Multisine design with minimum Crest Factor and its application for IHF measurement

Customer: NMP

Project: New York

Product: D-Cover

Test system: FT and AOI

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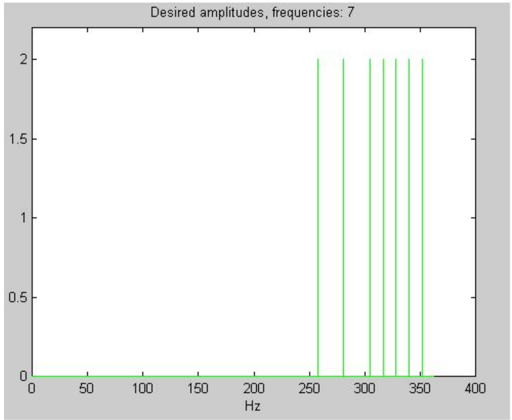
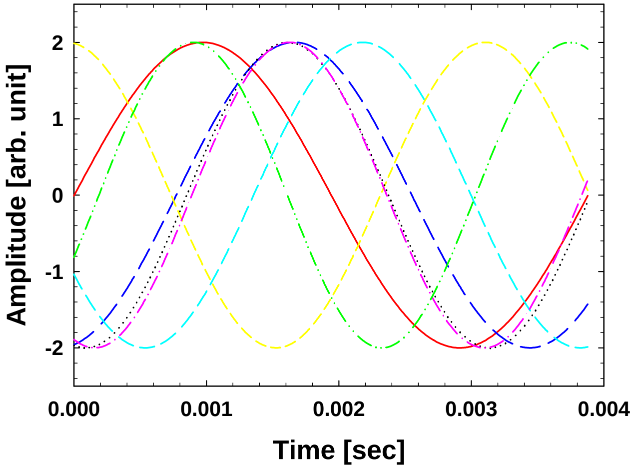
Multisine input signals

A multisine input is a deterministic, periodic signal composed of a harmonically related sum of sinusoid:

$$x(t) = \sum_{k=0}^{N-1} A_k \sin\left\{2\pi N_K \Delta f\, t + \phi_k\right\}$$





A_k: magnitudes of sinewave components of multisine
Φ_k: phase shifts for harmonic *k*
N_k: integer multiples of frequency spacing
$\Delta f = f_c / M$: sampling frequency / sequence length

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Definition of the Crest Factor

The Crest Factor (CF) of signal x(t) is the ratio of the £$_{\infty}$ (or Chebyshev) norm and the £$_{2}$ norm:

$$CF\left[x(t)\right] = \sqrt{\mathrm{PAPR}} := \frac{\left\| x(t) \right\|_{\infty}}{\left\| x(t) \right\|_{2}} = \frac{\max_{t \in [0..T]} \left| x(t) \right|}{\sqrt{\frac{1}{T} \int_{0}^{T} \left| x(t) \right|^{2} dt}}$$

Crest Factor Minimization

For a given multisine the reduced Crest Factor value can be obtained from the solution of a minimization problem on the function of the phase offset.

$$\min_{\{\phi_0, \phi_1, \ldots, \phi_{N-1}\}} CF \left\{ x\left(t, \left[\phi_0, \phi_1, \ldots, \phi_{N-1}\right]\right) \right\}$$

Problems with Minimax Solution

- Nonlonear optimization problem
- The solution call for relatively large scale numerical mathematics tools
- The computational time is rapidly increasing with increasing of the number of the multisine components

This problem requries the use of state-of-art optimization techniques

Software Developing Goal

The aim is to construct a program

i) which gives accurate results,

i)) that is amenable to real-time computation,

i))) and is thus consistent with the needs of the practising engineer.

Brief outline of the calculation method

- In our solution approach the method of *Guillaume et al.* is applied that is based on the Pólya's algorithm
- The problem is formulated in the MATLAB (**MAT**rix **LAB**oratory) program system which provides high accuracy built-in numerical functions

The iterative phase update equation can be expressed as

$$\mathbf{p}^{(i)} = \mathbf{p}^{(i-1)} - [\mathbf{J}^{(i-1)T} \mathbf{J}^{(i-1)} + \Lambda^{(i-1)}]^{-1} \mathbf{J}^{(i-1)T} e^{(i-1)} ,$$

where the real-valued phase vector is

$$\mathrm{p} = [\phi_0 \; \phi_1 \ldots \phi_{N-1}]^{\mathrm{T}} .$$

An FFT-based procedure is used to compute the Jacobian matrix ***J***.

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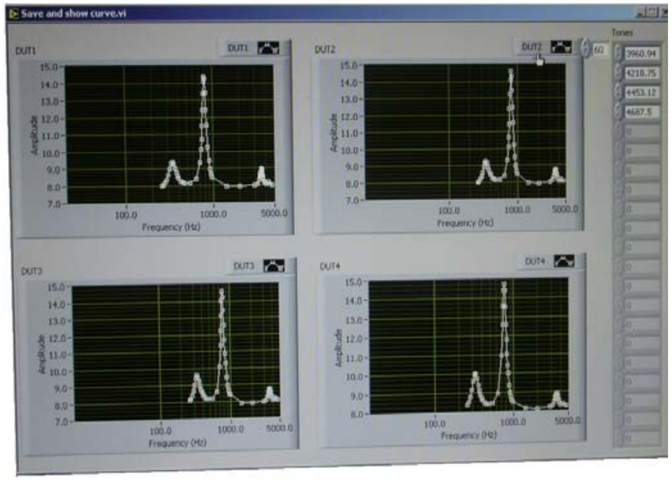
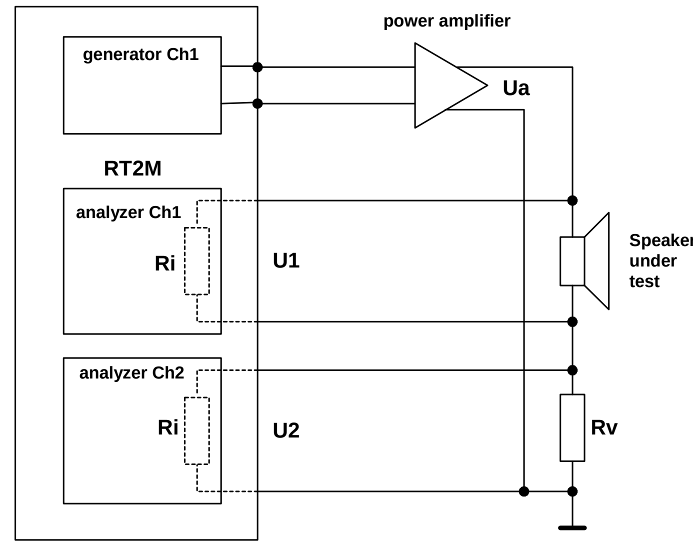
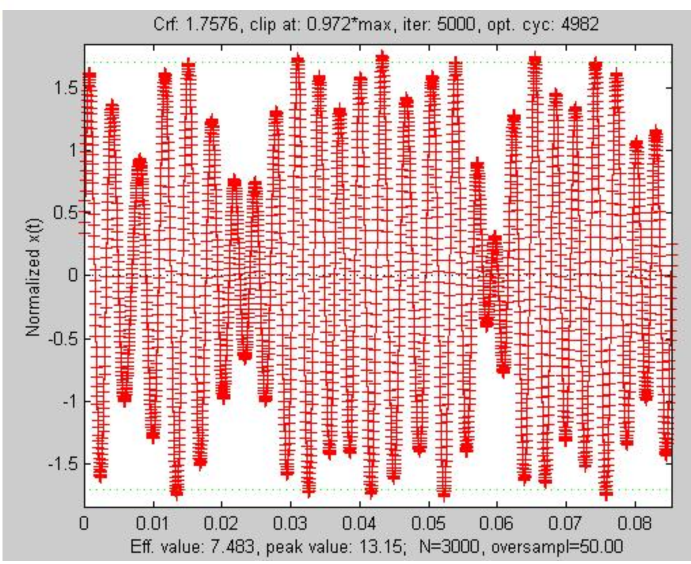
Example for the application: IHF speaker Impedance test







Amplitude	Harmonic numbers	Frequencies	Phase offset
2	22	257.81250	-0.0043
2	24	281.25000	-1.3636
2	26	304.68750	-2.5971
2	27	316.40625	1.6821
2	28	328.12500	-1.7556
2	29	339.84375	-1.9018
2	30	351.56250	-0.4176

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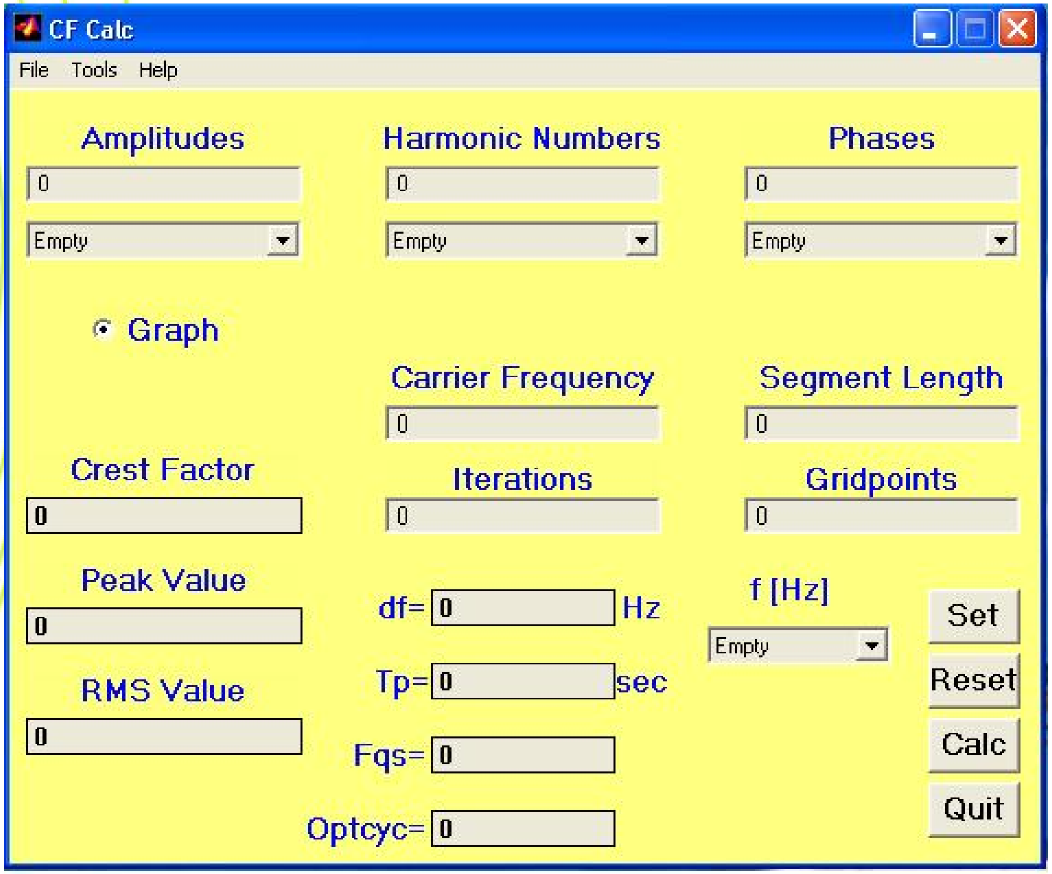
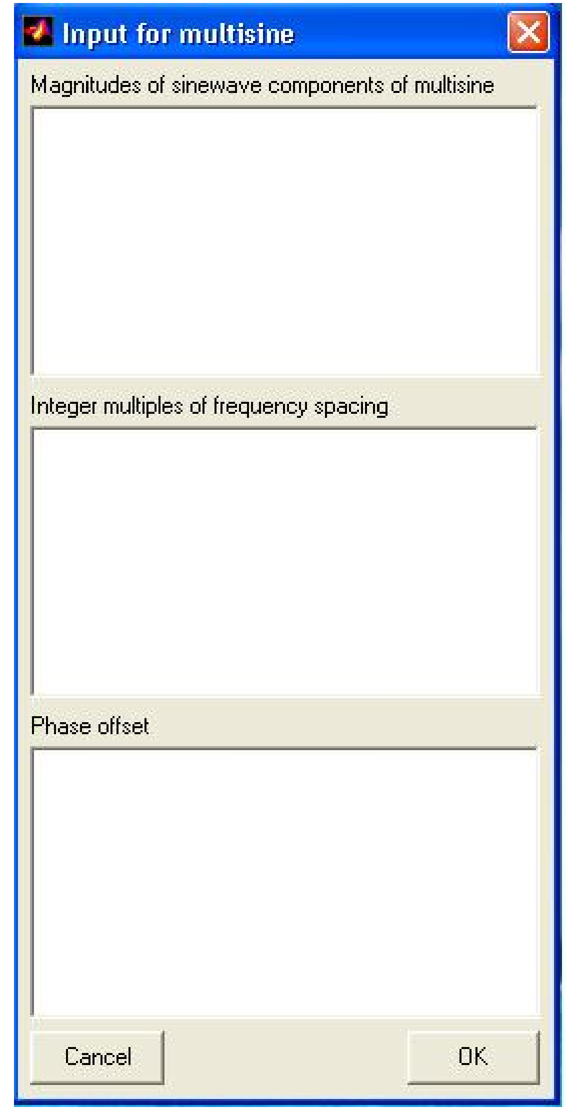
User interface of the program





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