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THE MEASUREMENT OF NONLINEAR DISTORTION USING BROADBAND NOISE

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The method of measurement of nonlinear distortions in loudspeakers using digital filters has been presented. Using MATLAB software packet developed by MathWorks it is possible to design necessary filters. The Simulink packet has been used for simulation of the measuring process. The level of the residual noise caused by finite slope of the filters has been determined. The static polynomial function has been applied for both: simulation and the measured objects.

Keywords: broadband noise, digital filter, nonlinear distortion.

1. Introduction

The method of measurement of nonlinear distortion with broadband noise as the testing signal and digital filters is described in this paper. The idea of measurement of nonlinear distortion using broadband noise has been developed by V. WOLF in 1953 [3] and continued by S. NIKAIDO in 1973 [2]. The analog filters were used in that research. The very complicated filters were the disadvantage of this method. The filters must have very steep slopes in order to avoid the influence of the residual noise on the measurement results. This noise is caused by finite slope of the band-stop and band-pass filters used in the measurement setup. Then, the analog filters consist of large number of elements and they are sensitive for the tolerances of elements: inductance coils and capacitors. The digital filters were applied for measurement of nonlinear distortion by IMAKA and OHGA [1].

2. Measurement method

The principle of the method of measurement of nonlinear distortion using broadband noise is presented in Fig. 1. The measuring signal – broadband noise is filtered by narrow band-stop filter. In our case the filter bank of 5/9-octave bandwidth has been applied. Central frequencies of the filters are equal to standard 1/3-octave bands. The filtered signal is put to the measured object, e.g. loudspeaker. The acoustic signal radiated by the loudspeaker is recorded by the measuring microphone then it is filtered by the band-pass filter with the same central frequency as the central frequency of the band-stop filter before loudspeaker. The bandwidth of the band-pass filter is slightly narrower than the band-stop one and we used 1/3-octave filters. When the measured object is linear, only the residual noise caused by finite slope of both filters appears in the filtered band. For nonlinear objects the product of nonlinear distortion occurs in the filtered band. Its level should be decidedly higher than the level of the residual noise.

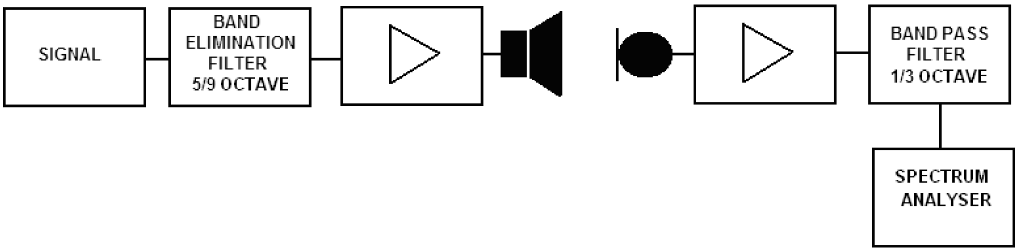


Fig. 1. Principle of measurement.

The advantage of this method is a spectral structure of the measuring signal similar to the spectral structure of the program usually transmitted by the loudspeaker. The results are in good accordance with subjective evaluation of nonlinear distortion. The required very steep slopes of band-stop and band-pass filters are the disadvantages of the method. The digital filters seem to be advantageous for application in this method.

3. Digital filters

The FIR-filters of Butterworth frequency response were implemented. They have a flat frequency response in the passing band. The band-stop filters at the transmitting part of the measuring setup have the bandwidth equal to 5/9-octave and the band-pass filters at the receiving part have the bandwidth equal to 1/3-octave. The filters have been designed using the Filter Design & Analysis Tool which is the part of MATLAB software. The design process is presented in [4]. In order to obtain sufficiently steep slopes of the filters, their order are high, e.g. for the band of 315 Hz the orders are equal to 4884 and 4242 for band-stop and band-pass filter respectively.

4. Simulation of measuring process using Simulink

The simulation of the measuring process has been realized using Simulink program. Simulink is the tool with its own graphic interface and it exploits MATLAB as the computing core. It is applied for the analysis of different dynamic systems. The white Gaussian-noise is given to the input of the system. Then it is filtered by the designed band-stop filter. The measured object is simulated by a non-linear static function $f(u)$. The signal from the output of the non-linear block is filtered by the designed band-pass filter. The input and output signals can be observed using Scope-block. The measure of the nonlinear distortion in the analyzed frequency band twenty logarithms of the ratio of the output and input signals RMS is the measure of the nonlinear distortion in analyzed frequency band. The block-diagram of the Simulink simulated system is presented in Fig. 2.

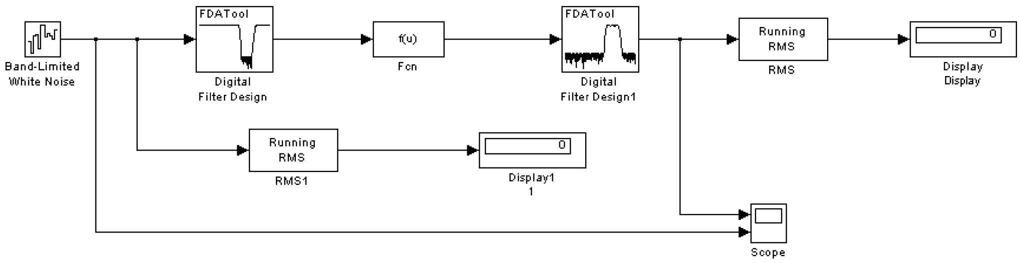


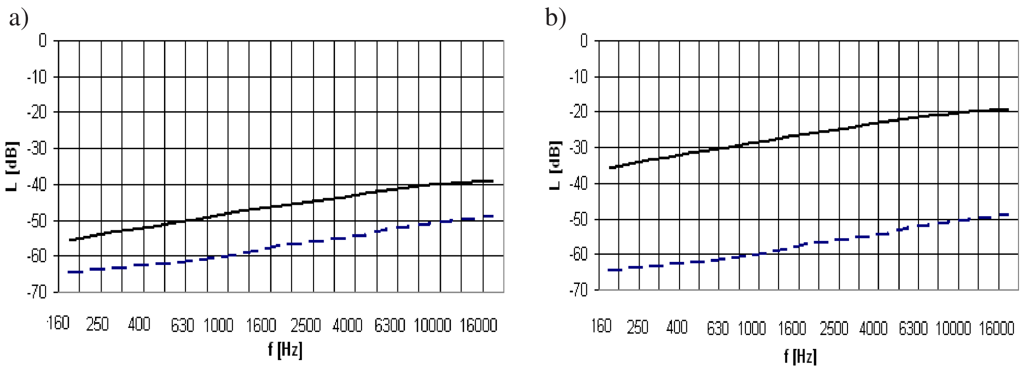
Fig. 2. Block diagram of the measuring system – Simulink.

5. Results of simulation

As the function $f(u)$ in the nonlinear block the polynomial function of third order has been applied

$$f(u) = u + Au^2 + Bu^3. \tag{1}$$

This function is typical for simulation of loudspeaker nonlinearity. The parameters A and B were changed in order to investigate their influence. The simulation was performed for frequencies from 160 Hz to 16000 Hz. The results are presented in Fig. 3. The product of nonlinear distortion is drawn with continuous line, and the residual noise – with dashed one.



[Fig. 3 a, b]

c) d)

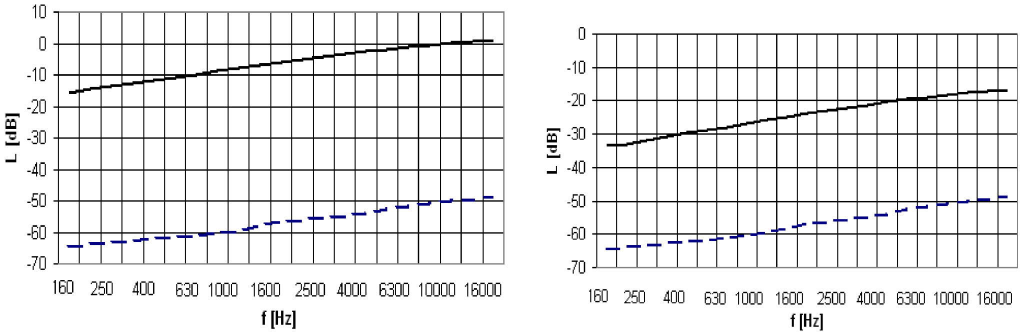


Fig. 3. Nonlinear distortion of the system (Eq. 1): a) $A = 0$, $B = 1/30000$; b) $A = 0$, $B = 1/3000$; c) $A = 0$, $B = 1/300$; d) $A = 1/100$, $B = 1/3000$. Dashed line – residual noise.

The dependence of nonlinear distortion level on A and B parameters for central frequency 1000 Hz is presented in Figs. 4 and 5.

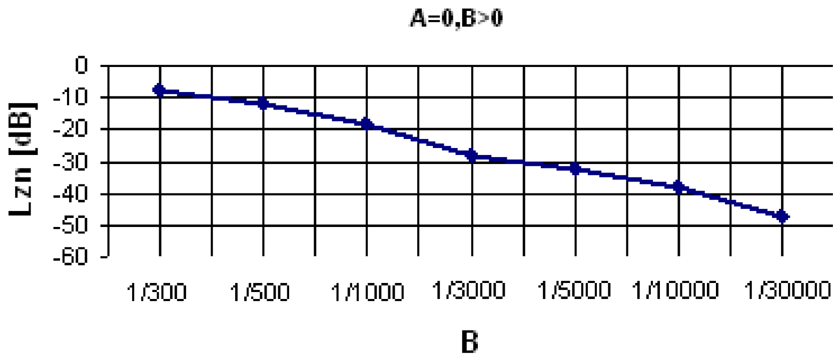


Fig. 4. The dependence of nonlinear distortion level on parameter B with $A = 0$ and $f = 1000$ Hz.

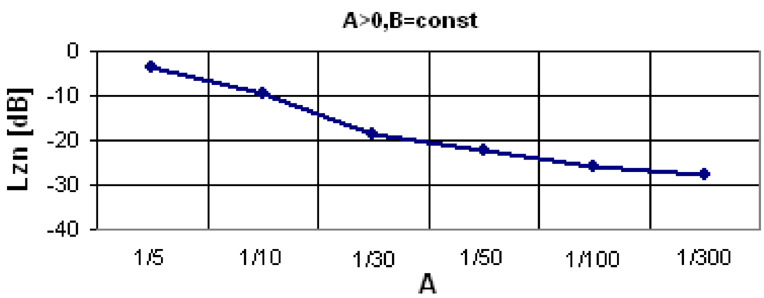


Fig. 5. The dependence of nonlinear distortion level on parameter A with $B = 1/3000$ and $f = 1000$ Hz.

The influence of parameter $A < 0$ also has been tested and results are identical as presented in Fig. 5.

6. Conclusions

The Simulink program for simulation of the measurement of nonlinear distortion has been developed. It uses the broadband white noise as the measuring signal and digital filters with relative constant bandwidth. For simulation of the nonlinear measured object the static nonlinear function has been applied.

When coefficient of nonlinearity are sufficiently high the product of nonlinearity is higher than the noise floor. Nonlinearity product increases with the coefficients of the nonlinearity. The noise floor as well as measured product of nonlinearity increase with frequency. The increase of their level is approximately 3 dB/oct. It is due to white noise – the signal with absolute constant PSD in the frequency function as the exciting signal, and the filters of relative constant bandwidth for the analysis. The pink noise would be better as exciting signal. The static nonlinearity, which does not depend on frequency, causes independents of nonlinearity on frequency. The actual loudspeaker is a dynamic system and it is expected that its product of nonlinearity should depend strongly on frequency.

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