Design of Triple–Mode Digital Down Converter for WCDMA, CDMA2000 and GSM of Software Defined Radio

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***Abstract*— Software-Defined Radio (SDR) is a rapidly evolving technology. SDR have been widely studied as a solution to support multiple competing and in compatible air interface standard in future wireless communications.**

In this paper, we present the design of a Digital Down Converter (DDC) module for triple-mode WCDMA, CDMA2000 and GSM. The designed module consists of digital mixer, CIC filter, and decimation filter and frequency converter. Theses sub-modules are software reconfigured in architecture to be compatible with WCDMA, CDMA2000 and GSM. The design is software configured with minimum hardware and maximum operating speed.

***Index Terms*— Software-Defined Radio (SDR), digital down converter, triple-mode, WCDMA, CDMA2000, GSM.**

I. Introduction

Software-Defined Radio provides software control for a variety of modulation techniques, wide-band or narrow-band operation. The advantages of SDR system over traditional wireless communication systems are flexibility and allowing multiple communication protocols to dynamically execute on the same hardware, thereby reducing the cost. Specific functions such as filters, modulation schemes, encoders/decoders, etc., can be reconfigured adaptively at run time [1]. This significantly reduces the cost of the system for both the end user and the service provider.

The basic idea behind the software radio is that the A/D converter is moved as closed as possible to the antenna and most functions are realized by digital signal processing. Hence the A/D converter operates on a very high sampling rate. The IF processing corresponding to a wide range of frequency bands plays a very important role in software radio [2].

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II. Digital Radio Receiver

The main idea of the digital radio receiver is to convert radio frequency (RF) signal into digital base-band signal .It can perform in three stages; convert RF signal into IF signal , digitized IF signal and demodulated IF signal to base-band signal. Fig. 1 illustrates the general structure of Digital radio receiver. RF signal amplifying by passing through RF amplifier, IF translator translate RF signal into Intermediating Frequency (IF) signal. Then IF signal is digitized by using analog-to-digital converter (ADC). Digital IF signal multiplied by digital Cosine and Sine to translate IF signal into base-band signal. Low Pass Filter (LPF) pass only base-band signal and reject pass-band signals. Base-band signal down sampled to decrease sampling rate into an original sampling rate. Base-band processing used to extract the original signal as Channel Equalizer, De-interleaver, Channel Decoder,etc.

III. Proposed Triple mode receiver

The idea of the triple-mode receiver is to define and realize practical software radio architecture capable of handling GSM, CDMA2000 and WCDMA modes. These modes share a common IF front-end and can be switched to each other by software reconfiguration.

The input bandwidth of IF signal is 5MHz centered at 69.12 MHz (IF signal), which covers one WCDMA channel. And sampling rates are chosen to be 30.72MHz for GSM, CDMA2000 and WCDMA. The desired IF spectral component is translated to 7.68 MHz.

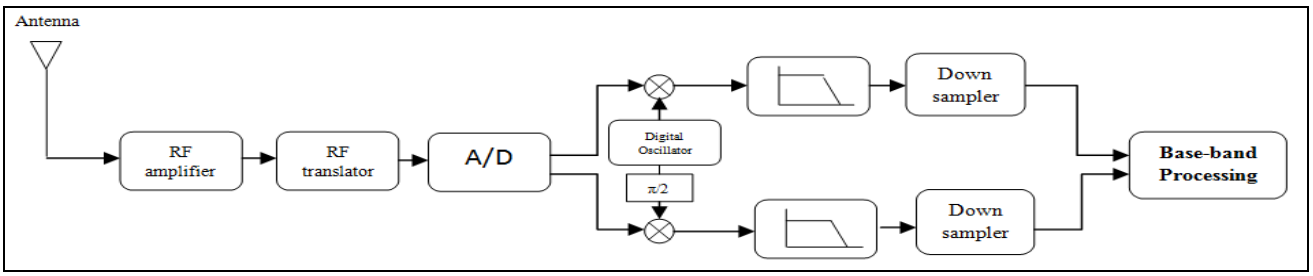

Fig.1 Digital Radio Receiver Block Diagram

Table 1 illustrates the Specification of GSM, CDMA2000 and WCDMA.

Table 1
Specification of GSM, CDMA2000 and WCDMA.

	GSM	CDMA2000	WCDMA
Channel spacing	200 KHz	1.25 MHz	5 MHz
Transmission bit rate	270.833 Kbps	1.2288 Mcps	3.84 cps

IV. IF Processing

After A/D conversion, the digital IF signal will be further converted to base-band by a digital mixer. To simplify the hardware complexity, the carrier frequency f_{IF} is chosen to be an odd multiple of a quarter of the sampling frequency as given in Eq. (1). Thus, the mixer can be performed by multiplying the input signal with the sequences [0 1 0 -1 …] and [1 0 -1 0 …] being digital representations of the sine and cosine signals at a quarter of the sampling frequency.

$$f_{IF} = \frac{n}{4} fs \, , n = 1,3,5, \ldots .. \quad (1)$$

Then the desired channels will be extracted from the 5MHz wide-band signal, this is realized by filtering [3].

A. GSM processing:

The purpose of this stage is to extract the 200 kHz bandwidth from the 5 MHz received signal and decrease sampling rate to original GSM sampling rate 270.0833 Kbps [5].

The over-sampled data are down-sampled by 64 and fractional down conversion by 576/325 to make 270.0833 Kbps GSM sampling rate. To satisfy the GSM requirement, a compensation FIR filter is used to attenuate the block signal at 200 kHz.

B. CDMA2000 processing:

The purpose of this stage is to extract the 1.25 MHz bandwidth from the 5 MHz received signal and decrease sampling rate to 4.9152 MHz it's a four times CDMA2000 chip rate 1.2288 Mcps [3].

The over-sampled data are down-sampled by 50 and up-sampled by 8 to make 4.9152 MHz. To satisfy the CDMA2000 requirement, a compensation FIR filter is used to attenuate the block signal at 1.25MHz.

C. WCDMA Processing:

The purpose of this stage is to decrease over-sampled data rate to WCDMA sampled data rate 3.84 Mcps.

The over-sampled data rate is down-sampled by 2 to make 15.36 Mcps it's a four times WCDMA chip rate 1.2288 Mcps [4],[7].To satisfy the WCDMA requirement, the pulse shaping matched filer is a 48-tap root raised cosine filter with roll-off factor of 0.22 is used.

V. CIC filter

The cascaded-integrator-comb (CIC) filter easily facilitates the implementation of high order and high sample rate digital filters. The CIC filter is widely used as the initial decimation filter due to its simplicity which requires no multiplication or coefficient storage [2], [6]. The net effect of the CIC filter is the attenuation of aliasing components. Note that the up and down sampling makes these filters time variant.

The two basic building blocks of a CIC filter are an integrator and a comb. An integrator is simply a single-pole IIR filter with a unity feedback coefficient.

The frequency response of the CIC filter can be expressed in closed form as shown in Eq. (2).

$$s(f) = \left[\frac{\sin \pi f}{\sin \frac{\pi f}{R}}\right]^{2N} \quad (2)$$

Where: N: CIC filter order.
R: down-sampling rate.

Used N=5 and R=32 for the GSM processing and R=25 for the CDMA2000 processing. Fig.2 shows the architecture of the fifth order decimating CIC filter.

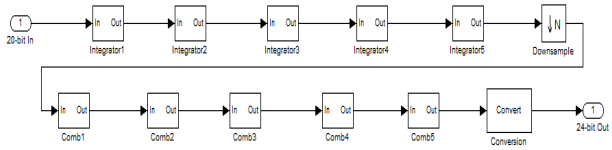

Fig.2 Architecture of CIC filters

Fig.3 illustrates the architecture of triple mode digital down converter.

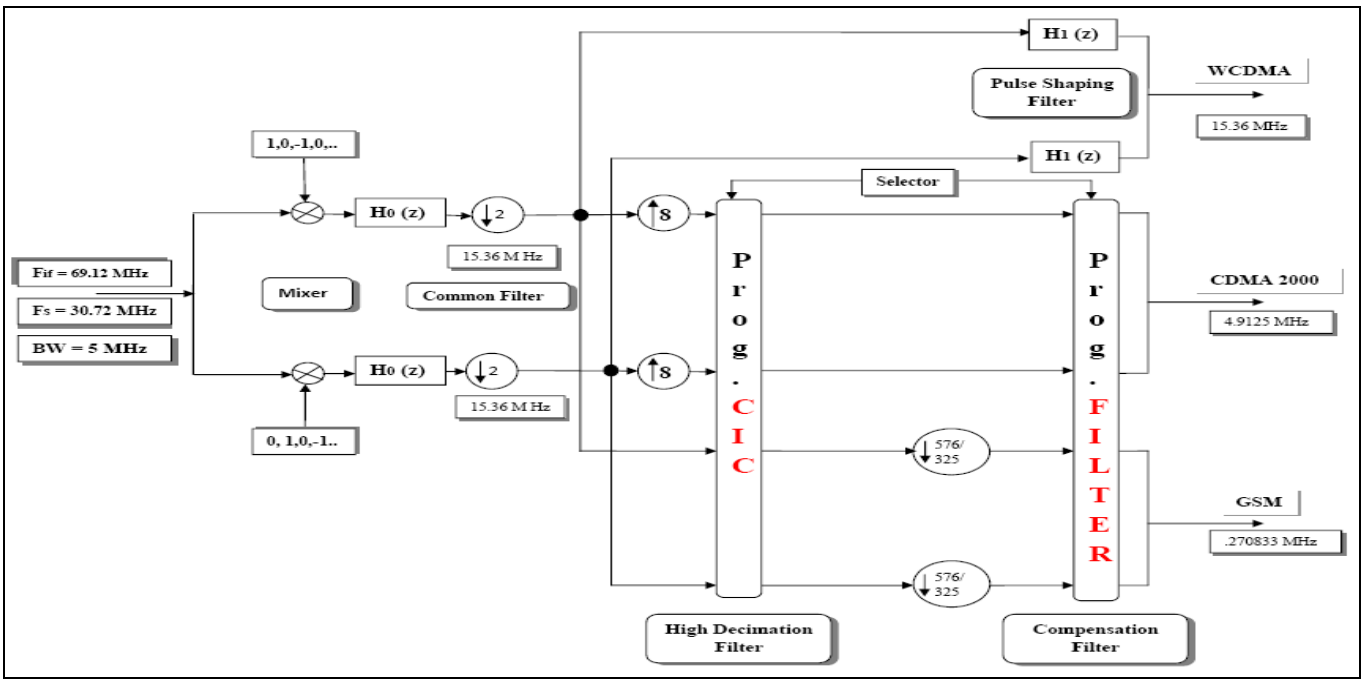

Fig.3 architecture of triple-mode DDC

We have used a common fifth order decimating programmable CIC filter for GSM and CDMA2000 which chose a down sampling rate according to processing mode.

We have used a Common tenth order programmable compensation filter GSM and CDMA2000 which coefficient uploaded according to processing mode.

VI. Raised Cosine filter

A raised cosine filter is designed for pulse shaping filter. Fig. 4 shows the frequency response of the raised cosine filter with different orders. Note that 25-order raised cosine filter has 40 dB attenuation at 5 MHz which meets the WCDMA specification.

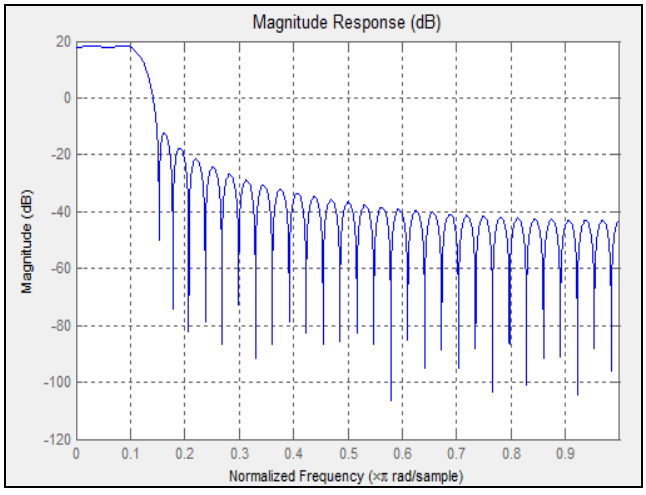

Fig.4 Response of Raised Cosine filters

VII .System Integration

The triple mode system has been integrated and simulated using Matlab Simulink. The simulation results are shown in fig.5 to fig. 9. Fig. 5 shows the spectrum of IF input signal centered at 69.12MHz. Fig.6 shows the same signal after sub-sampling at a rate = 30.72MHz. As shown in fig.3 the signal is multiplied by sine and cosine of quarter sampling rate. The resulted signal is applied to the WCDMA module to produce the waveform shown in fig.7. The same signal is applied to both CDMA2000 and GSM modules and produced the waveform shown in fig.8 and fig.9. Each signal in the last three figures is presented in the corresponding bandwidth and sampling rate. In Matlab, switching among the different modes is done manually, while in real life this will be done using a configuration packet.

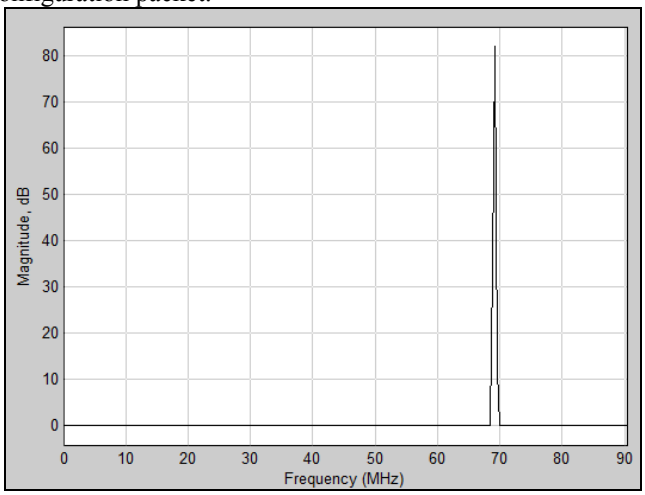

Fig.5 Spectrum of IF signal (69.12MHz)

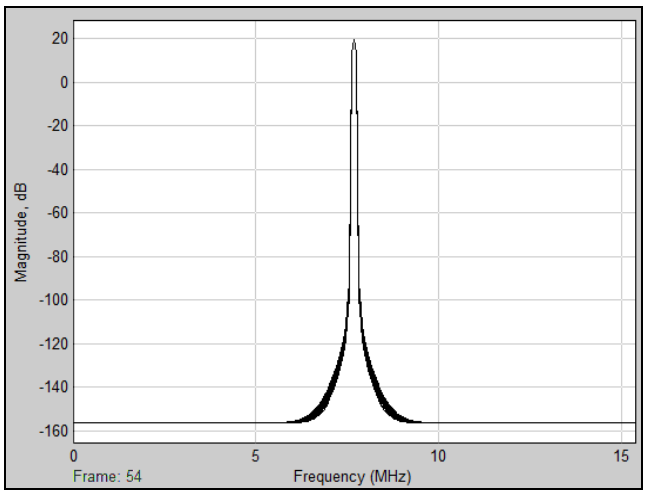

Fig.6 Spectrum of IF signal after Sub-sampling (7.68 MHz)

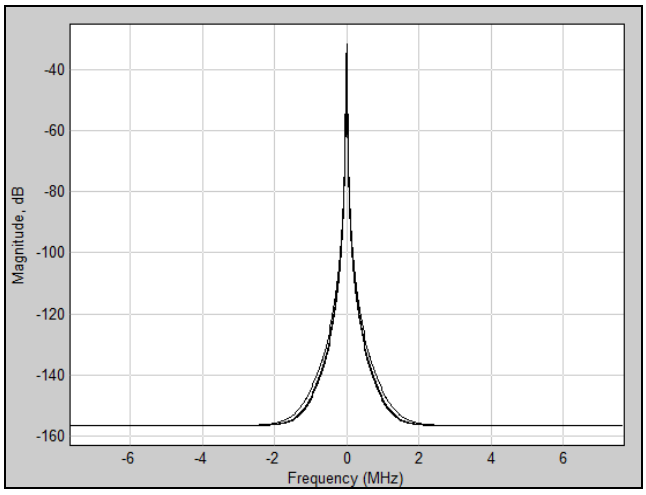

Fig.7 Spectrum of WCDMA Baseband.

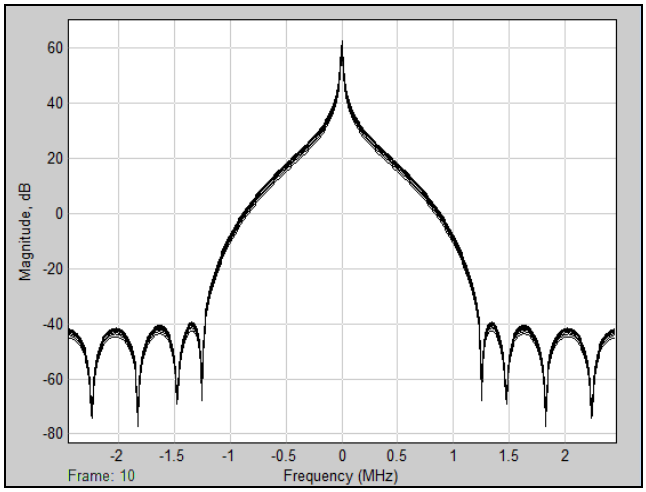

Fig.8 Spectrum of CDMA2000 Baseband

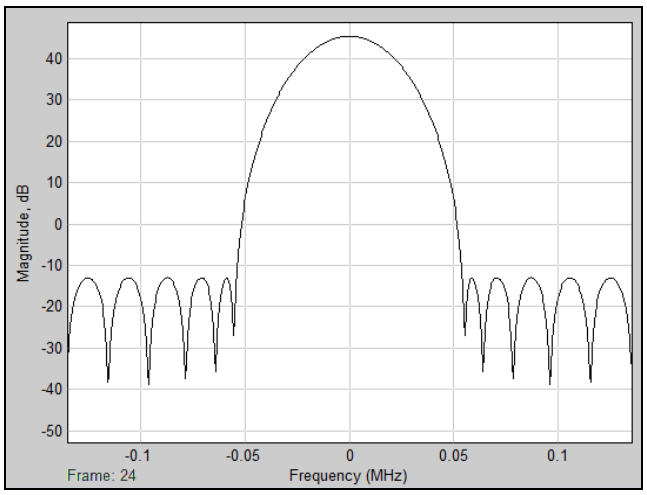

Fig.9 Spectrum of GSM Baseband

VIII. CONCLUSION

In this paper, the design of a Triple-mode DDC supporting mobile telecommunication standards for WCDMA, CDMA2000 and GSM were presented. A sub-sampled digital IF stage was proposed to support WCDMA, CDMA2000 and GSM while lowering the sampling frequency. Use of a programmable CIC filter and programmable filter blocks resulted in optimized hardware when implementing the system on an FPGA.

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