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Electronic sensing and identification of queen bees in honeybee colonies

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Abstract: ***This paper discusses the acoustic sound recording arrangements made for sensing and identification of swarming bees and queen bees in honey bee colonies. The distinct characteristics of sounds made by the queen bees are introduced and compared with those emanated by worker bees. A comprehensive frequency analyses are given. It is shown that queen bees emanate sounds at relatively high frequencies. An attempt was made control the behaviour of queen bees by Computer generated simulated sounds. The playback and artificially generated sounds were observed to have some effect on the bee behaviour. This study was conducted to remove bees from the hive and for the rapid identification of the queen.***

1. INTRODUCTION

During the removal of honey, chemical repellents such as Phenol (Carbolic Acid) and Benzaleyde are used by bee keepers to clear bees from the hive. The use of such chemicals are not recommended, and are banned in some countries because of risk of contamination. As a result bee keepers resorted to other methods such as brushing bees off honey combs or using electric air blowers, resulting in depletion of stock and reduction in honey production in the next round. These methods demand more manpower and consume more time than chemical methods. The authors of this paper have been researching into different methods of clearing the bees from supers Their methods are based on much gentle biological phenomena of honey bee behaviour. One method involves the creation swarming conditions to encourage bees to leave the hive, by inducing them to swarm [1]. Another method is by the imitation of the queen bee behaviour in the swarming situation. This method is used also in finding queens rapidly. In this paper, some results obtained in second method are reported together with field applications.

At present, most commercial bee keepers requeen each hive annually to increase honey production, the beekeepers visually search to find the queen bee in the colony. It needs trained eyes for successful identification and may also take up to 25 minutes per queen bee per colony. It is well known that the queen controls the colony. She dislikes competition and will not allow any other queens in the hive. In order to eliminate competition it uses various sensing mechanisms to identify the competitors, such as: odour and sound recognition. For example, during swarming time the response of unhatched queens to the sounds of newly emerged queens determines whether further swarms are issued or if the unhatched queens are to be destroyed. [2], [3].

Honey bees both emit and respond to acoustic sounds. Their communication by sounds has attracted many researchers in terms of acoustics [4], [5], [6]. It has also been shown that bees are able to detect low frequency air-particle oscillations from infrasonic frequencies up to 500 Hz [7]. In literature, experiments conducted generally indicated that acoustical, vibrational and other communication signals generated by honey bees are very complex. However, many researchers have clearly demonstrated that depending on the situation and message to be conveyed, the nature of acoustic waves emanated vary in frequency, amplitude, phase and beat rates.

This study concentrates on the sounds made by the queen bee. A computer based system is developed for recording and for playback of the sounds generated by the bees. Acoustic sounds have been recorded, analysed, modified and played back to control the behaviour. Since this project involves recording from biological specimens, the response during a recording session is not guarantied. Therefore the results, presented here, are by no means comprehensive for at least three reasons: 1) difficulties in experimental techniques of isolating of targeted sounds emanated by individual bees in a beehive, 2) the nature of sounds from each bee vary depending on the function of the bee within the social structure and the message to be conveyed. It is extremely difficult to design experiment which can identify and observe a particular behaviour and associated sounds in a colony situation, and 3) the sample of sounds emanated by the bees need to be sampled again for analysis and reconstruction. The sample of a sample may represent only a fraction of a particular message conveyed. That message as well as the associated sound characteristics may change in the next part of the sample. Nevertheless, in a abroad sense, a general consistency and regularity in the analysis have been observed, reported and discussed here. Some of the findings has been tried successfully for the control of the behaviour.

2. THE SET UP AND EXPERIMENTS

In the initial stages of the project an IBM compatible PC was equipped with a 16 bit sound card for recording and playback purposes. The sound card, Gravis Ultrasound (Max), supported .WAV files so that the editing, analysis and synthesis of recorded sounds could be made easily. A C^{++} based flexible software was developed for artificially generating sounds made by the bees as reported in literature. Signals with different fundamental frequencies, with selectable lower and higher harmonics, amplitudes and beat rates could be created and played through the sound card. Later, the hardware of the whole system has been replaced by a Pentium 100 computer with an in built sound card facilities while retaining the software.

A low distortion (NAD310) audio amplifier is used to amplify the signals generated by the computer. A major difficulty in the project has been the availability of appropriate speakers. For this project, the speakers need to be small in size, noise free and low in distortions to simulate natural sounds as close as possible. They must be able to handle high power sound requirements and at the same time have a wide frequency response. The commonly used sub-woofer speakers are not appropriate because of the sizes and the frequency responses. Although piezoelectric speakers have excellent frequency characteristics they are not available at high power ratings. In this project, many different speakers have been tested and the ones that resembled natural sounds most have been used with a compromise in power requirements. A very sensitive unidirectional microphone set was also purchased for recording purposes.

A number of experiments have been conducted for recording and analysis of the sounds. Tests were designed to observe the responses of individual bees or the response of entire colony by playing back of the recorded sounds and computer generated sounds. In some experiments either single worker bees or single queen bees were used. In the others, an entire colony in a hive or swarming outside were tested. In one experiment, a number of queen bees located at the proximity of each other but isolated in cases have been subjected to the generated sounds. Observations on the behaviour of the bees lasted from several minutes to several hours.

3. RESULTS AND DISCUSSIONS

The sounds generated by individual worker bees differ depending on the message to be conveyed, such as: "buzz-run" during swarming or sounds generated during waggle dance. As an example, the sounds generated by an airborne honey bee is shown in Figure 1. It can be seen in this figure, these sounds have beats in the form of envelopes. Each envelope can be isolated to be analysed separately. This approach ensures consistency in the results of analysis by making comparisons between the envelopes. A detailed waveform of a portion of the largest envelope is given in Figure 2 and similar waveforms could be viewed in the other envelopes.

A typical frequency analysis of a part of Figure 1 is illustrated in Figure 3. In this case, the first peak frequency is 220.7 Hz at -22 dB and the second peak frequency is at about 450 Hz at -30 dB. It is worth mentioning that the pattern of first and second peaks has repeated themselves consistently in different experiments. The first peak being between 200 Hz to 270 Hz and the second between 400 Hz and 550 Hz. In Figure 3, it can also be seen that bees generate sounds up to 11 kHz at -60 dB. After 11 kHz noise was predominantly present.

Queen bees do not readily produce sounds compared to worker bees in producing sounds. They usually emanate sounds only when they want to a pass a message, during swarming or if they are under stress. Therefore it was not an easy task to capture the sounds. In an experiment, about 150 queen bees confined in standard queen bee shipment cases, arranged in matrix form, were brought together. The communication sound that they generated were recorded by the same equipment as in the case of previous experiments. Figure 4 illustrates an example of the overall sound waveform generated by a queen bee. Figure 5 shows the detailed waveform of a portion of Figure 4. Figure 6 illustrates the aggregate frequency analysis of Figure 4.

Figure 6 illustrates that a queen bee generates most of the harmonics as a worker bee. But in this case, a single frequency of between 400 Hz to 550 Hz dominates. The queen bee also generate much higher frequencies. Comparison of Figures 3 and 6 shows that workers bees hardly generate any sounds greater that -48 dB at frequencies greater than 500 Hz whereas queen bees generate sounds at that level up to 5000 Hz. To make this point clear Figure 7 is included which illustrates the frequency spectrum of Figure 5. The maximum single frequency of 455 Hz can clearly be observed

Based on the findings reported here, acoustic sounds generated by the computer has been played back in the vicinity of the queen bees. The queen responded, but not always strongly, to the sounds believing that another queen is present. From time to time, some encouraging responses have been observed attempting to eliminate the other queen.

Figure 1. Sounds generated by individual airborne bee.

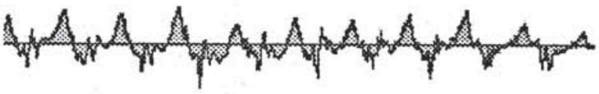

Figure 2. Detailed waveform of sounds made by single bee

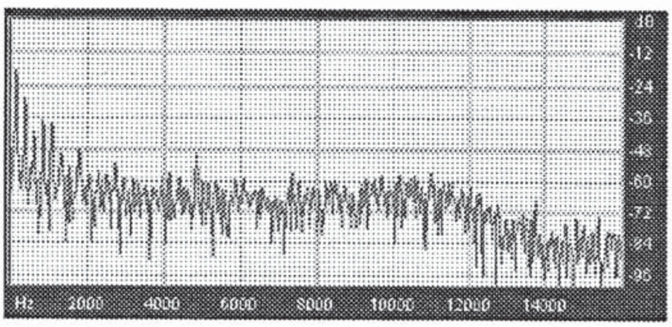

Figure 3. Frequency analysis of the sounds of worker bee.

Figure 4. Piping sounds generated by single queen bee.

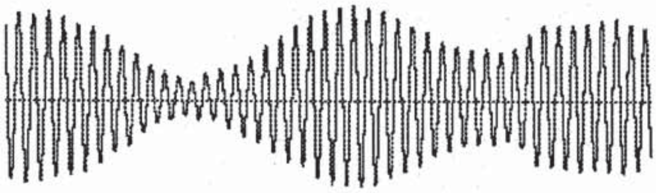

Figure 5. Detailed waveform of sounds made by queen bee.

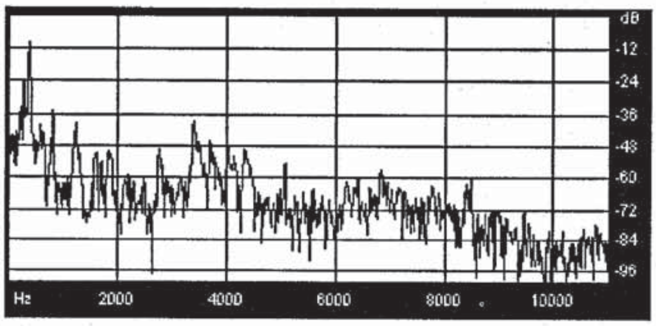

Figure 6. Aggregate frequency analysis of sounds of a queenbee.

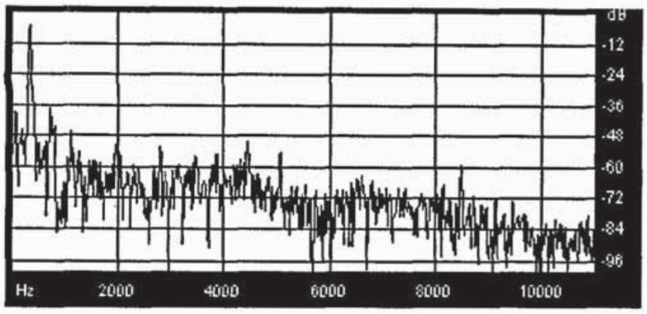

Figure 7. Detailed frequency analysis of sounds of a queen bee

However, the response of worker bees to the artificially played sounds are more consistent and encouraging. Experiments are continuing with by careful observations. Nevertheless, these responses appear to be somehow arbitrary. Unfortunately results are inconclusive to claim that the bee behaviour can be controlled purely by acoustic sounds. Millions of years of evolution seem to have created very complex codes and structures which needs further intensive research.

4. CONCLUSIONS

Acoustic sound recording arrangements made for sensing and identification of swarming bees and queen bees in honey bee colonies has been discussed. The distinct characteristics of sounds emanated by queen bees are compared with those of swarming worker bees. Based on the findings acoustic sounds generated by the computer has been played back in the vicinity of the queen hives. Computer generated sounds are observed to have some effect on the queen bee behaviour indicating that the arrangements made in this project are working. But, further research is necessary for complete control of bee behaviour by means of acoustic sounds.

ACKNOWLEDGMENTS

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