Performance Analysis of Pulse Shaping Filter for WCDMA Applications

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Abstract: The wireless systems with spreading of a signal experiences time delay which has to be smaller compared to symbol period of the data. The condition can’t be met in high data rate transmissions which make this delay to be greater than that of the data symbol period which results in inter-symbol interference (ISI) due to serial transmission. Therefore, a performance of pulse shaping filter for use in WCDMA needs to be optimized to reduce ISI for a rate of 2Mbps. The system is simulated in MATLAB with 16-QAM modulation and channel coding. The error rates are determined with a variation in the filter roll off factor (α). The results have shown that the performance of a wireless communication system depends on the filter roll off factor. Therefore, there must be a trade-off between filter complexity and power efficiency in determining an optimum roll-off factor which gives minimum error rate.

Keywords: Inter-symbol Interference, roll-off factor, pulse shaping filter, 16-QAM

I. Introduction

An efficient pulse shaping is required in communication systems to fulfil two requirements in a wireless communication channel. The need to generate band-limited channels and reduction of inter-symbol interference (ISI) which results from multipath signal reflections during propagation form the transmitter to the receiver are the two requirements that need to be satisfied by the pulse shaping filter. The pulse shaping filter is therefore applied to each symbol of the information signal to achieve both requirements. The sinc pulse meets both conditions as it uses the frequency domain to make a signal utilize the smaller portion of the frequency domain due to the windowing effect it has on each symbol period of a modulated information signal.

This pulse is also found to be periodic with maximum amplitude in the central point of the symbol time. When it is plotted in the frequency domain, it appears as a square wave thereby effectively limiting a communication channel to a specific frequency range. The information transmitted through a WCDMA wireless system at higher data rates undergoes a higher delay spread making the symbols to interfere. This causes the Inter-Symbol Interference (ISI) which is supposed to be reduced by the pulse shaping filter. This condition is unavoidable in wireless communication systems. The leakage of one symbol to the others due to high data rate is what makes the energy to be confined. The ISI is can be reduced by slowing down the signal transmission with the introduction of a delay between multiple bits. The pulse shaping filter (square root raised cosine filter) is implemented to offer this delay in WCDMA and next generation networks.
For this system model the square root raised cosine filter is used in the transmitter and receiver section so that the overall response of the system resembles that of a normal raised cosine filter. The impulse or time domain response of the raised cosine filter and the square root raised cosine filter in [1] are given by the equations;

\[ h_{RC}(t) = \frac{\sin \left( \frac{\pi t}{T} \right) \cos \left( \frac{\pi at}{T} \right)}{1-\left( \frac{2at}{T} \right)^2} \]  

This expression can be simplified further by introducing the sinc function (\( \text{sinc} \ x = \frac{\sin x}{x} \))

\[ h_{RC}(t) = \text{sinc} \left( \frac{\pi t}{T} \right) \cos \left( \frac{\pi at}{T} \right) \frac{1}{1-\left( \frac{2at}{T} \right)^2} \]  

The sinc function in the response of the filter ensures that the signal is band-limited. The time domain or impulse response of the square root raised cosine filter is given as;

\[ h_{RRC}(t) = \frac{\sin[\pi(1-a)t+\frac{\alpha t}{2}]}{\frac{\pi t}{T}1-\left( \frac{4at}{T} \right)^2} \]  

In the development of the WCDMA system model, the square root raised cosine filter is used in the transmitter and receiver section so that the overall response of the system reduces to that of the raised cosine filter such that;

\[ h_{RC}(t) = h_{RRC}(t)h_{RRC}(t) \]  

II. Survey of Related Literature

In [2] an investigation on the features of a pulse shaping FIR filter applied in Time Division Duplex (TDD) WCDMA transmitter and a comparison between TDD and FDD channel access methods for mobile terminal and base station communication was done. Since the TDD was a new duplex scheme for WCDMA, its time slots were located on the physical layer of the WCDMA and were divided into transmission and reception parts. This made it possible for the reciprocal transmission of information on the uplink and downlink channels.

The capability of TDD was handling up to 16 users per time slot. However, 15 time slots were contained in one WCDMA cell. It was found that the two pulse shaping FIR filters attenuated the adjacent channel from in-phase and quadrature phase components. The sampling rate and the complexity of the filter depended on the interpolation factors. The different filter parameters were used for various interpolation factors. This had an effect on the sampling rate, the filter complexity and its attenuation.

The literature involved an overview of the filter designs that were applied to in WCDMA and the performance analyzed based on the Bit Error Rate (BER) at a given data rate and channel conditions. A study was carried out on square root raised cosine filter for WCDMA at 5MHz. The effect of variation of roll off factor, group delay and interpolation factor on the SRRCF was also studied. The same study was done for flipped exponential family, flipped secant hyperbolic family and flipped secant inverse hyperbolic family. The WCDMA model was developed for the simulation of pulse shaping filter using the MATLAB Simulink library [3].

The user data rate for the model simulated was 64 kbps in a WCDMA system with a bandwidth of 5 MHz using different values of group delay. From the research done the optimum values of the filter parameters were found as follows. The optimum value of group delay D=6, optimum value of
interpolation factor $M=5$ and the optimum value of roll off factor 0.22. This was presented in [4],[5],[6].

In addition, an analysis on the effect of group delay on WCDMA based pulse shaping filter using discrete-time eye scope was done. It was reported that the opening of the eye became more complex as the value of $D$ is changed from 4 to 8 and the side lobe tail attenuation occurs more quickly as $D$ is varied from 4 to 8. Therefore, the group delay in practical implementations must be controlled to decrease the complexity of the filter [7].

The current study has analyzed the performance of the square root raised cosine filter which is applied in a WCDMA system that is delivering data at 2Mbps with channel coding over the additive white Gaussian channel. The performance was analyzed based on the BER determined at the receiver when the filter roll off factor ($\alpha$) was varied and the signal power to noise power spectral density kept constant.

### III. Methodology

This study involved the simulation of the WCDMA system model in MATLAB with the filter roll off factor ($\alpha$) varied from 0.1 to 0.9 and the signal power to noise power spectral density ratio ($E_b/N_o$) from 1dB to 11dB. The modulation format used is 16-QAM and the data is generated at 2Mbps.

The Bit Error Rate (BER) is then determined by comparing the number of bits received in error and the total number of bits transmitted. Keeping the $E_b/N_o$ constant at each level of it and the roll off factor varied. The BER was then recorded for each value of the roll off factor with convolution coding done over the Additive White Gaussian Noise Channel (AWGN) channel.

The convolution coding was done for a code rate of $\frac{1}{2}$, constraint length of 7 and the generator polynomial function taken as $poly2trellis [7,171,133]$ in octal numbers. The trace-back length of the Viterbi decoder was taken as 34 and hard decision decoding.

### IV. Results And Discussion

The filter roll off factor was varied while keeping the value of $E_b/N_o$ constant and the results plotted for 16-QAM modulation technique with channel coding implemented.

The graphs of BER against the filter roll off factor at each value of the ratio of signal power to noise power spectral density when convolution coding is incorporated in the system were plotted using MATLAB.

![Fig. 1: Variation of BER at 1dB](image)
Fig 2: Variation of BER at 2dB

Fig 3: Variation of BER at 3dB

Fig 5: Variation of BER at 4dB

Fig 6: Variation of BER at 5dB

Fig 7: Variation of BER at 6dB

Fig 8: Variation of BER at 7dB
From Fig. 1-11, the roll of factor (α) with the minimum value of the BER for each value of $E_b/N_0$ was noted and summarised in Table 1.

**Table 1: Roll-off factor with Minimum BER for each value of (E_b/N_0)**

<table>
<thead>
<tr>
<th>$E_b/N_0$(dB)</th>
<th>Roll-off factor with minimum BER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>0.2 or 0.3</td>
</tr>
<tr>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>0.3</td>
</tr>
<tr>
<td>8</td>
<td>0.3</td>
</tr>
<tr>
<td>9</td>
<td>0.8</td>
</tr>
<tr>
<td>10</td>
<td>0.3</td>
</tr>
</tbody>
</table>

From Table 1, it can be seen that for the system model that was developed and employing a pulse shaping filter the filter roll off factor which gives the minimum BER can be taken as $\alpha=0.3$ for all the values of $E_b/N_0$. This roll off factor gave the minimum BER for most values of $E_b/N_0$ and as such it can be taken as the optimum value of the roll off factor without increasing the complexity of the filter.

**V. Conclusion**

The WCDMA communication system has been simulated at a rate of 2Mbps over the additive white Gaussian noise channel that employs a pulse shaping filter and channel...
coding. The filter roll off factor was varied so that a value of it can be chosen which minimizes the error rate and improves the power efficiency. The results show that the performance of a wireless communication system that is using a pulse shaping filter depends on the value of filter roll off factor. The filter roll off factor was found to be $\alpha=0.3$ when filter complexity and power efficiency were considered.

References:


