

AMPLITUDE AND FREQUENCY MODULATION – A CHARACTERISTIC OF CANINE SOUNDGRAMS

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ABSTRACT

The present research aims to discover the amplitude-frequency characteristic of 102 recorded and prepared soundgrams of 6 dogs associated with different and concrete behavioral reactions.

Key words: soundgram, computer analysis, amplitude and frequency modulation.

Introduction

To discriminate one tone from a noise, the first has to hold one fundamental tone – the simple tone with the largest amplitude and lowest frequency, and few overtones, with parameters multiple of the fundamental tone's, within its spectral bandwidth. The noise as sound wave is consisted of chaotic aperiodically varying tones (Todorov, 2002).

Sound loudness is characterized by the wave amplitude along its spectrum. It is measured in decibels (dB). The frequency of sound defines its pitch, measured in hertz (Hz). In practice it is more convenient to work with high frequency short wavelength waves, than with low pitched long wavelength sounds (Brown C., 2017).

Analyzing different animal communicative signals we compare mainly their amplitude and frequency characteristics. After a lot of research we assume that animals and dogs in particular, code their signals predominantly in these two modulations – by dB and Hz. Following the sound along its bandwidth in amplitude-frequency relation, we are able to segment the signal into so called "modules", analogous to "syllables" in human language (Kostov Y., Alexandrova V., 2010). Most suitable for this aim is the bandwidth of a soundgram.

The other commonly used methods – spectrograms and waveforms of the sound signals, give only limited information about the sound elements. These methods benefit mainly the quantitative and visual assessment of the signal, neglecting the details. In other words spectrograms and waveforms picture only the macrostructure of the sound. Our main effort is to unravel the codes within the canine communication signals by revealing the microstructure, the micro fragments that construct them (Taylor, 2009).

According to Fitch, W. (2000), the evolution of speech can be studied independently of the evolution of language, with the advantage that most aspects of speech acoustics, physiology and neural control are shared with animals, and thus open to empirical investigation. At least two changes were necessary prerequisites for modern human speech abilities: (1) modification of vocal tract morphology, and (2) development of vocal imitative ability.

Kohonen self-organizing neural networks, also called self-organizing maps (SOMs), have been used successfully to recognize human phonemes and in this way to aid in human speech recognition. This paper describes how SOMs also can be used to associate specific information content with animal vocalizations (John Placer et al., 2006).

Materials and methods

For the aim of decoding animal communication sounds, expressed in soundgrams, we used computer analysis with computer extension. Database was registered and presented on oscillographic curve. Frequency of the sounds is measured (in Hz) as well as their intensity fluctuations (in dB).

The results from 102 soundgrams of 6 dogs in different and concrete behavioral reactions were registered, prepared and described. The published figures show the lowest, average and highest recorded values for frequency and amplitude, reflected on the oscillographic curve, as well as in digital form from the computer analysis.

We needed a technical solution which allows a detailed picture of the biphasic amplitude of the periodic sound fluctuations and the pause in between.

Our goal was accomplished and we succeeded to follow in details different sound oscillations in the bandwidth specter, and thus to receive the visual idea of modulated syllable encoded in the signal.

Results

Clear variations in frequency (Hz) and intensity (dB) values of the examined animal sounds were registered during our acoustic analysis.

The results we summarized as follows:

- in association with sound oscillations frequency (Hz): average frequency value; lowest and highest frequency value;
- in association with sound oscillations intensity (dB): average values for the highest and the lowest intensity fractions; lowest and highest amplitude value from the recorded sound signals.

The average frequency rate (Hz) of examined acoustic materials in different and concrete behavioral reactions in dog is 979.48 Hz.

Frequency range of the record in Fig. 1 marks close to the average frequency range registered in different and concrete behavioral reactions in dogs – around 242 Hz. There are low amplitude sharp peaked fluctuations on the recorded signal.

In comparison the record from Fig. 2 shows the lowest registered frequency value in canine sound signal – approximately 81 Hz. Fluctuations in the record are clear, forming groups.

The sound fraction of Fig. 3 describes the highest frequency rate – approximately 2912 Hz. On the record are expressed also sharp peaked low amplitude and low frequency packs of oscillations.

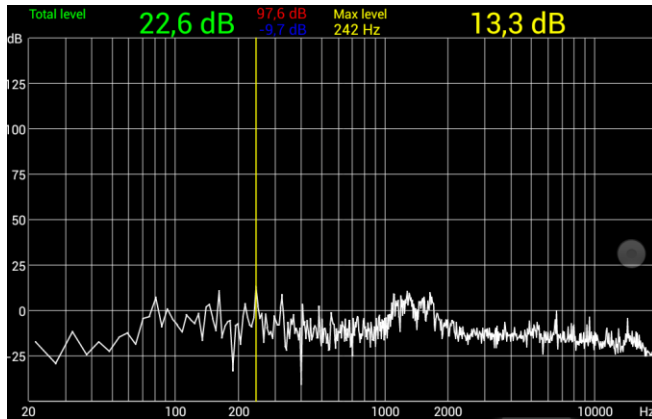


Figure 1: Average frequency value of sound oscillations (Hz) in dog.

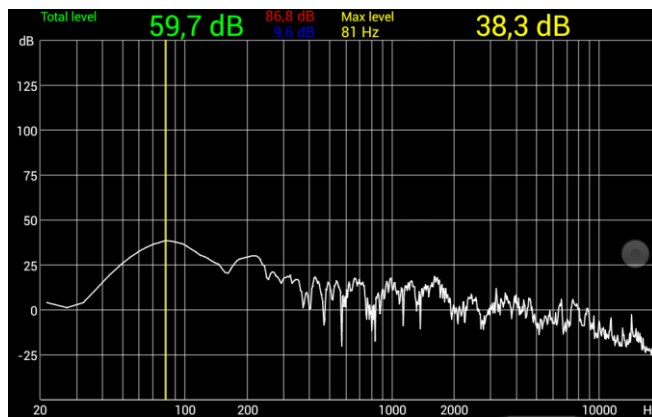


Figure 2: The lowest frequency value of sound oscillations (Hz) in dog.

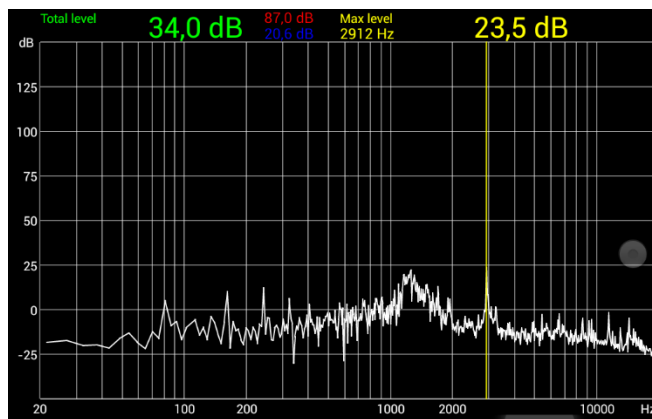


Figure 3: The highest frequency value of sound oscillations (Hz) in dog.

Average amplitude value of the sound fluctuations (dB) in different and concrete behavioral reactions in the recorded 102 soundgrams is 47.87 dB.

Amplitude range of the record on Figure 4 corresponds to the average amplitude value of the canine decibel diapason in concrete behavioral reactions – it varies between 28.5 – 43.7 dB. There are low amplitude sharp peaked oscillations of the sound, forming prolonged plateau.

In contrast, the record from Figure 5 marks the lowest amplitude values – varying between 10.4 and 20.8 dB. Sharp peaked fluctuations are close to the average numbers of frequency in canine sound signals.

Figure 6 shows the highest amplitude rates – between 45,3 and 62,9 dB. Intriguing is the fact that amplitude and frequency values here are in reversed relations.

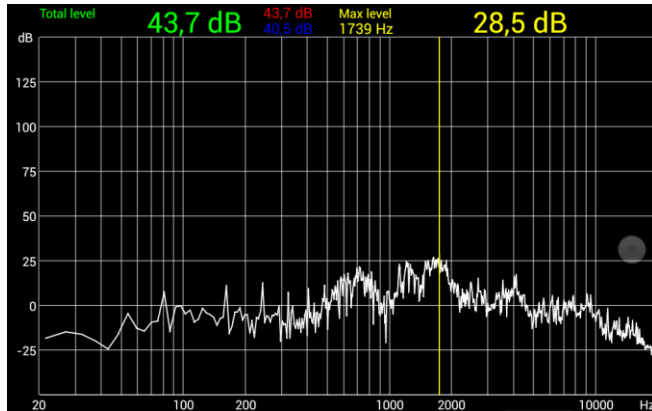


Figure 4: Average amplitude value of sound oscillations (dB) in dog.

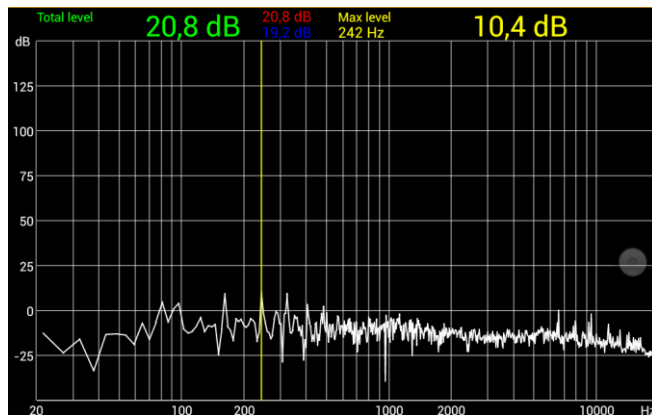


Figure 5: The lowest amplitude value of sound oscillations (dB) in dog.

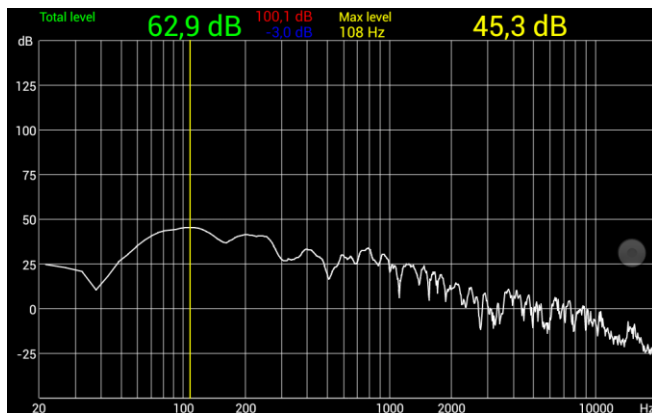


Figure 6: The highest amplitude value of sound oscillations (dB) in dog.

Discussion

In human language the soundgram displays every syllable from a phrase, registered as discrete submodules. Each submodule owns unique pattern – form, amplitude and frequency characteristics with pauses in between (Kostov Y., V. Alexandrova, 2009, 2011).

Authors assume that animals with highly developed glottis (vocalization) use synthesis (impulse modulation) when modeling sound waves along the bandwidth. They define these as "modules". Each module could be consisted of different amount of "submodules" and additional oscillations with varying amplitude and frequency. Then some specific for human language terms could be used to describe modules and submodules respectively as syllables and phonemes.

Language codes depend on the duration and different combinations between modules and their spatial arrangement across the bandwidth as well. Thus, the phrases (similar or different modules combined together) and the themes (packs of similar or different in their structure phrases) are formed in the animal communication vocalizations. Presented as soundgrams these language codes are accurately and precisely displayed and allow detailed analysis (Kostov Y., V. Alexandrova, 2009, 2011).

The same authors describe a dog's soundgram, consisted of two modules – a and b (Alexandrova, V., Y. Kostov, 2010).

Placer and Slobodchikoff (2004) do a research on communication signals of prairie dogs associated with certain predator. They cut each of the recorded calls on equal fragments and choose those four fragments of each record that are with the highest frequency. The two lowest frequencies out of this group of four, they define as representative acoustic units for each signal. The analysis shows unique pattern. Alarm calls which prairie dogs use encode specific combinations of acoustic models according to the species of the predator.

The acoustic structure of communication signals in canines shows specific contextual motives, light motives. The aggressive, dominant, annoyed canine barks always have low energy (frequency), whereas playful, friendly barks appear mostly as high pitched (Yin, 2002).

Zeng et al., in their research from 2005, affirm the significance of the amplitude-frequency modulation in human language recognition. They even define it as essential in such type of analysis. They prove that frequency modulation gives adequate results even in noisy environment, which cause many artifacts in traditional methods for speech recognition. Frequency-amplitude characteristics improve significantly the acoustic analysis. In their work scientists use "fast" and "slow" frequency modulation to follow sound resonance and word formation during speech production process in mouth. Nevertheless these examinations are conducted on humans and specify human language, this methodology could be promising in bioacoustic analysis of animal communicative vocalizations.

Kostov Y., V. Alexandrova (2010) register sound frequency of about 1050 Hz on a recorded canine communication signal which matches with registered from us frequency range in the same animal species.

Spiridonova P., V. Alexandrova (2020) report some amplitude and frequency data associated with concrete behavioral reactions in canines.

Kohonen used a SOM to create a recognition system for human speech that could detect phonemes from a continuous speech signal (Kohonen, 1988).

Conclusion

1. The applied method allows reading the sound signals in dynamics and thereby an accurate and precise visual idea of the modulated syllable encoded in the signal is achieved.
2. Such methodology successfully decodes even the tiniest pattern in canine communication signals, presented in soundgrams, in different and concrete behavioral reactions.
3. The data collected through the soundgram analysis can serve as a baseline in the classification of bioacoustic vocalizations.

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