Application of Musical Multitone Stimulus for Detection of Nonharmonic Distortion Products in Horn Drivers

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Multitone stimulus is known to provide test results that have a better correlation with perceived sound quality than a swept sine wave stimulus. An exhaustive review of multitone theory, history, and application is presented in [1] and [2] by Czerwinski et al. A well-known publication on multitone by R. Belcher [3] presents experimental evidence that multitone stimuli provides superior correlation with the audibility of nonlinear distortion than swept sine wave stimuli. Multitone stimuli, used in [1]-[3], have an equal spacing between the tones on a logarithmic frequency scale. Subjectively, the stimulus sounds anharmonic, dissonant, and noise-like.

The new MMM (Modulated Musical Multitone) signal was developed to bridge the gap between objective testing data and subjective perception of sound. The MMM signal consists of E-minor triads in several octaves with amplitude modulation to match the crest factor of particular musical signals.

In [4], MMM was used for the detection of audible distortion in horn drivers. In [5], the nonlinear response to the MMM signal was post-processed in the frequency domain to obtain the Multitone Total Nonlinear Distortion (MTND) response. MTND represents all the nonlinear distortion products averaged within a sliding window in the frequency domain [6]. The windowed and averaged value of spectral components within the sliding window are then plotted at the center frequency of that window. By repeating this process at different frequencies, distortion products can be identified across the frequency domain. In [5], this approach was used to profile nonlinearities in full-band loudspeaker systems by calculating MTND responses across various input voltage levels and plotting them as 3D graphs.

In the current work, the MMM stimulus did not have modulation (further called MM), and it is generated such that the highest frequency component of the triad A# minor corresponds to 19476 Hz, and the two tones have frequencies of 18640 Hz and 14791 Hz. MM was used to evaluate the high-frequency nonharmonic distortion products generated by two different compression drivers. Often, these distortion products are generally referred to as subharmonics [7]. There are nonharmonic distortion products that can be generated by a single high-frequency tone, unlike intermodulation (IM) distortion products. This paper is concentrated solely on these nonharmonic distortion products. This nonharmonic distortion stems from complex mechanical behavior of the diaphragm, and it is characterized by a complex spectrum.

Two compression drivers, loaded by the reference Holland – Newell axisymmetric horn, were used in the experiments. One driver was based on an annular flexural polymer diaphragm, and the other had a full-metal titanium dome diaphragm and surround assembly. Both drivers had similar motors and voice coils.

A finite impulse response (FIR) filter was used to flatten the sound pressure level (SPL) frequency responses of both horn drivers over the frequency range of 1.5 kHz to 20 kHz, and a high-pass filter (HPF) was used to cut the response to frequencies below 1.5 kHz. The input voltage was specified to provide 120 dB SPL at 1 meter from the mouth of the horn in a 2π anechoic chamber. The resulting nonlinear response consisted of difference IM products and nonharmonic products. The upper harmonics and the sum IM products remained above the audible range, and therefore, they are not of any interest to this paper.

Several output acoustical signals were recorded for each driver. In addition to the MM signal, which consists of a triad of tones, a single tone input and a dual tone input were recorded separately. To better distinguish the difference IM products from the nonharmonic products, output signals with more than one input tone were processed and displayed twice (with and without difference IM products). A real musical signal was reproduced and recorded as well.

The driver equipped with the annular flexural polymer diaphragm exhibited significantly better performance, both objectively and subjectively. This work demonstrates the strong influence of nonharmonic spectral components on the overall quality of horn drivers.

[1] E. Czerwinski, A. Voishvillo, S. Alexandrov, A. Terekhov, "Multitone Testing of Sound System Components – Some Results and Conclusions, Part 1: History and Theory", *J. Audio Eng. Soc.*, vol. 49, No. 11, 2001, November, pp. 1011 – 1048.

[2] E. Czerwinski, A. Voishvillo, S. Alexandrov, A. Terekhov, "Multitone Testing of Sound System Components – Some Results and Conclusions, Part 2: Modeling and Application", *J. Audio Eng. Soc.*, vol. 49, No. 12, 2001, December, pp. 1181 – 1192.

[3] R. Belcher, "A New Distortion Measurement (Better Subjective–Objective Correlation than Given by THD)," Wireless World, pp. 36 – 41 (1978 May).

[4] A. Voishvillo, B. Kakonyi, and B. McLaughlin, "Application of Modulated Musical Multitone Signal for Evaluation of Horn Drivers Sound Quality", Presented at the 147th Convention 2019 October 16–19, New York

[5] A. Voishvillo, B. Kakonyi, and B. McLaughlin, "Profiling loudspeaker nonlinearities using parametric multitone stimulus", Presented at the 149th Convention, Online, 2020 October 27–30

[6] A. Voishvillo, A. Terekhov, E. Czerwinski, S. Alexandrov, "Graphing, Interpretation, and Comparison of Results of Loudspeaker Nonlinear Distortion Measurements", J Audio Eng. Soc., vol. 52, No. 4, 2004, April, pp. 332 – 357

[7] F. Bolaños, "Measurement and Analysis of Subharmonics and Other Distortions in Compression Drivers", Presented at the 118th Convention 2005 May 28–31, Barcelona

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