GNU Radio based Real Time Data Transmission and Reception

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***Abstract** – Today the world is using the most advanced technologies everywhere. From electronic devices used for household to artificial intelligence there is a need for communication. Two devices may involve in a communication where one has to transmit data while the other needs to receive for the operation. The problem becomes evident if the systems are at a very larger distances. So we need to go for wireless communication.*

A software defined radio is a reconfigurable radio whose physical layer functions are mainly or fully defined by software instead of hardware. Because of their exibility and cost efficiency, SDRs allow the implementation of radio communication systems that are interoperable among different standards, protocols, frequency bands, user requirements and functionalities.

In this paper, real time data transmission and reception using different digital modulation techniques like GMSK, GFSK and DPSK are implemented using GNU Waveguru and GNU Octave tool.

***Keywords*-software defined radio, GMSK, GFSK, DPSK, GNU Octave.**

I. INTRODUCTION

SDR(Software Defined Radio) is a radio communication system where components that have been typically implemented in hardware are instead implemented by means of software on a personal computer or an embedded system. SDR are used for its simplicity and exibility. With the right software, a single SDR chip could perform the functions such as recording FM radio and digital television signals, read RFID chips, track ship locations, or do radio astronomy which makes SDR versatile.

What is GNU radio? GNU Radio is a free and open-source software development tool kit that provides signal processing blocks to implement software radios. It can be used with readily-available low-cost external RF hardware to create software defined radios, or without hardware in a simulation like environment. It is widely used in hobbyist, academic and commercial environments to support both wireless communications research and real-world radio systems.

II. LITERATURE REVIEW

Many techniques were developed in recent years. The main approaches of the techniques was to transmit and receive data without much hardware needed using GNU radio. In this section, a brief literature review is given.

In paper [1], the authors discuss about the emerging trends of SDR for the applications in modern communication systems.

In paper [2], the authors focus on SDR from a discrete-time sampling perspective and discuss the efforts that are currently being pursued in order to further bridge the gap between these discrete-time samples. Highlighting the advantages and current issues with SDR technology, this paper also presents several examples using a recently released, commercially available SDR platform.

In paper [3], the authors portray the exibility and reusability of SDR. SDR designers have turned to FPGAs to provide a exible and reconfigurable hardware that can support computationally intensive and complex algorithms which can be used in a multitude of voice, data, and multimedia applications.

In paper [4], the authors specify that the Gaussian Frequency Shift Keying modulation and demodulation is the most widely used modulation scheme for wireless communication as this scheme uses a brand new architecture based on reconfigurable CORDIC is involved which saves about 640Kbits memory units.

III. SYSTEM OVERVIEW

GNU Radio is a framework that enables users to design, simulate, and deploy highly capable real-world radio systems. This signal processing blocks can be linked together for building and creating the baseband part of the dedicated radio. The most basic structure of the constructed radio is as shown in Fig.1.

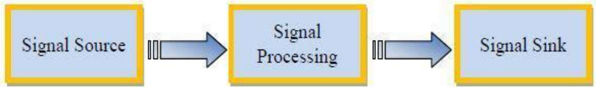

Fig.1: Basic Structure of GNU Radio Flow Graph.

It consists of three parts; signal source, signal processing and signal sink. Signal source is where the signal is generated. There is several signal source blocks available in GNU Radio for instance USRP, sound card (microphone), signal source (signal generator) etc. Signal Processing is where signal source is manipulated before it is loaded into signal sink block. Most of the baseband processing for signal manipulation is already available in GNU Radio for instance FIR filters, IIR filters, FFT, Multipliers etc. Signal sink is where the signal is translated into the form that user desired. Examples of signal sink are sound card (speaker), USRP, data in integer form, graph etc.

IV. IMPLEMENTATION

WaveGuru is a platform to generate and analyze baseband I/Q (In phase/Quadrature phase) signals which are compliant to specific technology standards. The WaveGuru box is used as the USRP. It is used to implement GNU Radio.

GNU Octave is mainly used in order to accept the real-time data from the user. It is one of the major free alternatives to Matlab. It is primarily intended for numerical computations. Octave helps in solving linear and nonlinear problems numerically, and for performing other numerical experiments using a language that is mostly compatible with Matlab. It can be also referred as a clone of Matlab. The octave code helps in taking the real time text input from the user and is later saved to a file.

Modulation Techniques:

a. GMSK (Gaussian Minimum Shift Keying):

GMSK is derived from MSK. It is unique due to the relationship between the frequency of a logical zero and one. The difference between the frequency of a logical zero and a logical one is always equal to half the data rate. In other words, the modulation index is 0.5 for MSK. The fundamental problem with MSK is that the spectrum is not compact enough to realize data rates approaching the RF(Radio Frequency) channel Bandwidth(BW). A plot of the spectrum for MSK reveals side lobes extending well above the data rate. For wireless data transmission systems which require more efficient use of the RF channel BW, it is necessary to reduce the energy of the MSK upper side lobes. The pre-modulation low pass filter must have a narrow BW with a sharp cut-off frequency and very little overshoot in its impulse response. A Gaussian filter which has an impulse response characterized by a classical Gaussian distribution (bell shaped curve) is shown in Fig.2. Notice the absence of overshoot or ringing.

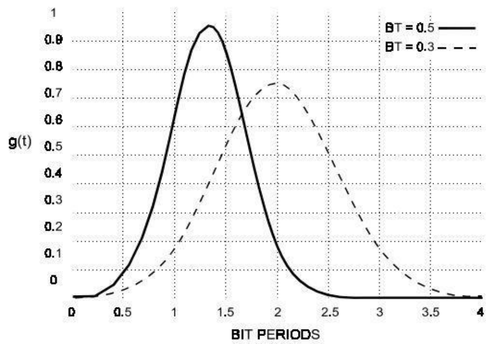

Fig.2: Gausssian filter impluse response

BT is related to the filters - 3dB BW and data rate by (1)

b. GFSK(Gaussian Frequency Shift Keying):

Rather than directly modulating the frequency with the digital data symbols, instantaneously changing the frequency at the beginning of each symbol period, Gaussian frequency shift keying filters the data pulses with a Gaussian filter to make the transitions smoother. This filter has the advantage of reducing sideband power, reducing interference with neighbouring channels, at the cost of increasing inter-symbol interference.

A GFSK modulator differs from a simple frequency shift keying modulator in that before the baseband waveform (levels 1 and +1) goes into the FSK modulator, it is passed through a Gaussian filter to make the transitions smoother so to limit its spectral width. Gaussian filtering is a standard way for reducing spectral width, called “pulse shaping” in this application. The Fig.3 shows the modulation of a particular signal.

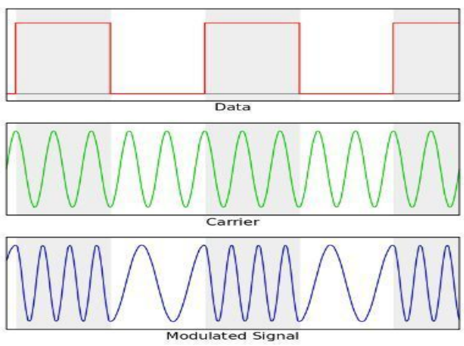

Fig.3: GFSK Modulation.

c. DPSK (Differential Phase Shift Keying):

In Differential Phase Shift Keying , the phase of the modulated signal is shifted relative to the previous signal element. No reference signal is considered. The signal phase follows the high or low state of the previous element. Thus DPSK technique does not need a reference oscillator. The Fig.4 represents the model waveform of DPSK. It is seen from the below figure that, if the data bit is Low i.e., 0, then the phase of the signal is not reversed, but continued as it was. If the data is a High i.e., 1, then the phase of the signal is reversed, as with NRZI, invert on 1 (a form of differential encoding).

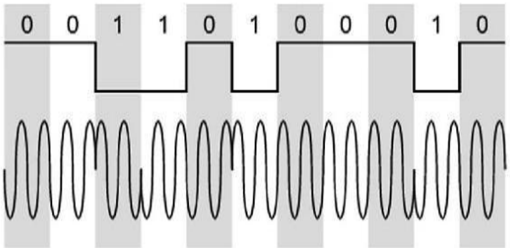

Fig.4: Waveform of DPSK.

DPSK Modulator: It encodes two distinct signals, i.e., the carrier and the modulating signal with 180^0 phase shift each. The serial data input is given to the XNOR gate and the output is again fed back to the other input through 1- bit delay. The output of the XNOR gate along with the carrier signal is given to the balance modulator, to produce the DPSK modulated signal.

DPSK Demodulator: In DPSK demodulator, the phase of the reversed bit is compared with the phase of the previous bit. That signal is made to confine to lower frequencies with the help of low pass filter. Then it is passed to a shaper circuit, which is a comparator or a Schmitt trigger circuit, to recover the original binary data as the output.

Text Transmission

The modulation techniques like GFSK, GMSK and DPSK are implemented to transmit the text data over a wireless medium.

a. Transmitter:

The flow graph of the transmitter of a text file is shown in Fig.5 where GFSK modulation is implemented. Similarly Fig.6 and Fig.7 shows the flow graph of transmitter which uses GMSK and DPSK modulator respectively.

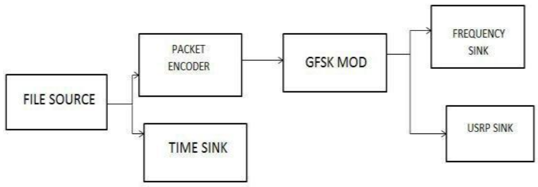

Fig.5: Flow graph of text transmitter using GFSK modulator.

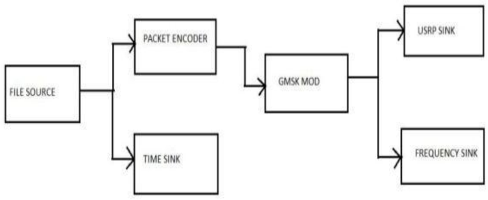

Fig.6: Flow graph of text transmitter using GMSK modulator.

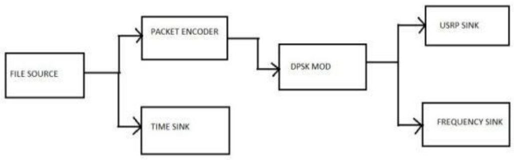

Fig.7:Flow graph of text transmitter using DPSK modulator.

b. Receiver:

The following flow graphs show the reception of text by using different demodulation techniques like GFSK, GMSK and DPSK as shown in Fig.8, Fig.9 and Fig.10 respectively.

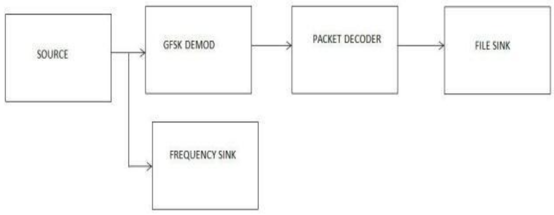

Fig.8: Flow graph of text receiver using GFSK demodulator.

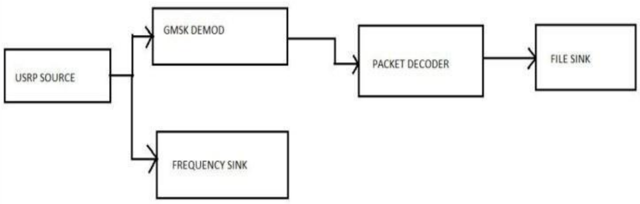

Fig.9: Flow graph of text receiver using GMSK demodulator.

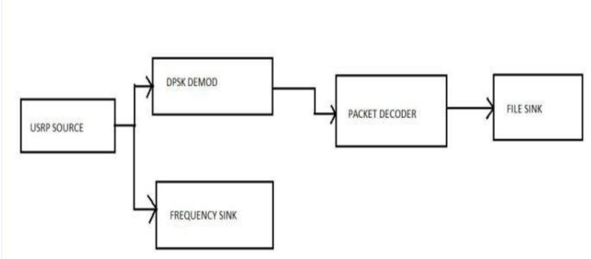

Fig.10: Flow graph of text receiver using DPSK demodulator.

V. RESULTS

A GFSK modulator is similar to a FSK modulator, except that before the baseband waveform (levels 1 and +1) goes into the FSK modulator, it is passed through a Gaussian filter to make the transitions smoother so to limit its spectral width. If the pulses are changed from 1 to +1 as 1, .98, .93, +.93, +.98, +1, and this smoother pulse is used to determine the carrier frequency, thus out-of-band spectrum will be reduced. The input is a byte stream (unsigned char) and the output is the complex modulated. Fig.11 is the transmitter flow graph created using GNU radio for GFSK modulation.

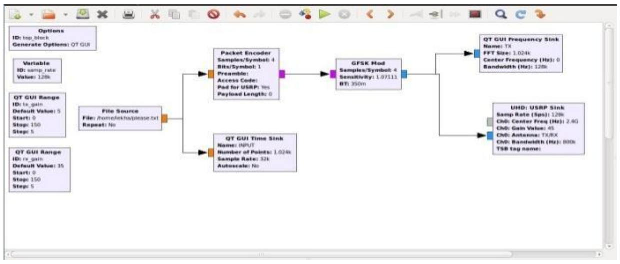

Fig.11: GFSK text transmitter flow graph.

GMSK Mod block is responsible for the modulation of the data before transmission. It provides the advantage of carrying out the modulation while using the spectrum efficiently. The roll-off factor also called as excess bandwidth can be specified. It is usually set to 0.35 to achieve minimum EVM(Error Vector Magnitude). Fig.12 is the transmitter flow graph created using GNU radio for GMSK modulation.

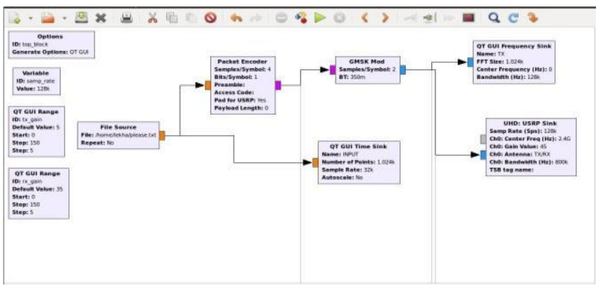

Fig.12: GMSK text transmitter flow graph.

DPSK modulation technique does not have any absolute carrier phase reference, instead transmitted signal itself is used as phase reference. Samples/symbol can be either 2,4,8 or 16 and it can be specified according to requirements. There is an option for using Gray coding. As gray coding is more advantageous, it is by default used while the block is selected. Fig.13 is the transmitter flow graph created using GNU radio for DPSK modulation.

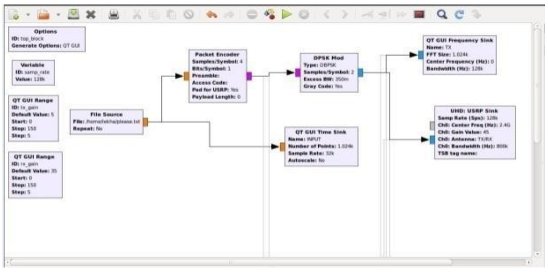

Fig.13: DPSK text transmitter flow graph.

Fig.14, Fig.15 and Fig.16 are the receiver flow graphs created using GNU radio for GFSK, GMSK and DPSK demodulations respectively.

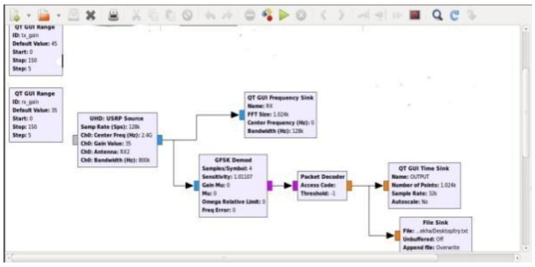

Fig.14: GFSK text receiver flow graph.

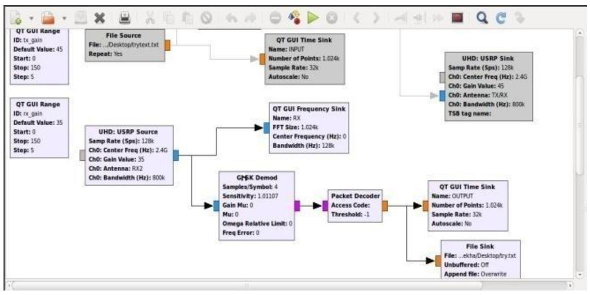

Fig.15: GMSK text receiver flow graph.

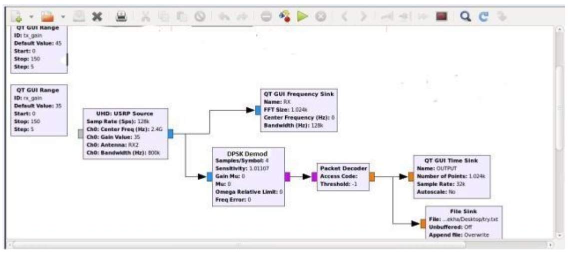

Fig.16: DPSK text receiver flow graph.

For different modulation techniques and different distances, different sizes of text file is transmitted and the resulting received power levels are tabulated in the Table.1.

Table.1: Power levels for different distances and data sizes.

Distance(m) /(Data sizes)	GFSK Modulation				GMSK Modulation				DPSK Modulation			
	1KB	10KB	100KB	5.2MB	1KB	10KB	100KB	5.2MB	1KB	10KB	100KB	5.2MB
2 (NLOS)	98.740	99.996	98.268	98.480	95.495	97.202	96.765	97.023	59.861	59.569	57.423	60.394
3.05 (LOS)	97.622	96.091	96.257	96.004	94.759	96.746	95.673	97.832	94.019	95.868	94.387	96.275
5.05 (NLOS)	59.795	61.230	58.487	60.892	58.436	57.369	56.397	53.413	64.803	60.780	61.315	61.886
4.42 (LOS)	64.969	66.889	65.600	64.594	64.021	70.008	62.698	66.232	70.162	67.207	66.121	66.326

The inferences that is made from the Table.1 are as follows:

- ✓ The receiver antenna placed at the distance of 3.05m which is in line-of- sight(LOS) of transmitter antenna has maximum reception power level.
- ✓ The antennas which are in line-of-sight comparatively have better reception power.
- ✓ Irrespective of size, as the distance increases the received power decreases.

For different modulation techniques, different data sizes and different distances, the transmitter gain is varied. The results are presented in the Table.2.

Table.2: Received power levels for different gains.

GAIN	Distance in meters (Data Sizes)	GFSK Modulation				GMSK Modulation				DPSK Modulation			
		1KB	10KB	100KB	5.2MB	1KB	10KB	100KB	5.2MB	1KB	10KB	100KB	5.2MB
35	2 (NLOS)	98.740	99.996	98.268	98.480	95.495	97.202	96.765	97.023	59.861	59.569	57.423	60.394
	3.05 (LOS)	97.622	96.091	96.257	96.004	94.759	96.746	95.673	97.832	94.019	95.868	94.387	96.275
	5.05 (NLOS)	59.795	61.230	58.487	60.892	58.436	57.369	56.397	53.413	64.803	60.780	61.315	61.886
	4.42 (LOS)	64.969	66.889	65.600	64.594	64.021	70.008	62.698	66.232	70.162	67.207	66.121	66.326
45	2 (NLOS)	57.569	63.112	53.549	52.447	50.858	52.994	49.719	48.813	55.496	62.826	59.923	55.828
	3.05 (LOS)	53.372	61.800	52.579	53.341	46.720	46.713	48.059	51.265	53.158	51.463	53.495	51.143
	5.05 (NLOS)	56.522	67.820	54.883	52.466	55.810	55.016	55.228	58.396	56.110	58.005	58.526	54.874
	4.42 (LOS)	59.478	66.810	59.506	57.178	53.771	54.412	55.353	53.673	60.046	59.519	60.634	54.865

The inferences that is made from the Table.2 are as follows:

- ✓ For the gain values less than 35, there is no reception of data irrespective of distance.
- ✓ The minimum gain required for successful reception of data is found to be greater or equal to 35.
- ✓ As the distance increases with the same gain for different modulation techniques, the reception power level decreases.
- ✓ As the gain value increases, the reception power level also increases comparatively.
- ✓ For gain values above 45, reception power level is saturated.
- ✓ The effect of data size when gain is varied for different distances is very minimal.

VI. CONCLUSION

In this paper, data is successfully transmitted over wireless media using GNU radio and USRP. Text is transmitted using different modulation techniques. Different sizes of text have been transmitted and received by multisystem simultaneously over different distances. Receiver system kept at near distances receive faster than systems at larger distances with different power levels.

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