Efficient Data Transfer Over Wireless Networks

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DOI: http://doi.org/10.5281/zenodo.2671473

Abstract

In the present day, efficiency in the field of communication is of utmost importance. In this study, data is transmitted over a wireless network supported by helical antennas. The efficiency is obtained by encoding the data by the Reed Solomon (RS) encoding scheme. The added advantage of this encoding scheme is its error detection and correction scheme in addition to the productive bandwidth usage. The data is encoded from the source and will be modulated using Quadrature Amplitude Modulation (QAM) scheme. The modulated data is then transmitted over a wireless network supported by the helical antenna. In the receiving end, the received signal is demodulated and then decoded. In this study, errors are introduced by the user to demonstrate the error detecting and correcting capabilities. The entire set up is simulated on the MATLAB version 9.5b 2018 software.

Keywords: *Data, Encoding, Helical Antenna, QAM, RS Code, Wireless Network*

INTRODUCTION

An image is a picture that has been created or copied and stored in electronic form. An image can be described in terms of vector graphics or raster graphics [1]. Gray-Scale image is referred to as monochrome image. They contain gray level information, no color information. It contains 256 gray levels. The process of encoding converts information from a source into symbols for communication or storage. Decoding is the reverse process, converting code symbols back into a form that the recipient understands, such as English or Spanish [2]. One reason for coding is to enable communication in places where ordinary plain language, spoken or written, is difficult or impossible. In wireless communication, the data transmission is extremely sensitive to burst errors that are commonly encountered. Since, the data under consideration is an image, the burst errors have an adverse effect pertaining to the quality of the image. The proposed solution is to have forward error correction (FEC). The FEC method is favorable as it has a clear cut advantage. FEC methods have a lower consumption of bandwidth and a high-efficiency error correction. This is the reason FEC is suitable for applications in wireless communication [1]. Hence Reed-Solomon (RS) codes are chosen, that are block-based error correcting codes with a wide range of applications in digital communications and storage. These codes are used in many systems including storage devices (including tape, Compact Disk, DVD, barcodes, etc.) [3]. In digital modulation, an analog carrier signal is modulated by a discrete signal. Digital modulation methods can be considered as digital-to-analog conversion and the corresponding demodulation or detection as analog-to-digital conversion. Here, the modulation technique being used is QAM (Quadrature amplitude modulation). It conveys two analog message signals or two digital bit streams by changing the amplitudes of two carrier waves [4]. In the field of communication systems, whenever the need for wireless communication arises, there is a necessity of an antenna. Here, a helical antenna is being used. A helical antenna is an example of wire antenna and itself forms the shape of a helix. This is a broadband VHF and UHF antenna. The frequency range of operation of helical antenna is around 30MHz to 3GHz. This antenna works in VHF and UHF ranges [5].

LITERATURE SURVEY

Phat Nguyen Huu et al. [1] dealt with the concept of implementing the multi-hop RS encoding scheme for image transmission over Wireless Sensor Networks. The novel algorithm proposed divided the encoding task into a large number of small processing components. The concept of implementing the multi-hop RS encoding scheme for image transmission over Wireless Sensor Networks is elaborated. The novel algorithm proposed divided the encoding task into a large number of small processing components. Comparison is made between RS codes of different N and K size and it is observed that the larger sized RS codes yield far superior results in comparison to the smaller ones. Since, the data under consideration is an image, the burst errors have an adverse effect pertaining to the quality of the image. One of the solutions proposed is to have forward error correction (FEC). FEC methods have a lower consumption of bandwidth and a high-efficiency error correction; hence, FEC is suitable for applications in WSNs. Thus, the RS encoding scheme is used.

Nir Drucker et al. [2] proposed the need to utilize redundancy of high importance in distributed storage systems in order to assure the availability and reliability. Different types of erasure codes were developed to offer a balance between storage costs and speed. Erasure coding allows setting arbitrary ratios of original data and coding data. RS algebraic decoding procedures can correct errors and erasures. Distributed storage systems utilize erasure codes such as RS codes and reduce the storage costs while efficiently handling data failures. Some developments in the field of erasure codes offer new efficient techniques that require mostly XOR operations, and are thus faster than GF operations. New instructions like "GF-NI" (Galois Field New Instruction) announced by Intel was introduced to accelerate GF (2^8). It is also explained how storage systems that use RS codes can benefit from it. The results ultimately show that there is 1.4 times speedup for vectored multiplication, and 1.83 times speedup for the actual encoding.

Sanjana P. Choudhari et al. [3] discussed about Reed Solomon (RS) codes that are a member of the family of non-binary BCH codes. In wireless communication, fading occurs which is variation of the attenuation of the signal in random process. This fading factor can cause burst errors in the signal which is being sent through the wireless channel. Reed Solomon codes are developed to be more effective for rectifying the burst errors in the signal. Due to this feature, RS code is used in the WiMAX network. LFSR (Linear Feedback Shift Register) is used to implement the generator polynomial. The decoder consists of syndrome, error location and correction. The incoming data stream which gets from the encoder is divided into blocks and by adding redundancy operate each block individually and this operation is performed by the decoder and the errors are rectified by utilizing the redundancy present in the received data. Thus, the Reed Solomon codes are more efficient and effective in correction of burst errors that are caused in the wireless communication.

Dayong Hu et al. [4] propose a simulation of 16 QAM modulation and demodulation based on MATLAB platform. The 16 QAM modulation and demodulation techniques have a clear cut advantage over the other modulation techniques. It has a high noise tolerance and a superior anti-noise performance. It is mostly suitable to work in environments which have a large signal-to-noise ratio and band-limited value. The platform chosen to simulate this modulation technique is MATLAB. It is chosen primarily because it has a superior edge in data analysis and processing, matrix calculation, numerical analysis, scientific data visualization, modeling and simulation of nonlinear dynamic and other functions. The software also provides an easy-to-use windows environment. Any random signal or image data can be used for demonstrating the modulation and demodulation techniques. The proposed method can also reflect change of various parameters as well as get the simulation image by compiling and running the Matlab program.

Marno van Rooyenb [6] suggested a high gain directional WLAN antenna that is analyzed since it covers all the frequency bands for IEEE802.11b/j and IEEE802.11a standards. A circular dual loop, a triangular monopole, a monopole-ring-patch, slotted and slot coupled patch, super shaped slotted and an angled dipole antenna were all proposed suitable for WLAN applications. The antenna design that was proposed is based on an ultra-wide band slot radiating element (SRE) which consists of a slot in the ground plane layer of a micro strip line and a complimentary micro strip stub approximately the same size as the slot. The wideband characteristics of the slot and complimentary micro strip stub were exploited to design a high gain directional antenna with high radiation efficiency suitable for WLAN and WiMAX applications. In comparison to the other WLAN antennas, the SRE antennas yielded more gain with similar physical dimensions. A reflecting ground plane is employed to achieve a unidirectional radiation pattern with an average gain of 9.1 dBi. The radiation efficiency above 95% in the WLAN and WiMAX frequency bands by optimization of the feed of the antenna.

Lin Guo et al. [5] suggested on-chip 3D antenna to designed at 4 THz that can be fabricated by a MEMS (micro electro mechanical systems) technology realized on a silicon substrate where, a MEMS on-chip helical antenna structure fed by the micro-strip on the substrate. This uses focused ion beam (FIB) process. The method used employs large-area irradiation of FIB on suspended film structures with the advantages of high flexibility, controllability and repeatability. Characteristics of antenna are large bandwidth, low reflection coefficient and good directivity. Results show that the antenna has a good performance across the needed bandwidth. The return loss of the transmission mode of the helix antenna stays below -15dB across 2.8 to 4.4THz. The radiation patterns keep good directivity and the average simulated gain of the antenna across the interest frequency band (3-4THz) is about 9 dB. The design shows a wide band input match, stable radiation patterns, and smooth gain responses. These characteristics and the simple, compact, low cost, and easy integration make the helix antenna highly suitable for the THz applications

METHODOLOGY

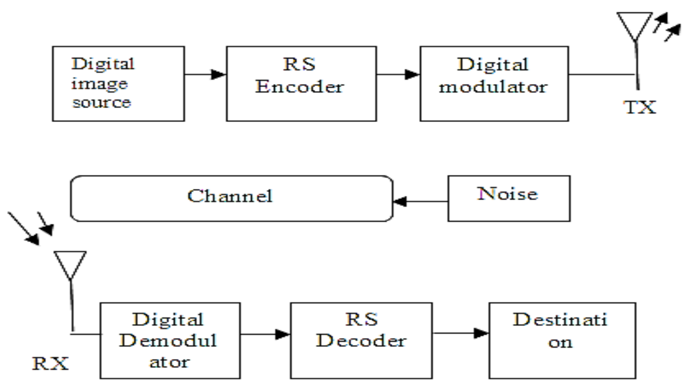

Figure 1: *Block diagram of implementaion of RS code in encoding and decoding images for wireless networks.*

Fig. 1 is the block diagram of the basic system adopted. The data under consideration is a gray scale image. The image is obtained from a digital source. It is then decoded using an RS encoder. The encoded message is then modulated using the Quadrature Amplitude Modulation (QAM) scheme and transmitted over a wireless network that is supported by helical antennas. The message transmitted over the channel is affected by noise. On the receiver side, the helical antenna receives the signal, and demodulates it using a QAM demodulator. The demodulated signal is then decoded using an RS decoder. The decoder detects and corrects (n-k)/2 errors that occur during the time of transmission. The decoded signal is then reverted from the matrix of pixel values into a gray scale image. Every block is explained in detail below.

Source

Source is the place from which data is taken or the origin of the data. The region from which the data that is to be transmitted originates is called the source, and the region or the device the data is sent to is called the destination or the target. In this study, the source data that will be used is a digital image. The digital image used is a gray scale image. At the destination, the image received is reverted to its original form which is a gray scale image. The digital representation of a grey scale image is the matrix of each pixel value in terms of numbers. The digital version of a gray scale image is considered. The value of the pixels will range from 0 to 255, where 0 represents black and 255 represents white.

Reed Solomon Encoding

Here, with m = 8 contains 8-bit symbols and the GF has 2^8 or a maximum of 256 elements [2]. When the RS Encoder adds 2t parity symbols to the original data of k symbols, 2t + k = n symbols are transmitted. RS Decoder at the receiver is then able to detect up to 2t symbols in error and correct up to t symbols in error. One of the salient features of the RS encoding scheme is the error detection and correction capabilities. It can detect and correct the errors even when the locations of symbols of errors are unknown. They can correct errors up to half the number of parity symbols added. If the error locations are previously known, it can correct up to 2t errors. Errors whose location is previously known are called erasures. Therefore, RS encoding scheme can correct up to t errors and 2t erasures. A combination of errors and erasures may be corrected as long as the sum of these corrections is lesser than the number of parity symbols added.

RS (n, k) can be constructed when both the Encoder and the Decoder agree on a code generator polynomial g(x) which contains 2t factors.

On the other hand, the encoder considers the k symbol block as a polynomial M(x) of degree k-1. The RS encoder constructs a polynomial T(x) which is known as the transmitted polynomial that contains n symbols or (k+2t) symbols as the output of the transmitter [2].

The Reed Solomon codes are mainly used for correcting the burst errors which are caused in the in the wireless channel. When data in the multimedia format is considered, the quality of the data becomes more important hence the errors that are caused must be detected and corrected [3]. The number of parity bits that are added to the data plays a prominent role. The number of parity bits depends upon the N and K value chosen. For N=255(since, grey scale image is considered which has 0 to 255 pixel values) and different values for K such as 223, 205, 175, 155, 135, 105, 101 is chosen and their respective t values, the error correction rate is noted and is shown in the Table 1. From the Table 1, observations are made that for N=255, k=101 has a t value of 77 and error correction rate is ~ 77%. Hence for the encoder design (255,101) is chosen.

Table 1: *Survey for different value of n, k and their error correction percentage.*

(n,k)	t	Error correction %
(255,223)	16	7.17
(255,205)	25	12.19
(255,175)	40	22.85
(255.155)	50	32.25
(255,135)	60	44.44
(255,105)	75	71.42
(255,101)	77	76.23

Reed Solomon Decoding
The Reed-Solomon decoder decodes the incoming transmitted message. The input transmitted signal is considered as R(x) which is a polynomial. The polynomial consists of two components, the transmitted message polynomial T(x), and the error that is introduced in the channel as a polynomial E(x) i.e.,

R(x) = T(x) + E(x)
Now, the decoder's task is to identify the E(x) so that T(x) can be calculated asfollows:
T(x) = R(x) + E(x)
Once the data is encoded, the encoded data has to be modulated to be sent through the channel.

Quadrature Amplitude Modulation
There are multiple different modulation techniques that can be used. In this scenario, QAM (Quadrature amplitude modulation) is used.

Like all modulation schemes, QAM converts data by changing some aspect of a carrier signal, which is usually a sinusoid in response to a data signal. The carrier signal in the QAM is the sum of two sinusoidal waves which have the same frequency but are out of phase with each other in 90 degree i.e. in quadrature. These are often called the "I" or in-phase component, and the "Q" or quadrature component [4].

The amplitude of each component is modulated which means the amplitude will be varied to represent the data to be carried before the two are added together. Amplitude modulating two carriers in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier.

In this project, digital QAM is considered where each component wave composes of samples of constant amplitude which occupies a uniform time slot and also the amplitude is quantized restricted to one of a finite number of levels, representing one or more binary bits of digital stream [4].

Digital QAM uses the constellation diagram with the constellation points which are arranged in square grid with equal horizontal and vertical spacing and other configurations are also possible. Since, in digital telecommunications the data is usually binary, the number of points in the grid is usually a power of 2.

The mostly used QAM schemes are 16-QAM, 64-QAM, 256-QAM. To transmit more bits per symbol a higher order constellation can be used.

If the points are closer together the mean energy of the constellation will remain the same. This makes them more susceptible to noise and other corruption; this results in a higher bit error rate and so higher-order QAM can deliver more data less reliably than lower-order QAM, for constant mean constellation energy.

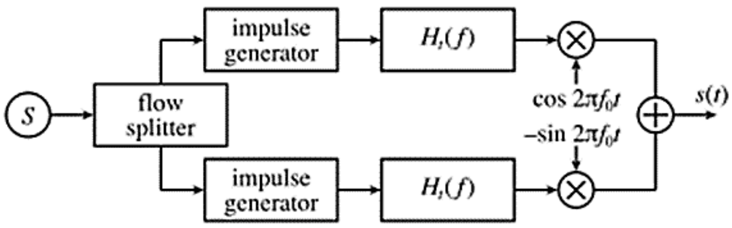

Figure 2: *QAM modulator.*

The basic block diagram describes a QAM modulator.

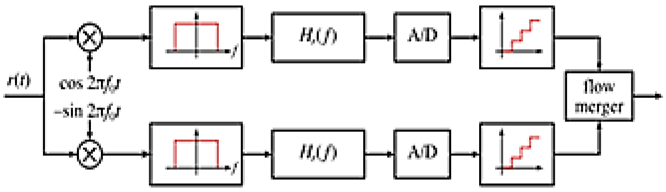

Figure 3: *QAM demodulator*

Fig. 2 shows the block diagram of Quadrature amplitude modulator. To preserve integrity of signal when amplitude of signals varies RF amplifiers should be linear. Flow splitter is fed with an input signal S and produces an output at impulse generator. Hence, the signals are used for modulation of carrier. Therefore, the two signals can be summed and processed in RF signal chain. Then, it is converted according to frequency and amplified.

The QAM demodulator is nothing but the reverse of the QAM modulator. Fig. 3 represents the basic block diagram of the QAM demodulator. The signals enter the receiver system, which are then split into two parts. Each part is applied to a mixer. One half has the in-phase local oscillator applied whereas the other half has the quadrature oscillator signal applied.

Assumption is made that quadrature signals are exactly in quadrature for the modulator. A further requirement is to derive a local oscillator signal for the demodulation that is exactly on the required frequency for the signal. Bit error rate for data is compromised if phase of carrier hasn't recovered. The block diagrams shown above show the generic QAM modulator and demodulator circuits that are used in a vast number of different areas. The circuits are made from discrete components and used in integrated circuits for providing large number of functions.

Antenna

The antenna that is used is helical antenna which is designed and implemented in MATLAB software.

Helical antenna or helix antenna is the antenna in which the conducting wire is wound in helical shape and connected to the ground plate with a feeder line. It is the simplest antenna, which provides circularly polarized waves [6].

Helical antennas have been widely used in multiple different applications such as mobile and satellite communications.

Helical antennas have two different modes of operations. They can function in either of the principal modes — normal mode or axial mode. The normal mode antenna is also called as broadside helical antenna. In this antenna, the diameter and pitch of the helix is small as compared to the wavelength. The radiation pattern of these antennas is Omni directional. The antenna almost acts as an electrically short dipole or monopole, equivalent to a ¼ wave vertical.

In the axial mode or end fire helical antenna, the diameter and pitch of the helix are comparable to the wavelength. This is a kind of directional antenna radiating the beam off the helix, alongside antennas axis.

The most commonly used mode of operation of helical antennas are axial mode which occurs when the circumference of the helix is comparable to the wavelength of operation. The helical antenna has maximum directivity in this mode and produces circularly polarized waves.

ALOGRITHM

1. Specifying conditions for RS encoding.
2. Choosing a primitive polynomial.
3. Creating a generator polynomial.
4. Generating a random sequence of numbers >= n which acts as the message.
5. Creating a Galois Field of the message Over 2^4.
6. Encoding the message signal using RS encoder.
7. Introducing Errors to the message signal.
8. Received Vector.
9. Decoding the message signal using RS decoder.

INTERMEDIATE RESULTS

Based on the algorithm mentioned earlier, we obtain the results as shown in the Fig. 4. The results obtained are for the RS (15, 11) scheme. The encoder used conditions n = 15 and k = 22. The degree m = 4. The message in this case has 11 elements.

The results of the encoding data using the RS encoding scheme is shown in the Fig. 4. Here, the message vector taken into consideration is 11 element vector of random integer numbers in the range of 0 to 15. The random integer generation function is used to generate the bits in random. The message vector is then encoded using the RS encoder. The encoding function takes in the value of the primitive and the generator polynomial defined by the user. Here, the primitive polynomial is taken to be 19. The resultant encoded message vector has 15 elements with 11 bits of message and 4 (n-k) parity check bits. The encoded message is then transmitted.

Fig. 5 shows the process of decoding the message. The encoded message is transmitted through the channel where it encounters noise. The received message has an error. To demonstrate the error detecting and correcting capabilities of the RS scheme there are errors which are introduced in the fourth and the sixth index. The received vector is decoded using the RS decoder. The decoder takes, as input the 15 elements received vector and corrects if there are any errors present. The output is the decoded message which is the original 11 elements.

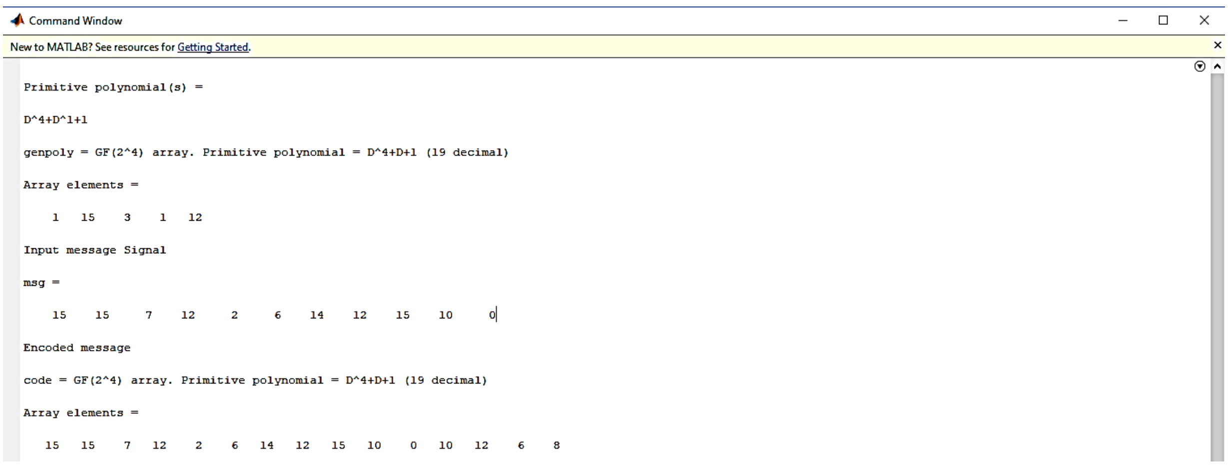

Figure 4: *Intermediate results: Encoding the message vector using RS encoding scheme.*

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Encoded message

code = GF(2^4) array. Primitive polynomial = D^4+D+1 (19 decimal)

Array elements =

   15   15    7   12    2    6   14   12   15   10    0   10   12    6    8

Recieved message

error_msg = GF(2^4) array. Primitive polynomial = D^4+D+1 (19 decimal)

Array elements =

   15   15    7   13    2    7   14   12   15   10    0   10   12    6    8

Decoded message

decoded = GF(2^4) array. Primitive polynomial = D^4+D+1 (19 decimal)

Array elements =

   15   15    7   12    2    6   14   12   15   10    0
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Figure 5: *Intermediate results: Decoding the recieved vector using RS decoding scheme.*

CONCLUSION AND FUTURE SCOPE

RS codes are proved to be more efficient. This study proposes a technique to encode data for efficient transmission of data over wireless networks. The RS scheme of encoding is used to encode a set of integer numbers in the results we have obtained. The resultant vector is the encoded vector with length of n bits. It is made up of k message bits and (n-k) parity bits. It is a linear block coding scheme where, message signal is divided into blocks of k bits to encode as a unit. The decoding process also yields a block k message bits after correction by discarding the (n-k) parity bits. This scheme can be applied to any form of data. Enhancements to the basic framework can be made in the future by utilizing data of various forms like text, voice, image as well as videos. The antenna which supports the network can also be enhanced by employing various changes in the antenna parameters. The transmission thus, with these changes can be made even more robust in tandem with other techniques like cryptography, steganography and network security.

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