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Simulation of FSK Modulation for Signal Transmission

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ABSTRACT

This paper dives into the topic of using the frequency-shift keying method of modulation in a digital communications system. When using a communications system, to transmit a signal through long distances efficiently is by modulating the signal. In digital communications, there are three shift keying techniques; amplitude, phase, and frequency. This research focuses on the implementation of frequency-shift keying in modulating and demodulating a signal using MATLAB.

Key words : Communication, Digital, Frequency Shift Keying, Modulation.

1. INTRODUCTION

Frequency shift keying (FSK) is the most used method of digital modulation in the high-frequency radio spectrum, being mostly used in telephone circuits, over telephone lines with caller ID (where the caller's number is displayed [1, 2]. It is also used when transmitting low-frequency radio signals in the very low and extremely low-frequency bands, as well as automatic meter reading
.
In frequency-shift keying, the frequency of a sinusoidal carrier signal is shifted from a mark frequency (for example, sending a binary 1) to a space-frequency (sending a binary 0), according to the baseband digital signal [3,4,5]. Frequency-shift keying is the same as using a binary digital signal to modulate an FM carrier.

Depending on how the signal was generated, a frequency-shift keying signal can be described as one of two types [6]. The first type is generated by switching the transmitter output line between two different oscillators. Using this method generates an output waveform that becomes discontinuous when the output line switches between the oscillators. This type of signal is called discontinuous-phase FSK because the signal is discontinuous during the switching times. This signal is represented by:

$$s(t) = A_c \cos[\omega_c t + \theta(t)]$$

$$= \begin{cases} A_c \cos[\omega_1 t + \theta_1], & for\ t\ in\ the\ time\ interval\ when\ a\ binary\ 1\ is\ being\ sent \\ A_c \cos[\omega_1 t + \theta_1], & for\ t\ in\ the\ time\ interval\ when\ a\ binary\ 0\ is\ being\ sent \end{cases}$$

where f1 is called the mark frequency (where the binary is 1) and f2 is called the space-frequency (where the binary is 0). θ1 and θ2 are the start-up phases of the two oscillators.

Frequency-shift keying transmitters are not usually built as previously mentioned, so the second type is most often used. When the data signal is fed into a frequency modulator, a continuous-phase frequency-shift keying signal is generated. This FSK signal is represented by:

$$s(t) = A_c cos\left[\omega_c t + D_f \int_{-\infty}^{t} m(\lambda) d\lambda\right]$$

The paper primarily focuses on implementing the frequency-shift keying modulation of a binary signal using the functions and capabilities made available in MATLAB. The researchers decided to pursue this research to develop a deeper understanding of the way frequency-shift keying modulation is performed and applied in communication systems. Applications implementing digital communication systems that use the frequency-shift keying modulation scheme have been researched already, showing the viability of the modulation scheme. Modulation schemes are primarily used in transmitting messages or data from one place to another, so a simple system that consists of a transmitter and a receiver is the most obvious application for frequency-shift keying. Research has been done on an application of this, where an 86–92 GHz frequency shift keying transmitter is integrated with an antenna for broadband millimeter-wave applications [7]. Another application of frequency-shift keying that doesn't necessarily require a conventional antenna is in the underwater acoustic communication system that uses multiple channel time frequency-shift keying [8]. Another research was done concerning underwater acoustic communication wherein frequency-shift keying was used in an ultrasonic underwater acoustic modem [9, 10]. Another

application is in the use of frequency shift-keying in noncoherent detection for low levels of visible light communication. This noncoherent detection used dimming frequency shift on-off keying, which is basedon the frequency-shift keying modulation scheme [11]. MATLAB, being a very powerful program for solving and simulating any system, can be used to great effect when dealing with frequency-shift keying modulation [12] such as shown in research dealing with improving the adjacent channel suppression of a multiple frequency shift keying signals [13]. These studies show that frequency-shift keying is a very useful modulation scheme that has numerous applications that are continuously being improved upon. The researches' decision to use MATLAB provided the means to see the various components of frequency-shift keying and being able to see the output from different inputs helps the researchers learn more.

Sending a message from one point to another is the very basis of a communications system. Nowadays, it is mostly used when calls, texts, or any kind of information has to be sent to faraway places. There are plenty of means to deliver information like antennas and cables. Since these means differ from one another most of the time, there have to be different methods of communication used to successfully deliver the information. When it comes to digital communications, an important thing that has to be considered is the type of modulation to be used to modulate the carrier signal. The different types of modulation in digital communications alter different characteristics of the signal. Knowing and understanding which characteristics should be altered to efficiently transmit and receive the signal is very important. The researchers aim to learn what frequency-shift keying is, how it is done, and what is the input and output of the modulation scheme.

Communication is very important in this tech-driven world. To be able to handle or improve upon it requires an understanding of how the processes are done for it to work. A major part of sending any information through a communications system is modulating the signal. Because there are different modulation schemes in digital communications, being able to understand the way frequency shift keying works is essential when creating a digital communications system. To be able to efficiently transmit and receive a signal no matter the distance is important to maximize the use of power and components to put in the system.

Modulating a signal is very important in communications because the information signals that are being transmitted face many obstacles before they reach a receiver. A common problem, especially in today's age, is that numerous signals are being transmitted everywhere all at once. More often than not, these signals, if not modulated, will interfere with each other. Modulation prevents this. Another problem faced when transmitting a signal without modulation is that the signal will not reach very far. A modulated signal will be able to travel huge distances depending on its carrier frequency. Because of this, it knows how frequency-shift keying modulation works will help the user understand how and when to use it.

For the project, the system is divided into three parts. The first part of the project is the implementation of the binary data into a digital signal. Following this, the second part of the system implements the FSK modulation onto the digital signal for transmission. The final part of the program creates white noise to be combined with the signal. The first part of the system was designed to accept an input of binary data which is then converted to a square wave digital signal. After this, the system then implements FSK modulation onto the signal. The carrier frequencies for the FSK modulation are coded into the program which can be changed and edited to the user's preference. After the signal is modulated and ready for transmission, the signal is put through an Additive White Gaussian Noise (AWGN) channel to simulate noise due to natural causes to give a more accurate signal representation that the receiver will accept. The system is designed in a way where the user can modify the inputs for the signal. Additionally, the signal to noise ratio can be altered to simulate the different intensities of noise that the signal may encounter.

2. LITERATURE REVIEW

In research by Indriyanto and Edward titled "Ultrasonic Underwater Acoustic Modem Using Frequency Shift Keying Modulation, they constructed an underwater acoustic modem with ultrasonic frequency using FSK modulation. Underwater acoustic communication technology is applied in different fields like underwater monitoring and surveillance system and underwater wireless sensor network. This utilizes water and sound waves as a propagation medium and to be able to communicate between nodes, an underwater acoustic modem is needed. The system is composed of microcontrollers, transducer, amplifier, and FSK modem. The experiment results showed that the frequency shift keying modem can send a text or data at 1200 bps through water media. The distance of 100 cm and 130 cm resulted in a BER value of 0% while at 170 cm, the value is at 35%. This shows that the increase in the number of bits sent and the increase in distance affects the value of BER.

Hema Kale's PC-PC communication using FSK modulator and demodulator paper focuses on an experiment using the FSK modulator and demodulator to make a connection between two computers. Data can be transmitted from one PC to another using Hyper Terminal and USB to TTL converter in the serial form [14]. The purpose of their research is to learn the basic technical theories of the use of USB to TTL converter and Hyper Terminal, interfacing analog electronic circuits and analog integrated circuits with the computer, serial data transmission of computers. The researcher aims to understand Acoustic Coupling with the use of the existing setup. To test the experimental setup, the researcher typed a random message on the first computer's Hyper Terminal. The

same message was automatically displayed on the second computer's Hyper Terminal without any delays or lag. The data transfer from one computer to another was successful using the FSK modulator and demodulator without any interference.

Artdhita Fajar Pratiwi, Purwiyanto, Galih Mustiko Aji, Chairunnisa, Achmad Munir's research is about using FSK modulation for radio communication of electronic information board applied for the early warning system for tsunami [15]. Frequency Shift Keying modulation equipped in radio communication is the most reliable system. When a natural disaster occurs, radio transmission can quickly reactivate in the wireless network since network infrastructures are destroyed during the calamities. The information on the tsunami warning from the local disaster relief agency is transferred to the researcher's proposed system that displays the warning visually. The radio communication with FSK modulation has the transmissibility of one frame per data which is composed of 8 bits which includes a start and stop bit within a second. This setup was effective in the creation of an early warning system for a tsunami.

In the study of FSK transmission circuit for remote sensors integration in distributed measurement systems by Visan, Lita, and Raducu, a design and implementation of a communication circuit that is utilized for transmission of the signals from sensors in long distances. The circuit can be integrated within the conditioning modules that are used to process signals from sensors that are connected to remote data acquisition systems [17]. The researcher's proposed circuit consists of the receiver and transmitter. The transmission part of the circuit functions with the technique frequency shift keying modulation with two discrete transmission frequencies of 400 kHz and 800 kHz while the receiver part is utilized as an asynchronous frequency shift keying demodulator. The maximum data transfer rate from their proposed circuit is 100kbits per second but can be improved by increasing the carrier frequency and utilizing more rapid circuits. The proposed circuit improved its immunity to spurious signals and electrical noises. With the proposed circuits, it's possible to multiplex signals from multiple different sensors to make the data transfer successful on the same physical channel.

3. THEORETICAL CONSIDERATION

Frequency shift keying has various important applications in radio communications, emergency broadcasts, and telephone circuits [18,19,20, 21, 22, 23, 24]. It's a frequency modulation system where data is transferred through the discrete frequency change of a carrier wave. Binary FSK is a modulation scheme utilized to send data between computers. In a binary manner to one or the other of two discrete frequencies, the data can be transferred through the shifting of the frequency of a continuous carrier. One frequency is assigned as the space-frequency while the other as the mark frequency and these correspond to binary one and zero. Mark frequency relates to the higher radio frequency by convention. The element length is the minimum duration of a mark or space condition and typical values range from 5 to 22 milliseconds. Shift frequency is the difference between space and mark frequencies and ranges from 50 to 1000 Hertz. Halfway between space and mark frequencies is called the nominal center frequency. The deviation is equal to the absolute value of the shift frequency and the nominal center frequency and is normally equal to one-half of the shift. FSK coding schemes can be classified into two major groups, synchronous and asynchronous. Asynchronous rely on special bit patterns to control timing during decoding [25, 26, 27]. It does not require a reference clock. While synchronous signals have space-to-mark and vice versa transitions in synchronism with a reference clock.

4. DESIGN CONSIDERATION

For the project, the group decided to simulate the system in MATLAB. MATLAB brings simplicity and utility which is why it is favored by the researchers [28, 29]. The researchers wanted the program to be editable by the user which is why they designed it in a way that the program could take any input and still display the correct waveform. Also, the researchers wanted to simulate real-life applications for the signals which is why they added an AWGN channel [30, 31]. This channel adds noise to the signal which is a close simulation to practical uses for the signal. The students decided to stop before FSK demodulation to focus on all the details included in FSK modulation. FSK demodulation would be a topic on its own with the details and complexities involved. Included in the following is how the researchers coded the program:

```
1  clc
2  clearvars
3  close all
4
5  x=[1 0 1 0 1 1 1 1 0 0 1];
6  bp=1;
7  A=1.5;                          br=1/bp;
   % bit rate
8  f1=br*2;                        f2=br*5;
   t2=bp/99:bp/99:bp;
9  mod=[];
10 for (i=1:1:length(x))
11     if (x(i)==1)
12         y=A*cos(2*pi*f1*t2);
13     else
14         y=A*cos(2*pi*f2*t2);
15     end
16     mod=[mod y];
17 end
18 c=[];
19 for n=1:1:length(x)
20     if x(n)==1;
21        j=ones(1,100);
```

```
    else x(n)==0;
        j=zeros(1,100);
    end
     c=[c j];
end
t1=bp/100:bp/100:100*length(x)*(bp/100
);
subplot(3,1,1);
plot(t1,c,'lineWidth',1.5);grid on;
title('Digital Signal of Binary Data');
t3=bp/99:bp/99:length(x);
subplot(3,1,2);
plot(t3,mod);
xlabel('Time');
ylabel('Amplitude');
title('FSK Modulated Wave');
%Introduction to the AWGN Channel%
 SNR=100;
 res=awgn(mod,SNR);
subplot(3,1,3);
plot(t3, res);
title('FSK Signal Introduced to Noise');
 xlabel('Time');
 ylabel('Amplitude');
```

5. METHODOLOGY

The students' goal for this project was to simulate a system that prepares a digital signal for transmission through FSK modulation. The group accomplished this goal by creating a software program that properly simulates and represents a signal before and after modulation. The problem that arises from software implementation, however, is that the results may be inaccurate when implemented in hardware applications due to several external factors [32,33,34]. To remedy this, the group plans to introduce noise to the system. This is done to simulate real-life properties and application which is why the system puts the signal through an AWGN channel. Although the group thought about using Simulink to accomplish the implementation, the group decided to use MATLAB codes instead due to its utility and simplicity. Additionally, the signals would be better represented in using the plot function in the software. The group aims to show the utility and importance that FSK modulation brings in signal transmission through the processes mentioned.

6. RESULTS AND DISCUSSION

Input: [1 0 1 0 1 1 1 1 0 0 1]

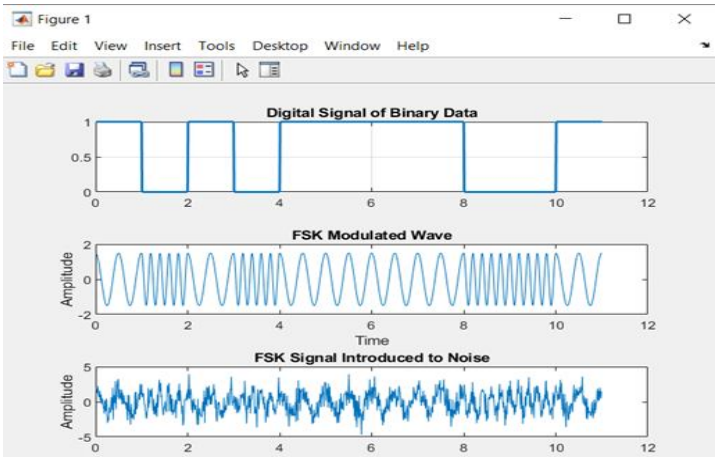

Figure 1: System having SNR of 0

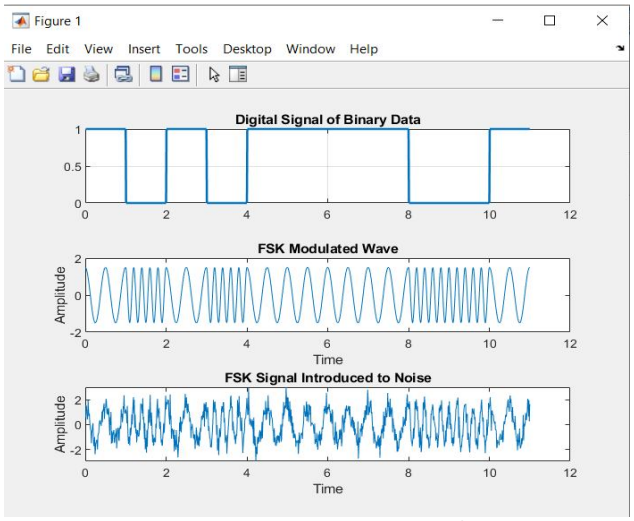

Figure 2: System having SNR of 5

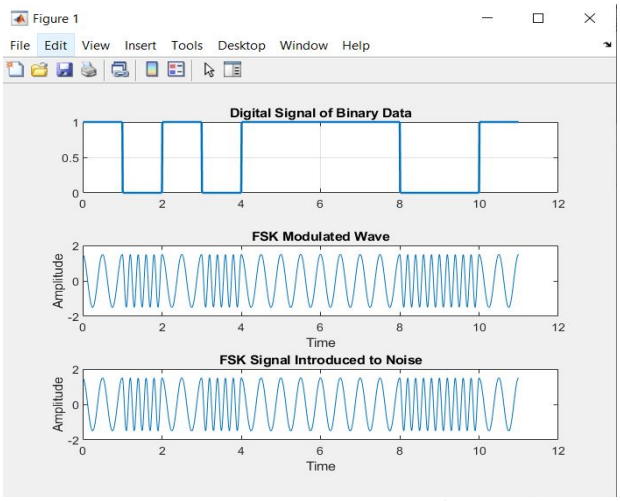

Figure 3: System having SNR of 100

As seen in the data in the previous section, the input bits are [1 0 1 0 1 1 1 1 0 0 1]. Figure 2.1 shows a system with SNR of 1. The first box in the figure shows the input bits in the form of a digital signal. The next box in the figure is the FSK modulated wave. As seen in the waveform, when the input is

0, the FSK modulated wave is compressed compared to the part wherein the input is 1. In the last box, the figure contains the FSK signal introduced to noise. As seen in the waveform, noise is introduced to the signal to simulate avoid inaccuracy in hardware implementations. In the next figure, the same input bits are used but the SNR of the system is now higher at 5. For the last figure, the same is done but the SNR of the system is 100. Comparing the three different FSK signals introduced to noise waveforms, it can be seen that as SNR increases, noise in the signal becomes lesser.

7. CONCLUSION

This project focuses on the use of Frequency Shift Keying modulation to efficiently transmit and receive signals without interference and minimal error. The aim of the group for this experiment was to simulate a system that prepares a digital signal for transmitting using the Frequency Key Shifting modulation technique. The objectives of the system were successfully met. At the end of the experiment, the group was able to develop a deeper understanding of how Frequency Shift Keying works, its functions, and how essential it is in the application in different communication systems today. FSK modulation is a widely used technique in the digital communications system like in radios and computers. This method is better than ASK in terms of noise immunity. Upon the research of the group, they were able to test and utilize the modulation scheme for better transmission of the signal given that there is an added noise to demonstrate a situation wherein signals transmitted have some kind of noise as a form of interference. This causes the transmitting of the signal to fail. With the fast-paced technology, we are faced with a problem of numerous signals are being transmitted all at once, the modulation scheme prevents this problem. The results of this project helped the group to understand the basic concepts and theories of Frequency Shift Keying modulation and applying it to provide a solution for an existing problem.

REFERENCES

[1] G. Kennedy and B. Davis, “Electronic Communication Systems,” 4th Ed. McGraw-Hill International, p. 509, 1992.

[2] A. Grami, “Introduction to Digital Communications. Elsevier Inc.,” 2016. https://doi.org/10.1016/B978-0-12-407682-2.00001-6

[3] L. Couch, “AM, FM, and Digital Modulated Systems in Digital and Analog Communications Systems,” 8th Ed. Pearson Education, Inc., publishing as Prentice Hall, One Lake Street, Upper Saddle River, p. 353, 2013.

[4] R. W. Middlestead, “Frequency Shift Keying (FSK) Modulation Demodulation, and Performance,” 2017.

[5] A. Henderson, and J. McGhee. “Multifrequency Binary Testing with Phase and Frequency Shift Keyed Modulation,” IFAC Proceedings. Vol. 26, No. 2, pp. 811-814, 1993. https://doi.org/10.1016/S1474-6670(17)48385-6

[6] B. Sklar, “Bandpass Modulation and Demodulation/ Detection” in Digital Communications Fundamentals and Applications,” 2nd Ed. Prentice Hall P T R, Upper Saddle River, New Jersey 07458, p 174.

[7] H. Chang, R. Hung, Y. Yeh, K. Chen, S. Wu and Y. Wang, "An 86–92 GHz Frequency Shift Keying Transmitter With an Integrated Antenna in 0.5$\mu{\rm m}$E/D-PHEMT Technology," in IEEE Microwave and Wireless Components Letters. Vol. 19, No. 11, pp. 749-751, 2009. https://doi.org/10.1109/LMWC.2009.2032026

[8] D. Wang, X. Hu, W. Su, X. Jiang and Y. Xie, "Research on multi-channel time frequency shift keying for underwater acoustic communication," OCEANS 2015 - MTS/IEEE Washington, Washington, DC, pp. 1-5, 2015.

[9] S. Indriyanto and I. Y. M. Edward, "Ultrasonic Underwater Acoustic Modem Using Frequency Shift Keying (FSK) Modulation," 2018 4th International Conference on Wireless and Telematics (ICWT), Nusa Dua, pp. 1-4, 2018. https://doi.org/10.1109/ICWT.2018.8527809

[10] H. Xiaoyi, D. Wang, Y. Linab, S. Wei, X. Yongjun, and L. Longcheng, “Multi-channel time frequency shift keying in underwater acoustic communication,” Applied Acoustics. Vol. 103, pp. 54-63, 2016.

[11] Józwiak, Rafał and Listewnik, Karol, “Research on Underwater Communication Modem with FSK Modulation,” pp. 1-6, 2018.

[12] W. Wang, “FSK Modulation and Demodulation Analysis Based on Matlab,” 2012. https://doi.org/10.1007/978-3-642-29084-8_5

[13] F. Knobloch, "Noncoherent dimming frequency shift On-Off keying scheme for low data rate optical street lighting communication," 2015 17th International Conference on Transparent Optical Networks (ICTON). pp. 1-5, 2015.

[14] D. Adionel Guimarães, and R. Adriano Amaral de Souza, “Exploring Practical Aspects of the FSK Modulation with Non-Coherent Matched Filter Detection,” Revista de Tecnologia da Informação e Comunicação. Vol. 5. pp. 22-28, 2015.

[15] L. Huan and Y. Wenhua, "A kind of better adjacent channel suppression multiple frequency shift keying signal simulation method based on MATLAB," 2015 IEEE 16th International Conference on Communication Technology (ICCT). pp. 174-177, 2015.

[16] H. Kale, “PC-PC Communication using FSK Modulator and Demodulator,” 2017 Sixth International Conference on Advances in Electrical Measurements and Instrumentation Engineering (EMIE). pp. 1-5, 2017.

[17] A. Pratiwi, Purwiyanto, G. Aji, and C. Munir, “FSK Modulation for Electronic Information Board Radio Communication of Tsunami Early Warning System,” 2018 International Symposium on Electronics and Smart Devices (ISESD). pp. 1-4, 2018. https://doi.org/10.1109/ISESD.2018.8605479

[18] Z. Xianming, and S. Kumar, “Effects of Rayleigh backscattering in single-source bidirectional fiber-optic systems using different modulation formats for

downstream and upstream transmission." Optical Fiber Technology. Vol. 14, No. 3, pp. 185-195, 2008.

[19] L. Torrizo, and A. Africa. "Next-hour electrical load forecasting using an artificial neural network: Applicability in the Philippines." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp 831-835, 2019. https://doi.org/10.30534/ijatcse/2019/77832019

[20] N. Zou, W. Li, B. Huang, Z.Xu, S. Xu, and C.Yang. "An optical continuous phase FSK modulation scheme with an arbitrary modulation index over long-haul transmission fiber link" Optics Communications. Vol. 285, Nos. 10–11, pp 2591-2595, 2012. https://doi.org/10.1016/j.optcom.2012.01.088

[21] A. Africa, G. Ching, K. Go, R. Evidente, and J. Uy. "A comprehensive study on application development software systems." International Journal of Emerging Trends in Engineering Research. Vol. 7, No. 8, pp 99-103, 2019. https://doi.org/10.30534/ijeter/2019/03782019

[22] E. Szczepaniak and Z. Piotrowski. "Radio transmission masking on the example of FSK modulation." 2017 Signal Processing: Algorithms, Architectures, Arrangements, and Applications (SPA). pp 394-399, 2017. https://doi.org/10.23919/SPA.2017.8166899

[23] A. Africa, A. Alcantara, M. Lagula, A. Latina and C. Te, "Mobile phone graphical user interface (GUI) for appliance remote control: An SMS-based electronic appliance monitoring and control system," International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp. 487-494, 2019. https://doi.org/10.30534/ijatcse/2019/23832019

[24] Sakaki, Hiroto and Yoshida, Satoshi and Nishikawa, and Kenjiro and Kawasaki, Shigeo, "Analysis of rectifier operation with FSK modulated input signal," Wireless Power Transfer (WPT). pp 187-190, 2013.

[25] S. Claessens, N. Pan, D. Schreurs, and S. Pollin, "Multitone FSK Modulation for SWIPT," 2019 IEEE Transactions on Microwave Theory and Techniques.Vol. 67, No.5, pp. 1665-1674, 2019. https://doi.org/10.1109/TMTT.2019.2908645

[26] E. Magsino, "Energy monitoring system incorporating energy profiling and predictive household movement for energy anomaly detection," International Journal of Emerging Trends in Engineering Research. Vol. 7, No. 8, pp. 151-156, 2019. https://doi.org/10.30534/ijeter/2019/08782019

[27] W. Johnson, "FSK: Signals and Demodulation", Vol. 7, No. 5, pp. 1-13, 1980.

[28] L. Sevgi, and C. Uluicik, "Testing ourselves: DigiComm: A MATLAB-based digital communication system simulator," Antennas and Propagation Magazine. IEEE. Vol. 56, pp. 260-269, 2014 https://doi.org/10.1109/MAP.2014.6821797

[29] X. Yin, "Design of FSK modulation system based on virtual instrument," WIT Transactions on Information and Communication Technologies. Vol. 61, pp. 525-530.

[30] C. Fu Wu, "Analysis, Design and Implementation of FSK Modulate Systems," Advanced Materials Research. pp.2625-2628, 2013.

[31] Holambe, Raghunath and Deshpande, "Mangesh. AM-FM: Modulation and Demodulation Techniques." 2012. https://doi.org/10.1007/978-1-4614-1505-3_5

[32] G. Guevarra, A.Koizumi, J. Moreno, J. Reccion, C. Sy, and J. Del Rosario, "Development of a quadrotor with vision-based target detection for autonomous landing," Journal of Telecommunication, Electronic and Computer Engineering. Vol. 10, No. 1-6, pp 41-45, 2018.

[33] A. Africa, P. Arevalo, A. Publico, and M. Tan, "A comprehensive study of the functions and operations of control systems." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp. 922-926, 2019. https://doi.org/10.30534/ijatcse/2019/89832019

[34] A. Africa, F. Espiritu, C. Lontoc, and R. Mendez, "The integration of computer systems into the expansive field of video games," International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 4, pp. 1139-1145, 2019. https://doi.org/10.30534/ijatcse/2019/22842019