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Disturbing Honeybees' Behavior with Electromagnetic Waves: a Methodology

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Abstract

Mobile phone companies and policy makers point to studies with contradictory results and usually claim that there is a lack of scientific proof of adverse effects of electromagnetic fields on animals. The present perspective article describes an experiment on bees, which clearly shows the adverse effects of electromagnetic fields on these insects' behavior. The experiment should be reproduced by other researchers so that the danger of manmade electromagnetism (for bees, nature and thus humans) ultimately appears evident to anyone.

INTRODUCTION

A pollinator crisis, especially concerning the honeybees, has been occurring during these last two to three decades [1]. Several causes have been proposed to explain the worldwide disappearance of the honeybees: the varroa mite, viral and bacterial infections, single-crop farming, pesticides, mobile apiaries, too severe winters, or genetically modified plants. There is no doubt that all these factors are harmful for the bees.

On the other hand, several reviews deal with the ecological effects of radiofrequency electromagnetic fields (RF-EMF), e.g. [2]. There are reasonable grounds for admiting that RF-EMF severely impacts the nature, the health of all living organisms (plants, insects, birds, mammals, ...) [3], honeybees included [4]. The latter hymenoptera fly often far from their hive, and rather high. Doing so, they approach RF-EMF of high intensities (due to the presence of masts), are impacted by the electromagnetism, and can no longer find their way. Indeed, it is known that honeybees possess magnetite crystals in their fat body cells and that they present magnetic remanence; these magnetite structures are active parts of the magnetoreception system in honeybees. Indeed, the presence of a mobile phone handsets in a hive has a dramatic impact on the bees' behavior: it induces the worker piping signal (a sound produced by the wings of the honeybees). Worker piping either announces the swarming process of the bee colony or signifies that the colony is perturbed [5]; this signal in a bee colony is not frequent, and when it occurs in a colony that is not in a swarming process, no more than two bees are simultaneously active.

Little attention, if any, has been given to the potential harmful effects of electromagnetic waves on nature in general and above all on honeybees. Therefore, a simple and affordable method for studying in more details the effects of RF-EMF on honeybees in the apiary was set up. It consisted in locally collecting and amplifying the ambient RF-EMF and in focusing this amplified signal on individual hives, with well established, commercially available techniques (Figure 1a & 1b) and using intensities approved by international regulations [6]. The bees' behavior then observed was the sound the workers emitted under radiation. The technique being clearly detailed in the present perspective paper, other researchers are invited to reproduce the experiment for confirming (or infirming) the effects of EMF on bees' behavior. Note that bees (as well as birds) fly and are thus susceptible to be exposed to EMF of rather high intensities.

MATERIALS AND METHODS

Bees' produced sounds

An acoustical method based on sound analysis for classification was used for precising the change of behavior triggered by the amplified RF-EMF on the honeybee *Apis mellifera carnica*. This method is essentially described in [5]. Briefly, the recording device consisted of a bidirectional compact microphone (Olympus ME-31) with frequency response from 70 Hz to 14000 Hz connected to a vocal recorder (Olympus LS-11). The recorded signals were digitized as a Waveform audio file format sound file with 160 kilobits per second (kbps) and 44 kHz sampling. The computer programs Audacity© (open-source software at SourceForge.net) and FFT Properties 5.0 (Dew Research LLC, SLO-3210 Slovenske

Konjice, Slovenia) were employed for the manual analysis of the sound files and for the generation of the audiograms (also called sonograms), spectrograms (oscillograms) and frequency spectra, or for the generation of the orbital phase (which is a visualization of the signal strength during a given period; Δt = 2 min for the latter two analyses), respectively. Note that, apart the sound analysis, other behavioral studies can be performed, as reviewed in [7,8].

The EMF exposure

The ambient RF-EMF spectrum was collected with a receiving antenna. This signal was filtered to remove all the frequencies below 800 MHz. The filtered GSM (Global System for Mobile communications) roaming signal was then adequately amplifed and was finally re-emitted onto the external back side of the hive containing honeybees. Other frequencies could easily be chosen using this experimental setup, for example: the Wireless Fidelity (WiFi), the Digital Enhanced Cordless Telecommunications (DECT), the Universal Mobile Telecommunications System (UMTS), the Digital Code Squelch (DCS), or the Terrestrial Trunked Radio (TETRA).

The receiving HF59B antenna (range 800 MHz to 3000 MHz), the emitting HF38B antenna (range 800 MHz to 3000 MHz), the high-pass filter HP800 G3 (to suppress the frequencies lower than 800 MHz), the RF-preamplifiers HV10_27G3 or HF30_27G3 (to increase the intensity of the signal by a factor of 10 or 30 dB, respectively) and the selective frequency filter FF6E were obtained from Gigahertz Solutions (D-90579 Langenzenn, Germany). The UHF-Bias Tee diplexer MKU BT 270 was obtained from Kuhne Electronic GmbH (D-95119 Berg, Germany). The SMA adapters (31 SMA-50-0-1 ; 32 SMA-50-0-1), the 10-meters-long WLAN cable (SMA ST-SMA 76110), the 0.25-meter-long cable (SMA 0-1337808-1) and the 12 Volts/25Ah lead accumulator (A512/25.0 G5) were obtained from Distrelec (CH-8606 Nänikon, Switzerland).

The ambient RF-EMF and the re-emitted RF-EMF signal described above were measured using a high frequency analyser HF59B (Gigahertz Solutions).

RESULTS

The intensities of the ambient RF-EMF ranged from 0.05 to 0.15 $\mu W/m^2$ (below 0.01 V/m) before amplification. The GSM-filtered and amplified RF-EMF had a value in the 80-100 $\mu W/m^2$ (0.17 to 0.19 V/m) range directly in the front of the emitting antenna and around 1 to 2.5 $\mu W/m^2$ (0.02 to 0.03 V/m) in the front side of the hive. These intensities are found in ambient environments [6]. Animals, including honeybees, are expected to be exposed to such or even higher intensities in the apiary, and above all while flying near masts.

Sound analysis in the beehive revealed that the bees initially remained calm for about 45 min after the onset of the amplified RF-EMF, but started to produce sounds that were higher in both frequency and amplitude about one hour after the onset of this amplification (Figure 1c). This observation is confirmed by the comparison of the frequency spectra of quiet and disturbed honeybees: the 110 Hz frequency peak was present with the former but missing in the latter (Figure 1d). A shift to higher frequencies was also observed (from 370 Hz to 405 Hz). The intensity of the sound in the hive was also higher for disturbed honeybees, as compared to quiet honeybees (Figure 1e; see also the y-axis in the frequency spectra in Figure 1d). This so-called worker piping signal (a behavioral signal) is naturally produced by disturbed honeybees (not shown; see [5] for details). Similar data were obtained with the other four experiments (not shown).

DISCUSSION AND CONCLUSION

The experimental design proposed in the present perspective article was set up in order to enable beekeepers and researchers in the field to easily reproduce the experiments with the use of conventional materials and userfriendly computer programs.

The present data strongly suggest that honeybee colonies are affected and disturbed by electromagnetic waves (RF-EMF). Few experiments (n = 5) using the experimental setup were performed; ethical questions arose after I was attacked by furious honeybees when a second experiment was performed at a week interval on the same hive. This honeybees' behavior might reflect the emotional nature of the worker honeybee: according to Lipinsky [9], a rich collection of symptoms of bee emotional agitation similar to that in "higher animals" and in man can be observed, such as specific postures, moves (runs), excitations of the Vegetative Nervous System (VNS), specific pheromone release, stereotypies (dances), freezing behavior, clustering, specific sounds release, engorgement with honey, and warm ups (a non-visible physiological symptom). Bees under different emotional agitation produce different sounds: hissings (3000 Hz), pipings (300 - 600 Hz), quackings (1000 Hz), tootings (1200 Hz) squeakings (300 Hz) etc.

Other parameters can be analyzed, such as the queen prolificacy (the egg laying rate of the queen), the brood area (comprising eggs, larvae and sealed brood), the bee strength (the total number of bee frames per colony), the honey stores (the area containing sealed and unsealed nectar), the pollen stores (the portion of comb containing cells filled with stored pollen), and the flight activity (the number of worker bees leaving the hive entrance per minute before, during and after exposure to RF-EMF). In order to perform robust statistical analyses, researchers in the field should follow published and established guidelines [10] for obtaining a valid number of experiments.

Bee colonies living in hives acting as Faraday cages (what should drastically reduce the delivered amplified electromagnetic waves) might be protected from these exogenous electromagnetic waves and might consequently not present that induced sounds production. Experiments are under way to test this hypothesis. Negative controls, apart the Faraday hive, could also be performed using the so-called Swiss Shield® NATURELL™ cotton fibre spun with a gossamer-thin 0.02 mm silvered copper thread, allowing effective shielding from electromagnetic radiation.

Public discussion focuses on the influence of electromagnetic

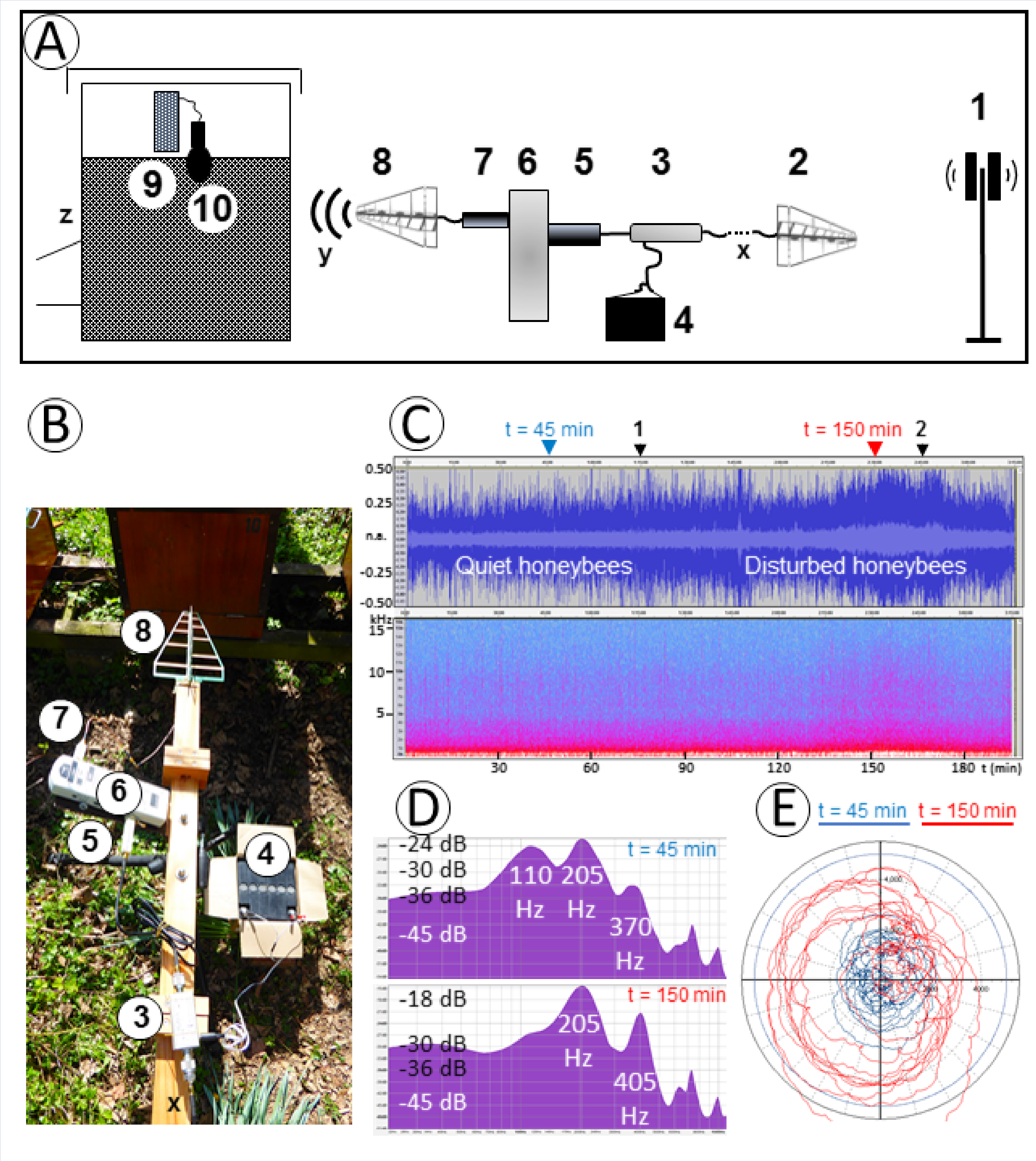

Figure 1. (A) Schematic drawing of the apparatus set in the field close to the hive. *1* Mast antenna in the near geographical area. *2* Receiving antenna. *3* UHF-Bias Tee diplexer. *4* Battery. *5* High-pass filter. *6* Selective frequency filter. *7* RF-preamplifier. *8* Emitting antenna. *9* Sound recorder. *10* Microphone. **x** denotes the 10-m-long SMA cable. **y** denotes a 3 to 4-cm distance between the antenna and the hive. **z** denotes the front side of the hive, about 60 cm away from the emitting antenna *8*. (**B**) Apparatuses in the field. (**C**) Audiogram (top; normalized: -0.5 to +0.5) and spectrogram (reported in kiloHertz (kHz)) of hive sounds. Time (t) is indicated in minutes. **1** and **2**: beginning and end of the RF-EMF emission, respectively. Blue and red triangles: sound samples lasting 2 min for analyses. (**D**) Frequency spectra (decibels, dB). (**E**) Orbital phase analysis of honeybees' sounds. For details, see text.

fields on the natural environment [11,12]. Mobile phone companies and policy makers point to studies with contradictory results and usually claim that there is a lack of scientific proof for negative effects of electromagnetic fields on animals and plants. The procedure presented in this work will allow its implementation, under scientific expertise. It should be used by several researchers. It could even be used for showing the effects of EMF on a wide range of living organisms. For the honeybees, a different experimental approach [reported in 13] might also be employed in parallel by a large number of beekeepers and researchers on the potential effects of manmade electromagnetism.

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DISCLOSURE

The author declares having no conflicts of interest.

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ii) Golden ratio (Sectio Aurea) in the Elliptical Honeycomb (J Nat Sci (JNSCI), 2(1):e173, 2016)

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