TSGR1#2(99)091

Agenda Item : 7.5

Source : Nortel Networks

Title : A new pulse shaping for the FDD mode of UTRA

Document for : Discussion

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1 Introduction

At the beginning of the SMG2 UMTS physical layer expert group, we proposed a new pulse shaping function as a replacement of the pulse shaping function (the root raised cosine filter with α=0.22) that was included in the Alpha Group report that was to be the basis for the XX documentation as far as the FDD mode is concerned. Our proposal that we will described later, was well received at that time (April 98) and several comments or questions were addressed to us. Later on, the issue of the proper selection of the pulse shaping was not re-discussed in the SMG2 UMTS physical expert group, because there were many other aspects to study and we were not yet in the specification phase.

In the framework of 3GPP, we are now entering into a specification phase, with as a preamble a merging phase, which aims at solving the differences that may exist mainly between the ETSI and ARIB documentation. The pulse shaping function is provided in the ETSI documentation and not in the ARIB specification. There should therefore be some discussion on this matter. As an input to those discussion we would like to provide WG1 with a description of our proposal for a new pulse along with some evaluation of that pulse in terms of time spread and spectral characteristics. This content of this paper is mostly identical to the contribution SMG2 UMTS L1 17/98. In this updated contribution we however address the points that were raised when the idea was first introduced.

This paper proposes to use as modulation pulse the square root of a sinc pulse with a gaussian function instead of the root raised cosine with roll-off parameter 0.22. The purpose is to reduce the time spread of the modulating pulse in order to lower the computational burden for both the transmitter and the receiver while keeping the same spectral properties in terms of bandwidth and adjacent channel protection.

2 Definition

The impulse response q(t) of the pulse shaping filter is given by the following relations :

p(t) = q(t)*q(t) where * denotes the convolution and $\mathrm{p}(t) = \mathrm{sinc}\left(\frac{p\,.t}{T}\right).e^{-\frac{t^2}{2s^2T^2}}$, where T is the chip duration $T = \frac{1}{4.096}ms$, s is a constant equal to 5 and sinc is the function $\frac{\sin(x)}{x}$.

When a matched filter is used in the receiver, the resulting impulse response in static propagation conditions is p(t) which satisfies the Nyquist criterion.

P(f), the Fourier transform of p(t) is given by :

$$\mathrm{P}(f) = \frac{T}{2}\left[\mathrm{erf}\left(\sqrt{2}p s T\left(f + \frac{1}{2T}\right)\right) - \mathrm{erf}\left(\sqrt{2}p s T\left(f - \frac{1}{2T}\right)\right)\right] \text{ with } \mathrm{erf}(x) = \frac{2}{\sqrt{p}}\int_0^x e^{-t^2}.dt$$

q(t) can also be seen as the inverse Fourier Transform of $\sqrt{P(f)}$. Figure 1 shows the normalised pulse q(t) with oversampling factor 8.

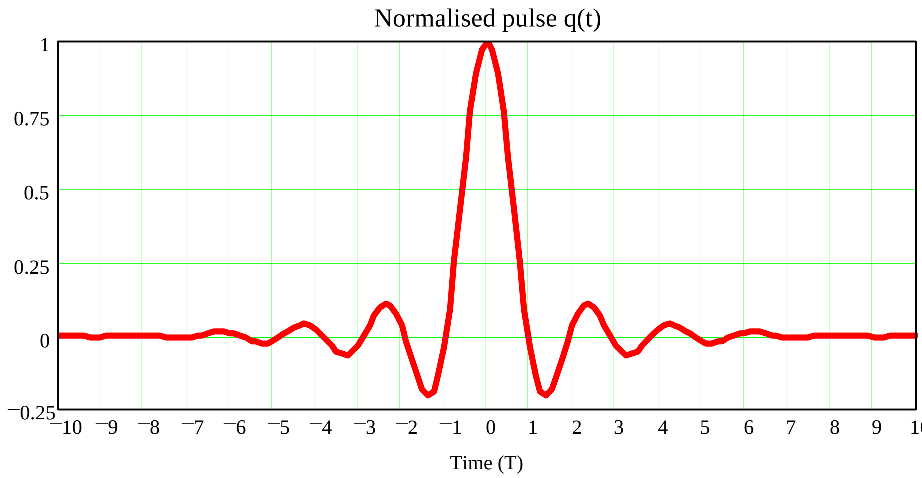

Figure 1

3 Spectrum of the transmitted signal

3.1 Theoretical

The power density spectrum of q(t) is $P(f)$. It is displayed on figure 2 as well as the root raised cosine power spectrum.

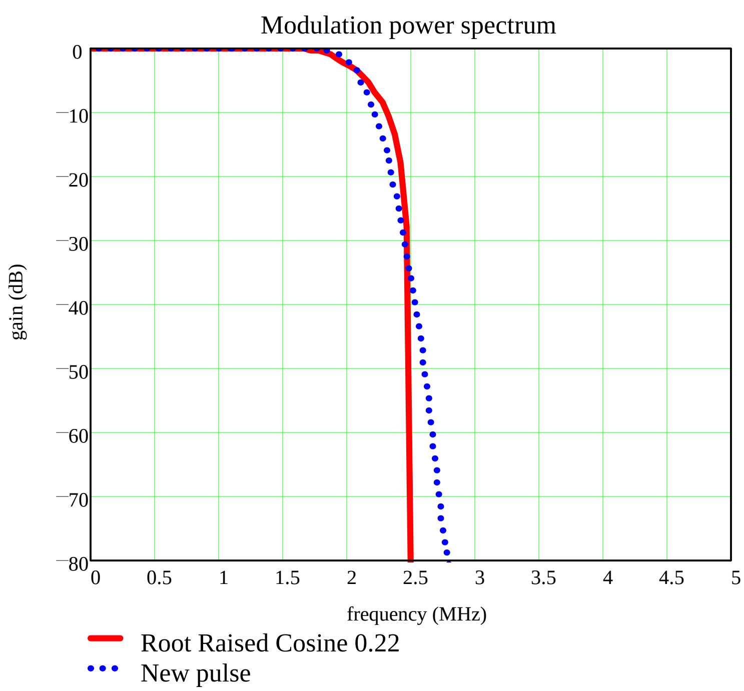

Figure 2

Adjacent channel protection is 41, 25 and 17dB with respective channel spacing 4.6, 4.4 and 4.2 MHz (45dB the value given in [2] for the root raised cosine is obtained with 4.45MHz channel spacing).

3.2 Practical implementation

In the transmitter, pulse q(t) is truncated and its coefficients are quantised. These two operations trade spectral performances against computational burden.

The minimum time spread needed to avoid exceeding out-of-band ripple and poor adjacent channel protection of the resulting spectrum is closely related to the amplitude decrease of the coefficients. The truncation must take the amplitude decrease into account.

Figure 3 plots the base 2 logarithm of the coefficients amplitude versus time spread in chip duration for both pulses. Only half of the coefficients are represented since the filter is symmetrical, 0 log2-amplitude corresponds to the central coefficient. The over-sampling factor is 8.

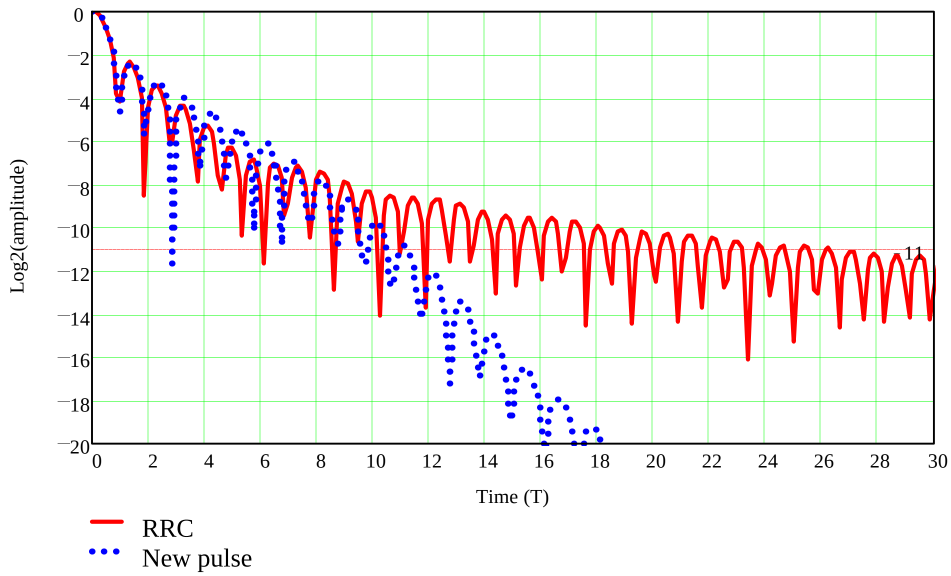

Figure 3

We observe that the new pulse has a much faster decrease which will allow to reduce the time spread when quantising on a given number of bits. Figure 4 displays the local maximums in a chip time duration.

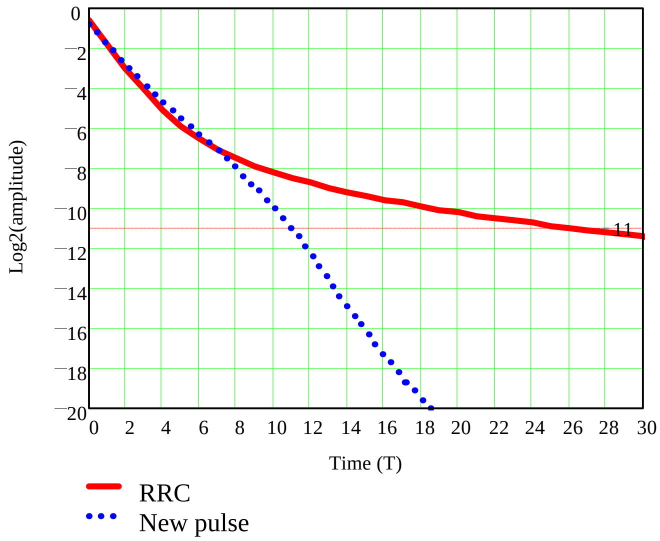

Figure 4

12 bits i.e. 11 bits plus sign is a classical value for quantising the coefficients of such pulse shaping filters.

Assuming that the criterion to fix the number of coefficient, consists in selecting all coefficients that can be quantised using 12 bits, then new pulse can be truncated to a 12 chip time spread whereas the root raised cosine has to be truncated to 27 chip duration time spread. If we increase the number of bits for quantisation, then the difference is all the more significant since the coefficients amplitude of the new pulse decreases exponentially.

Figure 5 shows the resulting spectra when quantising on 11 bits plus sign. The over-sampling factor is 8, the respective time spreads are 27 for the root raised cosine and 12 for the new pulse.

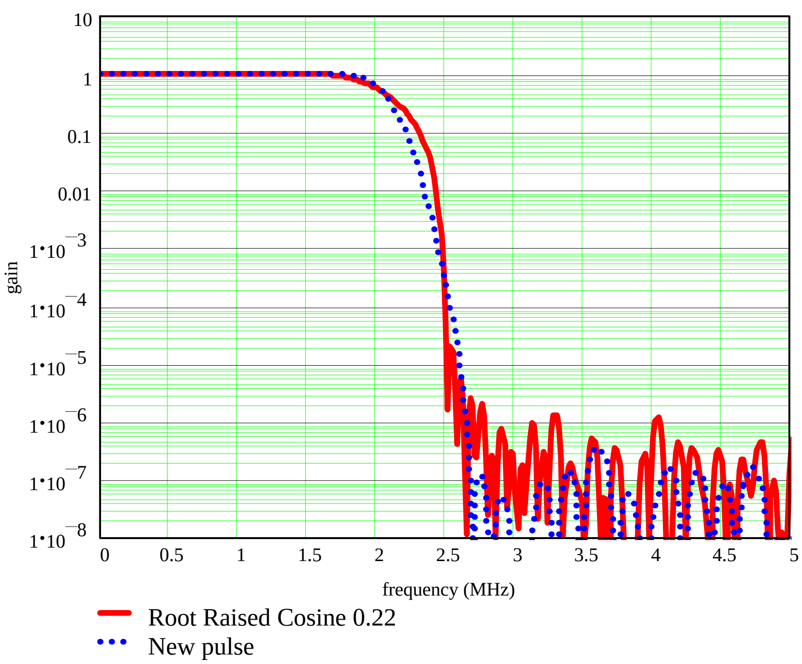

Figure 5

4 Answers to questions asked during SMG2 UMTS physical layer expert group meeting

When this new pulse was presented in the SMG2 UMTS physical layer meeting#1 meeting would found attractive and several comments were raised. We find useful to reproduce here comments and answers provided as follows :

- It was asked why we had chosen a pulse p(t) such that the $P^2(f)$ satisfies the Nyquist criterion, whereas inter-symbol interference is anyway introduced by the multi-path propagation. We answered that a pulse allowing to satisfy the Nyquist criterion may not be needed. In our approach we tried only to find a better pulse taking the same assumption as the original proposal as far as the Nyquist criterion fulfilment is concerned
- It was also asked what would be the impact of imperfect sampling. Figure 5 shows that the spectrum is nearly the same for the root-raised cosine and the new pulse, so for the “imperfect” sampling effect does not differ
- It was asked finally what would be the impact of non linear amplifier on the spectrum. The non linear amplifier will impact the spectrum depending on the peaks present in the signal or more globally the peak-to-average ratio. Looking at Fig-4 the coefficients amplitude decrease in a faster way for the new pulse than with the root-raised cosine and are similar for the first coefficients. The PAR should be nearly the same for both pulses so a non linear PA will equally impact the spectrum obtained considering both pulses.

5 Conclusion

The proposed pulse meets the same requirements as the root raised cosine with roll-off parameter 0.22 as far as bandwidth efficiency and adjacent channel protection are concerned. But with its shorter time support it will reduce the computational expense for generating the modulated signal as well as the receiver complexity. Therefore we propose this pulse as pulse shaping filter for the FDD mode of UTRA, as a replacement for the root raised cosine 0.22 in the merged document S1.13.

6 References

[1] : Concept group alpha ; Wideband Direct Sequence CDMA, WCDMA, Evaluation document (version 3.0), Part 1 : system description, performance evaluation.

[2] : Concept group alpha ; Wideband Direct Sequence CDMA, WCDMA, Evaluation document (version 3.0), Part 2 : questions in annex 1 ETR 0402 answers, link budget calculation, complexity analysis, rate matching.