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PERFORMANCE COMPARISON OF MODULATION SCHEMES FOR OPTIMAL DATA TRANSMISSION AT HIGH FREQUENCIES

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Abstract

In this paper, we investigate the performance of four modulation schemes to find out which has the best performance in terms of distance and noise immunity for operating at high frequencies. It explores digital modulation with software-defined radios transmitting video data through software applications installed in a computer. The findings in this paper are important to provide insight of the modulation scheme to be best utilized when transmitting data at underutilized frequency bands which are usually high frequency bands as observed from spectrum occupancy research.

Keywords: SDR, GMSK, GFSK, QAM, OFDM, GNU Radio.

1 Introduction

Modulation is the process of varying a carrier signal with the message signal and such changes the signal properties of the carrier wave. When we want to transmit signal from one location to another, we have to strengthen the signal. After undergoing the strengthening process, the signal travels a farther distance compared to when it is in the baseband without a carrier.

Different modulation schemes within the large sets of Analogue and Digital Modulation Schemes exist but in recent times, the digital means of modulation has been favoured due to many advantages of the digital data transmission.

Recent studies in the problem of spectrum scarcity and underutilization have shown higher underutilization at higher frequencies in the RF spectrum [1]-[3]. These frequency bands can be used in cognitive radio research to improve spectrum utilization through spectrum sharing between the secondary users and primary users. One of the important communication layers in a communication system is the physical layer which concerns modulation of the higher layer data link. It is therefore important to know the right modulation scheme to use for this kind of transmission at high frequency to ensure more data is transferred with increasing distance at high frequency.

This paper focuses on the analysis of the performance of four modulation schemes: Gaussian Minimum Shift Keying (GMSK), Gaussian Frequency Shift Keying (GFSK), Quadrature Amplitude Modulation (QAM) and Orthogonal Frequency Division Multiplexing (OFDM) with respect to two vary parameters; the amount of data transmitted and the distance, at high frequencies in Benin City, a metropolitan city in Nigeria, to be able to decide which best fits transmission in the underutilized regions of the radio spectrum.

This paper is organized as follows. Section 2 discusses the literature on the four selected modulation schemes which are used for the performance comparison purposes. Section 3 contains the measurement setup and equipment used. Section 4 presents analysis based on the measurement results obtained. Finally, section 5 outlines conclusions obtained from the comparison.

2 Theoretical Analysis

Gaussian Minimum Shift Keying (GMSK)

This is a form of modulation scheme used in a wide variety of digital communication systems. It is able to carry out digital modulation while effectively using spectrum bandwidth. The pulse-shaping Gaussian filter of GMSK is defined as

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$$g(t) = \frac{\sqrt{\pi}}{a} e^{-\frac{\pi^2 t^2}{a^2}}. \quad (1)$$

The parameter "a" is related to the 3dB bandwidth-symbol time of the gaussian pulse shaping filter, BT_s which is given in Eq. (2).

$$a = \frac{1}{BT_s}\sqrt{\frac{log2}{2}}. \quad (2)$$

Based on the choice of the bandwidth-symbol time the power spectral efficiency is affected. The widdest bandwidth corresponds to a value of infinity which reduces to its narrowest as the value of BT_s drops. In GSM, the choice of the bandwidth-symbol time is 0.3 which is optimally spectral efficient. GMSK has wide range of usage already, the most notable example being in the use of GSM cellular technology which has over 3 billion subscribers worldwide [4]. Due to these attributes, it was selected for use in this experiment.

Gaussian Frequency Shift Keying (GFSK)

This involves modulating frequency of signal with digital data symbols using a Gaussian filter to smoothen out the pulses to make the transition smoother. This modulation scheme reduces the sideband power, interference with neighbouring channels in the same band and also the chance of inter-symbol interference. These features prompted its selection for use in this experiment.

Quadrature Amplitude Modulation (QAM)

QAM is a method of combining two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth used in transmitting the signal [5]. QAM is used with pulse amplitude modulation (PAM) in digital systems, especially in wireless applications. It finds major application also in digital cable channels encoding and transmission via cable television providers. It is also used in Dial-up modems and Wi-Fi systems. These amongst others are some of the reasons it was selected for this experiment.

Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) is a method of digital signal modulation in which, a single data stream is split across several separate narrowband channels at different frequencies to reduce interference and crosstalk. Original data stream bits from the split are transmitted in a parallel form but at lower speed in each sub-stream relative to the original signal. This modulation scheme is applied in a whole lot of digital systems including WiFi, DSL Internet Access, 4G wireless communication, digital television and radio services [6].

Software Defined Radio (SDR)

This is a radio communication system that has components implemented by means of software on computer systems instead of traditional hardware. Hardware such as modulators and demodulators can be easily implemented on software ensuring reduction in hardware complexity. SDR systems are specially designed to be low cost and flexible making it possible to implement various radio systems with just changes in software parameters. In this setup it is used alongside the antenna to transmit and receive signals over a distance. The USRP B210 is the software defined radio used due to the fact that it is suited for such purpose and it is readily available.

GNU Radio Companion

GNU Radio Companion (GRC) is an open-source software responsible for software defined radio. It basically generates python codes from flow graphs to demonstrate and design the operation of a radio system in real life. It mainly consists of signal processing block library, system flow chart and signal visualizer. The GNU Radio framework controls further signal processing capabilities. Flow graphs for the receiver and transmitter of each of the modulation schemes are implemented with GRC. There are blocks to interact with the USRP B210 devices and various other blocks to process the signal as required. In this paper, flow graphs are created with GRC and then the source code is generated and executed.

VLC Media Player

VLC media player is a free portable and multi-platform media player. It supports many audio and video format, including streaming protocols. It was used in this work to visualize the received data and also to create a UDP stream.

3 Experimental Work

The main equipment/software majorly used in the experimental setup are two USRP B210 devices, omni-directional antennas (operating in the frequencies of 315MHz, 433MHz, 470MHz, 2.4GHz, 5GHz and 5.8GHz), GNU Radio 3.7 and two computers.

The experimental setup was implemented using the equipment/software listed and discussed in Section 2. The USRP B210 helps in transmitting the signals using the GNU radio companion software – an interface that lies on top of the GNU Radio 3.7 engine – to interact with the computer systems. The noise floor which is the average noise signal in the environment is first measured at different gain of the USRP receiver. Afterwards, data is transmitted in form of a video file from one laptop to another via the two USRP devices and the maximum distance obtainable for the transmission is gotten for the different modulation schemes.
For the data transmission, flow graphs for the different modulation schemes were created in the GNU Radio Companion software. In each case, two USRPs were used, one for transmission and the other for reception. The main data type used in the procedure is video because it occupies more bandwidth than other data types like audio, images and text. The procedure is carried out for the different modulation schemes at the different frequencies (315 MHz, 433 MHz, 470 MHz, 2.4 GHz, 5.0 GHz and 5.8 GHz) supported by the available antennas. A bandwidth of 3 MHz was used. It should be noted that first, the noise floor was evaluated at the different frequencies and at the chosen bandwidth of 3 MHz.
The noise floor was measured to have an idea of the average noise signal strength in the environment under consideration in Benin City, Nigeria in order to know at which point the signal of the data transmitted was buried in the noise floor. It was measured by basically connecting a USRP in receive mode at a very high gain of 60dB to get the surrounding signals without any noticeable signal transmitted at the same time.
Afterwards, the video file was trzansmitted from one computer to another via one USRP B210, over the air to the next USRP B210 to the receiving computer. At first, the transmitting and receiving ends were placed close to

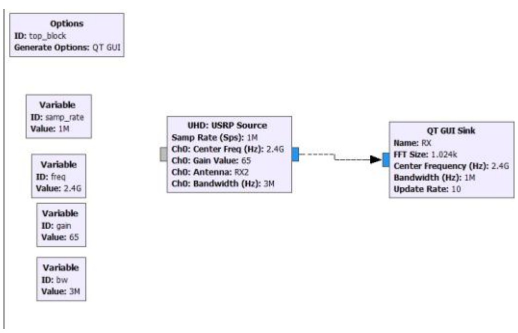


Fig. 1 GNU Radio Companion flowgraph for Noise floor measurement

each other with frequency spectrum plot being observed and the video playing. To vary the distance in the measurement, the receiving end is steadily moved away to certain distance values from the transmitting end until a maximum distance is reached at which the visible spectrum is buried in the noise floor. This process was repeated for each modulation scheme. Shown in Figs. 2 and 3 are the flow graphs for noise floor measurement, transmitter and receiver for the various modulation schemes.
The video file was first converted to a transport stream using VLC Media player, which was then fed into the flowgraph via a File source as shown in Fig. 2 at the transmitter end. The signal transmitted was then received over a distance by the receiving end into the File sink as shown in Fig. 3 from where it was sent to VLC Media Player for display.

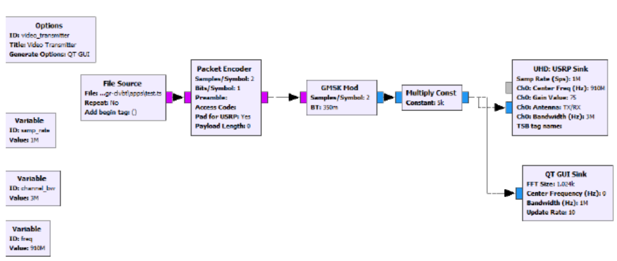


Fig. 2 GMSK Transmitter flow graph

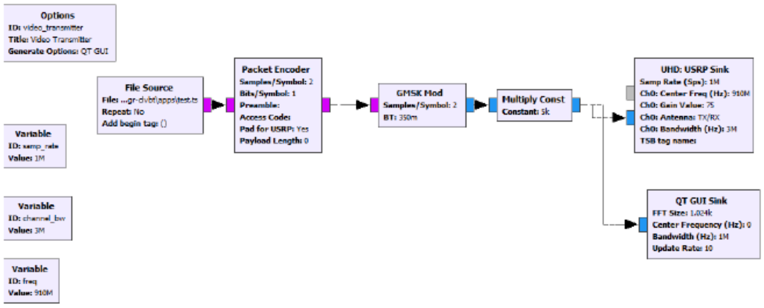
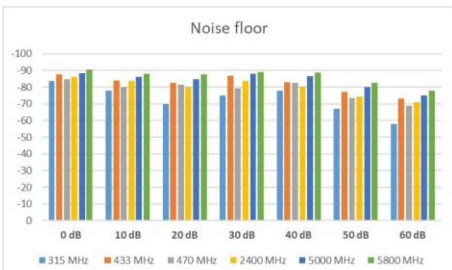


Fig. 3 GMSK Modulation Scheme Receiver

4 Measurement Result And Discussion

The average noise floor of the environment was measured as described above to ascertain noise levels. The values obtain show a varying form of signals which represent noise with the strength of these signals varying with gain of the USRP receiver. Shown in Fig. 4 is a bar chart showing the resulting noise floor levels



at the different frequencies.

Fig. 4 Noise Floor Measurement Results

The plot shows some major information which are as follows;

i. Environmental conditions that vary with time have an influence on the noise floor.
ii. The average noise floor for the particular environment under consideration is between -50dBm to -90dBm.
iii. Increasing the gain of the USRP means an increase in noise floor as every signal is amplified.

The results of each modulation scheme are presented and analysed in terms of their waveform, constellation plots, SNR and effective transmission distance. The Figs. 5 and 6 sre the frequency and constellation plots of the transmitter and receiver signals. The signal strength of the transmitter (lower plot) and receiver (top plot) are shown and the constellation plots for the transmitter (lower plot) and receiver (top plot) are shown in Figs. 5 and 6 respectively.

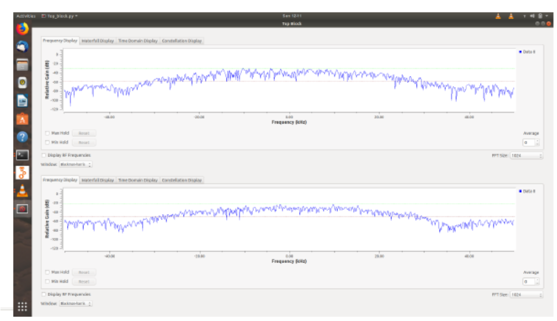


Fig. 5 GMSK Modulation Scheme FFT Plot

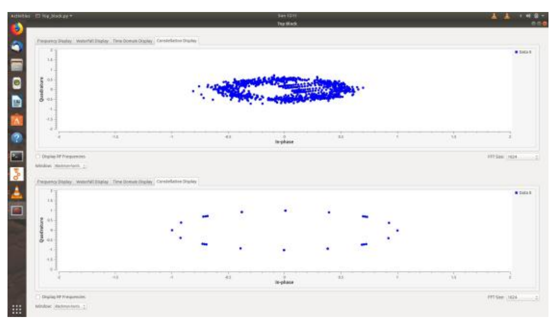
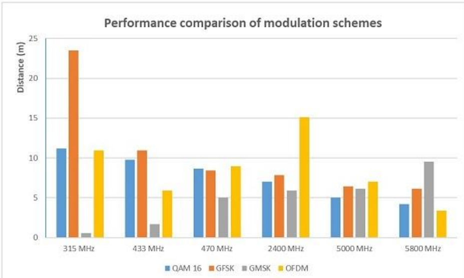


Fig. 6 GMSK Modulation Scheme Constellation Plot

The result of the distance measurement for the different modulation schemes at the various optimized frequencies



represented in form of a graph is shown in Fig. 7.

Fig. 7 Result of Maximum Distance Measurement

The bar chart in Fig. 7 shows the main features which can be summarized as follows:

i. Generally there is a decrease in distance for an increase in frequency for majority of the modulation schemes
ii. GMSK however is observed to achieve a higher distance of transmission for an increase in frequency
iii. GFSK achieves the highest distance at low frequencies
iv. The performance of OFDM with distance varies and is inefficient

5 Conclusion

In conclusion, GMSK among the modulation schemes compared had the best performance with distance and noise immunity. Also, due to the fact that GMSK achieves the highest distance at high frequency, it can be used for carrying out long distance transmission at these high frequency bands which are highly underutilized. The long distance transmission and noise resilience explains its popularity in the mobile communication among other advantages. Researchers in cognitive radio systems can employ GMSK at the physical layer for better system design while concerntrating on the spectrum sensing, management and mobility functions.

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