Area Estimation and Design Analysis of Gaussian Pulse Shaping Filter

Rajesh Mehra, Ginne

Abstract*-- Gaussian pulse shaping filters plays an important role in digital communications due to its intersymbol interference free property. The pulse shaping filter is a useful means to shape the signal spectrum and avoid Interferences. In this paper a Gaussian filter has been presented for pulse shaping in wireless communication systems. The proposed filter has been designed and simulated using Matlab. The simulated results show that the designed Gaussian filter can be implemented using 11 number of multipliers and 10 number of adders by providing11 multiplications per input sample and 10 additions per input sample. Thus the designed filter provides cost effective solution for mobile and wireless communication systems.

***Keywords*- FIR, GSM, HDTV, MATLAB, WLAN**

I. INTRODUCTION

Pulse shaping for wireless communication over time as well as frequency selective channels is the need of hour for 3G and 4G systems. The pulse shaping filter is a useful means to shape the signal spectrum and avoid Interferences. Pulse shaping filter plays an important in multirate signal processing for Software Defined Radio based wireless and mobile applications for error removal. In today's environment, however, digital transmission has become a much more challenging proposition. The main reason is that the number of bits that must be sent in a given time interval i.e. data rate is continually increasing. Unfortunately, the data rate is constrained by the bandwidth available for a given application. Furthermore, the presence of noise in communications system also puts a constraint on the maximum error-free data rate. The wide diffusion of wireless terminals like cellular phones is opening new challenges in the field of mobile telecommunications. Besides, the possibility to transmit not only voice but even data between terminals and end users of many kinds has fostered the development of new technologies and new standards for cellular communications [1]

In electronics and telecommunications, pulse shaping is the process of changing the waveform of transmitted pulses.

The purpose of pulse shaping is to make the transmitted signal better suited to its purpose or the communication channel, typically by limiting the effective bandwidth of the transmission. By filtering the transmitted pulses this way, the intersymbol interference caused by the channel can be kept in control. Typically pulse shaping occurs after line coding and before modulation. In RF communication, pulse shaping is essential for making the signal fit in its frequency band.

Manuscript Received July, 2013.

Mr. Rajesh Mehra Associate Professor, ECE Department, NITTTR, Chandigarh, India.

Mrs. Ginne M.E. Student, ECE Department, NITTTR, Chandigarh, India.

In a communication system, when the data is being transmitted in the form of pulses (i.e. bits), the output produced at the receiver due to other bits or symbols interferes with the output produced by the desired bit. This is known as Inter symbol Interference (ISI).

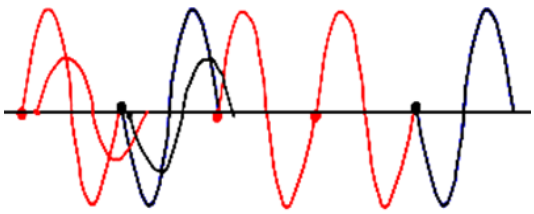

Fig. 1 Inter symbol Interference

The Inter symbol Interference introduces errors in the detected signal. It is a form of distortion of a signal in which one symbol interferes with subsequent symbols. ISI is usually caused by multipath propagation or the inherent non-linear frequency response of a channel causing successive symbols to "blur" together.

The Inter symbol Interference ISI arises due to the imperfections in the overall frequency response of the system. When a short pulse of duration T_b seconds is transmitted through a band limited system, then the frequency components contained in the input pulse are differentially attenuated and more importantly differentially delayed by the system. Due to this, the pulse appearing at the output of the system will be dispersed over an interval which is longer than T_b seconds. Due to this dispersion, the symbols each of duration T_b will interfere with each other when transmitted over the communication channel. This will result in the Inter symbol Interference (ISI).

In communications, the Nyquist ISI criterion describes the conditions which, when satisfied by a communication channel, result in no intersymbol interference or ISI. It provides a method for constructing band-limited functions to overcome the effects of Intersymbol Interference. Recently, there is increasingly strong interest on implementing multi-mode terminals, which are able to process different types of signals, e.g. WCDMA, GPRS, WLAN and Bluetooth. These versatile mobile terminals favor simple receiver architectures because otherwise they'd be too costly and bulky for practical applications [2].As digital technology ramps up for this century, an ever-increasing number of RF applications will involve the transmission of digital data from one point to another. The general scheme is to convert the data into a suitable baseband signal that is then modulated onto an RF carrier [3].

Pulse shaping filters are normally implemented as oversampled finite impulse response (FIR) digital filters. Gaussian filters are significantly better than RRC filters [4]. Gaussian FIR filters give significantly better BER performances than the conventional RRC filter.

The FIR structure with linear phase technique is efficient as it takes advantage of symmetrical coefficients and uses half the required multiplications and additions [5], [6].

II. GAUSSIAN FILTERS

Pulse shaping filters are used at the heart of many modern data transmission systems like mobile phones and HDTV to keep a signal in an allotted bandwidth, maximize its data transmission rate and minimize transmission errors. In many base band communication systems the pulse shaping filter is implicitly a boxcar filter. Its spectrum is of the form *sin(x)/x*. It has significant signal power at frequencies higher than symbol rate. In RF communications this would waste bandwidth, and only tightly specified frequency bands are used for single transmissions. Thus, the channel for the signal is band-limited. This is not a big problem when optical fiber or twisted pair cable is used as the communication channel. In communications systems, two important requirements of a wireless communications channel demand the use of a pulse shaping filter. These requirements are generating band limited channels, and reducing Inter Symbol Interference (ISI) arising from multi-path signal reflections.

Both requirements can be accomplished by a pulse shaping filter which is applied to each symbol. Pulse shaping filter are often used in communication transmitters for baseband processing in order to improve the transmission efficiency of a signal spectrum. The pulse shaping filters are widely used in Mobile Phones, HDTV, Space communication, Radar, Audio/data/CD/video system, Speech synthesis recognition, A/D and D/A conversion. The ideal pulse shaping filter has two properties. Firstly it should exhibit high stop band attenuation and secondly it should exhibit minimum inter symbol interferences (ISI) to achieve a bit error rate as low as possible.

The pulses are sent by the transmitter and these are detected by the receiver in any data transmission system. At the receiver, the goal is to sample the received signal at an optimal point in the pulse interval to maximize the probability of an accurate binary decision. This implies that the fundamental shapes of the pulses be such that they do not interfere with one another at the optimal sampling point. There are two criteria that ensure non interference:-

(i) The pulse shape exhibits a zero crossing at the sampling point of all pulse intervals except its own. Otherwise, the residual effect of other pulses will introduce errors into the decision making process.

(ii) The shape of the pulses be such that the amplitude decays rapidly outside of the pulse interval.

The rectangular pulse meets criterion number one because it is zero at all points outside of the present pulse interval. During the sampling time of other pulses it cannot cause interference.

The **rectangular function** is defined as:

$$\mathrm{rect}(t) = \Pi(t) = \begin{cases} 0 \text{ if } |t| > \frac{1}{2}, \\ \frac{1}{2} \text{ if } |t| = \frac{1}{2} \\ 1 \text{if } |t| < \frac{1}{2} \end{cases} \quad (1)$$

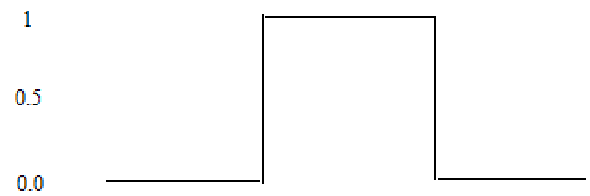

Fig. 2 Rectangular Function

It is also known as the rectangle function, rect function, Pi function, gate function, unit pulse, or the normalized boxcar function.

The disadvantage of rectangular pulse is that it has significant energy over a fairly large bandwidth. Its bandwidth extends to infinity because the spectrum of the pulse is given by the familiar sinc response. The unbounded frequency response of the rectangular pulse renders it unsuitable for modern transmission systems. This is where pulse shaping filters come into play. If the rectangular pulse is not the best choice for band-limited data transmission, then what pulse shape will limit bandwidth, decay quickly, and provide zero crossings at the pulse sampling times. The raised cosine pulse is used to solve this problem in a wide variety of modern data transmission systems. In electronics and signal processing, a Gaussian filter is a filter whose impulse response is a Gaussian function. Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time. It has the minimum possible group delay. It is a linear filter thus it is used as a smoother . This gives an output pulse shaped like a Gaussian function. Gaussian filter is used in GSM since it applies GMSK modulation. It is also used in GFSK and Canny Edge Detector used in image processing.

Mathematically, a Gaussian filter modifies the input signal by convolution with a Gaussian function; this transformation is also known as the Weierstrass transform. The Gaussian filter is non-causal which means the filter window is symmetric about the origin in the time-domain. No amount of delay can make a Gaussian filter causal, because the Gaussian function is never zero. Due to the central limit theorem, the Gaussian can be approximated by several runs of a very simple filter such as the moving average. The FIR Gaussian pulse-shaping filter design is done by truncating a sampled version of the continuous-time impulse response of the Gaussian filter which is given by:

$$h(t) = \frac{\sqrt{\pi}}{a} e^{-\frac{\pi^2 t^2}{a^2}} \quad (2)$$

The parameter 'a' is related to 3-dB bandwidth-symbol time product (B*Ts) of the Gaussian filter as given by:

$$a = \frac{1}{BT_s} \sqrt{\frac{\log 2}{2}} \quad (3)$$

III. SIMULATED RESULTS

The FIR Gaussian pulse-shaping filter design is done by truncating a sampled version of the continuous-time impulse response of the Gaussian filter. A continuous-time Gaussian filter has been developed with symbol time Ts = 1 micro-second. The proposed Gaussian filter has been designed and simulated using Matlab [7].

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

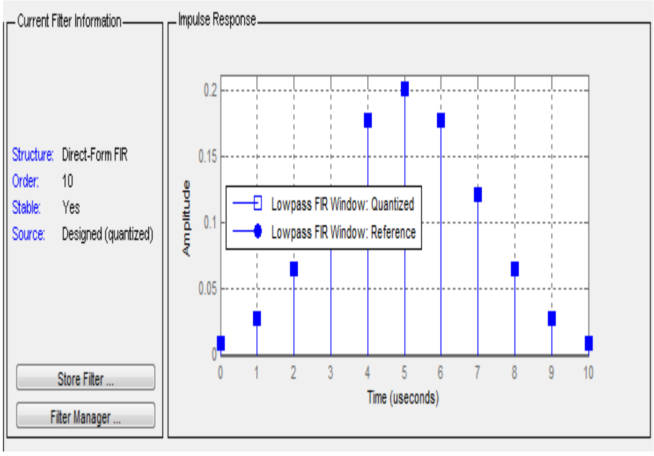

Fig. 3 Impulse Response of Gaussian filter

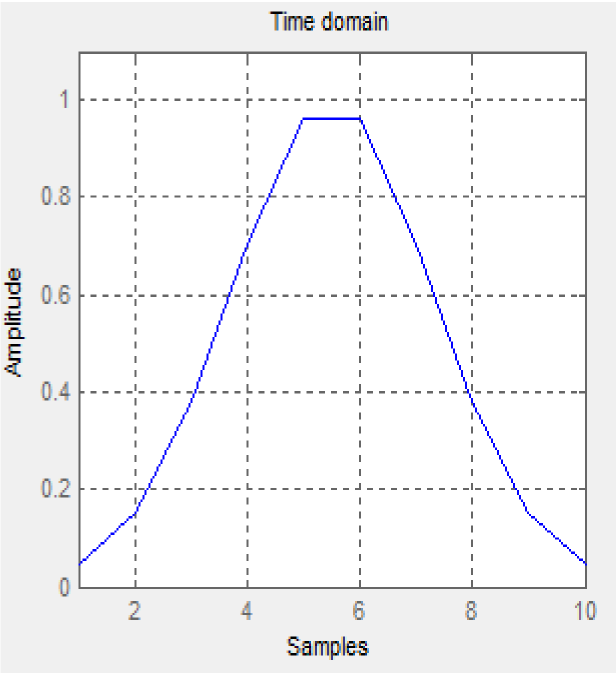

Fig. 4 Amplitude of Gaussian filter

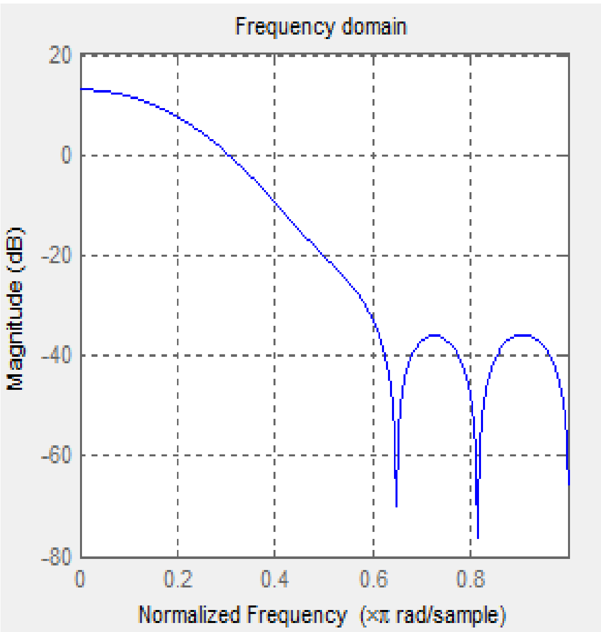

Fig. 5 Magnitude response of Gaussian filter

The proposed filter provides cost effective solution for mobile and wireless communication systems.

IV. DESIGN IMPLEMENTATION

FIR filters require no feedback. This means that any rounding errors are not compounded by summed iterations.

Table I. Filter Parameters

Filter Structure	Direct-form FIR
Filter Length	11
Stable	Yes
Linear Phase	Yes
Arithmetic	fixed

The proposed Gaussian filter is a Direct –form FIR with a filter length 11. The simulated results show that the designed Gaussian filter is stable. This is due to the fact that, because there is no required feedback, all the poles are located at the origin and thus are located within the unit circle (the required condition for stability in a discrete, linear-time invariant system).The designed filter has a linear phase by making the coefficient sequence symmetric; linear phase, or phase change proportional to frequency, corresponds to equal delay at all frequencies. This property is sometimes desired for phase-sensitive applications, for example data communications, crossover filters, and mastering.

Table II. Implementation Cost

Number of Multipliers	11
Number of Adders	10
Number of States	10
Multiplications per Input Sample	11
Additions per Input Sample	10

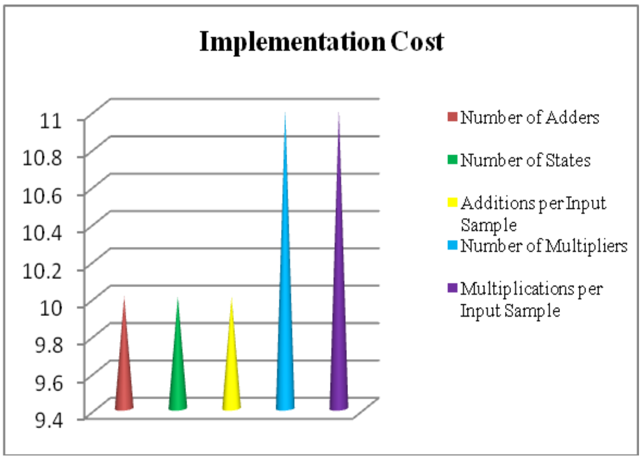

Fig. 6 Implementation Cost

The developed Gaussian filter structure is utilizing 11 multipliers, 10 adders, 10 states, 11 multiplications per input sample and 10 additions per input sample.

V. CONCLUSION

In this paper, a Gaussian filter has been presented for pulse shaping in wireless communication systems. The developed Gaussian filter is stable and has a linear phase. The simulated result of proposed Gaussian filter is utilizing 11 multipliers and 10 adders. The simulated results of Gaussian filter have shown very less area requirement in terms of multipliers and adders. So the designed filter may provide cost effective solution for pulse shaping in wireless and mobile applications.

REFERENCES

1. Wang Wei, Zeng Yifang, Yan Yang, Efficient Wireless Digital Up Converters Design Using System Generator" IEEE 9th International Conference on Signal Processing, pp.443-446, ICSP- 2008.
2. K. B. Huang, Y. H. Chew, and P. S. Chin "A Novel DS-CDMA Rake Receiver: Architecture and Performance" IEEE International Conference on Communications, pp-2904-2908, ICC-2004.
3. Rajesh Mehra, Dr. Swapna Devi, "Area Efficient & Cost Effective Pulse Shaping Filter for Software Radios" International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.1, No.3, pp. 85-91, September 2010.
4. Yutaka Jitsumatsu, Masato Ogata, and Tohru Kohda, "A Comparison between Prolate Spheroidal and Gaussian FIR Pulse Shaping Filters" International Conference on Signals and Electronic Systems, (ICSES), pp. 14-17, September 2008..
5. J. Chandran, R. Kaluri, J. Singh, V. Owall and R. Veljanovski "Xilinx Virtex II Pro Implementation of a Reconfigurable UMTS Digital Channel Filter" IEEE Workshop on Electronic Design, Test and Applications, pp.77-82, DELTA-2004.
6. Rajesh Mehra, Swati Singh, "Design of RRC Filter for ISI removal in Software Defined Radios " International Journal of VLSI and Signal Processing Applications, (IJVSPA) Vol.1, No.1, pp. 1-5, April 2011.
7. Mathworks, "Users Guide Filter Design Toolbox 4", March-2007.

AUTHORS PROFILE

Mr. Rajesh Mehra is currently Associate Professor at National Institute of Technical Teachers' Training & Research, Chandigarh, India. He is pursuing his PhD from Punjab University, Chandigarh, India. He has completed his M.E. from NITTTR, Chandigarh, India and B.Tech. from NIT, Jalandhar, India. Mr. Mehra has more than 17 years of academic experience. He has authored more than 100 research papers including more than 50 in Journals. Mr. Mehra's interest areas are VLSI Design, Embedded System Design, Advanced Digital Signal Processing. Mr. Mehra is member of IEEE & ISTE.

Mrs. Ginne is currently pursuing M.E. from National Institute of Technical Teachers Training and Research, Chandigarh India. She has completed her B.Tech from Govind Ballabh Pant Engineering College ,Pauri,Garhwal India. She is having two years of teaching experience in Neelakanth Institute of Technology, Meerut. Mrs. Ginne's interest areas are VLSI design, Wireless and Mobile Communication, Digital Signal Processing and Digital Electronics.