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DESIGN AND EVALUATION OF A MULTIPLE AMPLITUDE SHIFT KEYED BIT TO AUDIO TONE LINE ENCODER AND DECODER FOR ASCII CHARACTER COMMUNICATIONS

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ABSTRACT

This paper focused on the integration of line coding and nonlinear mixing in digital communication systems. The researcher's implementation of a bit-to-audio-tone encoder with a respective decoder. The encoder received a message from the user. The message that was inputted could be a symbol, and after it was fed into the system, it then produced audio. If the receiving end has the decoder, the audio when then be translated back to the original message. This study has benefits in the field of security systems because data can be accessed or hacked by those that have the skillset to do so. This digital communication system could be used to send information to a certain person, and since only that person has the digital decoder, only he/she can access the data. To others, the system would only produce an audio tune that would be unrecognizable by those receive it if they do not have the decoder. This research aimed to create a safer way to send and receive sensitive information without unwanted third parties to decipher it.

Keywords: line coding, spectrum analysis, non-linear mixing, synchronization, additive white Gaussian white noise, beat frequency.

1. INTRODUCTION

Digital baseband modulation or digital transmission method used on digital data transport was also called line coding systems. Different type of coded system delivered a varied reliable digital data transmission when baseband channels were used. The three branches of line encoded systems that were commonly used were divided into three different categories, unipolar encoding, bipolar encoding, and polar encoding. Other types of encoders employed made use of the frequency spectrum when the signal was modulated. Some examples of these encoders include amplitude shift keying and frequency shift keying that allowed the use of frequency to control the transmitted data. Also, other forms of information transmission include both amplitude and frequency shifting like Quadrature phase shift keying. Different types of modulation allowed the transmitted data to be received with reliability. When digital transmission systems transmit data, the reliability of the system was considered as one of the principal parts of a system for the information to be protected [1].

In this paper, a novel multiple bit-to-audio-tone encoder and decoder was presented. This designed system encompassed a unipolar system with a shifted keyed component for the frequencies that were used to transmit the given ASCII code. The eight-bit ASCII code that was used determined the bandwidth as well as the frequencies that were introduced into the system for transmission. Similarly, the receiver interpreted this data and translated the signal into the original code.

2. BACKGROUND OF THE STUDY

Digital Communications, a form of communication used to transmit data by encoding the information as a discrete signal, has multiple functions in everyday living. This mode of information transfer has allowed easy access to data from the transceiver to the receiver in a small amount of time. The data could be in the form of an image, audio, or video. There has already been plenty of research on speech-coding models through encoding and decoding. A research on the speech-coding systems focused on encoding an audio input through a 1300 bps sinusoidal encoder was able to show that the original message that was retrieved in the decoder was of acceptable quality and intelligibility [2]. The purpose of transmitting these forms of data was to increase efficiency in data transfer, but a feature that was added in several studies was the bit-to-audio-tone encoder. The purpose of adding such a feature into the already functioning system was to create a more efficient and safer means of message propagation. This study was pursued because it allowed the exploration of the different functions of a bit-to-audio line encoder and decoder that may have not already been discovered. Through this study, other applications that would be beneficial in the field of engineering could be applied in military-grade operations or to provide a safer network that is inaccessible to hackers.

In the transmission of digital communications, the main goal was to relay the information signal at its best meaning that there were no alterations in the original message, and the receiver would ultimately obtain the transmitted signal without discrepancies. This required the usage of a filter that would remove excess noise that attenuated the signal's strength and reduced its clarity. For this certain study, the researchers decided to add Additive White Gaussian Noise (AWGN) into the communication system. This was because the transmitter needed to mask the original message with something to prevent others from tapping into the message [3]. The noise was based on random processes that would cling to the signal until it was decoded. The changes in the bits were detected by computing for the average power spectral density per symbol time [4].

3. STATEMENT OF THE PROBLEM

The transmission of digital signals is often done by bandpass modulating radio frequency signals because this allows for the use of practical antennas as well as to avoid interference from other transmitting sources [5]. It is uncommon that any other form of modulating frequency is used for the same purpose. However, the possibility of audio-frequency-modulated digital signal transmissions may be explored for the development of low frequency, low bandwidth wireless digital systems. Such a system would not require an antenna, but rather a high-fidelity speaker and microphone to transmit and receive wirelessly. Furthermore, in real-world applications, the audio frequency range is among the most crowded, with up to 40 dB of noise in the medium of a quiet room [6]. This paper aims to evaluate the characteristics and limitations of such a digital system through the development of an ASCII character communications system employing a multiple amplitude-shift-keyed bit-to-audio-tone line encoder and decoder.

4. SIGNIFICANCE OF THE STUDY

The study proved to be significant due to the demand for digital transmitted signals. The rise of digital information has increased the requirement for better digital to analog converters as well as analog to digital to analog converters. The design of this analog to digital converters ensure a reliable way of sending and receiving signal information from one point to another while some specific aspects were considered, like the speed of the transmitted data, the accuracy of the transmission, and clarity of the transmitted signal. Different encoding schemes have already been designed. However, the information on the applied technology and different ways on how these technologies were executed, these different types of modulation encoders have been scarce since that type of technology has only been reintroduced recently. In this paper however having used one of the types of encoding amplitude shift keying this project presented, amplitude-shift-keyed Bit- to - audio tone line encoder and decoder, this has been made to produce a digital transmission between two sources. This project applied the use of the binary ASCII codes since the English alphabet has been commonly applied to different languages. Finally, the use of a noise generator was added to aid future researchers of designed projects with this as a basis.

5. DESCRIPTION OF THE SYSTEM

The proposed system consists of a bit-to-audio-tone encoder and its corresponding decoder. The encoder accepts a sequence of n-bit wide symbols, assigns a pure sine wave audio tone of a unique frequency to each bit location, then generates an audio signal of a fixed length for each symbol such that the corresponding tone for each high state bit is played. These n-bits may represent any type of symbol, such as ASCII characters. An additional audio tone with a unique frequency is added for synchronization. The audio signals are arranged in sequence, connected together, and written into a single .wav file. The decoder accepts an encoded audio file as input and obtains the original message sequence. This is done by evaluating its frequency spectrum, searching for changes in power for each of the bit-assigned frequencies that are expected to appear in the audio signal.

6. METHODOLOGY

The researchers developed simulations of the encoder and decoder sections proposed system in MATLAB, allowing for the adjustment of important parameters such as the symbol rate, signal-to-noise ratio, and the tone-to-bit assignments. The encoder section generates the tones active per symbol for the specified symbol rate, then sequences all audio before writing to file. The following flowchart shows the process of the encoder simulation in Figure-1.

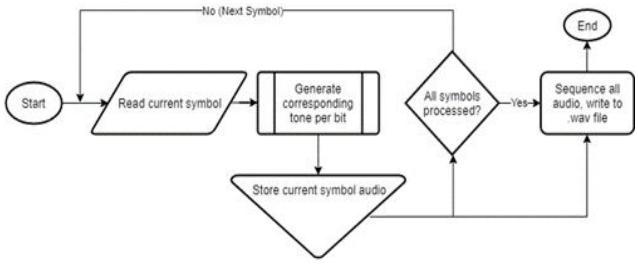

Figure-1. Block Diagram of the Encoder Algorithm.

The decoder section reads the audio file then samples the audio at a rate matching that of the transmitted symbol rate by detecting changes in the synchronization tone. If a change in the state of this tone is found, a new symbol is accepted. The decoder checks the assigned bits for the encoded information. The following flowchart shows the process of the decoder simulation in Figure-2.

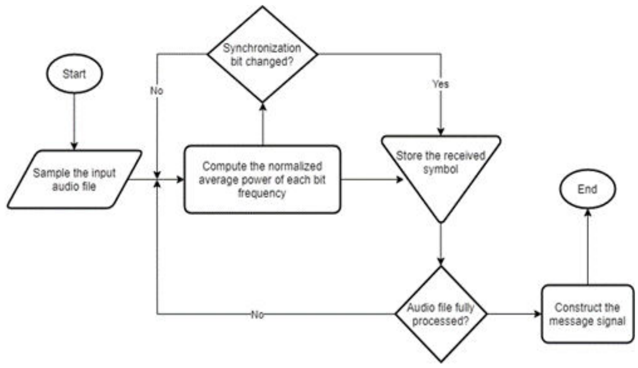

Figure-2. Block Diagram of the Decoder Algorithm.

7. REVIEW OF RELATED LITERATURE

7.1 Amplitude shift keying

To successfully accomplish all tasks of an optical label switching system with 622 Megabits per second frequency shift keying label and a 10 Gigabits per second amplitude shift keying payload, an optical frequency shift keying transmitted was utilized [7]. The optical frequency shift keying transmitted was carried out by the gross gain modulation in a semiconductor optical amplifier. It was seen that the key qualities of the system were optimized to achieve the best frequency shift keying and amplitude-shift keying signal performances. The system was also optimized to get the best performance from the input laser diode power, also utilized in [8]. The optimization was carried out to see the best performances also of the extinction ratio of the control light and amplitude shift keying payload. Moreover, the transmission performance of the amplitude shift keying payload and the frequency shift keying label was looked at after propagating in the 50-kilometer single-mode fiber. Similar orthogonal frequency division multiplexing experiments have been carried out over single-mode fibers as well to prove its consequent efficiency [9].

Amplitude shift keying modulation and single sideband spectrum formation were seen to usually be picked to enhance the efficiency of bandwidths and consequently provide for better and more simple system designs in radio over fiber systems with signal modulation issues [10]. Radio over fiber systems has also been made to be energy efficient for cloud radio access networks [11]. The duty cycle of the original data stream was seen to affect the amplitude shift keyed modulated signal in fiber channel transmission performance. Amplitude shift keying modulation and single sideband spectrum radio over fiber systems, with varying duty cycles in original data streams have been rarely studied but with their works, the system design may be possibly optimized. Their work focused on creating a single-sideband radio over fiber signal and analyzing the overall performance of the system due to the key index duty cycle. They also looked at the amplitude shift keyed signal modulated on a sideband that was carrying the original data wave with the various duty cycles and the bit error rate. A study has actually already been carried out to improve the parity-based error estimations through quantum bit error rates in quantum key distribution [12]. To analyze further, they utilized the duty cycle curve and energy consumption along with the original data.

An integrated distributed feedback laser or electro-absorption modulator has already been utilized to transmit modulation for 125 Megabits per second of frequency shift keying and 2.5 Gigabits per second of amplitude-frequency keying [13]. Their work was able to produce their results without critical degradation to the 2.5 Gigabits per second amplitude shift keyed data. Since network control was always seen as one of the key issues for wavelength division multiplexed networks, their work was able to present the results and characterization of the modulation interactions between the pair. Wavelength demultiplexers have still proven themselves to be useful in wavelength division multiplexing communications [14]. The amplitude shift keying and frequency shift keying modulation were focused on the transmitter and receiver pairs. Similarly, the mentioned focus was also seen in the creation of an adaptive neural network approach for automatic modulation recognition [15].

Optical signal propagation in single-channel transmission systems was thoroughly analyzed [16]. They noticed that it utilized novel high order modulation formatting types. Therefore, their work focused on analyzing the comparison between two specific types of high order modulation formats. Those specific types included amplitude shift keying and phase shift keying. Their work relied on calculating the nonlinear Schrodinger equation in utilizing the split-step Fourier method. They believed that through the utilization of high order modulation formats, optical network and system issues could finally have a key solution. Optical network issues have also been analyzed through modeling and simulation of self-organized criticality of intelligent optical networks concerning the sandpile model [17]. Overall, they wanted to be able to depict the modulated pulse behavior along with the display of how well suited the investigated modulation formats were when their transmission was affected by numerous channel impairments. Modulated pulsed signals were also observed in the application of waveform coding on its stepped frequency version [18].

A semiconductor laser was seen to be able to enter nonlinear period one dynamics through bifurcation because of intense changes in its field carrier coupling with the incoming optical carrier, or the external optical injection [19]. That was seen to be a result of the competition between the oscillation of the injection-imposed laser and the resonance of the shift cavity. It was seen that in terms of intensity and frequency of equally separated spectral components, they were very dependent on the level and frequency of the injection. It was through that that they realized the frequency variation or dynamical amplitude of the incoming optical signal of the frequency shift keying or amplitude shift keying was capable of resulting in the dynamical frequency and amplitude variations in each spectral component. Spectral components were also emphasized in the treatment and amplification of its signals in [20]. Through the selection of the optical frequency of the output carrier and having the least residual amplitude shift keying and frequency shift keying modulation, their amplitude to frequency shift keying and counterpart conversions were possible. As the conversion unit needed, a typical semiconductor laser was utilized. Semiconductor lasers and its characteristics were improved through asymmetric waveguide structures [21]. Their bit error ratio was also down to 10 to 12 through a slight power penalty. Frequency shifts of the optical carrier were also possible therefore allowing for simultaneous frequency conversion of the optical carrier.

7.2 ASCII character communications

If one needed to hide his or her data on the internet, a great hiding technique would have been steganography [22]. It was through steganography that CAPTCHA codes were covered by images via the image version of steganography [23]. CAPTCHA stood for Completely Automatic Public Turning test to tell Computers and Humans Apart. Basically, CAPTCHA codes were the crazy codes utilized in human response tests [24]. Human response tests were challenge-response tests to find out whether the user was a human or a computer. Usually, websites utilize and implement CAPTCHA codes for their registration methods to avoid spam and bots. Initially, CAPTCHA codes were generated then sent out in their encrypted form. They were simply embedded American Standard Code for Information Interchange, ASCII, onto an encrypted stego image [25, 26]. It was through that method that attackers were, therefore, unable to obtain the actual CAPTCHA.

Converting messages into code only understandable by a designated receiver was considered a science generally called as cryptography [27]. It was seen as the key that allowed technology to keep its systems safe. Along with the systems, all the data and infrastructures of every user needed to stay protected. That need has been growing exponentially as the internet is growing quickly. Through all the cryptography algorithms, the researchers focused on the relationship of each character with the one that came before it in the plaintext [28, 29]. Moreover, they wanted to link each character to its previous on in plaintext while decryption or encryption was ongoing. They believed that their algorithm was capable of handling any situation that needed cryptography [30].

The plain text was utilized mostly for the transmission of social media and news information [31]. Plain text allowed for usage in numerous platforms in a very light manner. It was somehow due to that reason that it became easier for attackers to misuse or access modifiable information that was not theirs. To target that issue, the secret text was put into the plain text therefore, showing up as cover text [32, 33]. It allowed for easier detection on any cover text change. The researchers wanted to use secret text embedding techniques in cover texts through mapping secret text binary digits onto that of the cover text using the American Standard Code for Information Interchange, commonly known as ASCII, characters [34, 35]. Their characters utilized punctuations, symbols, and spaces. Initially, they planned to encrypt the secret text with a one-time pad into ciphertext wherein each character was changed into binary numbers of 7-bits long. In comparison, the cover text was immediately converted to the same output type. Moreover, they wanted to map one bit of the secret text onto the first of the cover text character with the equivalent number of bits over and over again. That allowed for ensuring that all of the secret text was in the cover text. Each bit location was also assigned a stego key to allow for the extraction of the secret text from the cover text [36]. The cover text appearance was the same all throughout ensuring that everything was well hidden in steganography.

8. THEORETICAL CONSIDERATIONS

The system proposed in this paper employs distinct tones per bit location. The activation of a tone for a distinct bit resembles amplitude-shift keying, which has a maximum bit rate equal to its bandwidth [37]. As a consequence, the lowest frequency that appears in the signal would determine the maximum transmissible symbol rate. Digital audio signals are often sampled at 44.1 kHz, with some systems sampling as high as 96 kHz [38]. This imposes a limitation on the maximum frequency of a tone that can be used in the system without the effect of aliasing.

A common problem with the use of simultaneous tones is the presence of beat frequencies. When two sine waves of different frequencies are superimposed, the sum and difference of the two frequencies appear as stray components [39]. Both the sum and difference frequencies are exploited in radio communication, forming the upper and lower sidebands and determining the transmitted bandwidth. However, the proposed system in this paper may be subject to false bit triggering due to these beat frequencies. Thus, appropriate tone-to-bit assignments should be considered to tackle this problem.

When an audio signal is transmitted in physically, it is subject to natural noise. The Additive white Gaussian noise (AWGN) model is a basic noise model mimics the effect of many random processes that occur in nature [40]. It is often defined by its signal-to-noise ratio (SNR) which indicates the amount of signal present concerning the noise. AWGN noise and its SNR parameter may be simulated in MATLAB and added to an audio file.

9. DATA AND RESULTS

The researchers configured the audio signals to have a sampling rate of 48 kHz. As a result, the maximum transmissible frequency permitted by this setup to operate without aliasing was 24 kHz. The researchers forced the maximum frequency assignment to fall below this limit. To avoid the effect of sum and difference frequencies, the researchers utilized a geometric sequence of tone-to-bit assignments. For an 8-bit wide symbol, the most significant bit (D7) was assigned to 600 Hz. The following bits increase in frequency by a factor of 23/14, so that the least significant bit was assigned 19.4 kHz. The synchronization tone was assigned to 400 Hz. Consequently, the maximum symbol rate was 400 symbols per second. The following Table-1 shows the tone assignment per bit location.

Table-1. Frequency per Bit Location.

Bit location (n=8)	Frequency Assignment
D7	600 Hz
D6	986 Hz
D5	1.62 kHz
D4	2.66 kHz
D3	4.37 kHz
D2	7.18 kHz
D1	11.8 kHz
D0	19.4 kHz

Given the parameters above, the system was evaluated by transmitting the message ‘Hello, World!’ at 1, 100, 200, and 400 symbols per second, against signal-to-noise ratios of 90 dB, 20 dB, and 0 dB.

Table-2. Decoded Message.

	Decoded Message			
SNR in dB	**1 Bd**	**100 Bd**	**200 Bd**	**400 Bd**
90	Hello, World!	Hello, World!	Hello, World!	Eaiii..,Woiaj
20	Hello, World!	Hello, World!	Hello, World!	Eaiii..,Woiaj
0	Hello, World!	LEAdh.pSVrad	Hl,,GCE	3i>1

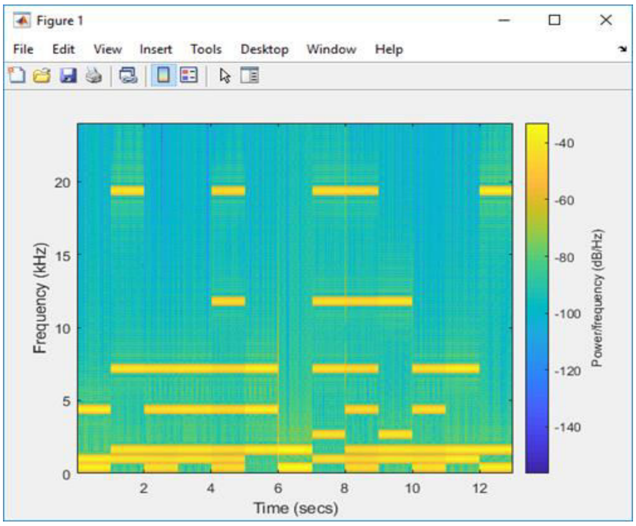

Figure-3. ‘Hello, World’ spectrogram (1 Bd, SNR = 90dB).

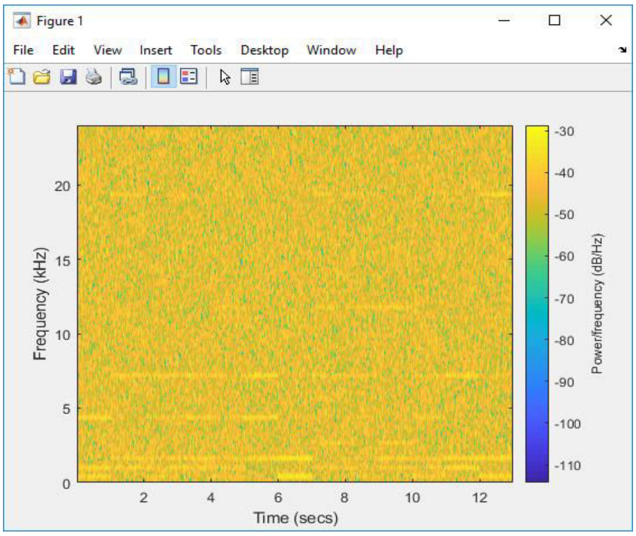

Figure-5. ‘Hello, World’ spectrogram (1 Bd, SNR = 0dB).

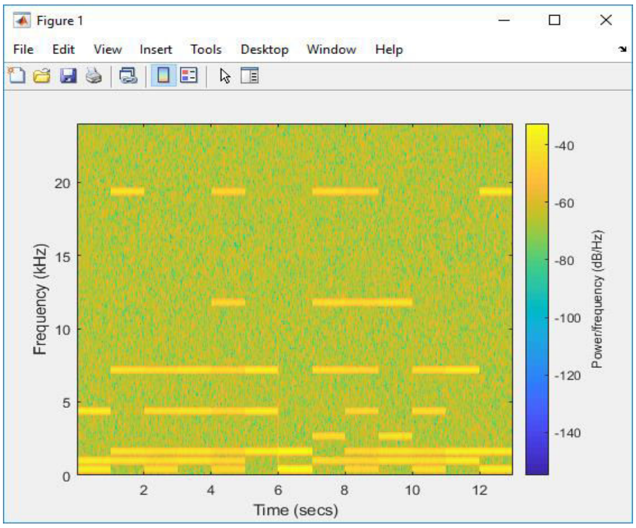

Figure-4. ‘Hello, World’ spectrogram (1 Bd, SNR = 20dB).

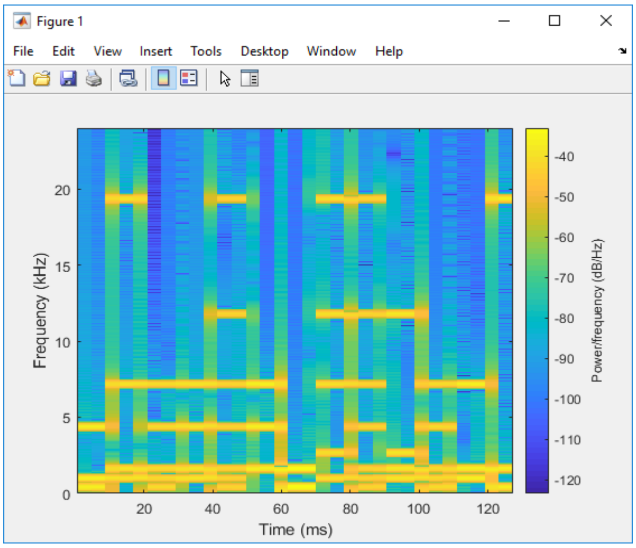

Figure-6. ‘Hello, World’ spectrogram (100 Bd, SNR = 90dB).

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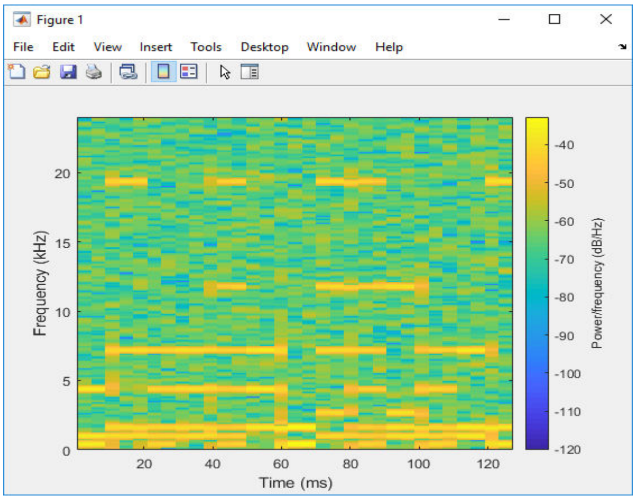

Figure-7. 'Hello, World' spectrogram (100 Bd, SNR = 20dB).

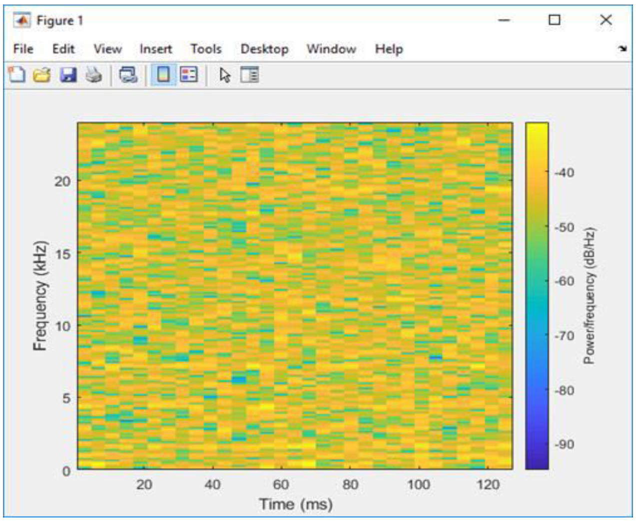

Figure-8. 'Hello, World' spectrogram (100 Bd, SNR = 0dB).

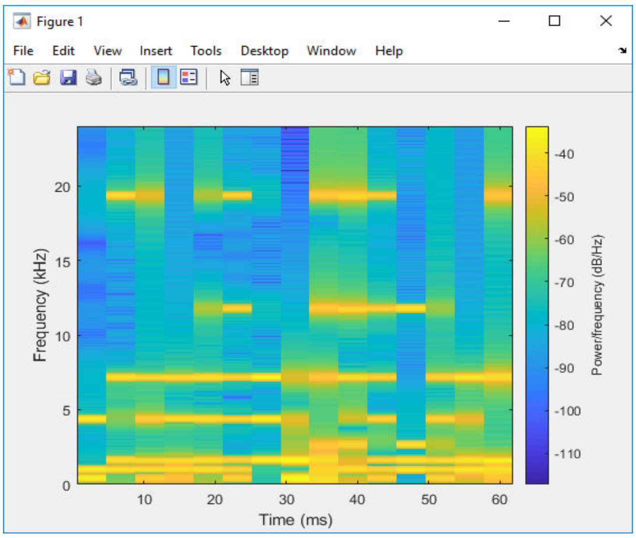

Figure-9. 'Hello, World' spectrogram (200 Bd, SNR = 90dB).

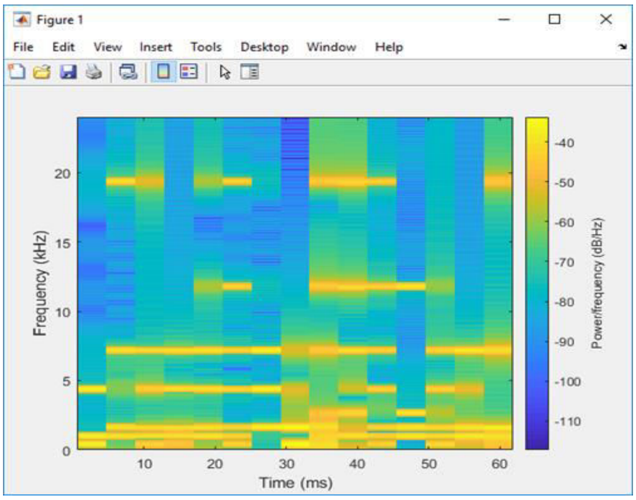

Figure-10. 'Hello, World' spectrogram (200 Bd, SNR = 90dB).

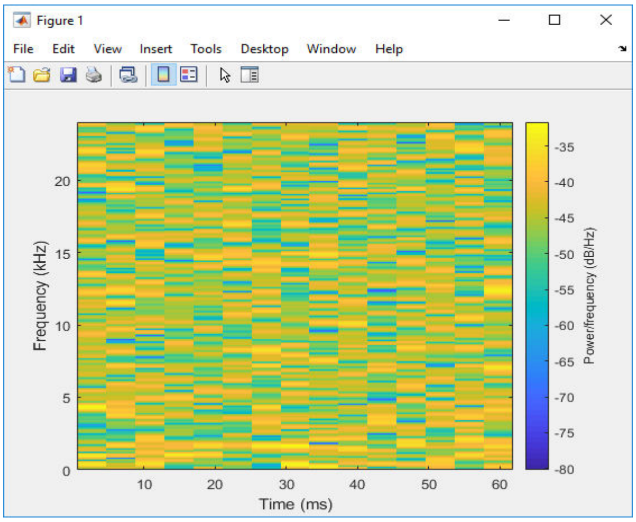

Figure-11. 'Hello, World' spectrogram (200 Bd, SNR = 0dB).

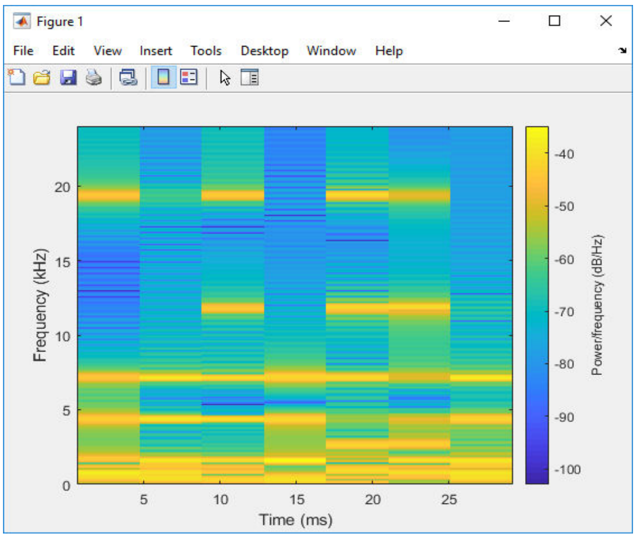

Figure-12. 'Hello, World' spectrogram (400 Bd, SNR = 90dB).

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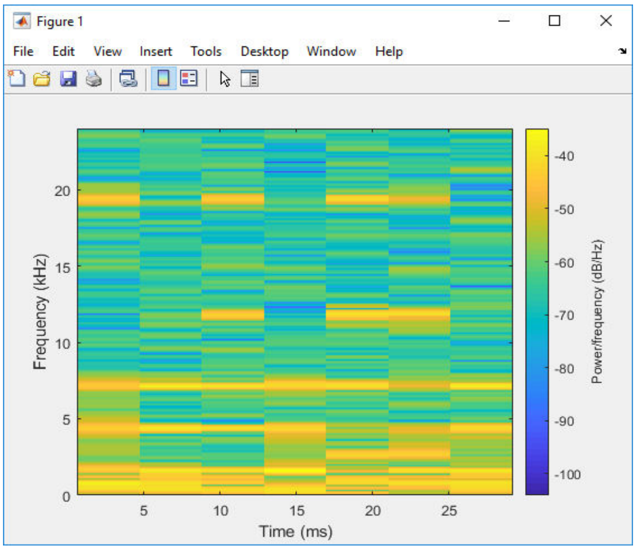

Figure-13. 'Hello, World' spectrogram (400 Bd, SNR = 20dB).

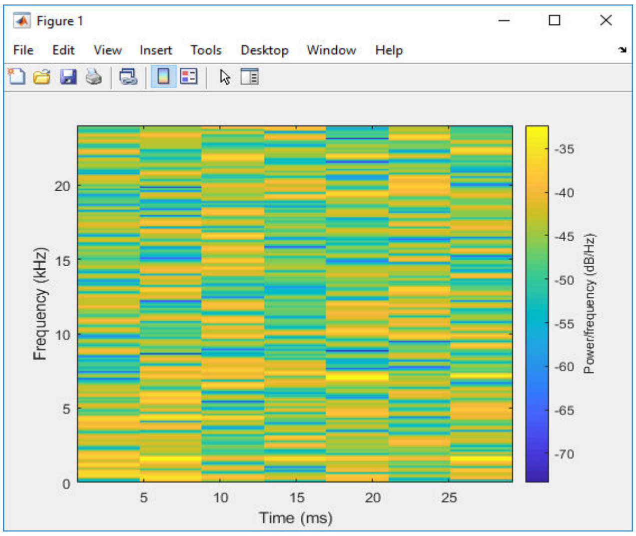

Figure-14. 'Hello, World' spectrogram (400 Bd, SNR = 0dB).

10. ANALYSIS OF DATA

From the results that were obtained above, the researchers were able to display the decoded message in four different scenarios: 1, 100, 200 and 400 symbols per second (Bd) just to test the effects of frequency on the decoded message from the 8-bit symbol. The more time that was allotted for the symbol, the more accurate the decoded message became. Unfortunately, some problems were encountered for all the levels of tones [41]. For the highest tone, aliasing is the major problem. Aliasing occurred due to the sampling rate not being enough which would cause distortions in the signal. The researchers were able to avoid this problem by using the sampling frequency which is 48 kHz. The frequency used had to fall under 24 kHz which is one half of the sampling frequency. For the middle tone, the problem was sum and difference in frequencies. The problem of sum and difference frequencies was that there would be interference between frequencies because they were too close to each other. The solution for this problem was to make sure that all frequencies had a certain range in between each other so that there would be no overlap which would also cause distortions in the signal. This was solved by the researchers using a geometric sequence. Lastly, for the bottom tone, the limitation would be the maximum bit rate because the researchers used Amplitude Shift Keying (ASK).

The four different symbols per second were exposed to different signal-to-noise ratios (SNR): 0 dB, 20 dB, 90 dB. When 1 Bd was exposed to 0 dB SNR, the phrase 'Hello World' was successfully decoded as the original signal. The same goes for the SNRs 20 dB and 90 dB. When 100 Bd was exposed to the three different SNRs, both 90 dB and 20 dB were able to produce the original message, but 0 dB was not able to do so. It produced a distorted message signal. For 200 Bd, the same scenario occurred wherein 90 dB and 20 dB were able to produce the original message, whereas 0 dB was not. Lastly, for 400 Bd, all three SNRs were unable to reproduce the same message from the transceiver. As the symbols per second were increased, the frequency decreased, therefore it provided less time for the system to decode the message. In addition to that, it was observed that the higher the SNR, the more accurate the decoded message would become. To make the signal much clearer Artificial Neural Network (ANN) in communications can be used [42, 43].

11. CONCLUSIONS

The built system delivered the transmitted digital signal; having applied the encoding method that was set up in the transmitter. The application of an added White Gaussian Noise enabled the channel to be considered a real-world transmission system with the added randomized signal, which acted similarly as real noise found in real-world systems due to how all frequencies are present in white noise. This paper displayed the effective values that applied to the system; this was shown via MATLAB simulation which created an audio file; having a file name as.WAV; where this audio file was able to get imported to the receiver simulation where the information signal is decoded. It could be noted however that this audio file could then be used to transmit the data over a given length. On the other hand, the MATLAB file also allowed text files to be imported into the program for longer word counts to be added to the message signal. Besides, different values were presented that would vary the sampling rate as well as the noise factor of the system. The results found displayed how the system has an optimal value to operate while maintaining the proper expected outputs. The researchers found that when the baud rate was increased the frequency decreased; and increased the speed at which the information was decoded. While the SNR scaled the decoded signal proportionally, changing the clarity of the signal. In conclusion, the built system was effective when a signal was applied to the transmitter at the same time efficient with the decoded message received from the transmitter. Also, the accuracy and the precision found was dependent on some parameters the researchers had to set. With these parameters in mind, the researchers also found that given a signal to noise ratio, if the system had the correct sampling frequency then the transmitted signal would still be able to receive the sent message from the transmitter.

12. RECOMMENDATIONS

Through the creation of the multiple bit-to-tone-audio line encoder and decoder, the researchers found that there were things that could have been improved on in the creation of the communication system. Since code can always be improved on, future analysts that would want to take on the research could create a simpler but more efficient code that would produce the same output in a shorter amount of time. Future researchers could also analyze the circuit that was created and replace components, if necessary, to create a more cost-effective, but equally efficient product. The implementation of the digital communication system could also be studied. For now, the current researchers have found that the main application of this digital system is to implement it as a security feature. Other researchers may find more fields wherein this topic could be implemented. Additionally, for encoding and decoding, a recurring problem that engineer faced when an encoding and decoding system was the decoding constraints. Due to imperfections in the feedback, there would be delays in the decoding of the message. The researchers recommend that a study on the Upper Triangle Network Coding (UTNC) by those that would want to tackle encoding and decoding in digital communication systems. The UTNC was studied to have successfully reduced packet decoding delays and has greatly reduced unnecessary retransmission in the system. Moreover, the researchers recommended that the sampling frequency was to be increased. This was because the time for the audio message was to be played was far too long to relay the original message. The time for each tone could not be shortened because it would the full wavelength of the tone may not be detected. Other researchers can try researching on ways to reduce the duration without affecting its wavelength. Lastly, other researchers could randomize the tones so that it would be more difficult if someone were to try to decipher the message without a decoder if they obtain enough samples of the audio tones and match them with the symbols.

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