



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

Customer: NMP

Project: New York

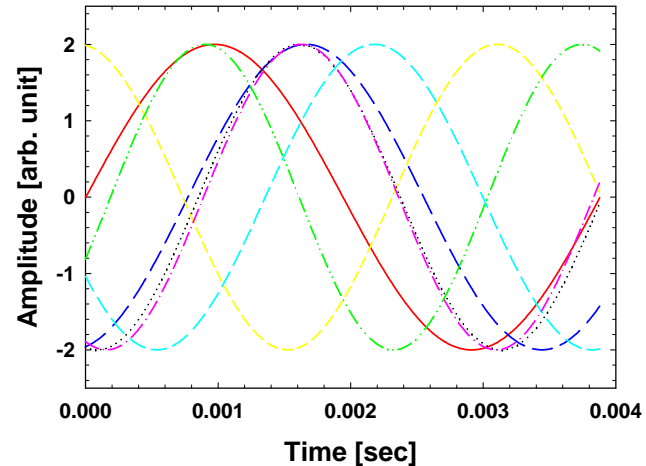
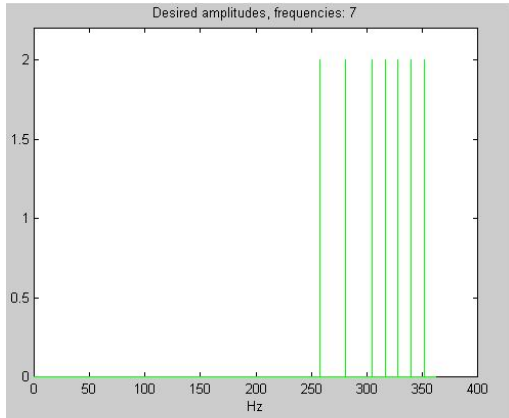
Product: D-Cover

Test system: FT and AOI

Multisine input signals

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

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



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

Definition of the Crest Factor

The Crest Factor (CF) of signal $x(t)$ is the ratio of the \mathcal{L}_∞ (or Chebyshev) norm and the \mathcal{L}_2 norm:

$$CF[x(t)] = \sqrt{\text{PAPR}} := \frac{\|x(t)\|_\infty}{\|x(t)\|_2} = \frac{\max_{t \in [0..T]} |x(t)|}{\sqrt{\frac{1}{T} \int_0^T |x(t)|^2 dt}}$$

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.

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



Problems with Minimax Solution

- Nonlinear 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 requiries 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

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

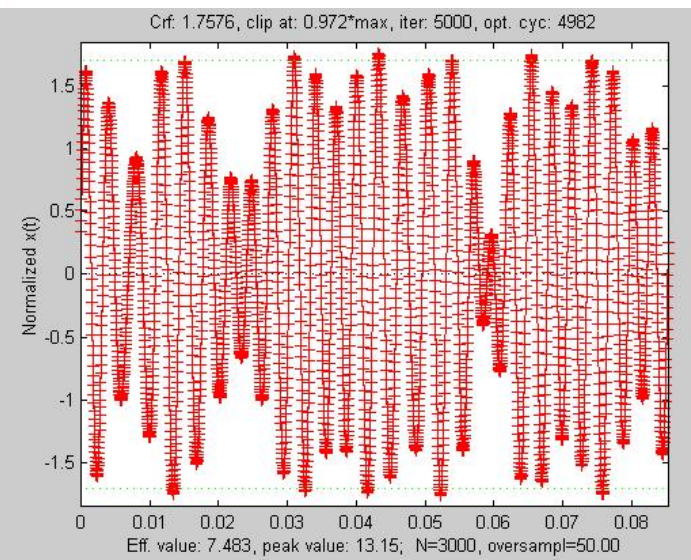
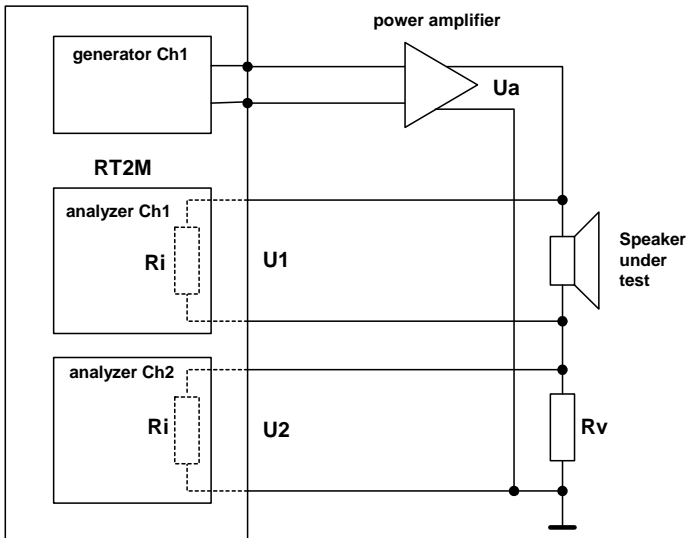
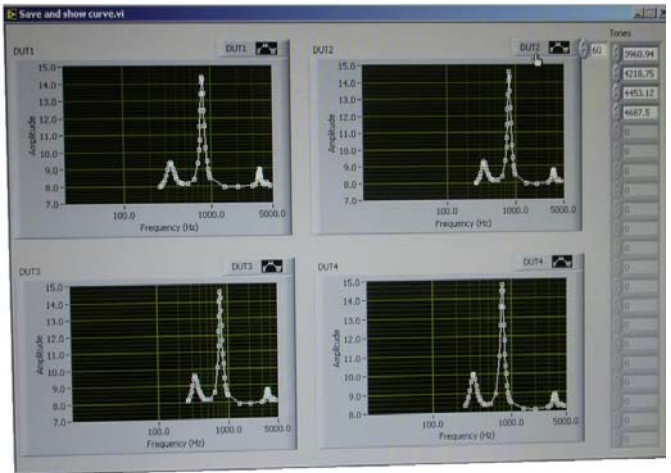
where the real-valued phase vector is

$$\mathbf{p} = [\phi_0 \ \phi_1 \ \dots \ \phi_{N-1}]^T.$$

An FFT-based procedure is used to compute the Jacobian matrix \mathbf{J} .



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



User interface of the program

The screenshot shows the 'CF Calc' application window with a yellow background. It features several input fields and controls:

- Amplitudes:** A text box containing '0' and a dropdown menu set to 'Empty'.
- Harmonic Numbers:** A text box containing '0' and a dropdown menu set to 'Empty'.
- Phases:** A text box containing '0' and a dropdown menu set to 'Empty'.
- Graph:** A radio button that is currently selected.
- Carrier Frequency:** A text box containing '0'.
- Segment Length:** A text box containing '0'.
- Crest Factor:** A text box containing '0'.
- Iterations:** A text box containing '0'.
- Gridpoints:** A text box containing '0'.
- Peak Value:** A text box containing '0'.
- RMS Value:** A text box containing '0'.
- df=:** A text box containing '0' followed by 'Hz'.
- f [Hz]:** A text box containing '0' and a dropdown menu set to 'Empty'.
- Iterations:** A text box containing '0' followed by 'sec'.
- Fqs=:** A text box containing '0'.
- Optcyc=:** A text box containing '0'.
- Buttons:** 'Set', 'Reset', 'Calc', and 'Quit' buttons are located on the right side.

The screenshot shows the 'Input for multisine' dialog box with a white background. It contains several sections for user input:

- Magnitudes of sinewave components of multisine:** A large empty text area.
- Integer multiples of frequency spacing:** A large empty text area.
- Phase offset:** A large empty text area.
- Buttons:** 'Cancel' and 'OK' buttons are located at the bottom.