Channel Filter Design Simulation for Wimax Digital up Converter

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Abstract*- In this paper a pulse shaping filter called channel filter is designed for digital up converter (DUC) block in WIMAX IEEE 802.6e standard. The requirement of the pulse shaping filter arises from two reasons one being generation of band limited channels and another reduction in interference. The pulse shaping filter used here is a root raised cosine filter (RRC) as it fulfils the conflicting requirement of communication systems. Design simulation and analysis is done using MATLAB with two windows namely Kaiser and Bartlett. A comparison is performed between their magnitude responses and implementation cost. From comparative analysis of results it can be observed that usage of Bartlett window with RRC technique has resulted in reduced cost due to less number of multipliers and adders requirements as compared to Kaiser Window.*

Keywords- *WIMAX, DUC, DDC, ISI, MATLAB, RRC, OFDMA.*

I. Introduction

The wireless communication systems have a major role and key features of assuring anytime anywhere the possibility of communication with others. The various wireless standards available today provides high data rates, improved range, good quality of service that assures an optimal scheduling of space, frequency and time. **WiMAX**- worldwide interoperability for microwave access is a wireless communication system for delivering broadband access services and to replace for DSL, cable or for network backhaul. The WiMAX standard used is designed to support scalable orthogonal frequency division multiple access (OFDMA) with the operating bandwidth of 10MHz [1].The key concept of OFDMA is that the sub carriers can overlap in a manner to avoid cross talk, achieved by making sub carriers orthogonal to each other. As a result, data can be sent by different users increasing bandwidth and reducing interference [2]. The name "WiMAX" was given by wimax forum that describes it as standards- based technology enabled the accessibility of last mile wireless broadband access as an alternative to previous standards [3]. WiMAX basically refers to interoperability implementing the IEEE 802.16 family of wireless network standards ratified by wimax forum. WiMAX is sometimes referred to as "Wi-Fi on steroids" and can be used for a number of applications including broadband connections, cellular backhaul, hotspot, smart grids and metering etc, it is similar to Wi-Fi but enables usage at much higher distances. It directly supports the technologies that offer triple-play services such as quality of service and multicasting these are inherent to wimax standards rather than being added to t separately. Devices that provide connectivity to WiMAX network are known as subscriber stations (SS), portable units include handsets (smart phones), PC peripherals, devices embedded in laptops etc. **The IEEE 802.16 Standard –** wimax is based upon IEEE Std 802.16e-2005[4] approved in December 2005 it is a supplement to the previous std 802.16-2004 that was amended to reach the new one. There are various improvements of 802.16e-2005 above 802.16-2004 that are-

1. The new standard added support for mobility (soft and hard handoff between base stations) that is one of the most important aspect of it and most basic of Mobile WiMAX.
2. Scaling of the fast Fourier transform to the channel bandwidth is done so as to keep the spacing between the carrier's constant across different bandwidths (typically 1.25 MHz, 5MHz, and 10MHz), constant spacing of carrier results in a highly efficient spectrum in wide channels and reduction in cost in narrow channels called as scalable OFDMA (SOFDMA). Other bands not multiples of 1.25MHz are defined in the standards but because the FFT subcarrier numbers are only 128,512,1024, 2048 other frequency bands might not have the same spacing that is optimal for the required implementations .
3. Adaptive antenna systems/ diversity schemes MIMO technology, hybrid automatic repeat- request (HARQ), low density parity check (LDPC).
4. Introducing downlink sub channelization, adding an extra quality of service for VoIP services.

SOFDMA (used in 802.16e-2005) and OFDM256 (802.16d) are not compatible hence the equipment installations vary.

The physical layer for WiMAX base stations includes – MAC/PHY interface, bit level processing, OFDMA symbol level processing, digital IF processing. The original versions of it specified a physical layer operating in range of 10 – 66GHz, more advanced versions including 802.16e also bring multiple antenna support through MIMO giving potential benefits in terms of coverage, self installation, power consumption, bandwidth efficiency and frequency reuse. Wimax is most energy efficient pre 4G techniques among LTE and HSPA+ by employing a scheduling algorithm for which the subscriber station needs to compete just once to make entry inside the network after that it is allocated an access slot by base station implying that it remains stable even in cases of overload.

II. PULSE SHAPING FILTERS

In electronics and telecommunications, pulse shaping is the process of changing the waveform of the pulses that are transmitted. Its requirement is to make the transmitted signal better suited for communication channel, typically by limiting the effective bandwidth for transmission. In this way by filtration of the transmitted pulses the interference level between the symbols can be kept under control. In RF communication it is necessary for making the signal to get fit into the frequency band. Thus bandwidth limited systems often employ pulse shaping techniques that allow for bandwidth contaminant while minimizing the likelihood of errors at the receiver. Typically pulse shaping occurs after line coding and modulation [5]. Before the availability of digital filters pulse shaping was done with analog filters but the response generated by these is affected by variations in values of components due to aging, temperature and specified tolerance ranges. In contrast the response of a digital filter is solely dependent on coefficients which are invariant to both aging and temperature. Therefore digital pulse shaping filters have become integral part of many digital data transmission systems. The consequence of pulse shaping is that it leads to distortion of shape of the original rectangular pulse into a smoothly rounded pulse with damped oscillations before and after +- ½ T points. The ripples occur due to convolution of rectangular pulse with raised cosine pulse response. Although digital filters typically produced a desired frequency domain response, they actually perform the filtering task in time domain. That is the impulse response is defined by coefficients of digital filter which produces the desired frequency response. Thus the task of digital filter designing is simplified to the knowledge of impulse response rather that frequency response.

The two requirements for wireless communication that demands use of pulse shaping filter being reduction in **a) intersymbol interference and b) band limited channels**. A sinc function meets both these conditions as it effectively utilizes the frequency domain to use a smaller portion of frequency domain and because of the windowing effect that it has on each symbol period of modulated signal [6]. The sinc function has a periodic nature and the maximum amplitude in the middle of symbol time. In frequency domain its appearance is square wave thus simplifying to limit the channels to a specific frequency range.

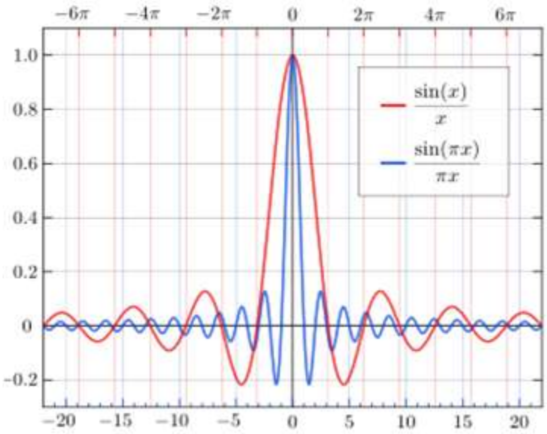

Fig.1. The normalized (blue) and unnormalized (red) sinc functions [7]

A. Reduction in Bandwidth of Channel

Basically when we modulate the carrier sinusoidal signal it leads to constant variation s in its amplitude and phase characteristic values. These variations of phase and amplitude occur at every two periods of carrier that is sharp transitions occur in absence of filter [8].

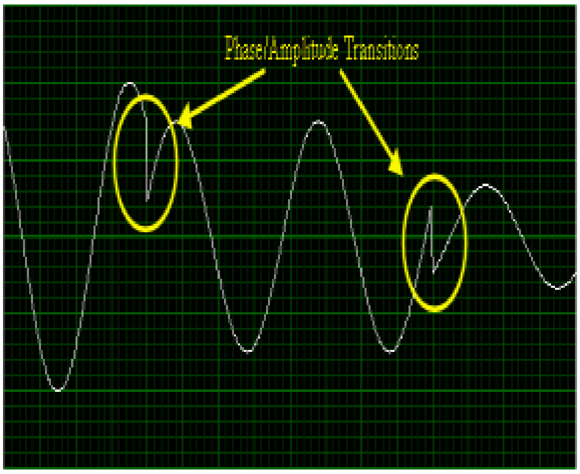

Fig2. Phase and Amplitude Transitions in an Unfiltered Modulated Signal[8]

These sharp transitions leads to high frequency components in frequency domain and its graph in frequency domain would represent significant amount of power outside the bandwidth that we need go limited for various reasons in a communication system. By the application of pulse shaping filter the sharp transitions are smoothened out and limited to the frequency range as required [7].

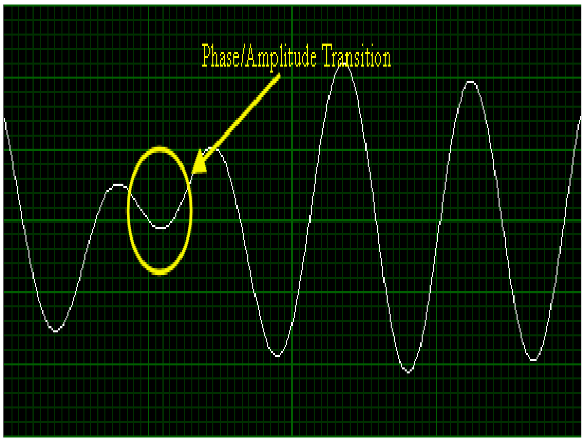

Figure 3- Smoothened response in the filtered signal [8]

The above process shows the smoothened transitions that are achieved with the application of the filter and thus limiting the maximum amount of power to a specific bandwidth.

B. ISI and its Reduction-

In telecommunications ISI is a form of distortion of a signal in which one symbol interfere with subsequent symbols. This is an unwanted phenomenon as symbols add the effects of noise and thus making communication less secure. This interference occurs due to mixing of one pulse with other due to its spreading in frequency [9]. It is usually caused by non linear frequency response of channel causing successive symbols to blur or due to multipath propagation. This introduces errors in the decision device at the output since due to mixing the correct sequence could not be determined. Thus the aim is to reduce it so as to reduce the error probability in the received signal this can be done by adaptive equalization or error correcting codes.

a) Multipath Propagation – In this reason a wireless signal from a transmitter reaches the receiver via many different paths. The causes of this include reflection, refraction, atmospheric effects such as ducting, ionosphere reflection. All the paths are of different lengths, thus signal arising at the receiver also varies leading to delays since they have different velocities and results in spreading and interference also changing the amplitude and phase of original signal.

b) Band limited channel – where one frequency response is zero above certain frequency, any signal passed through such leads to removal of frequency components above the cut-off frequency, components below this are attenuated. Such channels are present both in wired and wireless communications and leads to spreading of signal and distortion also.

C. Countering ISI-

a) Separation of signals in time using guard periods.
b) Designing systems such that impulse response is short enough that very little energy from one symbol mixes to the second.
c) Receiver equipped with an equalizer that attempts to undo the effect of channel by applying an inverse filter.
d) Applying a sequence detector at receiver that makes an estimation of transmitted signal using Viterbi algorithm.

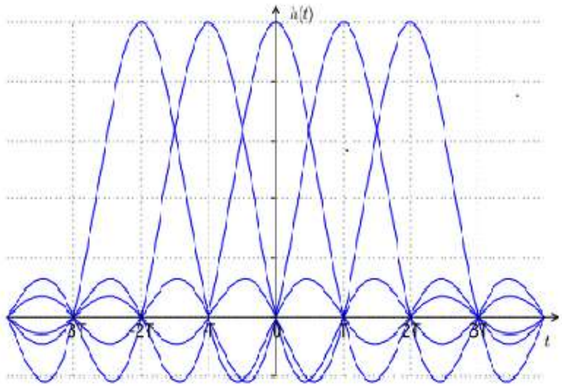

Fig 4- Raised cosine impulse showing zero ISI property [7]

III. ROOT RAISED COSINE FILTER

Use of RRC filtering is adopted in commercial communications such as cellular technology, space communication. RRC provides both the higher data rates while decreasing the number of channels. Using 90% power bandwidth RRC filtering is capable of improving spectral efficiency more than 75% also leads to improved BER performances. For an ideal low pass filter – it has zero ISI, narrow bandwidth channel both of which are physically not realizable and difficult to approach. Then came the solution of raised cosine (RC) filters, shown by Nyquist that if the frequency characteristic has odd symmetry at cut off frequency, the impulse response will contain zeroes at uniformly spaced intervals [10]. This was much easier to attain, function value is-

$$H(f) = \begin{cases} T, & |f| \leq \frac{1-\beta}{2T} \\ \frac{T}{2}\left[1+\cos\left(\frac{\pi T}{\beta}|f| - \frac{1-\beta}{2T}\right)\right], & \frac{1-\beta}{2T} < |f| \leq \frac{1+\beta}{2} \\ 0, & \text{otherwise} \end{cases} \qquad (1)$$

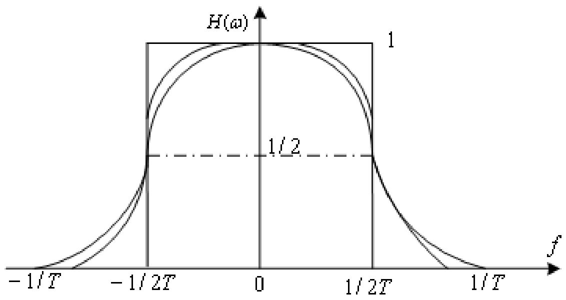

Figure 5- Frequency response of RC filter

Impulse response-

$$h(t) = sinc(t|T)\frac{cos\left(\frac{\pi\beta t}{T}\right)}{1-\frac{4\beta^2 t^2}{T^2}}$$

(2)

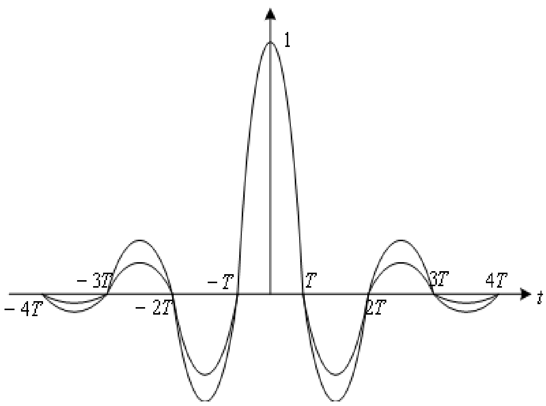

Figure 6- Impulse response of RC filter

The addition term $\frac{cos\left(\frac{\pi\beta t}{T}\right)}{1-\frac{4\beta^2 t^2}{T^2}}$ decays in time and hence reduces the trails and impact of jitter.

Another way of achieving raised cosine transfer function for overall channel is to take root of raised cosine filter in frequency domain and use this new filter in transmitter and receiver.

$$\sqrt{H\ (\omega_\pi)}\ =\ \sqrt{\frac{1}{2}\ (1 + \cos \pi\omega/2\omega_c}$$

(3)

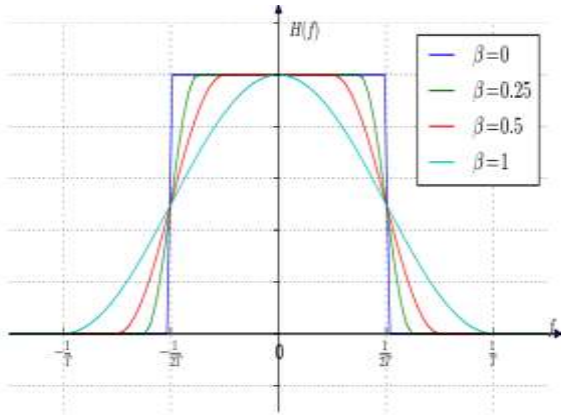

Figure- 7 RRC Filter Response

IV. Digital Up Converter

DUC's and DDC's are widely used in communication systems for converting the sample rate of signals and are important components of every modern wireless base station design. DUC are typically used in transmitters to filter, up sample and modulate the signal from baseband to carrier frequency whereas DDC performs the reverse operation demodulate, down sample and filter so that further processing on received signal can be done at low sampling frequencies [11].

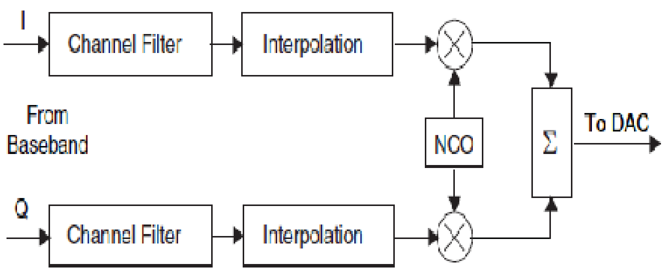

Figure 8- DUC Block Diagram [1]

DUC provides the link between the digital baseband and analog RF front end and is required on the transmitter of a generic transceiver.

DDC provides the link between the analog RF front end and the digital baseband of a receiver. The data is demodulated from the high frequency carrier and subsequently the sampling frequency of the data stream is reduced. The data stream is then compatible with the baseband modem [1].

For this DUC reference design, the sampling rate specifications are:

Baseband: 11.424 million samples per second (MSPS)

IF: 91.392 MSPS

Hence there is a total interpolation factor of 8.

The algorithm consists of three:-

1. Channel Filter – Applies pulse shaping to ensure that the spectral mask and restrictions imposed by the regulatory body are maintained.
2. Interpolation – The sampling frequency of the baseband samples are increased. Filtering is required to mask spectral images that appear as part of the interpolation process. Thus every interpolation block consists of a DUC followed by a filter.
3. Mixer/Combiner – A numerically controlled oscillator (NCO) generates two orthogonal sinusoids at the carrier frequency and these are mixed with the I and Q streams taken as inputs to two channel filters. Finally the outputs of the mixers are added together before being passed on to the digital-to analog converter (DAC).

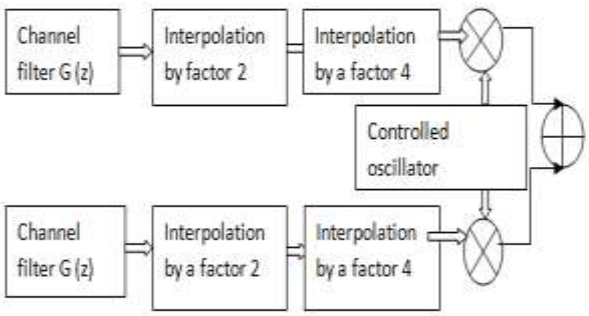

Figure9 - DUC Multistage Design [1]

DUC has two basic components for pulse shaping which is provided by SR(single rate) FIR filter and interpolation conversion ratio for WIMAX is 8 that is followed in two stages of L=2 and L=4 making total 8. For WIMAX sampling rate of input baseband signal is 11.2MSPS and this signal has to up sample by 8 to attain IF frequency of 89.6Msps [12].

V. PROPOSED DESIGN SIMULATION

A raised cosine filter is used here for designing of channel filter G(z) that is used for pulse shaping the two inputs that are I and Q channels basically. These filters are being used in front of interpolators that increase the sampling rate. There are many techniques available but we have here used RRC along with two windows Kaiser and Bartlett and a comparison of their magnitude and impulse responses is shown using MATLAB. The two channels given as input to the RRC are applied at the sampling frequency of 11.424MBPS, number of taps used are 111, rate change factor L is 1, intermediate frequency 91.392msps at the bandwidth of 10MHz.

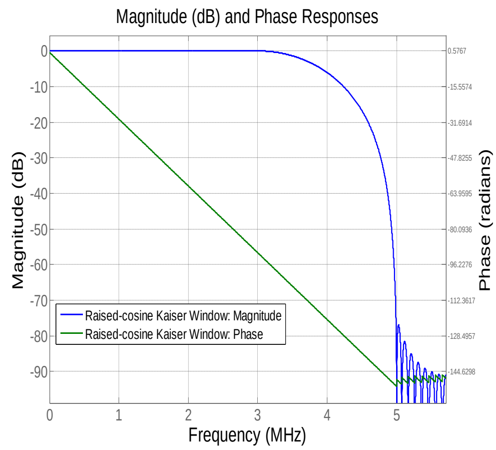

Fig 10. Magnitude and phase response of Kaiser Window

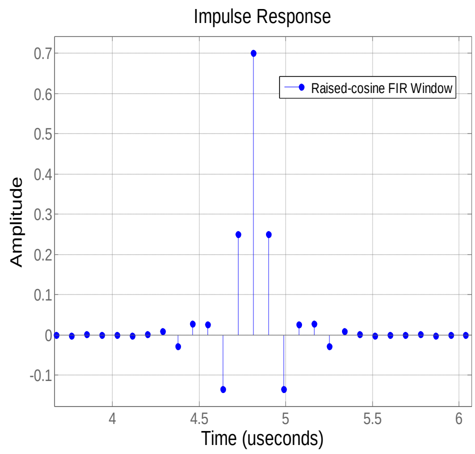

Fig11. Impulse response of Kaiser window

Figure 10 shows magnitude and phase response of Kaiser Window. There are attenuations in the stop band and the phase is linear in pass band . Transition bandwidth is of 1MHz. Figure 11 shows impulse response of Kaiser Window.

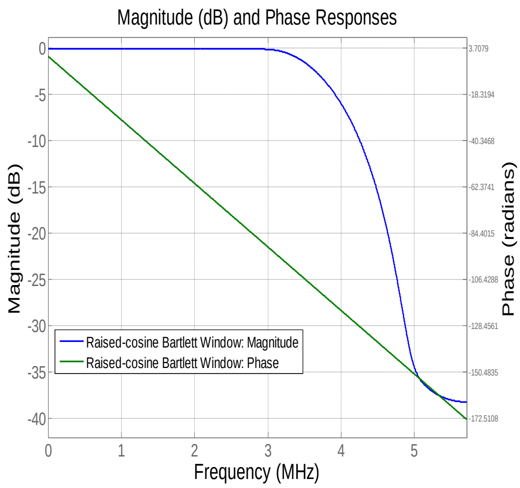

Fig 12. Magnitude and phase response of Bartlett window

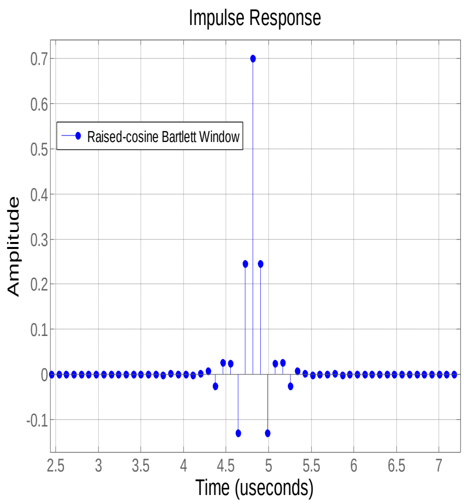

Fig 13. Impulse response of Bartlett window

Figure 12 shows the magnitude and phase response of Bartlett window. Phase response is linear in both in passband and stopband. Magnitude response has no stopband ripples. It has large transition width.

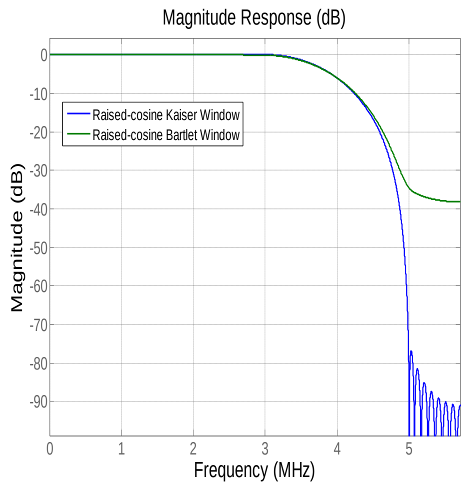

Fig-14 Magnitude response of Kaiser and Bartlett

The above figure shows the magnitude comparison between the Kaiser and Bartlett filters using RRC.

VI. TABLE I
IMPLEMENTATION COST

S. No	Features	Kaiser window	Bartlett window
1	Number of Multipliers	111	109
2	Number of adders	110	108
3	Number of states	110	110
4	Multiplications per input sample	111	109
5	Additions per input sample	110	108

VII. CONCLUSIONS

In this paper, a 111 Tap RRC Pulse Shaping filter has been presented with 0.5 roll off factor at a sampling frequency of 11.424 for up sampler DUC for the wimax application. The DUC filter has been implemented using RRC filter with Kaiser and Bartlett window. The cost of implementation is evaluated and compared on the basis of number of multipliers and adders used in the coefficient calculation. Analysis shows that the Bartlett window is much cost efficient as it has less number of multipliers and adders used than that of Kaiser approach. Also a comparison of magnitude response has been done among the two windows showing the presence of stopband ripples in Kaiser Window and are absent in Bartlett window. Whereas the Bartlett window has a large transition width compared to Kaiser. Thus we conclude that Bartlett window is more efficient on basis of implementation cost and less number of errors on basis of absence of stopband ripples.

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