Poster Abstract: Investigating the Biological Impacts of Radio Transmissions

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ABSTRACT

The past 40 years have seen an explosion of Radio Frequency (RF) transmitters, which motivates under-standing their impacts on the natural world. The European honeybee, Apis Mellifera, has been shown to sense the Earth's magnetic field. Human Radio Frequency (RF) transmitters alter this field. For example, recent work demonstrated that human-created RF interferes with the common robin's ability to orient themselves. This work proposes an experimental design to determine if honeybees can sense RF transmissions in frequencies from 1 MHz (AM radio) to 6 GHz (WiFi). We deployed a custom-designed RF bee feeder near bee hives to test honeybees' RF sensing abilities.

CCS CONCEPTS

• **Hardware** → *Biology-related information processing*; • **Computer systems organization** → *Embedded and cyber-physical systems*;

KEYWORDS

Honeybee, Bee feeder, RF, Sensing, Biological impacts

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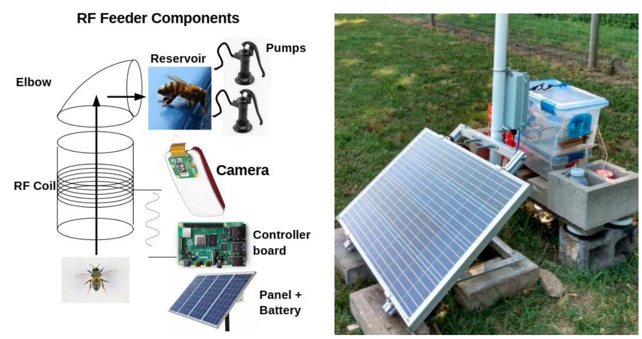
1 INTRODUCTION

The technology trends decreasing the cost of electronics over the past 40 years have powered the explosion of terrestrial Radio-Frequency Electro-Magnetic Fields (RF-EMF). The increased scale



(a) RF feeder components (b) Real deployment

Figure 1: RF feeder

of anthropogenic RF-EMF represents an unprecedented environmental change for organisms that rely on sensing weak EM fields. Indeed, anthropogenic RF-EMF has been shown to disrupt the magnetic compass orientation in a migratory bird [1]. There is evidence that numerous species use the Earth's magnetic field for navigation and orientation, ranging from bacteria, to fruit-flies, cockroaches, salmon, sea-turtles, birds, and possibly cetaceans [5]. In this work, we seek to elucidate if human generated RF fields have measurable biological impacts. Given prior work has shown some evidence honeybees can sense both Direct (DC) and Alternating Current (AC) magnetic fields [4], they are a promising organism to investigate. Our experiments extend prior works by investigating if honeybees can sense modern wireless communications' RF-EMF.

To determine if honeybees can sense RF signals we built a bee feeder that is equipped with several sensors and actuators as shown in Figure 1. A bee must go through a tunnel which is surrounded by a coil of wire. A controller board is attached to a wire coil, and can send a static or A/C signal to it, thus generating a static magnetic field or a radio wave. The coils have sufficient space to see the bees moving through. We use a camera to record video of the bees' motion and store it to a compact flash memory card on the controller board. Thus bees must pass through the tunnel to get a sugar-water reward. The interior of the tunnel contains an RF-EMF field. Also, we use two peristaltic pumps to provide either sugar water to a reservoir around an elbow. The elbow is used so the bees do not have visual cues as to what the state of the feeder is. Finally,

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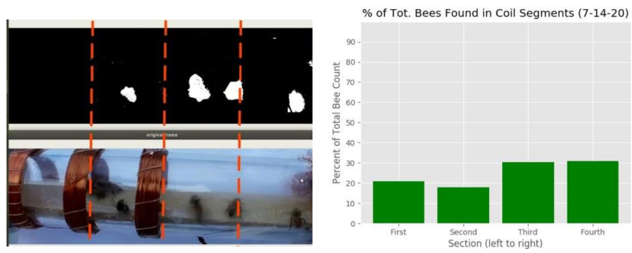

(a) RF feeder components (b) Real deployment

Figure 2: Bee counting using OpenCV

for ground truth purposes, we use a magnetometer attached to a wireless sensor for measuring the magnetic field strength.

2 APPROACH

Our experimental approach fits honeybees' natural foraging behavior closer than prior work laboratory-based studies, although we also follow classical animal studies by associating and RF-EMF field with a reward [2, 3] or a punishment. We constructed a feeder where the bees must pass through an RF-EMF field to reach a reservoir filled with either water with added sugar(reward), or added quinine(punishment). Given that our approach can scale to entire hives, it is also more statistically sound than prior approaches using only a few bees, which can have serious statistical flaws because of their low number of observations.

Training Protocol: We divided the training into two phases. First, we train the bees to associate the feeder location with food by both "kidnapping" bees at the hive and bringing them to the feeder, as well as having the bees associate a scent put into the sugar water, and leaving a scent trail from the hives to the feeder. During this phase, no cycling occurs and the RF field is left on.

The second part of the training phase uses cyclic states over time. The active and passive states proceed in cyclic order with the time between phases lasting on average 1 hour. We recorded video during this phase to test the video algorithms and see if the bees are making progress.

Testing Protocol: during the testing phase, the pumps are alternating *phases* of putting sugar water (S) and quinine water (Q) in the reservoir. The starting phase of either S or Q is randomized each morning. A phase has a base length of 3 hours, which is randomly adjusted by +/- 15 minutes. Thus, the cycles are gradually shifted over time to discourage bees from associating time-of-day to reward/punishment. During the S phase, the RF of the coil is turned on. During the Q phase, the current through the coil is disabled. A video camera records the tunnel, and the video saved to flash on the controller board. Using OpenCV, we subtract static backgrounds and isolate dynamic pixels in each frame that represent bees. By calculating the size of each isolated group of pixels, we estimate the number of bees present in any given video frame. As a result, we track overall activity relative to the cycles (Figure 2). We also divide the tunnel into discrete segments and get counts for each segment.

3 PRELIMINARY RESULTS

The initial findings are shown in Figure 3. This figure shows the population of bees at different times for three clear days (i.e. no rain). The x-axis shows time, the y-axis shows the bee count in a video frame, and the lower orange line shows a (S) interval as a one on the Y-axis and (Q) as a zero. Our initial results show a high correlation of bee count with the (S) intervals. Once the bees are trained, a high bee correlation with the RF field, even when there is no reward, would be strong evidence the bees use the RF field as a reward signal.

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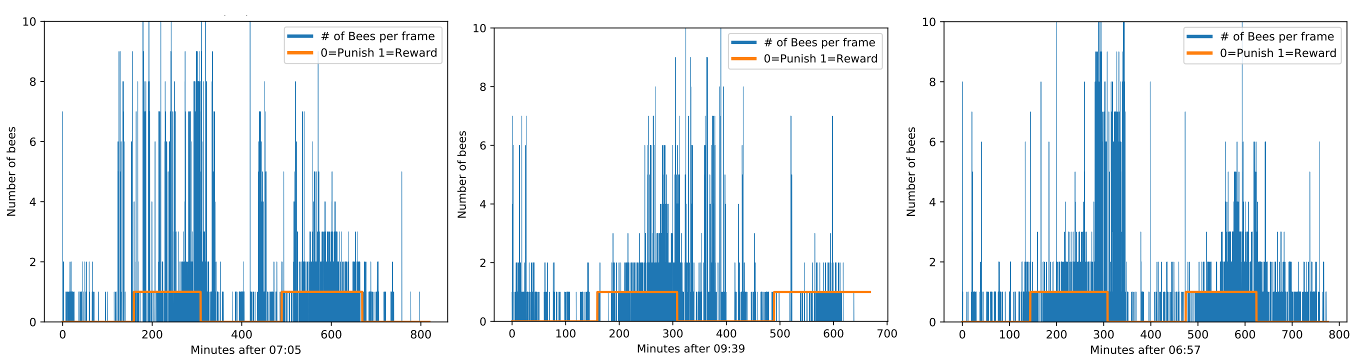

(a) Day 1 (b) Day 2 (c) Day 3

Figure 3: Number of bees per cycle over different days.