TSG-RAN Working Group 4 meeting #3
Tokyo 29-31, March 1999

TSG RAN R4-99-104

Agenda Item : 7.2 , 7.3

Source : Nortel Networks

Title : A new pulse shaping function for the FDD and TDD modes of UTRA

Document for : Discussion

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1 Introduction

It was decided at last RAN meeting that the pulse shaping definition was now in the scope of the RAN Working Group 4 [1]. The subject was before treated within the Working Group 1 and Nortel Networks submitted a contribution ([2]) on that subject at the WG1 meeting #2 (Yokohama 22-25, February 1999).

[2] is a proposal for the replacement of the root raised cosine filter (roll-off factor of 0.22) by a filter whose impulse response is the frequency square root of a sinc and a gaussian function. [2] outlines that the spectral properties and the adjacent channel protection were identical to the root raised cosine filter while the time spread of the pulse was lower, resulting in a reduction of the computational burden associated with this function. This proposal was well received by WG1 members, and also in April 98 when this was first presented at SMG2 UMTS Physical Expert Group (Contribution SMG2 UMTS L1 17/98).

This subject has now to be treated in Working Group 4 and the present document is proposed as an input for the discussion in that group. This paper proposes a new filter for the baseband modulation. The impulse response of that filter is the frequency square root of the sinc function multiplied by a Kaiser-Bessel window. This document provides a description of this proposal, to be compared against the actual root raised cosine filter and the "gaussian" modulation submitted in WG1 [2].

In a similar way, the aim of this new proposal is to reduced the delay spread while keeping spectral characteristics similar to the root raised cosine filter.

2 Definition

2.1 Impulse response

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 with $\mathrm{p}(t) = \mathrm{sinc}\left(\frac{p.t}{T}\right).w\left(\frac{t}{T}\right)$

- $w(t)$ is the Kaiser-Bessel window given by $w(t) = \dfrac{I0\left(pa\sqrt{1-\left(\frac{t}{b/2}\right)^2}\right)}{I0(pa)}$ for $|t| \leq t$
- *I0* is the zero-order modified Bessel function of the first kind.
- sinc is the function $\dfrac{\sin(x)}{x}$.

For our application $T = \dfrac{1}{4.096}ms$, $a=4$, $b=26$.

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. Figure 1 shows the normalised pulse q(t).

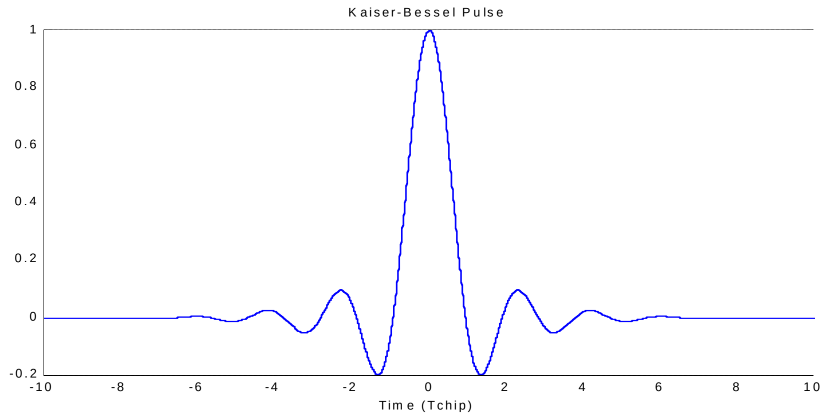

Figure 1 – Kaiser-Bessel impulse response

2.2 Spectrum

The Fourier transform of p(t), is proportional to P(f) :

$$\mathrm{P}(f) = T^2 \int_{-\frac{1}{2T}}^{\frac{1}{2T}} W\big[(f-u)T\big]du \quad \text{with } W(f) = \frac{b}{I0(pa)} \frac{sh\left(pa\sqrt{1-\frac{f^2b^2}{a^2}}\right)}{pa\sqrt{1-\frac{f^2b^2}{a^2}}}$$

q(t) can also be seen as the inverse Fourier Transform of $\sqrt{\mathrm{P}(f)}$.

The power density spectrum of q(t) is $\mathrm{P}(f)$. It is displayed on Figure 2 as well as the root raised cosine and the gaussian modulation power spectrum.

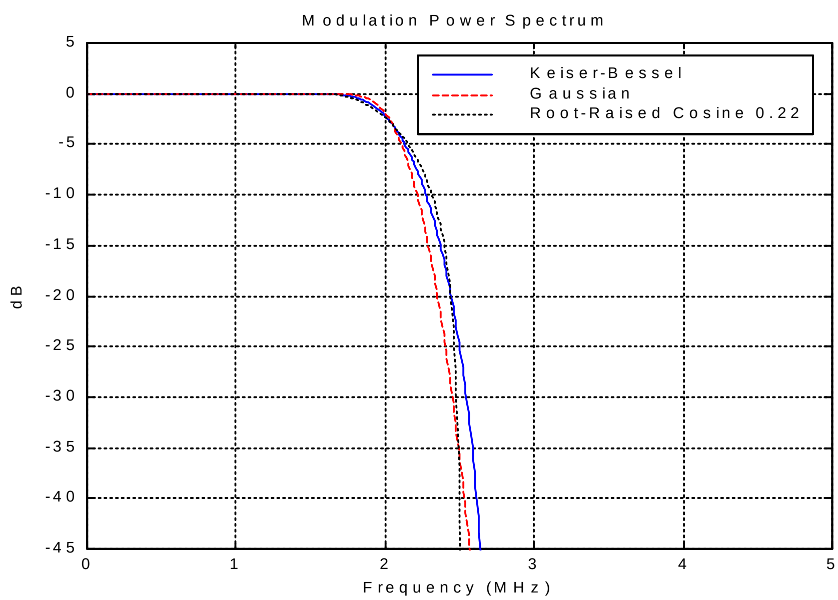

Figure 2 – Power density spectrum comparison

3 Performance

3.1 Practical implementation

In the transmitter, the pulse q(t) is truncated and its coefficients are quantified. 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.

From the time spread point of view, it clearly appears that if we wish to quantify the pulse on a given number of bits for instance 12, the Kaiser Bessel and Gaussian pulse will result in considerably shorter pulses : 9 and 11 instead of 24 chip periods time spread.

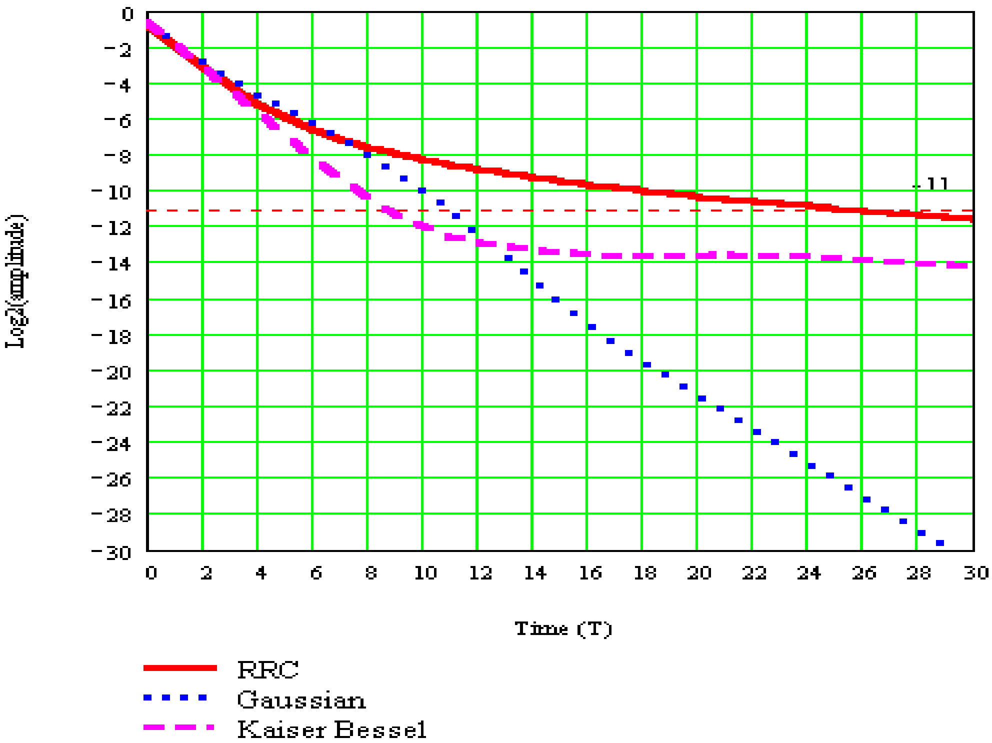

Figure 3 - base 2 logarithm of the coefficients amplitude

3.2 Adjacent Channel Protection

Figure 4 is the plot for the three pulses of the adjacent channel protection ACP versus pulse length.

The ACP is evaluated using the following formula :

$$ACP = \frac{2 * \int_{0}^{Fc/2} \left|H(f)\right|^4 \mathrm{d}f}{\int_{Fa-Fc/2}^{Fa+Fc/2} \left|H(f-Fa)\right|^2 . \left|H(f)\right|^2 \mathrm{d}f}, \text{ where}$$

- H(f) is the fourier transform of the truncated pulse g(t)
- Fa is the frequency offset : Figure 4 is plotted with Fa = 5 MHz
- Fc is the chip rate, 4.096 MHz

This characterises either the ACLR for the transmitter or the ACS for the receiver. Considering a 12bit quantization and an ACP value of 60 dB, the time spread can be reduced from 14 chip periods for the RRC 0.22 to 8 with the gaussian pulse and up to 6 for the Kaiser-Bessel pulse.

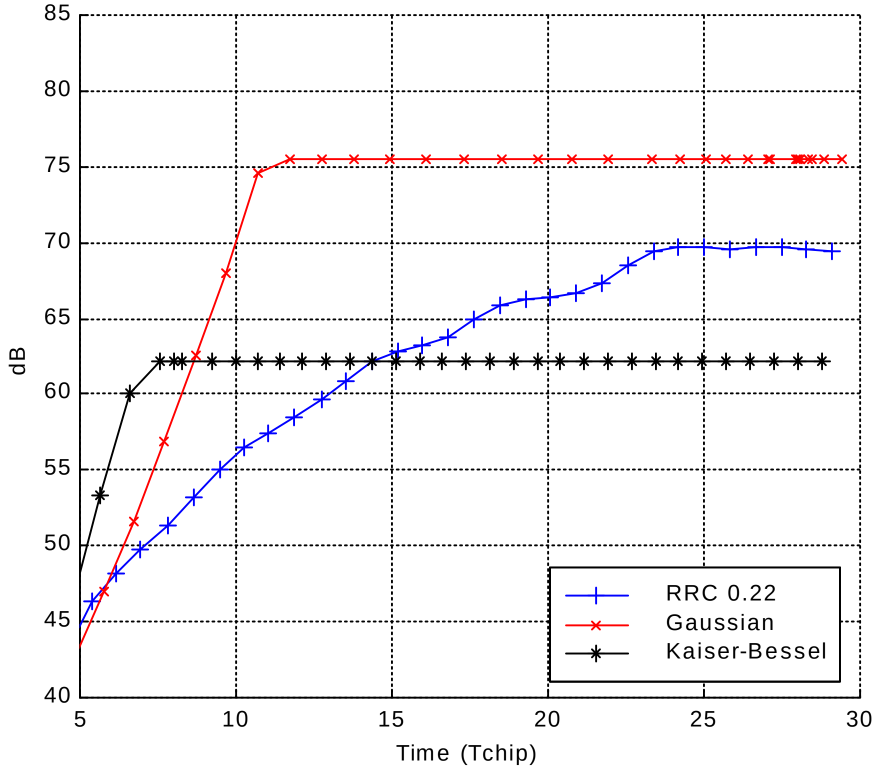

Figure 4 – TX-ACLR or RX-ACS performances

3.3 Peak to average ratio

Peak to average ratio is an important parameter when defining a modulation since it has a direct impact and the Power Amplifier of the transmitter. The higher the peak to average ratio is, the more linear the power amplifier should be, the more its efficiency decreases.

Figure 5 below gives the cumulative distribution function of the amplitudes of the modulated signal. It could be noted that the three modulations have equal performance with respect to this characteristic.

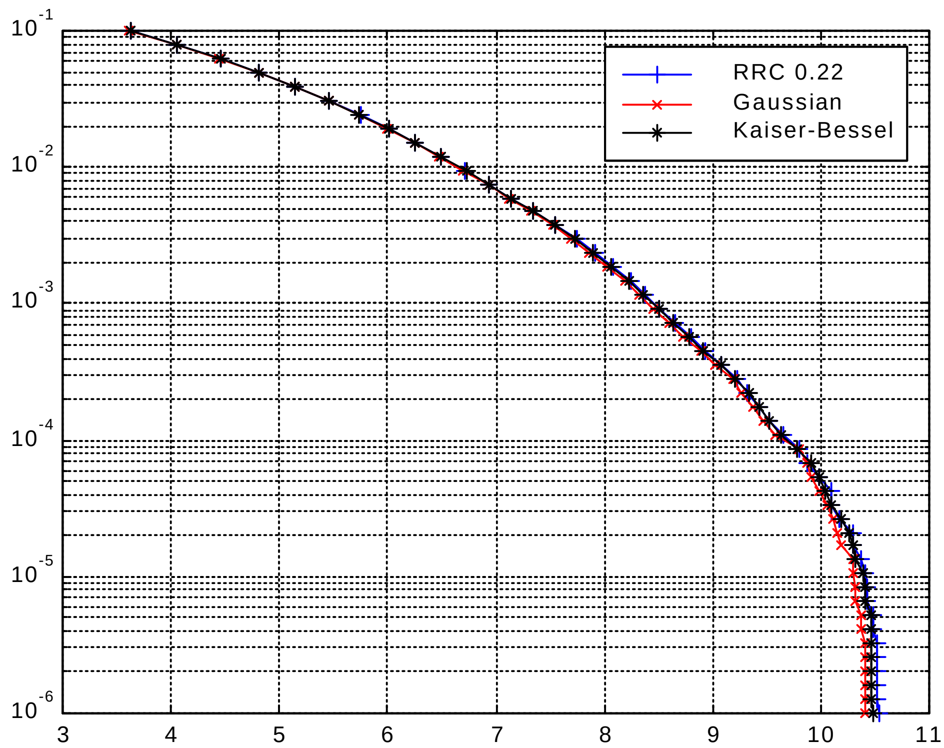

Figure 5 - Cumulative distribution function of the amplitudes of the modulated signal

4 Conclusion

This document proposes a new pulse (referred as 'Kaiser-Bessel' pulse) to define the modulation for UTRA. This pulse has been compared to the Root raised cosine (Roll-off 0.22) and to the pulse presented at 3GPP RAN WG1#2 meeting and described in [2] (referred as 'Gaussian' pulse).

The three impulse responses under consideration meet the same requirements with respect to

- bandwidth efficiency
- adjacent channel protection
- amplitude distribution

But with its shorter time support the Kaiser-Bessel pulse 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 both FDD and TDD mode of UTRA, as a replacement for the root raised cosine 0.22 in the document S4.01(FDD) and S4.02(TDD).

5 References

[1] : RAN and RAN WG Chairmen and Convenors, "Organisation of the work within RAN and between RAN and other TSGs", TSGR#2(99)162

[2] : Nortel Networks, "A new pulse shaping for the FDD mode of UTRA", Tdoc TSGR1#2(99)091