TITLE **Text for informative annex on modulating RFI tones**

PROJECTS RFI testing

SOURCE: KPN, TNO Telecom

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STATUS Proposal; for Decision

ABSTRACT An informative annex is required to example how to generate a band limited noise modulation signal (for modulating the RFI tones) without violating the associated crest factor restriction of that modulation noise.
This text is intended as an improvement of the proposal in TD23 (from ke Kommunications-Elektronik), to fix formulation errors in TD23, and to extend the list of implementation examples.

Annex "X" (informative) Examples on modulating the carriers of a Broadcast RF noise generator [G5]

To demonstrate that the performance of xDSL modem under test is compliant with the associated standard, the test setup requires a noise generator capable of generating modulated carriers (RFI tones) that meet the requirements in clause X.X.X. Special attention has to be paid that the modulation of these carriers is not only limited in frequency (band limited "white" noise), but also limited in crest factor, all according to clause X.X.X. There are many ways of implementing such a device, and this informative annex provides only a few examples on how such a signal could be generated in practice.

discrete frequency component approach
One of the many ways to generate bandlimited "white" noise, is a pseudo random approach, where the bandlimitation is guaranteed by using a discrete number of frequency components, all with equal amplitude:

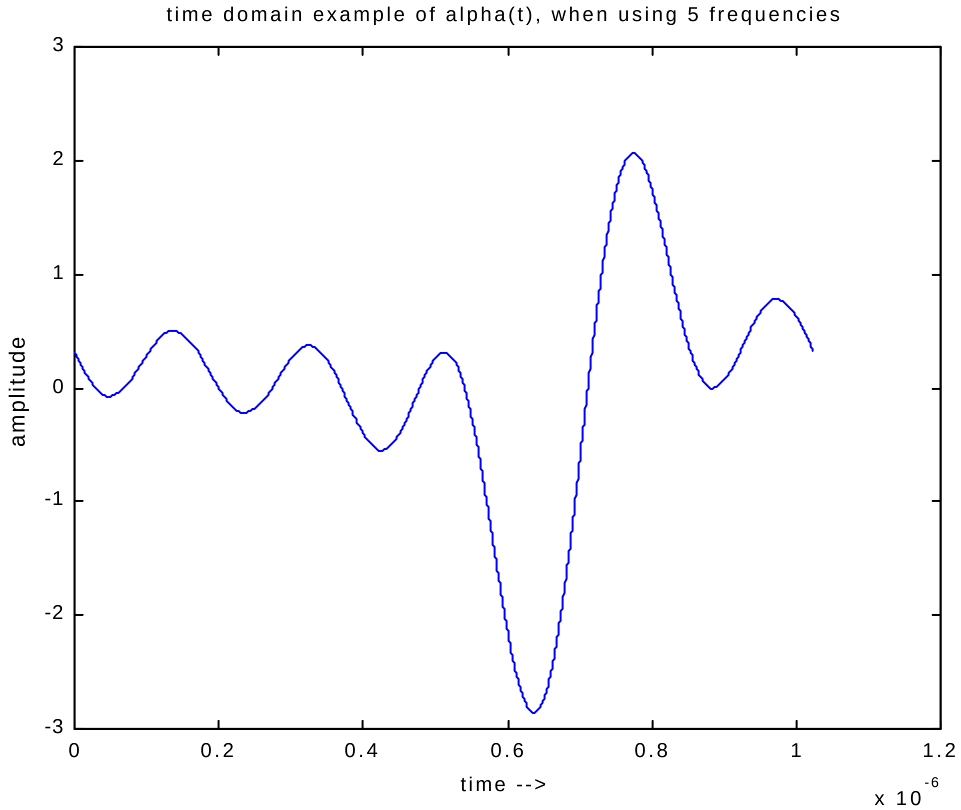
$$a(t) = \sqrt{2/M} \times \sum_{q=1}^{M} \cos\left(2p \times f_q \cdot t + y_q\right)$$ M components, arbitrarily located

The above expression is scaled in such a way that the mean value of a(t) equals zero, and that the rms value equals one. Under these conditions hold that the crestfactor equals the highest absolute peak within a(t).
This crest factor varies with the values of y_q and can be very large when chosen at random
The result is that, without any special measures, the crest factor of signal a(t) may easily exceed the specification in clause X.X.X This should be prevented because it causes overmodulation of the carrier. Below are examples how to achieve this.

solution 1: limited frequency component component

One way of restricting the crestfactor of $\alpha(t)$ is by limiting the number of frequency components M significantly. Values as low as M=5 will guarantee that the maximum crestfactor requirement will always be met, but the resulting modulation signal $\alpha(t)$ will hardly represent a "white" appearance of the bandlimited noise. However it is assumed that in several cases the uses of M=5 is adequate for RFI testing, provided that the frequency components f_q and phases ψ_q are selected as follows:

please add a specification/guideline for selecting the set of f_q
and the why the phase (or time offset) has to be handled
see TD23 for possible descriptions
the 5-tone signal below, is NOT what is to be generated !!!!!



solution 2: maximum frequency component component, and controled phase

Another way of restricting the crestfactor of $\alpha(t)$ is by restricting the phase components ψ_q, to enable that the number M can be seleced as high as possible. The advantage of this is a significantly improvement of approximating the white nature of the bandlimited modulation noise. This makes the solution wider applicable then the first solution.

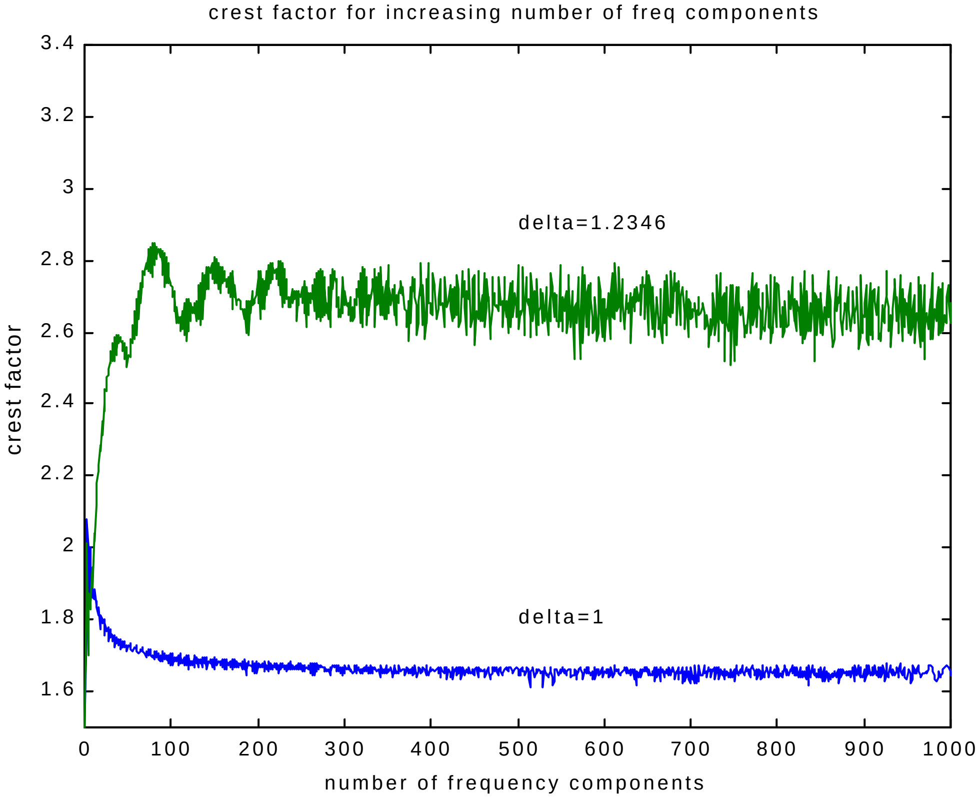
This high number of M is the natural result when using arbitrary waveform generator to generate pseudo random noise by repeating a waveform of N samples. Waveforms, build-up from $N \geq 2^{18}$ samples, are commonly adequate for generating noise up to f_{max} = 1 MHz. The periodic nature of waveforms with N samples causes that the spectrum of the pseudo random signal is build up from equally spaced frequency components at spacing $\Delta f=2/N \times f_{max}$ .This spacing is 7.6 Hz or lower when the above example numbers apply.
When a carrier frequency is to be modulated with noise $\alpha(t)$ that is bandlimited up to a frequency Δb , then this modulation signal is also build up from M<N equally spaced frequency components. This number equals $M = round(\Delta b/\Delta f) = round(\Delta b/f_{max} \times N/2)$. This number is in the order of M=655 when the above numbers apply and Δb=5kHz. The natural way of expressing this bandlimited "white" noise $\alpha(t)$ is therefore a sum of a large number (M) equidistant frequencies, each of them with equal amplitude and a dedicated phase.

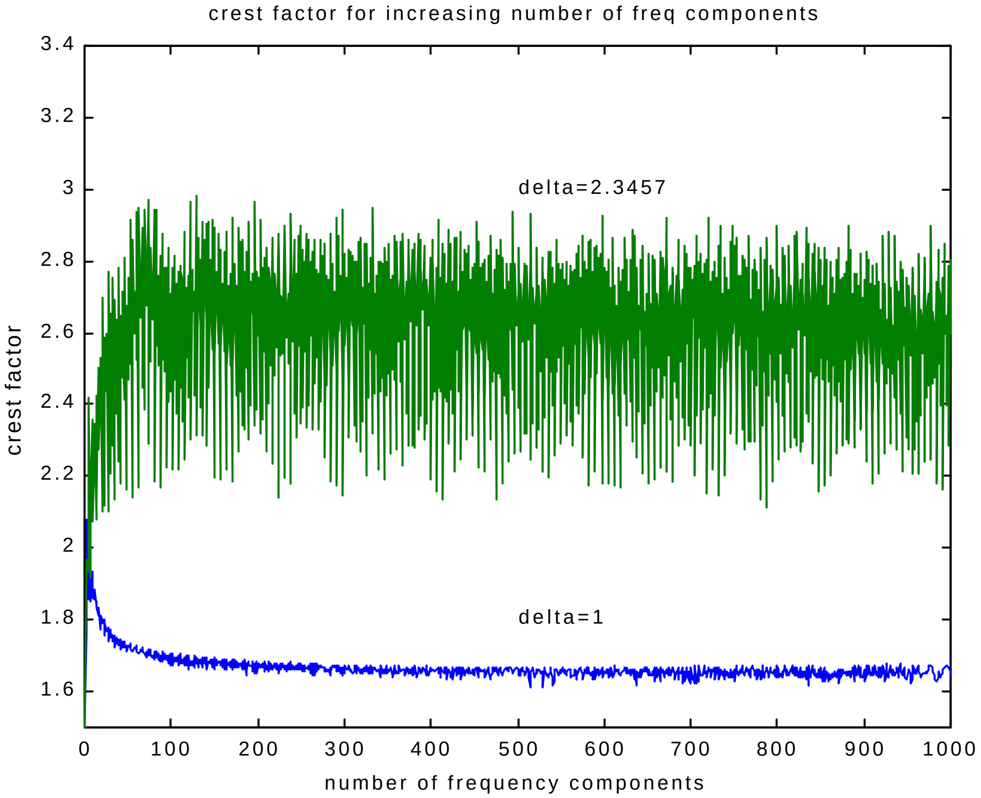
$$a(t) = \sqrt{2/M} \times \sum_{q=1}^{M} \cos\left(2p \times (q \times \Delta f) \cdot t + y_q\right)$$ M components, equidistant

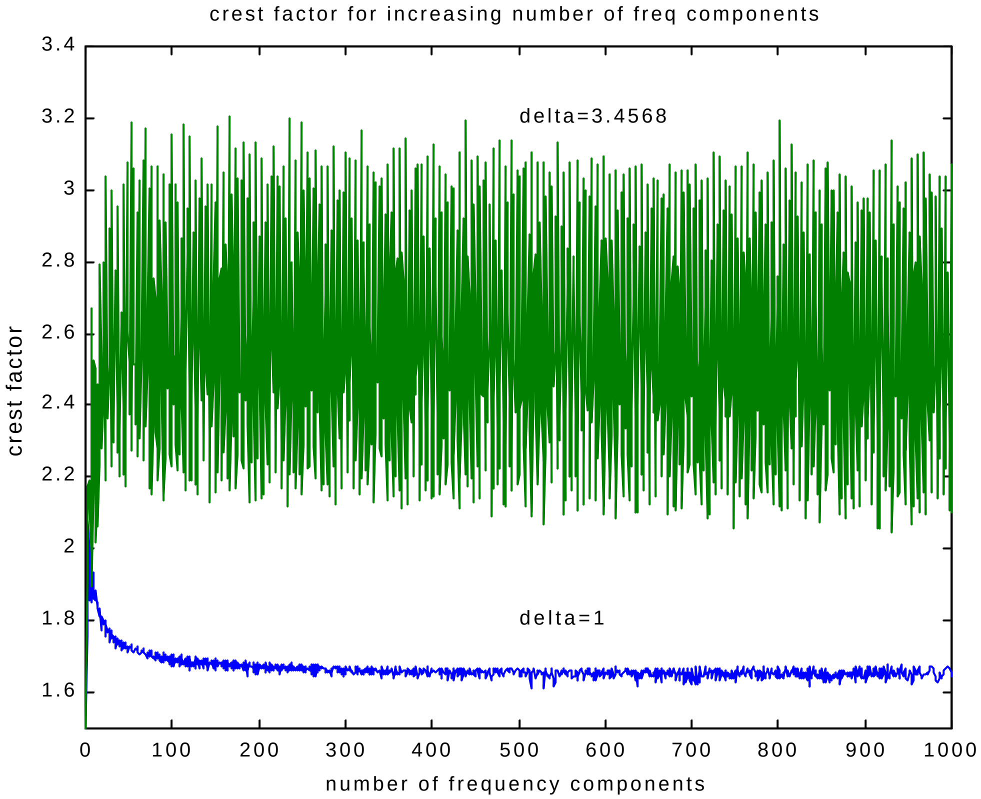
The crest factor can be made sufficiently low for well designed combinations of ψ_q, including those expressed below. This holds especially when δ=1 in this expression.

$$y_q = 2p \times q \times \left(\frac{(q-1)}{2 \times M} \times d \right)$$

Figure [*] to [*] show this crest factor for an increasing number of frequency components M, when the above phase restriction is applied. It is shown for a few values for δ, and demonstrates that the crestfactor remains controlled for small deteriorations (δ≠1) of this "optimal" phase restriction. The use of this factor d enables a convenient way to apply different modulation signals for modulating different carriers.




crest factor for increasing number of freq components
delta=2.3457
delta=1
crest factor
number of frequency components
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
0
100
200
300
400
500
600
700
800
900
1000


crest factor for increasing number of freq components
delta=3.4568
delta=1
crest factor
number of frequency components
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
0
100
200
300
400
500
600
700
800
900
1000