Software Defined Radio Theoretical Analysis and Design Approach

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Abstract: **Now a days radio has become a common thing for every individual in the world. There has been many developments in radio after its invention in 1895 by Marconi. Particularly the concepts like cognitive radio and Software defined radio have been great advancements in communication. In this paper we will explore the inner working of software defined radio with an in depth description of its inner structure and working. We will also deal with the internal block diagrams of SDR transmitter and receiver. Imagine a radio in which most of the operations are software controlled, SDR brings this into reality by selecting modulation and demodulation frequencies using programmable devices like FPGA, DSP and ASIC. This SDR also provides signal enhancements (equalization) and filtering. Generally in Software Defined Radio every aspect of its operation is performed by controlling software. This paper on a whole gives an information regarding SDR transmitter and receiver.**

Keywords: **SDR, Digital Up Conversion, Digital Down Conversion, FGPA, Decimation, Interpolation**

1. INTRODUCTION

Software defined radio has revolutionized electronic systems for variety of applications including communication, data acquisition and signal processing. It is an emerging technology for processing radio signals by means of software Techniques. Todays mobile applications feature an abundance of radio standards with ever increasing bandwidth. This leads to a demand in both increased design productivity and flexibity after device deployment. Software techniques are considered as solutions to quickly design flexible mobile applications. This SDR is also called as ITS information transfer system that combines technology from the historically separated fields for computers and radio's. This technology has been emerged from a military application which has gained much attention among researchers and practitioners working in the communication field and it has been identified as one method to enhance the flexibility and usability of wireless communication systems.

In the past , the less operating speed of analog-digital converter and limited processing ability of reconfigurable chips for digital signal processing became a reason to slow down the development of SDR towards useful commercial applications. The advancements in semiconductor (FPGA) technology has made to increase the operating speed, which proved to be a major advancement for SDR in commercial applications. The main advantage of SDR is its ability to change operating characteristics such as operating frequency range, modulation, bandwidth , maximum power radiated Or conducted output power and network protocols by changing the software programs executing in processing resources. In SDR generally operating parameters are determined by software. The main advantage of the SDR is it allows effective spectrum usage by allowing equipment to be reprogrammed to more efficient modulation types. Simply we can define software defined radio as the radio in which some or all the physical layer functions are software defined.
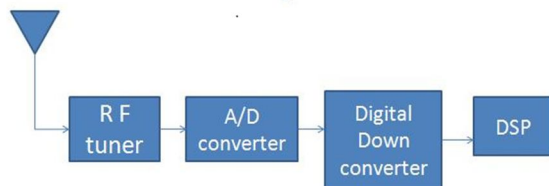
2. SDR RECEIVER

Generally for a normal analog radio receiver super heterodyne receiver is a perfect example. In this receiver first we will receive an RF signal from the antenna and it is amplified by RF amplifier and it is given to a mixer where down conversion takes place and the RF frequency is converted into Intermediate frequency IF frequency (down conversion)which depends on the modulation used.
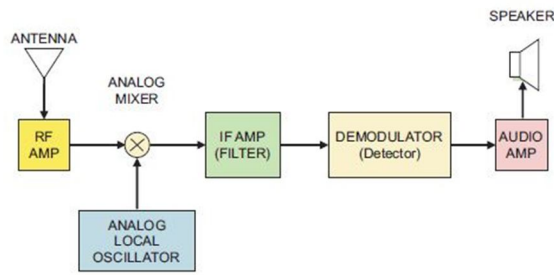
super heterodyne receiver

The signal is then fed to IF Amp which acts like a narrow band pass filter and it limits the bandwidth equal to the baseband signal that we are going to receive. This signal is demodulated to get the desired baseband signal. But in Software define radio we will use the digital IF signal for detecting the baseband signal . In SDR receiver the process will be same until the analog IF signal generation using mixer (RF tuner). After this IF signal is converted into IF samples using Analog to Digital converter. The reason for converting analog into Digital is the flexibility to choose the operating parameters like frequency and bandwidth by means of software techniques. These IF samples are converted into baseband samples by means of a process known as **Digital down conversion** .
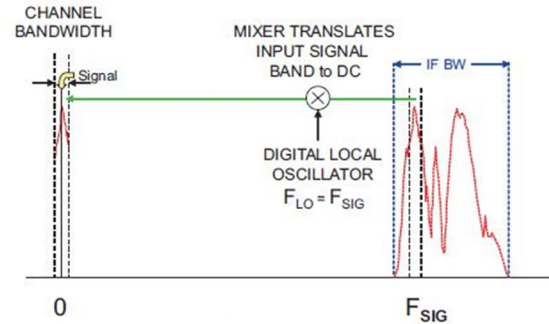

SDR receiver

2.1 Digital Down Conversion

This is the process in which the IF samples are converted into baseband samples by means of a digital mixer and oscillator. The reason for preferring converter over common filter is , It is difficult to extract particular band from a signal when sample rate is high. A Normal Filter can provide many malfunctions while detecting particular range of frequency at high data rate. By using Digital Down Converter (DDC)it is quite easy to extract particular band because DDC makes the frequency band of interest to be moved down the spectrum so the sampling rate can be reduced. DDC mainly consists of 3 parts. 1.digital mixer 2.digital oscillator and 3.FIR low pass filter. Digital mixer and local oscillator converts IF samples down to baseband. The FIR low pass filter limits the signal bandwidth and acts as decimating low pass filter. This down converter consists a lot of hardware including filters, adders and shift register memories to get the job done.. The DDC is typically a monolithic chip or FPGA IP, and it is an

important part of SDR. The digital baseband samples are fed to a DSP which performs tasks such as demodulation and decoding. Normally these functions are handled with specific IC's and programmable DSP's. Generally at the output of mixer high frequency wide band signals form the A/D converter input is translated down to DC as complex In phase and quadrature component which is equal to the local oscillator frequency.

Mixer translating signal to DC

This is quite similar to analog receiver except the mixing was done down to a IF frequency in analog receiver. The Local oscillator in the DDC uses a digital phase accumulator which switches between frequencies. So FSK signals are generated without any transients. The variations in frequency of Local oscillator is entirely dependent on A/D clock which is synchronous with the sampling frequency. After the translation or conversion it is fed into FIR filter. The FIR filter acts as a decimator which decrease the no of samples per second and this is purely based on nyquist criterion.
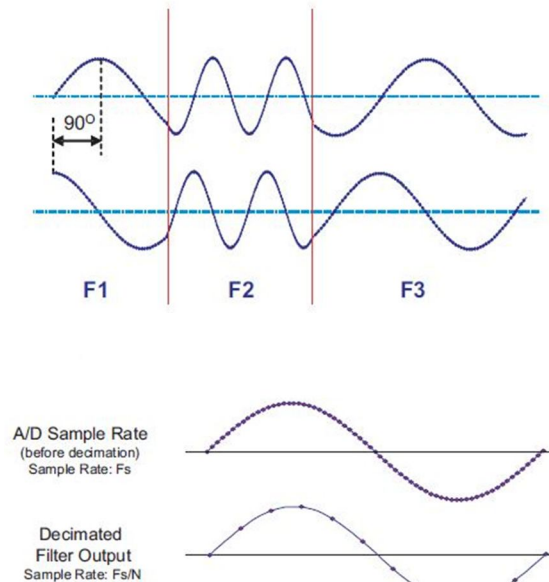

oscillator frequency and decimated output

The above fig shows the frequency switching, normal A/D sampling rate and decimated filter output where the decrease in frequency (or samples) is based on sampling rate in the A/D

converter. This process of decreasing samples is called decimation. If the decimated output rate is kept higher than the bandwidth of the output signal then no information is lost. The advantage of the decimated signal is it can be processed easily, can be sent at lower rate or stored in less memory. So precisely this Digital Down converter (monolithic chip) performs two functions

1. Frequency translation with the tuning controlled by the LO(local oscillator)
2. Low pass filtering with Bandwidth controlled by the Decimation

signal processing in DDC
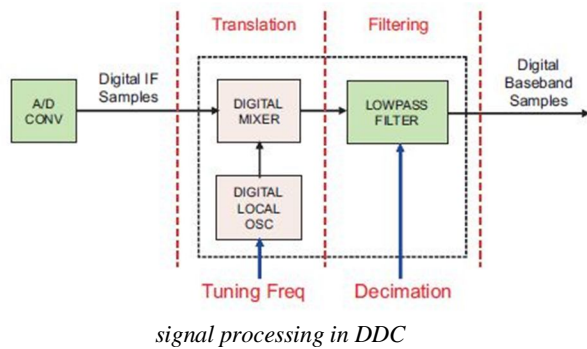
The two functions mentioned above are seen in the figure.

3. SDR TRANSMITTER

In the transmitter we will reverse the process that we have done in the transmitter. In this the baseband signal that we are going to transmit is given to the DSP processor which will generate the corresponding baseband samples based on the sampling rate given. These baseband samples are converted into IF samples by means of a procedure known as **Digital up conversion .** This translation is done by a digital up converter (DUC) and this consists of 3 parts 1.interpolation filter 2.digital mixer 3.digital oscillator. After conversion the digital IF samples are converted into analog IF samples using D/A converter and this sent into a RF converter which converts IF frequency to RF Frequency for transmission and then fed to the antenna.


SDR transmitter
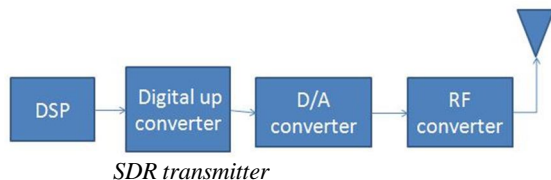
3.1Digital up Conversion

The digital up converter will converts digital baseband samples into digital IF samples . As mentioned it consists of an interpolation filter which will increase the no of samples per second and the mixer with local oscillator will complete

the translation. Inside the DUC the translation IF frequency is determined by the local oscillator.

The mixer generates one output sample for each of its two input samples and the sampling frequency at the output must be equal to the sampling rate of Digital to analog converter, which states that the local oscillator sampling rate and baseband sampling rate must be equal to the digital to analog converter sampling rate. The local oscillator is adjusted to have same sample rate as of digital to analog converter but the baseband sample will have a lesser sampling rate , and this problem will be rectified by a interpolation filer which will increase the sampling rate of digital baseband signal.
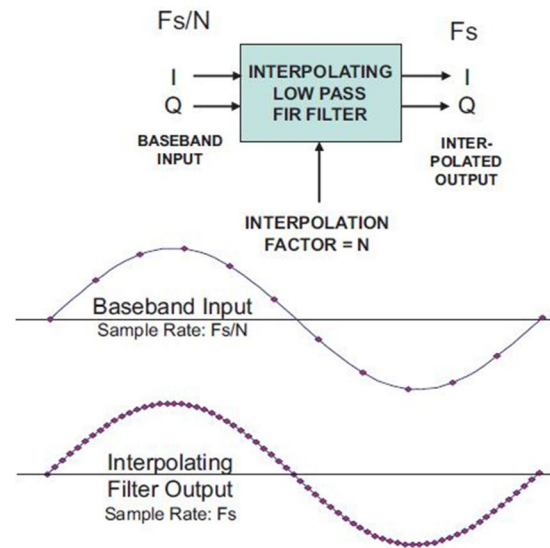
From the figure it is certainly evident that the operation performed by the interpolation filter is the inverse operation performed by the decimator. Then the two operations performed by the digital up converter is 1.Filtering and 2.Translation

DUC signal processing
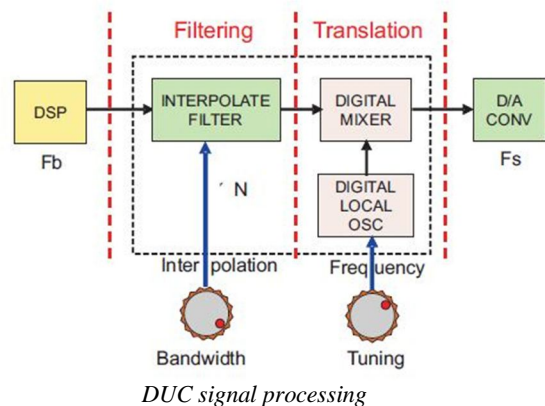
Lets say that the ratio between output sampling rate and the input baseband sample rate be N and this determines the interpolation factor. The bandwidth knob in the above figure the bandwidth knob shows the programmability of interpolation factor (say N) to select the desired input signal bandwidth. The

tuning knob represents the programmability of the local oscillator frequency to select the desired IF for translation from baseband.

4. MERITS AND DEMERITS

4.1 Merits:

SDR provides many advantages when it comes to the issues of constrained spectrum resources, increasingly swift changes in wireless standards and cost effective products .As the required technology has been matured we can see SDR delivering high bandwidth applications with a good quality of services. The major advantage is ,it is quite flexible and adaptable to system developers. It has many applications in network security and navigation also because of its robust nature.

4.2 Demerits

Design specifications are some what challenging when it comes to capture the minimum allowable signal. It is difficult to translate high sampling rates.

5. FUTURE TRENDS

5.1 future trends

The first generation of SDR is developed in the year 2004. Due to the developments in technology, there has been significant improvements in signal processing, connectivity ,and in the quality of RF components such as mixers and data converters. With current scenario it is possible to implement most narrow band communication though not without effort and expertise. In recent years there has been development towards wide band solutions such as WCDMA and OFDM technologies. The SDR platforms are challenged by increasing bandwidth, reducing minimum signal strengths and reducing maximum allowable vector magnitudes.

5.2 Design issues

The primary parameter of interest for the design is receiver sensitivity, receiver noise figure ,transmitter power levels , and transmitter phase noise. These parameters determine the blocking performance of receiver. The GSM standards presents the most challenging requirement as it requires a successful reception of -104dBm

Signal in the base station, -102dBm for the GSM/GPRS hand set in the presence of a 0dBm blocker. To capture the smallest required signal in Presence of blocker we need to have a analog to digital converter with dynamic range of over 106dBm. These are some of the design issues faced by SDR in different frequency ranges.

6. CONCLUSION

Software defined radio has offered many compelling benefits to the radio system designers , but the only open question is how to effectively implement and manage flexibility in a wireless system. Software radio platforms offer researchers and developers the ability to develop their applications in advance of designing customized hardware. Finally software defined radio is very helpful in terms of operating parameters (band width), and this will become a great tool in communications with the help of developing technology in coming years.

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8. BIOGRAPHY

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