


ISSUES OF BIOACOUSTICS

VIBROACOUSTIC LANGUAGE OF BEES AND POSSIBILITY OF ITS UNDERSTANDING

APIVOX SMART MONITOR
HANDBOOK AND THE FEATURES OF ITS USAGE IN THE APIARIES




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THE BOOK 1

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THE BOOK 2

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Throughout all the history, people wanted to understand what birds and animals living next to them "say". If someone could understand it a little bit, then such a person was considered to be just a magician. Knowing the language of animals and birds was an essential feature of all magical characters of fairy-tales. So, is it really possible ? Can we understand how their "language" works, and can we understand what they "say" ?

In this book are collected and rethought, the results of works of American and European scientists who worked in 20th and at the beginning of the 21st century, closely related to the field of acoustic control of bees. Their works were devoted to the behavior of bees, their life and the characteristics of communication and signalization. Each of them only came into contact with what we now call - Acoustic Control of bee colonies, but each of them made an invaluable contribution to world science. Perhaps, the moment came when the quantity should go into quality. Their works became the basis, on which my ideas were born and turned into hypotheses, which were built, tested, crumbled and built again during this four years. I am publishing this book with the hope, that progressive scientists and practitioners from all over the world will pick up these ideas, and will learn to understand and take care of bees much better than now.

I also want to thank everyone who helped me to do this work - my wife, my mother and my children. I want to thank my friend from Spain, s-r Davila, the well known in Catalonia queen breeder, who helped me to test the device. I want to thank my American friends, Kendall Davis, Marvin A. Huie, Doug Blankenship, who helped me to test and improve the device at various times. From Russian colleagues, I would like to thank Vyacheslav Ivanovich Lebedev, Director of Russian Research Institute of Beekeeping, who allowed me to test the device in the apiary of the institute and conducted a series of useful consultations on the issue of heating in bees.

ANIMAL COMMUNICATIONS - FUNDAMENTAL VIEWS AND FACTS

Scientists, zoologists and linguists, began to study this problem a long time ago ... Many species of animals that emit various sounds and cries, became the objects of their researches. During this time, was accumulated some knowledge about the voices of various animals and birds and even insects ... But, apparently, there is still no common understanding of the problem. As a result, no one has developed a unified approach to the problem of understanding the "languages" of living beings, although everyone made certain conclusions based on their researches ... Let's try to combine all these disparate knowledges, and try to formulate a method for decrypting the "language" of animals ...

So, what scientists say ... They argue, that undoubtedly, the language of man is more complex and sophisticated than the "language" of animals. But does this mean that there is a qualitative difference between communications of people and communications of animals, or is it all a matter of degree? This question has no definite answer from scientists.

For a long time it is known, that the relationship of social animals sometimes reach considerable complexity. Already in animals, with the simplest ganglion nervous system, living in large associations — bees, termites, ants, etc. — can be observed not only complex instinctive individual behavior , but also extraordinarily developed instinctive reactions to the “language” of an individual member of the community (By the word “ language "we understand any system of signals).

The “language” of animals with the ganglion nervous system is poses, acoustic signals, chemical (“olfactory”) information and all sorts of touches. The behavior of insects in communities strikes the observer with general expediency and consistency. However, this coordinated expediency is due only to stereotypical reactions of animals receiving information. In their reactions one cannot see the slightest comprehension, no processing of information... immediately after receiving the signal, follows action, embedded in the "program" of the functioning of this animal .

In the community of higher animals (birds, mammals) also exists a certain forms of relationships. And, any kind of association of animals in community, inevitably causes the appearance of a “language”, needed for the contacts between community members.

But at the same time, the functions, purposes and the level of development of their “language”, corresponds to the level of development of biological organism.

Stage number	Who belong to this stage	Maximum available reflection levels	Maximally available levels of manifestation of activity
4.	Human	Consciousness	Not only behavior, but also activity
3.	Primates and higher animals	Reflection of connections between subjects	Behavior based on the reflection of the situation in general
2.	Animals with a tubular nervous system, but simpler than higher animals	Subject perception	Conditioned reflexes, skills, unconditioned reflexes, instincts
1.	Animals with reticular and ganglion nervous system	Elementary sensitivity	Unconditioned reflexes, instincts, it is possible formation of unstable temporary connections.

In animal communications, you can sometimes even find a number of features, more characteristic for human language communications. For example, the signals used in human language are very arbitrary, since in their physical features they are not similar to those characteristics of the surrounding world, which they designate. This abstract quality is also found in the communicative behavior of honeybees (Apis melliferd), the study of which was first undertaken by Karl von Frisch, but it is very relative and very limited.

The main element that is considered in this context, is the bees' dance, which conveys information about the location of the source of nectar. The honeybees' dance is symbolic in many ways too.

Another feature of the human language is that it is an open system, in which new messages can be included. Bee dance can inform about new food sources, but, apparently, this is an example of a rather limited "openness". Rather, it is a set of specific signals, used only in one case, and not used in other areas of bees' life, except for delivering of products, which are necessary to sustain life, to the hive. A set of such contingently "open" groups of signals applicable to specific life situations, seems to constitute the "language" of each animal species.

But only one thing cannot be found in the "language" of animals — the "language" of animals, unlike the language of humans, cannot serve as a mean of transmitting experience. Therefore, even if we assume that any individual outstanding specimen in its individual experience finds a number of ways to most easily obtaining food, it will not be able (even if it is assumed that it will have such a need) to transfer its experience by means, available in arsenal of "language" of animals.

So let's consider the main characteristics of such a "language", based on the researches and conclusions of specialists, who studied the "languages" of birds and other animals, including the primates - animals, closest to us in their development.

It is known that all animals use a rather limited number of signals in their "language" ... and yet, if animals are able to use the language, then we can expect, that the closest to human, in this regard, will be highest apes. In these animals, voice reactions and mimic movements are distinguished by refinement and complexity. Therefore, we can assume, that they are talking to each other in a language, that is not yet understood by us. Various attempts have been made to establish, whether higher monkeys are able to use the language, which use human.

But, as it turned out, the chimpanzee's sound repertoire has only about 13 sounds, and they can also produce sounds with some kind of intermediate characteristics. Monkeys use these sounds both for remote communication and for close interaction. They distinguish the voices of familiar individuals and constantly use sounds to maintain contact with each other, when they are in dense undergrowth, or if there are any other obstacles, that prevent them from seeing their fellow tribesmen. Based on the motions of intention, mimic reactions, smells and sounds, that one monkey produces, other animals of the group can identify it, determine where it is, what its motivational state is and, quite likely, what it does. However, there are no even signs of a true language !!!

It was found, that some animal species emit alarm signals, that differ according to the type of danger. Others, having heard these sounds, take actions corresponding to the nature of the detected danger. These observations suggest, that they are able to exchange information about external stimuli.

Analysis of voice reactions, chimpanzees for example, showed, that each monkey's sound reproduction, is associated with a specific reflex activity, that is, it works in the context of the actions performed. There were established several groups of sounds: sounds emitted when eating, sounds of defense or sounds of aggression, sounds associated with the manifestation of sexual functions, etc. Animals of one community orient themselves towards each other's voice responses. Voice reactions additionally inform members of the community, about the status of their brethren, and thus, make it possible to orient behavior within the community. The hungry are moving to the place, where appetizing grumbling is heard. Healthy and well-fed pay attention to the sounds of playing tribesmen and, thus, are able to meet the needs of movement or orientation. The leader rushes in the direction of aggressive sounds of fighting monkeys, in order to restore order in the herd...

In addition, except there is a difference in the contextual meaning of sounds made by animals, but there is also a group and territorial diversity of this sounds.

One of such examples ... is dancing bees' telling about the sources of nectar... The speed of waggle dance indicates the distance to the food source from the hive, while the exact ratio between the speed of the dance and the distance, is determined by local "arrangements". Apparently, different geographic races of bees use different "dialects". Thus, the same element of the waggle dance means approximately 75 m in the German honeybees, approximately 25 m in the Italian bees, and only 5 m in the bees from Egypt. But if all the bees in the colony adhere to this arrangement, then ,it does not matter what specific distance the element of their dance corresponds to.

When studying the marking cries of adult male monkeys, and their disturbing cries, it was found, that the latter are very similar, while the other cries of adult males "noticeably diverge." The shouts of adult males serve to gather a group before migrating, and to maintain distances between groups of the same species. If the cries of different species were similar, there could be confusion ...

We came to the idea, said Peter Marler, a well-known animal communications researcher, that dialects, for example, in birdsong, serve to limit the intensity of gene flow between separate local populations, maintaining the integrity of local gene pools, and possibly, promoting adaptation to local conditions.

Peter Marler also believes that, under certain conditions, dialects are likely to perform the same function in humans. A society of people adapts to the local conditions of existence for some time, so in prehistoric times such an adaptation could be achieved by limiting the intensity of gene flow between different human populations, which was achieved, among other things, by the difference in dialects or languages. At that time, Marler argues, the differences in the ecological niches of individual tribes should have been almost as large, as that of the full-fledged species of other organisms.

FEATURES OF "LANGUAGE" OF ANIMALS. POSSIBILITY OF ITS ANALYSIS AND INTERPRETATION.

Researchers of behavior and communication in animals, including Harvey Sarlz, believe that the use of some devices, specifically designed for speech analysis, can darken and blur the picture in a comparative interspecific analysis of the semantic aspects of communication. "The spectrographic analysis of human speech is only important when analyzing the sounds that make up words," says Sarlz. "The possibilities of such an analysis are limited to a very small number of variables characterizing speech, namely, those that distinguish one phonemes from others. Such an analysis gives a minimum of useful information "... we add - in the case of its application to animals, without taking into account the context.

Exactly in this vein the "languages" of animals and insects must be analyzed, in order to achieve their understanding. Only from combination of sounds themselves, and the events, during which these sounds were made, their meaning can be understood.

So, the main features of "languages" of animals for us, who want to understand them and, if possible, to decipher them, become the following :

- Relative narrowness of "language", which means the inability to use its parts for creation of new messages, not "uploaded" in the "language" in advance.
- The limitedness of the "language", which means the presence of a finite, usually small, set of signals, that are used in communications.
- Reflexive use of signals in communication of individuals or group communications. This means a high degree of signal binding to a specific situation or action taken.
- The importance of the context in which the signal is used. It is the context that can become the key to understanding of the "language" of animals.
- The possibility of using the same signals in different contexts, due to limitation of the “dictionary”, can become a hindrance in the exact understanding of the meaning of the “words” of the "language" of animals.
- The possibility of some territorial diversity even within the same species of animals, can also create certain difficulties, as revealed in different groups, for example, of killer whales or bees...

Basing on this list of characteristics, we can say, that deciphering of the language of animals, be it dolphins, whales or bees, is possible using two methods or two stages of research:

- The first stage is the use of the method of spectral analysis, which should help to find the minimum indivisible elements of the "language" of animals in all their variations. It is necessary to take into account, that when using this method by biologists, were accumulated, and must be simultaneously eliminated, a lot of mistakes and misunderstandings.

- The second stage is the compilation of a “dictionary” of the investigated “language”, on the basis of visual, acoustic, vibration, and other possible types of control, that is, the comparison of the elements obtained during the first stage and their combinations, with the context, that is, with specific situation in which each "word" or a combination of the words of investigated "language" is used.

It is the reflexivity of the emission of communication signals by one animal in a particular situation, and the innate understanding and recognition of them by other animals that capture the message, and the reflexivity of response to the received signal, allows us to hope, that technical means of monitoring of signals, and of fixing the behavior of the issuer and receiver of the signals, will allow us to understand, if not exact meaning of the message itself, then at least to fixate the event that caused the appearance of the signal. In future, the reverse effect can be used, in order to understand what is happening, on the basis of the analysis of signals, emitted by animals.

Researches of sounds of some animals has been conducted for a long time and thoroughly. Primates are already have small “dictionaries” of their shouts and gestures. At the same time, whales and dolphins are still not understood by us, due to the nature of their communications. Basing on loudness and the length of screams, we can think that distance between the emitter and receiver of the signals is significant, which in its turn makes it difficult to understand the context of communications. The bees, too, were not overlooked, and we know about their dances and some of the signals, such as queen piping. These events and the very existence of signals have been thoroughly checked and confirmed, although, I must admit, that the structure of these signals is still not quite known to us.

On the basis of a lot of works of scientists, we came to the conclusion, that all languages of living beings with a speech not so developed as the language of human being, are ultimately combine coding and intonational modulation. This means that the understanding of each emitted sound is encoded by a combination of the frequencies of signals which make up this "chord", and in the intonation of the signal, is encoded contextual and emotional components of the message.

By the way, human also sometimes switches to intonational signals. And it happens in situations very similar to those, in which animals use their intonational "language". For example, in the forest, gathering mushrooms, we behave quite like dolphins or whales, who in the water do not see too far, and call up, in order not to lose each other. We also do the same ... we all remember our screams "aa-uuuu" ...Like this, we look for those with whom we went into the forest... Like this, we, guided by a return cry, go in its direction, so not to get lost. Bees in the dark of the hive behave very much the same way ... Their signals primarily attract the attention of others ...

Why do so many living beings use them? It seems to us, that at first, because of their technical simplicity. More over, they actively attract attention of the one to whom they are intended, and easily transmit information about the context - that is, about the current state and mood of the one, who emits these signals ...

Now, let's examine possibility of understanding of the "language" of bees ....

BEES :

THE PURPOSE OF BEES.
EXISTING TYPES OF COMMUNICATION IN BEES.

So, for a very long time we looked at bees and their life, and it seemed to us very complex and well organized. But, as the potential of scientific researches has increased, we have become more and more aware of the details of this life. It turned out that everything is not so difficult. There are simply things, that we do not quite understand. One of these questions was the question about communications of the bees with each other, and with the whole society.

Initially, it was believed that bees communicate with each other through tactile contacts and pheromones, then there were ideas that in addition, they communicate using the language of vibration signals. Each time, speaking about communications of the bees, we put into these words a meaning, inherent only for phenomenon connected with human. Reasonableness, meaningfulness and transmission of figurative and sensual information ...

But it seems to us, that everything is much simpler in this case. As life shows us, the task of a community of small and attractive biological robots named "bees" - is only the pollination of plants. And this is the mostly important function. A huge number of plants rely on them. Otherwise, they all will die. And the whole life of the community of bees, is aimed at accomplishing this work, one of the most important works on Earth. In order to stimulate bees to this work, plants secrete nectar containing sugars, from which, after processing, bees obtain "high-octane fuel" for their "motors" - honey. All other works - processing of nectar and maintenance of reproduction, are given to the will of unconditioned reflexes. Or to the will of the simplest program laid in the bee.

The bees' community lives as a self-adjusting mechanism with feedbacks, that allow the system to be regulated and maintain an optimal balance. Each bee, participating in the system, has its own simplest program. The program is so simple, that it does not require serious communication between individuals. Only the simplest - at the level of sign language, or at the level of communication of primitive animals, or as we wrote above - unconditioned reflexes and instincts.

In this, convinces us the fact, that over the millennia of communication with humans, bees have not been able to change their programs and adequately respond to the intrusion of human into their life. In addition, this convinces us in the lack of evolution as a global process, and the perfection of technical arrangement and algorithms of functioning of living beings, makes us believe that we all have one genius Creator.

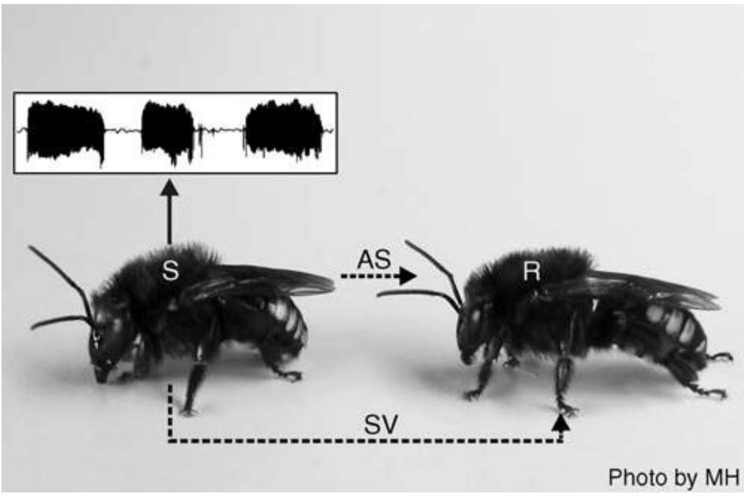
THE CLASSICAL FOUNDATIONS OF THE THEORY OF VIBRO-ACOUSTIC COMMUNICATIONS IN BEES

In this part of our work, we will use excerpts and retellings of individual sections of the book "Insect sounds and communications", chapter "Vibratory and Airborne-Sound Signals in Bee Communication (Hymenoptera)" Michael Hrncir, Friedrich G. Barth and Jurgen Tautz.

When coming across the term “bee communication”, almost automatically an image of the legendary “figure-of-eight movements” of the honey bee (Apis mellifera) crosses most people’s minds. Expressions like “dance language” or “bee language” are associated with the name of the

Austrian scientist Karl von Frisch (1886 – 1982), who observed that the body movements of foraging honeybees on their return to the nest from a valuable food source correlate with both its direction and its distance (von Frisch, 1965). Ever since this pioneering discovery, people have been fascinated by this concept of a "symbolic language" in which an abstract code (the waggle dance) is used to transmit information about remote objects (the food source). However, intensive investigations over the past decades, and steadily improving observation and recording methods, have revealed that the honeybees' communication is of an intriguing complexity which we are only beginning to understand in depth. The dance movements with their intrinsic complexity are but one chapter of the whole story of communication processes that coordinate several hundreds or thousands of individuals belonging to a single bee colony. Since the beginning of the 17th century, it has been established that bees emit "sounds" audible to the human ear (Butler, 1609). It would, however, be misleading to denominate these "sounds" exclusively as "acoustic" in terms of human experience because it is the sensory world of the bees which has to be considered. What we humans perceive as "sound" (the pressure waves of airborne sound) is not necessarily the physical aspect of the signal perceived by the bees. This chapter is an attempt to outline the current knowledge of "sounds", and the other types of potential signals associated with these "sounds" emitted by social bees, honeybees (Apini). We ask the following questions: How are the signals produced by the bees? What is the true physical nature of the "signals" actually or potentially perceived by the bees? The important question about the biological significance of the "sounds" is not easily answered because the behavioural response of a bee to a certain signal much depends, not only on the behavioural context, but also on the recipient's motivation. Deciphering the messages and meanings of different "sounds" (message: information provided by the sender; meaning: influence on the behaviour of the receiver; Seeley and Tautz, 2001) is therefore essential for a comprehensive understanding of the bees' communication.

SIGNALS



The sense of "hearing" for a long time had been interpreted in human terms and restricted to the perception of airborne sound, specifically of the sound pressure waves it represents. Hence, it was attributed only to those animals equipped with sound pressure receivers, "eardrums" or similar membranes (von Buddenbrock, 1928, cited in Autrum, 1936). After suspicious membranous structures on bees' antennae, the antennal pore plate organs (sensilla placodea), had been demonstrated to be chemoreceptors instead of "eardrums" (von Frisch, 1921), bees were considered deaf to airborne sound for anatomical reasons. However, ever since the German zoologist and physicist Hansjochem Autrum (1907 – 2003) demonstrated the ability of insects to perceive minute substrate vibrations (Autrum, 1941; Autrum and Schneider, 1948) and that hair-like structures, such as some insect antennae, can function as sound velocity receivers (Autrum, 1936), it has been clear that "hearing" in arthropods is not at all confined to the perception of sound pressure waves.

If we strive to understand the behavioural relevance of an animal's signal, the "sensory world" in which this animal lives has to be considered (Barth, 1998). To understand fully acoustic communication in bees, the physiological and ecological constraints on their communication have to be known how behaviourally relevant signals are produced, transmitted and perceived .

SIGNAL PRODUCTION

A variety of different "sounds" have been described in bees (Armbruster, 1922; Hansson, 1945; Kirchner, 1993a, 1997). Most of them are characterised by a low fundamental frequency (300 to 600 Hz, Table 32.1) and its harmonics (Woods, 1956; Simpson, 1963; Esch and Wilson, 1967; Michelsen et al., 1986a, 1986b; Pratt et al., 1996; Hrncir et al., 2000, 2004a, 2004b; Seeley and Tautz, 2001; Aguilar and Bricen˜ o, 2002; Thom et al., 2003) (Figure 32.2, also Figure 32.4 and Figure 32.5). Yet, in contrast to other insect taxa like cicadas and crickets, bees are not equipped with structures especially designed for the effective production of acoustic signals, a particular problem being their small size relative to the wavelength of the sound potentially emitted (Michelsen and Nocke, 1974). It has been speculated that bees produce sounds by a kind of "siren mechanism" (Woods, 1956), compressing air in the air sacs and releasing it through the abdominal spiracles (Woods, 1956; Lindauer and Kerr, 1958). Simpson (1963) refuted this theory of pneumatic signal production by demonstrating that the ventilation movements, expansions and contractions of the abdomen (Bailey, 1954) are not at all synchronised with the acoustic signals (piping) of honey-bee queens (Apis mellifera).

THORACIC VIBRATIONS

Resonant sound-producing mechanisms occur in many insect groups (Bennet-Clark, 1999a). In bees, which do not possess a stridulation apparatus, a harp or a tymbal (Schneider, 1975), the "sounds" are generated by rhythmic thoracic oscillations (Figure 32.2). This is also true for the wing movements, which are generated with the help of an indirect wing mechanism (up- and downstrokes of the forewings are caused by rhythmic oscillations of the thorax, maintained by stretch activation of the antagonistic indirect flight muscles) (Pringle, 1957; Nachtigall, 2003). However, the oscillation frequency of the thorax is usually significantly higher during the presumed signal production than during flight (Armbruster, 1922; Hansson, 1945; Soltavalta, 1947; Esch and Wilson, 1967; King et al., 1996). Experimentally, the wing beat frequency in bees during tethered flight can be increased by partially clipping or fully amputating the wings (Soltavalta, 1947, 1952; Lindauer and Kerr, 1958; Simpson, 1964; Esch and Wilson, 1967). This increase presumably is a result of a reduced damping of the oscillating system due to a reduced wing area (Esch, 1967a). "Signalling", however, is not necessarily equivalent to "flight with amputated wings". The motor pattern of the indirect flight muscles when producing "sounds" differs significantly from that during flight (Esch and Goller, 1991; King et al., 1996). During signal production, an unequal shortening of the antagonistic indirect flight muscles and the resulting presumed closure of the scutal fissure are thought to alter the vibratory characteristics of the thorax in such a manner that the flight system vibrates at a higher frequency (King et al., 1996). A modulation of the fundamental frequency of the "sounds" has been described in honeybees (Esch, 1967a, 1967b; Esch and Wilson, 1967; Michelsen et al., 1986a, 1986b; Pratt et al., 1996; Seeley and Tautz, 2001; Thom et al., 2003; see also Figure 32.5) and in stingless bees (Hrncir et al., 2000; Figure 32.2). Increasing muscle contraction leads to an increasing stiffening of the thorax and thus to higher oscillating frequencies. A decrease of the damping of the oscillating system with decreasing wing area and wing-beat amplitude increases the frequency of the thoracic vibrations (Schneider, 1975). Hence, the highest frequency of the thoracic vibrations is seen when wings are completely folded (Esch and Wilson, 1967; Schneider, 1975). The fundamental frequency of a "sound" could thus be easily modulated by the bees through opening and closing the wings along with the signal (Seeley and Tautz, 2001).

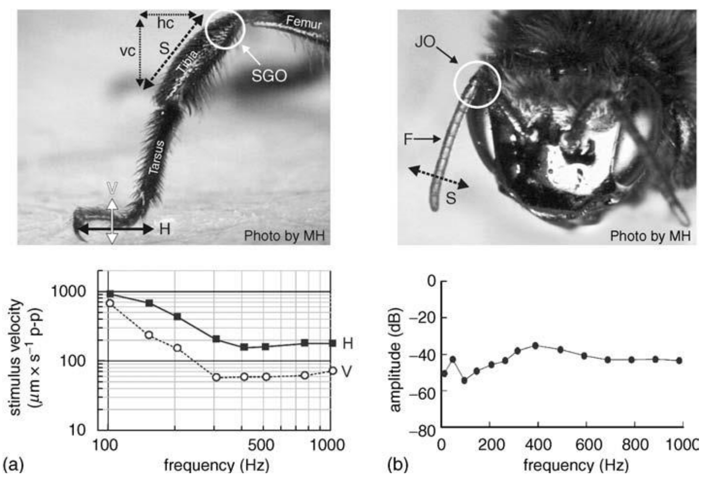
SIGNAL TRANSMISSION AND PERCEPTION

To justify the terms "signal" and "communication", a crucial question has to be asked: Who understands these signals? The importance to identify potential recipients requires clarification of the physical nature of the signal and of the mechanisms of both transmission and perception of the signals.

We know several types of signals, used for various purposes, and produced by different bees - two types of queens singing signals, worker bees singing, including scouts on a swarm cluster, signals of foragers and recruits.

But how is transmission of these signals realized ? There are two ways of transmission - the vibration of the substrate, that is the combs, on which the bees are located, and using air flows.

The mechanism by which the thoracic vibrations of bees are transmitted to the substrate is most obvious during queen and worker piping in honeybees. Here, the signals are directly transmitted to the substrate through close contact between the vibrating thorax and the comb (Esch, 1964; Simpson, 1964; Michelsen et al., 1986b; Pratt et al., 1996; Thom et al., 2003). However, even without such a close contact between the oscillating system and the substrate, signalling bees actually do generate measurable substrate vibrations (honeybees: Nieh and Tautz, 2000; stingless bees: Hrncir et al., 2000; Nieh, 2000; bumble bees: Kirchner and Ro¨ schard, 1999), their legs acting as a mechanical link between thorax and substrate (Storm, 1998; Tautz et al., 2001). In honeybees, the waggle movement was shown to improve the transmission of the signal from the vibrating thorax through the legs to the walls of the comb (Tautz et al., 1996). Both the maximum application of force exerted by a bee on the rims of the cell walls and the production of the thoracic vibration occur when the bee is fully laterally displaced (Esch, 1961b; Storm, 1998). By increasing the effective mass and through a mechanical coupling to the substrate the bees optimise the conditions for injecting the energy of their thoracic vibrations into the comb at these turning points of the waggle movement (Tautz et al., 2001).



Arthropods have a variety of mechanoreceptors capable of detecting substrate vibrations (Markl, 1973; Barth, 1986). In bees the vibration sensitivity has been predominantly attributed to the subgenual organ, a chordotonal organ in the proximal part of the tibia of each leg (Scho¨ n, 1911; Autrum and Schneider, 1948). This receptor responds to vibrations in the axial direction of the tibia (Figure 32.3a). When the leg accelerates due to substrate vibrations, the inertia causes the haemolymph, and the subgenual organ suspended therein, to lag behind the movement of the leg which mechanically stimulates the receptor cells (Kilpinen and Storm, 1997; Storm and Kilpinen, 1998).

Electrophysiologically, the highest sensitivity of the sensory cells is to vertical vibrations at frequencies between 150 and 900 Hz, with a response threshold of 0.06 to 0.15 mm/s peak – peak (Kilpinen and Storm, 1997). Indeed, both the fundamental frequency (honeybees: 200 to 500 Hz, Michelsen et al., 1986a, 1986b; Kirchner, 1993b; Nieh and Tautz, 2000; stingless bees: 350 to 600 Hz, Hrncir et al., 2000) and the amplitude of the substrate vibrations produced by bees (honey-bees: from 0.08 mm/s peak – peak, Nieh and Tautz, 2000; up to 6 mm/s peak – peak, Michelsen et al., 1986b) overlap with this optimal range of the receptor. The average response threshold of the subgenual organ, however, increases by approximately 10 dB when the stimulus changes from vertical to horizontal (Rohrseitz and Kilpinen, 1997; Rohrseitz, 1998) (Figure 32.3a).Freely walking bees keep their legs in a variety of postures and the stimulus for the sensory cells(vibration in the axial direction of the tibia) certainly comprises both a vertical and a horizontal component (Figure 32.3a). Hence, the orientation of the leg of freely walking bees relative to the substrate (Figure 32.3a) is of great importance for a bee's sensitivity to substrate vibrations (Sandeman et al., 1996; Rohrseitz and Kilpinen, 1997).

AIRBORNE SOUNDS

Transmission. Autrum (1936) pointed to the possibility that hair-like structures sensitive to weak air currents could serve as receptors of sound particle velocity. The bees' wings, which are not essential for the production of the "sounds" (Soltavalta, 1947; Lindauer and Kerr, 1958; Esch and Wilson, 1967; Schneider, 1975), are, however, of considerable importance for transforming thoracic vibrations into airborne sounds (Esch and Wilson, 1967; Michelsen et al., 1987; Michelsen, 1993, 2003). It was demonstrated that the bees' wings act as an asymmetrical dipole emitter (Michelsen et al., 1987; Michelsen, 1993): sound pressures above and below the plane of the wings are 1808 out of phase, which generates pressure gradients of 1 Pa/mm (in the dorsoventral direction) close to the edges of the wings. This creates a zone of intense air particle movements close to the abdomen of a bee (amplitude of particle movement: 1 m/s peak – peak, decreasing rapidly with distance from signalling bee; Michelsen et al., 1987). Measurements of the air flow behind honeybees created during the waggle dance further indicate an intense motion of the air with peak velocities of about 15 cm/s at a distance of 1 mm from the dancer (Michelsen, 2003). As deduced from studies on a mechanical model of a dancing bee (for details, see Michelsen, 2003), an "air jet" is generated by the vibrating wings during "sound" production. Air moving out from the space between the wings and the abdomen during wing vibrations caused a jet air flow moving away behind the abdomen of the model bee. The direction of the air jet was constant and independent of the direction of the wing movement (Michelsen, 2003). In contrast to the rapid decrease in amplitude of the near field sound (Michelsen et al., 1987), the amplitude of the air jet decreased more slowly and linearly with distance to the signal source (Michelsen, 2003).

Perception. Near the sound source most sound energy is in particle movement. Hence, flagellar structures such as hairs or antennae may function as particle velocity detectors (Bennet-Clark, 1971; Tautz, 1979, Barth, 1986; Eberl, 1999). It has long been demonstrated that bees are able to detect air currents by means of the Johnston's organ, a chordotonal organ in the pedicel of the antennae (McIndoo, 1922; Snodgrass, 1956). The sensory cells of this organ are stimulated by the deflection of the flagellum (distal part of the antenna). As in flies (Ba¨ssler, 1957), however, the Johnston's organ of bees was attributed primarily to the detection of flight speed (Heran, 1957, 1959). In a detailed analysis of the mechanical and physiological properties of the antennae of honeybees, Heran (1959) demonstrated that the Johnston's organ is most sensitive at oscillation frequencies of the antennae between 200 and 300 Hz. The author hypothesised that the bees might even be able to detect the recruitment sounds produced by dancing honeybees, which also range from 200 to 300 Hz (Esch, 1961b; Michelsen et al., 1987). The conversion of airborne acoustic energy into antennal vibrations, and the subsequent transmission of vibrations to Johnston's organs, has been described in flies (Eberl, 1999; Go¨ pfert and Robert, 2001, 2002). Similar to the sound receiver system in flies (Go¨ pfert and Robert, 2002), air particle oscillations deflect the flagellum of honeybees like a stiff rod (Kirchner, 1994) (Figure 32.3b). It has been suggested that airborne sound (air particle velocity) together with thoracic vibrations induce vibration of the receiver's antennae, and that the bees, similar to flies, do use the Johnston's organ to detect air particle oscillations evoked by the bees' "sounds". This mechanism of "sound" perception was proposed for honeybees (Kirchner et al., 1991; Dreller and Kirchner, 1993, 1995), for stingless bees (Nieh et al., 2003) and for bumble bees (Hensen and Kirchner, 2003).

BEHAVIOURAL RELEVANCE

As stated before, the term "acoustic" is misleading because "airborne sound" does not sufficiently describe the physical nature of the signals considered. On the other hand, the term "mechanical signals" would include too broad a variety of signals like tactile cues or even the honeybees' dance movements, which goes beyond the scope of this chapter. The signals described below (Table 32.1) have historically been denominated as "sounds" because they contain a component which the human ear can hear and which can be measured with a pressure microphone. We have already illustrated how thoracic oscillations are transformed into "signals" of a physical nature perceivable for bees: substrate vibrations and airborne sound (particle velocity or air flow). However, it has not been clarified yet whether only one (and which) of these two signal modalities is predominantly used by bees in the respective behavioral contexts.

TYPES OF SIGNALS

- Queen's "singing" - tonal and pulse sequences with frequencies in the range of 400-500 Hz, produced by young queens.
- Hive protection signals. We will hear these signals if we hit the hive. Woods called them "Hiss" of the hive... Almost all bees in the hive emit this signal at the same time. And the stronger and clearer it is, the better and healthy the family.
  - The chorus of worker bees is more diverse. It includes
  - "Singing" of foragers, these signals always issued by foragers during the waggle dance. As a rule, this is a series of not tonal, but the "train" of pulses, accompanying the dance.
  - Stop signals of recruits, issued by them during waggle dance of foragers.
  - Singing of scouts on a swarm cluster.
  - Singing worker bees, randomly moving around the hive before tremble danses.

All these signals have been repeatedly investigated by scientists in different situations. The simplest signals are - queen's quacking, and queen's piping. The context is fully understandable here. The most studied signals are those, which associated with waggle dance of foragers. And the least studied are all types of "singing" of worker bees.

By the way, exactly these signals - the "singing" of worker bees, we consider to be the main type of signals used for information transfer in the hive. As a fact, these bees work as messengers, who carry information to all ends of the hive. All these signals are tonal or close to them, and this fact also confirms our assumptions.

We will not talk here in details about all the signals, because for each of them, there is a place in our new theory of communications in bees. Now let's talk about the important features of the analysis of vibro-acoustic signals in bees.

TECHNICAL FEATURES OF ANALYSIS OF VIBRO-ACOUSTICAL SIGNALS OF THE BEES

How can we analyze these vibro-acoustic signals, how can we understand their frequency composition and other parameters. A typical system for analyzing sounds consists of combination of a microphone, audio recorder and\or computer for analyzing and mathematical processing of acoustic signals data, perceived by a microphone, and a system for displaying results of sound processing. Sometimes all these instruments can be combined in one device - in a smartphone.

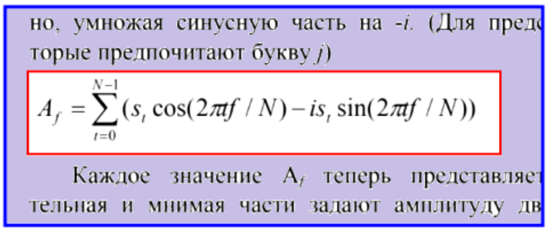
So, what features we found when analyzed the acoustic signals of bees, and why.... For a long time we did not understand what was happening too... Especially because we make all analysis of the spectral composition of audio signals "on the fly", that is, in real time.... Such type of analysis has its complexities and features.

We came across the solution accidentally... After all, we too, in the beginning of our project, went along the well-trodden path ....

When we take the frame with the bees from the hive and bring the microphone of our device close to it, then we do not see any clearly expressed picture of the signals .... although with an ear, we can hear a light rumble of bees on this frame ....

Powerful honey collection and a very strong family of Carnica breed working on it, asked us another riddle .... We conducted control, and looking at the device, blocked the porch, obstructing bees to get into the porch. The bees waited patiently, hanging in the air behind us ... But when we withdraw, opening the way, a powerful wave of returning bees covered the porch and the board.

It would seem that our device, the microphone of which was placed in the depth of the hive, should show a powerful signal of work .... But instead of this, the signal subsided, turning into something, similar to the picture of "white noise"... But once we again blocked the way to incoming bees, the signal grew again, becoming more clean and understandable .... It would seem to be a paradox .... but really, the source of paradox was not the bee by itself....



но, умножая синусную часть на -*i*. (Для пред

торые предпочитают букву *j*)

$$A_f = \sum_{t=0}^{N-1} (s_t \cos(2\pi f / N) - i s_t \sin(2\pi f / N))$$

Каждое значение A_f теперь представляет

тельная и мнимая части задают амплитуду дв

The reason for this paradox is that all modern computer sound analyzers are built on the basis of using so-called Fast Fourier Transformation - a complex mathematical algorithm that allows to describe almost any signal in the form of a set of sinusoids of different amplitude and frequency, thus creating a picture of the spectrum of a periodic signal. A wonderful algorithm that is now used by all who work with digital audio - with its recording, processing, storage .... And this algorithm gives excellent results. (A Programmer's Guide to Sound, Tim Kientzle)

Without any muse and thinking, method of analyzing of signals, using its spectrumб built on the basis of Fast Fourier Transformation, decided to use all biologists, studying the sounds of living beings, including the sounds of bees !!! And this became a catastrophe for the whole topic of acoustic control !!!! What's the matter? Why? After all, in sound recording and sound reproduction it works perfectly ....

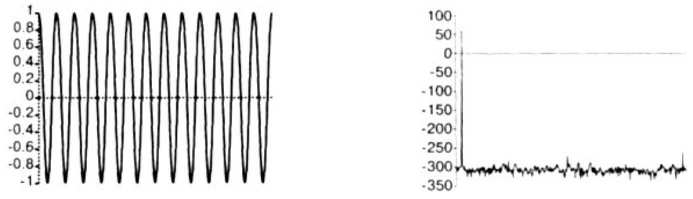


Рис. 24.8. Синусоида и ее БПФ

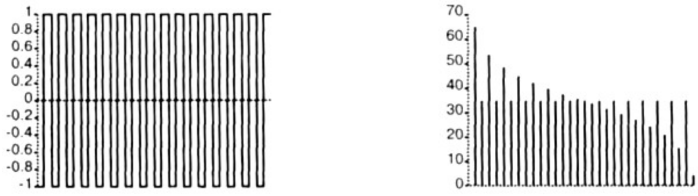
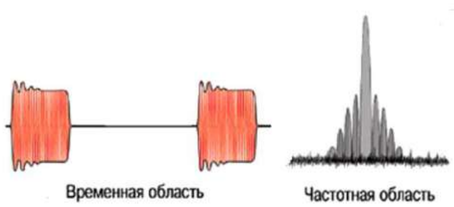


Рис. 24.9. Прямоугольная волна и ее БПФ

Рис. 24.11. Случайные данные и соответствующее БПФ

The fact is that the Fourier Transform is designed to work with a PERIODIC signal, lasting for a fairly long time. If the signal is not periodic and not long, and there is no time to analyze it for a long time, then special additional algorithms come into play ... They begin to introduce assumptions, considering such signal harmonic, and long .... However, the shorter the signal, the worse it all works .... The Fast Fourier Transformation algorithm has a lot of possible ways of representing a real signal because of the shortness of the signal, and the spectrum diagram begins to pulsate. The longer and purer the signal, the better and purer it is displayed in the spectrum picture, that the Fast Fourier Transformation is building. This is why, are so strong and clean the ventilation signals, which bees emit very loudly and continuously, practically with almost one and the same frequency...



But single short pulses, filled with a periodic signal of a certain frequency, give a picture with which are constantly working experts of combat radar systems. They also do not really like the Fourier Transform, preferring other methods of analyzing of such signals, including hardware ones... (Skolnik, MI, Introduction to Radar Systems, 2nd ed., New York, NY: McGraw-Hill, 1980 [2] Agilent Technologies, 2007 A / D symposium Presentation, Radar System Performance Measures, Agilent symposium CD Publication number 5989-6075EN, 2007)

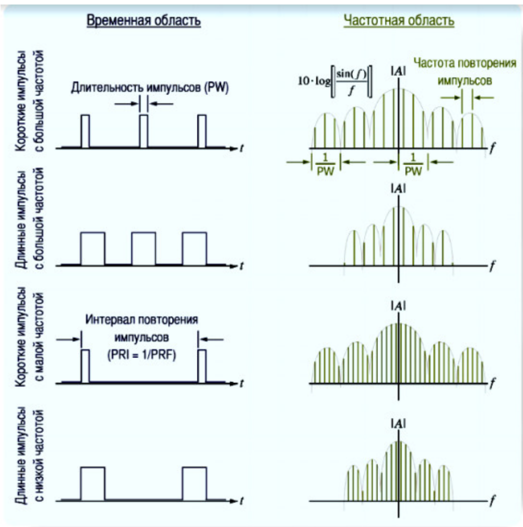


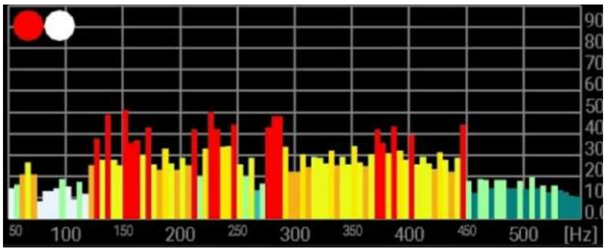
Рис. 6. Спектральная характеристика зависит от скорости повторения и ширины импульсов. Преобразование характеристики из временной области в частотную показывает влияние изменения ширины импульса (PW) и интервала повторения импульсов (PRI) или частоты следования импульсов (PRF).

The matter is that depending on the duration of the pulse, and the frequency of its repetition, the picture of spectrum, obtained on the basis of Fast Fourier Transform, have different appearance, regardless of the fact, that the fundamental frequency of signal, with which the pulse was filled, stay all the same. And, first of all, this refers to instruments and programs showing the result, that is, the signal spectrum diagram, in real time. And after all, exactly such devices and programs tried to create, all developers of the systems for analysis of autistic signals of beehive ....

What's the matter? The fact is, that the parameters of spectrum of pulsating signal, obtained on the basis of Fast Fourier Transform, directly depend on characteristics of emission of this pulse.

The less often the pulses go one after another, the more the diagram is filled with bars at frequencies, closely adjacent to the fundamental frequency. The longer the pulses, the more narrow the diagram, and the less the "wings" spreading along the frequency scale.

What does all this have to do with the sounds of bees? Behold ! The sound created by the bees due to vibration of tergites, like any other sound, produced by a vibrating object, including musical instruments, has, in addition to the fundamental tone, harmonic and non-harmonic overtones, that add columns to the diagram of the frequency spectrum of signal, obtained by means of the Fourier transform. In addition, the signals emitted by the bees are short pulses or pulse sequences, and therefore additionally create lateral "wings" around the main "bars" of the fundamental frequencies - the fundamental frequency (fundamental tone) of the signal and its harmonic and non harmonic overtones. And if there are a lot of bees and they talk a lot, and talk abruptly, then we will get a picture of a powerful background signal on the screen of the device, which works on the basis of FFT algorithms.



We believe, that exactly this effect we saw, when a cloud of foragers landed on the board and went into the porch. Their powerful flow of short impulse messages, addressed to nectar receivers, and the signals which they issued during the unloading of nectar, forced the Fourier Transformation algorithm to turn a previously perfectly adequate picture of the signal spectrum, into some kind of "semolina porridge" .... This is a clear sign **that all the bees are issuing a series of short signals, in a limited frequency range, in which signals are better heard for them...** Exactly this, also confirms our theory.

Thus, we state the following:

True communicational vibro-acoustic signals of bees - is a set of short pulses of certain frequency or sum of frequencies, following with certain interval, and being markers of type of activity of bees, or communicative signals. These markers and communication signals do not carry in themselves a meaningful, in our understanding, information, as letters or words, but they are only a means to attract attention, and markers of performed works or emotional states .... All these signals are used together with tactile signals and vision.

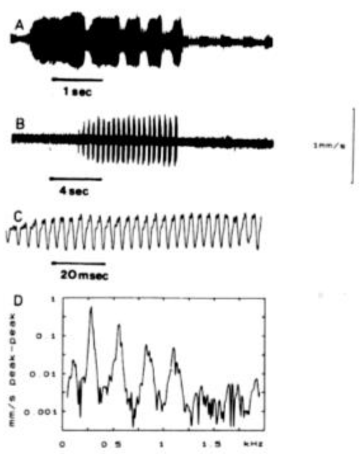


Fig 1. Queen piping signals. Time functions of tooting (A) and quacking (B) have been recorded as vibrations of the comb. Tooting is characterized by an initial rise in amplitude of each syllable (C). A typical amplitude spectrum of a quacking signal (D) shows a fundamental frequency of 300 Hz and some harmonics.

So can we in principle understand what the bees say, if we use instruments based on the Fast Fourier Transform algorithm?

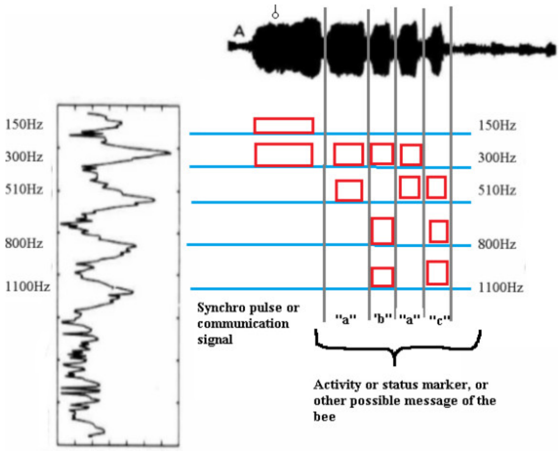
It seems to us, that this is possible. In the case of bees, this is possible if we will technically single out a separate signal of one bee from all the noise of bee "crowd", using, for example, an instrument such as a laser vibrometer... Precisely mass character of these sounds create a problem for their accurate identification and recognition !!! But not only this.....

In addition to the problem with the processing of short pulses, the Fast Fourier Transform working in real time, have another problem which can be more important than previous... It consists in the fact, that we completely lose the time binding of the frequency components of the signal during our analysis.

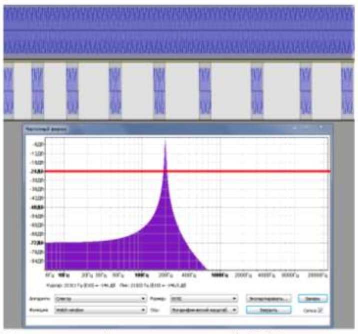
We get a very much averaged picture, which only tells us, that such frequencies were present in the signal, which was fixed and digitized during time period, equal to the measurement and processing interval. Durations, the relative position of the signals of different frequencies, that make up the diagram, are completely lost within the measurement and processing interval, radically distorting the picture of real sound parcel !!!

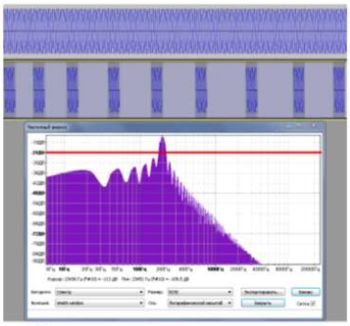
The example given here, can be depicted absolutely in the other way on the timeline, if we assume, that the harmonics of the fundamental tone, shown in the picture of the signal of queen "singing", may be not dependent on the fundamental tone of the sound. Exactly in this way it happens in a human's voice.

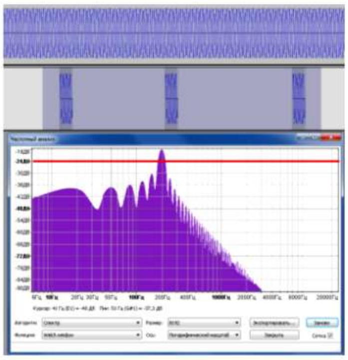
This not only changes in tonality of the signal, but also changes its meaning, that is, changes the phoneme, which we perceive as "sound", or the sound image of the letter ...

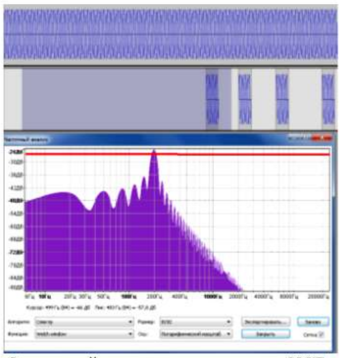


After all, from the relative location of these frequency components can depend, which specific "letter" or "hieroglyph" was transmitted by the bee.


Непрерывный сигнал частотой 200Гц


Импульсная последовательность с частотой заполнения импульса 200Гц

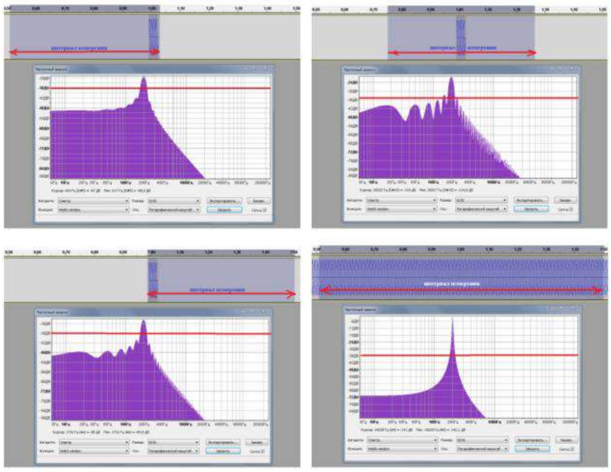

серия из трех импульсов идущих с большим интервалом и заполнением 200Гц


Одиночный импульс с заполнением 200Гц

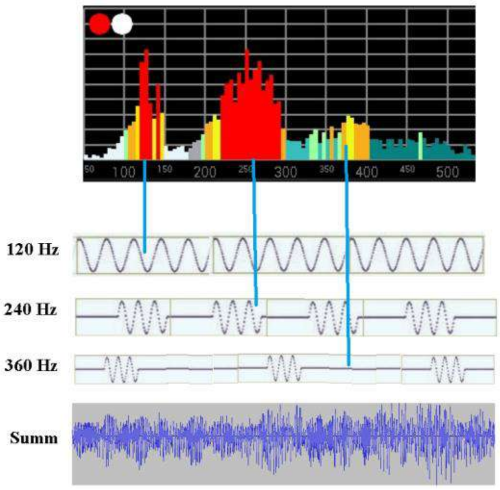
The same problem, but in a slightly different form, exists when analyzing the records of acoustic signals. What is important here, is that to obtain a certain accuracy, it is required to collect a certain number of points in order the FFT formula can "start working." This means, that obtained result will be correlated with the entire duration of the interval, that was required for us in order to collect the required number of measurements. That is, somewhat exaggerating, we can say that the short pulse that fell into this interval, the FFT algorithm equates to a series of pulses, or a signal that continuously lasted throughout the whole measurement interval.

Quite so, the result of FFT work looks like, as it was previously shown on the picture of queen piping signals. We can not say exactly, what frequencies among five clearly visible on FFT diagram, are contained in each of the five fixed vibro-acoustic pulses. We only can see all frequencies, which were contained in the entire sequence of pulses. But really, it could be a code package, containing one or more "letters" or "hieroglyphs" ...

A similar error can be made by using the "sliding window" method, in order to get more detailed diagram on the timeline. The fact is that if the "window" interval have such lenght, that a short pulse will be seen in the "window" for example three times, during "sliding", then the FFT algorithm will construct the diagram, as if the lenght of this pulse was equal to two lengths of used "window".



In sum, these errors also lead to what we have been talking about - to a strong averaging of the result and to almost complete loss of the time-binding of frequency components of the signal to the timeline.



Why do we still consider it possible to understand the language of bees.... The point is, that the dependence of the parameters of the Fourier Transform diagram on the parameters of the initial pulse, makes it possible to make reverse calculation. That is, based on the parameters of the diagram, we can say what was parameters of impulse, and the system which generated it ... What was the amplitude and the fundamental frequency of the signal, what was the duration of the message and the frequency of repetition of these pulses. That is, what are the parameters of the signal source... This is in particular, the main work of the system of reconnaissance and target designation - AWACS (Airborne Warning and Control System).

If we see on the screen diagram of the spectrum with columns of different widths and heights, then we can unambiguously state, that the pulse signals, the image of which we see on our diagram, have a different amplitude, duration and repetition period. In general this corresponds to the volume of their presence in general background of sounds in beehive. There is still exists an issue of correctly synchronizing of these frequency components of the signal, but this is a solvable technical issue ...

Referring to the experience of specialists in radar reconnaissance, we can restore the characteristics of the source of sound, and the structure of the sound parcel itself "in real time".

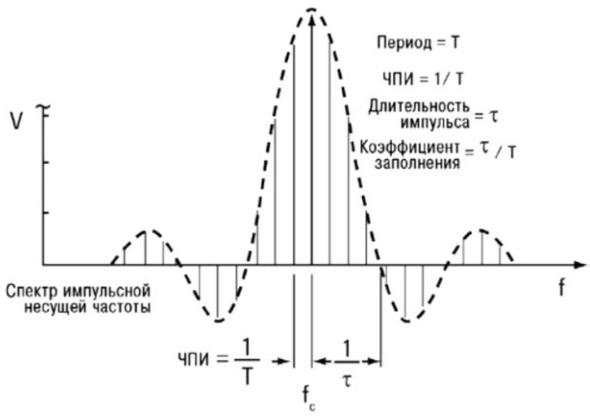


Рисунок 14 – Спектр импульса

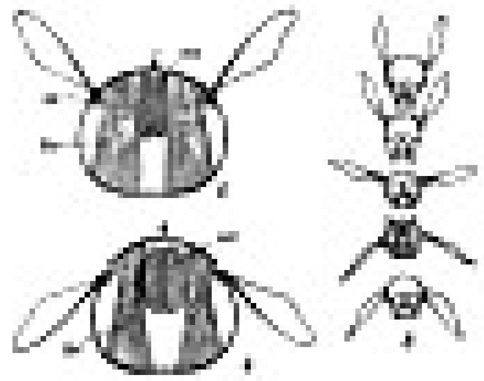
Another variant, is the recording of the signal and its careful analysis in the laboratory. This can help to make the "alphabet" or "dictionary" of the language of bees. And then, using all known algorithms of speech recognition, you can analyze the sounds of bees, and comparing them with a previously known "dictionary", it will be possible to translate into a human's language, what the bees "talk" about in their hives... perhaps, using a little bit generalized phrases ...

Exactly in this way our Remote Monitoring System of the State of Bees' families work. The recordings, which you send to us, will be analyzed using Apivox algorithms and using special programs for analyzing sound and speech. And basing on received data, we will write you about the general state of your bee colonies.

THE PECULIARITY OF THE ANALYSIS OF SIGNALS OF BEES, EMITTED BY THE WINGS, AND EMITTED ONLY BY VIBRATIONS OF BEE'S THORAX.

In order to understand the essence of the question, let us repeat once again the statements of authoritative scientists about these two types of sounds made by the bees:

The signals emitted by the wings of bees are in the range of about 70–250 Hz. And this signals, emitted by the wings, have peculiarities, associated with the biological structure of the wings. Let's refer to the classic book of Langstrott - "The Bee and the Hive" ...



"The musculature of the honeybee wing consists of indirect muscles that are not connected with the base of the wing and the rectus muscles, connected to its base. Indirect muscles play a major role during flight. Their volume is very large, and they fill almost all chest cavity. One type of indirect muscles, is attached from the inside to the skeleton of the thoracic region in the dorsal-ventral direction. These are vertical muscles. Other type, is located in the longitudinal direction. When contraction of the vertical muscles, the mesonotum is lowered, flattened, presses against the base of the wing, and the wing rises upward. With subsequent relaxation of vertical muscles and contraction of the longitudinal muscles, wings descend, and the mesonotum rises and becomes convex again. Change of contractions of the vertical and longitudinal muscles occurs very quickly: the frequency of wing strokes can be 200–250 per second...

...These high-frequency muscles constitute the most active of all contractile tissues, that have ever appeared in animals, in the process of evolution. Nervous centers do not send motor impulses to the muscles of the wings in such a high rhythm. This rhythm exceeds the rate of electrical processes on the surface of the cell membrane. The muscles of the wing come to the state of contractions by themselves, under the action of stretching. They work on the principle of a resonating system, the frequency of their compactions is determined by the degree of their tension..."

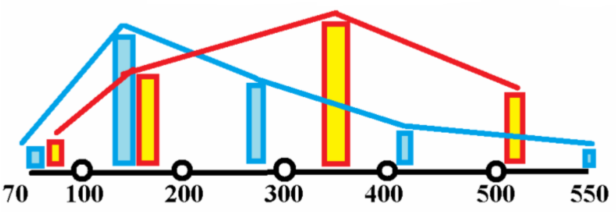
Here is the phrase, which is so important to us! ... "The resonant system" ... This means, that we get the classical oscillatory mechanism, operating according to the classical laws of physics. And this is the main characteristic of the signals, generated by the wings - aeration, ventilation, flight.

That is why, signals of the wings except the main tone, create an overtones multiple to the main tone - x2, x3 ... and \ 2, \ 3... and all subsequent .....

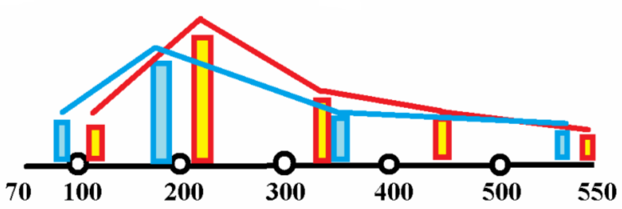
What do we know about the sounds, created by the vibration of the bee's thorax ... "... The process of functioning of the muscles of indirect action, when bees make sounds , differs significantly from the process of functioning of these muscles, during the flight ... (Esch and Goller, 1991; King et al., 1996) It is believed that during the production of (vibro-acoustical) signal, the uneven shortening of antagonistic muscles of indirect action and the associated closure of the slit of scutellum, which cause the change of vibration characteristics of bee's thorax in such a way, that the "flight system" of the bee vibrates at a higher frequency (King et al., 1996). ... . "

Exactly this was fixated, in the process of our research! Vibro-acoustical signals, generated by the bee thorax, do not have the correct classical harmonics around the main signal. Rather, the true signals emitted by the bees, are the signal of the fundamental frequency (main tone) and the “wings”. This "wings" can always be visible on diagram with one and the same parameters — the basic tone, +1\2 of main tone, + 2\2, + 3\2 of main tone and so on .... and -1\2 of main tone, -2\2, -3\2 of main tone and so on .... for each subsequent.

These characteristics of the two signals allow a person, who understands their nature, to see difference between real communicational signal of the bee and ventilation, in case of their simultaneous appearance on the screen. After all, the range of bees' signals is very narrow, and the imposition of signals and their "harmonics" occurs constantly. (In this case, we will call the “harmonics”, for simplicity, both types of additional signals appearing around the main signal.). Let's have a look at examples....

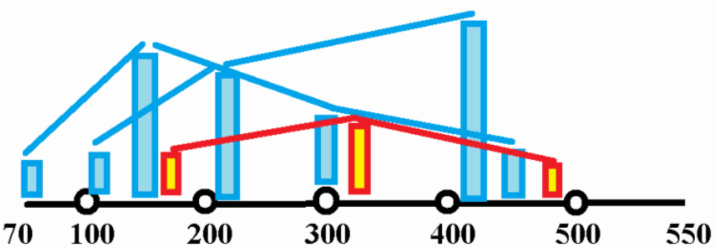


Ventilation (140Hz+harmonics) + work (350Hz+harmonics)



Ventilation (180Hz+harmonics) + work (220Hz+harmonics)

The first situation is quite common in the summer time, the second is more characteristic for winter and for autumn.



Signals of flying bees (200Hz+400Hz) + ventilation on the porch (150Hz+harmonics) + work (320Hz+harmonics)

The third combination, is the most unpleasant of all. Such a picture arises, if the microphone (wired or internal) is not in the depth of the hive, but on the porch of the hive, when recording or measuring. At the same time there is a strong honey collection, and the family of bees is also strong enough. A lot of bees arrive to the porch at the same time, and in the entrance there are many bees ventilating the hive. In this case, the signals of work are very poorly distinguishable.

This situation is the error of the person, who is taking the measurements, as the work signals are completely suppressed, and diagnosis will be very far from reality.

A NEW THEORY OF COMMUNICATION IN BEES. PRINCIPLES OF ORGANIZATION OF LIFE AND THE USAGE OF SIGNALS.

So, if we take into account all the technical nuances of studying of short and long vibro-acoustic signals, what can we learn? Can we understand what the hive is buzzing about?

Let's return to the bees. How their program of functioning is arranged. Their program, is a sequence of blocks, that switching according to time - according to the age of the bee. In these blocks there is a list of works, that the bee can perform at this age. For example, at the age of up to 3 days, the bee can only cleans the cells for laying eggs by the queen, and have no choice. Either this work, or no any work. The time relay clicks, and the program shifts to another block - at this age the bee can fulfill several jobs - feed the brood, build the honeycombs ..., the time relay clicks, and the bee moves to the direction of the porch - now the bee can receive and process nectar, guard the porch, build honeycombs. ... and so on. Of course, this view is simplistic, but it gives an understanding of the situation ...

How does the bee choose what work to do? Scientists claim, that bees make any work that they meet on their way of their moving along the hive. Bees are not attached to one place, but move freely along the hive. This allows them to take part in any kind of work that suits them by their age. How can they understand that they are needed? There are two ways here: the first way is when the bee herself finds the work to do, encountering with markers, which are situated on her way, and begins to do this work - for example, to feed the larvae.... Another way, is when someone turns her attention to the need of participation in some work. For example, the bees, running all over the hive like messengers, and carrying messages, about the need to take part in certain works ... In both cases, occurs simple communication. A group of bees who felt the need to do one and the same work, forms clusters so well known to scientists, who have studied the process of heating in bees.

Let's have a look at all kinds of possible signals, that take part in communications in bees, except tactile contacts.... This is signaling with the help of pheromones and vibro-acoustic signals. We believe that neither pheromone signaling, nor vibration signals, carry any meaningful information in our understanding of this word. This is just the simplest way to draw attention to an event, process, or individual, at the same time, transmitting some information about the current state and mood of the one who transmits the signals ...

PHEROMONE SIGNALS.

- Pheromones are used by working bees mainly outside the hive, in order to mark the way to a rich source of nectar, for new foragers. And they, having received general information about the direction and the range from waggle dance, fly in this direction, checking the way with the help of pheromone labels, left by scouts...

- If the bees have a feeling, that the queen is lost, they organize a pheromone "beacon" covering with its "dome", a large space around the hive. Queen, hitting in this cloud, will understand that the porch of the hive is somewhere near ...

- The only pheromone exists in the beehive, is the pheromone of the queen, serving to ensure that our little simpatico robots - the bees, do not scatter in other families ... After all, they do not care which family to live in, and for what community to serve .... This is why, we change queens so easily, and create offshoots and packages. Their internal programs do not provide loyalty of the bee to one queen or to one family. Simply, while queen's pheromone exists, they are orients to it.

- The queen is also not tied to the place. It is known that the queen can enter the wrong hive on returning from the marriage flight. It is known that when we want to insert new queen to the family, we may let her go in any porch of any beehive, and she goes there, as it was her own home. She does not care, what kind of family she will fall into. She will live and lay eggs in any... This often happens in large apiaries, because the program installed in our female robot, do not envisage apiaries !!! And we constantly use the fact, that bee's programs can not be reconfigured, or as we say - bees can not evolve... Living beings can adapt, but their participation in the process of evolution is still not noticed...

THE MOST NOTICEABLE VIBRO-ACOUSTIC SIGNALS, WHICH CAN BE USED AS MARKERS OF DIFFERENT TYPES OF ACTIVITIES.

VENTILATION - VIBRO-ACOUSTIC SIGNALS OF COLLECTIVE WORK, PERFORMED BY THE BEES AT ANY TIME OF DAY AND NIGHT, AND IN ANY SEASON.

Marker and communicational vibro-acoustic signals are always present, but due to the fact that they are short and varied, they create a kind of background buzz of the hive... But there are signals, powerful and prolonged, issued simultaneously by a sufficiently large number of bees. What are these signals and what do they serve ...

And the answer to this is obvious - it is ventilation of the hive and the aeration of brood! And that's why...

The beehive in which the bees live, has many advantages and amenities ... except for one - good ventilation. This is done in order to maintain at any time the most important, and necessary parameter of family life - the temperature, necessary for ripening of the brood. But even in this case, no one cancels the breathing! In order to do all this works, one need energy, and energy is the result of the metabolic

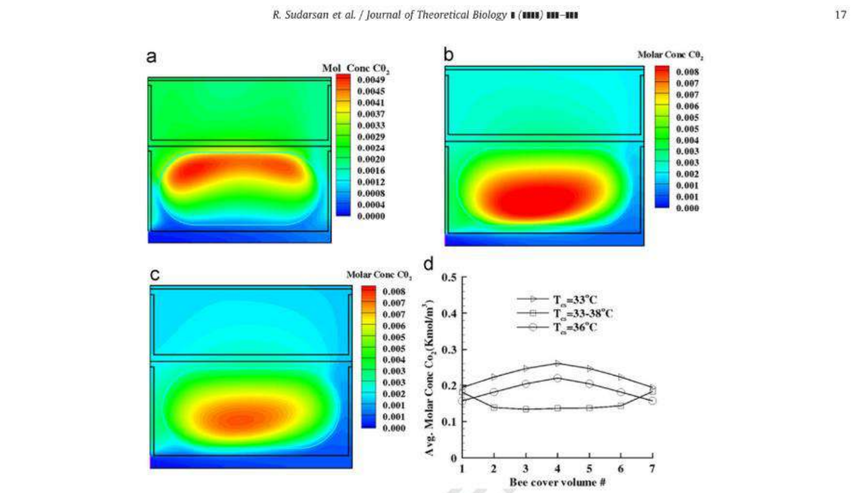


Fig. 7. Contour plot of molar concentration of carbon-dioxide (K mol/m^3) on a YZ plane passing through central bee cover volume (#4 of #7) for different comb wall temperatures studied in Case A where (a) $T_{cs} = 33-38$ °C (b) $T_{cs} = 33$ °C and (c) $T_{cs} = 36$ °C and in (d) plot of average molar concentration of carbon-dioxide in the different bee cover volumes.

process, that is, burning of honey and proteins in an oxygen atmosphere, with the release of energy! But also, with production of a by-product - carbonic gas. This gas, accumulating up to a critical amount, can cause a family to fall into a coma ... This effect we use during artificial insemination of the queens. Carbon dioxide acts as an narcosis. So, bees can not leave it in the hive .... And a large mass of bees is occupied with ensuring the breathing of the family!

Exists another side of the issue, not so obvious ... As
we said, our cute bees are biological robots working according to a certain program, in which all their actions and parameters of these actions for different situations, are pre-installed....

And breathing in this program is also present. The program has data on how to supply oxygen to resting bees, and how to ventilate brood, how fast they should blow on water drops, while cooling the hive, and with what speed to blow on nectar droplets, removing moisture from the future honey ....

And this is extremely important for us! This means, that ventilation in its diversity, carries certain information about the life of the family. It seems that this is impossible?

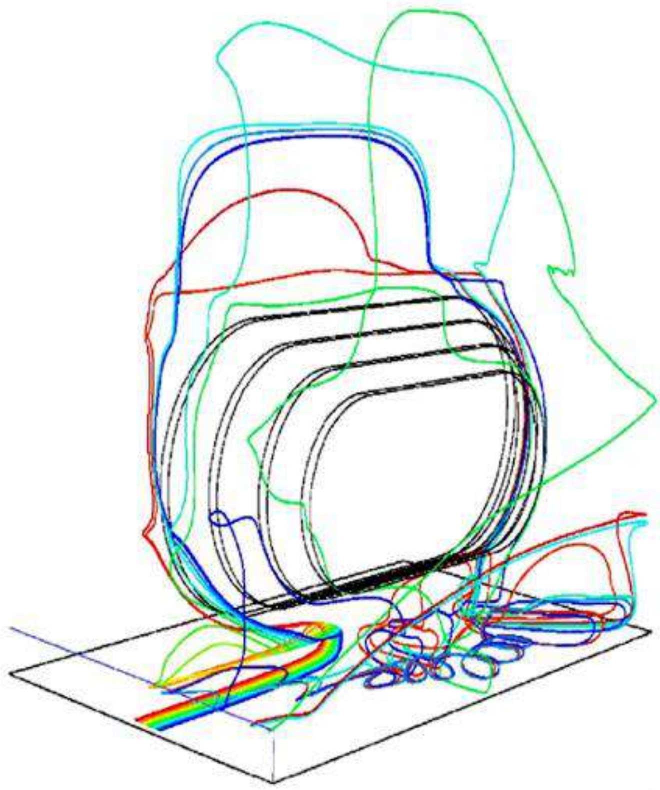


Fig. 14. Plot of path lines introduced in front of frame #5 in a model beehive with $\beta_{gradient} = 70-30$ at $T_{amb} = 27.5$ °C. Each path line is colored differently for visual perception. For purpose of visual clarity, the frames and the walls of the beehive in brood chamber and honey supper have been made transparent and only the bee cover volumes in one half of the beehive has been shown. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

But why ... after all, we know how we can determine according to breathing, whether our child is asleep or not, we can determine that a person has climbed on foot to the 5th floor, or ran after the bus... Our breath betray us, when we are excited ....

The basis of these analysis, is lying our breathing, although we draw conclusions not simple and not obvious .... In fact, we draw conclusion about performed work on the basis of the type of breath of the person who performed it. The same thing make a good doctor, who uses stethoscope to listen to our lungs and, on the basis of our breathing, make diagnoses about our disease - bronchitis or pneumonia .... The same thing, we can do too....

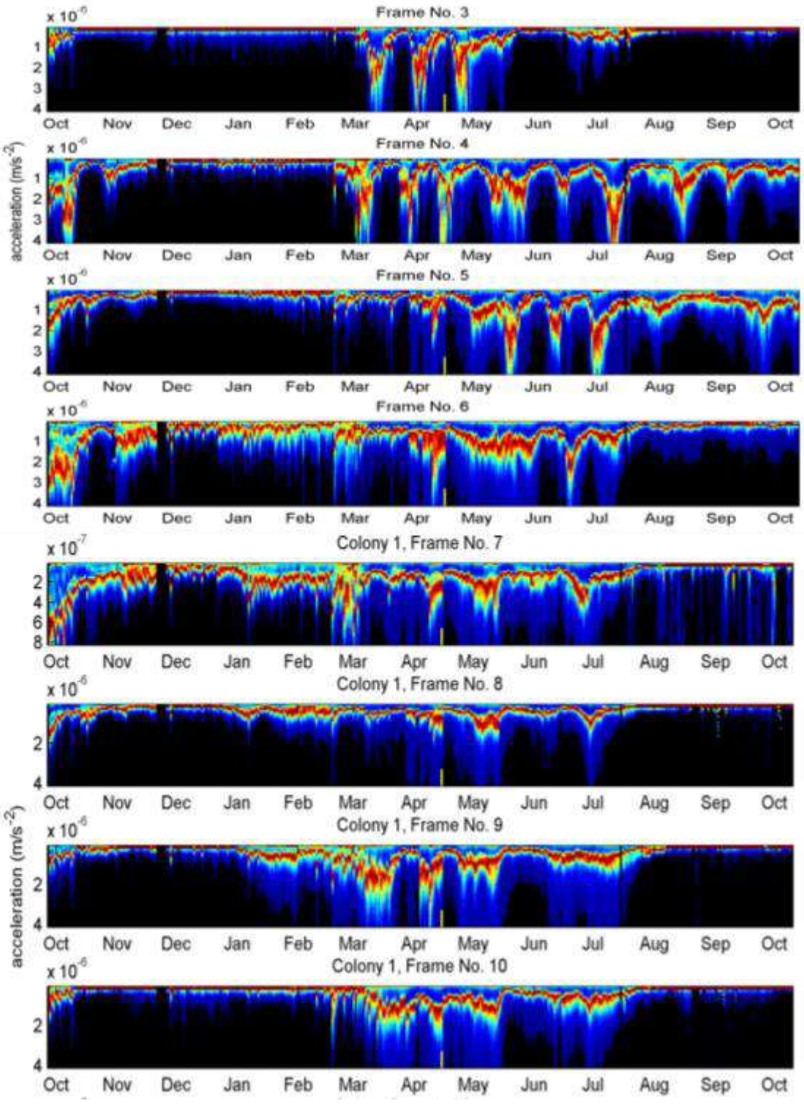
Just like a doctor, we can hear the breathing of bee family, and make a diagnosis about her well-being. Immediately, many unclear questions can be explained:

- Why signals in winter and summer can be the same - because making the same in-hive works, bees breathe about the same, and so, ventilation is required more or less identical ...

- Is it right, that the frequency range associated with the passivity of bees is lower, and the frequency range associated with active work is higher? It is quite reasonable - after all, in a calm state it is required less oxygen, much less than during active work, and the force of air supply to groups of resting bees, and working bees, will, of course, be different! More active work requires more active ventilation!

All this can explain, why on the basis of analysis of ventilation signals, we can also draw the right conclusions about the state of bee family... Because each type of activity corresponds to a certain consumption of oxygen and the release of carbon dioxide, which must be removed with the optimal performance, programmed in our small and pretty "biological robots" - bees ....

BROOD CARE - THE MOST IMPORTANT SIGNAL IN THE BEEHIVE.

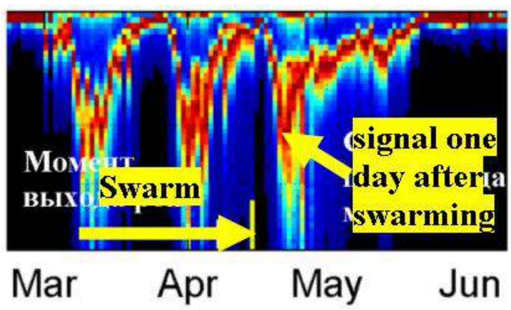


The signal that we associate now with brood, was noticed by the inventor of the Apidictor Eddie Woods and formed the basis of his device. Using this signal, he predicted swarming and gave recommendations on the best time for replacement of the queen. We are also used this signal, not really understanding its real meaning...

A breakthrough occurred when new studies were carried out with the purpose to clarify the relationship between the vibrational signals produced by the bees and the number of broods in the hives. (European Union's Research Executive Agency project reference No. 315146).

The only obtained result of their work was that they detected a low-frequency signal that appeared on the brood frames and corresponded to the development cycle of bee, from egg to adult insect - 21-26 days, and that there is no such a signal in winter. The European researchers did not notise systematic character of its appearance and disappearance.

Our own studies have shown an unambiguous dependence of this signal on the brood, and shown the possibility of its use in diagnosing the state of bee colonies. We called this signal “brood care” because we have not fully studied its exact significance. We have additionally noted that the signal in the spring begins to appear in the center of the nest, and that the signal strength on the frames reaches its peak in the middle of summer, and in spring and autumn the signal is weaker and less regular.



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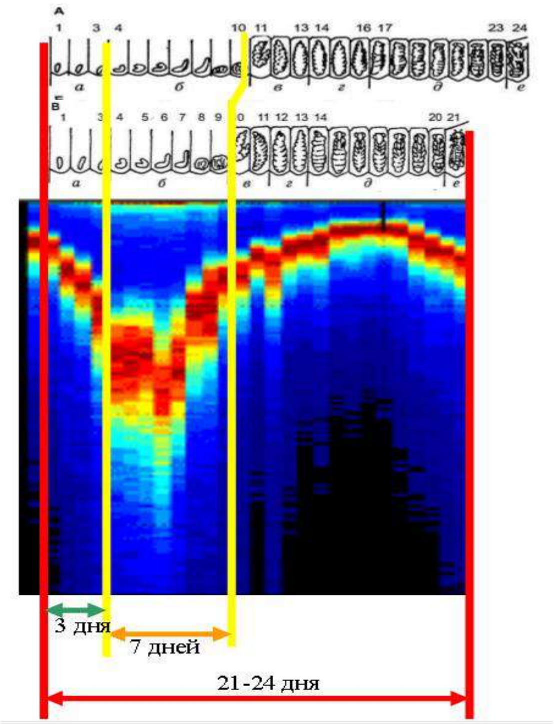
We used different partial results of experiment and made full diagram of life of bee family during one year. Using this diagram, we were able to understand everything, what happened with the brood in the family during the year. We noticed that the signal follows the queen in her movement all over the hive.

Finally, the most important thing that led to the conclusion that this signal is not directly related with the queen, is that the diagram shows, that after the fetal queen has left with the swarm, the signal once again appeared on one of the frames, where the queen spent her last days in the hive! So, our signal is not connected with the queen itself, but it seems to be connected with the results of her activity - and that is the brood.

All this allowed us to make the following conclusion about the nature of the signal

The signal, detected and fixated in the experiment, the "warble" signal, detected and fixated by Woods in 1952, signal which was fixated during our own experiments - are the signals, generated by young bees-nurses during the care on open brood.



This is well combined with the diagram and the development cycle of the bee in the cell of comb.

• The first three days after egg laying, the bees do not emit any signals, but merely maintain the microclimate in the nest at the desired level. Including the frame with fresh eggs.

• During the time of larvae exit from the eggs, the young bees collects on the honeycomb with the open brood, and the signal strength grows to the maximum. It is possible that this occurs at the time of the first mass supply of larvae with food.

• After this, the signal remains at a maximum levels, until will come the time to seal the larvae. As the cells are sealed, the signal weakens, and fades completely. Now it will not present on this frame, ideally up to11 or 14 days, (depending on quantity and the type of brood, which presents on this frame) until young bees will mature, and not come out of the cells. Then the queen will receive possibility to return to this frame and to start laying eggs again... But, she can return in time, or later, or much later ... depending on her job on another frames.

So, we believe that the vibrational signal received during the experiment, and the signal of "singing of the hive" received by Woods is a signal, emitted by the bees - nurses caring for the brood.

THE BROOD CARE SIGNAL, AS A MARKER OF THE RELATIVE AMOUNT OF BROOD IN THE FAMILY.

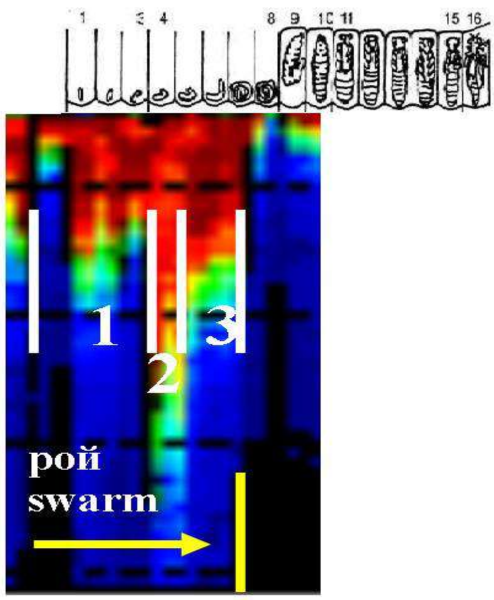
So, on the basis of the diagrams, obtained by European scientists, we can state, that the signal, created by bees-nurses in normal, everyday life, is not exists in the family constantly, but only at the moments of care for the larvae.

The signal appears with big or very big force, but only during 7 day interval and only on the frames with open brood - during feeding and aeration. In sum, the signal will not have much power in the hive. With a small amount of open brood (usually 1-2 frames), it will be almost not audible. With weak work and a large number of simultaneously laid eggs, the signal can gain a lot of strength and can be heard in the hive, especially in the evening after finishing work on the honey collection. The signal can be heard in the early spring when the queen starts to lay a lot of eggs, and the honey collection and processing is not strong, and in autumn, after the end of the honey collection, when there is no works on processing the honey, and the queen still continues to actively lay eggs.

Thus, unlike Woods, we consider the signal as a sign, or feature of the activity of the bees - nurses, and not a sign of their passivity, as Woods said.

BROOD CARE SIGNAL AS A MARKER OF PREPARATION FOR SWARMING

Why do we believe, that the "brood care" signal can be associated with swarming process, and can serve as a marker of this event ... This is why....



The diagram clearly shows a short and sharp peak, two weeks before the release of the swarm.

The same signal, but longer and more powerful, is observed when the bees - nurses starts to feed larvae of worker bees on the frames where the queen worked. In addition, if usually this signal appears on the frame where the queen worked a few days ago, then before swarming it appears in the entire hive almost simultaneously. This synchronism gives it such a big strength.

Our assumptions are as follows:

Phase one - the increase of this signal is connected with a general increase in the number of brood, at first in the nest, and then in the whole beehive after the hike of the queen inside the hive, in order to find all free cells, for laying more new eggs on all the frames of the hive, in order to ensure the maximum possible quantity of brood, before the swarm goes away.

We want to quote Gaidak's words from the book "The Bee and the Hive ... " ... During swarming period, before laying the queen cells, the egg-laying activity of the queen increases. Once it was fixed, that the queen lays 62 eggs in 45 minutes, that is, 1968 eggs per day. In the nearest vicinity of the queen bees become excited, they constantly and persistently offer her food .... they make the queen continue egg laying "....... This increases the number of bees - nurses on all frames of the hive. Bees-nurses, according to scientists, are not tied to one place, but freely move inside the hive, periodically finding a suitable job for themselves. So the appearance of signal of medium strength on all frames, is most likely connected with this process.

Phase two - A sharp, avalanche-like increase of the signal in 2-3 times. A narrow peak appears on the diagram. Here is a quote from Gaidak's book "The Bee and the Hive" ... "... At such time, the queen moves for a long distances (up to 240 meters per day) .... The queen examines all new queen cells and lays eggs in them. After the exit of the queen larvae from the eggs, the bees - nurses provide them with abundant food .... " . Thus, we believe, that the explosion of activity of the bees-nurses is associated with the laying of eggs in the queen cells by the old queen. Bees make a lot of new queen cells, and they are scattered all over the hive. Huge amount of feed - royal jelly, should be placed in them at the same time, during very short period. This huge amount of food should be made and placed during two-three days, and this causes an explosion of activity of the bees - nurses on all the frames of the hive. As we know, queen cells are simply surrounded by the bunches of bees-nurses !

Phase three - the peak drops as sharply, as started, after the first supply of queen cells with food. The number of bees-nurses on the frames starts to decrease. But the signal after reduction, remains until the sealing of queen cells and brood around them... Let's quote from Gaidak's book "The bee and the hive" .... " ... After laying eggs in the queen cells ... the number of bees feeding the queen decrease... sometimes they even refuse to feed her. Despite this, the queen continues to lay several eggs a day, until the day of swarm departure, and even including this day ... The decline of laying eggs leads to the fact that a large number of bees-nurses remains jobless ... They fill the entire space of the hive ..."

So, the signal before swarming, appears with increasing strength to an average level, on all the frames on which there is no queen and her escort, starting about 2 weeks before swarming and ending with the release of the swarm. Signal strength, despite the average level, can be significant, since a signal is produced simultaneously by a large number of bees on all frames. During the process of control, the signal can be well audible already 7-10 days prior to the beginning of swarming.

THE BROOD CARE SIGNAL AS A MARKER OF "QUEENLESS"

In order to understand what was happening in the hive at the moment when the queen was lost or died, we turned to Woods' idea of the "singing" of the hive, and the result of work of British scientists. Since we believe that the signal used by Woods is issued by the bees caring for open brood, we assumed the following ....

After the queen was taken away, or was lost by the family, besides natural anxiety and excitation of part of the bees, after a while, depending on the general condition of the family, the mechanism of the restoration of the queen will be started. The queen can be restored, if the family takes timely measures to grow new queen from larvae of worker bees.

This process has, apparently, several stages ....

The first stage - is the awareness by the bees of the very fact of loss their queen. This stage is characterized by anxiety and excitation of a part of bees, the supply of aromatic signals (ventilation with an open Nasonov gland), etc. It should be noted, that during honey harvest, this stage can be somewhat more prolonged.

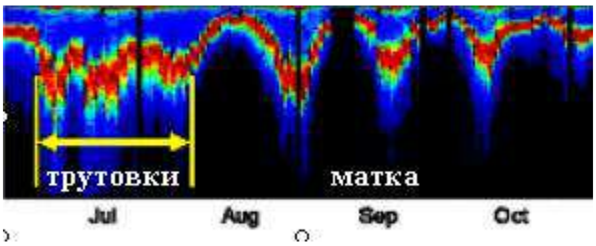
The second stage - is the active preparation of bees-nurses for the laying new queen cells, using larvae of worker bees. This stage consists in a sharp activation of bees-nurses, on the background of general calming of the in-hive works. Apparently, this preparation consists of intensive feeding of all larvae in the hive, with additional portions of food, heating and aerating them. Bees can do this, in order to give the family a chance to lay cells for new queens, on any open brood, of any age, on any frame, in any quantity, if the old queen in close future will not return. Usually, when it comes to the survival of a species, nature does not skimp. As a result of this powerful activation of the bees-nurses, we see a signal of "singing" of the hive, or "brood care" as we called it, which we consider to be the sign of feeling "queenless" by the bees, and the sign of "readiness of the family to accept a new queen." Or to replace it with their own new queen, which will be received after the future laying of new queen cells.

The third stage - is the decrease of the signals of bees-nurses, which mean almost complete disappearance of the "brood care" signal, and transition of the bees to new state - to laying of new queen cells, using larvae of worker bees. At this stage, the family calms down, and all bees stars their usual jobs.

Thus, the signal and behavior of the bees, which we call " signal of queenless ", in fact, is the stage of preparing of the family for the restoration of the queen. That is why, when changing the queen, it is so important to do this during initial part of the second stage. While the bees have not yet lost faith in the fact that the queen will return back.

THE BROOD CARE SIGNAL AS A MARKER OF THE PRESENCE IN THE FAMILY, OF WORKING BEES, WHICH LAY UNFERTILIZED EGGS.

Let's have a look at the processes, occurring in the family, in which the queen was lost, and there is no open brood for laying new queen cells. This may happens, for exsample, when a young queen perish during a mating flight ...



In the family, which has lost the queen, immediately appears working bees, laying not fertilized eggs. The number of such bees is large enough, and they spread eggs almost in all frames without a system. They do not lay eggs much, but this can be compensated by a large number of egg-laying worker bees. Therefore, the signals of bees-nurses arise almost on all the frames of the nest of the hive and have less force, since the number of broods is smaller than that, when the queen is working. But constant replenishment of open brood by egg-laying worker bees, results to the fact, that the signal keeps constantly until the death of the family... Usually, all other signals subsides. The work in the hive become disorganized.

So, in these four short chapters, we tried to show, why the "brood care" signal can become a marker of various functional states of the family, either alone or in combination with other signals.

Its combination with other markers allowed us to create new modes of our acoustic control device....

ADDITIONAL ACTIVE NEST HEATING. A NEW SIGNAL , WHICH BESIDES ITS MAIN MEANING, IS INVOLVED IN THE PROCESS OF PREPARATION OF BEES FOR SWARMING, AND IN THE PROCESS OF RESTORATION OF THE QUEEN.

The signal, which we now consider, earlier we have always called a sign of the presence of passive bees in the hive. This is the lowest frequency signal in the range of signals, associated with working activity of bees. Exactly with this signal we begin our scale of activity of bees and the works which they perform.

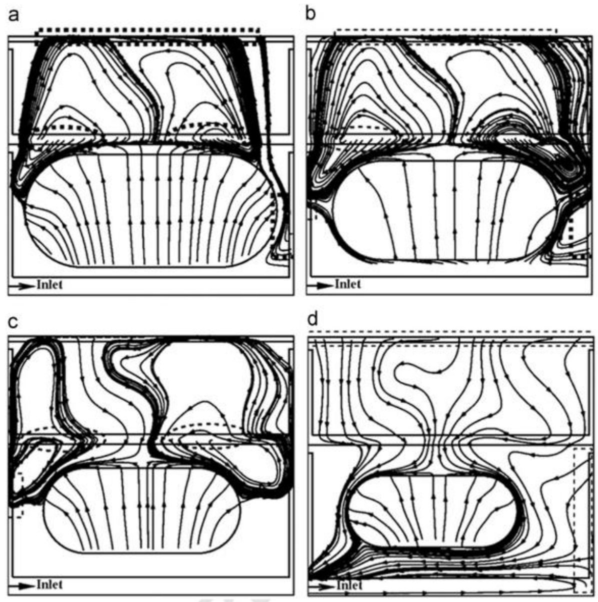
What has changed, and what made us reconsider its meaning.... A lot of our observations, and the results of the work of American and European scientists, made us to think about the problems, solved by the bees which create this signal ....

Characteristic of this signal as "passive bees" sounds a bit strange ... usually bees find for themselves any job appropriate for their age. Really passive bees sit on honeycombs almost in a state of anabiosis, saving energy, and it is known that before flying or starting their work, they need considerable time to warm up, in order be able to perform this work or flight. Thus, those bees which emit the signal, named "the signal of passive bees", should not be “passive”, but should be engaged in some job, may be not very active, from our point of view ...

And now let's consider the most common characteristics of our signal, which prof. Eskov calls - the signal of "passivity" ... It was noticed that this signal is almost always present when families are not very active - in autumn, in winter. But at the same time, the signal decreases and disappears in winter, when the hive warms up by the sun, and the bees become more active, and produce additional heat. The signal may present in the sounds of the hive in early summer, in the morning, when it is still cold, and is practically absent in summer in the afternoon, during intensive honey collection. The signal may be present in afternoon, but it was thought, that this was a signal of bees, which do not have any work.... What this is a sign of weak honey harvest, and in the same time, of excessive strength of bees' family .

Let's continue .... Consider the signs that made prof. Taranov to call this signal - a signal of "active, swarm bees"... This signal appears and gain a main strength in the period, one to two weeks before exit of swarm. This was the reason, why this signal was attributed to the young bees, who lost their job of caring for the brood, during the pre-swarm decline of egg-laying activity of the queen. It was believed, that these passive young bees form the basis of the future swarm. It was professor Taranov, who proposed in his method of "artificial swarming", to separate this bees from the rest of the family. But most likely, this method simply separate the young bees that did not ever fly , and who do not know where to return from the elder bees ... They find the queen, and create an analogue of swarm cluster around her.

Now let's consider our arguments, which are based on the latest researches of scientists, and our own observations. Our hypothesis is that these signals are neither signals of "passive bees" nor signals of "active swarm bees", but are signals of worker bees, occupied with an active heating of the nest and hive in summer, and the "winter ball" or cluster, in winter. We propose to distinguish this state from passive heating, which does not cause any generation of vibro-acoustic signals, due to the low power of vibrations, and from passive maintenance of heat, by creating "thermal insulation" by the bees from their own bodies, at the periphery of the nest. We believe that this signal is created by worker bees, more than 22 days old, located in the peripheral part of the nest.



In a relatively cold climate, this place is situated in the lower and back parts of the frames.

These bees, apparently, are situated among a large group of bees, providing heat insulation and heating of the entire hive during the day, and especially, before swarming. In this group there are bees, providing all three types of heating, and changing them one to another, depending on the need. This mean - according to outside temperature, the volume of the nest, and the stage in the life of the family.

Let's consider now the features of the appearance of this signal, which made us think, that this is a signal of "active heating" of the hive. At first, let's have a look at **summer period ...**

It is known, that the "passive bees" are always detected at the bottom parts of the combs and in other parts of the hive free from brood ... But it is exactly through these places, the main air flows go, which these bees can regulate, block, or heat, providing comfort for the bees and for the queen throughout the hive.(Flow currents and ventilation in Langstroth beehives due to brood thermoregulation efforts of honeybees Rangarajan Sudarsan , Cody Thompson, Peter G. Kevan , Hermann J. Eberl)

prof. Eskov have s a very correct phrase about this situation - "... The resistance of the bee family to long and deep cooling, is largely associated with the ability of bees to regulate the thermal return of the nest, through a change in its thermal insulation. Even slight cold snaps in summer, force the bees to gather in the zone of cells with brood. At the same time, they are most closely

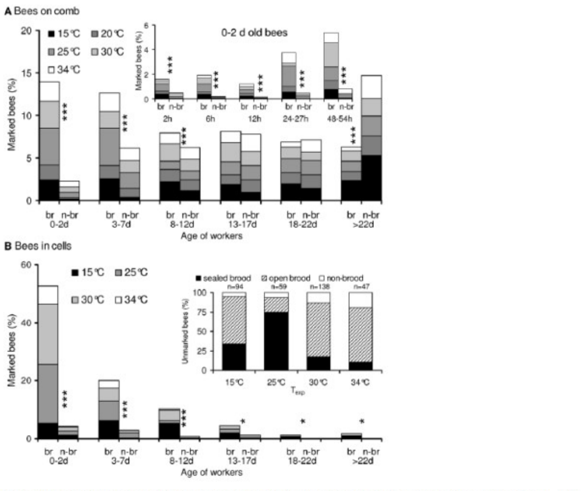


Figure 3. Frequency of honeybees of different ages on brood (br) and non-brood (n-br) areas. Shading of bars = thermal stress (T_{exp}). (A) Marked bees on combs; 100% = 12732 bees (measurements) of all age classes. Insert: detailed analysis of 0–2 d old bees. (B) Bees in cells; 100% = 350 bees of all age classes. Percentage of bees in brood nest cells per age class (young to old): 92.5 (184 of 199), 87.5 (70 of 80), 92.3 (36 of 39), 76.2 (16 of 21), 100.0 (5 of 5), 100.0 (6 of 6); no significant differences between age classes ($P>0.05$, $Chi^2=0.00$–6.08). Insert: distribution of unmarked bees on brood and non-brood areas ('nn' in Figs 7, 8); n = bees = 100% (per T_{exp}). (A, B) Significant differences between brood and non-brood: * $P<0.05$, *** $P<0.001$, Chi^2 test.
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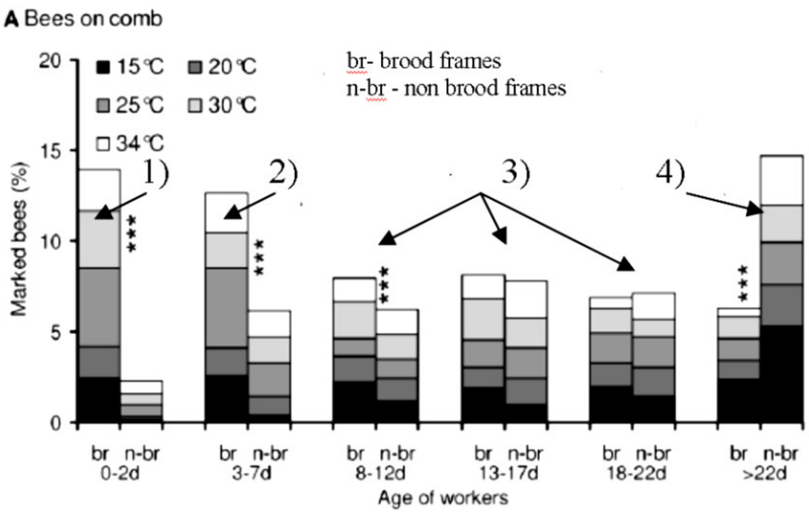
grouped in the peripheral, more cooled parts of the inter-frame space, forming insulating shells from their bodies , which help to reduce heat loss ... "

Contrariwise, in countries with hot climate, when opening a hive, one can see a huge number of bees not in the bottom of the hive, but above the frames. This is logical if we talk about thermoregulation! In cold climate it is necessary to regulate and warm up the air flow, which go from the bottom of the hive upwards, between the frames with brood, and then, when it is saturated with carbon dioxide, to move it downward, back to the porch. In hot climate, with the absence of thermal insulation under the roof, the bees gather at the top of the frames and create a thermal insulating layer from their bodies, at the same time without blocking of the flow of cooler air from the porch.

This made us think, that this signal is somehow connected with heating, and maintaining a stable temperature in the nest. And that this signal can be considered a marker of the active heating of the hive. Confirmation can be obtained by analyzing of temperature of the bees, located at the bottom of the frames , with the help of instruments that allow to make non-contact temperature measurements.

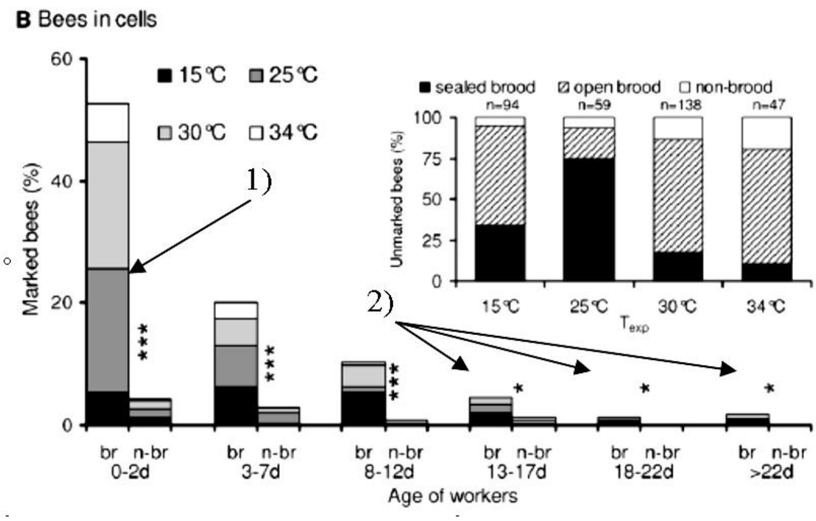
Let's consider in details the diagram, obtained by Austrian scientists in the process of their researches... (Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider Institut fu¨ r Zoologie, Karl-Franzens-Universitat Graz, Graz, Austria) It shows the interdependencies of the location of the bees on the combs, and their age, and the temperature to which they are heated. This diagram fully confirms our ideas....

Let's have a look at the diagram of interdependence of parameters of bees, placed on the surface of the combs (and not inside the cells)



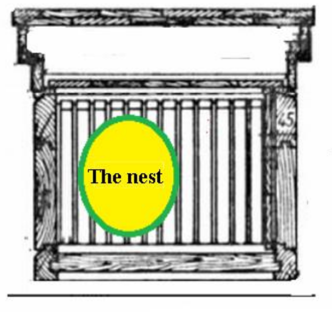
1) Please note, that maximum number of the youngest bees up to 2 days old, are placed on the combs with brood. They are not yet involved in thermoregulation and they only warm themselves in warm comb cells. But on the combs without brood their quantity is minimal.
2) All young bees, which are able to participate in thermoregulation, are on the frames with brood too. And a bit elsewhere in the other parts of the hive.
3) Bees of different ages, performing in-hive works, are distributed on combs with brood and combs without brood almost evenly.
4) Flight bees at the age of more than 22 days, in the maximum quantity - i.e. in quantities exceeding the number of bees of the other ages, are located in places, where there is no brood. And in these places there are both - resting (or "passive") flight bees, the temperature of which is minimal - 15C, as well as the bees, engaged in active heating of the hive, the temperature of which varies from 25C to 34C ...

So, we can say, that obtained results clearly show the presence of "active heating" in places, where there is no brood - that is, along the periphery of the nest. Including the bottom of the frames. This shows the presence of "active heating" with the participation of flight bees, which, as we said, at the moments preceding the swarming, engages in this work many flight bees, reducing the productivity of the families. A non-trivial conclusion follows from this: <u>it is necessary to warm bees' families exactly in pre-swarming period, in order to significantly reduce the loss of early honey in apiaries...</u>



The second diagram, which show the characteristics of the bees which were registered inside the cells, also gives us important information. It confirms some of the provisions of our theory of "conditioning" the nest of bees, in which we argued, that the bees do not warm brood, climbing into free cells, but only warm themselves using the heat of brood and combs! This statement is confirmed by the diagram :

1) 95% of bees , climbed into the cells on the combs with brood, are the bees of earliest ages, which by themselves, are not yet able to participate in thermoregulation process.
2) Adult bees practically never climb into the cells. So, heating the brood through empty cells, is a hypothesis devoid of meaning. And this is perfectly confirmed by the present study...



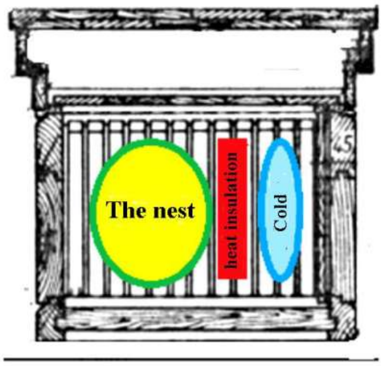
Our own observation can be a good example of this statement. It was a study of acoustic background of the hive. We used a wired microphone and an Apivox Smart Monitor app, in order to study the acoustic background in "bystreets" of the hive, during cool summer evening. Our result, by itself, was quite strange. We fixated the sound characteristics of the entire hive and did not go into details. The structure of the nest looked like it is shown on this picture.

All "bystreets", in which the nest was located, gave quite good working signals. It was quite freshly, but the bees of Carnica breed flied for nectar and brought something. All signals, fixated in the nest zone, corresponded to good working state of the family. (on the photo the porch is in the bottom of the picture). More or less, the picture in all "bystreets" of the nest, was similar.

The nest ends. Ahead 4 more "bystreets". Next we can see the frames with honey in different quantities. There are some bees that work with honey, but the main nectar processing is going within the nest. There are not many bees in the family. This is an offshoot.

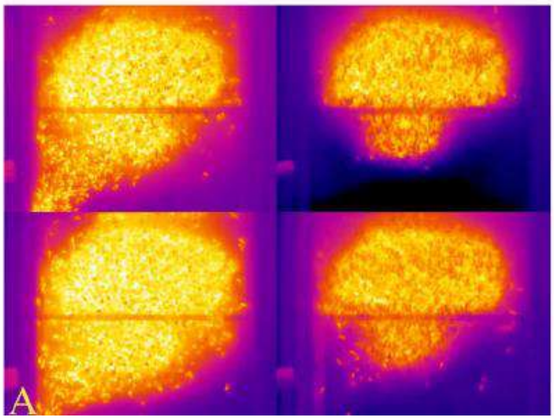
And in the next street after the nest, we see a sharp change in the signals. (on the photo, the porch is on the top of the picture) There are almost no even echoes of the work, that goes in the nest. No high frequency signals. We can see only signals in the low frequency part of range of working state. Previously we thought, that these were "passive bees" and did not attach importance to this signal and to all this situation...

And only now, understanding the peculiarities of "active heating" and "passive heating", i.e. of the blocking the heat losses of the nest, which provides the most economical mode of heating of the brood, it becomes clear, that this was some kind of “crust”, made from the bodies of worker bees, that cut off warm nest, shifted to one of the walls of the hive,(due to its small size) from the rest of the cold part of the hive, not occupied by the bees! On the left, the nest is protected by the wooden wall of the hive, on top with a warming pillow. And on the right, the bees created a "bystreet", in which old bees gathered in order to block its contact with the cold and empty part of the hive.



front view

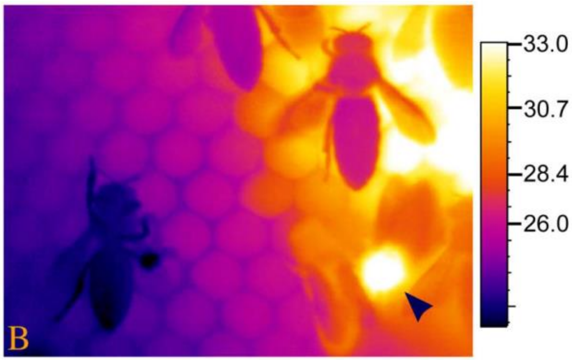
We consider this picture, to be a good visual example of behavior of bees, which provide optimal thermoregulation of the nest, with the help of silent "passive heating", and "active heating" which create a vibro-acoustical signals in the low-frequency part of "working range"(200-400Hz).



On this thermal photo, obtained by American scientists in the other experiment, it is clearly seen, that at night, all bees come closer to the brood zone, and create a rather dense and thin protective "crust" of thermal insulation. During the daytime, this protective "crust" is more friable, and inside of it, appears groups of strongly heated bees, which are placed on some distance from the brood part of the nest.
(Mapping Sleeping Bees within Their Nest: Spatial and Temporal Analysis of Worker Honey Bee Sleep Barrett Anthony Klein1, Martin Stiegler, Arno Klein, Jurgen Tautz)

If you take into account their location and temperature, you'll understand, that this is worker bees, occupied by “active heating” of the hive, and creating comfortable conditions for all bees, working outside the brood part of the nest. They are not as hot as bees warming brood, but not as cold as "passive"- resting, bees.

On this thermal photo, which we took from the same work, it is clearly visible, how the thermal picture of the bees differs. Very bright bees - are the bees actively warming the brood, more pale - worker bees, and bees merging in color with cold empty combs in which there is no brood - these are resting "passive" bees.



Let's consider now thermoregulation of bees in winter, in the conditions of the winter cluster (or clew)...

Studies conducted in sixties in Russia show the position of the family's thermal centre at various external temperatures. (As an example, we present several temperature charts obtained by T.S. Zhdanova (1967) in a field experiment.)

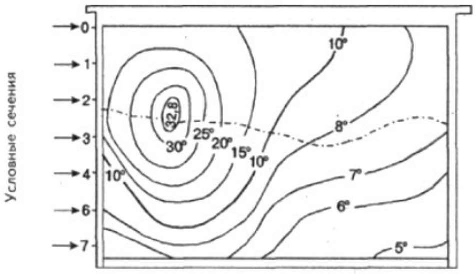


Рис. 3.16. Распределение температур в центральной улочке при t = +6 °C снаружи

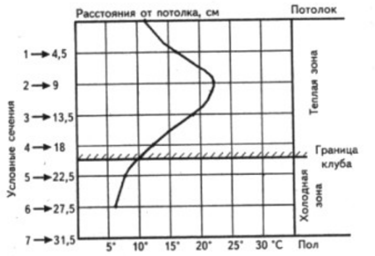


Рис. 3.18. Распределение средних температур по условным сечениям 1 – 7 (см. рис. 3.16)

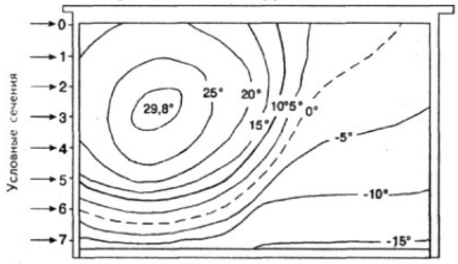


Рис. 3.17. Распределение температур в центральной улочке при t = –20 °C снаружи

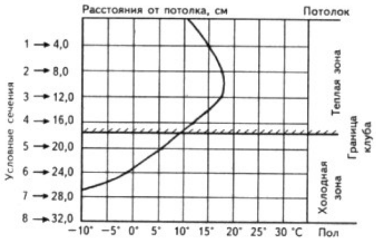


Рис. 3.19. Распределение средних температур по условным сечениям 1 – 7 (см. рис. 3.17)

It is perfectly visible, that thermal center of the bees' cluster (or clew) at any external temperature is shifted to the upper part of the hive. But it is well known, that the heat in winter is generated inside the center of bees' "clew", and not on its periphery.

Let's have a look at an excerpt from the work of German scientists, which шы also confirms our ideas... (Thermal investigations of a honey bee colony:thermoregulation of the hive during summer and winterand heat production of members of different bee castes L. Fahrenholz, I. Lamprecht, and B. SchrickerInstitut •r Zoologie der Freien Universit~it Berlin, K6nigin-Luise-Strasse 1-3, D-1000 Berlin 33, Institut fiir Biophysik der Freien Universit/it Berlin,)

"...The temperature in the center of the wintering "clew" of bees is maintained at an average level of 21.3 ° (maximum 33.5 °). As the ambient temperature rises, the central temperature of the winter "clew" drops, while the peripheral temperature rises slightly. With a decrease in external temperatures, the peripheral temperature decreases slightly, while the central temperature of the cluster rises. Linear dependencies are observed between the central temperature and the ambient temperature, as well as between the central temperature and the temperature difference between the peripheral temperature and the ambient temperature.

Microcalorimetric measurements of heat generation for three castes of the honeybee — workers, drones, and queens of different ages, were performed. Among these groups, adult worker bees showed the highest rates of heat production .... "

This is why, we believe that the signals so well heard from the top of the frames, covered with fabric ceiling, in winter, are the signals of “active heating” of bees' cluster or "clew", created by adult worker bees.

Exactly these signals we observed in the hive with the help of a microphone placed on the upper frames of the hive of wintering family. Let us give an example of such an observation:

Here we can see the measurement, made the usage of a wired microphone, placed on top of the frames on the textile coverage, under a heat insulating pillow. This place gives a good acoustic contact with the cluster of wintering bees.

The result is clearly visible. We observed, at an external temperature of about -10C and and in the presence of fact, that the sun light does not fall on this hive, only signals in the low-frequency region of the working range, which corresponds, according to our opinion, to the signals of "active heating", in this case, of the winter "clew".

To be one more feature of the creation of "active heating" signal, we consider the appearance of the bees, creating it ...

On the thermogram, obtained by Austrian scientists, you can see two bees actively warming the hive. Under the picture is the caption "... The measurement was made in the peripheral zone of the observation hive, during the "cold stress "..."

(Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider Institut fu¨ r Zoologie, Karl-Franzens-Universitat Graz, Graz, Austria)

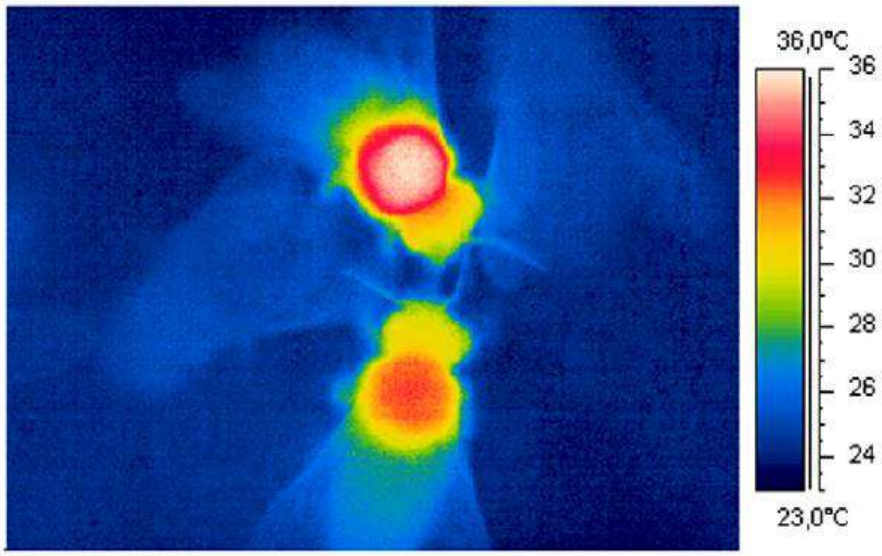


Figure 1. Close-up thermogram of honeybees. Left and right: ectothermic bees (light blue: $T_{thorax} = 25.2°C$ and $24.9°C$). Top and bottom: endothermic bees (white: $T_{thorax} = 35.6°C$; orange: $T_{thorax} = 32.4°C$). $T_a = 25°C$, $T_{cell\ rim}$ ~24°C. Measurement performed in a peripheral area of an observation hive during high cold stress ($T_{exp} = 20°C$).
doi:10.1371/journal.pone.0008967.g001

Beside this, pay attention to the position of the wings of the bees. They are ajar. Bees doing regular hive jobs move with fully folded wings. And only the bees occupied by thermoregulation open them up, regardless of whether they retain heat without heating, creating only "thermal insulation" from their bodies, or actively heating up the hive, the "clew", or the brood. Apparently, such position of the wings allows them not only to make better "thermal insulation", but to produce the vibrations, necessary for heating, but not capable of causing the movements of the wings...

Let us now consider, how the "active heating" signal, can be connected with the process of swarming ...

The signal, which we study now, can be fixated before swarming, when the queen should lay eggs, in almost all the hive, in order that after the departure of the swarm in the hive was born as many worker bees as possible, and when she should lay eggs in all new queen cells, scattered by the bees around the nest, where the temperature is usually not suitable for rearing of worker bees and queens.

In such situation bees should heat the entire space of the hive, in order to make all these possible.

Decrease in flight activity of Russian bees before swarming in comparison with bees of Carnica breed, suggests that these are not young bees without work, but adult worker bees, including flight bees, who had to start doing another thing - for example, to heat the hive, in order to make natural breeding process possible. Otherwise, what is the reason that the bees, flying normally for honey, suddenly stopped doing this?

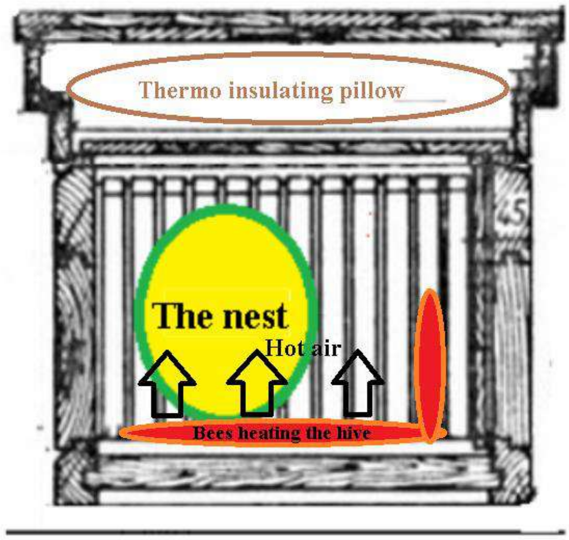
At the same time, the bees of Carnica breed, being a mountain bees, is more cold-resistant, and their flight for honey collection immediately before swarming, is not much worse, than during all other time...

Prof. Eskov write about the swarm - “... the beginning of the development of a new family is considered to be the settlement of the swarm in a dwelling ... Already in the first minutes the temperature in the central part of the hive with empty frames rises from 19C to 26C, reaching in 15 minutes 37 degrees Celsius ..... If there is a fertilized queen in the swarm, then in a few hours, temperature will be stably maintained at 33-35 degrees Celsius ... Without stabilization of the thermal mode in a dwelling, development of the bees' family is impossible. The temperature of 33-35 degrees Celsius is necessary not only for development of bees' brood, but also for stimulating the queen to fulfill her primary function - egg laying ... "

In addition, he write - "... Temperature in the area of growing the queens is characterized by high stability. Near queen cells of all types, temperature is weakly affected by external temperature fluctuations. For example, when external temperature decreases from 23 ° C to 11 ° C, the temperature near the queen cells decreases on the value not more than 0.5° C.... "

Austrian scientists argue, that the stability of temperatures in the hive during the ripening period of sealed brood is much more important, than during the period when eggs and larvae are heated. Even the slightest drop in temperature below 32C leads to mass ugliness in the resulting adult bees. And this is a serious factor, which means that maintaining a stable, high temperature in the zone of sealed brood, is a factor of family survival. And it’s not a fact that honey collection is more important at the moment ... (Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider Institut fu¨ r Zoologie, Karl-Franzens-Universitat Graz, Graz, Austria) We believe, that in relation to the future queens, it is even more important !!! It is likely possible, that this is why the signals in the range of low frequencies increases so much before swarming.

If these signals are the sign of heating the beehive, then, this means that the following occurs:



Elder worker bees (in cold climate zone) gather at the bottom parts of the frames, shutting the bystreets and forming clusters, in order to generate heat and protect the nest against drafts. After all, almost the entire hive becomes a nest. It is well known, that before leaving with the swarm, the queen lays the maximum number of eggs throughout the hive. In addition, the bees scatter new queen cells throughout the hive, and are even make them on frames with honey. In such situation, is not enough local high-precision heating of the brood part of the nest. It is necessary to preheat the entire hive, in order to make it possible for the queen (as it was written higher) in principle, to go through all the hive, and to lay eggs on all frames and in all queen cells...

So, increase of this signal, precedes the process of egg laying by the queen in all suitable spaces of the combs, and in future swarming queen cells, scattered throughout the hive, including of course the nest, where all this is done firstly.

Somewhat later, the signal is gaining full strength. This happens when the most of the brood is sealed. It is known, that the larvae during period of transformation into a mature insect, require a much more accurate temperature maintenance, than is required for eggs and larvae in open brood.

Then, this signal becomes the strongest in the hive. This was observed by everyone, who investigated interconnection of acoustic signals, with the process of swarming. But all of them did not correctly interpret its nature... They thought, that this sound is emitted by a cluster of passive nurse bees, which can't find more open brood for care, and can't find another work in the hive according to their age...

May be this statement is not so wrong, but such "passive" bees do not generate sounds, they seat still on the frames, with very low temperature of their bodies, in the state close to hibernation, saving their energy, and family resources ...

Another function of the signal can occur in the absence of fertile queen, when the bees make new queen cells, using open brood of worker bees. The signal at this time can be quite strong.

Prof. Eskov write ... "... The duration of development of members of a bee family is directly related to temperature. The development of bee brood from the moment of its sealing at 34-35 degrees Celsius, lasts about 12 days. This time increases for two days at 31 degrees Celsius, and decreases for a day at 38 degrees Celsius ... "

Exactly this fact can cause a sharp rise of signals, associated with brood care and heating of the nest. After all, after the loss of the queen, the bees seek to restore the queen as quickly as it is possible, and to grow new bees as quickly as it is possible.

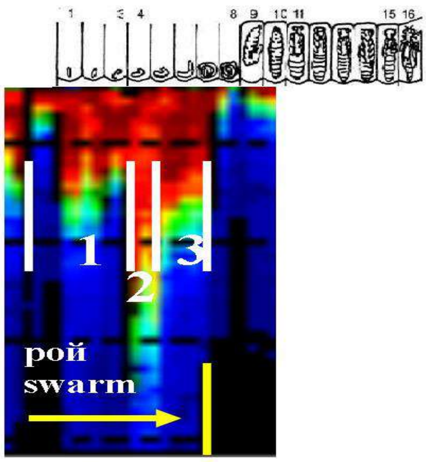
Especially strong signals of "active heating" are possible, if all queen cells and worker bees' brood are already sealed. But this may not happen ... because unlike the state of natural swarming, the laying of new queen cells occurs on the frames, which already have brood, in the warmest part of the nest, which will not be expanded. Everything continues to be done in the same way, as it was done before the loss of the queen. Only appears new queen cells.

It should be noted, that described situation is characteristic for a complete family, that has not been previously divided in half. When we are creating offshoots, we can destroy the balance of the brood, young bees, and flying bees, and situation may arise, when "active heating" will be required, since natural passive heating will not be enough due to the insufficient number of bees in offshoot. And then, the half of the family in which there is no queen, will be forced to start "active heating" of the hive...

So, we'll repeat once again. Our statement is as follows - the signals, visible in the low frequency part of the range of working signals, and previously called - "signals of passive bees" or signals of "active swarming bees" are not those, but they are marker signals of worker bees, engaged in "active heating" of the nest and the hive in summer, and of the "winter clew" (or cluster) in winter time.

JOINT USAGE OF "BROOD CARE" SIGNAL AND "ACTIVE HEATING" SIGNAL, AS A MARKER OF CLOSE SWARMING.

In the process of monitoring of such an important parameter in the life of bees' family, as the beginning of swarming, are used, as we believe, two signals of different origin, which ultimately show us, that the process of swarming begins.



We already mentioned both signals as such, but now we need to tell, why we decided to use them together, and what became the basis for making such a decision.

Let's start with the signal, which we call "brood care".

In 2017, within the project "Swarmonitor" , with the financing of the European Union, were carried out studies, which purpose was to clarify the relationship between the vibrational signals produced by the bees and the number of brood in the hives. (European Union's Research Executive Agency project reference No. 315146 Honeybee Colony Vibrational Measurements to Highlight the Brood Cycle Martin Bencsik ,Yves Le Conte,Maritza Reyes,Maryline Pioz,David Whittaker,Didier Crauser,Noa Simon Delso, Michael I. Newton Published: November 18, 2015).As we have already said, thanks to obtained results, it became possible to change point of view at many events taking place in the bee family.

On the diagrams, obtained by European scientists, it is clearly visible a short and sharp peak, two weeks before the release of the swarm. The same signal, but longer and more powerful, is observed when the bees - nurses starts to feed larvae of worker bees on the frames where the queen worked. In addition, if usually this signal appears on the frame where the queen worked a few days ago, then before swarming it appears in the entire hive almost simultaneously. This synchronism gives it such a big strength. As we already said, we called this signal - "brood care " signal...

Our hypothesis about the process of preparing bees for the beginning of swarming, taking into account the analysis of two signals, consists in the following:

<u>The first stage</u>- the growth of "brood care" signal is associated with an increase in the egg-laying activity of the queen and filling of all free cells in the nest. This stage passes without participation of second signal. If you use our device Apivox Smart Monitor in Swarming Control mode, you'll see that arrows begin to approach the yellow zone more and more often.

<u>The second stage</u> - The further task of the queen is to go through the hive in search of all the vacant places for egg laying, on all the frames of the hive, in order to ensure the maximum possible amount of brood in the hive, after the swarm leave. In addition, the bees must build new queen cells on the periphery of the nest, where there are no suitable temperature conditions. The expansion of the nest zone, necessitates the strengthening of measures to maintain the temperature, necessary for rearing of worker bees and new queens. And the signal of "active heating" starts to appear in the hive.
Oddly enough, but most of the bees which do this, are flight bees. In addition, it was noted, that exactly flight bees almost never enter the brood part of the nest in the process of heating the hive. (Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider)

Transition of flight bees to the work on heating the hive, leads to a decrease in flight activity of the family, which can be noted especially in the presence of thermophilic breeds of bees, such as Russian breed. In the same time, in the families of bees which breed was born in mountains, such as Carnica breed, the flight activity decreases significantly less. The transition of bees to the heating of a larger volume of the hive is accompanied by the beginning of the rise of "active heating" signal, and If you use our device Apivox Smart Monitor in Swarming Control mode, you'll see, that the arrows begin to approach to the border of the red zone.

As the entire volume of the hive becomes suitable for laying eggs, the queen expands the egg-laying zone. The "brood care" signal rise and stabilizes. So, the appearance of signal of "brood care" of average strength on all frames of the hive, is most likely connected exactly with this process.

<u>The third stage</u> - A sharp, avalanche-like increase of "brood care" signal by 2-3 times. A narrow peak appears on the diagram. We believe, that this is the explosion of activity of nursing bees, associated with the laying of eggs by the queen in the queen cells, on the background of overall increase of number of open brood in the hive. Normally, the quantity of them is high enough, and they are scattered throughout the hive. A huge amount of feed, royal jelly, should be placed in them practically, simultaneously. This enormous amount is required to be produced during three days, and this causes an explosion in the activity of the nurse bees on all the frames of the hive. As we know, queen cells are surrounded by bunches of nurse bees! In addition, no one cancels the continuation of works on the care of the rest of the brood in the nest. And this is the moment, when our device already confidently shows the borderline state between working state of the family and swarming state.

After laying new queen cells, heating of the hive become more intense. Maintaining the temperature throughout the hive should be more accurate. At this time, the signal of "active heating" begin to increase, and If you use our device Apivox Smart Monitor in Swarming Control mode, you'll see, that the arrows are shifting , deeper into the red zone.

<u>The fourth stage</u> - the peak of "brood care" signal drops sharply after the first massive loading of the queen cells with the feed. The number of bees- nurses on the frames with queen cells decreases.

The signal decrease, but remains until the sealing of queen cells, and the brood around them... The work of bees with queen cells does not stop life in the hive. The brood in the nest matures and the bees gradually seal it. The "brood care" signal gradually decreases, and the "active heat" signal becomes the main signal in the hive. Why? For what reason ? Because it is exactly pupae for their transformation require maintaining the temperature as accurately as possible! Much more accurate, than it is required for eggs and larvae. They allow to have a slightly lower temperature in the nest... Sealed brood and sealed queen cells do not allow this. A miracle occurs inside them - the larva at first turns into a shapeless mass, and then it takes the form of a pupa, with an almost complete set of organs of an adult insect ... And this miracle requires from the bees to maintain needed temperature with high stability. (Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider Institut fu¨ r Zoologie, Karl-Franzens-Universitat Graz, Graz, Austria)

Step by step, under the influence of bees, the queen reduces egg-laying. The decline of the egg-laying leads to the fact, that a large number of bees-nurses remain idle. In order, not to hinder the work in the nest, those bees who do not find work in the hive, passes into a real "passive state", without surplus movements and generation of vibro-acoustic signals, and having housed in a certain way, become a “crust”, which protect the nest and frames with brood from heat losses. So, we believe, that exactly like this, the process of preparing for swarming, looks like from the point of view of vibro-acoustic signaling and acoustic control.

URGENT ACTIVE HEATING.

REINFORCED CONVECTION HEATING, THE TASK OF WHICH IS TO QUICKLY RESTORE THE TEMPERATURE IN THE HIVE, WHICH IS NECESSARY FOR THE ACTIVE WORK OF THE BEES, OR FOR BROOD REARING. IN SPRING AND SUMMER, ITS PRESENCE IS USUALLY ASSOCIATED WITH A LARGE NUMBER OF SEALED BROOD, AND SOMETIMES WITH THE PRESENCE OF QUEEN CELLS. IN WINTER - WITH A SHARP COOLING OF CLUSTER OF WINTERING BEES.

The existence of this type of heating was assumed by us for a long time, but unfortunately we did not have enough observations to confirm this effect. Some data from our summer observations and from experiment conducted in winter time allowed us to confirm our ideas. What is the meaning of our idea .... The point is, that for heating of a large volumes as quickly as possible, or for fixing some kind of emergency situation, there is needed the most efficient method of heating and transferring of heat. This is convection, which, in combination with heating of the bee itself, can provide the fastest heating of the nest, the wintering bees' cluster, or the hive as a whole.

The use of this heating method in conjunction with the other three known methods - heat insulation, passive heating, active heating with generation of vibro-acoustic signals without movement of the wings, allows not only to maintain the temperature in the most economical way, but also to eliminate the consequences of emergency situations. In addition, the work of the bees, as an active process, is also accompanied by the release of heat. This is not a heating method, but this process participate in the overall picture of creating and maintaining heat in the nest too.

What exactly the mechanism of urgent heating is ... We assume, that in addition to silent heating, and heating with thorax vibration, exists the type of heating, which use wings flapping as a source of heat generation. This mechanical loading reduces the resonant frequency of vibration of the muscles of thorax, but increases the amount of work done, as a result, producing more heat. This also improves heat removal and provides forced convection, redistributing the heat in an optimal way over the volume of the nest or in the winter cluster.

Why is it better to flap wings with a frequency of about 100 Hz, than to vibrate with a higher frequency? Or why not to flap wings with a frequency much more than 100Hz? It is thought because in all cases Nature avoids the waste of energy and life resources. Unfortunately, any living being is not forever. Each has its own resource. And everyone save and cherish it, lengthening their lives.

And what about vibrations and flapping of the wings? In order to understand this, we will give an example: When we freeze, we begin to shiver. Muscles vibrate, producing heat. If this does not help and we continue to freeze, then the shiver becomes stronger ... we just start to shake. Muscles begin to perform even more work, releasing more heat. But the surest way to quickly warm up in the cold time, is to start waving hands and running. So, our muscles make more work, and produce more heat. Further, our internal convection starts working. Yes, and we have it too. Convection of blood begin to transfer heat to our internal organs, warming them. We get warm, stop shivering, and stop running and waving our hands. Our body warmed up and went out of the critical phase of cooling.

Realizing that we all have a single Creator, we draw a direct analogy, believing that the general algorithm for the functioning of living beings is one and the same ... And the bees act quite similarly to us... When it become cold, bees begin to strain muscles, producing heat without vibration. By the way, we are also know how to do it ... If this does not help, the bees begin to vibrate, emitting more heat, thanks to the accomplishment of more work. If this does not help, then the bees begin to flap their wings, as we do with our hands... By doing more work, they achieve production of more heat! Moreover, in the result of these actions, the bee blows on her own body, and on everything that surrounds her...

What is the reason for the importance of such a blowing ... The reason - is the efficiency of heat transfer ....

We have no doubts about the effectiveness of convective heating. Convection is a process of heat transfer during moving of volumes of liquid or gas (fluid) from the place with one temperature to the place with another temperature. In this case the heat transfer is inextricably linked with the transfer of the medium itself, which is essentially a heat carrier.

Convection of heat is always accompanied by conduction of heat. The joint process of heat transfer by convection and conduction is called convective heat transfer.

The intensity of transfer of heat(or cold) from one medium to another is characterized by the transfer coefficient, which depends from each environment. If environments have dramatically different coefficients of heat transfer, the heat transfer rate is determined by the environment, which makes it the most slowly.

What else affects the intensity of heat transfer. Of course, it's the relational speed of movement of one media over other. As you know from the basics of heat transfer, the heat transfer coefficient increases with increasing of the speed of heat carrier, in our case air flow. But not indefinitely. There is an optimal ratio of speed of air flow, relative to the stationary environment, which is characterized by maximum quantity of the transmitted heat, with expenditure of optimal amount of energy to move the heat carrier. In our case, the two environments are - the body of the bee, and blowing air. If you will use forced blowing of solid body by air flow, instead of free convection, then heat transfer coefficient increases twice.

Additionally, the heat transfer depends on the shape and geometry of the body, blown by the air. The larger the contact area of solid body with air flow, the higher heat transfer. The less streamlined is the shape of the solid body, blown by the air, the higher the coefficient of heat transfer.
In all these, bees are not too much lucky. Their streamlined body covered with a chitinous exoskeleton is not the best heat exchanger. This means that the rate of heat transfer from the body of bees to the air flow will not be very high. So, the flapping of the wings provide air flow, removing heat from the body of bees and transferring it to the brood and other parts of the nest can't be very high. And frequencies rate of emitted sounds can't be very high.

Such sounds with the frequencies above 20 Hz. people can hear as a very low sounds, and our device can register them, if their frequencies are higher than 70 Hz. And indeed, our device captures such signals at times of tense situations in the bee family. The frequencies that we fixated, were in the range of about 100 Hz and by the type of picture of the spectrum could be attributed to the signals, created primarily by bee wings, since they have the correct multiplicity of harmonics x2, x3 ... etc.

And how do the bees use their heating capabilities at different situations of their life ...

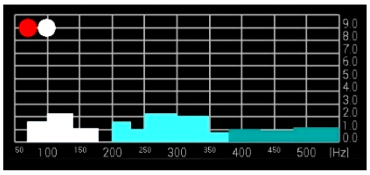
Settling into a new home, the swarm immediately begin to maintain the temperature, necessary for the beginning of egg laying by the queen. Then the bees begin the process of maintaining the temperature using thermal insulation and passive heating of the nest. Further, if it is necessary to maintain the temperature in a larger volume, the bees use additional active heating. In cases of a sharp drop in temperature, the bees immediately use urgent heating. After restoring the temperature balance, this type of heating stops and the bees go over to more economical forms of heating.
Let's consider the examples of our observations, which we believe, confirms our ideas...

Recently, we conducted an experiment on cooling the nest of hibernating bees with the fixation of changes in the background signals in the hive. The results were very interesting. At the outside temperature of -15C , we received data, possibly confirming our hypothesis about the "conditioning" of the hive, that is, the use of ventilation of lowest force, in order to improve the heat removal from the bee's body in emergency moments of severe cooling of the nest ...

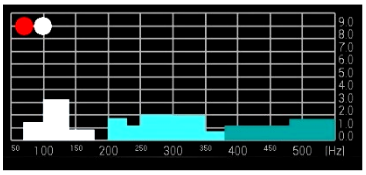
We assumed that in addition to heating, which is usually silent, heating with the performance of flapping of the wings can be used by the bees. This reduces the resonant frequency of vibration of muscles of thorax of the bee, but adds improved heat removal and provides forced convection.

When we removed the warming pillow and left only a thin fabric, separating the upper part of wintering bees cluster from the street and made measurements, we saw how the signals characteristic for various jobs in the warm nest began to change, and turned into signals of the lowest frequencies ventilation, and thorax vibrations which in sum provide the best heating and convection of warm air.

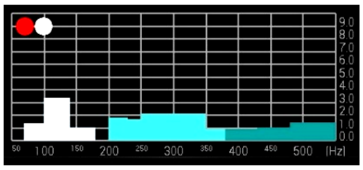
When the pillow was returned, after 20-30 minutes, the signals changed again, and began to correspond to the performance of in-hive works and feeding... We managed to simulate this situation two times in a row. The predominant signals were - heating and convection.



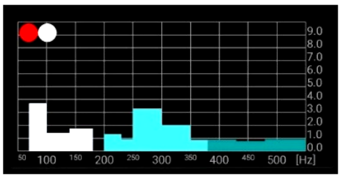
The hive roof is removed. Bees are disturbed.



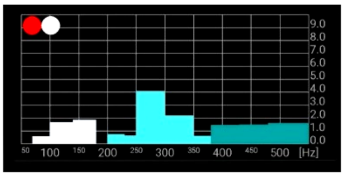
Bees feel cold. Appeares slight active heating.



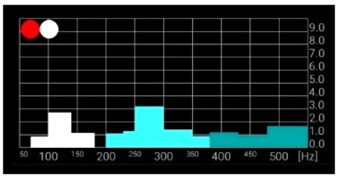
Bees enhance active heating .



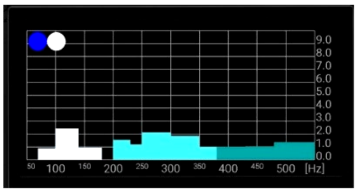
The warming pillow was deletted from the hive. Outdoors temperature -15C. Bees begin to freeze. Bees starts active heating, using the type which we named "conditioning".

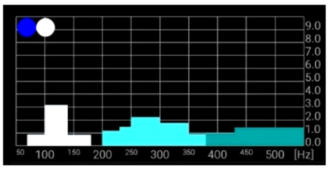


Pillow was returned. It become a little warmer for bees. Active heating become weaker.



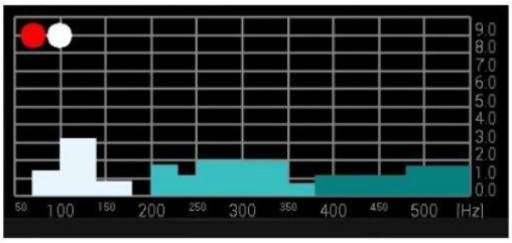
The bees calmed down a bit. Active heating still exists.



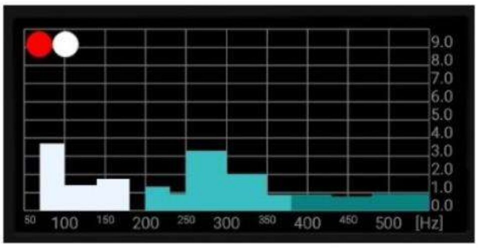


In spite of the fact that the bees become calmer, they are continue active heating, using both methods - active heating without flapping the wings, and heating with the use the wings - creating by them, a slight extra blowing..

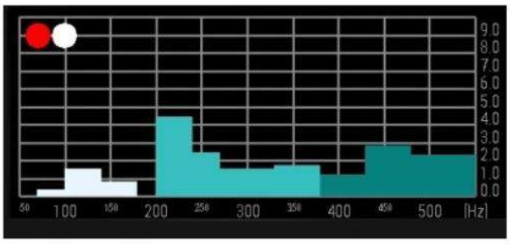
Further research conducted using our archives, showed, that this situation is not unique. The same signals were recorded in the summer in a very specific situation. This once again confirms the immutability of the principle of life support in bees, and its independence from the season of the year.



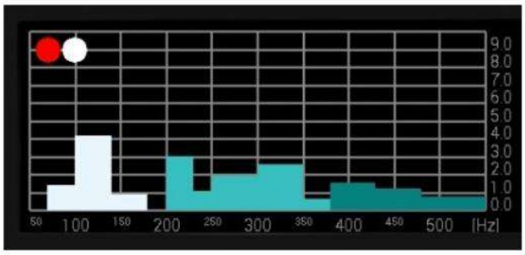
Winter. Bees felt cold after the opening of the hive . Outdoors temperature is -15C.



Winter. In the hive was deleted warming pillow, and the bees got a contact with cold air. They started the process of heating, which we named urgent heating



Summer. The hive #3. Sealed brood and queen cells. Active heating of the hive.



Summer. The hive #5. Sealed brood and queen cells. Possible lack of bees for simple heating. Active heating of the hive. This kind of heating process we named urgent heating

...

The appearance of the signals, was absolutely similar to our winter urgent heating, but was recorded in June, in the family, in which there was sealed brood and queen cells. And we already expected a close exit of the first queens. It should be noted, that at this time, in June, it was pretty cool. The bees in the hive were less than they needed, because these families, in which we were waiting for the queens, were practically divided in half. Thus, the number and age composition of bees in these families did not allow them to use passive or active heating. And the bees used the most efficient method of heating - heating with convection or as we called this effect - "urgent heating with convection".

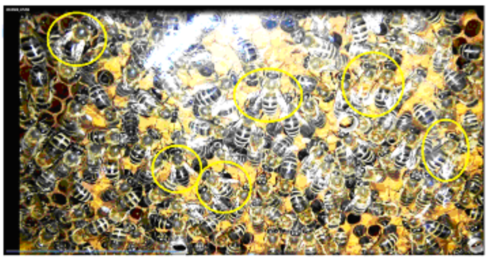
As another confirmation, can serve an experiment, in which was used our observation hive, which we moved from sunny outdoors place to the cold room. In this situation, when the bees placed on the frame with sealed brood felt cold, they shifted from the passive state to active ... At first, they made attempt to retain heat, and then they shifted to active heating and urgent active heating. Here you can consistently see all the phases we talked about. And in the last phase, it seems to us, we can see the signals of both types of heating - of active heating and of urgent heating with convection.

Yes, unfortunately everything is not so simple. We do not yet know, whether there is a combined mode, when a bee can vibrate warming the chest, and at the same time, to blow on itself using her wings. Apparently, since the same muscles are involved in both modes, the bees cannot perform two types of work at the same time. But they can do it in turn! After all, the vibro-acoustic signals which were recorded by the scientists, were lasting for about 0.2 seconds or less. This means, that for our eyes, a periodic change of heating process to flapping by the wings, will be not noticeable... But the device, based on the Fourier algorithms, will record two chains of pulses with different frequencies of the fundamental tone - one will correspond to the heating with the use of vibration of the thorax, the second will be created by heating with the help of wings flapping ! The possibility of this, we have to find out in our further researches.

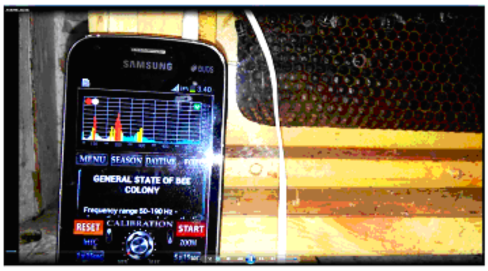
19-51 Immediately from apiary... We place the hive in cold room. All bees with folded wings. It's quite warmly inside our observation hive ...

20-23 We can see the bee flapping her wings... she is heating and aerating the brood. This is the third level of heating. When the bee generate more heat and use convection to move it to needed places...

19-57 We can see bees with slightly spread wings are already working - they heat the brood. The wings are in a position of mechanical fixation, allowing the thorax muscles to vibrate, producing heat, without flapping of the wings... This is the second level of heating.

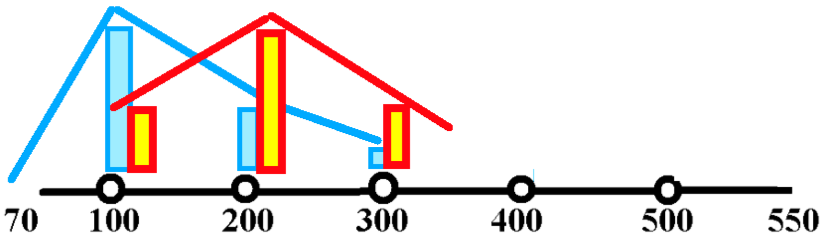


20-23 And as a result, we have the opportunity to observe the appearance of vibro-acoustic signal that we are expecting. By the way, the location of the harmonics around the frequency of the fundamental tone says, that despite the low frequency, this signal is created most likely not by the bee's wings, but by the vibration of thorax of the bee...



There is another possibility that is much more prosaic. It is possible that in this situation we hear a few bees doing the work on heating the brood. But one of them use "active heating", and the others have already switched to "urgent heating", considering, it seems, that it is better to overdo, than to freeze sealed brood.

it seems to us, that on the diagram it should look like this:



Экстренный конвекционный обогрев с основным тоном в районе 100 герц и активный обогрев за счет вибрации торакса пчелы с основным тоном в районе 200 герц.

And only Apivox algorithms, after processing the signals for a long period of time, will determine the priorities in this mix of signals, and will give diagnosis about the state of bees, in correspondence with the average situation for the selected time interval.

Thus, we can once again state the presence of four modes of thermoregulation in bees.

- Performance of every-day in-hive works, leading to heat generation due to metabolic processes, and further heat preservation due to thermal insulation and creation of clusters.

- Passive heating with virtually no any vibration of the thorax, but with the heating of the bee's chest.

- Active heating with powerful vibration of thorax and creation of vibro-acoustic signals in the low frequency zone of the working range, without the participation of the wings, which are fixed in slightly open position.

- Urgent heating with the work of the muscles of the thorax in resonance mode, similar to ventilation, but in which the wings operate at extremely low frequency, which leads to the development of the maximum amount of heat, and creating a weak air flow, providing improved removal of heat from the body of the bee, and spreading it inside the hive.

REAL COMMUNICATIONAL AND MARKER SIGNALS OF THE BEES.

Communicational signals ... this group of vibro-acoustical signals is well known, because for a long time it was the object of researces of American scientists. They call this group "Piping" or "singing" signals. They are emitted both by worker bees, and queen bees.

- Bees in different situations emit a lot of different signals. There were recorded at least 8 types of signals emitted by different bees in different situations. But all of them have one peculiarity - practically all of them are situted in one, very narrow frequency diapazon.

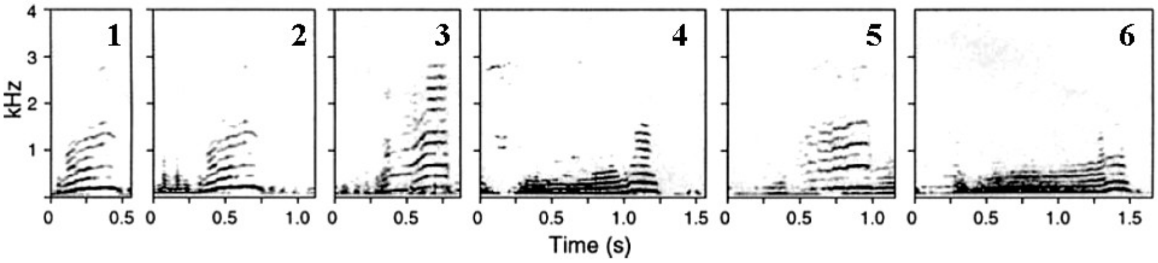
This is the frequency range between 200Hz and 500 Hz. Moreover, variations in the frequency of each "piping" signal, which scientists have fixated at different times, could be up to 100Hz. And the ranges of different "piping" signals overlap very much.

So how can bees encode and transmit information using these signals? The studies of the structure of these signals of bees were not conducted, or were conducted very superficially, therefore our "statements" today much more like a "hypothesis".

So, let us remember our Creator again ... If the principles of functioning of all living beings are close, then we can assume that the so-called "formants" can be used as a carrier of information in the sound signals of bees, as well as in the sounds of human language. Formants are the set of pitch and specific harmonic signals that uniquely characterize a particular sound. Each vowel sound of our language can be described by three or four main formants. They define the understanding of sound. The rest of the harmonics only give a "color" to the sound. The bees' signals can also be arranged in the same manner. The only thing we do not expect to see - is that the sounds emitted by the bees will form words ....

Consider an example of spectra ... Here we see the signals that the worker bees were making before the swarm left its place. (Worker piping in honey and preparing for a liftoff. Thomas D. Seeley, Jurgen Tautz).

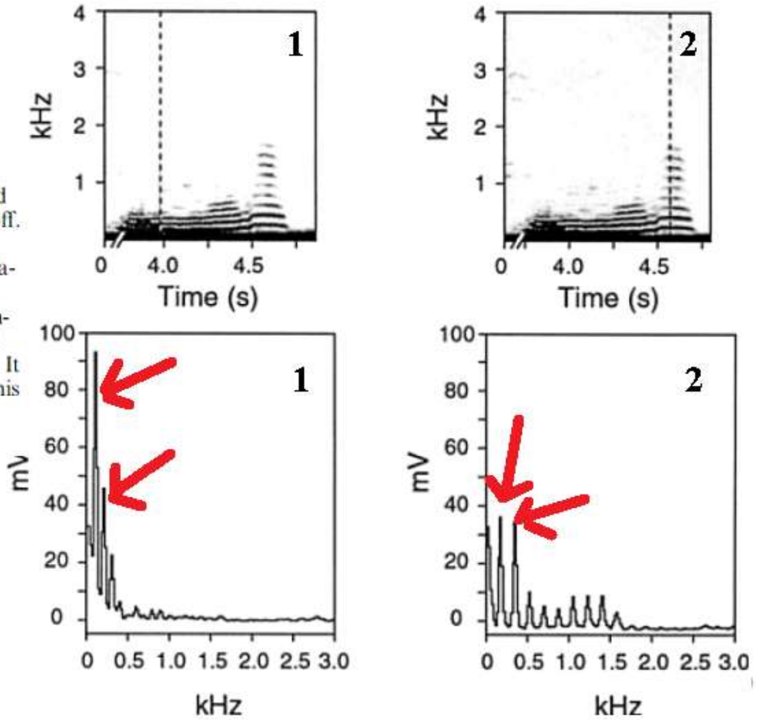
Fig. 4 Sonagrams of six piping signals recorded from workers in a swarm shortly before liftoff



The spectra show the main frequency components of the signals emitted by the bees. Moreover! It can almost be said with confidence, that the bees emitted various types of the signals - there is a group of signals with a time-varying tonality (1,2,5), and there are signals that can be considered consisting of 2-3 sounds (3,4 , 6) of different tonality, and possibly, having in their composition different formants.

This assumption is seen especially clearly in the following figure. The sonogram and local spectrum diagrams taken in different phases of the signal, emitted by the worker bee before the swarm leave, show the presence of different formants in the signal, consisting, as we said, of two different sounds.

Fig. 5 Spectrograms for the early and late phases of a typical piping signal produced in a swarm shortly before liftoff. Notice the rise in the fundamental frequency and, simultaneously, the striking appearance of numerous high-frequency harmonics, toward the end of this pulse of sound. It is these harmonics that give this signal its characteristic high-pitched sound



..

One more example of single-tone and two-tone signals can be seen in the following diagram. (Worker piping in honey bears and preparing for a liftoff. Thomas D. Seeley, Jurgen Tautz)

The first two signals (a, b) belong to the worker bees that dance tremble dance, summoning up bees - nectar receivers. The other two signals (c, d) belong to the worker bees on the surface of the swarm, just before the swarm leave.

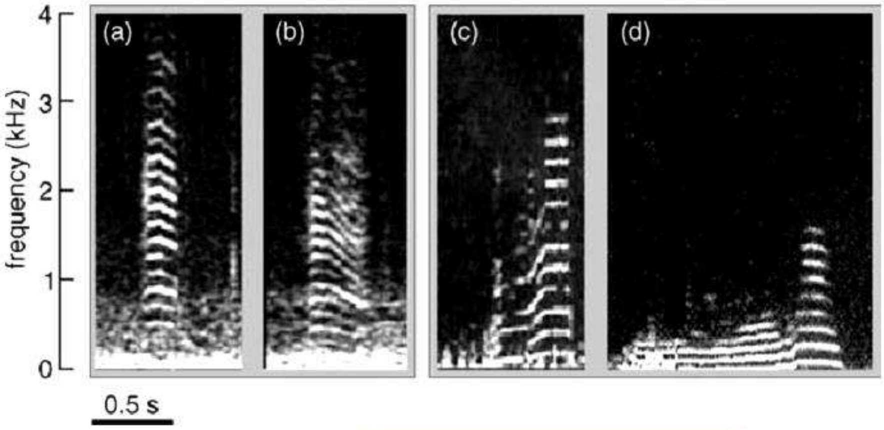
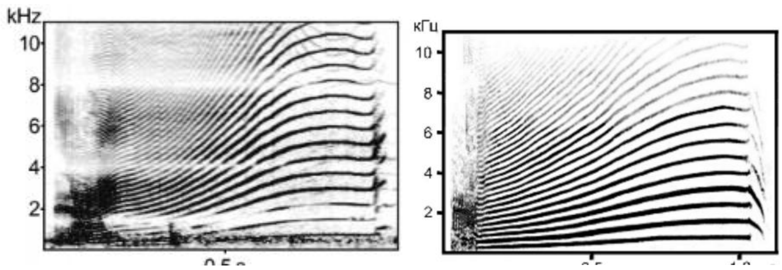


FIGURE 32.5 Worker piping in honeybees. (a, b) Sonograms of two piping signals emitted by tremble dancing nectar foragers showing the frequency modulation during the piping. (After Thom, C., Gilley, D. C., and Tautz, J. Behav. Ecol. Sociobiol., 53, 199 – 205, 2003. With permission.) (c, d) Sonograms of two piping signals recorded from workers in a swarm shortly before lift-off. Note the rise in fundamental frequency and the appearance of numerous high frequency harmonics towards the end of each piping pulse. (After Seeley, T. D. and Tautz, J. J. Comp. Physiol. A, 187, 667 – 676, 2001. With permission.)

On the basis of these diagrams, it is possible to unambiguously state, that these signals have different construction, and different components in their composition.

So, it can be argued, that the real communicational signals of bees are the short signals of different tonality, individually or in their combination, transmitting the simplest information about an event, condition or need of a bee emitting them. Their main task is to attract attention, and convey a description of the state or event, to which they attract the attention of other bees.

It is important to note, that today in bioacoustics exists a serious misconception, that does not allow scientists to begin the study of the sounds of animals seriously. The error is the misuse of the spectral diagram itself. Using it in the form of a sonogram leads to the fact, that so-called "envelope" picture of the distribution of the frequency bars of the diagram over time, or the "frequency contour", is perceived by biologists as an acoustic signal itself. But it is not a signal ... It is only graph... And this misunderstanding, became the basis of wrong by itself conception - "... categorization of frequency contours ...." , which is mentioned in almost all bioacoustic researches ...



For better understanding of the situation, we will give an example ... In the figure, you see rather simple signals with varying tonality. Do we see a change of information here? Most likely - no. In all animals, intonational changes carry only additional information about the state and the mood, whether this information is interrogative or affirmative, a threat or complaint ... This shows how much additional information may contain intonation, or a change in the frequency contour of a signal over time. But this changes does not affect the transmitted information itself. By pronouncing the sound "a" we can convey it as a question, as a statement, as neglect, as an understanding ... and all this - is one sound ... by the way, for us, not carrying any meaningful information at all !!!

Difference in duration of the signal, and its frequency modulation, can only carry a purely technical function. Extended sounds, and pitch-modulated sounds, are better heard from afar, they stand out better in monotonous noise ... No matter how long we will sing , for example, the sound "a", and how much we will modulate the tonality in which we sing, we would learn nothing new about about the content of "song". But despite everything, we will still understand, that this is "a", and not something else ... The only thing, which we will know, if we will analyze this "singing", is the capabilities of the vocal apparatus of the one, who emits this "song" ...

This once again remind us of the need, to use very cautiously modern technologies, and methods of mathematical processing. In order to use them, you need to understand previously, what you are exploring, and what results you are expecting to get... Otherwise, you will accumulate only digital garbage that nobody can understand and use.

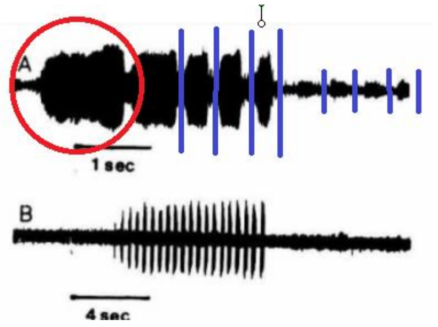
So, what does all this mean for us - researchers of vibro-acoustical signals of bees .... This means that in future, it is quite possible to analyze the "vocabulary" of bees, and then, to make a register, and to define the structure, of communication vibro-acoustic signals for further use in diagnostics of the state, and, possibly, in controlling the behavior of bees. But this is a question of our future researches ....

So let's take a closer look at all the types of communicational vibro-acoustical signals, which are known for today...

QUEEN "PIPING" OR "SINGING"

- One signal seems to be very important for many people... This signal is the " singing " of the queens... But we think it bears within itself very simple information ... The singing of old queen before leaving the hive, speaks young queens not to show up to her eyes, until she is gone, otherwise they will die... and they are clearly understand this ! Without any doubt, this signal is tonal. Because of its nature, it is also called "queen singing".

- "Singing" of young queens... this is the simplest challenge to battle ... Queens answer the challenge, and rush to understand who will remain the only female bee in this community...There is no other task or other sense in this signal...



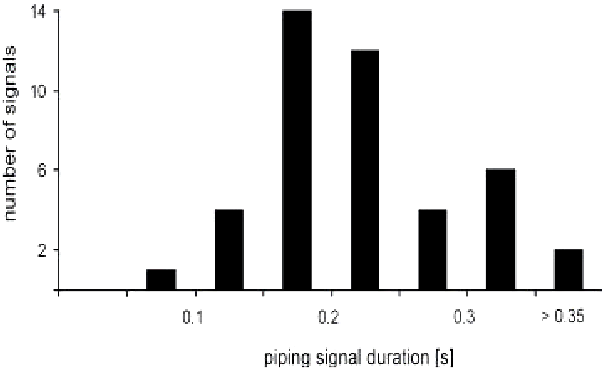
These signals are partially tonal, like all, it seems, communication signals. At the beginning you can see tonal pulse, then, it pass into a series of marker pulses. And although the basic frequencies of both signals are very close, their different construction in terms of tonality and temporal sequence, allows them to be perfectly distinguished.

On the basis of their construction and tonality, you can easily understand, who emit each of these signals, and to whom each of them is intended... This signal was also recorded by American scientists and subjected to analysis. Let's analyze it too ...

In the figure marked with the letter A) you can see the signal of singing of young swarming queen, which just came out of the queen cell, and became for some time the hostess of the hive... As you can see, its structure can be well explained by our theory... At first is emitted tonal signal, which goal is to attract attention, and then a series of pulses, which is marker for the young queen, or marker of her current state...

The second signal with the letter B) belongs to the queen, which is still located in the capped queen cell. So, she answers the first queen. The signal is not accompanied by a communicative impulse, but contains a marker of the young queen which haven't escaped from the queen cell, yet. Apparently, in the case of an immediate response, it is not needed to transmit a communicative signal, the only appointment of which, is to attract attention. We think, this is because the answer is expected by those to whom it is intended.

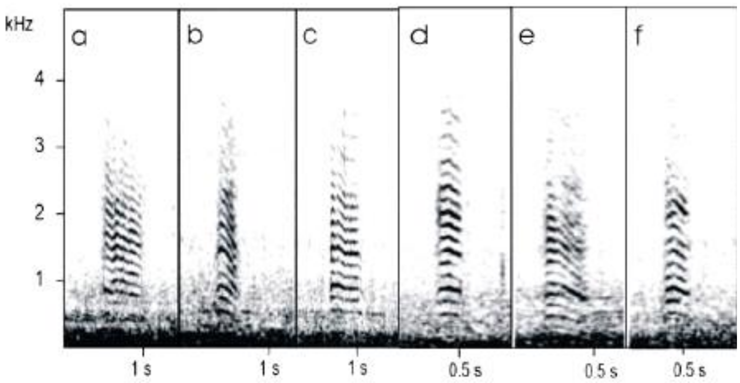
WORKER BEES PIPING, OR "SINGING"



Signals of worker bees are more diverse and are more frequent in the hive, than signals of queens. Here, there are signals that are clearly tonal, signals with a limited change in tonality, and signals consisting of pulse sequences.

The exact temporal and tonal structure of these signals still poorly studied. There were recorded signals of 270, 380, 540 Hz ... That means, that the range of this signals is very wide. And still there is no accurate and reliable data about principles of usage, and about meaning of all these signals.

The signals of worker bees are rather short. Most of the recorded signals had duration of about 0.2 seconds.



As we wrote a little bit earlier, almost all the signals of "singing" of worker bees are tonal and modulated in its pitch. As an example, you can see the spectra, obtained by German scientists for the signals of "singing" (piping) of foragers. (Dynamics and Communication Structures of Nectar Foraging in Honey bees (Apis mellifera) Dissertation zur Erlangung des naturwissenschaftlichen Doktorgrades der Bayerischen Julius-Maximilians -Universität Würzburg)

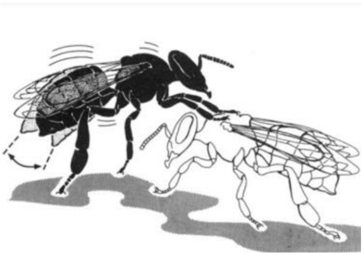
Their observations show, that most of the signals have a rise of tonality in the first quarter of the signal, and a steady decrease in tonality in the rest of the signal. The basic frequency of the main tone was not defined with high reliability, due to the strong background noise in the hive.

Foragers piping can be frequent or rare. The number of "songs" of foragers was fixated in the quantity from 0 to 9.8 songs per minute. But on average, about 4 songs per minute. Since the singing of foragers is unambiguously tied to the course of the daytime honey collection, their appearance and number, is unambiguously connected with the course of the honey collection, and with the number of dances of the forager bees.

The majority of these short signals or "songs", about 99%, are issued by those foragers who then dance the "tremble" dance. But not everyone who dances this dance "sings". Only 48% of the dancers issue piping signals ... This may mean, that the dance by itself, and "singing" by itself, have similar, but different in principle, tasks.

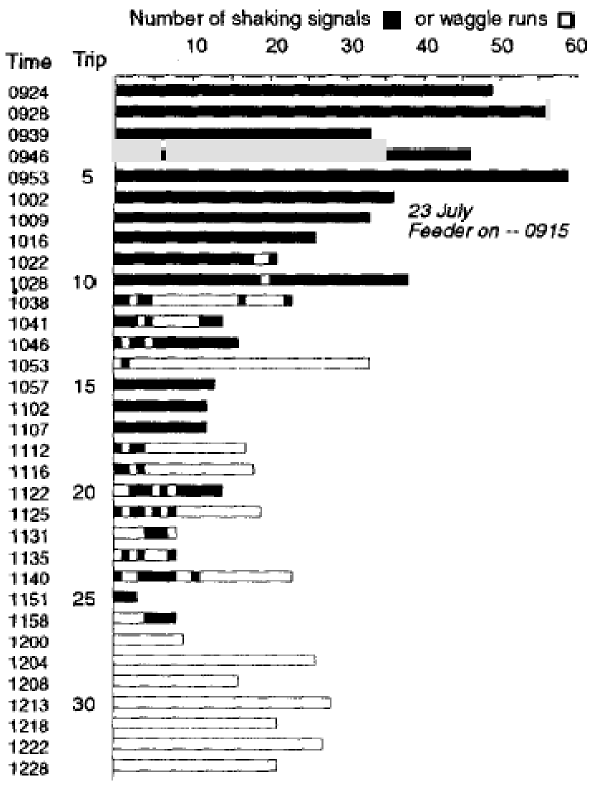
So, let's now consider all kinds of signals emitted by worker bees ...

SIGNALS OF FORAGERS, RETURNING TO THE HIVE AT THE BEGINNING OF THE DAY, WHO ESSENTIALLY MADE A JOB OF SCOUTS



Let's have a look at another situation, known to everyone - the bee comes up to another bee, puts paws on it, and performs a series of vibrations with abdomen, at a frequency of about 16 hertz. This is the most famous, and visible communicative signal in the community of bees. (The Shaking Signal of the Honey Bee Informs Workers to Prepare for Greater Activity Thomas D. SEELEY, Section of Neurobiology and Behavior, Cornell University, Ithaca, N.Y. 14853, USA)

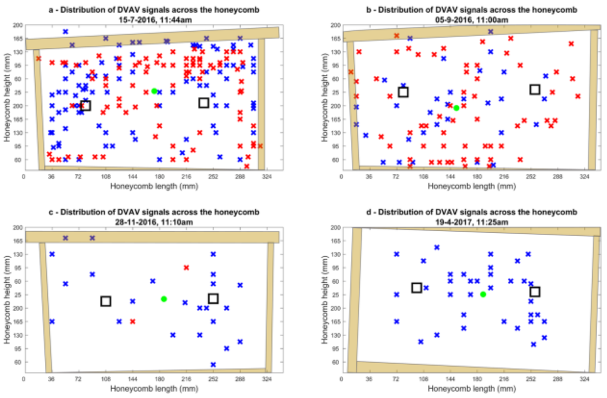
The bees - foragers, which arrived from their first successful flights do not immediately begin their dance of one kind or another, but at first, they move along the hive emitting vibration signals known as "shaking signals" (or dorso-ventral abdominal vibration -DVAV), which serves as an alarm-clock, waking up "passive bees" which should become new foragers. Depending on air temperature, it take about 1-2 to 30 minutes for these bees to warm up to the temperature, allowing them to work actively.



 This occurs at the beginning of the day, when the flow of foragers is not yet great. The first 5-10 flights ends with emittance of this vibration signal with a frequency of 16-22 Hz.

And only many times having ascertained the quantity and the quantity of nectar in a the place, which they found, and awakened passive bees, foragers begin their "waggle" or "tremble" dances. (The Shaking Signal of the Honey Bee Informs Workers to Prepare for Greater Activity THOMADS . SEELEY and others)

These bees emit signals almost evenly, over the entire area of the combs, apparently, trying to



bring information about the beginning of honey harvest to almost all, able to work, bees in the hive, wherever they are placed.

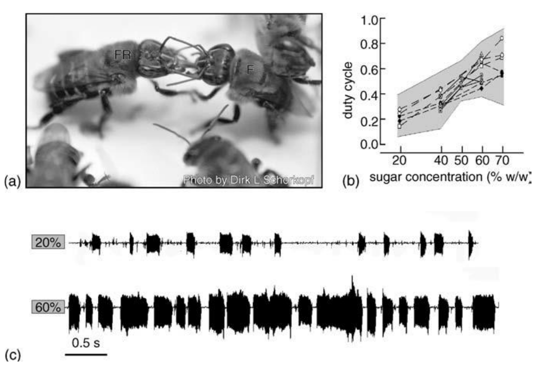
Thus, after emittanse of these signals by the growing amount of scouts, gradualy grows the number of foragers and receivers, which previously were "passive", and the life in the hive is activated as a whole.

Exists other variations of this signal, also emitted by the bees moving along the frames. They were called "buzz of running bees" (buzz running). Their meaning has not yet been understood by scientists. These signals can be considered as communicational, because their task is to reach someone's hearing, and activate attention on a specific problem.

SIGNALS OF FORAGERS, ARRIVING WITH HONEY AND CONFIDENT IN THE USEFULNESS OF THE SOURCE OF NECTAR WHICH THEY FOUND

- Bees foragers, arriving with nectar, produce a vibro-acoustic signal in the range of about 265 hertz. It is this frequency range, that can be better captured by the sensory elements in the legs and antennas of the bee. But none of the bees use this frequency, as the sub-carrier frequency in the apparatus with amplitude modulation. They do not encrypt information in the duration and intervals between signals. In any case, no scientist could say so. And this is true, because communicative vibration-acoustic signals, are just a means of attracting attention ... Forager emit these signals, in order to invite "receivers" to pay attention to him, and to do what they are waiting for, here - to take and then to process nectar brought by him... because that's why they are here. And they do not need any explanations, what is required of them - they already know it, exactly for this, they went downwards, stood up facing to the porch, and waited... It's enough just "to slap them on the shoulder", saying "here am I "...

SIGNALS OF FORAGERS DURING UNLOADING



If the nectar receivers meet the bee immediately after arrival, and start unloading, then in the process of unloading, the bee emits signals, intended for the receivers and future recruits, and which are uniquely related with the quality (sweetness) of brought nectar. The sweeter the nectar, the stronger and more frequent impulses, emitted by the bee in the process of unloading.

This signal (train of impulses) can, in principle, be considered as the quality marker of brought nectar.

SIGNALS OF FORAGERS AFTER UNLOADING, IN THE PROCESS OF "WAGGLE" DANCE

When unloading is finished, the foragers begin their dances. And again we can see almost the same train of almost identical impulses - marker signals, starting and ending with communicational signals. Within the series, all signals are of the same type and follow at practically the same interval. All the bees around, who see dancing forager, and who "hear" the message, will understand, without any doubts, what she wanted to say ....

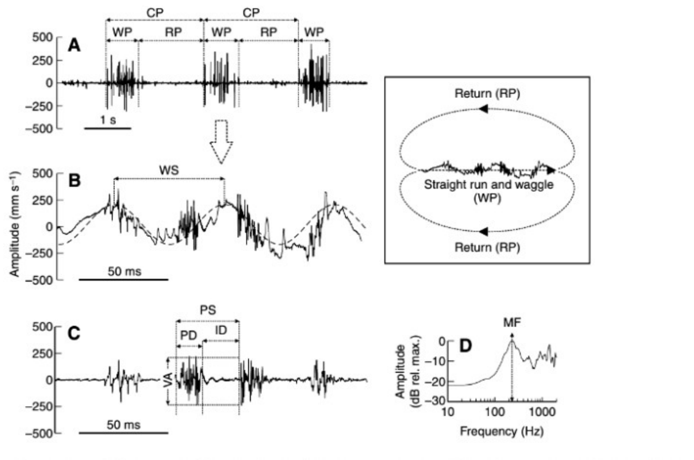
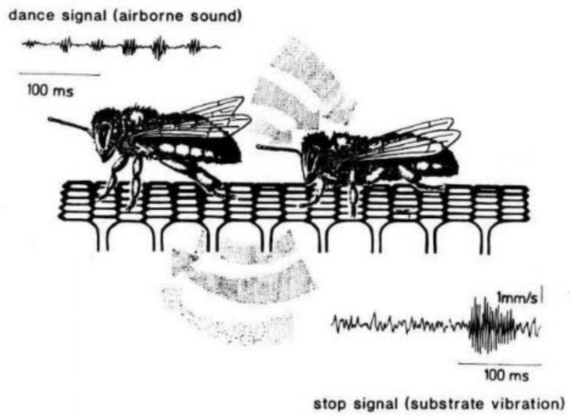


Fig. 1. The honey bees' waggle dance. (A) A dance cycle (CP, cycle phase) is divided into a waggle phase (WP) and a return phase (RP), during which the forager circles back to the starting point of the waggle run (inset). During the waggle phase, foragers often generate thoracic vibrations ('dance sounds'). Thus WP can be separated into two main mechanical components: (B) the waggle movement itself (emphasised by dashed line; WS, waggle sequence), and (C) the pulsed thoracic vibrations (frequencies <20 Hz filtered out digitally for better visualisation). PD, duration of a single pulse; VA, velocity amplitude (peak to peak, p–p) of a vibratory pulse; ID, duration of the interval between two subsequent pulses; PS, pulse sequence (PD+ID). (D) Frequency spectrum of a vibratory pulse indicating the main frequency (MF=0 dB).

But now she "talk" with the future foragers - with "recruits". She tell them about the direction of flight to the source of nectar, and with the help of vibro-acoustical signals, about the quality of nectar. The higher it is, the more powerful and frequent the forager's signals are, attracting more “spectators” and thus, increasing their chances of being heard by future "recruits". The more chances the family will have to get high-quality honey, the less power it will be required its for subsequent processing.

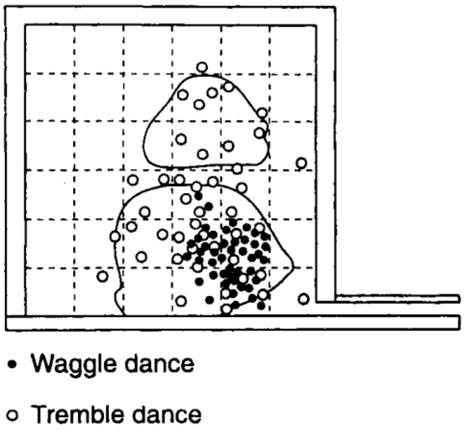
As you can see, this signal serves for potential recruits, as a marker of the perspectivity of flight for nectar, coordinates of which source were indicated in the process of forager's waggle dance.

THE SIGNAL OF RECRUITS, OR "STOP SIGNAL"

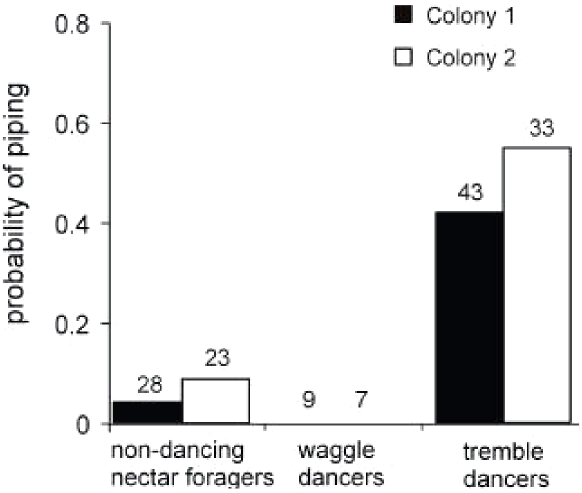


The forager bees in the dance emit a vibro-acoustical signal - saying "pay attention to me ! I want to tell you something important ! " ... The recruit responds with vibrational signal - "I heard you, and understand you...", or the so-called "stop signal". The signal, after which the forager bee, as a rule, ends its dance. That's all the information which is transmitted using these two vibro-acoustical signals ... and besides this, thermal vision of the bee allows her to see in the darkness of the hive, the waggle dance pattern, and its direction... No more communications are needed to understand the task. This signal is rather short too, and its structure was not verified yet by the scientists.

THE SIGNALS OF FORAGERS, WHICH COULD NOT WAIT FOR UNLOADING



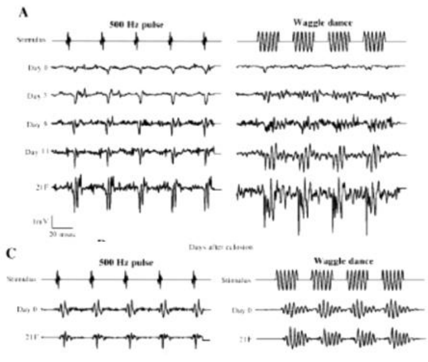
Forager bees, who were not unloaded immediately within the first 40 seconds after arrival, run inside the hive, performing "tremble dance", a dance, which calls new receivers of nectar. Sometimes, there were fixated dozens of bees, performing such a dance on the combs. After this, the number of bees - receivers of nectar, increased dramatically. (Thomas D. Seeley · Susanne Kühnholz Anja Weidenmüller The honey bee's tremble dance stimulates additional bees to function as nectar receivers)



This dance is called "tremble" dance, and the structure of this signal should be a little bit like tonal single, which is called worker bees piping. But exact parameters of this vibro-acoustical signal, produced by the foragers, are not known yet. It is known, that themost of the signals of "singing" of worker bees are performed by those bees, who perform the "tremble" dance.

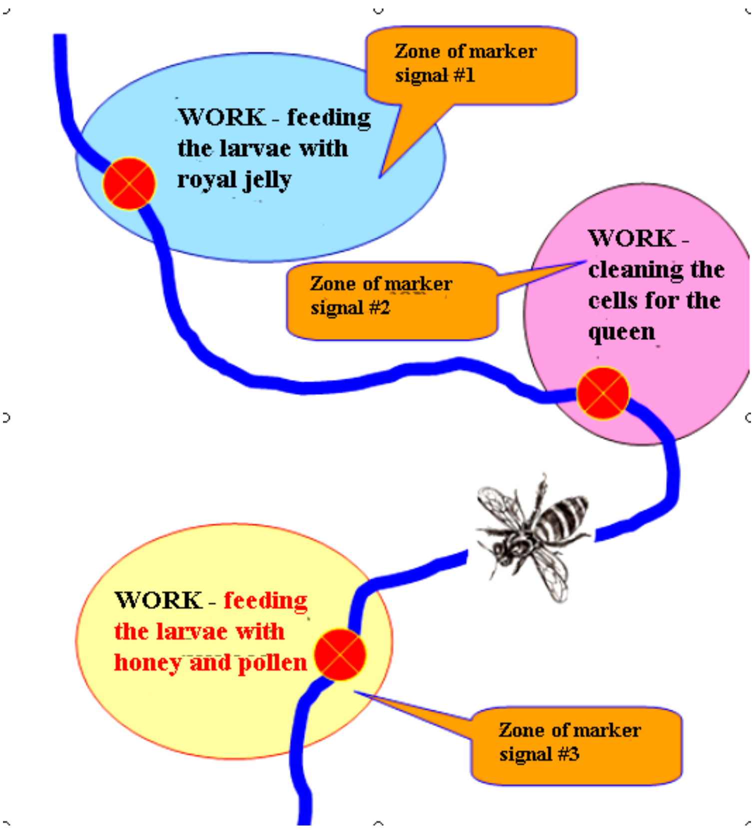
MARKER SIGNALS

Marker signals are not so noticeable. Well known for today signals of forager bees that can be attributed as "marker signals", are signals, issued by them in the process of unloading and waggle dance. They show the stage of unloading process, and the quality of nectar, brought by the bee. And their appearance depends on the quality of nectar which was found by forager.



As a rule, these signals looks like the sequences of pulses of different duration. Moreover, the amplitude and duration of each pulse in the sequence, depends on the quality of nectar, found by the bee. As an example, you can see on the picture, the signals emitted by the bee while unloading nectar, fixated during special experiment, at a concentration of sugar syrup in a feeder 20% and 50%.

PRINCIPLES OF USING VIBRO-ACOUSTIC MARKER AND COMMUNICATIONAL SIGNALS IN THE PROCESS OF BEES LIFE, IN PARTICULAR DURING THE SELECTION OF WORK IN THE HIVE.



The first variant. Self-dependent selection of work by the active bee. Let's suppose, that a bee of the age of about 5 days, moves along the hive. Its own marker is set in the "position" - "free", or it does not emitted in principle. The bee falls into the zone of action, of vibro-acoustical marker signals of the group of bees No. 1, engaged in feeding the larvae with royal jelly. Her internal program verifies the possibility of joining this cluster ... she analyzes the correspondence of work to the her age... The answer is "no", this work can not be performed yet. It's too early. Her glands are not matured yet

The bee continues her movement... and falls into the zone of action of vibro-acoustical marker of the group of bees number 2. This marker determines the work of the bees on cleaning the cells for laying eggs by the queen. Her internal program analyze situation. The answer is "no". The bee has already left this age range.

The bee continues her movement ... and falls into the zone of action of vibro-acoustical markers of the group of bees number 3. They are engaged in feeding the larvae with honey and pollen. The internal program of the bee analyze situation... The analysis shows, that according to the age of bee, this work is quite suitable for her. The bee joins the cluster...

Here we want to give our own example, as it seems to us, of a similar situation ...

It is much easier to observe the bees on the landing board than in the depth of the hive. A good honey harvest gives an opportunity to see the work on drying honey right here.

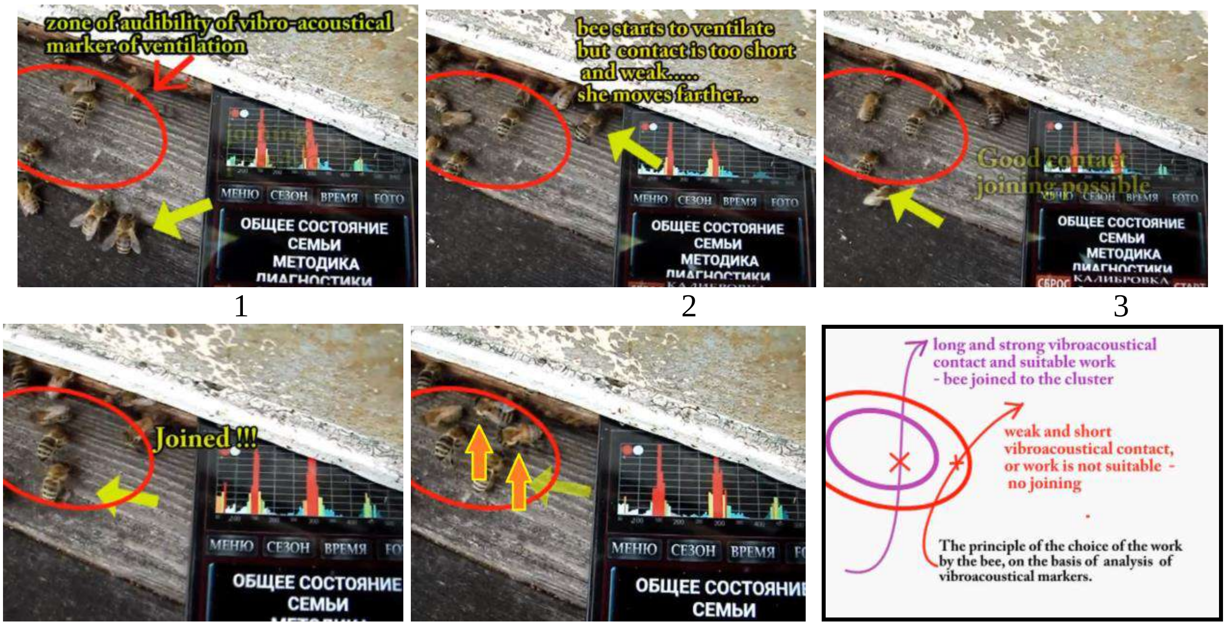
So, we are considering the situation now, when on landing board of the hive, two bees perform a job on removing moisture from the hive. Their work, as we see on the screen of Apivox Smart Monitor, creates a set of vibro-acoustical signals.

One bee moves in the direction of the depth of the hive (1)... she falls into the coverage zone of the vibro-acoustical marker of ventilating bees... She stops for a while, her wings involuntarily begin to perform movements as if she starts ventilating the hive .... but apparently, either the marker signal was too weak, or the contact was too short, but she stopped movements of the wings (2) and went further, completely leaving the coverage zone of marker signal.

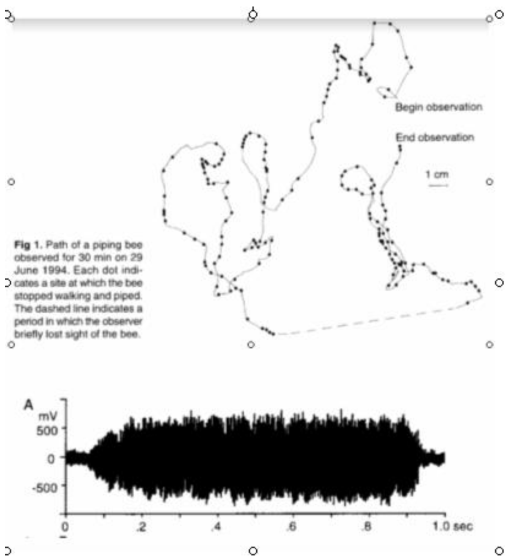
The second bee (3) moves closer to the center of the marker coverage zone and gets almost to its center. She immediately begin to work on ventilation of the hive (4), moving slightly to the right, and by this, widening the coverage zone of marker signal.

Almost in the porch itself, are visible two bees, which apparently, also felt the presence of a marker signal (5), but after analyzing it, which is evident from their indecisive behavior, they did not go deeper into the zone of action of marker signal of the hive ventilation...

In the diagram, we depicted the possible dependence of the probability of joining of the bee to the cluster, from the place and duration of contact (6).



In addition, it was clearly visible the moment of analyzing the possibility of joining the cluster by two bees (5). It remains not clear why the first bee did not join the work, although it almost began to perform it involuntarily.



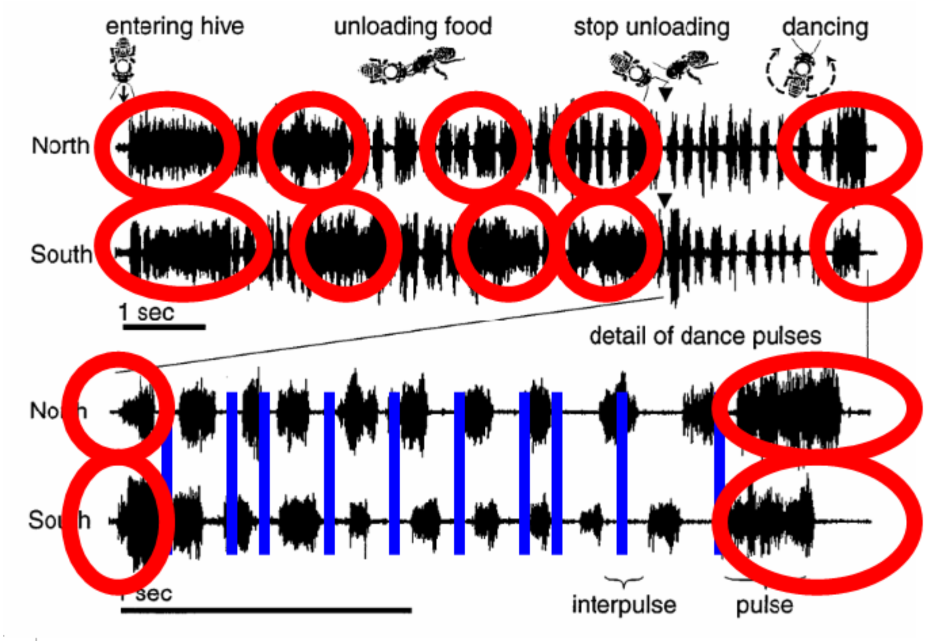
<u>The second variant. Selection of the work on the basis of notification of the need to participate in specific work.</u>

Here starts to work those vibro-acoustic signals, which we have called “true communication signals”. In this example we can see the signals, known as "worker piping", or signals issued by worker bees. Emitting this signal individual bees can run for hours on the frames, transmitting this signal from 15 to 30 times per second. Very similar to herald ! After these signals are sent, young bees, which were previously "passive", begins to come to life, and start joining the work.

(Worker piping associated with foraging in undisturbed queenright colonies of honey bees SC Pratt, S Kühnholz, TD Seeley, A Weidenmüller Section of Neurobiology and Behavior, Cornell University, Ithaca, NY 14853, USA (Received 11 January 1995; accepted 9 November 1995)).

Naturally, only those bees join the cluster, for which it is permissible from the point of view of their age restrictions. In this case, this is young bees at the age that allow them to work on receiving nectar from foragers.

The main characteristic of these signals is the duration of their emission - up to 2.5 hours, and the enormous distances, that herald bee runs through, spreading her "news".



Now let's proceed to the real example recorded by American scientists in the course of their experiments on the study of dance of bees and of signals, corresponding to them. (The food recruitment dance of stingless bee apis Melipona panamica Nieh1998)

Here we can see the whole complex of communicative and marker signals, produced by forager bees in the process of unloading. Exactly here you can see the use of tactics of calling other bees, to do specific work.

The figure shows the signals of two different bees - foragers, which flied to different feeders. Pay attention to the picture of how the bees unload nectar .... When the bee arrives, it emits a powerful monotonous signal, in order to attract the attention of the bees, which will take nectar for further processing. That is a communicative signal, which forces the bees which hear it, to take part in the work on unloading nectar. As soon as the process of unloading starts, communicative signal become weaker, turning into a series of marker signals, talking about the quality of brought nectar.

All this examples we consider to be a possible confirmation of our idea of the meaning, and of division into groups, of vibro-acoustical signals of bees. And what eventually, will we get useful for us as a beekeepers, if this theory is correct and can work ? This is the most important question for us!

The fact is, that knowing the main composition of the frequencies of the "hieroglyphs", characteristic for certain types of activities of bees, and realizing that the number these "hieroglyphs" should not be so big, we can understand the main trend of works inside the hive, if work exists in principle. This statement works well, when it is required the simultaneous participation in work of a large number of bees. In such situation, marker messages begin to create characteristic maxima on the spectral diagram, rising above the total mass of the "discordance" in the hive, consisting of communicational and marker messages of bees, occupied by different works. This statement is especially applicable to works on ventilation of hive, removal of moisture from nectar, aeration of brood, works on honey processing...

Highlighting these maximums in a certain ranges, and analyzing their combinations, we can diagnose the state of the family and the composition of the most massive works, performed by the bee family. This analysis is forming the basis of diagnostic messages that our device issue, after the finishing of the process of control of the sounds inside the hive.

Comparison of the quantity and strength of signals in different frequency ranges is laid down as a basis in the algorithms for determining of preparation of the family for swarming, and in analyzing of the readiness of the family for honey collection, and in algorithm of analyzing situations, related to the problems with the queen.

So, where, in what part of the hive, and when, the bees' signals are better heard ? Where from, we should make measurements, in order to get maximally reliable information about the family ...

THE PLACE AND THE TIME OF APPEARANCE OF VIBRO-ACOUSTIC SIGNALS DURING HONEY COLLECTION SEASON

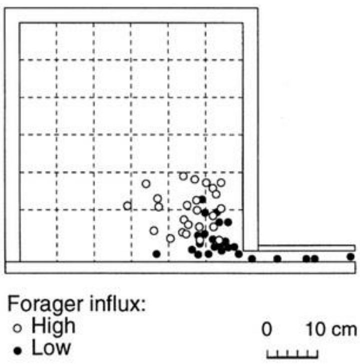
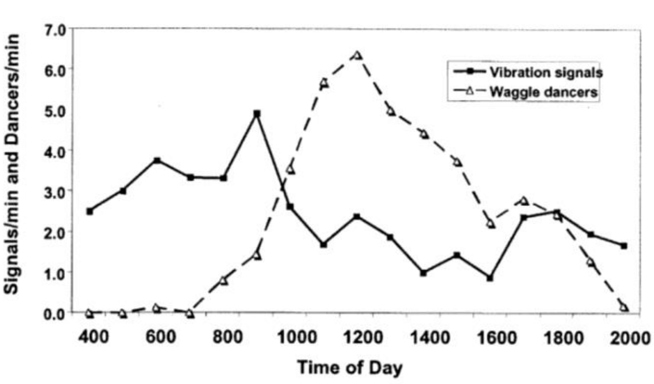


FIG. 5.—Comparison of the spatial distributions of nectar unloadings at times of high and low influx of nectar foragers. (After Seeley 1995.)

The main volume of communicative vibro-acoustic signals in summer, in the presence of honey collection activity, moves to the lower part of the combs, opposite the porch in so-called "logistics zone". The system of work of "logistics zone" extends to both ingredients brought by the bees to the beehive - honey and water. And in both cases, the system operates on the principle of a self-balancing system with feedback, based on the time interval during which the product was taken from forager. (Honey bee colonies are group-level adaptive units. Tomas Seeley. - Am Nat 97)

In addition to communicative signals, directly associated with the transmittance of nectar from forager to young bees which will process nectar and with dances of foragers, there is another group of communicative signals, which are especially pronounced at a peak moments when the bees radically change composition of their works. These signals scientists call modulating signals.

The appearance and amplification of these signals are often associated with events such as - a renewal or an increase in honey harvest after stopping or easing of it, contact with dancing foragers, changes in the needs of food products for a bee society, the new more powerful sources of nectar flow, seasonal changes in the honey-producing flora. (Stanley Schneider, Lee Lewis. The vibration signal, modulatory communication and the organization of labor in honey bees, Apis mellifera. Apidologie, Springer Verlag, 2004)



General signal level of the bee society varies during the day and has its own, highly pronounced rhythms related to honey collection. Small peaks of signals activity occur in the afternoon and often coincide with increased activity of waggle dances. Stronger peaks are observed early in the morning and may precede the onset of honey collection activity, for a few hours. Evening peak can also be quite large and its size directly related to the success of present day honey collection.

According to all, previously told, our main recommendation states:

- if you want to know the general status of the bee society, then it is the best to do it as close to the peak of flight activity of bees, as possible. As it is shown in the diagram, it is time from 11 to 14 hours. At this time, the work should be the of most intense as it is possible. Passive bees should be in the minimal amount. This time period, very well characterize today's honey harvest .

- If you want to know possible information about the previous day - was it a good honey harvest or bad, and whether there is a hope for the continuation of good honey harvest, then you can get the local information when measuring from 7 to 9 am. Of course, time of measurement depends on the weather. It can be determined experimentally for the region.

- Evening measurement during the time beginning from reduction and to the complete absence of flight activity from 16 to 19 hours, will give you a rough understanding of the results of the last working day. Local data that you get in this time, will determine the amount of supposed by the bees works for evening and night time.

- Night measurements, made from top of the frames with combs through the lap, taking into account the duration of the time interval which has elapsed since the termination of flights of bees, will help you to understand the volume of remained honey which is subject for further processing and storage. The longer busyness of the bees with intensive honey processing, the greater was their today's "prey".

DEVICE FOR ACOUSTIC MONITORING OF BEE FAMILIES - APIVOX SMART MONITOR

THE MAIN MODES.

So what the device for acoustic control of bee families is? The device Apivox Smart Monitor was a logical development and growth of the first device of this series - Apivox Auditor. New data and a new look at the processes, occurring in the bee family, gave impetus to improving the functionality of the device, which in its turn, made it possible to create a device with more possibilities.

The main task of the device remains unchanged - the operative control of the state of bee families at various moments of their life, in any situation, including in the absence of telephone communication and the Internet.

The basic modes of operation of the device have undergone a significant addition, allowing to learn even more about the state of bee family. Let's consider all these modes ...

Monitoring - in this mode device starts its work by default, after switching on. The purpose of this mode is to achieve correct settings of the device, allowing you to see the bees' signals qualitatively and confidently, in order to obtain correct results of further analysis of the family's state. The second function of this mode is to quickly monitor the current state of the family, using a bar chart, or long-term monitoring of signals in the form of a sonogram..

General State Control - is the basic mode of the device, which gives the most complete assessment of the family's condition, its working capacity on honey collection, possible problems with the queen, predicts the onset of a swarming condition, estimates the number of brood. All this can be done at two intervals of different lengths, with obtaining instantaneous, or more averaged information. The result of control in this mode is a text message describing the state of the family, and diagram for more advanced users.

Readiness to Accept New Queen - this mode is used for control of readiness of the bees' family to accept new queen after removing the old one. This mode allows you to find the best moment for introduction of new queen in the family after removal of old one. Everyone can see the first phase of the sensation of loss of the queen by the bees - anxiety and ventilation on the porch with open gland of Nasonov, but the second phase can be seen only by our device - when the bees realized that the queen will not return back, and are ready either to build queen cells, using open brood of worker bees, or to accept any queen. It is this exact moment will show our device in Readiness to Accept New Queen mode

New Queen Acceptance Control - this mode we use after removal of old queen and placement of new queen in the hive. This is essentially the continuation of the work of the previous mode. Its task, is to show how the process of acceptance of a new queen is going ... If the signals associated with the loss and recovery of the queen subsides, the anxiety disappears, and the family shifts to normal work, then apparently there is a tendency for the adoption of a new queen ... Otherwise, excitation is usually does not subside for a long time ....

Swarming Control mode - is a procedure, designed for quick assess of the state of bees' families, regarding to the readiness for swarming. As a rule, already the borderline state shown by the device, ensures that you will find swarming process at the stage of making of swarming queen-cups on peripheral frames of the nest. And this means that you can immediately take measures, so this family will not lose about two weeks of summer season, and you will not lose bees and honey.

Brood Control mode - is a procedure that allows you to see the trend in the state of the reproductive activity of the family. This control takes some time and is presented in graphical form for more clarity of the trend. The position of the graph, shows the approximate ratio between the amount of work on brood care, to the total volume of work in the family. This mode is designed to control families mainly in early spring and autumn.

Control of the Readiness of the family for Honey Harvest - this is a procedure that allows to see the tendency in the correlation of works on development and reproduction of bees' family, and works on collection and processing of marketable honey. The use of this mode will show you, whether the family is ready to produce marketable honey, or its flight activity will be aimed at meeting only own needs of the family. After all, good honey collection is possible only when in-hive works and honey collection activity are balanced.

INSTALLATION OF THE APP, AND THE FIRST STARTING

1) Save the received application in your archive.
2) Check settings of your smartphone
• Check that loading of external applications is enabled in the setting of smartphone.
• Check that the GPS geo location is enabled
• Verify that your smartphone is connected to your Google Account which you have specified in the order.
3) Download the application to your smartphone. Find it using file manager and execute it. When asked whether to install the application, answer in the affirmative. After downloading, you can launch the application.

When you start the program for the first time, the program may not start because of discrepancy between the data recorded in it, which you provided when ordering, with real ones. This is the result of the process of verification of your data.

- If at the start of the program you see an error with the code 1 - Then the smartphone which you use, does not have Google account, which you specified in order form.

- If at the start of the program you see an error with the code 2, and after it the number - Then the IMEI number or serial number of smartphone which you use now, does not correspond to the application. If the program is installed on the correct smartphone, then send us this number (better screenshot of error shield) and we will fix the program.

- If you see an error with code 3 - your location does not match the country you specified in order form.

In any case, If verification error occur, please contact us and we will solve the problem.

HIGH-QUALITY SET-UP OF MICROPHONES AND MONITORING OF ITS CORRECTNESS. OTHER SETTINGS AND FEATURES OF THE WORK.

INTERNAL AND WIRED MICROPHONES SET-UP.

After entering the Settings menu, start a phased configuration of your device settings.
Press the button MENU and go to the Main menu of the device. Here you have to do presets and settings in order to ensure the correct work of your device in future.
Press the " Mic. Selection" button. A new window will open where you can see the options of choosing an internal mic, wired mic or Bluetooth headset as a main microphone. The internal microphone of the smartphone is set by the default. It has the highest flexibility and allows you to start work almost immediately.
Select wired mic or internal mic. According to the type of mic you are going to set-up now.
Press the "Mic set-up" button, corresponding to selected mic. A new window will open where you can see the graphic equalizer and special buttons. Your task is to align the performance of your microphone as much as possible to eliminate distortions during the construction of the acoustic signal spectrum.
In order to do this, turn on the “White noise” signal (we have audio file with this signal on this page, or you've already received it together with the app) with maximally possible volume on the external source of the sound.
Now we have developed the function of automatic correction of the microphone characteristics. Turn your smartphone microphone to the sound source. Click the "Auto" button and after 10 seconds equalizer will be automatically installed in the correct position. Don't stop audio track. Look at the signal again. If you think that the setting is not successful, repeat it again.
Repeat it with all types of mics you have, and going to use.

After the setup procedure you must check correctness of your settings.

The correctness of settings can be checked :

while playing audio track of " white noise" -
1) In Monitoring mode on the uniformity of the "white noise" chart line across the entire width of the range.
2) In mode Swarming Control - right indicator. The arrow should be in the middle of the scale or at least in the yellow zone.
3) In mode Readiness to Accept new queen - left indicator. The arrow should be in the middle of the scale or at least in the yellow zone.
4) In mode Acceptance Control

Window 1 - both indicators. The arrow should be in the middle of the scale or at least in the yellow zone.
Window 2 - the central indicator. The arrow should be in the middle of the scale or at least in the yellow zone.

After this procedure, you can stop audio track of "white noise".

Manual correction of LF band:

If you do not have speakers with good quality in low frequencies, (normally, you don't have) and after automatic tuning you can see in the "Monitoring" mode in the complete absence of sounds, some bars at frequencies of 50-100 Hz, then you should do the following:
- Find the quietest room in the house where there is no extraneous noise
- Go there with smartphone, and close the door)))
- Connect the microphone and the corresponding setting.
- Enter the microphone equalizer adjustment mode.
- You have to see in full silence, 2-3 left columns of equalizer chart, raised. The number depends on the quality of your audio system. The worse it is, the more you will see the raised bars. Normally, you'll see 2-3.
- Align them so that they will be equal in height, to the other columns. To do this, use the sliders corresponding EQ bands. To make the adjustment more accurately move the slider "Scale" down. Scale will increase and you will be able to make the adjustment more accurately.

After these procedures your mics and app are ready to work !
If you do not have acoustic system or you do not have acoustic system of good quality, with characteristics of frequencies range not worse than 70(80) Hz-18000Hz or you are not sure that you can correctly make settings, then in principle, if you have a smartphone of sufficiently high quality, it is possible not to do set-up at all . At least you will not degrade the characteristics of your device. But with good equipment and skills, the settings are preferable. If you already made settings, but you think, that they are not so good, click the "All settings reset" button in the menu. This will return all settings to the original value.

BLUETOOTH HEADSET. THE ORDER OF SETTING AND THE RULES OF OPERATION

For smartphones with the Android operating system version up to 5 we have developed a beehives control program which can use Bluetooth headset. To work with it you need to:
• Turn Bluetooth mode on your smartphone to On.
• Turn On the headset.
• Search and connect the headset to your phone.
• If the headset is not compatible with your smartphone, then our program will not be able to operate it.

Further, our program can work with or without Bluetooth headset. If you want to set up Bluetooth headset, you must make the following :
• Turn on the headset and connect it to your phone.
• Insert it in the ear as it is necessary to control sounds and headset communications.
• enable APIVOX AUDITOR application.
• Enter Main menu by pressing the "Menu" button on the main screen.
• When the main menu appears, press "Mic. selection ". The unit will switch to the next menu level. Select "Bluetooth Headset". All control signals you will hear in the earphone of the headset.
• If you want to work with Bluetooth headset for the first time, then you must make settings. To do this, click "Mic. set-up". You will hear a sound signal and the equalizer settings window will be opened to give you opportunity to adjust the microphone settings. We strongly recommend you to make setting using the automatic mode. Turn on the "white noise" signal (we have av track on this page) on high-quality speaker system, place the headset in 10-20 cm. from the speaker column and click the button "Auto" on the screen. The procedure lasts 10 seconds. When set-up is finished, the equalizer sliders will occupy the position corresponding to the new setting. If you think that the

setting is not very good (perhaps because the influence of acoustic noise) make set-up again. Then, you can make changes manually if it is necessary. After this, click "back" button on the EQ screen. The program will return to menu screen. Click "back" and the program will go to the Main menu window. Press "Menu" button on the main screen of the device. You will hear a sound in the headphone, and the Main menu window will be closed. All this procedure is necessary for the correct set-up of your headset.

• If all settings were made earlier, and you only want to change mic type, then, after selecting "Bluetooth headset, click "back" and the program will go to the Main menu window. Press "Menu" button on the main screen of the device. You will hear a sound in the headphone, and the Main menu window will be closed. All this procedure is necessary for the correct set-up of your headset.

After the setup procedure the device is finished, You are ready to operate, using the internal\wired microphone. It is enough to make adjustments only once. Re-adjustment may be necessary if the program data has been erased or lost..

• After that you can place the Bluetooth headset in the beehive, or in the framework of a controlled beehive, and go to make the control remotely. This is especially useful for the control of the hive during all day. Average time of the headset 8-10 hours.

• Do not turn off the headset during the time when the program is still working. This may cause program failure. If this happens, you have to go to smartphone's menu settings to turn on the smartphone's Application manager, then find APIVOX AUDITOR application and delete application data. After that the program can be restarted correctly. But after this, you must set-up configure all types of microphones again.

• To turn off Bluetooth headset correctly, it is strongly recommended that you must access the Main menu and switch the unit to "built-in mic." mode, an go out keeping correct sequence of actions ("built-in microphone", "back", "menu"). All the sounds of the buttons you will hear in the headset earphone. After your device is switched to work with internal microphone, you can turn the power of your headset off, and if you want, Bluetooth mode of smartphone too. After this, all sound you will hear from built-in speaker.

During using Bluetooth headset it is important not to forget that a considerable distance from the hive in which you placed your gadget can lead to a distortion of the measurement results because due to deterioration of communication quality. It is not very essential for human voice transfer but for the accurate measurement of bee's acoustic signal parameters - it is not acceptable. Therefore, we recommend you in the process of monitoring not to go further then 4-5 meters from the hive, or about half the allowable distance specified for headset in its instruction.

When you are making tuning of the device using generator of "White noise" , you must produce it very close to the speaker of sound system on which reproduced audio track. The volume shall be high enough to ensure that you drown out every possible acoustic interference in the room where the tuning is performed.

The correctness of settings can be checked :

1) In Monitoring mode on the uniformity of the "white noise" chart line across the entire width of the range.

2) In mode Swarming Control - right indicator. The arrow should be in the middle of the scale or at least in the yellow zone.

3) In mode Readiness to Accept new queen - left indicator. The arrow should be in the middle of the scale or at least in the yellow zone.

4) In mode Acceptance Control

Window 1 - both indicators. The arrow should be in the middle of the scale or at least in the yellow zone.

Window 2 - the central indicator. The arrow should be in the middle of the scale or at least in the yellow zone.

If you do not have speakers with good quality in low frequencies, (normally, you don't have) and after automatic tuning you can see in the "Monitoring" mode in the absence of noise some bars at frequencies of 50-100 Hz, then you should do the following:
- Find the quietest room in the house where there is no extraneous noise
- Go there with smartphone, and close the door)))
- Connect the microphone and the corresponding setting.
- Enter the microphone equalizer adjustment mode.
- You have to see in full silence, 2-3 left columns of equalizer chart, raised. The number depends on the quality of your audio system. The worse it is, the more you will see the raised bars. Normally, you'll see 2-3.
- Align them so that they will be equal in height, to the other columns. To do this, use the sliders corresponding EQ bands. To make the adjustment more accurately move the slider "Scale" down. Scale will increase and you will be able to make the adjustment more accurately

When you are working with a Bluetooth headset, it is important not to forget, that a significant distance from the hive in which you placed your gadget can lead to a distortion of the measurement results due to poor communication. If this is not essential for voice transmission, then for accurate measurement of the parameters of the signals of bees, this is not permissible. Therefore, we recommend that you not to move further than 4-5 meters from the hive, or about half the allowable distance of work with the headset, specified in its passport.

ADJUSTING OF MICROPHONE GAIN FOR MONITORING MODE

First of all, when you start to work with the hive, adjust the microphone gain in order to see all the peaks and highs from blue to red. With microphone gain, (use the rotary control with the toggle "MIC", switched to ON) you can choose the most suitable signal amplification to draw a clear picture of the signals. This adjustments are made in Monitoring mode, which is the "default" mode, when you are starting your work with device, and between measurements, if any other mode is not selected.

NAME SETTING OF SCREENSHOTS GROUP

The application has a feature that allows you to make a screenshot of the screen during operation. Also, you can now specify the name or number of the hive to which a series of screenshots belongs. "Foto" button is used for both functions. A short press - and it makes screenshot and saves the file as "the name or number of the hive_ Year. Month. Date. Hour. Min. Sec " And "the name or number of the hive" is always added to the name of the screenshot. If you want to take screenshots when working with another hive, do a long press on the "Foto" button. You will see a screen for entering the name or number of the hive. Click on the line and virtual keyboard will appear. Type the name or number of the hive and click "yes." New prefix for files group name, will be saved in memory and will be added to all subsequent screenshots. You may change prefix at any time. The last written prefix, persists after the application is turned off.

PRE-SETTINGS FOR WORKING IN GENERAL STATE CONTROL MODE

Before you start working with these mode, it is necessary to make the installation using 2 buttons on the screen next to Main menu button of the device, and one in the Main menu of the device.

First button selects the time of day (day\night) but not in the sense of light and dark, rather in terms of flight activity of the bees. Flight of the bees for nectar is either still happening or it stopped. Another button - is the selection of the season (winter\summer). The division is also conditional. **We consider to be the "Summer" - time of the year when bees fly for nectar collection. We consider to be the "Winter" – is the period of the passive location of the bees in the conditions close to the winter cluster without any attempts to fly for nectar or to use liquid feed.** So, in some countries there is no Winter in our meaning.... Thus, by selecting current conditions of life of bees by these two buttons, we define the expected seasonal and temporary state of bee colony, and the range of their likely behavior.

Press the "Menu" button on the screen and go to the main menu of the device. Press the "Measuring lag" button. A new window will open where you can choose the length of the delay interval between pressing the "Start" button and the actual beginning of the measurements. This is done in order to isolate the devise from sources of interference - street noise, wind, etc., when measuring from the top through the lap. This interval will allow you to either cover up a smartphone put on a lap with pillow, or close the cover of the hive, or use other means to eliminate acoustic noise, including noise from the beekeeper ...

In order to take a measurement, you need to set it's interval. You can chose 15 seconds interval (1x15sec) or close to 3 minutes interval (5x15 sec).

Then just press the "Start" button and, with the delay that you set in the Main menu, the process of measuring and averaging the results will begin.
After the time required for the measurement, the message about the general state of bee colony will appear in the diagnosis window.
Longer measurement interval and larger number of samples for averaging will give you,   higher probability of a reliable diagnostic results. You can save the picture, using the "FOTO" button.

The size of text in the text window on the screen of app can be too big or too small - this is up to the settings of your smartphone... If you need to correct it , then you should go to   "settings" - "screen"-"text size" of your smartphone, and make text bigger or smaller ....

FEATURES OF MAKING MEASUREMENTS

The next step - is correct work with bees... We receive questions about strange results of measurements, which obviously do not correspond to the time and season.

Let's understand in details the causes of this phenomenon. And the cause of this phenomenon is usually one and the same - the device does not hear the bees .... So why does we obtain this strange result?

For smartphone (or tablet) there is no notion - "no sound" ... it use automatic amplifier, which try to find something, making amplification higher and higher... till it will find something among interferences ....

The picture of signals in the Monitoring mode is not the subject to this phenomenon (automatic amplification) .... Therefore, we are always talking about the need to see the signal in the Monitoring mode before making measurement in General State Control mode. And only if it is clearly visible when gain is not more than 1-8 points on the scale of the rotating regulator (... up to one quarter or one third of the scale), then we can say that this is the signal of bees

In order to give you possibility to monitor this situation, we have made a signal quality indicator, which is located in the right corner of the screen of Monitoring mode. If the gain is normal, you will see a green quadrate with white tick. If the gain is already strong, but you can still work, you will see a yellow quadrate with red tick. If the gain is so strong that it is not advisable to work, and you need to change the place of control, you will see a red quadrate with yellow exclamation point.

Loudness of the signal depends on the breed of bees.... Russian bees are good audible with amplification 1-4 points, Carnica Peshets bees - with amplification 2-6 points, Carnica Troisek - with amplification 4-10 points ... But independently of points number, you should see good picture of bees sounds ... That's the main rule !!!


If you do not see any clean and stable signals, do not try to make amplification very big.... Simply change the measurement location. Especially it is important in autumn and winter, when bees become more quiet, their sounds subsides and the bees go to the upper part of the hive, where it is warmer ... to the upper bars of the frames or to the upper box. Then it is much more effective to make measurements from the top of the frames covered with a textile lap. The textile isolates the bees from you and from the light ... you less disturb them, but the textile does not prevent the sound from passing. The microphone can hear bees well.

When you work using Bluetooth headset, and trying to make measurement through the porch, it is necessary to insert it deeper into the porch (5-6cm) or it will hear only bees flying around the porch... and your measurement will be incorrect.

In any case, only the visual control of the signal in the Monitoring mode will tell you about what result you will get - the result of the analysis of the sound of bees, or the airplane flying over you

BEFORE YOU WILL START TO WORK, USING APIVOX SMART MONITOR

I hope that you have already read the instructions, and are ready to start working with the device. Excellent. Then I will say a few words as a recommendation ...

1) In our device it is very important to make good tuning of microphone tract. Almost all modes use a balance between signals in the high and low frequencies, so the smoothness of diagram of microphone characteristics is very important. Be sure to do the setup procedure, following the instructions. Be sure to check the settings, and if the deviation is too large, then make the adjustment again and again ... Of course for boundary states, this is not so important .... But the time of the transition through zero may be somewhat shifted. This is not particularly important, but not pleasant. The fact is that the device is made so, that it forgives small and even average errors.

All the results that the device shows, are relative. The basis- is the general background of the hive. Therefore, strong and weak families produce the same results if they have equal percentages of the works, performed in the family. In addition, to issue diagnostic messages it is used the system of threshold values. This means, that between two thresholds there is a certain range, in which the value of the measured parameter can fall. Exactly this, allows you to have some deviations and errors in the setup.

2) The smartphone is very specific device. Its built-in microphone the best for hearing in-hive signals. It is designed for use in "hands-free" mode, and therefore has an automatic gain control system .... it very well hears distant sounds. Especially it is valuable in autumn, spring, winter. Wired and Bluetooth headset on the contrary, hear the sounds worse. Smartphone limits their

possibilities to hear distant sounds. After all, they are always used in noisy places and smartphone must muffle the noises, in order to detach speaker's close voice. But, as a rule, this does not cause serious inconveniences in the summer. (How to make a wired microphone, there is a video and instruction on the web page.) In winter, even putting a microphone on the frames with wintering bees, you can sometimes not to hear anything ... it is possible in situation, when the bees are doing well. This is especially true for bees of Grey Mountain breeds.

3) Do not start immediately after setting up work with bees in real conditions. Try to work at home using test signals. See what results you will get, how to adjust the gain to get a good picture in Monitoring mode, how the charts behave with different signals. What type of screens you will see in different modes, and what's the difference between them. All this will greatly facilitate your subsequent work with bees.

4) Have a look at my films on YouTube channel ... they will be useful to you in terms of what you can do with the device, and how I use a smartphone to get a good results. All this is not staged shooting. This video was shot during the real work.

5) Do not attempt to use the instrument continuously and continuously compare readings. The maximum averaging is only 3 minutes. For a longer interval, the readings become too much averaged, because the bees change jobs many times during the day, and the signals are not very stable. Just need to do the measurements at the right time. The best results on the general condition can be obtained in the middle of the day during the most active work. And in the evening, when the flights were almost over. Usually at this time, work on caring for brood is better heard. There is night mode, but it is unlikely to be used ....

6) It is very important to use the appliance correctly, that is, You must be sure, that the device accurately hears the bees inside, and not outside the hive. This is the main problem in getting bad results. Flying bees very much spoil the measurement results. If you see a powerful stream of arriving and departing bees, then it's better to postpone measurements until the evening. In principle, it's clear that the family works well.

7) The device we called - "Assistant of the beekeeper", and not his "substitute" ... use it according to this statement ... If the bees are all right, then it will not tell you anything supernatural, but if something is brewing, then you will see it both in the diagram and in the diagnostic messages ... Or if some family causes doubts in you .... Then the use of the device makes sense.

8) Do not use modes intended for usage in a certain time at another time. They are built on the identification of features that are characteristic or not characteristic for a certain season. So using them in another season, you will get a strange diagnosis. For example, swarming control - if in the beginning of summer it will give you a diagnosis of possible swarming, and it will most likely be true, but if you use it in the fall, its diagnosis may be the same, although there can not be any swarming ... just in autumn in the family accumulates passive bees, which will wintering, and do not participate in the work now. But in the spring such passive bees would constitute the basis of future swarm ... The same with the time of measurements. There are intervals (and we warn about them) when changes the composition of in-hive works and the signals turn into a kind of "semolina porridge". This time is good for scientists, not for practical beekeepers. But, in principle, we do not prohibit taking measurements at this time. Although not recommended.

9) You can always contact us and ask a question, provided that you read the instruction and your question concerns application of the device in some situation.

OBSERVATION OF BEES' FAMILIES, USING MONITORING MODE

In Monitoring mode, you can see signals in the range from 50 to 550 hertz, which, according to scientists, is the main range of significant signals of the bees. According to changes of the signals in this range, you can roughly say about the state of the family at a given time.

Signals of bees are very short and constantly pulsating, so you always see a rather approximate picture. For a more complete understanding of the question, there is a sonogram screen, to which you can go to, by scrolling the diagram from left to right.

This screen allows you to see all signal changes in the last 90 seconds. You can see the current trend of changing signals in the entire range from 50 to 550 hertz.

The diagram screen and the sonogram screen can be enlarged to the full screen size of the smartphone by short pressing on the chart screen or sonogram.

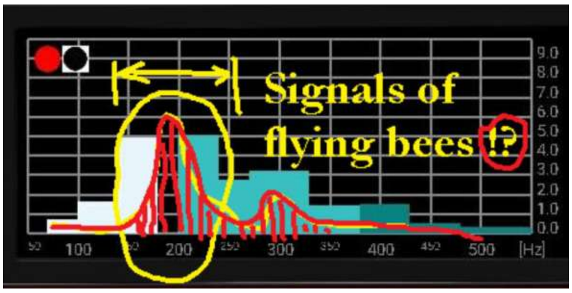
CHECKING BEE FAMILIES USING GENERAL STATE CONTROL MODE

The main feature of this mode is averaging of obtained instantaneous values, which makes it possible, to understand the general state of the family better, than using observations in Monitoring mode. Those signals that may appear to us large, during averaging may turn out to be insignificant, because of the rarity of their appearance, and vice versa.

Getting a diagnosis in this mode is absolutely not difficult. You just need to install a smartphone in the porch of the hive, so that in Monitoring mode you can clearly see the bee's signals, select the measurement duration, select the General State Control mode using corresponding button, and press the "Start" button. After a while, the measurement will start. The result will appear in the text box. You can make a screenshot and save the diagnostics. In order to proceed, click the "Reset" button. The device will be ready for continuation of measurements.

In order to make diagnose of the state of bees' family using this mode, you can use the built-in microphone of the smartphone, an external microphone or a Bluetooth headset that will function as a wireless microphone. The best variant - is the one, that you always have with you - that is, the built-in microphone of your smartphone. This mic and associated with it electronic part of smartphone are made especially for catching of sounds around you on mostly wide distance. This is very important, when you use "hands free" mode of your smartphone... In all other cases, when you use mics connected through epy socket for headset, microphones hear sounds at a much shorter distance. This is the feature of all headsets. They should not hear very distant sounds. In principle, all headsets give not bad results, but the best, and most general data, you will get when using the built-in microphone.

It is advisable to place the microphones deeper, so that incoming and outgoing bees do not interfere with the control. Especially strongly interfere with the measurements overflights of young bees, and powerful work of bees on honey collection, when the sound of flying bees are so strong, that it is required to place the microphone very deep in the hive so as not to hear these disturbances, or to place it on the frames covered with textile, and cover with pillow, in order to eliminate sounds of flying bees. And generally speaking, it is better not to make measurements at all, under such conditions. It is better to take measurements in the evening, when the quantity of flights of bees will decrease significantly.



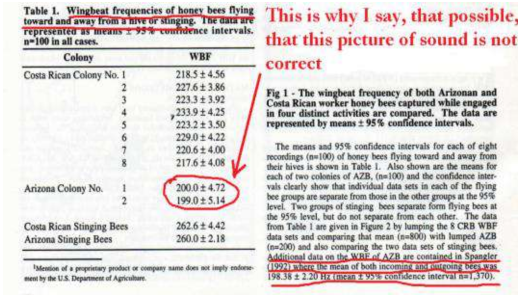


Table 1. Wingbeat frequencies of honey bees flying toward and away from a hive or stinging. The data are represented as means ± 95% confidence intervals. n=100 in all cases.

Colony		WBF
Costa Rican Colony No.	1	218.5 ± 4.56
	2	227.6 ± 3.86
	3	223.3 ± 3.92
	4	233.9 ± 4.25
	5	223.2 ± 3.50
	6	229.0 ± 4.22
	7	220.6 ± 4.00
	8	217.6 ± 4.08
Arizona Colony No.	1	200.0 ± 4.72
	2	199.0 ± 5.14
Costa Rican Stinging Bees		262.6 ± 4.42
Arizona Stinging Bees		260.0 ± 2.18

[1]Mention of a proprietary product or company name does not imply endorsement by the U.S. Department of Agriculture.

This is why I say, that possible, that this picture of sound is not correct

Fig 1 - The wingbeat frequency of both Arizonan and Costa Rican worker honey bees captured while engaged in four distinct activities are compared. The data are represented by means ± 95% confidence intervals.

The means and 95% confidence intervals for each of eight recordings (n=100) of honey bees flying toward and away from their hives is shown in Table 1. Also shown are the means for each of two colonies of AZB, (n=100) and the confidence intervals clearly show that individual data sets in each of the flying bee groups are separate from those in the other groups at the 95% level. Two groups of stinging bees separate form flying bees at the 95% level, but do not separate from each other. The data from Table 1 are given in Figure 2 by lumping the 8 CRB WBF data sets and comparing that mean (n=800) with lumped AZB (n=200) and also comparing the two data sets of stinging bees. Additional data on the WBF of AZB are contained in Spangler (1992) where the mean of both incoming and outgoing bees was 198.38 ± 2.20 Hz (mean ± 95% confidence interval n=1,370).

At night, when the guard is very active, and if the bees are very evil, you can make measurements from above - from the top of the frames, through the tissue, covering frames, but the results of measurement will be somewhat understated.

In winter, it is better to carry out measurements through the upper porch of the upper body box of the hive, or through the tissue covering the frames. In principle, the microphone can be placed on the frames under the tissue in the fall, leaving a wire and a connector for connecting to the smartphone from the outside. The main task for us - is to make condition in which our device will hear the sounds of bees. This is especially true in winter, when bees do not perform almost any work, and they are heated, as it is known, very silently. At this time, when the temperature outside is not very low, bees behave so quietly, that such breeds, as the gray mountain bees of Caucasus, or Carnica, do not emit almost any sound. Only significant problems can cause bees to emit very loud sounds in winter. Clearly, there are more loud bees - bees of the Russian breed, which are originally, more thermophilic breed.

In a multi-box hive, in summer, if the device does not hear the bees through the lower porch, you can try to use the upper porch of the lower body-box for control. This will bring the microphone closer to both the logistics zone and the nest.

So, what kind of diagnostics can be obtained in this mode ... Firstly, in what condition is the family, is it active or passive, does it work well, or is there any unemployed bees, which can provoke swarming. If the balance is broken, the device will warn you about the possibility of onset of swarming state. If the family has a lot of bees engaged in caring for brood, the device will also warn you, since sometimes it can be a sign of loss of the queen.

In winter version of General State Control mode, diagnosis is not fundamentally changes, because the list of in-hive works is unchanged, both in summer and in winter. They may be or may not be, but if some works exists, then they are all still the same .... Therefore, the appearance of working signals in winter is to certain extent, a normal phenomenon, but their excessive amount in winter, is already a sign of problems. And the device will warn you about it. In spring, the number of works and associated signals will increase, especially when the beehive will be warmed by the sun. During such time you can see a practically summer set of signals. The only difference is that bees work with honey stored in combs, and not with nectar brought from the fields.

As we already said, in this mode our device can give you a warning, about the possibility of problems with the queen. If this happens during the day time, then perhaps you should check the family. Such diagnosis is possible with a recent loss of the queen, or if the family already has no open brood for the withdrawal of new queen, and there are worker bees laying unfertilized eggs. If a warning appeared in the evening, it is possible that there is a lot of brood in the family. When the work on collection and processing of honey stops, the signals associated with brood care can be quite loud.

As we already said, in this mode our device can give you a warning, about the possibility of problems with the queen. If this happens during the day time, then perhaps you should check the family. Such diagnosis is possible with a recent loss of the queen, or if the family already has no open brood for the withdrawal of new queen, and there are worker bees laying unfertilized eggs. If a warning appeared in the evening, it is possible that there is a lot of brood in the family. When the work on collection and processing of honey stops, the signals associated with brood care can be quite loud.

Our device can give a warning about the possibility of loss by the queen, ability to lay eggs. As a rule, at the same time, the work in the hive is disorganized, and the bees are very excited. A similar condition can be in the family, immediately after a large inspection of it by beekeeper. But right after that, it's definitely not recommended to carry out any kind of measurements. Nothing but the excitement of bees, the device will not show you.

EXAMPLE OF THE APIARY CONTROL, USING GENERAL STATE CONTROL MODE

Good example - Termination of honey harvest after the rains, and its restoration. Both can be clearly seen and confirmed by the observation of beekeepers.

1, 2, 3 - good weather and honey harvest in Texas flowering golden rod — storm prediction bees feel future storm — day after storm temperature fall

6, 7, 8, - days after storm. The fall of temperature and nectar production.
9. - we can see restore of nectar production. But it's lower than before...

MONITORING THE FAMILY STATE, USING SWARMING CONTROL MODE

In the process of monitoring of such an important parameter in the life of bees' family, as the beginning of swarming, are used, as we believe, two signals of different origin, which ultimately show us, that the process of swarming begins.

We already mentioned both signals as such, but now we need to tell, why we decided to use them together, and what became the basis for making such a decision.

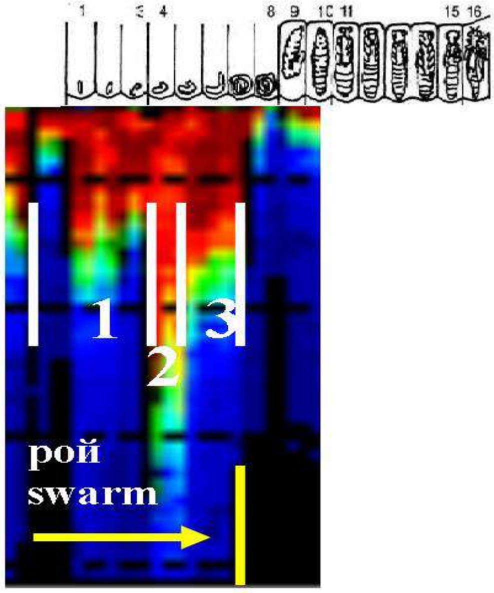
Let's start with the signal, which we call "brood care".

In 2017, within the frameworks of the "Swarmonitor" project , with the financing of the European Union, were carried out studies, which purpose was to clarify the relationship between the vibrational signals produced by the bees and the number of brood in the hives. (European Union's Research Executive Agency project reference No. 315146 Honeybee Colony Vibrational Measurements to Highlight the Brood Cycle Martin Bencsik ,Yves Le Conte,Maritza Reyes,Maryline Pioz,David Whittaker,Didier Crauser,Noa Simon Delso, Michael I. Newton Published: November 18, 2015).

As we have already said, thanks to obtained results, it became possible to change point of view at many events taking place in the bee family. On the diagrams, obtained by European scientists. it is clearly visible a short and sharp peak, two weeks before the release of the swarm.

The same signal, but longer and more powerful, is observed when the bees - nurses starts to feed larvae of worker bees on the frames where the queen worked. In addition, if usually this signal appears on the frame where the queen worked a few days ago, then before swarming it appears in the entire hive almost simultaneously. This synchronism gives it such a big strength. As we already said, we called this signal - “brood care" signal.

So, our assumption about how the preparation for the beginning of swarming takes place, taking into account the analysis of two signals, consists of following:



<u>The first stage</u>- the growth of “brood care” signal is associated with an increase in the egg-laying activity of the queen and filling of all free cells in the nest. This stage passes without participation of second signal. If you use our device Apivox Smart Monitor in Swarming Control mode, you'll see that arrows begin to approach the yellow zone more and more often.

<u>The second stage</u> - The further task of the queen is to go through the hive in search of all the vacant places for egg laying, on all the frames of the hive, in order to ensure the maximum possible amount of brood in the hive, after the swarm leave. In addition, the bees must build new queen cells on the periphery of the nest, where there are no suitable temperature conditions. The expansion of the nest zone, necessitates the strengthening of measures to maintain the temperature, necessary for rearing of worker bees and new queens. And the signal of "active heating" starts to appear in the hive.

Oddly enough, but most of the bees which do this, are flight bees. In addition, it was noted, that exactly flight bees almost never enter the brood part of the nest in the process of heating the hive. (Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider)

Transition of flight bees to the work on heating the hive, leads to a decrease in flight activity of the family, which can be noted especially in the presence of thermophilic breeds of bees, such as Russian breed. In the same time, in the families of bees which breed was born in mountains, such as Carnica breed, the flight activity decreases significantly less. The transition of bees to the heating of a larger volume of the hive is accompanied by the beginning of the rise of "active heating" signal, and If you use our device Apivox Smart Monitor in Swarming Control mode, you'll see, that the arrows begin to approach to the border of the red zone.

As the entire volume of the hive becomes suitable for laying eggs, the queen expands the egg-laying zone. The "brood care" signal rise and stabilizes. So, the appearance of signal of "brood care" of average strength on all frames of the hive, is most likely connected exactly with this process.

<u>The third stage</u> - A sharp, avalanche-like increase of "brood care" signal by 2-3 times. A narrow peak appears on the diagram. We believe, that this is the explosion of activity of nursing bees, associated with the laying of eggs by the queen in the queen cells, on the background of overall increase of number of open brood in the hive. Normally, the quantity of them is high enough, and they are scattered throughout the hive. A huge amount of feed, royal jelly, should be placed in them practically, simultaneously. This enormous amount is required to be produced during three days, and this causes an explosion in the activity of the nurse bees on all the frames of the hive. As we know, queen cells are surrounded by bunches of nurse bees! In addition, no one cancels the continuation of works on the care of the rest of the brood in the nest. And this is the moment, when our device already confidently shows the borderline state between working state of the family and swarming state.

After laying new queen cells, heating of the hive become more intense. Maintaining the temperature throughout the hive should be more accurate. At this time, the signal of "active heating" begin to increase, and If you use our device Apivox Smart Monitor in Swarming Control mode, you'll see, that the arrows are shifting , deeper into the red zone.

<u>The fourth stage</u> - the peak of "brood care" signal drops sharply after the first massive loading of the queen cells with the feed. The number of bees- nurses on the frames with queen cells decreases. The signal decrease, but remains until the sealing of queen cells, and the brood around them... The work of bees with queen cells does not stop life in the hive. The brood in the nest matures and the bees gradually seal it. The "brood care" signal gradually decreases, and the "active heat" signal becomes the main signal in the hive. Why? For what reason ? Because it is exactly pupae for their transformation require maintaining the temperature as accurately as possible! Much more accurate, than it is required for eggs and larvae. They allow to have a slightly lower temperature in the nest... Sealed brood and sealed queen cells do not allow this. A miracle occurs inside them - the larva at first turns into a shapeless mass, and then it takes the form of a pupa, with an almost complete set of organs of an adult insect ... And this miracle requires from the bees to maintain needed temperature with high stability. (Honeybee Colony Thermoregulation – Regulatory Mechanisms and Contribution of Individuals in Dependence on Age, Location and Thermal Stress Anton Stabentheiner*, Helmut Kovac*, Robert Brodschneider Institut fu¨ r Zoologie, Karl-Franzens-Universitat Graz, Graz, Austria)

Step by step, under the influence of bees, the queen reduces egg-laying. The decline of the egg-laying leads to the fact, that a large number of bees-nurses remain idle. In order, not to hinder the work in the nest, those bees who do not find work in the hive, passes into a real "passive state", without surplus movements and generation of vibro-acoustic signals, and having housed in a certain way, become a “crust”, which protect the nest and frames with brood from heat losses.

This is the second peak of the signals that our device will show, although it shows the first peak, more than a week before, when the bees started to construct swarming queen cells. What is the apparent difference between the first and the second peaks? The difference is that the first peak, generates a "brood care" signal, and the arrows of the device are shifted to the yellow zone. The second peak is the peak formed by the "active heating" signal, and at this stage, the instrument's arrows will enter the red zone. The stronger the "active heating" signal, the deeper the arrows will go to the left in the red zone. If the "brood care" signal is still strong, the arrow will be in the red zone in the right, closer to the yellow zone.

So, our device will at least twice warn you about the beginning of the process of swarming in the family - at the second stage of preparation for swarming, you will most likely see the boundary condition between work and swarming. But this is already an important warning. It is worth personally inspect such a family.

Methodology for the diagnosis.

Indicator called "Mood tendency" shows the peak position of the signal in the frequency range. Green Zone – the working status of the bees. Red Zone - passive, pre-swarming impulse of the bees.

The "Tendency power" indicator shows the ratio of signal power in the operating state and in the passive pre-swarming impulse. Green Zone - the signal power in the working area is higher than in swarming area, and the swarming is unlikely. The Red zone indicates that the signal power in the swarming impulse area is higher than in the working area. The swarming is possible. The greater deviation from zero in the red zones - mean the higher probability. Joint indication of devices on the red zone means the highest probability of bee colony getting into swarming impulse.

If you are interested in diagnosis of swarming, it's better to make monitoring procedures in the day time when the working activity must be high . At this time there must be no unemployed bees. At night time you can hear the sound of worker bees relaxing after the whole day of flights , interfering with accurate diagnosis.

In the Swarming Control mode it is possible not correct or borderline diagnosis in such conditions:

- When Queen cells are already laid. Swarming rush of bees subsides, bees start their normal work, until free young bees begin accumulating, and transforming into future swarm. At this time it is necessary, additionally, to make diagnostics using General State Control mode, which can diagnose the presence of not fertilized queen or queen cells. During this period, bees are characterized by some excitement.

- When the family have not fertilized queen or queen cells after the loss of the queen. Gradually the bees capping brood, they have no new brood to feed, and step by step a lot of bees without any job accumulates in the hive. In the absence of a honey flow, this is very similar to the accumulation of bees for future swarming. You can diagnose this condition using General State Control mode.

- Do not use this mode in early spring, autumn, or warm winter. This mode is designed to determine the state of natural swarming on the basis of control of the balance of the number of bees employed in the collection of honey and passive, unoccupied bees. In the autumn-spring time almost all bees have no work and they are mostly passive. Therefore, the diagnosis will not be correct.

AN EXAMPLE OF CONTROL OF THE BEE FAMILIES IN THE APIARY, USING SWARMING CONTROL MODE.

There were three hives for comparison

#1 #8 #2

##1, 2 – Carnica breed, #8 Mixed breed The family in the hive #2 is the biggest with a lot of brood.
The first tests using Swarming Control mode made close to 11-00 in the morning shows :

#1 borderline state **#8 active working state** **#2 close to swarming state**

<u>Visual control of the families show us the following :</u>

The hive #1 - 5 brood frames, more than 2 of them with open brood. A few closed drone brood cells. The family have working state now, but Swarming state is not so far.

The hive #8 – 5 brood frames, mostly with capped brood. No drone brood. The family have working state.

The hive #2 – 7 brood frames. 5 with capped brood, 2 with eggs and larvae. 2 queen cups on 11^{th} frame (1^{st} honey+pollen, 2-8 brood, 9-10 honey+pollen, 11-clean frame with 2 cups, 12-honey). The beginning of Swarming state !!! We have close to 14 days for prevention of the loss of bees.

CHECKING OF THE RELATIVE AMOUNT OF BROOD IN THE FAMILY. BROOD CONTROL MODE.

This procedure is designed to check the relative number of brood in the family of bees, mainly in winter-spring and autumn, that is, in the absence of significant work on the collection and processing of honey.

The Brood Control mode shows the ratio between brood care, and other in-hive works. This mode allows you to see the beginning of the brood's withdrawal during wintering and its build-up in spring.

The screen of this mode is made in the form of a graph, since the bees' signals are not stable and it takes some time to see the main trend. They are not stable during the day and at different times of the day. The chart can have many sharp jumps, which depends on the number of bees and the work they perform.

The chart characterize the state of bee family as follows :

- If the graph is red and is situated at the very top of the screen, then the family is intensely caring for the brood.
- If the graph is red and is situated near the zero line, this usually means activation of brood care process after its absence, or decreasing the relative amount of brood requiring care, if it previously exists.
- If the graph is white and is situated near the zero line, then after the absence of brood, we can talk about the beginning of the process of building up the strength of the family. In the case of previous presence of a large number of brood, it can be said about significant decrease of the number of brood, requiring attention of young bees.
- If the graph is white and is situated in the bottom of the screen, you can talk about the almost complete absence of brood.
- The larger the amplitude of the oscillations of the graph down, the less bees are engaged in care for the brood.
- The larger the amplitude of the upward trend, the less bees are engaged in in-hive works, and more bees are caring for the brood.
- The less fluctuation in the schedule, the more uniformly all works are done in the family, the less bees are changing the types of activity, depending on the need. This indicates a sufficient number of bees in the family and about presence of balance in their age composition.

This mode takes into account the fact, that during the transitional season in the family there can be passive, unemployed bees. This is why, this mode is recommended to be used mainly during spring and autumn, as well as in the late evening time in the summer. In summer, for analysis of the state of the bees' family, it is recommended to use Honey Harvest Readiness Control mode, where the honey collecting activity of bees in summer is taken into account, and included a slightly different view of the in-hive works of the bees.

It should be noted again, that indications, which you see on the chart, are relative, and may fluctuate, depending on the time of day and season. Naturally, intermediate values can occur both, during the day time, and during honey harvest season, but in general, the understanding of the trend persists.

Bearing in mind the fluctuations in the activity of bees, we have made a graph that allows us to see not a momentary state of the family, but a trend in time. Therefore, in order to obtain more reliable data, it is necessary to spend a certain time on the measurement, and to obtain a graph for a longer period of time. We usually use intervals from 5 to 15-20 minutes, depending on the complexity of the situation.

AN EXAMPLES OF CONTROL OF THE APIARY USING THE BROOD CONTROL MODE

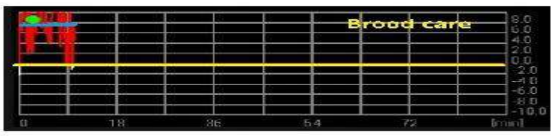
During this inspection, control of three families in different states was carried out. Beehive number 1 - strong family with a fetal queen that does not interrupt the process of egg laying. A lot of worker bees. The family works normally. Beehive number 5 is an offshoot without queen but with 3 brood frames, brood is mostly open. On the frames was found more or less two dozen queen cells. Bees fly only from time to time. Beehive number 8 - family was devoid its queen. A capped queen cell was given to the family. The queen has already come out, all remained open brood was capped. Bees fly normally.

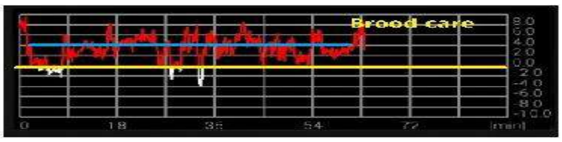
The hive #1, where exists fertil queen which did not stop to lay eggs. The bees work on honey collection The brood care is as usual.

The hive #5, where exists a lot of new queen cells and there is no queen. The bees take care of queen cells... A few bees work on honey collection.

The hive #8, where new queen just came out of queen cell. The queen is still infertile. All brood in the hive is capped. No any kind of brood care needed. The bees work on honey collection

Control carried out using Brood Control mode, during time period from 20 minutes to 1 hour showed the trends existing in families. In a normal family, in which the process of brood withdrawal was not interrupted and is in a balanced state, the graph is white, but is in the vicinity of the zero line. In a family that has focused all its attention on preserving the open and capped brood and queen cells, almost forgetting the honey collection, the schedule is red. In a family in which all the brood is capped, the queen is still unfertile, and there is no open brood, the graph is white and is at the maximum distance from the zero line, saying that there is absolutely no work on brood in the family.





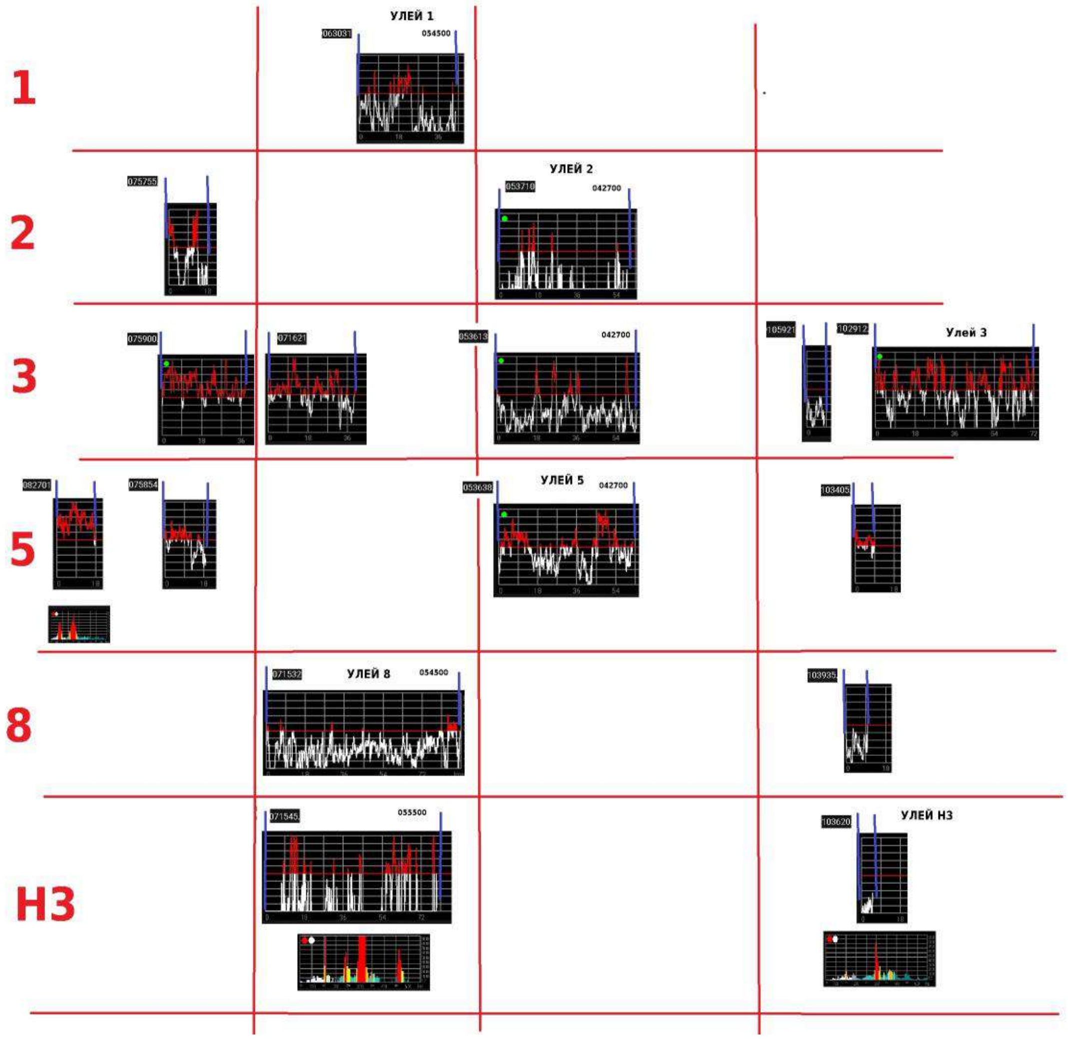
It is clearly visible the force of the signal when bees had open brood and queen cells, and it is clearly visible, that the force of the same signal when mostly all brood and queen cells are capped, become twice less, but do not disappear at all !!!

Control carried out in beehive 5 after sealing queen cells and brood, showed that care of the brood is still preserved, but less bees are involved in this work, and they devote more time to other works.

ANOTHER EXAMPLE OF THE COMPLEX CONTROL OF THE FAMILIES OF OUR EXPERIMENTAL APIARY, CARRIED OUT USING BROOD CONTROL MODE.

During the whole day, all families were monitored at approximately the same time. All results of these measurements are shown in the picture, which take into account the measurement time too.

Diagnosis showed not bad results. Conformity of the readings of the device and the state of the families was very high. You have already seen the results of the previous control of three of these families. This control was made about a week later.



Family number 1 - strong family with an old queen, from this family was made offshoot without a queen (family number 3) - graph is predominantly white, with red "caps" - the family is in working state, it has a lot of brood, and the bees periodically take care for it.

Family number 2 - strong family with an old queen, from which was made offshoot without a queen (family number 5) - graph is predominantly white, but the number of red "caps" on the graph is bigger - the family is in working state, but due to the large number of brood, bees take care for it much more time.

Family number 3 - Offshoot without queen, in which future queens are growing for all new families. Here is a lot of open brood and queen cells, and here we placed our frame with artificial queen cups and larvae. There ia a lot of bees, but flights are few - graph is mostly red in the morning and in the evening. This speak about powerful brood care in the absence of honey collection. During the day, we can see less brood care activity, because more bees fly to collect nectar for brood and bees working inside the hive.

Family number 5 - Offshoot without a queen. In the nest it have brood of different age, and new queen cells. There are a lot of bees, but they do not fly very well. - The graph is predominantly red throughout the whole day. This indicate a constant need for brood care, even to the detriment of flying for honey. And in its turn, this indicate presence of sufficient quantity of food for bees and brood.

Family number 8 - A full-fledged family which was not divided. But old queen was deleted, and the family was given a capped queen cell. Now the family has a young queen, which has not yet begun laying eggs. Family in normal working condition, actively working on honey collection. Diagnostics show practically full abcence of brood care.

Family H3 - is a nucleus with a pair of frames of brood of different ages and a fertile queen. In this family quite small amount of bees, but the bees fly a little. - The amplitude of the graph confirms the small number of bees. They are almost unable to do different things at the same time, this is why the graph have so much throws in different directions ... At first, all the bees work on honey processing, then they work on brood care... The works are equivalent in strength, the average line of the chart is near zero.

So, you can see, how diagnostics using the Brood Control mode gives an idea of the differences in condition and development of different families of the apiary.

CONTROL OF THE FAMILY USING READINESS FOR COMMODITY HONEY HARVEST CONTROL MODE.

This procedure is designed to monitor the condition of the family in spring and summer. The procedure shows the relative balance of works, aimed to build up the strength of the family, and works on collection and processing of honey. This ratio indicates whether there is a chance for the beekeeper to receive at the moment marketable honey, or the family is working only to meet their own needs.

Balance in the spring in the direction of increasing the strength of the family is a natural process of development of bees' family. In the spring, such a shift has a positive value. The family is gaining strength. But in the summer, when the commodity honey harvest begins, the lack of daytime and evening works on processing of honey means, that all honey is consumed by bees and brood, and does not reach the storage. That means, that honey supply is lower than the family's own need for food, and it does not make sense for beekeeper to hope, that such a family will give the commodity honey at the moment. The beekeeper is required to take appropriate measures - either to reduce the number of brood in order to rid the bees from in-hive works, so they could fly for honey, or to move the family close to strong source of nectar ....

The screen in this mode is made in the form of a graph, since the bees' signals are not stable and it takes some time to see the main trend. They are not stable during the day and at different times of the day. The graph has many sharp jumps, which depends on the number of bees and the work they perform.

The chart characterize the state of bee family as follows :

- If the graph is red, and is situated at the top of the screen, then the family is in the process of building up strength. The work of such a family on commodity honey harvest is unlikely possible.
- If the graph is red, and is situated near the zero line, then we can say, that the family is close to the working state. The process of building up the forces in the final stage and the use of commodity honey is possible.
- If the graphical is white and is situated near the zero line, then we can talk about the transition of the family to the working state. The family continues to build strength, but this process is in the final stages. The family can start using commodity honey harvest.
- If the graph is white and is situated at the bottom of the screen, we can talk about the working state of the family, and its full readiness to use commodity honey harvest.

- The larger the amplitude of the oscillations of the graph down, the more possible usage of commodity honey harvest at the moment.
- The larger the amplitude of the oscillations of the graph upward, the less possible usage of commodity honey harvest at the moment.
- The less fluctuation in the graph, the more uniformly all works are done in the family, the less bees are changing the types of activity, depending on the need. This indicates stability of the indicated ratio, and respectively, indicates stability of the explored state of bees' family.

It should be noted again, that indications, which you see on the chart, are relative, and may fluctuate, depending on the time of day and season. Naturally, intermediate values can occur both, during the day time, and during honey harvest season, but in general, the understanding of the trend persists.

Bearing in mind the fluctuations in the activity of bees, we have made a graph that allows us to see not a momentary state of the family, but a trend in time. Therefore, in order to obtain more reliable data, it is necessary to spend a certain time on the measurement, and to obtain a graph for a longer period of time. We usually use intervals from 5 to 15-20 minutes, depending on the complexity of the situation.

AN EXAMPLE OF CONTROL OF THE APIARY, USING READINESS FOR COMMODITY HONEY HARVEST CONTROL MODE

In our the apiary, on June 7, took place the process of control of five families. Two families were strong enough, had brood and a large number of bees and fetal queens, and also both families had honey in their stores. These are families with beehive numbers #1 and #2. Earlier, on May 14, from these families were made offshoots, after receiving prediction of our device, that the families are preparing for swarming. These are the families in the hives number # 3 and # 5. Family in the hive #8 was not divided, but old queen was deleted, and the family was given a capped queen cell, grown in the family #3.
The control, which took place on June 7, passed in bad weather conditions. In the morning and early day time, monitoring showed weak results of the work of families ,because of cold weather.

But in the middle of the day, the sun came out, and became warmer. The bees started to fly very active. Of course, the results of work for all families were different, but fully consistent with their current state.

The best results were shown by the family #2, then by the family #1, then by the family #8, then by offshoots - #5 and the worst was offshoot #3.

Personal inspection of the beehives showed, that in offshoots #3 and #5 and the family #8, all queens were fertilized, and began laying eggs. The number of eggs laid in each family does not exceed a few dozen pieces. A large number of bees were concentrated on the frames around eggs.

Nevertheless, in the absence of brood, all families got some honey. In the stores actively work the bees of the families # 1 and # 2 and somewhat worse, of the family # 8

Results of monitoring of General State of families in the evening.

Family №1

Nectar processing is weak

Family № 2

Processing of nectar is very strong

Family № 3

Active heating, brood No honey processing

Family №5

Passive state of the family. Practically no processing of nectar.

Family №8

Processing of nectar with medium force.

The result of control, using the mode Readiness for Work on Honey Collection

19-30

The condition is close to the working.. Family can use honey flow

19-40

Working state. of the family. The family works on commodity honey collection

19-40

Family is in the process of building up the forces. Use of honey for its own needs

17-57

Family in the process of groth. Use of honey for its own needs.

18-44

Borderline condition The development of the family is not complete but honey flow can be partially used for collection of marketable honey.

The results of control showed full compliance with results, obtained during personal inspection. With greater or lesser extent, honey harvest is used by the families #1, #2, and #8. Completely unprepared for honey collection offshoots #3 and #5. Their condition indicates that families are eager to build up their strength and are aimed for further development. It is possible, that their mood may change after their queens begin to actively lay eggs, and the prospect of the family's survival will improve significantly.

Further control of the apiary in 2018 with the use of these mode showed the complete conformity of the state of families to the indications of the device. After a sharp drop in honey collection and cold snaps, which lasted about 10 days, the recovery of the honey crop went in experimental families very differently. Some families kept increase the number of bees and brood, and began to collect honey well, some having eaten honey from the nest housing, allowed the queen to fill it with brood completely, creating the need to spend a huge amount of incoming nectar on feeding the brood, which made it impossible to start the commodity honey collection immediately with the appearance of nectar from the meadows. To restore the collection of honey, we created an offshoots with fetal queens from such families. This allowed the main family to switch to collecting honey.

The first withdraw of honey, produced at the end of June, gave the following results:
Family number 1 - gave about 2 mediums of marketable honey.
Family number 2 - gave 2 mediums of honey
Family number 3 and number 5 - did not give marketable honey
Family number 8 - gave about 1 medium of marketable honey

MODES INTENDED FOR USE IN THE PROCESS OF DIRECT REPLACEMENT OF OLD QUEEN WITH A NEW QUEEN

USAGE OF THE MODE - READINESS TO ACCEPT NEW QUEEN

This mode is used when the queen is replaced with a young one in the main family, as well as when creating offshoots or dividing the family in half with anti-swarming purposes. The main task of the mode, is to determine the degree of sensation by the bees of queenless, and according to this, readiness of the bees to accept new queen, or the place where the queen is absent.

At first, when we started developing our device, we decided to use Woods observations described in his patent for Apidictor. It is in this patent was described the "Singing of the Hive", which appears, when the family lose the queen, and where was indicated presence of the best time interval, when it is better to introduce new queen in the family. We used this data and the verification showed that this method works.

But recently, as we have already said, there appeared new data of European scientists, which gave us new understanding of the process, that Woods described in his patent .... So, what happens in the family after the loss of the queen, or after removal of fertile queen from the family, in order to replace it with young one, but with existence of open brood, needed for her natural recovery.

Let's return again to the ideas of Woods. In his patent for the Apidictor, he described this state of bees family as follows: "... If you removed the queen, the hive starts to "sing". You can see the energy of this signal on "Warble " indicator. When this signal reaches its maximum, the new queen could be simply introduced to the honeycomb and it will be accepted without any contrivances .... If the beehive remains without the queen for so long time, that the signal of "Singing" fades and returned to its original value, but its level slowly changes - "floats", then it will be very difficult to introduce new queen in such family. This period can lasts from 20 min to

4-5 days ...... ". So, these are the facts of the behavior of bees, set forth by Woods, and what is the reason for this behavior of bees?

We believe that everything looks like this: After the queen was taken away, or was lost by the family, besides natural anxiety and excitation of part of the bees, after a while, depending on the general condition of the family, the mechanism of the restoration of the queen will be started. The queen can be restored, if the family takes timely measures to grow new queen from larvae of worker bees.

This process has, apparently, several stages ....

The first stage - is the awareness by the bees of the very fact of loss their queen. This stage is characterized by anxiety and excitation of a part of bees, the supply of aromatic signals (ventilation with an open Nasonov gland), etc. It should be noted, that during honey harvest, this stage can be somewhat more prolonged.

The second stage - is the active preparation of bees-nurses for the laying of "fistulous" queen cells. This stage consists in a sharp activation of the bees - nurses, on the background of general calming of the in-hive works. Apparently, this preparation consists of intensive feeding of all larvae in the hive, with additional portions of food. Bees can do this, in order to give the family a chance to lay the "fistulous" queen cells, on any open brood, of any age, on any frame, in any quantity, if the old queen in close future will not return. Usually, when it comes to the survival of a species, nature does not skimp. As a result of this powerful activation of the bees - nurses, we see a signal of " singing" of the hive, or as we called it "brood care" signal, which we consider to be the sign of feeling "queenless" by the bees, and the sign of "readiness of the family to accept a new queen." Or to replace it with their own new queen, which will be received after the future laying of queen cells using the open brood of worker bees.

The third stage - is the subsidence of the signals of bees-nurses, and transition of the bees to new mood - to laying of the "fistulous" queen cells. At this stage, the family calms down, and all bees stars their usual jobs.

Thus, the signal and behavior of the bees, which we call "queenless signal", in fact, is the stage of preparing of the family for the restoration of the queen. That is why, when changing the queen, it is so important to do this during initial part of the second stage. While the bees have not yet lost faith in the fact that the queen will return back.

Methodology for the diagnosis.

WINDOW 1

On the screen you can see two indicators :
- Left indicator shows trend of correlation between the normal condition of the family (passive or working state) and the feeling of queenless. Green zone - queenless is not felt by the family. Red zone - the family feels queenless.
- Right indicator shows the signal strength of queenless relatively to the overall background. Higher the signal volume - increases the value indicated by device - the arrow moving in the direction of the red (max) zone.
- Joint arrows indicating as far right as possible in the red area means the maximum degree of the feeling of queenless by the family.

WINDOW 2

- On the screen you can see the graph, which use as data monitored on the time axis, the value of ratio between the normal state of the family (passive or working state) and the state of feeling queenless. The graph window has dimensions for 1.5 hours of continuous monitoring. After filling out the window, it is shifts. Values below zero (white) indicate a lack of queenless sensation in the family. Values above zero (red) show the presence of the signal, which means feeling of queenless in the bee family.
- It is recommended to put new queen in the family, when you see the achievement of a maximum values of the graph of queenless signal. The signal can be held from dozens of minutes to an hour. Before introducing a new queen into the hive, it is recommended to wait for stabilization of the "red cap" on the chart. And after this, insert the queen into the hive without delay!

In brief, the order of control is as follows:

1) Without deleting of the queen, turn on the "Readiness Control" mode.
2) Switch to the graph (Window 2) and watch for about 10-15 minutes. If the graph is white, then you can continue. If read - it is not good time to change the queen.
3) Delete the queen. The device continue to draw a graph.
4) If the chart passes into the upper half and becomes completely red, it means a sense of queenless by the bees. Wait for the maximum of the schedule or approach to it. This is the best time for the return of the queen. Do not wait for the return of the graph to the white zone, but be sure that you are close to the peak of red part of the graph.

In any case, the device does not make any decisions. The final decision - what to do, always make the beekeeper.

We do not recommend to use this mode, in order to determine the queenless of the family in normal everyday conditions. Acoustic signal, which is used in this mode, disappears in a short time after the loss of the queen. It can stay for a long time only if the queen is lost, and the family don\'t have young brood to make queen cells.

USAGE OF THE NEW QUEEN ACCEPTANCE CONTROL MODE.

Development of the mode Control of acceptance of new queen, we started, using the patent of prof. Eskov, but after a while our tests showed inaccuracy of his statements. We found more convincing signals and states of bees, telling us about probability of acceptance of new queen, by the bees. In our opinion, a sign of this trend - is the rapid calming of the family and its transition to its normal working condition.

This means, that disappear signals speaking about excitation of bees, and about preparation of bees for making fistular queen cells, and appear signals which can be associated with usual in-hive works, and processes associated with honey collection.

Methodology for the diagnosis.

WINDOW 1

On the screen you can see two indicators
- Left indicator shows trend of correlation between the normal condition of the family (passive or working state) and the feeling of queenless. Green zone - queenless is not felt by the family. Red zone - the family feels queenless.
- Right indicator shows trend of correlation between the normal condition of the family (passive or working state) and the negative excitation of bees, meaning that the new queen is not accepted yet.
- The value on the scale says about the power of trends.
- Green zone indicates that the negative excitation in the family and the feeling of queenless goes down and the family returns to its normal state.
- Red zone tells about the continuing of negative trends and about non-acceptance of the new queen.

WINDOW 2

On the screen you can see 3 indicators
Central indicator shows the trend of correlation between acceptance and non-acceptance of new queen, comparing the signals in the ranges, indicating the reception of the queen and the negative excitation and rejection of new queen . Indicator tells us about the strength of this trend. Color zones - green on the prevalence of the reception of the queen, red - the prevalence of the rejection of the new queen.
- Left indicator shows signal strength, meaning the reception of the queen relative to the overall background of the hive. When the value on indicator is bigger, then higher the probability of acceptance of new queen by the family.

- Right indicator shows the strength of the signal of negative excitation or the rejection of a new queen relatively to the overall background of the hive. When the value of this signal become bigger, then becomes less probability of acceptance of a new queen in the near future.
- After the queen is accepted, all signals in the hive subside. Usually this happens more or less quickly. The indicators which shows the power of the signals go to the left to minimum values, and trend indicators are in the center of the scales near the zero values.

- When we have the trend to rejection of the new queen, the signals remain strong enough for a long time. They do not fade away, but only pulsating.

WINDOW 3

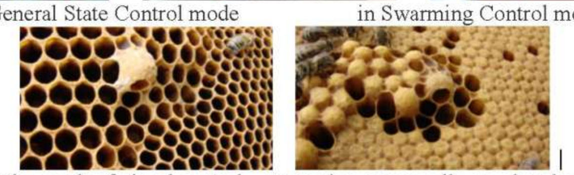
- On the screen you can see the graph, which use as data monitored on the time axis, the value of ratio between acceptance and non-acceptance of new queen, comparing the signals in the range that indicates a reception of the queen with signals in the range of negative excitement and non-acceptance of new queen.
- The graph window has dimensions for 1.5 hours of continuous monitoring. After filling out the window, it is shifts.
- Values below zero (red) indicate that the family do not accept new queen. - - Values above zero

(white) shows that the bee family is going to accept new queen.
- The amplitude values on the chart tells about the power of trends.

JOINT USAGE OF SEVERAL MODES

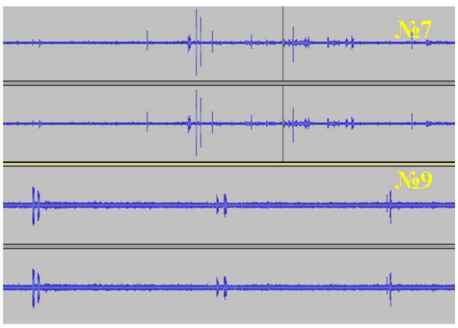
As you know - "one head - is good, but two - is much better" ... and in our case too. The joint use of several modes will allow you to understand more accurately, the state of the family, and assess the problem. In addition, some states of the bees' family become clear only when you use General State Control mode, which is the most averaged. But sometimes this becomes its minus.

diagnosis in General State Control mode   in Swarming Control mode


and the result of visual control - swarming queen cells are already made ...

Swarming control - it is advisable to start this procedure, using the Swarming Control mode of the device, and supplement it with one more test, using General State Control mode. This will help in case, when the queen cells are already laid, and the process of preparing for swarming is in full swing.

ANALYSIS OF SOUND RECORDINGS FROM TWO DIFFERENT HIVES USING DIFFERENT MODES OF APIVOX SMART MONITOR



Here we can see a screenshot, on which, in the sound file editor, we can see the appearance of two audio signals, recorded one after another at interval of several minutes, in two different hives, on a warm sunny day at the end of August. This is hives No.7 and No.9.

According to our opinion, at a glance, and aurally, these signals are distinguished only by the fact, that the first signal is slightly weaker. We can not understand other differences.

But we conducted an examination of these families, and we know, that their states are different, and after all measurements we will tell about their real state...

So, at first, we will use the basic control mode - General State Control mode. We will carry out control, using a long measurement interval. Here is the result of our measurement....

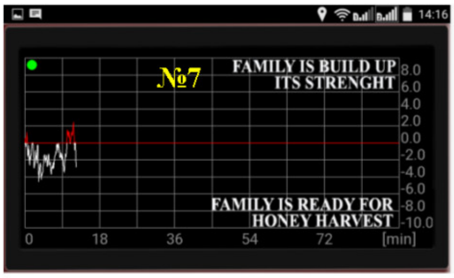
It is immediately visible, that there are differences in the composition of the signals, and diagnostic messages confirm this...

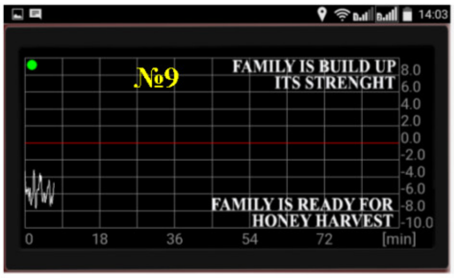
Family in the hive №9 actively collect honey and make in-hive works. All works are active and strong.

The family in the hive No. 7 practically does not work on honey collection and only make in-hive works. Apparently, it does not have enough strength to work on honey collection.

We will conduct one more check of these families using Readiness for Commodity Honey Collection Control mode. This should show general trends between in-hive works, including brood care, and works aimed at honey collection. And what is more important, we will see their distribution over time, that is, the main trend, taking place in these families. So, the measurements are carried out, and we see the result...

The measurement result unambiguously shows the difference in behavior and condition of the bees in two families.





In the beehive No. 7, bees are in the borderline state between in-hive works, including caring for brood, and honey collection. And caring for brood, sometimes prevails.

In the beehive No. 9, the bees are in working state, and can use honey harvest. The work on honey collection is not ideal, the family also has in-hive works, which are needed to be done. But honey is delivered and processed.

Thus, monitoring shows that families have different states....

Family No. 7 is trying to maintain or build up strength, using domestic stocks of honey. Honey harvest is not used.

Family number 9 use honey harvest, but not as active as we would like. And now, beekeeper himself have to determine the cause - whether this depends on the strength of the family, or on the strength of honey harvest.

Now, a few words about the families, which live in these two hives......

Hive No. 7 - This is offshoot with 4 frames of brood of different ages, and without queen. Bees must grow a new one. Offshoot is located near the main family, so most of flight bees returned to the old place. Bees practically do not fly out.

Beehive number 9 - is a small family, which was in the beginning of the summer an offshoot. It have young queen, 3-4 frames of brood, bees flying for nectar, but activity is not very high.

So you could be sure that the diagnostics that you can get using Apivox Smart Monitor fully corresponds to the state of the families. The only thing about which the beekeeper should not forget, is that the device can not replace him, but will only help him to see some things, which he can not see and can not hear by himself.

MORE EXAMPLES OF COMPLEX CONTROL OF BEES' FAMILIES IN DAILY PRACTICE, USING ALL POSSIBLE MODES OF OPERATION OF APIVOX SMART MONITOR DEVICE.

Analysis of the record. Strong family. Italian breed. December 11.

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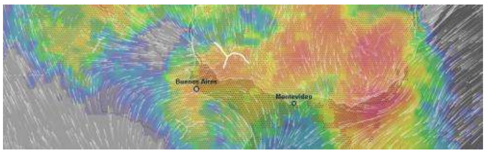


It is known that there is beginning of summer in the location of the apiary , possible swarming, on this day there is heavy rains, possible thunderstorms.

1) Analysis in "Monitoring" mode shows in dynamics the presence of signals and their correlations. Already at this moment it can be said that in the family occurs the following - there is no ventilation, the nest is heated, the strong signal of caring for the brood, there is an attempt to organize work with honey, but it is sporadic.

2) Analysis in "swarming control" mode gives a rather strong signal of possible swarming. It is possible that this is due to rainy weather. Sometimes dominate working mood. But in any case, in the presence of a signal of such strength, it is worthwhile to inspect the family for the presence of swarming queen cells in the phase of building.

swarming tendency

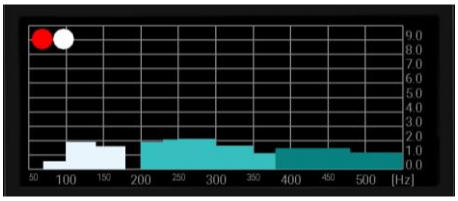
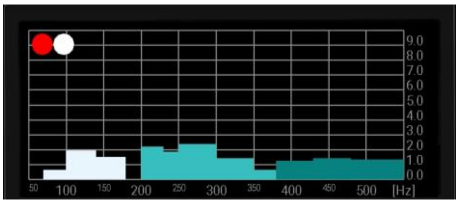
swarming tendency

tendency o start the job

3) Next check using "Brood Control" mode shows that the family spends very little time for in-hive works, while the brood care signal is very strong. This once again confirms the possibility of swarming. At the beginning of honey harvest season, family that does not collect honey and grows a lot of brood is very suspicious. It may be a sign of preparing for swarming.

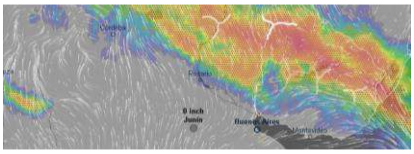
4) Testing in "Readiness for honey collection" mode confirms, that in addition to work on brood care , there are job or attempts, to organize it, associated with honey collection. But this work is very weak. The schedule does not leave the red zone. The strength of work, associated with honey collection is negligible. And only sometimes it becomes compatible with the power of work on brood care.

5) Checking in the main mode of the device - "General State Control " mode on both intervals gave result, which allow us to talk about the overall working condition of the family, but as it is seen in the diagrams, the work is very weak? a lot of bees are heating the hive... The state is close to passive. Brood care and heating are not strong enough to speak about very close swarming, but the trend is possible ....

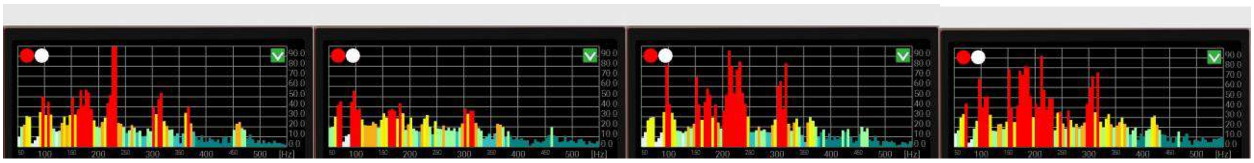
Overall result of control - In any case, this family should be examined, especially if the rest of the families of the apiary do not show such state, but work normally on honey collection. During examination, you need to look for swarming queen cells in the process of construction.

<u>Analysis of the record. Italian breed. December 12.</u>



The weather at the location of the apiary - the thunderstorms are gone and the weather is Sunny. The probability of a strong honey harvest is not great. Most likely the rain washed away the nectar.

1) Analysis in "Monitoring" mode shows, that there is a lot of signals and they are very diverse. There are small signals in the range, associated with the work on honey collection. In low-range diapason there are signals of heating and in-hive works, but they are not strong. An important difference - the presence of signal of ventilation.



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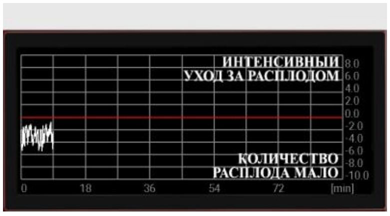
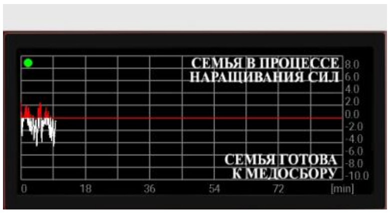
2) Analysis in "Swarming Control' mode shows border state, with the trend in the direction of work on honey collection. Apparently, the improvement in the weather affected the work of the family. But periodical returning the arrows to the yellow area, indicates the desirability of inspection, if other families
are busy working on honey collection. If all the families are in the same state, we can hope that this is only a reflection of the weak nectar production after heavy rains...

Borderline state

the deviation of arrows in the direction of work on the honey collection, but the strength of the work is not great

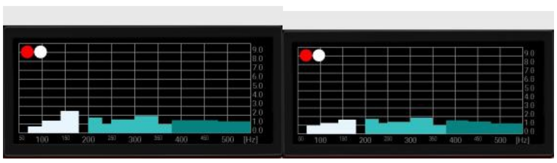


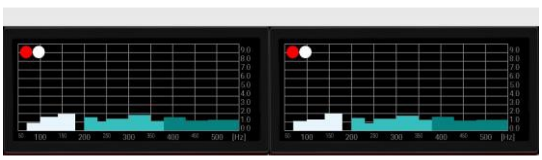
3) The check using “Brood Control” mode, shows that the presence of in-hive works made the brood care signal not the main signal in the hive. Apparently, the intensity of work on brood care and of other in-hive works, are about the same. In this mode, the trend towards swarming is not observed.



4) Testing of the family using “Readiness for honey collection” mode, indicates a honey harvest, which has appeared in nature, but it is used partially for the needs of the family, and partially, for collection of commodity honey. In any case, the use of honey collection is weak.

5) Check using "General State Control" mode on both intervals, showed almost identical results. The variability of the signal in time is not high. Diagnostic of the state of the family is the following - Increased ventilation associated, as a rule, with nectar drying, active heating of the hive. The work signals are in the range, corresponding to the work on honey collection. But the strength of these works is not very high.





Overall result of control - The family shows a low working activity. The state is quite balanced. Swarming is unlikely possible in closest time.

A few words about heating signals

We managed to peep a very interesting thing ... In the upper photos you can see a cluster of bees below the frames in the left side of the hive, in a family, in which the young queen just started laying eggs. You see that group of bees, which creates a protective shell and warms the brood from below. Previously we used to think that these were passive bees. Now we believe, that this is a group of older bees, who participate in the thermoregulation of the nest in two variants: passively - creating a shell that retains heat from their own bodies, and actively - generating heat with creation of low-frequency sounds. When our device Apivox Smart Monitor hears these bees, it gives a message about additional active heating, which in summer is usually required only if there is a lot of brood in the family. This signal is especially strong when there are queen cells in the family. In winter, this signal is present almost constantly, saying that the bees are alive and warm themselves.

The bottom photo is a visible confirmation of our words ... This is one of those frames that the bees have warmed up ... Fine sealed brood confirms the magnificent quality of the young queen ....

TAKING MEASURES AGAINST THE PREMATURE EXPANSION OF THE HIVE OF BEE FAMILY, BASED ON INDICATIONS OF APIVOX SMART MONITOR ACOUSTIC CONTROL DEVICE.

Experimental family of bees after personal control, which showed 6 frames of brood, was expanded with additional body-box, with combs and frames with honey (8 frames in total) and pillows along the edges, which was placed atop of the first body-box. It was assumed, that the strength of the family was sufficient for such a procedure.

But it was not so. Control, carried out in three beehives participating in our experiments, after 5 days showed the following picture - Hive No. 8 - worked perfectly, Hive No. 5 worked perfectly, in general, even better than No. 8. In both families there was a slight heating of the brood, almost at the level of background values, and good work on honey collection. The experimental family differed radically from them. The main job in the hive was heating of the brood. (Additional heating) The flight of bees was much weaker. It was decided to inspect the family.

№8


№5


Exp.

In the process of examination, there was found 9 frames of uneven-aged brood. There was a lot of sealed brood, which caused the need for heating, because of the fact, that increment of volume of the hive after installing the second body-box worsened the temperature conditions in the nest. The second body-box was removed, and after a few hours the control was repeated in two modes.

Exp.


Exp.

In the Brood Control mode our device showed, that the family intensively work with brood. And this is understandable - there was a lot of open and sealed brood in the nest. At the same time, our device, in General State Control mode, showed that the number of bees that had been engaged in heating of the nest was much less than before, and disengaged bees switched to the other work inside the hive.

This fact showed us, that expand of the hive was made too early, or it was better to place second body-box under the first one... Thus, the situation was fully understood and corrected, due to diagnostic, made with the help of Apivox Smart Monitor.

INSPECTION OF THE FAMILIES USING APIVOX SMART MONITOR IN WINTER MODE

Today we examined all our families from the upper part of the hive, without taking the frames off the body-box. The main goal was to understand how and where the winter cluster is formed ...

Э-1

8-1

5-1

Э-2

5-2

8-2

After this inspection, which cooled the nests of the bees and greatly disturbed them, the Apivox Smart Monitor app was used to check the general state of the bees and to assess the presence of open brood in the nest. We used the General State Control mode in winter variant and the Brood Control Mode.

E-1

Beehive E-1. According to the first screenshot, after an external examination at a temperature of + 7C, the bees began emergency heating of the nest. At the same time, there are usual in-hive works. The second screenshot explains, why such a strong heating was required - there is still an open brood in the nest. The graph is high enough in the red zone. Apparently, a large number of bees in the hive allows to continue to grow brood, although in significantly smaller volumes. This is the reason why the free fall of the mites is still does not subside.

8-1

Beehive 8-1. According to the first screenshot, we very much bothered the bees of this family. The excitation signal is very strong. But overall state of the family is normal. Emergency heating is not required. This indicates a high probability of the absence of an open brood. The family is engaged in its internal affairs. The second screenshot shows that there is no open brood or very few. The chart is in the white zone, although not very deep.

5-1

Beehive 5-1. According to the first screenshot, the family is disturbed and chilled. There is emergency heating. But it is not very strong. In-hive works are proceeding as usual. The second screenshot may explain the reason for the emergency heating. The family seems to have small leftovers of an open brood. The chart sometimes goes into the red zone, although quite a

bit.

E-2

Beehive E-2. The first screenshot shows that the family was disturbed. There is excitement of bees. And there is also an emergency heating of small power. Bees restore thermal conditions in the nest. According to the second screenshot, there is no open brood or there are minor residues. The chart does not leave the white zone, although sometimes it approaches to a zero mark.

5-2

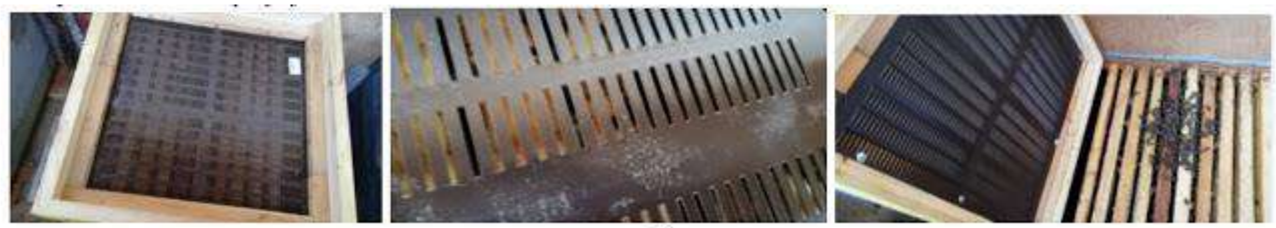
Beehive 5-2. The first screenshot shows that the bees have already calmed down and are in normal condition. The second screenshot shows that with a high degree of probability there is no open brood in the family. The chart is completely in the white zone, but the pulsation of the chart is noticeable. This can indicates the possibility of the care on open brood, but of very insignificant force.

8-2

Beehive 8-2. The first screenshot indicates that the family is in good condition. Activity is not high, but they do not use the emergency heating. The second screenshot indicates that there is no open brood in the family or its number is not significant.

So, we can state, that in no one family except E-1, there is most likely no brood at all, or its quantity is not significant. If it exists, it should be only the remains of sealed brood. There is no, with high probability, an open brood. The presence of brood in E-1 beehive, will for some time, provoke a free fall of Varroa mites, which can still multiply in the remaining brood.

I would like to note the work of the new type of inner cover. So far, its work can be considered successful. Due to the plastic lattice with gaps of 2-3 mm, normaly used for collecting of propolis, our inner cover makes it easy to carry out acoustic control of bees, although the light somewhat interferes with them, to carry out visual control of wintering bees without opening the hive, and then, if necessary, during frosts, will allow you to put a pillow of moss on top of it to remove metabolic moisture, which can condense at the top of the hive ...



It should be noted that the lattice is about 2 cm above the frames and the bees do not close the holes with propolis. We are also integrated a wired microphone into the middle of inner cover, which allows us to control bees in winter and summer without lifting the roof of the hive.

Personal inspection confirms results of diagnostic, made by Apivox Smart Monitor

Yesterday we, once more time, checked the correspondence between the acoustic signals, which accompany brood care, using Brood Control mode of Apivox Smart Monitor, and real presence and quantity of open brood in the families of our experimental apiary...

E-1

1.1 1.2 2.1 2.2 3.0

Family E-1 (this family lives in the hive of our new design, the goal of which to eliminate Varroa mites in the family)

Pay attention to this group of screenshots.. Here is clearly seen that in the middle of the day the bees were actively working (1.1, 1.2), the bees paid very few attention to the brood care. By evening, the work had weakened, and the volume of brood care had relatively increased (2.1, 2.2) and was almost equal in strength, to the rest of the hive works. The last chart, obtained late at night (3.0), shows that all in-hive works has weakened, and open brood care has become priority work in the family. But, accorfing to our chart, we can say, that there is not a lot of open brood in this family. The chart is close to zero line...

1.1 1.2

E-2

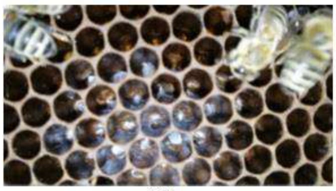
Family E-2

In the hive E-2, the situation is somewhat different. Open brood care signals are not visible at all ....

In screenshot 1.1 it can be seen that the bees are quite active in collecting honey. Screenshot 1.2 says, that there is very few works on open brood care. Other in-hive works prevail. And indeed it is. Inspection of the family showed the presence of approximately 3 frames with sealed brood, and almost complete absence of an open brood. That is why the signals of open brood care are so small, or completely absent during daytime.

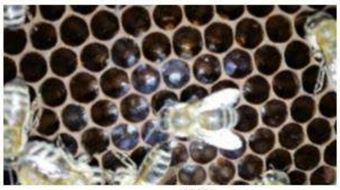
5-1

1.1



2.3

2.1



2.2

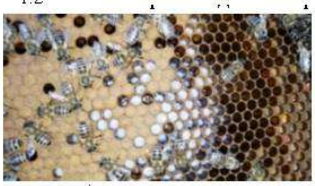
Family 5-1

Screenshot 1.1 taken at the beginning of the evening suggests, that the family should have an open brood. When examining the family, at first, it seemed that there was no brood at all.... This is clearly visible in picture 2.1. But the graph spoke about completely different situation... This is why, we took a couple of shots quite close, and afterwards, on the computer, at high magnification, we saw that our device did not make a mistake !!!!! Open brood is really exist !!!! Pictures 2.2. and 2.3 clearly confirm this. Although there is not a lot of cells with open brood and the eggs and young larvae are not yet easily noticeable, but they are exists! Apivox Smart Monitor was right, as usual !!!

1.1

1.2

5-2



Family 5-2
Thease two charts were received at different time. One of them was received in the afternoon, when the bees worked actively, collecting honey, and the second - late in the evening. Diagram 1.1 shows, that there are times when work is maximized, and there are times when brood care appears in the family, but its strength is not enough to become the main work in the hive. Late in the evening, when the bees no longer fly for honey, the work on open brood care periodically become the main work in the hive. Diagram 1.2 shows this quite obviously. Everything speaks for the fact, that the family has an open brood but its emount is not very high...

Personal control of the hive showed, that there was a certain amount of sealed brood on 1 frame, and a rather large amount of open brood, on two more frames. There was found eggs and larvae... This perfectly confirms the readings of our device Apivox Smart Monitor.

8-1

Family 8-1

Despite the late evening hours, there are no any signs of open brood care. Thermometers are also recorded very low temperatures in the hive. Most likely there is no brood in the family. Personal inspection was not carried out.

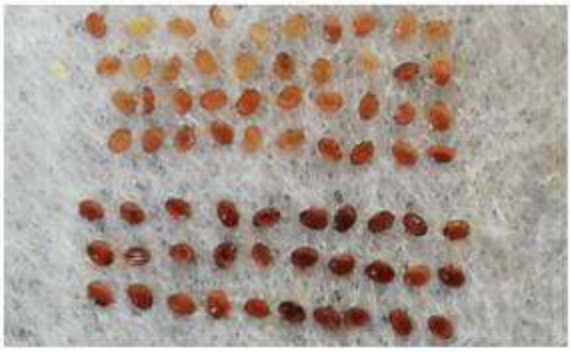
APIVOX SMART MONITOR AND THE MITES

It was conducted routine monitoring of families. The weather is cold. In the afternoon + 7-10C, but even at this temperature, several bees (of Carniolan breed) from almost all families flew out in search of nectar. In addition, tests were made for the presence of an open brood. This will allow to correlate the consist of free falling mites and the estimated presence of brood residues ...



Beehive E-1. 70 mites in 5 days. The ratio of mature to immature mites in free fall is 30/40.

E-1

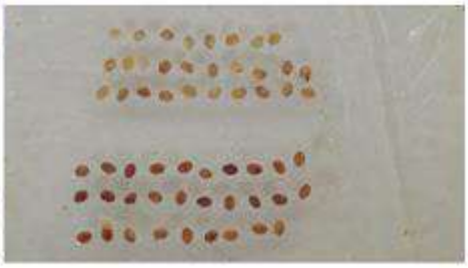
The situation in the family has changed. It seems that brood withdrawal is ending.

There is practically no open brood. The fall of an immature mites comes from the last sealed brood. The state of the family is normal.

If you compare the readings 5 days before and now, you can see the difference! The first screenshot shows the unambiguous presence of an open brood, the second tell about the possible minimum residues of open brood or full absence of it ... Given that this is autumn, and there is practically no work in the hive, the graph, although white, is close to the zero line.

Beehive 8-1. 57 mites in 5 days. The ratio of mature to immature mites in free fall is 17\40

8-1



Diagnostics has not changed compared to the previous time. At the same time, a large fall of immature tick when diagnosing the absence of an open brood suggests, that most likely, there was the last mass exit of young bees from a sealed brood ...

Beehive 5-1. 1 mite in 5 days. There are no immature mites.

5-1

This family is the smallest. Since it remains with the old queen, the brood was given to it less than to the other part when the main family was divided, and she gained not too much strength. In fact, only 6 out of 10 frames are covered with bees ....
Despite the fact that it got colder, the brood care signal has almost disappeared. Now, there are no "red caps", from time to time appearing on the chart .... And a small peaks of red color appear due to the general weakness of in-hive works, because the graph is too close to zero line.
Apparently there is practically no brood, which is confirmed by the fact, that there is too few mites and all are adult, that is. This mean, that the mites were not in the brood, but on adult bees.

Beehive 5-2. 20 mites in 5 days. The ratio of mature and immature mites in free fall is 10/10.

8-2

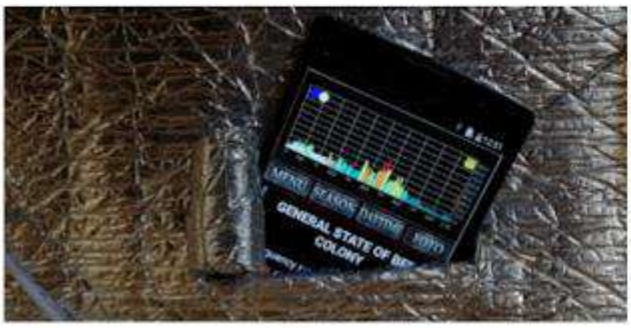
Diagnostics show that there are no differences from the previous period. There is no open brood or very few. A free fall of immature mites indicates the outcome of young bees from the last sealed brood.

Beehive 8-2. 10 mites in 5 days. There are no immature mites.

8-2

Diagnosis once again showed the normal state of the family and the absence of an open brood. The free fall of only a mature mites, indicates the absence of young bees coming from the sealed brood, which is also does not exist ... All mites falled from adult bees.

The usability of our new inner cover of the hive is once again confirmed ... together with an insulating coating made from foamed polyethylene with foil to reflect heat, which can be rotated by the reflecting surface inward.



In addition, you can make holes in it for better acoustic contact, or put your smartphone on the lattice under it.

In addition to all these recommendations, we suggest you to follow our films on YouTube channel. We always talk about new tests and about new experience in usage of old methods. There is always something to see and learn, for the users of our device.

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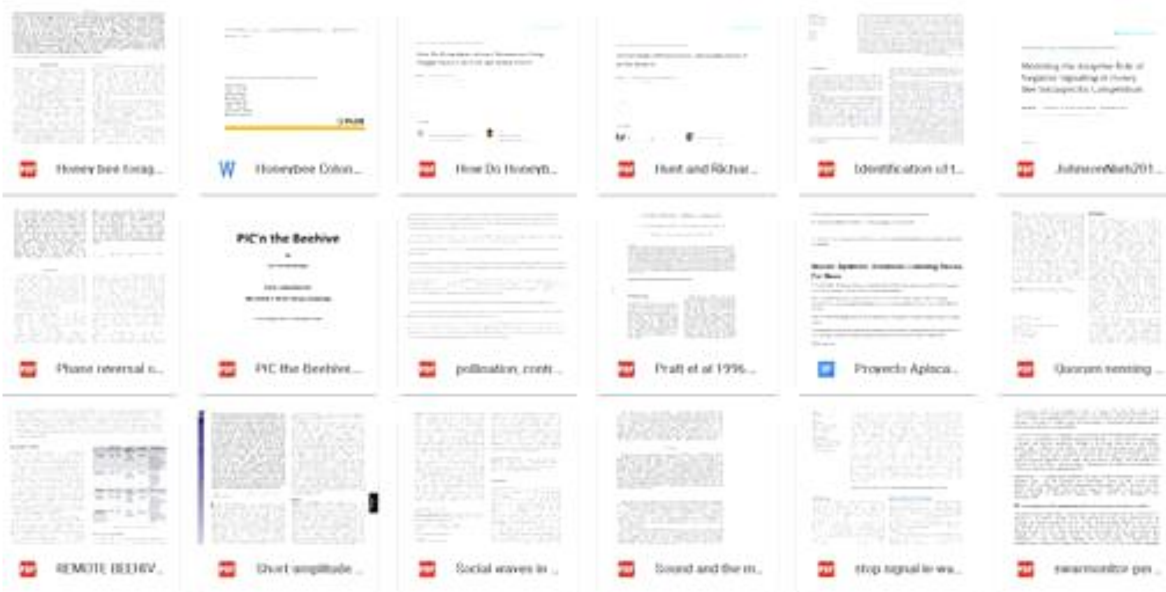
Títol de l'obra: **New theory of communications in bees, and the possibility of deciphering the language of bees. Use of new ideas in the acoustic control device Apivox Smart Monitor**

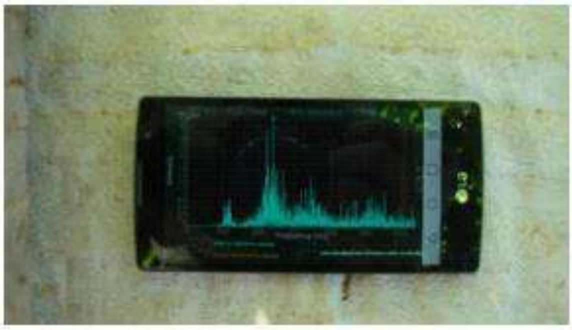
THE HISTORY OF DEVELOPMENT AND NEW RESEARCHES

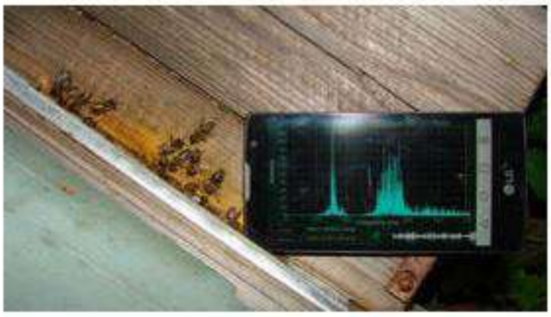
THE YEAR 2015

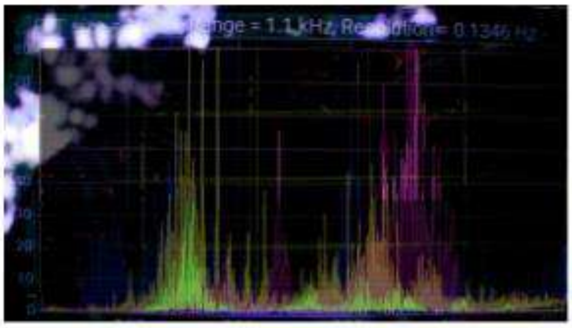
The development of APIVOX AUDITOR began in the spring of 2015 with selection of scientific works related to the topic of acoustic control.
As it turned out, there was not too many such a works. Most of the works were done by scientists from the United States and several works were from Russia.



For the whole summer we studied scientific materials, and conducted testings using a conventional spectrum analyzer. But the results were mediocre enough, although they confirmed that the signals really exists, and they are divided into several main groups. The change of signals during the day was noted.



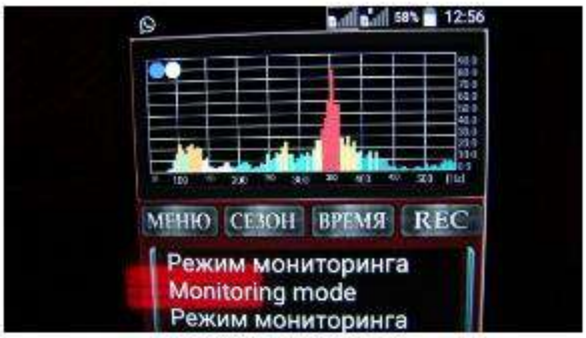




In September 2015, the direct development of algorithms and the writing of the program began. In November 2015, we began verification of the parts of the program in real conditions.

THE YEAR 2016

Next tests were conducted in January 2016. We checked Monitoring mode and General State control mode.



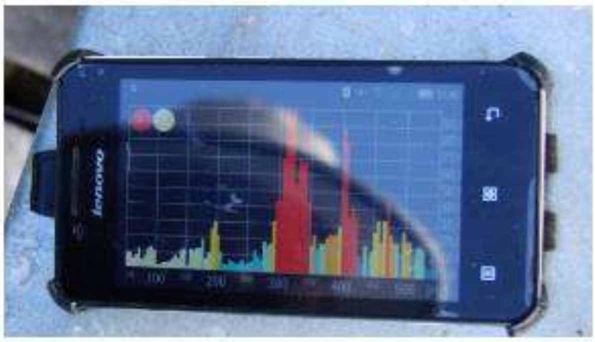
In the beginning of March, the development of the program in its primary form was completed. Now it was required to carry out mass measurements to understand the correctness of the algorithms and the work of interface of the device. But how can this be done? In Russia was still winter. It was decided to continue works in Spain. Spring, and honey harvest in Spain have already begun in February. This is why, our researches has moved to 5000 kilometers in the direction of the south.

The first measurements took place at the small urban apiary in Tarragona. Here it was possible to check the state of bees, associated with the swarming process. Almost all hives had swarming queen cells. Here, when testing the device in Swarming Control mode, we realized that there is an intermediate state when the bees subsides after the laying of swarming queen cells. In future, our device had to take this into account.




Then we moved to a small apiary, situated far in the mountains in the province of Priorat, which is famous for its red wines. Here the bees worked on the flowers of rosemary. The work was weak. The General State Control mode was tested.

The next testing was carried out in the province of Tarragona, on the apiary where reared queens of Iberian bee breed. Swarming Control mode and Monitoring mode was checked.

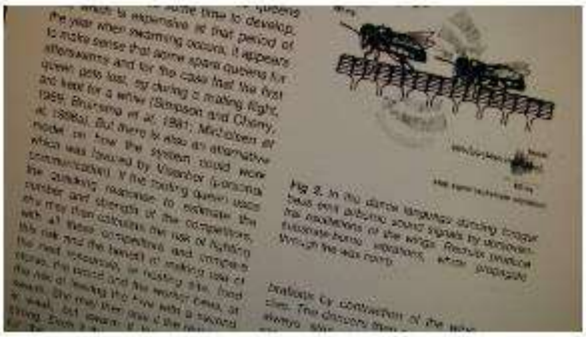


The next place of testing was the apiary in the valley of the river Ebre, on which were placed nucleuses with young queens. Here, the results of our measurements confirmed, that the size of the family does not matter for proper diagnosis of the general condition of the family, thanks to our algorithm which allocate useful components of the signal.

The next place of testing was a commodity apiary, located close to the blossoming oranges in the valley of river Ebre. Here we tested, General State control mode, and Swarming Control mode, which gave good results - three out of four diagnostics of swarming state, turned out to be correct. Testing of the Readiness Control mode has shown, that the algorithm is needs to be changed.

The next place of testing was a commodity apiary actively working on honey collection in mandarin gardens in the province of Alicante. Here it was possible to obtain results characterizing the high flying activity of families. Only the General State control mode was tested.

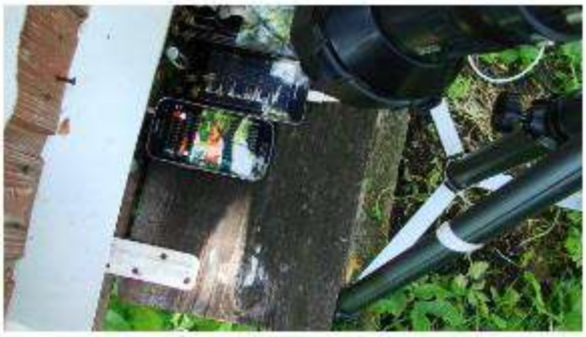
Obtained information was enough to correct the program and improve some of the modes. Improvements have affected the General State Control mode. The Readiness Control mode was adjusted. There was found and studied new scientific works, concerning acoustic control of the bees.

By the time of completion of work on the correction of the program, the spring had reached Russia. Now it was possible to study the Swarming state of bees, and to make replacement of queens using Readiness Control and Acceptance Control modes in Russia. In Spain, the summer heat began.


The first tests of the device in the Readiness Control mode, showed that the signal exists, but the program needs to be altered in order to reliably fix the "hive singing" signal.


The program was adjusted and testing of the device with a new algorithms and new capabilities began. In particular, with the graph of the signal change in Readiness Control mode.

The next stage of testing was held in the apiary of the Russian Research Institute of Beekeeping in Rybnoye, Ryazan. The task was to obtain a large number of measurements in General State control mode, in the period of honey collection. Here, the presence of passive bees during the honey collection was fixed and scientifically explained.




All the further summer and autumn the device was tested in the modes of Readiness Control and Acceptance Control, as well as monitoring of the condition of families using General State Control mode. The last correction was successful. There were several direct replacements of the queens with good results. We made a lot of videos, that formed the basis of many films.




Was written a few articles for Russian beekeeping magazine

In the late autumn, we started to test our device in winter mode.

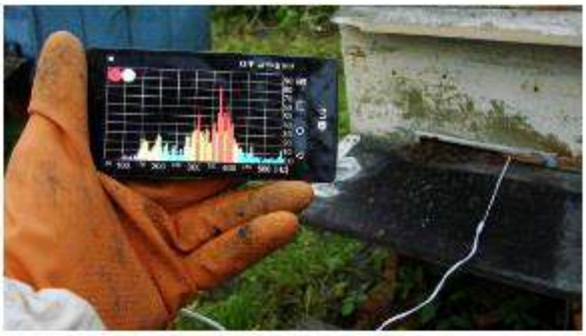
THE YEAR 2017

Testing of the device in winter mode continued at the apiary of the Russian Research Institute of Beekeeping, where we've got the possibility to test three groups of wintering bees in the premises and on the street. As a result of testing, the winter mode was adjusted . Basing on the results of the monitoring, we made recommendations concerning the features of winter control of bee families.

In June, a pilot test of the bee family was conducted in urban conditions. The results were excellent. The control did not cause aggression of the bees. The results were very interesting.

Further on, during summer time, there were conducted a lot of tests with different types of microphones in different modes.

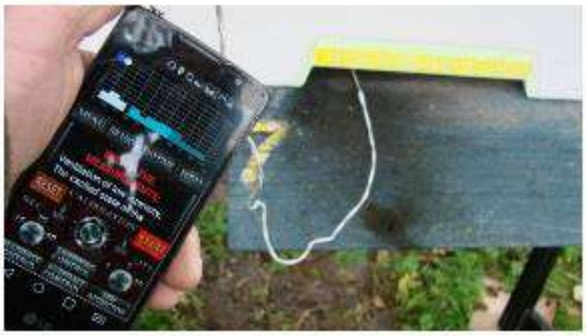
In general, the summer and autumn of 2017 were devoted to improvements in the capabilities of the device in Monitoring mode and General State Control mode, regarding the diagnosis of problems with the queen, and monitoring of the working state of bees' family.



New visit to the apiary of the Research Institute of Beekeeping helped to collect a lot of additional statistical information.


During the late August honey harvest, a study was made of a set of signals, accompanying the work on the collection and processing of honey.


New testing of bee families in winter mode began In the autumn of 2017. The bees were placed on the street in the pavilion.



THE YEAR 2018

In February and March 2018,we monitored the families, hibernating in the street in the pavilion, using microphones inserted in the hives. Some features of control of different bee breeds in cold weather conditions were revealed.

In March, we began tests, the purpose of which was to determine the relative number of brood in bee families. These studies became possible after a serious theoretical studies, based on the researches of European scientists. Preliminary results showed the possibility of such a diagnosis in principle.

Today we conducted new tests, devoted to determining of number of brood in the bees families. We tested three family of different power. The strength of the signal depends on the number of bees in the family, and the proportional number of open brood, as well as on the strength of the honey collection and the ability of the family to use it.

The whole May was devoted to obtaining new data on the use of the device in Swarming Control mode. As always, the device revealed a propensity to show borderline diagnosis already in the beginning of the swarming process, at the stage of construction by bees of swarming queen cells.

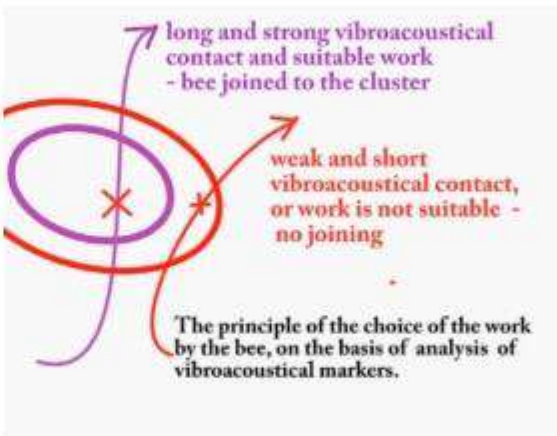
In addition, were conducted new tests, the main goal of which was to find the part of the family, where remained the queen, after division of the family in half ,without searching for the queen. Testing was successful. The location of the queen was found with high accuracy. On the base of materials of control, it was made video.

In our small workshop was made an observational beehive to conduct experiments with the goal to identify the correspondence of acoustic signals to certain actions of bees.

At the end of July, once more time a series of tests using the hive with glass walls was conducted. These tests showed the possibility of determining the kind of work performed by the bees, according to the sounds emitted by working bees. During experiments was obtained a clear separation of the signals in the brood zone and in the honey processing zone of the nest.

Based on the data obtained in the transparent hive, as well as thanks to the results of other observations, was developed a new theory of communication of bees using vibro-acoustic signals.

n the first days of August, with the help of new version of the program "APIVOX SMART MONITOR" was carried out testing of all families of experimental apiary. During this testing, according to our opinion, was confirmed the possibility of correctness of our new theory of communications in bees...



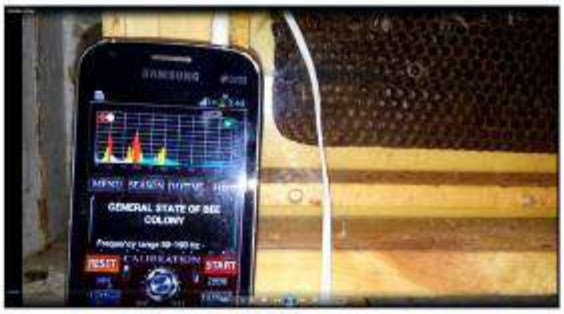
In September we worked with our observation hive and the rest of experimental families. And we've got some new results....

19-51 Immediately from apiary... We place the hive in cold room. All bees with folded wings. It's quite warmly inside our observation hive ...

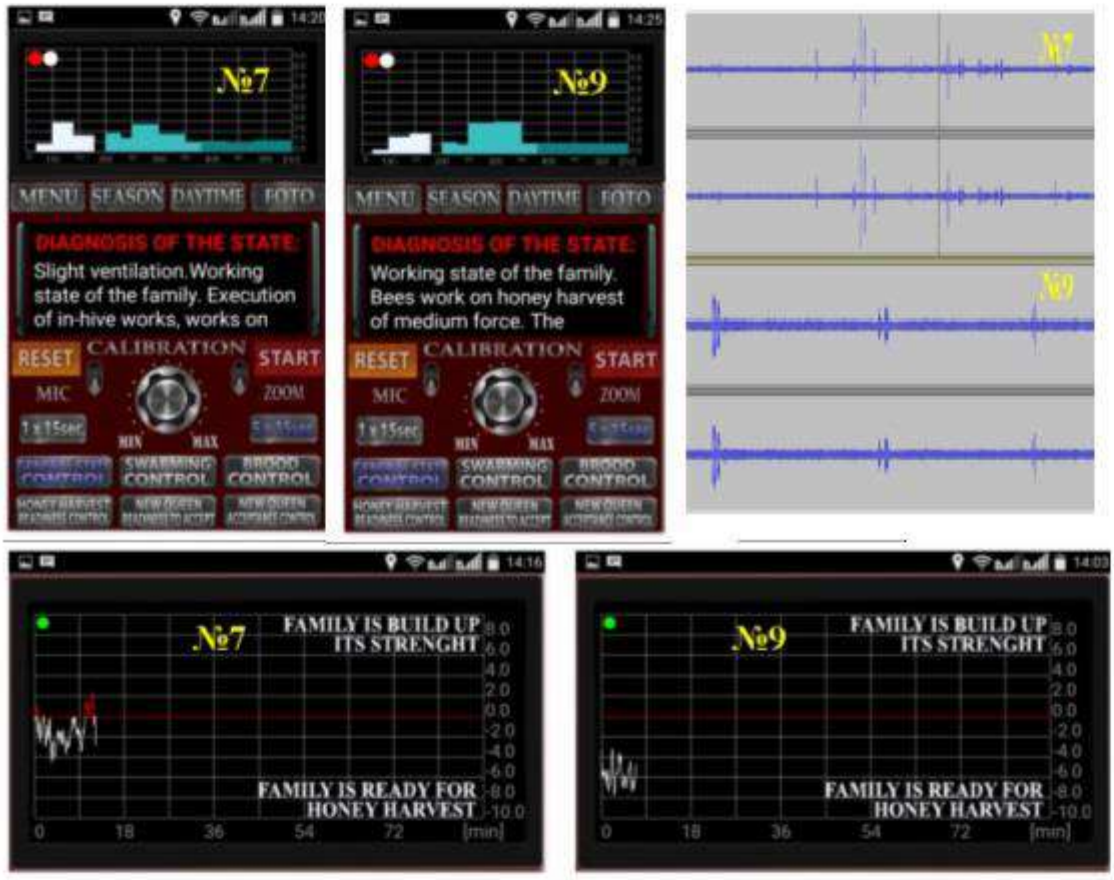
20-23 We can see the bee flapping her wings... she is heating and aerating the brood. This is the third level of heating. When the bee generate more heat and use convection to move it to needed places...

19-57 We can see bees with slightly spread wings are already working - they heat the brood. The wings are in a position of mechanical fixation, allowing the thorax muscles to vibrate, producing heat, without flapping of the wings... This is the second level of heating.

20-23 We can see signal in the lowest range of ventilation... Less than 100Hz. This is the range of conditioning, as we called it... When the bees use convection for spreading of heat or cold which was taken off her body by moving air... We think, that this confirms our theory of conditioning of the bees' nest.



In September, we analyzed sound recordings from two different hives, using different modes of the Apivox Smart Monitor. On the picture you can see the appearance of two sound signals, recorded at intervals of several minutes in two different hives on a warm sunny day at the end of August. In our opinion and hearing, these signals are distinguished only by the fact that the first signal is somewhat weaker. We are not able to understand other differences.
But we conducted an inspection of these families, and know that their condition is different. So, for the beginning, we use the main control mode - Control of the General State. We will carry out control on a long interval of measurement. We get the result. Measurements in the General Condition Monitoring Mode and in the Readiness for Honey collection Control Mode showed significant differences in the condition of families. One of them is busy with providing its survival, the other is actively working on honey collection.
The result is absolutely correct. One family - queenless offshoot with 4 frames of brood, and without bees which can fly for nectar collection, the second - a offshoot with young queen, which works well and later, gave 20 kilograms of honey.



In October we conducted one more experiment, with the main goal - to control vibro-acoustic signals of bees in the state of the wintering, as well as signals which appear in the process of transition of bees' family to the active state. In addition, there was elaborated, the procedure of assistance to the bees' family during wintering period, with its shifting to the active state, with careful monitoring of the acoustic background of the family, and after the bees could change place and get food, with subsequent return to the state of hibernation.
All parameters of the bees state were controlled, from the phase of beginning of active works and ventilation, till shifting the bees to the passive state after they did all needed works. We could observe the work of the queen and her retinue... and care on brood... And after all, slow transfer to the state of hibernation.
The technique of help for wintering family has fully justified itself. Moreover, it was once again checked and fixed the composition of the signals, accompanying the transition of the family to the active state, similar to the spring one, when the sun begins to warm the hives.

At the same time, we made our best for popularization of the app and the method of acoustic control in the international beekeeping community. It was written a lot of articles in the scientific journal of the European community. We worked with beekeepers from the United States and Romania.

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Acoustic control of bee families. One more step forward.

Contributed by: private researcher

A new technology of control of bee families, named Apivox Auditor, based on the acoustic signals, which they generate, showed excellent results in the second season of its testing in apiaries. New algorithms for allotment of useful components of acoustic signals of bees, and the creation of table of states of bee's colony, based on scattered data received by researchers from Britain, the United States and Russia, gave stable and quite reliable results.

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Features of acoustic control of bees families. Diagnosis of swarming state according to the quantity of passive bees in the family.

Contributed by: individual researcher

For today, there were many attempts to make metodics of prediction of the beginning of swarming in the familes of bees. To do this, scientists tried to use different methods of obtaining data, and mathematical processing of these data. But the simplest and most effective was method of acoustic control, based on ideas of Prof. Eskov and supplemented with new algorithms for obtaining and processing of received data, created by engineers of Apivox Auditor team...

Diagnosis of swarming state is based on the theory, that the basis of swarm is always a young bees, which are not involved in the works of the family. That is, passive bees. These bees are not ready to go on a fight for the honey, or there is no honey in nature, but they do not work inside the hive, too. Neither caring for the brood, no processing honey. So, it occur an imbalance in the family, provoking the bees to transition to the natural

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Beekeeping magazines has published a couple of new articles with materials of our work. https://www.beeculture.com/product-reviews-4/?fbclid=

Bee Culture

The Magazine of American Beekeeping

we understand their language? Likely not, until now. Most beekeepers know colonies can hiss, queens can pipe & workers do their waggle dance. But did you know there are many other sounds that the colony can make in order to communicate? Colonies warble, wave, moan, crackle, plead, quibble and rip a quilt. The Bees are always communicating with each other. We just don't know how to interpret their detailed communication system, until recently. What if we could "listen in on" their conversations? If we could "eves drop" in on the colony, I wonder what we'd learn? Does such a tool even exist?

Yes! It's called the **"Apivox Smart Monitor"**. This is a multi-function "listening app", able to interpret the colonies communication and then translate this information back to us, in the form of dials and graphs. Not found in traditional app stores. Custom written to your Android device; cell phone or tablet. Apple IOs is too restrictive for recording sounds, sorry. A 4gb download. Comes with a detailed Operators Manual. Using a Bluetooth ear piece, slipped into the porch opening, synced with your device and the Apivox app. Apivox is a standalone app, no need for internet connections.

Benefits are many; we get a three weeks heads up on swarming condition, before a queen cell ever appears. We can determine queen rightness, or absence. We're able to determine if the bees are working on building honey reserves. In Winter we're able to determine if CO_2 levels are too high and the colony is stressed. We're able to determine queen acceptance, or rejection. Able to determine a honey harvest is ready. Determines intense brood rearing or not. And much more!

If you'd like to learn more about the Apivox Smart Monitor, Cost is: $40 and can be ordered through ***ApivoxAuditor.com***, Developers website: ***ApivoxAuditor.com***.

Developers name: Serjio Glebskij.

Our website: ***www.littlecreekbeeranch.com/Apivox-Auditor.html***

In November we formulated the main ideas and started the development of WORLD-WIDE SYSTEM OF DIAGNOSTIC OF THE STATE OF BEES' FAMILIES, ON THE BASIS OF ANALYSIS OF VIBRO-ACOUSTIC SIGNALS EMITTED BY THE BEES, USING APIVOX SMART MONITOR ALGORITHMS

December were devoted to theoretical work. Our communication theory has been substantially refined and new hypotheses were formulated... All this will allow us to improve our application. It is possible that thanks to our new ideas, next year we will be able to make a new mode for those beekeepers, who engaged in breeding queens.