



Characteristics of Hail Dropping Noise in Urban Environment

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Abstract: *In the submitted work the noise characteristics of hail dropping strikes in urban environment are analyzed. In light of ground observations through crowd-sourcing mobile applications two hail storm recording spectra are compared. It is shown, that the low frequency component has strong influence on noise energy.*

Keywords: *acoustics FFT, STFT, digital sound processing.*

INTRODUCTION

Nowadays, severe storms that produce hail of significant amount or size and that caused major losses, have been reported and studied in numerous areas around the Europe [4, 2283–2297], [5, 51–54]. Hail events are among the most costly weather-related extreme events in several European regions, causing substantial damage to crops, vehicles, buildings and other infrastructure [2, 1–3]. Thus, they can be seen as a natural hazard with high risk potential, being of particular interest to the insurance industry and risk management.

Analyses of hail frequency and/or intensity changes during recent decades also show large uncertainties. In light of global warming, it is still a matter of debate whether the number and/or severity of hailstorms has increased over the last decades and is expected to increase in the future. However, the available source of information displaying the direct impact of hail on vulnerable structures is the damage data from insurance companies [3, 1–2].

The question about existence tendency to increasing the hailstorm damage in the future if global temperatures still increase is actual. It is known novel method to estimate the impact of climate change on convection, the so-called “pseudo-global-warming” approach, where present-day hail events are simulated with a high resolution local area model both in current and future atmospheric environments [5, 51–54]. Severe weather phenomena like hail streaks, will, however, remain too small to be explicitly resolved for some time to come. Irrespective of the potential solutions, it must be clear that these cannot be found without knowledge of where severe weather did develop in reality [1, 575–586].

One way to make monitoring is making the standardized direct ground observations such as those from automatic hail sensors. The other way, valuable and low-cost, are ground observations through crowd-sourcing mobile applications or drone-observations to detect the spatial pattern of areas affected by hail [6, 1–5].

The goal of this paper is to analyze some of the spectral characteristics of hailstones sound of striking with hard and semi-hard surfaces in urban area.

There are atmospheric sound propagation measurements to many purposes, but in urban areas with concentration of buildings the environment has specific features. Our measurements were made in an urban environment. This is important remark, because of initiated in this case noise and the noise in natural environment (without building areas) have different characteristics. Moreover, the modern urbanization leads to a concentration of large masses of people in the cities [5, 51–54].

HAIL NOISE CHARACTERISTICS IN URBAN AREA

The experimental setup include PULSE data acquisition unit 3560B Brüel & Kjær has wide dynamic range exceed the 160dB [6, 1–5].

Here are regarded sounds from hailstone strikes. The first was in Veliko Tarnovo, Bulgaria May 20, 2013, and the second from Poiana, Brasov, Romania 02 June 2018.

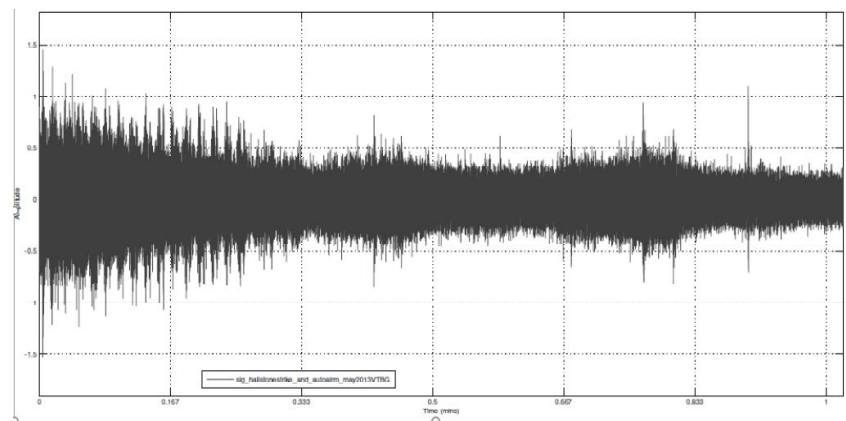


Figure 1. Registered noise of hail strikes plus auto alarms 61.3sec, 4019400 samples (15.4 Mb size of raw data,), sample frequency $F_s = 65536\text{Hz}$, microphone 4193 and PULSE data acquisition unit 3560A Brüel & Kjær; 20May 2013, 17h:58m EEST, air temperature 23.2°C; Veliko Tarnovo, Bulgaria, GPS: 43.072078, 25.60695.

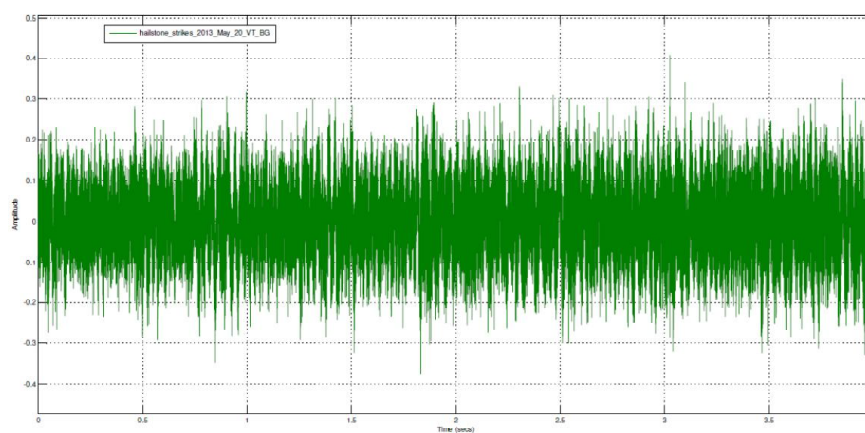


Figure 2. Part of registered noise of hail strikes, 4sec duration (see 18-22sec. fig1.) 20May 2013, Veliko Tarnovo, Bulgaria

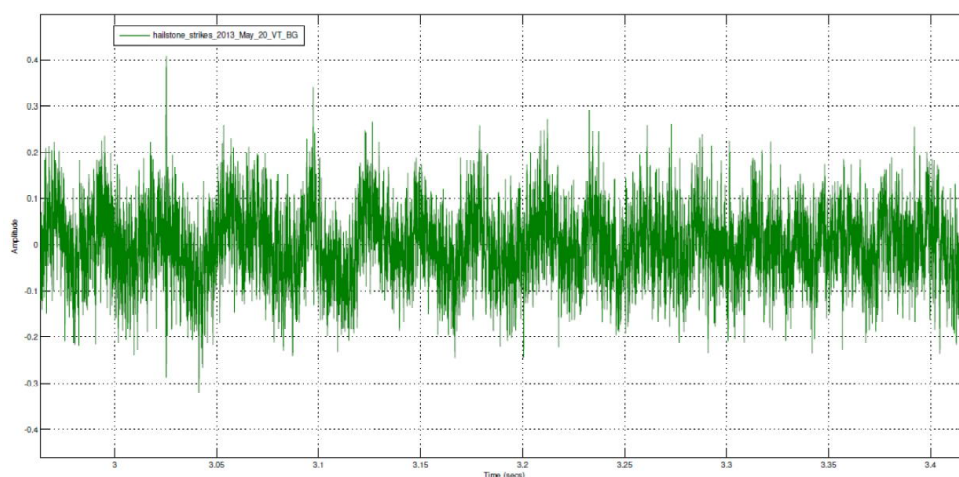


Figure 3. Zoom part of hail strikes, 0.4sec (see 3-3.4sec. fig2.), 20 May 2013, Veliko Tarnovo.

° The conditions for the first situation in concrete urban environments was: 20May 2013, 17h:58m EEST, air temperature 23.2°C; GPS: 43.072078, 25.60695.

The registered record of noise of hailstone strikes plus noise of auto alarms was imported as array in workspace in MatLab. The signal array consist 4019400samples with sample frequency 2to16 samples per sec (signal time duration 61.3sec), shown in Fig. 1. In the part 0.2 of minute is seen the regular squeaky sound of auto alarms.

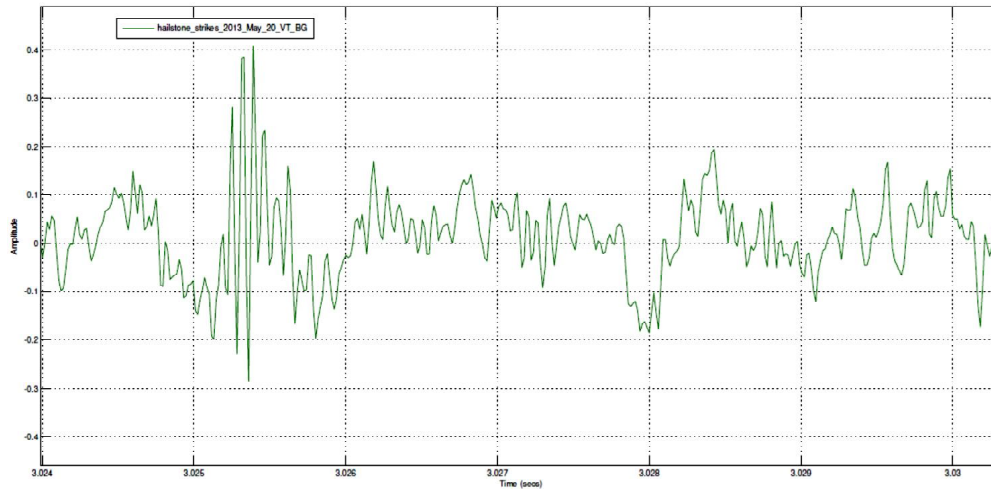


Figure 4. Zoom part of noise, 0.006sec duration (see fig3.). 20May 2013, V. Tarnovo.

Zoom parts of signal from Fig. 2 in time domain are illustrated in Fig. 3,4. Estimation of components of power spectrum density (PSD) of sample of signal with 4 sec. duration see fig. 2, is made in MatLab with nonparametric method Discrete Fourier Transform (DFT), with Fast Fourier Transform (FFT), $N = 2^{18}$, are illustrated on Fig. 4.

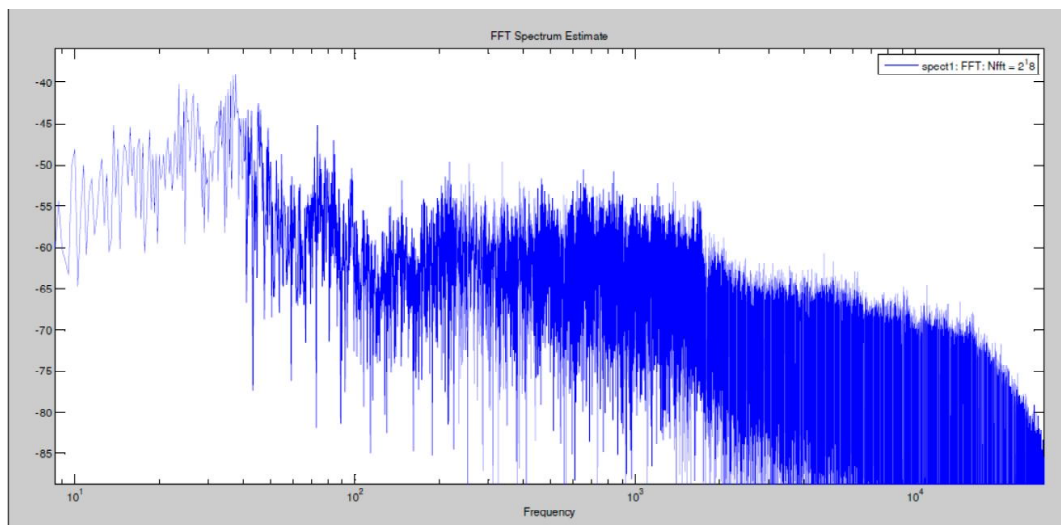


Figure 5. Power spectrum density (PSD) of sample of signal with 4 sec. see fig.2, with Fast Fourier Transform (FFT) 2to18. Magnitude of PSD in dB, logarithm frequency from 10Hz to 20000Hz. 20 May 2013, Veliko Tarnovo.

Signal's PSD after using Welch method with the Hann window (or hanning or raised-cosine window)) is presented on Fig. 6 where bandwidth is 10 Hz – 20000 Hz for noise of hail (4 sec. signal see fig.2). The Short Time Fourier Transform – STFT with 2to16 Hanning window, overlap 0.5 for 2 to 18 samples, sample freq. $F_s = 2\text{to}16\text{Hz}$ is illustrated.

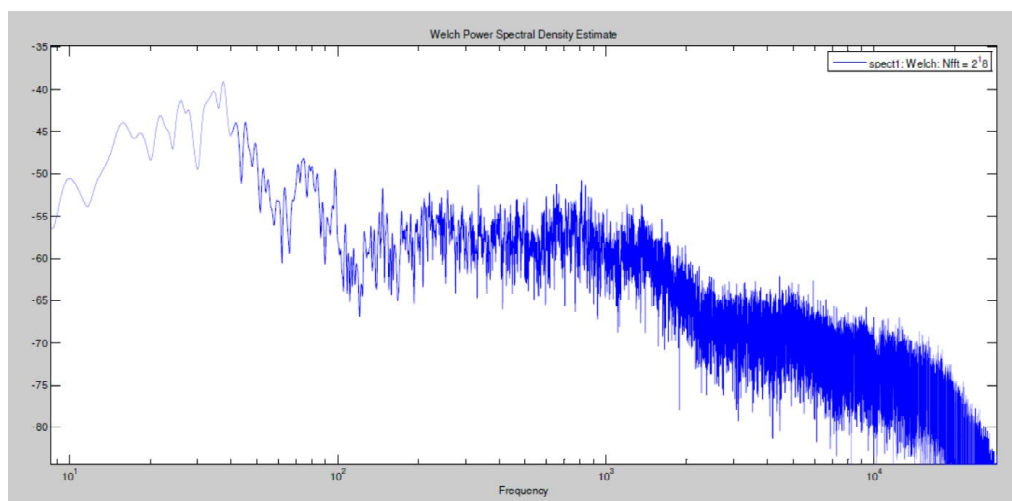


Figure 6. The smoother spectral components, in dB, bandwidth 10 Hz - 20000 Hz for noise of hail (4 sec. signal see fig.2). STFT with for 2 to 16 Hanning window, overlap 0.5, Welch method for 2 to 18 samples, sample freq. $F_s = 2$ to 16Hz. 20 May 2013, V. Tarnovo

Here can be seen the strong components, concentrated in the interval from 20 to 40 Hz, Figure 5, 6. The specific properties of the propagation medium in urban area caused the resonated sound waves. It can be seen that the strong harmonics are in this interval, 20...40 Hz, i.e. exist standing acoustic waves, corresponded to distances $L=2\lambda$, from 34 to 17 m (if the assumed velocity of a sound waves is $\lambda=343$ m/s, temperature 23.2°C).

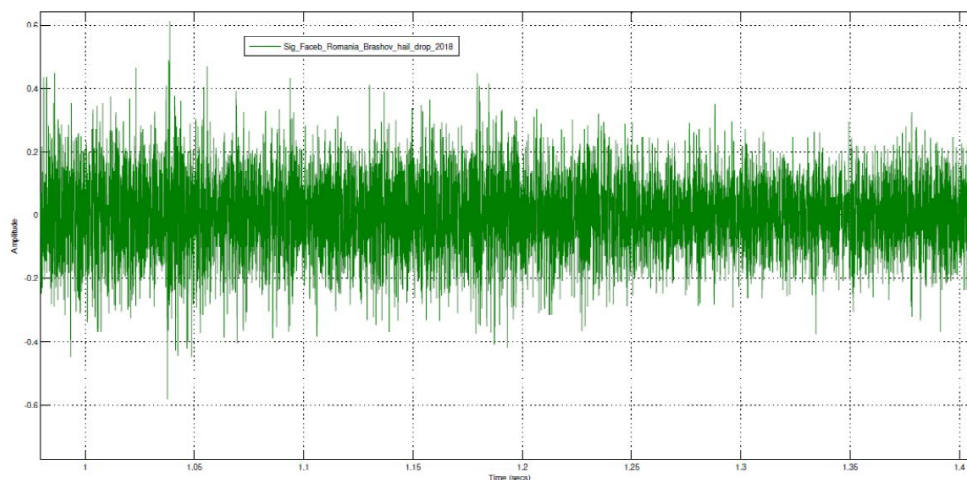


Figure 7. Imported in MatLab noise of hail strikes 4.6sec, (861 kb size of data, 02 June 2018, Poiana, Brasov, Romania, source: Report of Roxana Cojoccea, Hailstorm in Brasov, www.facebook.com/severeweatherEU/videos/2237486323141123/

◦ The second situation is record of hail dropping in Poiana, Brashov, 02 June 2018, Romania 2018. It was “Hailstorm in Brasov, Romania, June 2! Report: Roxana Cojoccea/Meteoplus” online at „<https://www.facebook.com/severeweatherEU/videos/2237486323141123/>“. Dimensions of hailstones are below 2cm. The sound record of noise of hailstone strikes was exported from the source video clip and after that was imported as array in workspace in MatLab. Further, the signal array are cropped to the 2 to 17 samples (signal time duration 4.6sec), shown in Fig. 7.

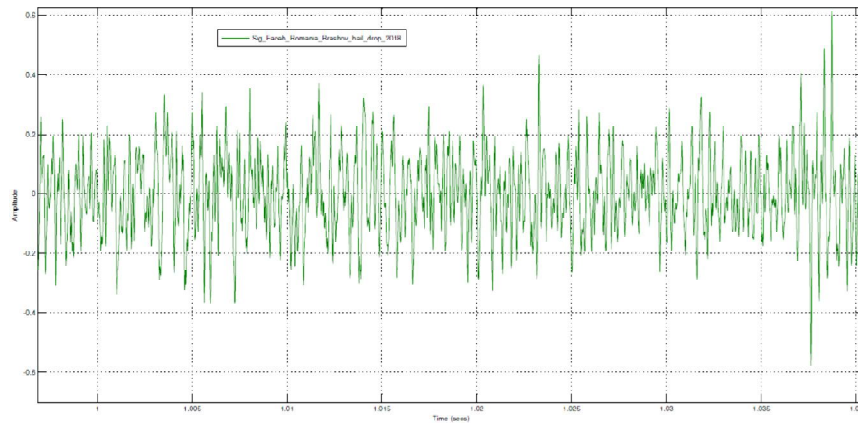


Figure 8. Zoom part of hail storm noise, 0.004sec duration (see fig7.), 02June 2018, Poiana, Brasov. Zoom parts of signal from Fig. 2 in time domain are illustrated in Fig. 8, 9.

It can be seen in fig. 9 that the waveform of the captured signal is smoother than the first signal shown on fig 4.

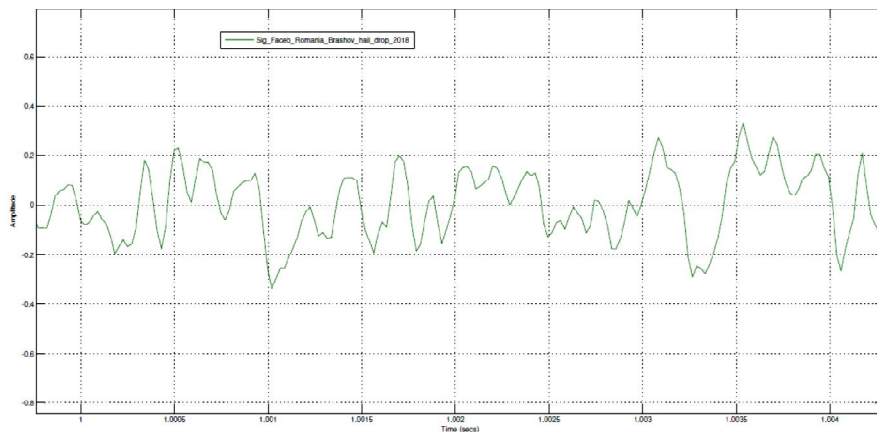


Figure 9. Zoom part of hail noise, 0.004sec duration (see fig7.), 03 June 2018, Poiana, Brasov.

Estimation of components of PSD of signal, see fig.7 with 4.6 sec. duration, is made in MatLab with nonparametric method DFT, with FFT, where $N = 2^{18}$, is shown on Fig. 10.

It can be seen in Figure 11 that are not present strong components, in the interval below 100 Hz. The spectra comparison for the two situations is illustrated on the Figure 12, where the size of window is $N_w = 2^{14}$. Probably the reason is in the type of sensor (microphone of device) that registered the noise and/or the compression algorithm.

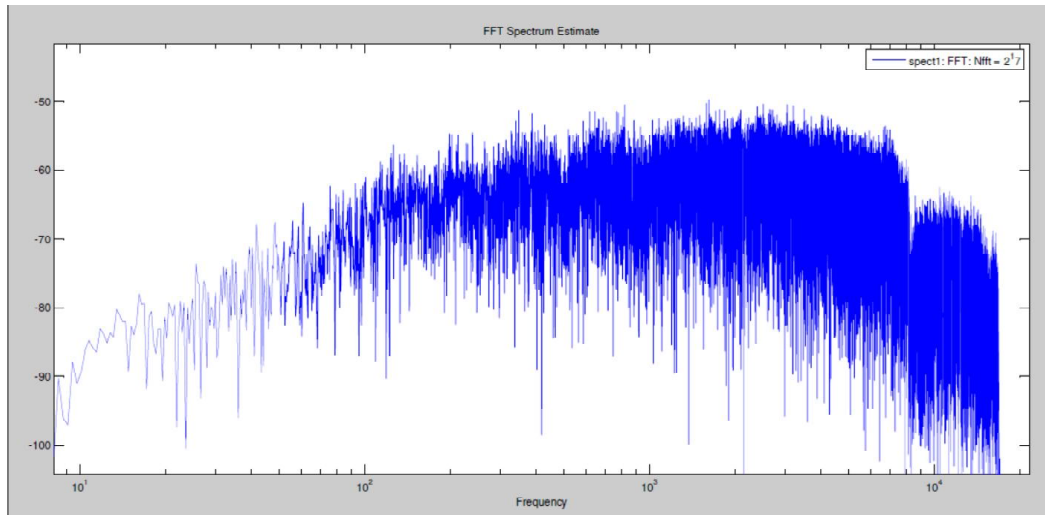


Figure 10. The spectral components in bandwidth 100 Hz ...20000 Hz for noise of hail (see fig7.), DFT with FFT for 2to17 samples, for hail dropping may 2018 Romania

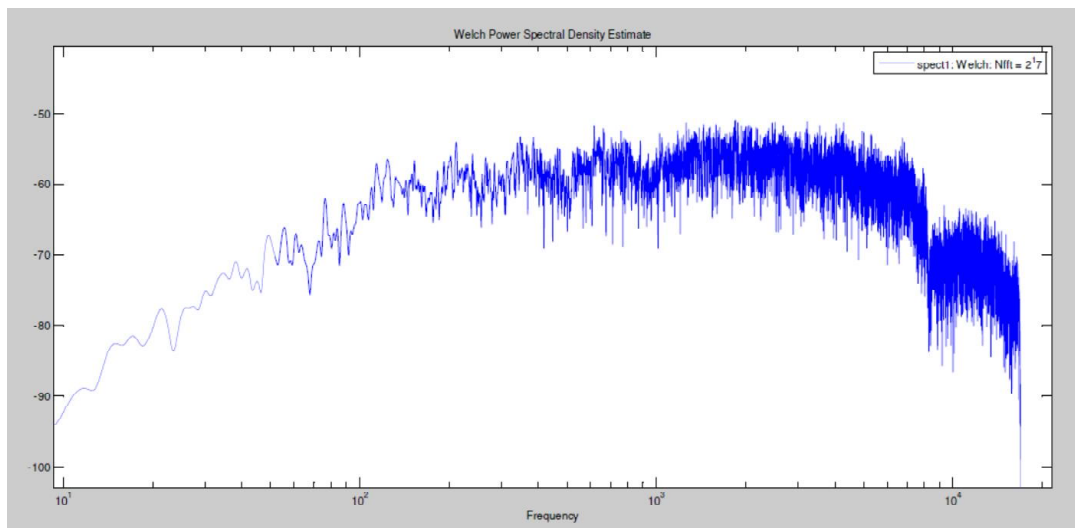


Figure 11. The smoother spectral components in bandwidth 10 Hz ...20000 Hz for noise of hail. DFT with Hanning window size 2to15, overlapping 0.5, Welch method for 2to17 samples (see fig7.) for hail dropping may 2018 Romania

CONCLUSIONS AND FUTURE WORK

In this work two hail storm recording spectra are compared. In situation with professional hardware was seen the strong low frequency spectral components are present in registered signal. In second case (online report of hail storm) the low frequency spectral components did not detected.

If we can regard the ground observations for hail storm through crowd-sourcing mobile applications it is important to know the opportunities that are provided by the mobile devices. There is possibility of the information incompleteness, both from the sensor and from the transmitting channel limitations.

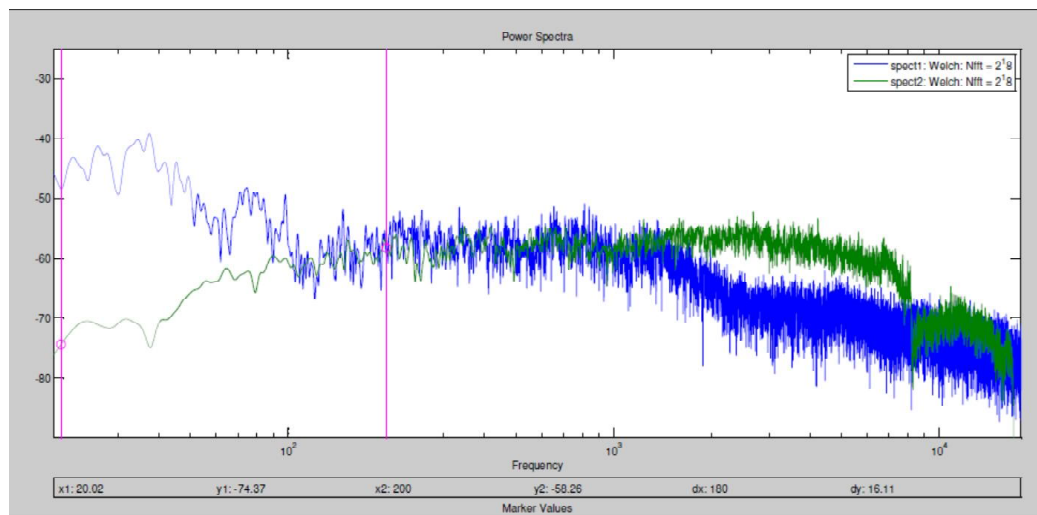


Figure 12. The spectral PSD components in bandwidth 20 Hz ... 10000 Hz for two noises of hail (spect1 in blue Veliko Tarnovo, Bulgaria and spect 2 in Poiana, Romania). STFT, Welch method for 2 to 18 samples with Hanning window size 2 to 14, overlapping 0.5.

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REFERENCES

- [1] **N. Dotzek, Groenemeijer, Feuerstein, Holzer. 2009.** Dotzek, P. Groenemeijer, B. Feuerstein, A. M. Holzer. Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD. *Atmos. Res.* 93, 575–586. DOI:10.1016/j.atmosres.2008.10.020.
- [2] **EEA. 2017.** European Environment Agency: Hail. Retrieved from <https://www.eea.europa.eu/data-and-maps/indicators/hail/assessment>.
- [3] **Kapsch, Kunz, Vitolo, Economou. 2012.** Kapsch, M., Kunz, M., Vitolo, R., Economou, T. Long-term trends of hail-related weather types in an ensemble of regional climate models using a Bayesian approach. *Journal of Geophysical Research.* 117. DOI.org/10.1029/2011JD017185.
- [4] **Kunz, Sander, Kottmeier. 2009.** Kunz, M., Sander, J., Kottmeier, C. Recent trends of thunderstorm and hailstorm frequency and their relation to atmospheric characteristics in southwest Germany. *International Journal of Climatology.* 29, 2283-2297. DOI.org/10.1002/joc.1865.
- [5] **Martius, Hering, Kunz, Manzato, Mohr, Nisi, Trefalt. 2017.** Martius, O., Hering, A., Kunz, M., Manzato, A., Mohr, , Nisi, L. Trefalt, S. Challenges and recent Advances in Hail Research – A report from the 2nd European Hail Workshop. *Bulletin of the American Meteorological Society.* 99, 51-54. DOI.org/10.1175/BAMS-D-17-0207.1.
- [6] **Trifonov, Ivanov, Hajnal. 2014.** Trifonov, T., Ivanov, I. S., Hajnal, É. Noise pollution in urban environment by some natural phenomena. In *Proceedings of the 9th International Symposium on Applied Informatics and Related Areas, 12 Nov. 2014, (AIS'2014).* Óbuda University Székesfehérvár, Hungary.