Software defined radio for wireless networks

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***Abstract*— The recent growth of wireless system services has resulted in huge number of compatible and incompatible air interface standards. The military has also experienced problems with incompatibility of radio formats during various joint operations. When we bring the wireless visions to light, it is becoming crucial that the desire for information to quickly pass the limited bandwidth capabilities of the standardized 3G network. The growing dissatisfaction with the efficiency limitations of 3G is leading to the rapid development of 4G network To enable these two paradigm shifts there is an urgent need to make them compatible. This paper contributes the fundamental concept of the software defined radio by using mathematical models to describe this rapidly emerging technology in the characterization of similar technologies like programmable digital radios.**

A software-defined radio consists of a programmable system in which the functional changes can be made by just updating the software. In this paper, a software defined radio QAM (Quadrature Amplitude Modulation) modem system is implemented by using LabVIEW. LabVIEW is a widely used graphical programming system which allows designing of system in an intuitive block based manner which reduces time as compared to the generally used text based programming languages. Basically, this paper shows the ease with which a software defined radio system can be built and examine via the LabVIEW.

***Keywords*— SDR, QAM , LabVIEW.**

I. Introduction

Early radio systems would be termed as Hardware Defined Radios as the full range of capability was provided totally by the hardware elements. As software engineering began to grow, manufacturers shifted to developing Software Controlled Radios, with limited functions being reconfigured by software. Today our area of interest is true Software Defined Radios, radios that implement a specified range of capabilities through software. In its purist form, the term software radio refers to the rearrangement of the radio interface by software, possibly using over the air (OTA) download, by analog-to-digital (A/D) conversion at the antenna side. An ideal software radio is shown in Figure 1. Analog to digital and digital to analog converters at the receiving and transmitting antennas and at handset allow all radio reception, signal generation, reception, coding, decoding etc. functions to be performed in software. While such an implementation it is already feasible at very low frequencies (VLF) [1]. As a result, in recent years a more practical definition has emerged in personal communications, which encircle rearrangement at any level of the radio protocol stack by software either by over the air download or by any other means. This software radio also includes many non-digital signal processing hardware components like radio frequency conversion and distribution, anti-aliasing filters, power control, etc. But the increased performance and continually dropping costs of such technologies of analog to digital and digital to analog converters, high speed digital signal distribution, DSP chips and embedded computing are leading a shift toward software intensive approaches especially in large scale telecommunication applications.

A number of definitions can be found to describe Software Defined Radio, also known as Software Radio or SDR. The SDR Forum, working in collaboration with the Institute of Electrical and Electronic Engineers (IEEE) P1900.1 group, has worked to establish a definition of SDR that provides consistency and a clear overview of the technology and its associated benefits. Simply put Software Defined Radio is defined as [2]: "Radio in which some or all of the physical layer functions are software defined".

Software Defined Radio (SDR) Forum defines SDR technology as " The radios that provide software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (like hopping), and waveform requirements of current & evolving standards over a broad frequency range" [3].

There is a present day issue concerning the way worldwide people use technologies to communicate. Although the typical means for satisfying this need is by means of cell phones, there are many forms of communication now a day. The radio is a general term. The current method for implementing these devices is through fabrication in hardware, defined as software defined radios. This form of communication device is made permanent by nature, creating the need to replace components if any advancements or adjustments are to be imposed upon the system by a set of inbuilt programs. In today's fast paced world it is quite often and is one motivation for implementing a new technology to manage these situations. Another motivation originates from the increase in spectral traffic; with the trend that everyone own a cell phone with wireless internet that's capable of streaming live video, the amount of available bandwidth is an issue. Software-defined radio technology is the solution to all of these problems as well as the focus of this project. The goal of the project is to showcase the benefits, usability, and capability of SDR using LAB View.

This paper discusses a software defined radio (SDR) system built using Lab VIEW software. A software defined radio consists of a programmable communication system where functional changes can be made by updating software [4]. As in digital communication systems, the transmitter of a SDR system converts digital signals to analog. These waveforms are then transmitted to the receiver, which are down converted, sampled, and demodulated using software on a reconfigurable baseband processor. Normally, high-performance digital signal processors like FPGAs are used as the baseband processor.

Basically, the programmability and flexibility of a SDR system makes it possible to be used in omnipresence network environments.

The telecommunications industry stress on our demand for information by shifting from voice only networks to networks that provide both voice and data services. The wireless telecommunications industry seeks to provide us with access to this data anytime and anywhere via an unbound communication link. The initial push behind the shift from 2G (digital voice) to 3G (digital voice and data) cellular networks was motivated by the desire to merge these two most popular trends of the 20th century: the exponential growth of the cellular market and the surprising explosion of the Internet, both of which stimulated an economic prosperity in the late 1990s [5] .

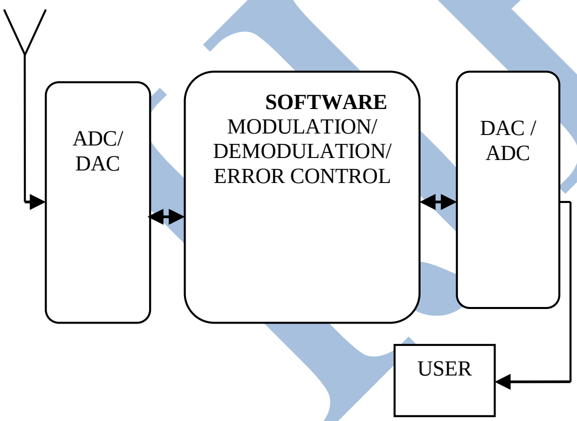

Fig.1: Ideal Software Radio

Because of the need to keep these devices both portable and low cost, it is unlikely that Internet browsing will emerge as the primary application of the growing cellular network [6]. Proponents of these networks have, as a result, suggested a wide variety of alternative uses as : (1) m-Commerce (the ability to perform monetary transactions using a mobile only); (2) Video (the ability to view live streaming video for example ,of the party on the other end of the link); (3) PIM (Personal Information Management) ; (4) Location Specific Information (the ability to provide information related to the user's current location, including maps); (5) infotainment (participating in gaming); and (6) the Classics (online browsing and voice communication). The growing discontent with the limitations of 3G has led to increasing interest in 4G networks, While the vision of a 4G network is at best, it is clear that two essential model shifts will be required to support this network. The first model shift redefines spectral usage and the second redefines the handheld.

In this paper, QAM (Quadrature Amplitude Modulation) is chosen to be the modulation scheme of the designed software defined radio system as this modulation is widely used for data transmission applications over band pass channels like FAX modem, high speed cable, multi-tone wireless, and satellite channels, digital cable television and cable modem, etc[7],[8].Here, the software implementation of the QAM modem system is accomplished using Lab VIEW software as a time-efficient and cost effective solution. Lab VIEW is a graphical programming environment developed by National Instruments that allows high-level design via it's flow-chart intuitive block-based programming as compared to the commonly used text-based programming languages in other software. A design using Lab VIEW is achieved by integrating different blocks, components, called Virtual instruments. SDRs are ideal to be used for multi carrier, single carrier, single band, and multiband and multi mode transceivers. The key point is that SDRs have the ability to go beyond simple single channel, single mode transceiver technology with the ability to change modes randomly because the channel bandwidth, rate, and modulation are all flexibly determined through software. These characteristics can be changed by direct input, floppy disk, over the air download or through the use of careful signal analysis to determine analytically how the information is coded through a process. This is termed as Cognitive Radio.

II. SDR ARCHITECHTURE

The foundation of any digital system is its architecture. The term architecture refers to the software, hardware or a combination of the two. Such advanced services in the field of telecommunication are on an evolutionary path which began in the early 1980's. Figure 2 illustrate the general system architecture of software defined radio. The ideal software radio architecture is shown in Figure 2. It consists of three processing blocks: 1) an analog to digital converter (ADC), 2) a digital signal processor (DSP), and 3) a digital to analog converter (DAC). The received analog signal band is directly digitized at the antenna output by the high speed analog to digital converter. This digitized signal samples are then forwarded to the digital signal processor. In the ideal software radio, all of the signal processing algorithms required to perform various functions such as tuning, filtering, equalization, demodulation, error detection, error correction, decoding, etc., are written in a high level or block based language then compiled to the target architecture of a general purpose digital signal processor. With this ideal software radio architecture, a single receiver could be reprogrammed to accommodate any broadcast standard or air interface simply just by updating software algorithm. Finally, demodulated and properly formatted data is sent to the digital to analog converter to generate the analog output. From the receiver side the RF from the antenna is converted down to an intermediate frequency by mixing or multiplying the incoming signal with the local oscillator. The IF is filtered and then mixed down to baseband signal. The baseband modulated signal is then demodulated to produce the analog signal, and the reverse functions are performed for the transmitter. The numbers of conversion stages rely upon the RF operating frequency, and theoretically it is also possible to add stages and push the operating frequency higher. The architecture pushes the analog conversion stage to as close as possible to the antenna, in this case prior to the power amplifier (PA) in the transmitter side and after the low noise amplifier (LNA) in the receiver side. The separation of carriers, uplink/downlink frequency conversion to baseband is performed by the digital processor or processing resource. Also, the channel coding and modulation are performed digitally by the same processing resources at baseband.

Software for the ideal architecture is in layered form so that the hardware is completely abstracted from the application software. A middle layer achieves this functionality by covering up the hardware elements into objects and providing services that allow the objects to communicate with each other thorough a standard interface. Middle layer covers the resource management, operating system, hardware drivers, and other non-application specific software. The combination of hardware and middle layer is generally termed as a framework.

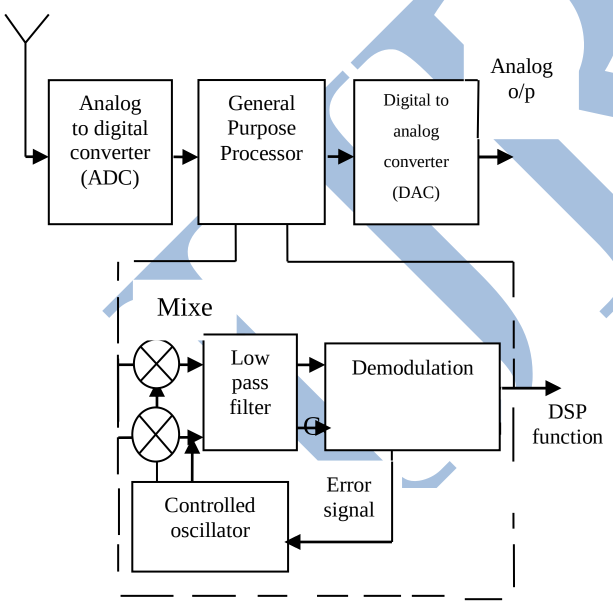

Fig 2: General System Architecture

III. DIGITAL MODULATION METHODS

Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal (high frequency signal), with a modulating signal that typically contains information to be transmitted. A process of modulation is done by the device known as modulator. There are three parameters of a radio signal requires to be change to produce modulation. A Demodulator is a device that performs demodulation, the inverse of modulation.

The aim of digital modulation is to transfer a digital bit stream over an analog band pass channel. For example, over the public switched telephone network or a limited radio frequency band.

The aim of analog modulation is to transfer an analog baseband or low pass signal. For example, audio signal [9].

The digital modulation techniques are based on keying:

- PSK(Phase Shift Keying)
- FSK(Frequency Shift Keying)
- ASK(Amplitude Shift Keying)
- QAM(Quadrature Amplitude Modulation)

PSK (Phase Shift Keying): In this modulation keying the data signal is modified by changing the phase of the information signal. The binary symbol 1 is represented by a phase change of the main information signal. To transmit 0, we change the phase again as shown in figure 3. PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase.

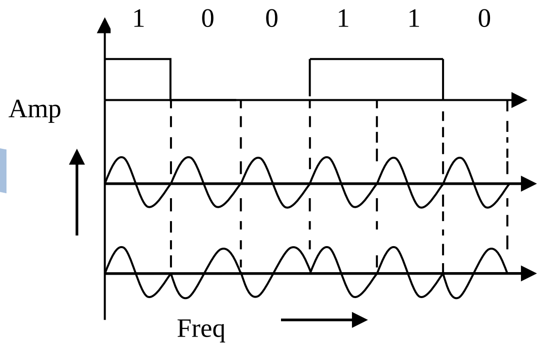

Fig.3: Phase Shift Keying

FSK (Frequency Shift Keying): In this modulation keying the frequency of the carrier is changed with respect to the information signal keeping all else as fixed.

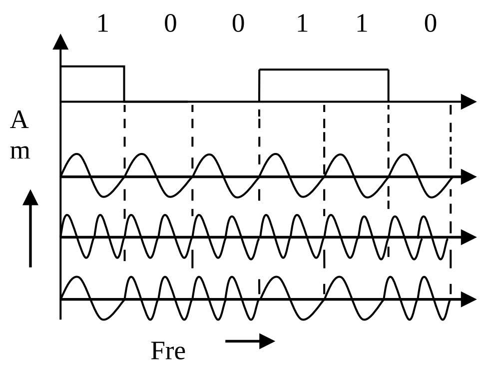

Fig.4: Frequency Shift Keying

The binary symbol 1 is represented by transmitting a fixed frequency carrier wave keeping the amplitude constant. To transmit 0, we change the frequency again keeping the amplitude constant as shown in figure 4.

ASK (Amplitude Shift Keying): In this modulation keying the amplitude of the carrier is changed with respect to the information signal keeping all else as fixed. The binary symbol 1 is represented by transmitting a fixed amplitude carrier wave keeping the frequency constant.

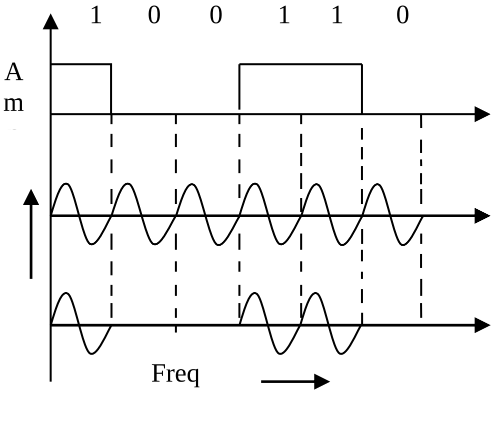

Fig.5: Amplitude Shift Keying

To transmit 0, we change the amplitude again keeping the frequency constant as shown in figure 5. One special form of ASK is On-Off keying (OOK), where one amplitude is kept zero

QAM (Quadrature Amplitude Modulation): In this modulation technique in which two sinusoidal carrier waves, one of them of exactly 90 degrees is out of phase with respect to the other one, are used to transmit over the channel. As the two carriers occupy the same frequency and differ by the phase shift of 90 degrees, each can be modulated separately.

Constellation: A constellation diagram is the representation of this digital modulation process in the form of phasor diagram or on the complex plane. The constellation diagram as shown in figure 6 represents the different positions for the different forms of quadrature amplitude modulation states. With the increase in the order of the modulation, the number of points on the QAM constellation also increases [10]. The diagram shown in figure is the constellation diagram of different positions for the different states within various forms of quadrature amplitude modulation. With the increase in modulation, the number of points on the QAM constellation Diagram also increases [11].

Bit rate and Baud rate: Baud rate means number of signal elements per second. Baud rate for different values of bit rate is different with different modulation techniques, which represents number of signal elements per second.

The table shows some examples of how baud rate gives different bit rates with different modulation techniques.

Modulation Technique	Baud Rate	Bit Rate
4 PSK	N	2N
8 PSK	N	3N
16 QAM	N	4N
32 QAM	N	5N
64 QAM	N	6N
128 QAM	N	7N
256 QAM	N	8N

Table 1: Baud Rate with different Bit rate with different Modulation Technique

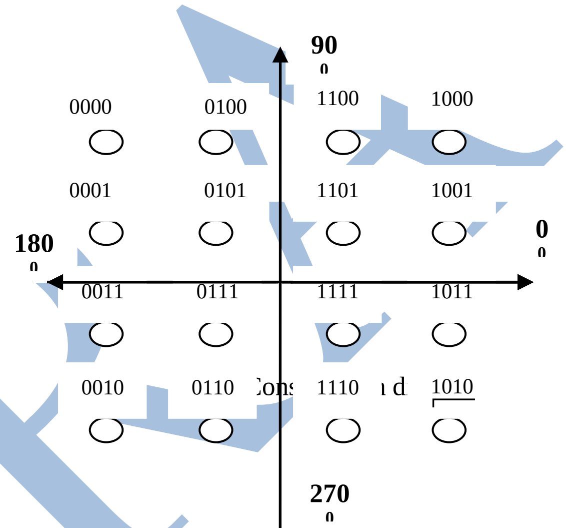

Fig.6: Constellation diagram

CONCLUSION:-

In this Paper Software Defined Radio is discussed for Wireless Applications like Wimax, 4G, DVB, GPS etc. The advantages of SDR include reduced component cost because hardware specific components are replaced by DSPs and FPGAs. The number of components tends to be lower. DSP components can compensate for problems in other areas of the system. SDR products are to a significant degree "future proof" and can be improved by a simple software upgrade only, with minimum equipment downtime. New features and functions can be added easily. SDR product is easier and cheaper to manufacture and maintain, hence it is typically considerably cheaper than a conventional product of comparable parameters.

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