Colony Collapse Disorder and RF Interference with Bee Navigation

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Introduction

Bee anatomy clearly shows that bees are "RF-active". Human-generated radio-frequency (RF) signals may interfere with hive-generated RF homing signals, causing navigational confusion for the bees thus explaining the disappearance of bees in colony collapse disorder (CCD). The impact of human-generated radio-frequency signals on bees has only been lightly studied. The results from existing studies combined with some of the collapse symptoms suggest that additional study is warranted.

Bees as RF-Active Creatures

Consider these discoveries about bee anatomy:

- *"The integuments of bees have semiconductor and piezoelectric functions. This means they are transducers of pulse modulated high frequency microwave-fields into an audio frequency range. Several constructions of the integument work like dielectric receptors of electromagnetic radiation in the microwave region"* [1]
- *"In the abdomen of bees are definitely found magnetite nanoparticles. Magnetite is an excellent absorber of microwave radiation at frequencies between 0.5 and 10.0 GHz through the process of ferromagnetic resonance. Pulsed microwave energy absorbed by this process is first transduced into acoustic vibrations (magneto acoustic effect)."* [2]

It is clear that honey bees are "RF-active." It is not farfetched, then, to imagine that bees can generate, as well as receive, RF signals given their fascinating electro-magnetic anatomy.

Hints of Navigational Interference

Consider these colony collapse symptoms:

- Collapsed hives feature "missing" adult bees. Rather than finding dead or dying adult bees in or near the hive, the adults are simply absent. This lack of "victim" bees stymies efforts to determine the cause of the colony collapse.
- The queen and juvenile bees in collapsed colonies are often healthy.

The absence of adult bees in or near the collapsed hive suggests that navigational disruption could be involved in their disappearance. The mites and viruses affecting bees result in dead and dying bees in and around the hive, suggesting other mechanisms may be at work in the dramatic event of CCD in which the adult bees disappear.

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[1] Dr. rer. Nat. Ulrich Warnke, University of Saarland, April 2007, www.uni-saarland.de/fak8/warnke
[2] Dr. rer. Nat. Ulrich Warnke, University of Saarland, April 2007, www.uni-saarland.de/fak8/warnke

Expansive Geographic Footprint of Human-generated RF

Some researchers have suggested that the wide geographic coverage of CCD in itself invalidates the possibility of RF interference with bee navigation.

> *"Most honey bee colonies are kept in rural areas away from urban areas with a high concentration of cell phone towers or cell phones. This past year while sampling CCD colonies in various parts of the U.S., USDA-ARS researchers were unable to remain in cell phone contact, emphasizing the lack of cell phone or cell phone tower influence on bee colonies in rural areas."* [3]

This information is helpful, but not conclusive. Human-generated RF from a variety of sources blanket the globe.

+ RF signals such as cell phones propagate far beyond their functional range, e.g. you can be outside of cell phone service range but still have sufficient signal for E-911 location triangulation.
+ The impact of the satellite services would be global or nearly global (depending on the transponder coverage), regardless of human population density. Satellite signal coverage extends equally across both urban and rural areas. For instance, Figure 1 shows the coverage of a single Ku-band beam from Intelsat satellite G-3C. Receive levels on the earth are quite weak but, in a specific bee-occupied frequency band, even such weak signals could be potentially disruptive, assuming bees do use low intensity RF for navigation.

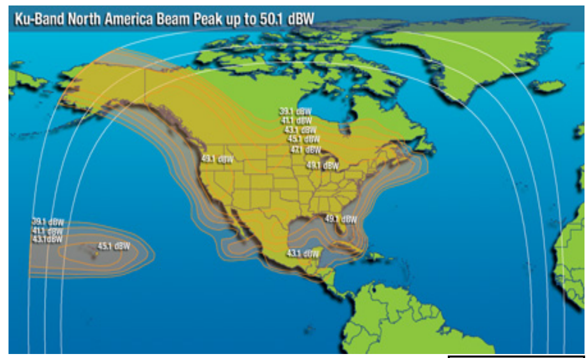

Figure 1

+ Point-to-point microwave communications links are often depicted as precise point-to-point transmissions. Despite the signal shaping qualities of modern antennae, the signal does disperse beyond the receiving tower laterally as well as vertically, creating a large area of potential RF interference (Figure 2). A great many point-to-point microwave links have been established in recent years. Such technologies have also been quite commonly deployed to reach remote rural areas.

  Beyond mere interference, perhaps bees that enter such an area-of-impact actually mistake the point-source of the data link as the homing beacon of the hive, homing to the transmission tower rather than to the hive.

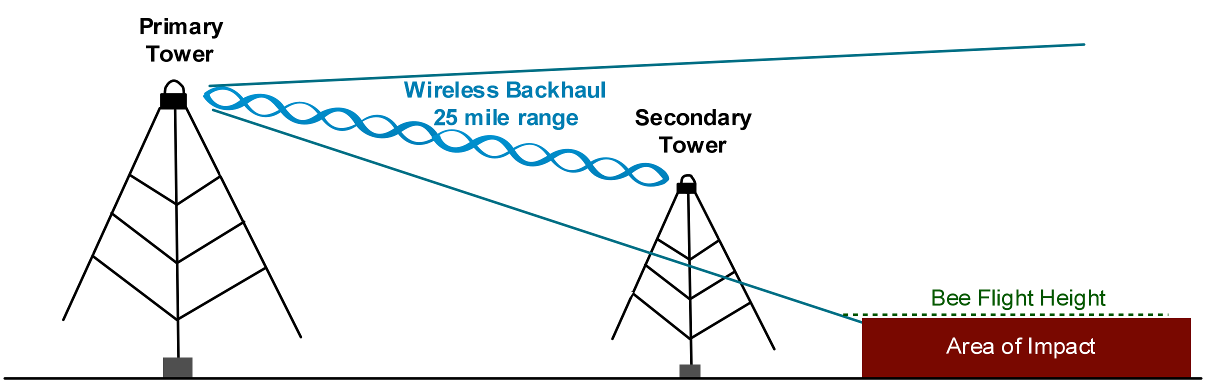

Figure 2

[3] Kevin Hackett and Jeff Pettis, USDA/ARS, April 2007

Explaining Selective Impact of CCD in Same Physical Area

Consider the following Colony Collapse symptoms:

+ *"First hand observations by USDA-ARS scientists investigating CCD colonies in California, Florida and other locations, have shown that colonies in the same apiary remain healthy while others are totally lost."* [4]
+ Approximately one-third of hives have been lost per year starting in 2006. The majority of the losses occur over the winter when the lack of leaves increases the range of many human generated RF sources (depending on the frequency).

Selecting a Frequency: Assume that the queen and juvenile bees generate a RF homing beacon to guide adult bees back to the hive. If this is true, then the queens must have a way of avoiding interference with neighboring colonies. In this model, when establishing a new hive or moving into new territory, the queen "listens" to the neighborhood to detect the homing signatures of other hives. She then picks from among her frequency options to generate a homing signature for her colony. The queen sets the pitch and the juvenile bees join in, creating harmonics to increase the amplitude of the homing signal to be received by foraging adult bees.

Three Non-Overlapping Frequencies: Extending the model further, consider the possibility that a queen has only three non-overlapping homing frequencies from which to choose. We'll call the three frequency choices "red", "blue" and "green" as in Figure 3. Three neighboring colonies would each select a distinct frequency. When the queen "listens" to the neighborhood to select a frequency she would not be listening for weak RF signals, but rather the harmonically amplified signals of other hives.

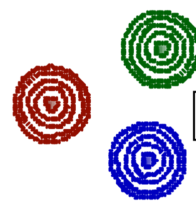

Figure 3

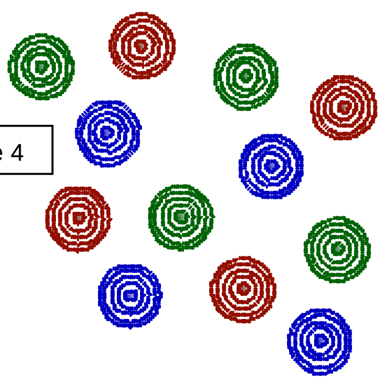

Figure 4

Non-Overlapping Frequencies – Larger Geography: Zooming out geographically, we see how the queens from a dozen colonies in the same area might organize their frequency choices to minimize interference. In Figure 4, the four "green" queens can hear one another's distant "green" homing-beacon, but pick "green" because their closest neighbors are using the "red" and "blue" homing frequencies. Similar efforts are involved in crafting large Wi-Fi networks. Keeping the noise floor low enough for effective communications would be the key for bees just as it is with Wi-Fi networks.

Collapse of the "Red" Hives: Consider that the theorized human-generated-RF might only impact one of the three bee homing frequency choices – say the "red" frequency. Adult bees from the "red" colony would become lost and/or exhausted from the navigational interference. Perhaps they even follow a point-source of human-generated RF, leading them far from the hive. The "red" colonies collapse, leaving us with only the "green" and "blue" hives (Figure 5). The number of colonies in the geographic region have been reduced by one-third.

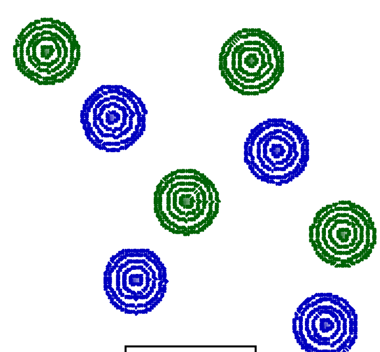

Figure 5

[4] Kevin Hackett and Jeff Pettis, USDA/ARS, April 2007

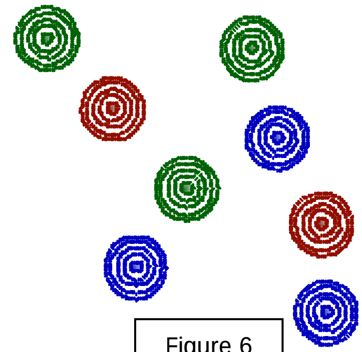

Figure 6

Dynamic Readjustment of Frequency Selections: With the "red" colony homing frequency now vacated, queens would alter the frequency mix to minimize interference with neighboring hives (Figure 6). In this frequency shifting, some colonies would move into the vacated "red" frequency, beginning the cycle of navigational interference and colony collapse over again.

Inconclusive Study of Cell Phone Interference

Existing studies repudiating a link between RF and bee navigation have not been conclusive.

> *"In the very small study in question, base stations of mobile phones (these stations send out electromagnetic signals to mobile phones) were placed in a few hives, which would expose the bees to unnaturally high levels of electromagnetic radiation; yet, researchers were only able to demonstrate marginal and not statistically significant effects."* [5]

High intensity RF interference would not have the same impact in terms of the bees' signaling if the experiment did not infringe into the bees' theoretical homing frequencies, although there could be other bee-health impact from high intensity RF.

Conclusions

- Bees are RF-active creatures.
- Human-generated RF interference with bee navigation and homing offers a plausible explanation for some of the symptoms of CCD.
- Existing studies have not ruled out RF interference as a potential cause of CCD.
- There are multiple potential sources of RF interference with bee navigation that have not been fully explored.
- It is likely that such RF interference, if it exists, represents one of several factors impacting bee health.
- Additional study of human-generated RF impact on Colony Collapse Disorder is warranted.

Next Steps

1. Test the presence of bee-generated RF signals in hives. This will require spectrum analyzers and sensors operating in a wide set of frequency bands and with sensitivity down to millionths of watts. Probably best conducted by moving three hives into an RF shielded room.
2. If bee-generated RF is detected, catalog deployments of RF services in the bees' operating frequency ranges.
3. If bee-generated RF is detected, map hive collapse reports in geographic information system (GIS) with layers for the month of collapse to enable study over time.
4. If source of suspected RF interference is in a licensed band, then also add deployment maps over time for the given technology to the GIS database.

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[5] Kevin Hackett and Jeff Pettis, USDA/ARS, April 2007