

Bit Error Rate Analysis of Square Root Raised Cosine Pulse Shaping Filter

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Abstract— Advanced digital signal processing has the capability to modify the characteristics of a signal and to improve it. The role of digital processing techniques for wireless communication has been ever increasing. Wireless communication systems are highly complex and require a interdisciplinary knowledge from the performance of digital modulation to the channel capacity. Use of digital pulse shaping filters provides solution to many of the problems of wireless communication systems. In this paper analysis of square root raised cosine pulse shaping filter for WCDMA at a data rate of 960 Kbps for the performance of BER has been proposed. Based on the Simulink model of Matlab, this paper represents the performance of BER at constant roll off factors for number of values of group delays. The optimum value of group delay for minimum BER for two different roll off factors has been calculated.

Index Terms— WCDMA, 3G, Pulse Shaping, RRC, SRRC, BER, ISI, Roll-off factor, Group delay.

I. INTRODUCTION

The application of emerging digital processing techniques has increased the capacity of wireless system and also had improved the communication quality efficiently by reducing all types of interferences. Increase in system capacity is due to the digital modulation techniques along with advanced digital signal processing applications in wireless communication. Different wireless techniques like GSM, CDMA, WCDMA used all over the world, are facilitating the end user with higher data rate services [1]. The first generation (1G) cellular network transfer voice data only and has certain limitations like no encryption, the sound quality is poor and less speed. The second generation (2G) improved by introducing the concept of digital modulation. The third generation (3G), the generation of mobile telecommunication standards allows simultaneous use of speech and data services and offers data rates upto 2Mbps, which provides services such as video calls, mobile TV, mobile internet and downloading [2].

Out of numerous approaches of multiplexing wireless users, one way is Code division multiple access method (CDMA). This method allows numerous signals to occupy a single transmission channel optimizing the use of available bandwidth. Users are multiplexed by distinct codes in CDMA unlike FDMA in which orthogonal frequency bands are allotted. By using a Direct Sequence Spread Spectrum (DSSS) signal the performance can be increased. The processing gain and coding gain offers many DSSS users to acquire the similar channel bandwidth. This is the basic fundamental of wideband-CDMA (WCDMA). It is derived from CDMA, known as IMT 2000 DSS (direct spread spectrum) [3].

WCDMA (3G) wireless technology is considered to be a wideband technology which make use of wide bandwidth. In this user bits are spread by multiplying the user data with Chips which are pseudorandom bits or signature sequence [4]. 3G wireless technology offered higher data speeds. This technology has turn up as the most widely used air interface and is a member of the UMTS family (Universal Mobile telecommunication System). Its specification has been created in the 3rd Generation Partnership Project (3GPP) which is a joint standardization project of the standardization bodies from Europe, Japan, China and Korea. 3G include radio channels that are 5MHz wide. To lead a carrier bandwidth of 5 MHz a chip rate of 3.84Mcps is required. WCDMA (3G) make use of the DS-SS (Direct Sequence Spread Spectrum) channel access methods and FDD (Frequency Division Duplex) method to achieve higher speeds and support large number of users.

The main aim of 3G communication is to allow many end users to send information or data over the same channel bandwidth. On the other side at the receiver end the signal is recovered from the known code sequence. The code signal is provided with a wider bandwidth than compared with the that of the data signal. This encoded procedure broadens the signal spectrum. This results in spread spectrum modulation and for this reason the resultant signal is known as

spread spectrum signal. For this reason, CDMA is commonly known as spread spectrum access. This 3G system has higher capacity and greater flexibility in providing multimedia services with different transmission rates. Wireless standards like WCDMA, CDMA etc use the concept of baseband pulse shaping to minimize ISI and additive noise effects in the wireless channels [5].

II. PULSE SHAPING FILTER

Pulse shaping is a spectral processing technique used to make transmitted signals better, by limiting the useful bandwidth of the transmission. In other words, a digital signal system is used for changing the waveform of the transmitted pulses. Digital filters are the building blocks in digital signal processing. Filter usage in communication systems led to enhanced performance in terms of power consumption and speed. These digital filters change the characteristics of signals in time and frequency domains.

Filters used in digital transmission systems use the concept of pulse shaping so that the signal remains in the allotted bandwidth. It also maximizes its data transmission rate and reduces transmission errors. Two conflicting requirements are the demand for high data rates (information) and the need for narrow bandwidth (more users, more channels, less noise). If the channel is narrow, then the symbol will be too wide. As a result of this, at the sampling point (time) there will be signal (tails) of the previous and the next symbols. This is called Inter Symbol Interference (ISI) [6].

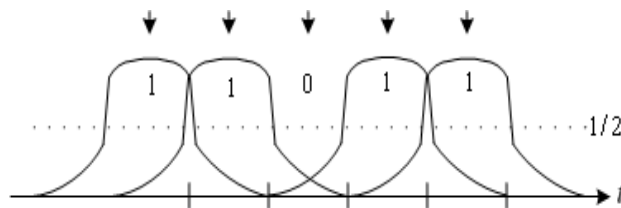


Fig. 1 Narrow channel resulting ISI [6].

One way is to use an ideal low pass filter (ILPF), rectangular in frequency. Thus it will result in no ISI and narrow bandwidth. But the matter of concern is that it is unrealizable and almost difficult to approximate. If attainable, it requires extreme precise synchronization. But synchronization is an issue (jitter in the signal are

not beneficial). The normalized Sinc(t) function is represented as

$$\frac{\sin \pi t}{\pi t} \quad (1)$$

Pulse shaping filter reduces not only the Inter symbol interference but also reduces adjacent channel interference.

The time and frequency response is shown in figure below

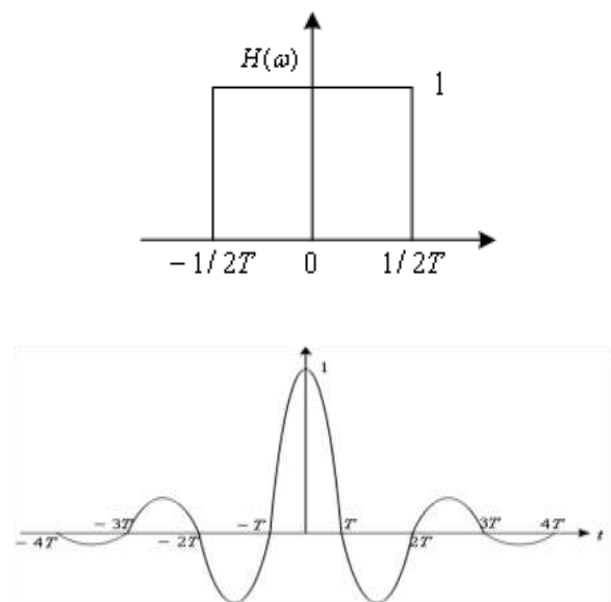


Fig. 2 Ideal response of a Filter (Frequency and time domain) [6].

The idea behind pulse shaping is that pulses are transmitted by the transmitter and received or recovered at the receiver end in a data transmission system. The signal is sampled at the receiver side at such a point in the pulse interval so that the probability of an accurate binary decision is enhanced. [7, 8]. This means the pulses should be of such a shape that they do not interfere with each other. The amplitude of the pulse decays rapidly outside of the pulse interval is determined by the shape of the pulses. This ensures non-interference between samples. The timing jitter adds errors when sampling adjacent pulses which can be reduced if the pulse decays quickly outside the pulse interval [9].

Non-interference can also be ensured by exhibiting a zero crossing at the sampling point of all pulse intervals

except its own. This requirement is by a rectangular pulse as it is zero at all points outside the pulse interval. It bypass interference during the sample time of other pulses. But the rectangular pulses has significant energy over a wide bandwidth so they are not suitable for modern transmission system. Then if rectangular pulses is not the ideal choice then raised cosine filter was the solution of above problem [9,10]. The most commonly used filters to avoid ISI are raised cosine filter and root raised cosine filter. These filters are frequently used for pulse shaping in digital modulation. The transition band of Root raised cosine (RRC) filter is similar to a cosine curve and the response fulfill the Nyquist Criterion [11]. A time domain pulse fulfill these requirements.

In the Raised cosine filter

1. Effect of jitter can be reduced.
2. It is much simple to realise.

According to Nyquist Criterion, the frequency response exhibits an odd symmetry at the cut off frequency, the impulse response will result in zeros at specified spaced intervals. The raised-cosine filter is an implementation of a low-pass Nyquist filter having vestigial symmetry property [12]. In other words its spectrum exhibits odd

symmetry about $\frac{1}{2T}$.

Thus Nyquist criterion is fulfilled by raised cosine filter by suppressing the spectral distortion at integral multiples of the sampling rate.

Influence of roll-off factor β is that it is a measure of the excess bandwidth of the filter. It is the bandwidth occupied outside the Nyquist bandwidth of $\frac{1}{2T}$, where T is the symbol-period [13].

Raised cosine filter has the impulse response, in terms of normalized Sinc pulse as

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

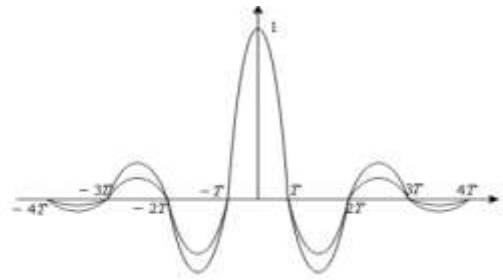


Fig. 3 Plot of Impulse response of a Raised cosine filter [6].

Sinc term is included in impulse response that ensures that it has zero crossings as like ideal low pass filter.

$$\frac{\text{sinc}(t) = \left(\frac{\sin \pi t}{T}\right)}{\frac{\pi t}{T}} \quad (3)$$

It also includes another term

$$\left(\frac{\cos \pi \beta t / T}{1 - (4\beta^2 t^2 / T^2)}\right) \quad (4)$$

That decays in time hence reduces the tails reducing the impact of jitter. The square root is used in frequency domain and filter is then so called as Root Raised Cosine filter. The frequency response of RRC Filter can be found taking square root of RC filter the frequency response. Raised Cosine filter transfer characteristics can be achieved by cascading the transmitter and receiver characteristics [6].

In digital signal processing applications, different sampling rates enhance the flexibility of radio communication technology. With this the processing of different types of signals with different sampling rate is possible without the need of expensive analog filters [14].

Sampling rate can be changed by using Up sampler and Down sampler. Digital frequency conversion offers greater flexibility and higher performance in terms of attenuation [15].

The following figure represents the block diagram of WCDMA communication network.

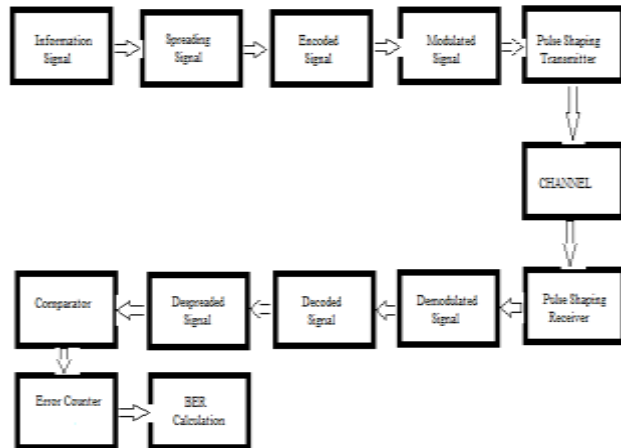


Fig. 4 Block diagram of a WCDMA Communication Link

III. PROPOSED MODEL FOR SIMULATION

A simulation model based on Matlab R2013a Version on Square Root Raised Cosine Filter for WCDMA is used. The pursuance of BER can be analyzed for different numbers of group delay of the RRC Filter. From the Matlab Library, a Simulation model has been created to calculate BER.

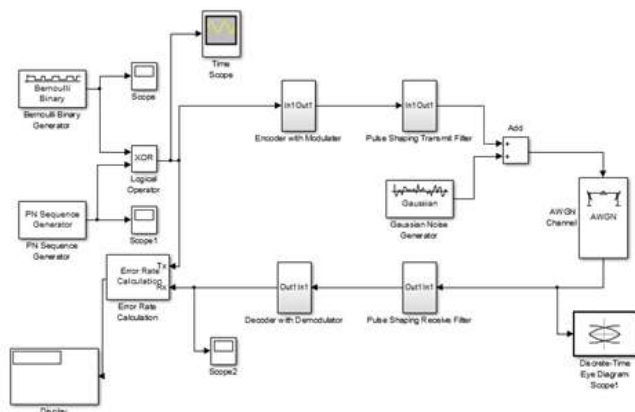


Fig. 5 Simulation model for WCDMA

- This model is used for
- 1 Analysis of BER for different values of Group Delay at constant Roll off Factor.
 2. Analysis of BER for two different Roll off Factors for optimum value of Group Delay.

The Simulation result has been executed for a data rate of 960 Kbps. Parameters of SRRC Filter are changed

for Group delay at constant Roll off factor (β)=0.22, Up sampling and Down sampling factor =8 and Samples per frame = 4.

Bernoulli Binary Generator generate random binary information signal. Block parameters for the Bernoulli Binary Generator need to be arranged in terms of sampling rate for a data rate of 960 Kbps.

Following is the simulated waveform of the data input sequence

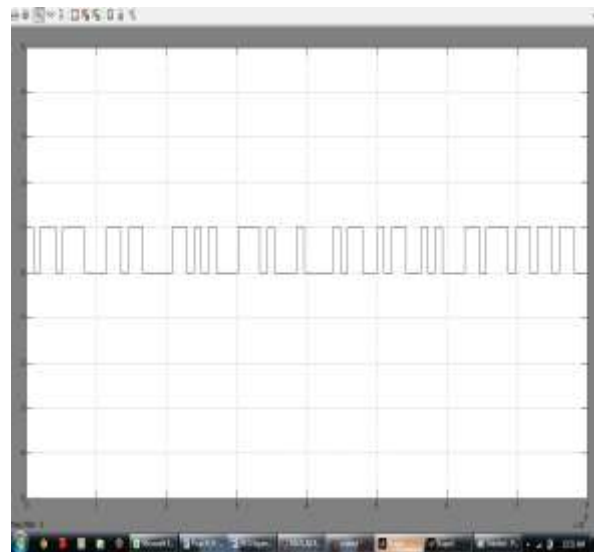
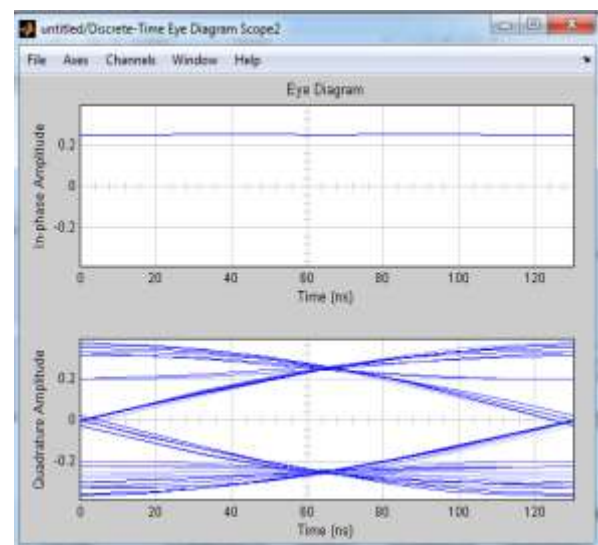


Fig. 6 Scope Output of Bernoulli Binary Generator.



Eye Scope Diagram for RRC Filter

PN Sequence Generator in Simulation model generates Pseudorandom Noise (PN) Sequence. It is

used to generate a Chip rate of 3.84 Mcps for 5 MHz bandwidth in WCDMA

This PN Sequence generates noise sequence which can be used to spread the binary information signal [16]. Block parameters for the PN Generator are set in terms of sampling rate for Chip rate of 3.84 Mcps.

Following is the simulated waveform of the spreading chip sequence.

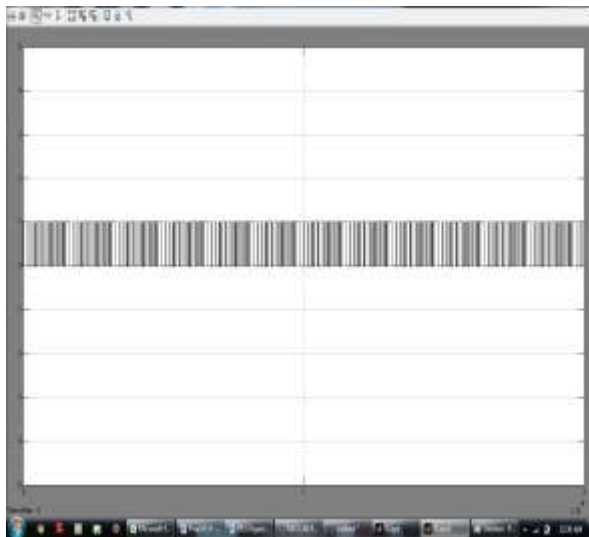


Fig. 8 Scope Output of PN Sequence Generator.

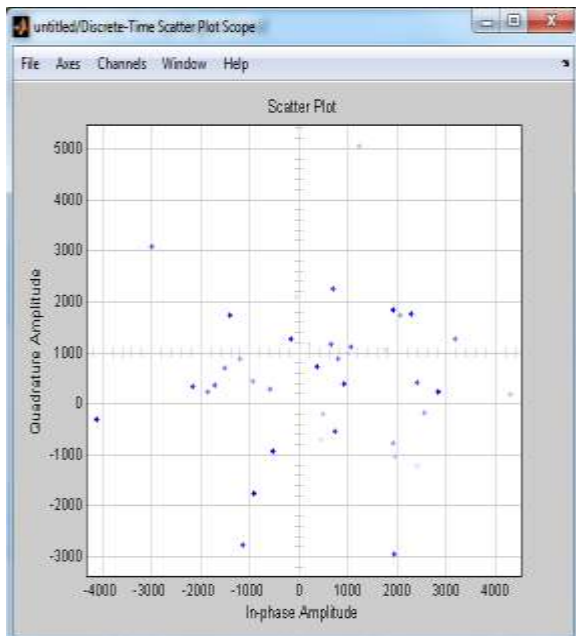


Fig. 9 Time Scope Scatter plot.

IV. RESULTS AND COST ANALYSIS

At Data rate 960 Kbps corresponding BER values are measured for different values of Group delay (D =2, 4, 5, 6, 8, 10) using Matlab. BER is used as a parameter for performance evaluation [17].

The results are summarized in tables I and II shown below

Table I. Roll off Factor (β) = 0.22

S.No.	Group Delay (D)	BER
1	2	0.5033
2	4	0.4915
3	5	0.4933
4	6	0.485
5	8	0.4733
6	10	0.5111

Table II. Roll off Factor (β) = 0.5

S.No.	Group Delay (D)	BER
1	2	0.4902
2	4	0.4967
3	5	0.5046
4	6	0.4876
5	8	0.4863
6	10	0.5111

The Simulated graph shows the comparison between BER values for different values of Group delay for $\beta=0.22$

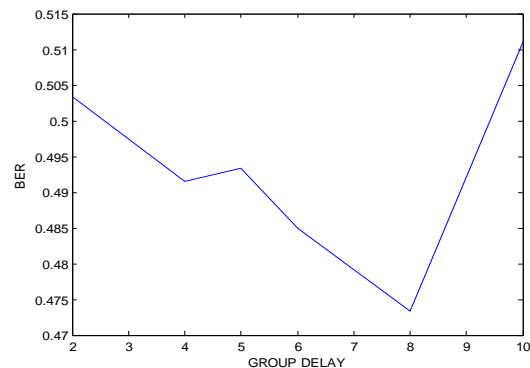


Fig. 10 Plot shows variation of BER versus Group delay for $\beta=0.22$

The Simulated graph shows the comparison between BER values for different values of Group delay for $\beta=0.5$

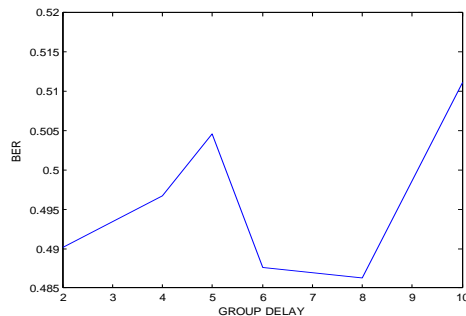


Fig. 11 Plot shows variation of BER versus Group delay for $\beta=0.5$

Results shows the optimal performance of BER is for Group Delay (D) =8 for both $\beta =0.22$ and $\beta =0.5$.

The proposed filter is a Direct-Form FIR Filter with a filter length 11. The cost and the performance of the design has been analyzed and compared for the two roll off factors. As the filter length increases number of multipliers and adders also increases which increases the cost. More closer the roll off factor to zero means steeper is the transition and the filter approaches the ideal characteristics.. In addition for roll factor $\beta = 0.22$, performance is better in terms of bit error rate.

Tables III & IV shows the Filter parameters and Implementation cost.

Table III. Filter Parameters

Filter Structure	Direct-Form FIR
Filter Length	11
Stable	Yes
Linear Phase	Yes (Type 1)

Table IV. Implementation Cost

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

V. CONCLUSION AND FUTURE WORK

Analysis and evaluation of BER performance for WCDMA Network using OQPSK modulation technique with the Square Root Raised Cosine Filter has been carried out in this paper. The Stimulation has been studied at 960 Kbps data rate. Two constant roll off factors are considered for which bit error rate performance is evaluated for different group delays. The result shows the optimum value for Group Delay for minimum Bit error rate. It can be concluded that for a chip rate of 3.84 Mcps of WCDMA, best results are obtained for at a high data rate of 960 Kbps in terms of BER. The study is informative to enhance the efficiency of WCDMA network. Future scope of the work can extend for higher data rates such 1Mbps, 2Mbps. The simulation Model can be formulated for other pulse shaping families such as Beaulieu pulse shaping Filter, Guassian pulse shaping filter etc. AWGN Channel used can be replaced by other multipath fading channel to study the system under other mobile radio channels.

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