Potential Biological Principles of Hornet's Natural RADAR, Tracking, Positioning, and Wireless Communication Systems

Summary Paper

J. Gavan; M. Haridim
HIT-Holon Institute of Technology, Faculty of Engineering, 52 Golomb Street,
Holon 58102, Israel mharidim@hit.ac.il

Abstract

The late great entomologist Professor Jacob S. Ishay of the Tel-Aviv University faculty of Medicine found that the hornet's body produces a considerable amount of electrical energy using photo-voltaic effects. Using an electronic microscope Prof. Ishay has demonstrated to the authors the existence on the hornet's body of two spike arrays with very short spikes, not unlike the electromagnetic array antennas in RADAR and wireless communication systems. Similar but simpler systems occur **in some mammals and insects. Later, Prof. Ishay and his team discovered that the two hornet's antennae include also spike arrays and exhibit photo-voltaic effects. In a bionic sense, this allows for a new hypothesis of hornets' positioning system similar to GPS but consisting of one transmitting source (e.g., the queen) and three receivers on the hornet's male body. This may make direction finding by wireless communication possible at larger distances from cooperative targets.**

In this paper, we present the biological RADAR hypothethesis of hornets *antennae* with short spikes that may act also as 3 phased-arrays with extremely short monopole dielectic elements. Also, a comparison with other biological systems is provided. Due to the thiny physical dimensions, the frequency range of the hornets' phased array *antennas* is estimated to be be in the newly explored THz band.

The current progress in wireless positioning systems was set off by recent great improvements in the traditional electronic and electromagnetic technologies. Yet on our Earth, there exist a number of creatures, mammals and insects, that possess extremely sophisticated and accurate *alternative* capabilities, on which perfect Mother Nature has been "working" for millions of years, and which they use to track and position their friends and foes. For instance, it has been well known for more than 70 years that bats developed superior-ultrasonic acoustic RADAR acting from 10 to 200kHz to detect, locate, and hunt their prey. Elephants, dolphins, whales, and other mammals also possess their own very low frequency acoustic wireless systems for RADAR, communication, and positioning. There are also several small insects, like moths, that possess detection, communication and localization systems for mating and other purposes at extremely high frequencies , up to the optical range, due to their small physical dimensions[8]. Nowadays scientists study also these biological systems to improve the man-made positioning systems.

The late great entomologist Professor Jacob S. Ishay **of the Tel-Aviv University faculty of Medicine**, dedicated his life to hornets' research. Prof. Ishay installed hornet nests near the window of his laboratory at the 5th floor of the Medicine faculty building of the Tel Aviv university, not highly appreciated by his neighbours though nobody has been stung. So far, several theories have been developed trying to explain how hornets can hunt their prey, easily localize their nests at distances up to a few km, and how male hornets track and fertilize queens belonging to other nests. Prof. Ishay has found that the hornet body produces a considerable amount of electrical energy by means of photo-voltaic and piezo-electric processes [1]. He has also indicated that hornets cannot operate in darkness, since they use photo-voltaic cells as their energy source.

The authors had the privilege to know Prof. Jacob S. Ishay as a friend and coleague. He was a true scientist of honor and integrity. Through an electronic microscope Prof. Ishay and the authors have observed a multitude of very short spikes of 3 different lengths located on the body skin center of local oriental hornets. Photos of these spikes are shown in Fig.1 [2]. Prof. Ishay and his team have measured the dimensions of the spikes in order to estimate the frequency ranges assuming that the estimated length of the spike was around a quarter wavelenght [3] for optimal radiation. The extremely short length of the hornet spikes (dielectric antennas) points at extremely high operation frequencies, of 100's GHz and THz.

Based on our previous experience in Radio Detection and Ranging (RADAR), radio communication, RFI, direction finding ,GPS systems and the findings of Prof. Ishay, we have arrived at some interesting conclusions [1-3,10]: The short spikes may act as phased-array antennas with extremely short monopole elements transmiting and receiving wireless radio or acoustic signals. This is analogous with the well-known acoustic RADAR tracking and location systems of bats, operating at ultrasonic frequencies from 10 to 200 kHz [4,5]. However for spike dielectric antennas at extremely high frequencies and with limited mechanic energy, it is more probable that the propagating signals are carried by EM waves instead of longitudinal acoustic waves. This novel hornet hypothesis could replace the former related to the terrestrial magnetic field or pheromone scent trails [3].

The hypothesis suggested in this paper assumes that the significant electrical energy in the hornet body, found and measured by Prof. Ishay [1,3], is partly converted to EM waves to operate biological RADAR and direction finding (DF) systems in the THz frequency bands. Calculations show that hornets' THz RADAR operation range for detecting and positioning their prey is limited to 10's of meters, which is similar to the operation range of predator bats as will be calculated in the presentation. Such RADAR and DF systems are perhaps less developed for honey bees. The bees are more similar to fruit eating bats that possess less sofisticated and effective at shorter distance than those for the insect-eating bats as it was proved [4,5].

The significantly higher operation ranges required for the hornets to localize their nests, can be explained by the operation of the nest hornet sentinels. The nest hornet sentinels transmit signals continuously during the day time which may be received by remote hornets. The remote hornets, even far from their nest, receive the transmited signals which help them to localize the exact position of the nests [3,6]. This can be explained and computed using the line of sight Friis radio communication model, rather than the RADAR equation[7]. The remote hornet positioning system can be precisely explained by a triangulation process, similar to an inverse GPS, modeled by a transmitting antenna from the nest sentinels or the queen hornets [3,7] and three receivers located on the body and on the 2 antennas of the hornet as shown in figure 2.

Our hypothetical hornet RADAR and DF wireless communication systems may explain their short range hunting RADAR and astonishing three dimensional long range guidance and localization abilities. But these hypotheses have yet to be confirmed by precise measurement results that correlate with the parameters of the sub-millimeter radiated power sources. The estimated natural hornets' RADAR system wavelength bands are far beyond the usable longer radio microwaves and millimeter wave bands, and shorter than the Infrared bands. Therefore, the likelihood of experimental detection of the hornet's radiation up to date has been very small since the THz frequency technology development was in its infancy [9]. Preliminary tests were done by Prof. Ishay using different kind of hornets but the proper equipment in the THz frequency bands was not available to obtain reliable proof of concept. But today, with the availability of accurate and sensitive measurement

equipments in the THz frequency bands it will be easier to prove our Hypothesis [3,9]

When Prof. Jacob Ishay passed away his laboratory was closed, and therefore a new cooperation with entomological experts in Hornets and bees is required to validate our hypothesis. Validation of our proposed hypothesis will open new horizons for the existence of other similar three-dimensional insect or bird RADAR and direction finding systems. Furthermore, it could also be useful for research on flying insects and birds and in novel millimeter and sub-millimeter wavelength improved wireless systems for new applications. It is also very interesting to investigate the possibilities of applying nanotechnology circuitry on cyborg hornets for influencing them to fulfill similar tasks like those implemented by DARPA and other R&D institutitions on bats and insects for intelligence, explosive detection and other remote sensing missions[11].

Recently, huge yellow legged hornets from the Far East have reached France,Italy and neighboring countries in Europe, and are exterminating honey bees which contribution to nature and agriculture are tremendous [12,13]. Expert use of hornets advanced tracking and localization systems developed in this paper may also help in protecting the honey bees.

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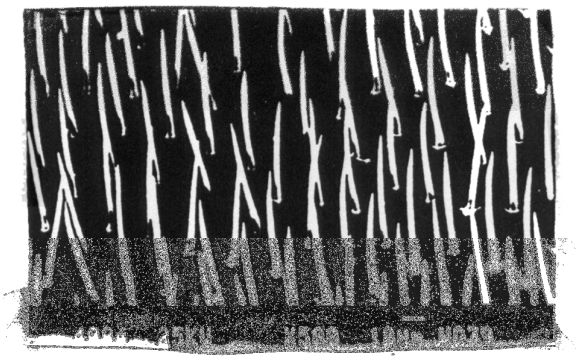

Figure 1 : The densest hornet phased array (n=1). Spikes are about 55 μm long, spaced 20-25 μm from each other.

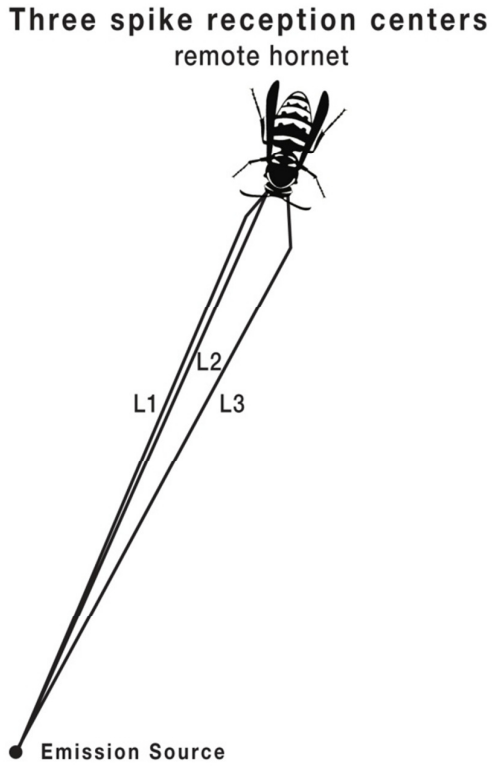

Figure 2: The Hornet Communication Based DF Technique with 3 Reception Centers L1, L2 and L3 for Remote Cooperative Target Detection .

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