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MODULATION CLASSIFICATION USING CYCLIC FEATURE DETECTION

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***Abstract-* Modulation classification plays a vital role in the fields such as satellite communication and military communication. Modulation classification is needed to preserve the signal information content of the transmitted signal. Automatic Modulation Classification (AMC) is the automatic recognition of the modulation format. It acts as an intermediate step between signal detection and demodulation. Feature Based (FB) method is the most suitable AMC. One of the FB methods is Cyclostationary which can be applied to linear modulation classification and to low SNR signals. Cyclostationary technique is implemented in LabVIEW which is more flexible for both time domain analysis and frequency domain analysis.**

Keywords- LabVIEW, Universal Software Radio Peripheral, Frequency Shift Keying, Binary Phase Shift Keying, Quadrature Phase Shift Keying, Minimum Shift Keying, Cyclic Domain Profile.

I. INTRODUCTION

Interference for transmissions is unavoidable in a coexistence, which leads to decline in spectrum efficiency. The classification of signal plays a vital role in spectrum sharing and interference management. Wireless communication system is a rapidly growing technology with numerous innovations and constantly emerging technology in various applications. Thus, the increase in usage of limited spectrum, results in various communication impairments such as interference, jamming and intrusive noise. So the transmitted signal may not be received properly by the receiver. Modulation classification can be used to overcome these problems. It is an intermediate task between signal detection and demodulation to overcome all types of communication impairments. Transmitted Signals should be securely received whereas hostile signals must be located, identified and ignored. AMR techniques are classified into two classes: Likelihood-Based (LB) and signal statistical Feature-Based (FB) approaches. In LB approach, AMR is a multiple-composite hypothesis-testing problem. It is based on building a probabilistic model for the received signal and decision is made to classify the modulation type by comparing the likelihood functions or the likelihood ratio against a threshold. In the FB approach, mapping relationship that conducts mapping of time-series signals to the feature field and these featured parameters are used for signal recognition. Feature extraction is based on various parameters of signals, such as instantaneous amplitude, phase, frequency, wavelet transform (WT), statistical features, and cyclic cumulants. In feature selection, the most relevant features must be utilized to improve the classification accuracy. After the signal features are extracted, they pass through classificatory decision to identify the modulation type. It not only produces suboptimal performance but also has low computational costs. Therefore, this approach achieves near-optimal performance when it is systematically designed. Some feature based modulation classification algorithms are based on the use of signal cyclostationary algorithm. The technique used in this work also comes under the category of feature based methods. This type of algorithm can be applied to linear modulation classification and to low SNR signals. Modulation classification is used in wireless security and communications such as jamming, anti-jamming, device or RF finger printing, signal authentication, interference hunting etc. LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) developed by National Instruments (NI), is a data acquisition, instrumentation and control programming tool widely used in industry. It is a graphical programming environment with many software features and hardware options is the main reason for its increasing popularity.

The paper had demonstrated through some experimental outcome of the concepts, in the course on wireless communication using the ability of the LabVIEW programming environment. The graphical programming environment is easy to learn and simple to transform an equation or concept to a working program. This work is hard to implement in hardware setup and complex but this technique using the LabVIEW software can be done. The proposed work deals to preserve the signal information content of the transmitted signal and to avoid various forms of communication impairments such as interference, jamming etc.

II. SOFTWARE AND HARDWARE DESCRIPTION

LabVIEW provides a single graphical design tool for algorithm development, embedded system design, prototyping and interfacing with real-world hardware. National Instruments is increasingly focusing on the capability of deploying LabVIEW code onto an increasing number of targets. The LabVIEW graphical programming environment with the included examples and documentation makes it simple to create small applications. The practical benefit of the graphical approach is that it puts more focus on data and the operations being performed on that data, and abstracts much of the administrative complexity of computer programming such as memory allocation and language syntax. G Programming language is an Intuitive and flowchart-like dataflow programming model with shorter learning curve than traditional text-based programming. It naturally represents data-driven applications with timing and parallelism.

LabVIEW contains a powerful optimizing compiler that examines the block diagram and directly generates efficient machine code, avoiding the performance penalty associated with interpreted or cross-compiled languages. From a technical standpoint, G (Graphical) is a graphical dataflow language in which nodes (operations or functions) operate on data as soon as it becomes available, rather than in the sequential line-by-line manner that most programming languages employ. Universal Software Radio Peripheral (USRP) is a Software Defined Radio Device which can be reconfigurable RF device that includes a combination of host-based processors, FPGAs, and RF front ends. These devices can be used for applications such as multiple input, multiple output (MIMO) and LTE / Wi-Fi test beds and radar systems.

Fig.1: USRP

Fig.1 shows USRP. Each RF channel includes a switch allowing for Time Division Duplex (TDD) operation on a single antenna using the TX 1, RX1 port, or Frequency Division Duplex (FDD) operation using two ports, TX1 and RX2.

III. METHODOOGY

This paper describes methodology to generate MSK, FSK, QPSK and BPSK modulation using LabVIEW. The developed algorithm will perform classification and detection of modulated signal. To classify the modulation type of transmitted signals using cyclic feature detection technique. Most modulated signals exhibit the property of cyclostationary that can be exploited for the purpose of classification which is done in terms of Cyclic Domain Profile (CDP). Fig.2. shows the block diagram of system architecture.

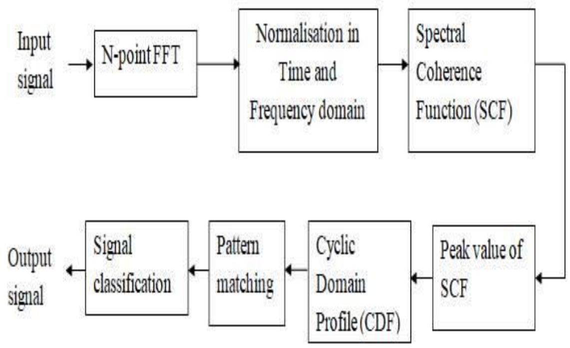

Fig.2: Block diagram of system architecture

IV. SYSTEM IMPLEMENTATION

This section describes the method of implementation in LabVIEW. Input of the transmitter is given through modulation techniques. Modulation is the process of changing the characteristics of the carrier signal, in accordance with the instantaneous values of the message signal. Message signal is incompatible for direct transmission over a long distance. In order to increase the strength of the message signal, modulation with high carrier frequency wave is required. Fig.3 shows the block diagram of modulation. Carrier signals are high frequency waves it is generated from RF oscillator. Baseband signal is the message signal as it modulates carrier signal. Modulator takes the instantaneous amplitude of baseband signal and varies amplitude or frequency or phase of carrier signal. These two signals are combined in modulator, which results as modulating signal. It goes to an RF-amplifier for signal power boosting and then feed to antenna. Modulation of MSK, BPSK, QPSK, FSK is done and transmitted.

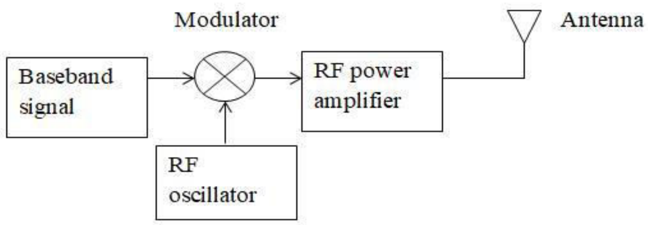

Fig.3: Block diagram of modulation.

FSK represents the changing or improving the frequency characteristics of an input binary signal in accordance with the carrier signal. Amplitude variation is one of the major drawbacks in ASK, so it can be applicable for only few applications. Low spectral efficiency of ASK leads to the wastage of power. FSK overcomes the drawback of ASK.

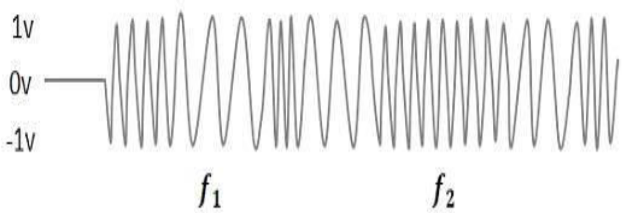

Fig.4: FSK modulated signal

Fig.4 shows Input binary signal. The output of a FSK modulated wave is high in frequency for a binary High input and is low in frequency for a binary Low input. In BPSK, the sine wave carrier takes two phase reversals such as 0° and 180°. It is also called as 2-phase PSK or Phase Reversal Keying.

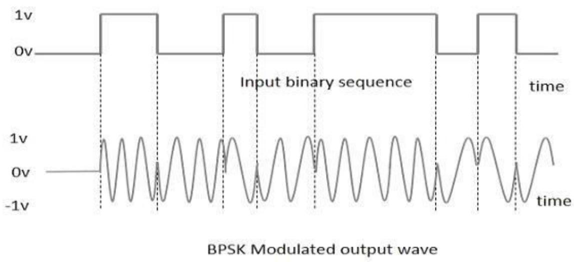

Fig.5: BPSK modulated signal

Fig.5 shows BPSK modulated signal. In BPSK, the phase shifts will be either 0° or 180°, which indicates whether the transmitted bit is 0 or 1. The Modulated sine wave will be the direct input carrier or the inverted 180° phase shifted input carrier, which is a function of the data signal. In QPSK, the incoming bit stream can be parallelized so that every two incoming bits can be split up and shift the phase of a carrier frequency. The sine wave carrier takes four phase reversals such as 0°, 90°, 180°, and 270°.

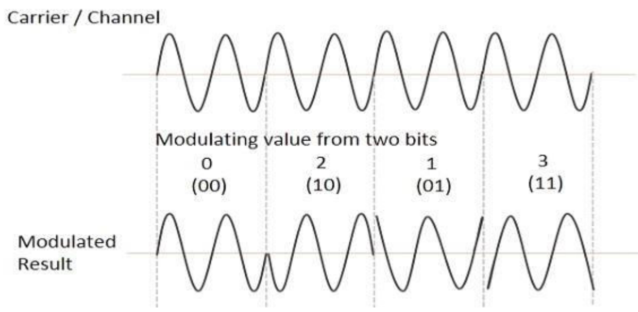

Fig.6: QPSK modulated signal

MSK is a form of continuous phase frequency shift keying, providing spectrum efficiency & enabling efficient RF power amplifier operation. It is used in GSM and widely-used digital cellular mobile system. MSK can be viewed as either a special case of binary continuous-phase frequency shift keying (CPFSK). In MSK, there is no phase discontinuity because the frequency changes occur at the carrier zero crossing points.

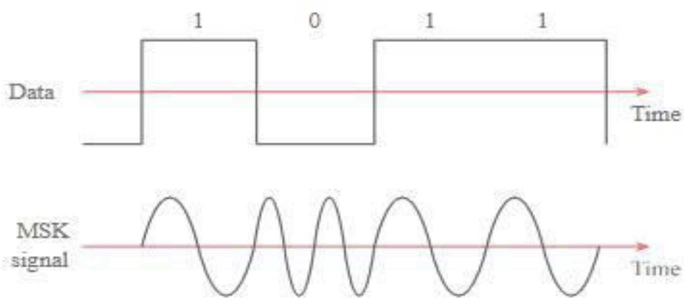

Fig.7: MSK Signal

Fig.7 shows MSK Signal. It can be seen that the modulating data signal changes the frequency of the signal and there are no phase discontinuities. This arises as a result of the unique factor of MSK that the frequency difference between the logical one and logical zero states is always equal to half the data rate. This can be expressed in terms of the modulation index, and it is always equal to 0.5. It can be used for both analog and digital input signals. The input NRZ sequence and the delayed sequence are encoded using multiplier and modulated in FM modulator for frequency shift in the encoded signal. USRP is used to receive the transmitted signal and send to the receiver for classification of signal. The NI USRP connects to a host PC creating a software defined radio. Incoming signals at the SMA connector inputs are mixed down using a direct-conversion receiver to baseband I/Q components, which are sampled by an Analog-to-Digital Converter (ADC). The digitized I/Q data follows parallel paths through a Digital Down Conversion (DDC) process that mixes, filters, and decimates the input signal to a user-specified rate. The down converted samples are passed to the host computer. For transmission, baseband I/Q signal samples are synthesized by the host computer and fed to the USRP at a specified sample rate over Ethernet, USB or PCI express. The USRP hardware interpolates the incoming signal to a higher sampling rate using a Digital Up Conversion (DUC) process and then converts the signal to analog with a Digital-to-Analog Converter (DAC). The resulting analog signal is then mixed up to the specified carrier frequency.

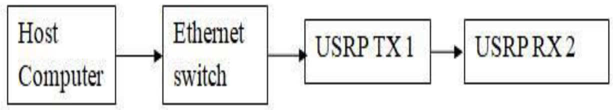

Fig.8: Hardware Setup of USRP

Fig.8 shows the configuration of the USRP hardware setup that facilitates the synchronization between the reference clock sources of the transmitter and the receiver. Each transceiver has one antenna connected to either port. For desired operation, the transmitter should be at least half a wavelength of the carrier frequency used. The methods used are Automatic modulation classification (AMC), Cyclostationary Feature Detection (CSD), Normalization. AMC is the automatic recognition of the modulation format of a sensed signal. For an intelligent receiver, AMC is the intermediate step between signal detection and demodulation. The purpose of AMC algorithms in a radio receiver is to identify the existence of a signal in a particular frequency band at a given location and then determine the modulation type being employed in the spectrum. AMR techniques are classified into two classes: Likelihood-Based (LB) and signal statistical Feature-Based (FB) approaches. Generally, for Signal classification, LB method is not appreciated; FB method is the most suitable method for signal classification. One of the FB methods is Cyclostationary which is used for modulation classification. Cyclostationary Feature Detection (CSD) technique deals with the inherent cyclostationary properties or features of the signal. Such features have a periodic statistics and spectral correlation that cannot be found in any interference signal or stationary noise. It can be applied to linear modulation classification and to low SNR signals. AMC uses cyclic feature detection on the receiver side to classify among BPSK, QPSK, FSK and MSK modulation schemes. USRP Txr 1 selects one of the four modulation schemes to transmit a randomly generated stream of bits. The USRP Rxr 2, upon receiving the signal, extracts its cyclostationary features and classifies the modulation scheme. First the cyclic periodogram of the received signal is calculated using N-point Fast Fourier Transform (FFT). These FFT values are then smoothed both in time and frequency domain and normalized to generate the SCF of the received signal. Then the CDP is calculated for each cycle frequency from the peak value of the SCF. Based on the pattern matching, signals are classified. Normalization of series time data eliminates the artifacts. Normalization segments provided data into M contiguous blocks of N samples each, to compute the cyclic periodogram for each block, and average the results. Spectral correlation function (SCF) is the covariance of the two spectral components and divided by the geometric mean of the variances of those spectral components. SCF is obtained by infinite-time averaging of the cyclic periodogram. SCF is the computational efficiency of the FFT which can be used to control and characterize the cyclostationary of a given signal in an efficient manner with a reasonable total computational cost. So that latency is reduced. Cyclic domain profile (CDP) is used for signal classification due to their pattern matching capabilities. It is obtained from the peak value of the SCF. It is unique for each modulation technique.

V. RESULTS AND DISCUSSION

This section discusses results of the above stated modulation techniques.

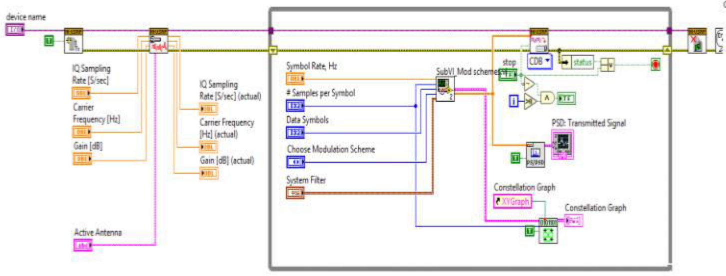

Fig. 9: Block diagram of transmitter block

Fig.9 shows the Block diagram of transmitter block. USRP transmits the generated signal via USRP Txr 1. Transmitter block calls the sub VI to generate modulation scheme which provides the desired modulated signal. The sub VI generates one of the four modulations such as BPSK, QPSK, FSK and MSK. Fig.10-13 shows the modulation scheme for BPSK, QPSK, FSK, MSK. These blocks generate the modulated BPSK, QPSK, FSK, MSK signals.

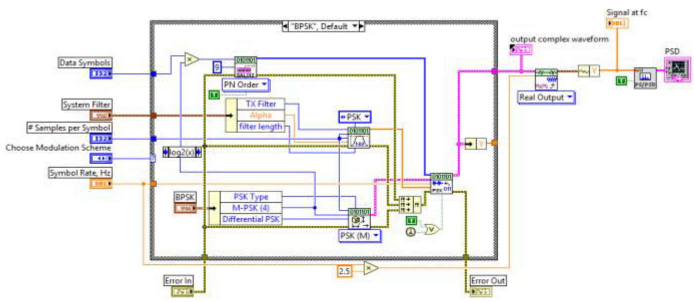

Fig.10: Modulation scheme for BPSK

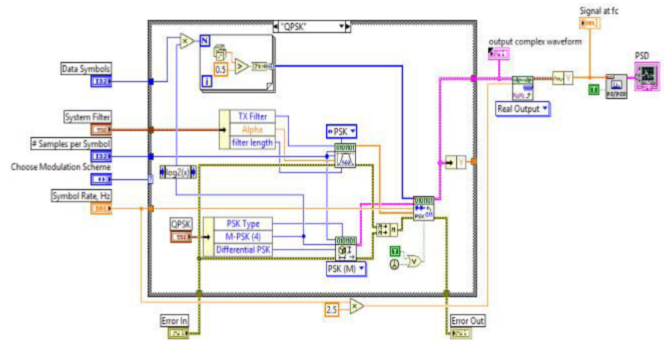

Fig.11: Modulation scheme for QPSK

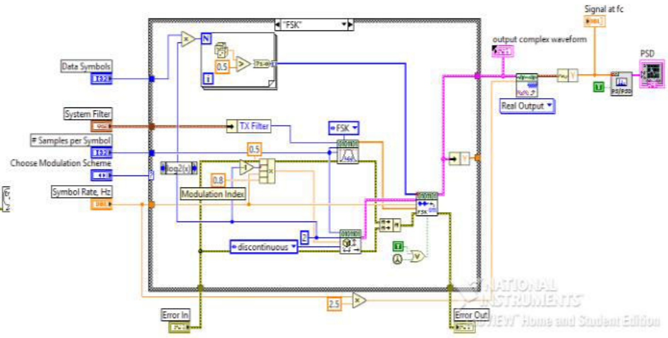

Fig.12: Modulation scheme for FSK

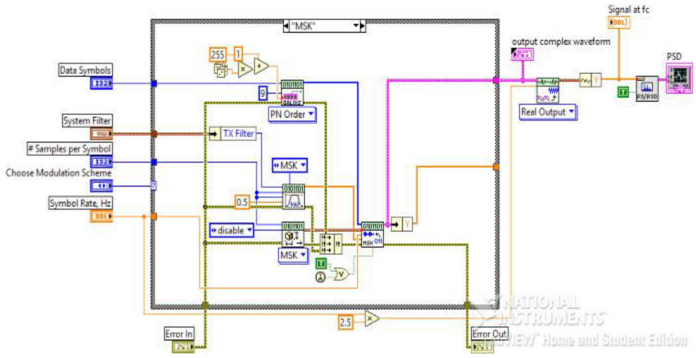

Fig.13: Modulation scheme for MSK

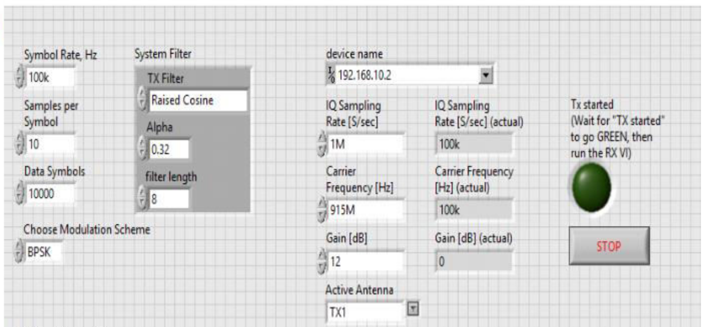

Fig.14: Front panel of Transmitter block

Fig.14 shows the front panel of Transmitter block. Symbol rate and samples per symbol are set to 100 KHz and 10sps respectively. Corresponding USRP device name is noted from

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configuration utility and uploaded in FP. Constellation diagram is the graphical representation of signal modulated by a digital modulation scheme. It displays the signal as a two-dimensional scattered diagram in a complex plane. The Fig. 15-18 depict the constellation of BPSK, QPSK, FSK and MSK.

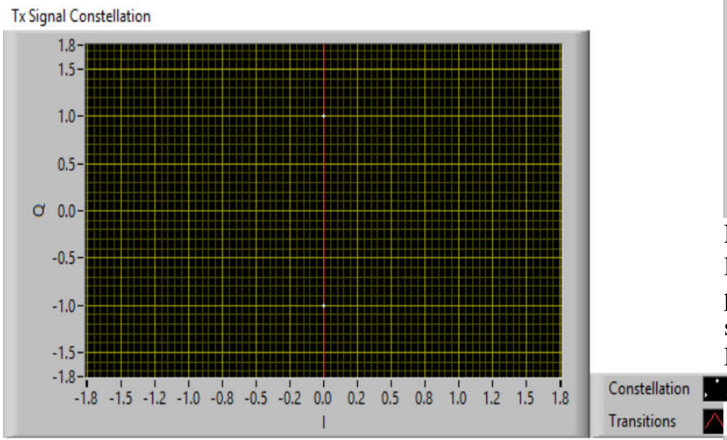

Fig.15: Constellation diagram of BPSK

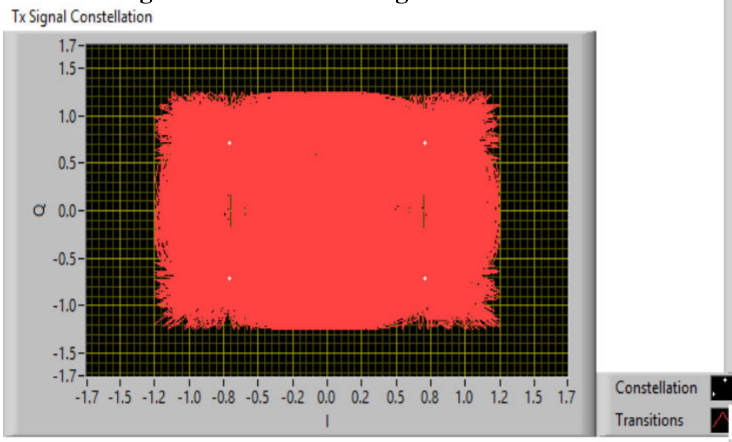

Fig.16: Constellation diagram of QPSK

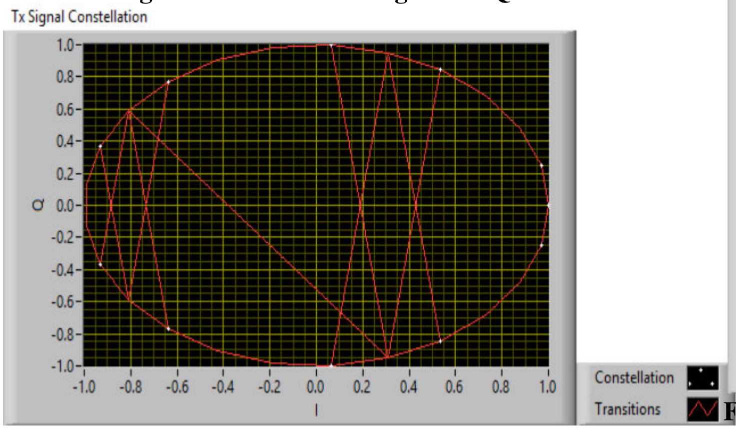

Fig.17: Constellation diagram of FSK

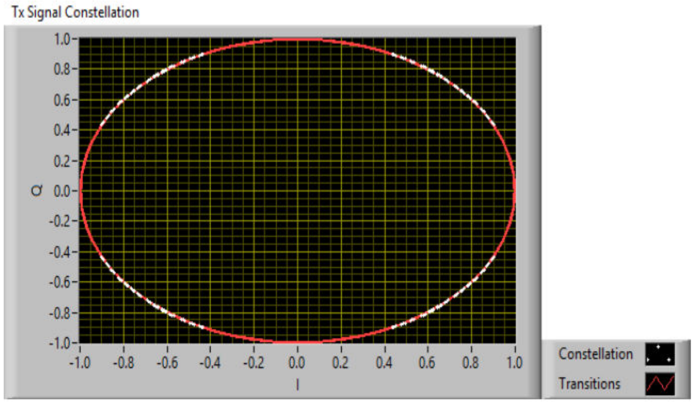

Fig.18: Constellation diagram of MSK

Power Spectral Density (PSD) describes the distribution of power into frequency components composing the signal. It shows at which frequencies variations are strong and weak. Fig.19-22 shows the PSD of BPSK, QPSK, FSK, MSK.

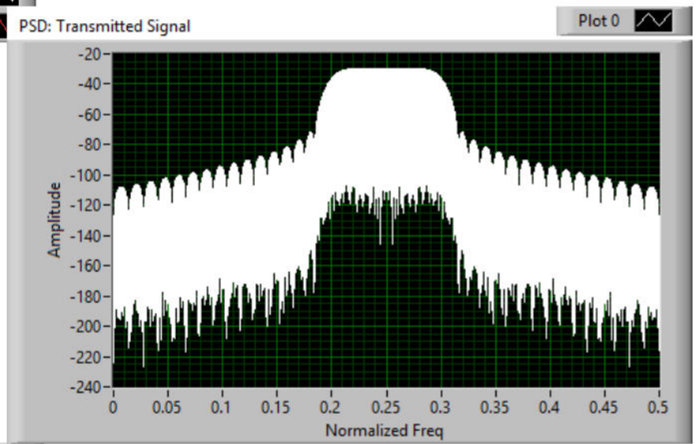

Fig.19: PSD of BPSK

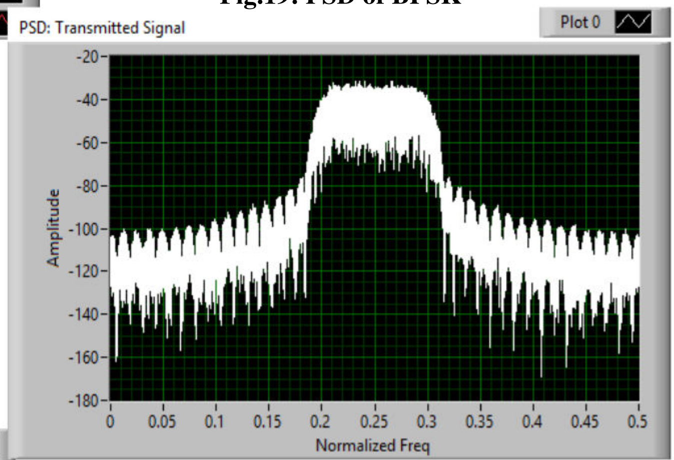

Fig.20: PSD of QPSK

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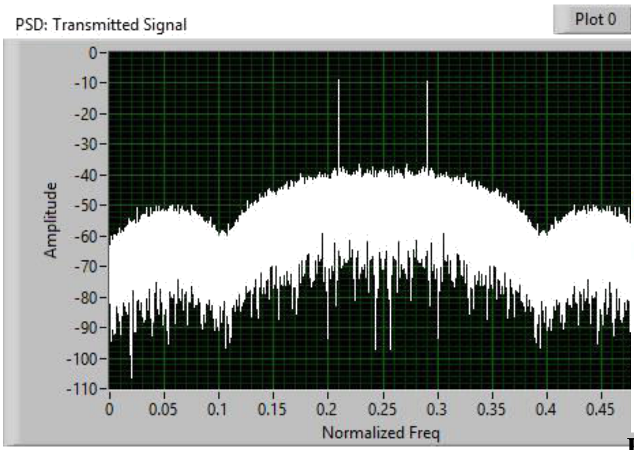

Fig.21: PSD of FSK

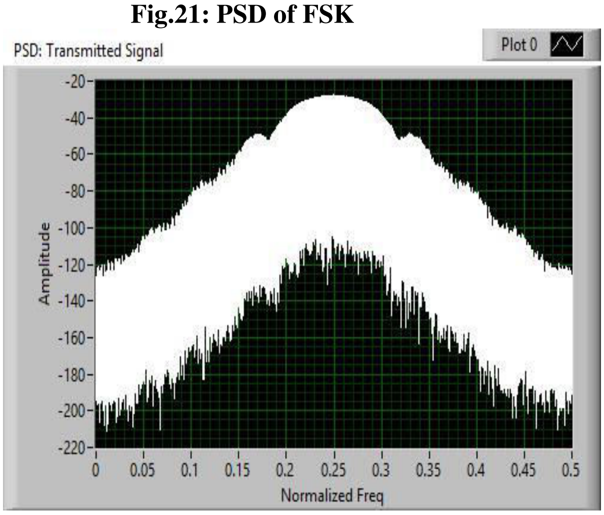

Fig.22: PSD of MSK

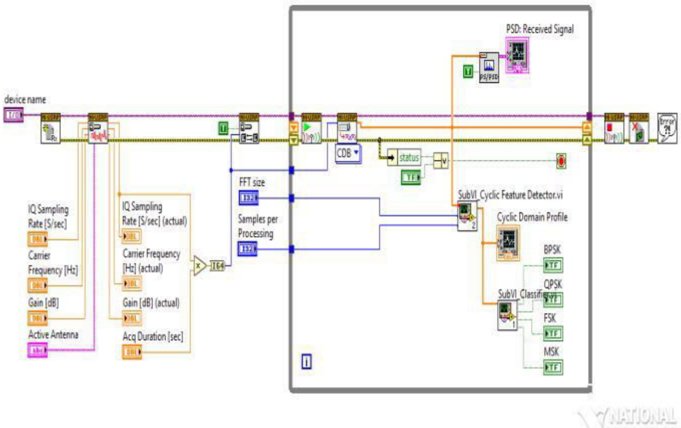

Fig.23: Block diagram of receiver block

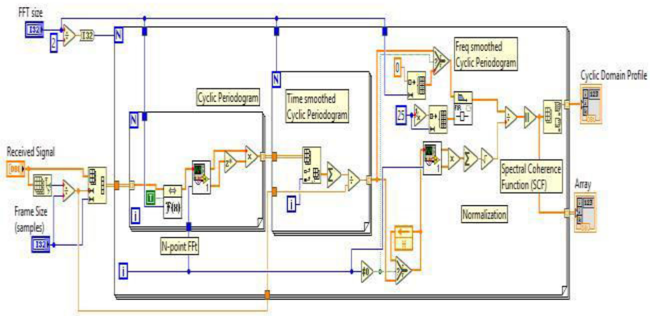

Fig.24: Block diagram of cyclic feature detector

Fig.23 shows block diagram of receiver block and Fig.24 shows the block diagram of cyclic feature detector. Receiver block calls the sub VI to generate CDP for the incoming signal. Fig.25-28 shows the front panel of BPSK, QPSK, FSK, MSK which shows the output of receiver block. Fig. 29 shows the front panel of cyclic feature detector which shows the output of receiver block.

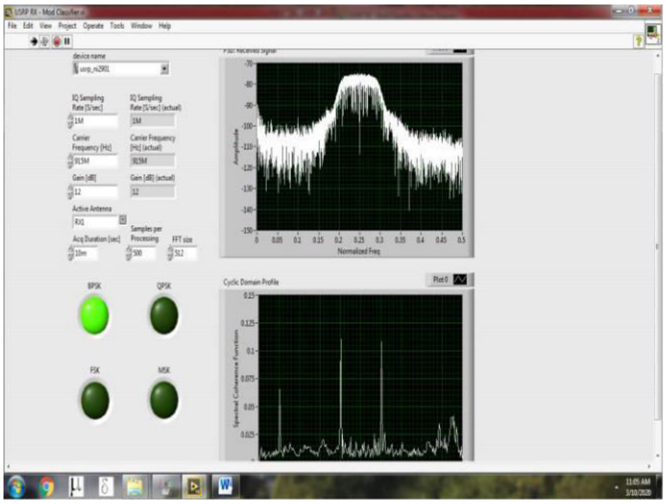

Fig.25: Front panel of receiver block (BPSK)

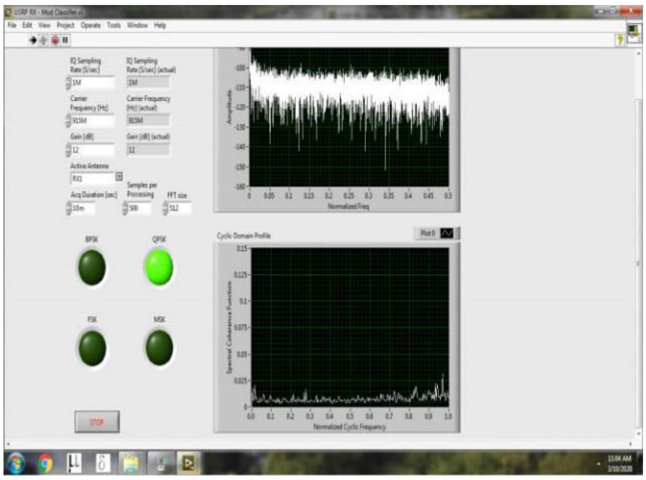

Fig.26: Front panel of receiver block (QPSK)

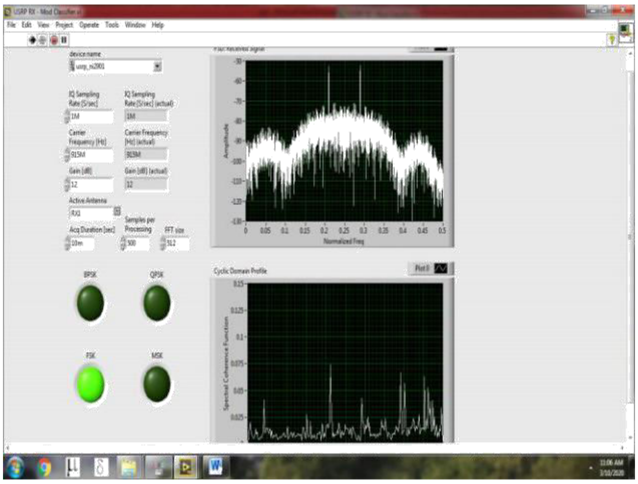

Fig.27: Front panel of receiver block (FSK)

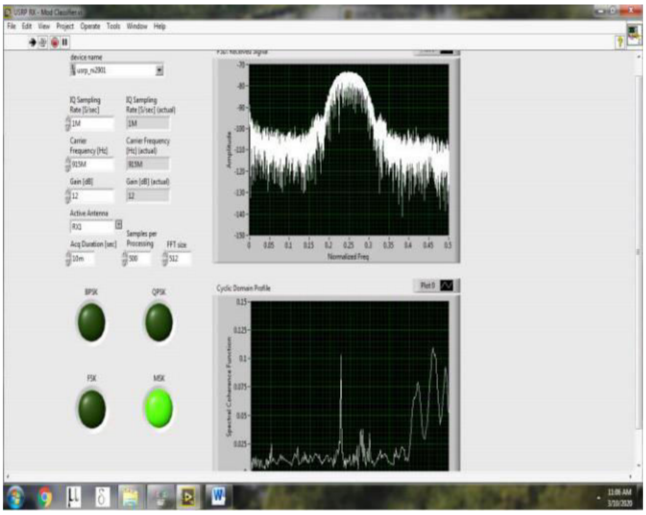

Fig.28: Front panel of receiver block (MSK)

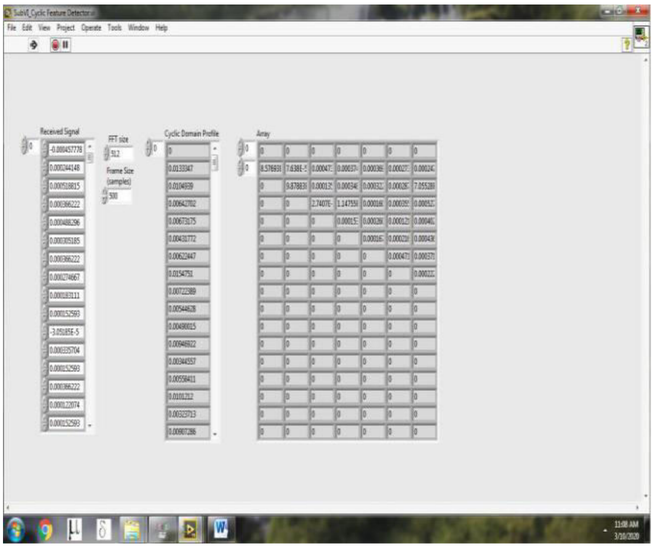

Fig.29: Front panel of cyclic feature detector

VI CONCLUSION AND FUTURE WORK

This paper demonstrated the user-friendly environment detection of modulation techniques which are useful in wireless communication system which is verified in LabVIEW. The simulation and the output waveform of the different modulation techniques have been conversed in this paper. The choice of modulation technique is purely dependent on the type of precise application. Many applications may need higher accuracy in reception of data, while the other constraint may be existing bandwidth or power. The facility provided by wireless communication system can be significantly improved with the help of proper selection of modulation scheme. The importance of this paper is to classify the modulation technique. Modulation techniques are explained and discussed using LabVIEW and USRP and concluded that the hardware implementation is complex.

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