formerly mentioned bit stuffing procedure is what adds difficulty to the process of machines that perform detection of information or data binary bits. The presentation of more than a few demodulation algorithms is done through this document. These algorithms lie in unique and different contexts that are in phase shift - either familiar or not familiar - and either multi-user or just mono-user transmissions. Based on all of this, the document presents a proposal for a receiver system that uses the Cyclic Redundancy Check which is in existence within the signals of automation identification system which are not only used for the detection of possible errors but are also used for the correction of those possible errors as well [25].

8. THEORETICAL CONSIDERATIONS

Reed Solomon codes are linear block codes and are examples of Bose-Chaudhuri-Hocquenghem codes (BCH codes). They are specified with a variable number of bit symbols as RS (n,k), which translates as making an n-symbol codeword by adding some parity symbols to k data symbols with that variable amount of bit symbols. The k data symbols are obtained from an encoder. If looking at a symbol size f, codeword length n bytes can only be a maximum of one minus 2 raised to the power off [26]. A code with 4 bits can only be 15 bytes long. However, by making select data symbols 0 and re-inserting them into a decoder, Reed Solomon codes may be made shorter. RS (n,k) codes are particularly well equipped to handle situations where several bits are received as an error at the same time - a phenomenon that is called a burst error. A symbol is considered to be or have an error if either any or all of the bits in a codeword are determined as wrong. Correcting errors is something that Reed-Solomon decoding procedures can accomplish. They can also correct what are called erasures, which are what occurs when the position of a symbol that is classified as an error is known due to demodulators in systems involving digital signals [27]. Decoders are able to perform corrections on twice as many erasures as it can with errors. The pros of using Reed-Solomon codes for signal error detection or correction are that the range of code rate is relatively big, the decoding techniques have notable efficiency, a redundancy check is at its highest efficiency and block length is adjustable. This explains why Reed Solomon codes are typically used in applications that require really good quality signal reception, large-signal power, and long-distance transmission are involved. These applications include high-powered modems, storage devices, and satellite communications among others. One other journal mentions something called the Residue Number System [28]. It inherits the benefits of modularity and parallelism. These result in property of fault tolerance in the system. This system results in more error protection rather than just detection or correction. This is due to the fact that limited to each hardware unit is the propagation of a carrier signal. The number system has the potential to be quick in its operation and has good reliability which both makes it good as a digital encoder in a system which is largely frequent to produce noise and, therefore, errors. Finally, one last academic document that talks about error detection is one that cites one of its procedures, the Cyclical Redundancy Check. It preps readers up by going through what main characteristics define demodulating message signals. The two that are mentioned are that the message is sent to a bit stuffing procedure and that the signal is modulated due to the intervention of a modulation technique called Gaussian minimum shift keying. The formerly mentioned bit stuffing procedure is what adds difficulty to the process of machines that perform detection of information or data binary bits. The presentation of more than a few demodulation algorithms is done through this document. These algorithms lie in unique and different contexts that are in phase shift - either familiar or not familiar - and either multi-user or just mono-user transmissions [29]. Based on all of this, the document presents a proposal for a receiver system that uses the Cyclic Redundancy Check which is in existence within the signals of automation identification system which are not only used for the detection of possible errors but are also used for the correction of those possible errors as well. Developed using the redundancy check technique is an algorithm that is based on an extended trellis which, and it is called the Viterbi algorithm. It consists of a couple of states - a trellis code state and a Cyclic Redundancy Check state. These states are what characterize the trellis of that Viterbi algorithm.

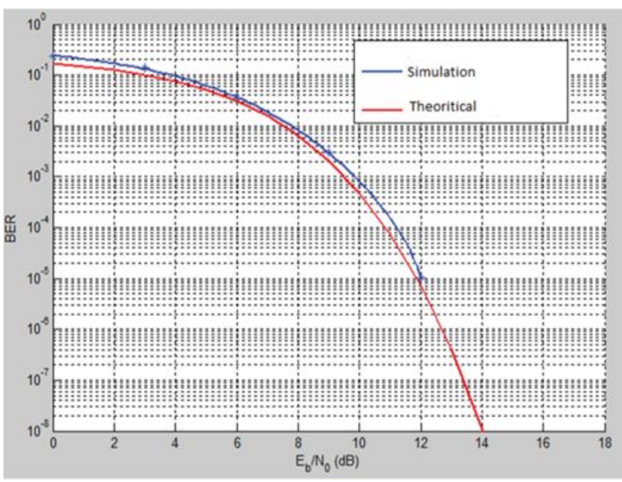

Figure 3: Simulation of the Reed-Solomon Block Diagram

This specific graph shows the extracted Bit Error Rate performance curve through its function tools. It is said to be the amount of error in relation to time. It is shown that BER execution gets better as the rate of code lowers.

9. ANALYSIS OF DATA

For this study to provide accurate and precise results, the concept of performance analysis is executed. The type of analysis to support the claim of the Reed-Solomon being very efficient is through the BER or Bit Error Rate which is extracted from the Bit Error Rate function tools. In this particular graph, it is shown that as the Signal to Noise Ratio increases, the capability of error-correcting increases as well which makes the relationship between errors and capability of corrections are directly proportional in terms of RS code usage. A simple way to put and expound a Bit Error Rate is it being curves that direct the given systems Bit Error Rate yields opposing heightened noise occurrence which in the graph, symbolizes Eb/No (dB), the said comparison of energy and noise spectral density. This performance checking method was used to test and confirm the theoretical projection of what Reed-Solomon codes can do. It is said that in digital communications and transmission, bit errors are inevitable. Bit errors are data in which are altered due to surrounding factors like noise. The Bit Error Rate may be improved with the use of certain techniques and one of them is applying error correction codes. The Bit Error Rate Test or BRT is a method of testing patterns using binary ones and zeros. Reliance on the knowledge about the software program MATLAB and SIMULINK was heavy. The Reed-Solomon code was simulated in the said software. It was found that the Reed-Solomon is optimal for handling errors in a burst. Based on the Bit Error Rate curve, it can be said that the Reed-Solomon codes, the Bit Error Rate execution have drastic positive change as the code rate decreases and to immense block extent. The specific code that well packed for burst errors, are found to be highly utilized in signal and information transfer at this point in time.

10. CONCLUSION

This project has been very insightful to the group. The project itself has defined it uses clearly when groups implement to try out the Simulink and make it successful. The Reed-Solomon error detection and correction has been concluded that the shown result has been seen to detect the error and correct it, afterward as shown in the data and result. The target was to show that at some point, the group's result as seen show the right and error detection rate when comparing the original from the received data result. The groups made sure that the data is readable, as seen in the design, the design has included a block that has a converter and also made use of the rectangular QAM baseband to make the logic frequency. The groups were able to see that the result came out correct comparing the simulation and theoretical. The thing about Reed-Solomon is that data being transmitted must be correct and when things go wrong the reed Solomon code detects the error and correctly, which is made use a lot and was better use when many errors have been done, since this Reed-Solomon is best in many errors or in bulk as the studies have concluded. When this system is converted into a database. It can follow the studies of [31,32,33].

The thing about the Reed-Solomon is that many companies use this in a lot of variety of ways; however, many that knows how to use Reed-Solomon don't want to share, since its powerful and very useful anyway, as we can see, mobile phone is anywhere and data are being transmitted all the time from this, the group can say that wrong message can be done at some point. To the point, all the time, the group's research that this Reed-Solomon has been the best and powerful error detection and correction. In the end, this project was very insightful and very interesting and can be used in future reference.

11. RECOMMENDATIONS

The concepts of digital communications are as applicable in the present-day real world as any concept has ever been. In every corner of any society that involves advanced communications among people, either a smartphone, a computer or an internet server can be found. Among the communications media the people use on an everyday basis, digital is easily the most preferred due to its great efficiency and quality in transmitting and receiving signals from one place to another. Music signals are crisper sounding, television displays are clear and not grainy, and transducers are better at detecting signals and using them to make the nearly lightning-quick decision based on their construction or programming. This is why learning the concepts that fall under and are related to digital communications is a highly useful practice especially if one wants to understand how digital communications works, and even more so if one intends to invent a software program or a hardware device involving any of these concepts [30]. However, even if one has completely mastered the electronic parameters, the transmission, and reception, or the different components involved, the learning will never be complete unless the error detection and correction are not at least made very familiar to him or her, because this is the difference-maker for digital communications versus its counterpart analog communications. It is a constantly essential part of the digital communications system block diagram - it falls under the channel coding blocks. All signals that are handled by a well-functioning system go through redundancy checks and either of the two aforementioned error correction protocols if needed. This is why it is necessary that one understands these error protection concepts especially if the invention of projects involving digital signals is on the mind of the learner. The basics should be mastered and knowledge of the different types of error detection or correction procedures similar to the Reed Solomon codes should be familiarized. Learning all of these may help anybody helping out or adding more in a society that highly depends on digital technology and digital signals.

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