DECIMATION FILTER DESIGN AND NOISE ANALYSIS FOR MULTISTANDARD WIRELESS COMMUNICATION

Pooja Bande

***Abstract*—** In this paper, decimation filter is designed for communication standard namely 4G-LTE and further did noise analysis for seven communication standard includes GSM, WCDMA, WLANa, WLANb, WLANg , WiMAX and 4G-LTE. Decimation filter design for all communication standards is developed in matlab using guide environment. Noise exist in all communication system, noise can also be generated internally as a result of inter symbol interference (ISI), intercarrier interference (ICI) and intermodulation distortion (IMD). These source of noise decrease the signal to noise ratio (SNR) which limits the spectral efficiency of the system. It is therefore important to study the effect of noise on the bit error rate. For noise analysis, noise is added to the input sequence of decimation filter of orthogonal frequency division multiplexing (OFDM) receiver for all communication standard. Here, noise signal added with the help of AWGN channel and OFDM in the system. Output graph shows the graph between bit error rates Vs signal to noise ratio (SNR) for all communication standards, High signal to noise ratio means input signal is less corrupted by noise and with the help of decimation filter design, user can perform quick design and analysis of decimation filter for all standard without extensive calculation.

***Index Terms* –** Multistandard Communication Receiver, Sigma Delta analog to Digital converter, OFDM system.

I. INTRODUCTION

Recently, a worldwide convergence has occurred for the use of Orthogonal Frequency Division Multiplexing as an emerging technology for high data rates. In particular, the wireless local network systems such as WiMax, WiBro, Wi-Fi and the emerging fourth-generation (or the so-called 4G) mobile systems are all OFDM based systems. OFDM is a digital multi-carrier modulation scheme, which uses a large number of closely-spaced orthogonal sub-carriers that is particularly suitable for frequency-selective channels and high data rates [1], [2]. Multimedia communication over radio channel requires Wireless transmission system to offer high efficiency, one of the best modulation techniques will definitely be OFDM that meets such requirements with reasonable complexity [3]. Because of the high in-band signal-to-noise ratio (SNR) proposed by sigma–delta converter, this kind of converter is currently included in transceivers schemes [4], [5]. Sigma–delta converters are designed to shape the noise away from the band of interest [6]. The decimation filter (decimator) is one of the basic building blocks of a sampling rate conversion system. The decimation filter performs two operations: low-pass filtering as well as down-sampling. The filter converts low resolution high bit-rate data to high resolution low frequency data. It has been widely used in such applications as speech processing, radar systems, antenna systems and communication systems. Considerable attention has been focused in the last few years on the design of high efficiency decimation filters. In 1981, Eugene Hogenauer [7] invented a new class of economical digital filters for decimation and interpolation (converting the sampling rate from low to high) called a cascaded integrator comb (CIC) filter. This filter was composed of an integrator part and a comb part. No multipliers were required and the storage requirement was reduced when compared with other implementations of decimation filters. The CIC filter can also be implemented very efficiently in hardware due to its symmetric structure.

This oversampling based technique supposes the use of a digital filter to prevent quantization noise aliasing during sampling rate decreasing. This decimator filter needs to perform both filtering of the out of band quantization noise and the adjacent channel blockers. The focus of future fourth generation (4G) mobile system Supporting high data rate services such as deployment of multimedia application which involves voice ,data, pictures & video over the wireless network. Orthogonal frequency division multiplexing (OFDM) is a promising candidate for 4G-LTE because of its robustness to the multipath environment.

In this paper, decimation filter is designed for communication standard 4G-LTE. And for noise analysis, noise signal is added to the input Sequence of decimation filter for all standards. Noise signal added with the help of additive white Gaussian noise (AWGN) channel & OFDM in the system. SNR varied from 5db to 25 db and given to AWGN channel for noise analysis.

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II.RECEIVER ARCHITECTURE

The simplest multi-standard terminal is realized by means of several transceivers, one for each standard operating separately. However the high cost, high power consumption and large area do not meet the demands for modern integrated techniques. To overcome these problems appropriately, selection of the receiver architecture is quite important. This work will give an overview on the consideration [11], [12]. Decimation filter is designed for SDR front-ends based on communication standard 4G-LTE. For extracting narrowband signal from wideband sources two signal processing procedure requires i.e. Decimation and Interpolation. As the digital hardware becoming faster there is a need for software solution, so, software defined radio communication is taken as receiver architecture.

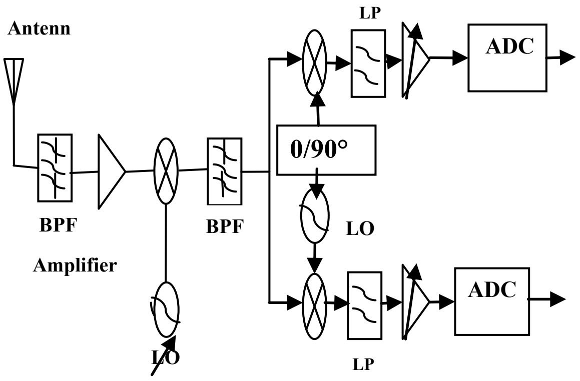

Fig.2-1. Super heterodyne receiver with second IF is zero

III. SIGMA DELTA MODULTOR

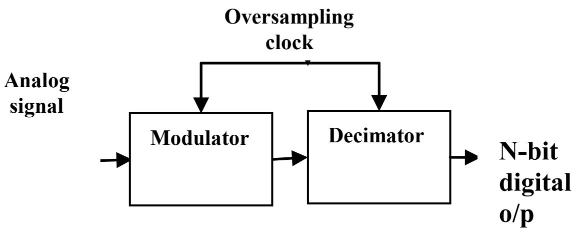

Fig. 3-1. Sigma Delta A/D converter

A. Modulator

The modulator is the analog part of a sigma-delta ADC. The final output resolution of the ADC is dependent on the order of the modulator and also the oversampling ratio set at the Modulator stage. Since the modulator uses the principle of oversampling, the need for antialiasing filter is eliminated and analog input signal can directly be sampled using the Oversampling clock. Due to over sampling of the analog signal, the accuracy of the analog circuitry can be compromised with the speed. The modulator pushes the quantization noise to higher frequencies, which can be filtered out using a digital low pass filter at the decimation stage. The modulator outputs a 1-bit over sampled digital data, which is applied as an input to the decimator. The basic block diagram of the modulator design is shown in Fig.3.1. The difference between the analog input and the output of a digital-to-analog converter (DAC) is applied to an integrator, which is quantized to generate a pulse density modulated 1-bit digital output.

B. Decimator

The process of digitally converting sampling rate of signal from higher rate fs to a lower rate fn is called decimation. Decimation in strict sense means reduction by 10 percent but in signal processing decimation means a reduction in sampling rate by any factor. Basically a decimator is a digital low pass filter, which also performs the operation of sample rate reduction. The sigma-delta modulator does operation of noise shaping and hence the noise is pushed to higher frequencies so that the decimation stage following the modulator can filter out this noise above the cutoff frequency, fn. The band limited signal can then be resampled by discarding K – 1 samples out of every K samples, where K being the oversampling ratio. By averaging K samples out of the quantized sigma-delta output, the decimation filter achieves a high output resolution and also the frequency of the output data is at twice the input signal bandwidth which is the nyquist rate.

IV. MULTISTAGE DECIMATION FILTER

Analog signal coming from the low pass filter in the receiver structure is converted into digital signal using analog to digital converter which consist of Sigma Delta modulator and decimation filter. There is lots of work done in the multi-standard communication on the modulator, here decimation part is highlighted. Decimation is done in multistage to reduce hardware complexity and power consumption of DSP processor. The sampling rate is down converted from the over sampled rate of sigma-delta modulator to a data rate that can be conveniently processed by existing DSP processors. This minimizes the power consumption of DSP processors for demodulation and equalization. The decimation filter consists of a low pass filter and down sampler. The purpose of decimation filter is to remove all the out-of-band signals and noise, and to reduce the sampling rate from oversampled frequency of the sigma-delta modulator to Nyquist rate of the channel [22].

A. Filter structure and design

1) Cascaded integrated comb (CIC) filter

Hogenaur devised a flexible, multiplier free cascaded integrated comb (CIC) filter that can handle large sampling rate changes suitable for hardware implementation [7]. The basic structure of hogenaur CIC filter is shown in figure 4.1.

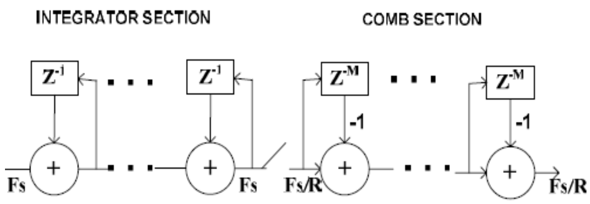

Fig.4.1. CIC Filter

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This consists of integrator and comb filter as two basic building blocks. So it is an infinite impulse response (IIR) filter followed by a finite impulse response (FIR) filter.

2) Half band filter

Half band filters are a special class of symmetric FIR filters used in second stage of multistage decimators.
Half band filters are characterized by equal pass band and Stop band ripples ($\delta_p = \delta_s$).

3) FIR filter

The third type of filter used in multistage decimator is FIR filter. The CIC filter response exhibit a droop in the pass band which progressively attenuates the signals [22]. The pass band droop and stop band attenuation increases as the number of section of CIC filter increases. The FIR filter used in the last stage performs decimation and CIC droop compensation.

Fig.5-1. Decimation Filter design for Multistandard wireless communication

V. DESIGN METHODOLOGY

In This paper, Multistandard decimation filter is designed using signal processing toolbox and filter design toolbox of MATLAB. Decimation filter design will help the user to perform a quick analysis of a decimation filter for multiple standards without doing extensive calculation and to see magnitude response, pole zero plots and filter coefficient for all stages of communication standard. For noise analysis, input is given to the OFDM transmitter and then signals pass through AWGN channel, channel adds white Gaussian noise to the input sequence. Noise is added to the input sequence using the AWGN Channel block, from the Channels library of Communications Block set [10]. Noise signal addition is done with the help of Additive Wide Gaussian Noise (AWGN) channel & OFDM in system. Here signal to noise ratio we are varying from 5dB to 25dB & has been given to AWGN channel for noise analysis. Added Noise is a Random signal.

In digital transmission, the number of bit errors is the number of received bits of a data stream, over communication channels that have been altered due to noise, interference, distortion or bit synchronization errors [17]. The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. SNR is actually the ratio of what is wanted (signal) to what is not wanted (noise). A high SNR means the signal is less corrupted by noise. Low SNR means the signal is more corrupted by noise. In this paper, SNR varies from 0db to 25db Bit error rate changes. For 4G-LTE when SNR=25 db, min BER=9.718e-6, when10,00,000 bit transmitted then 9 bit error received at output and max BER=0.000204,When 10000 bit transmitted then 2 bit error received at output.

VI. RESULT

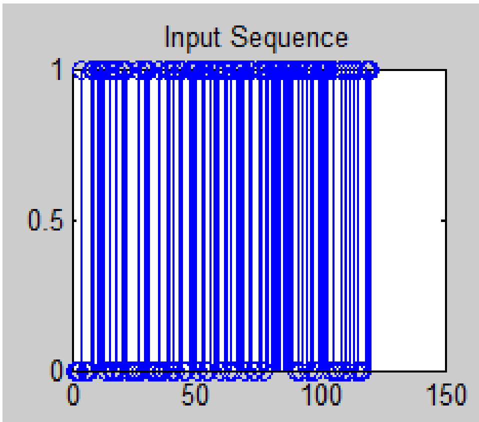

Fig.6-1. Sampled I/p sequence

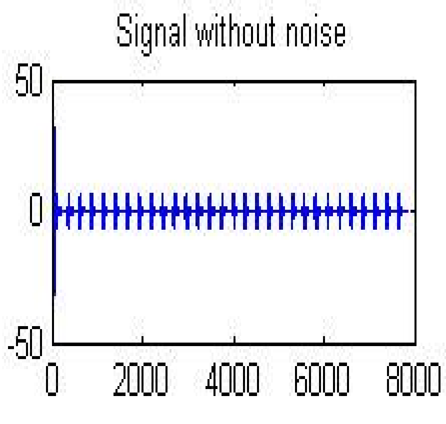

Fig.6-2. Transmitted sequence without noise

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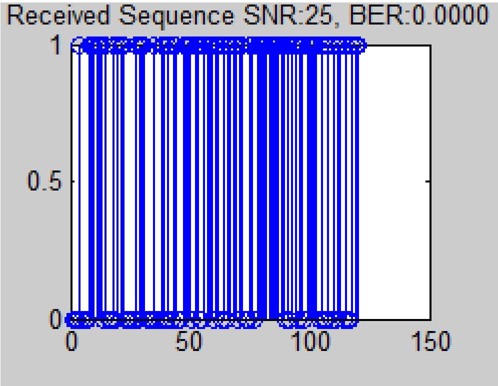

Fig.6-3. Received sequence

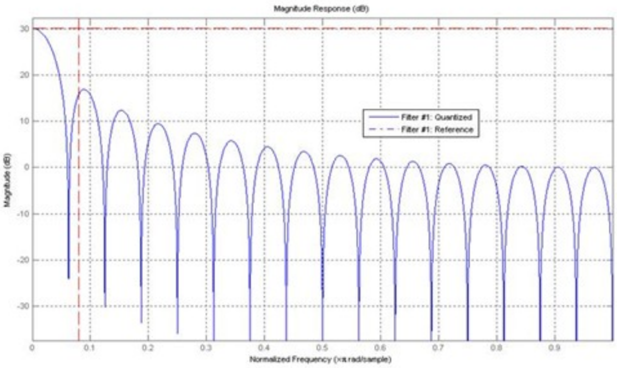

Fig.6-4. Magnitude responsee of 1st stage CIC filter for 4G LTE

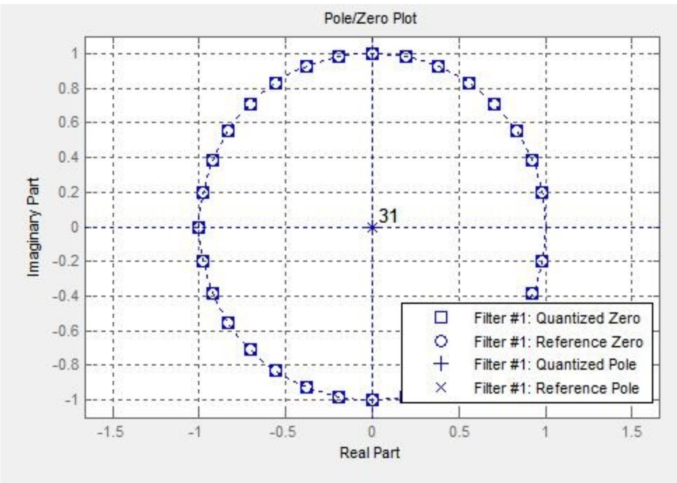

Fig.6-5. Pole Zero plot of 1st stage CIC Filter for 4G LTE

AWGN channel block adds white Gaussian noise to a real or complex input signal.

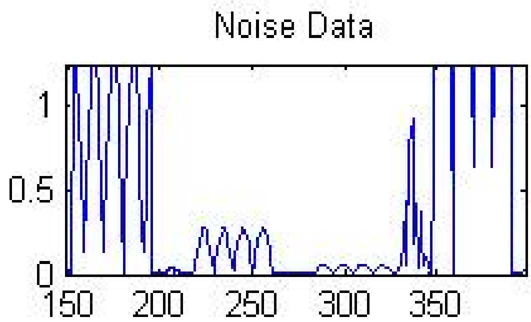

Fig.6-6. Noise Waveform

Y= awgn (x, snr) adds white Gaussian noise to vector signal x. if x is complex, awgn adds complex noise. This syntax assumes power of x is 0dbw. The bandlmited White noise generates normally distributed random numbers that are suitable for use in continuous or hybrid system.

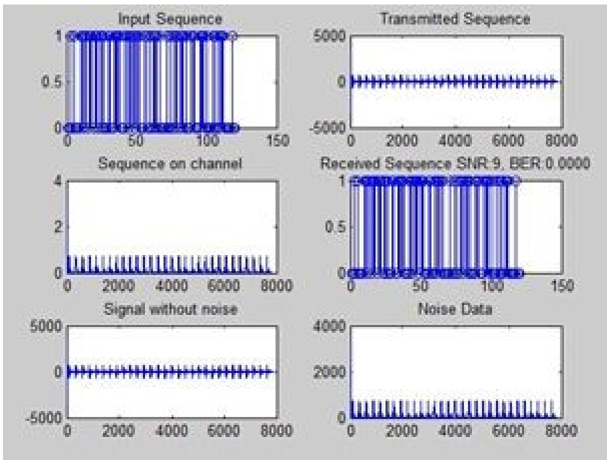

Fig. 6-7. Received noisy sequence when SNR = 9 db and Filter coefficients for CIC filter

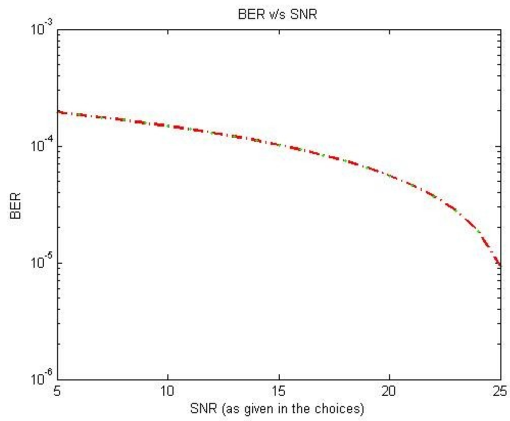

Fig 6-8. BER VS SNR plot of CIC filter

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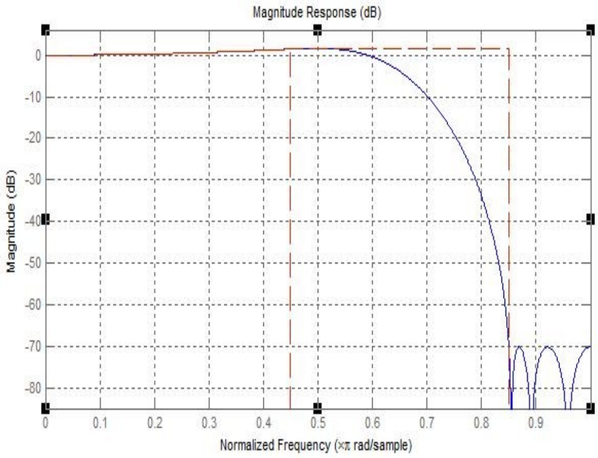

Fig.6-9. Magnitude response of 2nd[t] stage CIC compensation FIR filter for 4G LTE

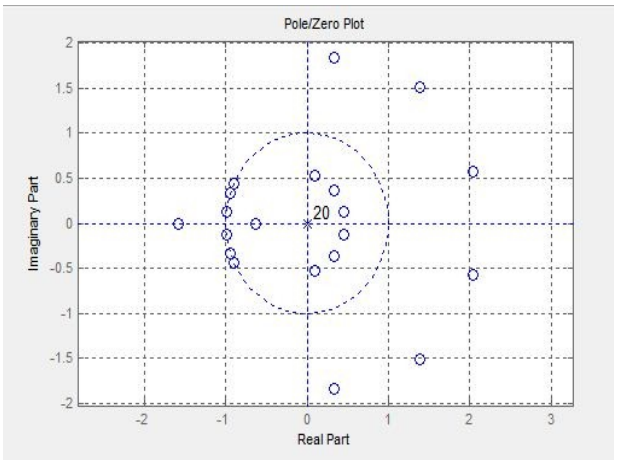

Fig.6-10. Pole Zero plot of 2^{nd} stage CIC compensated FIR filter

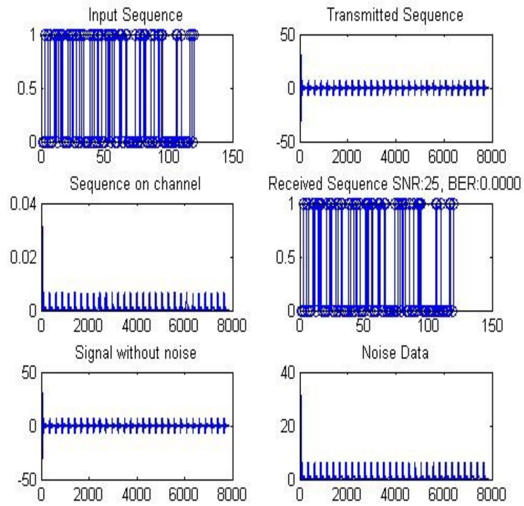

Fig 6-11. Received noisy sequence when SNR=25db and filter coefficient for CIC compensated FIR filter

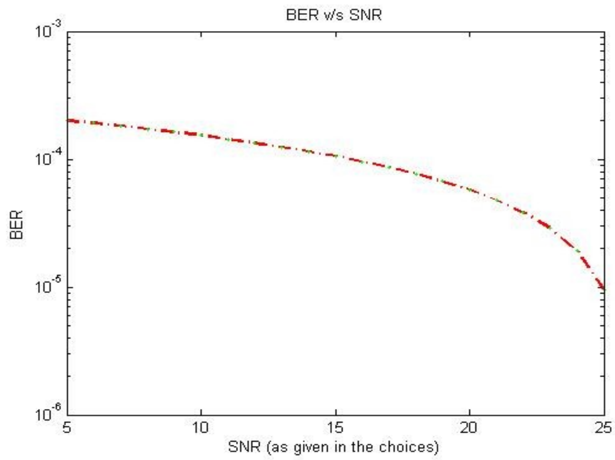

Fig.6-8. BER Vs SNR plot of CIC compensated FIR filter

Table. I. Min-Max BER at SNR=25 db for all standard

Communication Standard	Min BER	Max BER
GSM	0.0004762	0.01
WCDMA	0.000119	0.0025
WLANa	5.29×10^{-5}	0.001111
WLANb	2.976×10^{-5}	0.000625
WLANg	1.905×10^{-5}	0.0004
Wi-Max	1.323×10^{-5}	0.000278
4G LTE	9.718×10^{-6}	0.000204

VII. CONCLUSION

Decimation of a signal at high frequency using FIR or IIR Structures are very complex since it needs a lot of multiplications and hence system cost is increased. In CIC filter as the number of stages increases its stop band, attenuation improves but pass band droop increases. In many applications monotonically decreasing pass band droop has to be compensated. CIC filters are very economic, computationally efficient and simple to implement in comparison with FIR or IIR for large rate change due to lack of multipliers. So, here multistage decimation filter is designed with CIC filter in first stage, half band filter in second stage and CIC compensated FIR filter in third stage. In this paper decimation filter is designed for 4G LTE, it consist of two stage, CIC filter in first stage and CIC compensated FIR filter in second stage. With the help of decimation filter user can see magnitude response, pole zero plot and filter coefficient for multiple stages of communication standards. And for noise analysis, output graph shows graph between signals to noise ratio Vs Bit error rate. When SNR varies from 0db to 25 db, min-max bit error rate changes for all communication standard .and when SNR=25db, we get

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BER=0.00 at output. For 4G-LTE at SNR =25db, bit error rate is low as compared to GSM, WCDMA, WLANa, WLANb, WLANg and WiMAX. High SNR=25db means input signal is less corrupted by noise.

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