Design of an Efficient Antenna for Asian Hornet (*Vespa Velutina*) Tracking Using Insect Telemetry

David Toribio and Arno Thielens
Ghent University-Imec, 9000 Gent, Belgium, http://www.ugent.be

***Abstract*—The Asian hornet (*Vespa Velutina*) is an invasive voracious predator of wild pollinators in Europe. The only means of containing their fast spread is to destroy their nests, at the invasion front. Radio-telemetry tags have been tested successfully for drone-based Asian hornet tracking. However, there are inefficiencies in these tags due to near-field interactions between the hornets and the tags' antennas. Additionally, there is a need for lighter tags with smaller antennas. Therefore, this work presents a hornet-specific monopole antenna design, operating at 866 MHz. To this aim, the influence of the hornet on the monopole's radiation performance is characterized, using numerical simulations in which a hornet model, obtained by micro-CT scanning was used. These showed that, when the monopole is in proximity to the hornet and connected to a 50 Ω source, reducing the wire's length to 99 mm would optimize impedance matching, leading to 0.004% of the input power to reflect. Moreover, results showed that the near-field interactions between the hornet and the monopole can lower its radiation efficiency by 20%, and its maximum gain by 1.14 dBi.**

I. Introduction

The Asian hornet (*Vespa Velutina*) is an invasive alien species, that poses an immediate and substantial threat to wild and domesticated pollinators [1]. Their speed of establishment indicates that the only means of containing their spread is to locate and destroy colonies at the invasion front. Radio-telemetry has been used successfully to track Asian hornets [1]–[3], however its use has been limited due to its transmitter weight and antenna length, which may impede hornets' flight [1]. Nevertheless, they remain an attractive approach because of their relative longer signal range, their traceability, and their use of a lighter receiver which make it more suitable for drone-based hornet tracking than other tracking approaches such as: harmonic radars, radio-frequency identification (RFID) systems, sattelite based global positioning systems (GPS) or visual-sensor based systems [2].

Radio-telemetry tags have been successfully tested for Asian hornet tracking at 138 - 220 MHz showing acceptable signal ranges [1]–[3]. However, the successful validation of drone-based hornet tracking [2] opens the opportunity of using higher operating frequencies since drones can keep a short a distance from hornets, potentially leading to lighter system designs.

When an antenna is placed in the vicinity of a dielectric medium, near-field interactions occur which can significantly affect antennas' reflection coefficient, radiation pattern and efficiency [4]. In this work, a hornet-specific antenna is designed to operate in the short-range device license free band SRD 860 (863-870 MHz), and two optimizations are evaluated. Moreover, the influence of the antenna's near-field interactions with a hornet on its radiation performance is characterized using numerical simulations.

II. Methods

In this work, a monopole antenna design and two optimizations are presented for Asian hornet tracking. For their characterization, numerical simulations were performed using the finite-difference time-domain (FDTD) method in Sim4Life (ZMT, Zurich, Switzerland). The hornet 3-D model was the same used in [5].

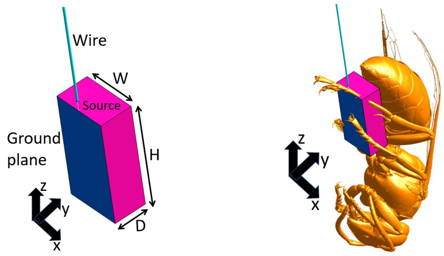
The monopole design proposed is based on the dimensions of a mock-up hornet tag which was successfully carried by live hornets in experiments performed in collaboration with the Laboratory of Molecular Entomology at Ghent University. The design consists on a wire connected to the ground plane of a printed-circuit board (PCB), using a voltage source (line source) of 0.75 mm connecting the radiating element to the ground plane as shown in Fig. 1a.

The first optimization consisted on decreasing the wire's length to achieve resonance at the SRD 860 band, within which, 866 MHz was chosen as the target frequency. Thus, it aimed at determining how much the resonance location could be improved without using impedance matching, while keeping weight to its minimum. The second optimization consisted on further decreasing the wire's length to optimize impedance matching to a 50 Ω source.

Gaussian simulations in free space and in proximity to the hornet were performed to determine the influence of the radio-frequency electromagnetic fields (RF-EMF) near-field coupling between the hornet and the monopole on the magnitude of the reflection coefficient ($|S_{11}|$), and the monopole's input impedance as a function of frequency in the range of 600 MHz - 1.2 GHz. Moreover, harmonic simulations at 866 MHz were performed to compute radiation efficiencies, gains and directivities. The configuration used for the simulations in proximity to the hornet is shown in Fig. 1b. The dielectric properties of the hornet and of the PCB's FR-4 material were quantified as conductivity (σ) and relative permittivity (ϵ_r). The dielectric properties of the hornet were obtained using the same database and interpolation used in [4]. Table I lists the properties of the monopole and the hornet model.

Table I: Characteristics of the monopole antenna

Properties	Value	Properties	Value
Wire's length (mm)	150	σ (S/m) (hornet)	0.75
Wire's diameter (mm)	0.15	ϵ_r (PCB)	4.2
H x W x D (mm)	7.25 x 3.8 x 2.25	σ (S/m) (PCB)	0
ϵ_r (hornet)	45.23		



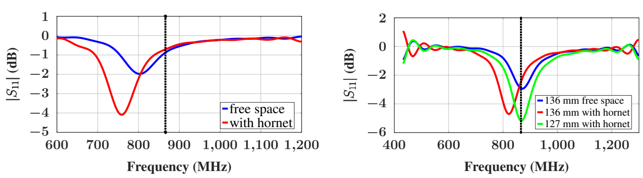
(a) (b)

Figure 1: Sim4Life models: (a) Monopole antenna, (b) In proximity to hornet.

III. Results

Fig. 2a shows that the mismatch efficiency of the monopole antenna in free space is optimized at 805 MHz. Moreover, it shows that, placing this antenna in proximity to the hornet leads to an increment of the reflection coefficient of 0.16 dB, at 866 MHz, which leads to 85% of the input power to reflect.

Fig. 2b shows the simulation results for the first optimization. This figure shows that in free space, a wire's length of 136 mm achieves resonance at 866 MHz. Also, it shows that placing this 136 mm monopole in proximity to the hornet shifts the resonance to lower frequencies. Moreover, it shows that a wire's length of 127 mm achieves resonance at 866 MHz, when the monopole is in proximity to the hornet while reflecting 30% of the input power.



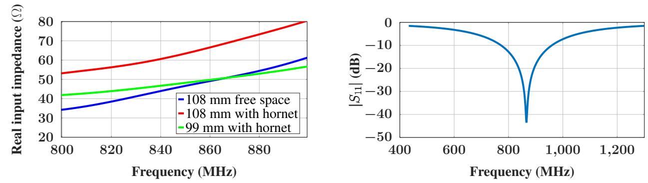
(a) (b)

Figure 2: Reflection coefficient: (a) For the 150 mm monopole (b) For the first optimization.

Fig. 3a shows simulation results for the second optimization. It shows that further decreasing the wire's length to 108 mm makes the real input impedance equal 50 Ω in free space, at 866 MHz. Also, it shows that placing this 108 mm monopole in proximity to the hornet, increases the real input impedance to 69 Ω, and that a wire's length of 99 mm would optimize impedance matching to a 50 Ω source, when the monopole is in proximity to the hornet, at 866 MHz.

In addition, simulations showed that this second optimization leads to an input impedance of 50.68 + j311.39 Ω. Therefore, an inductor of 57.23 nH placed in series with the 99 mm monopole would achieve resonance at 866 MHz. Fig. 3b shows that this configuration would lead to only 0.004% of the input power to reflect.

Harmonic simulations showed that the near-field interactions between the tag and the hornet can lead to a decrease of



(a) (b)

Figure 3: Second optimization: (a) Real input impedance (b) Reflection coefficient

the radiation efficiency by 20% and of the gain by 1.14 dBi, as shown in Table II.

Table II: Radiation characteristics for the second optimization

Characteristics	Free space	With hornet
Radiation efficiency (99 mm)	1	0.8
Maximum gain (99 mm)	2.04 dBi	0.90 dB
Maximum directivity (99 mm)	1.98 dB	1.98 dB

IV. Conclusion

In this manuscript, a hornet-specific monopole antenna was designed to operate at 866 MHz, and its radiation performance was characterized in free space and in the vicinity of a hornet 3-D model using numerical simulations. It was found that, when the monopole is in proximity to the hornet and connected to a 50 Ω source, reducing the wire's length to 99 mm optimizes the impedance matching leading to only 0.004 % of input power to reflect. Moreover, it was found that the near-field interactions between the hornet and the monopole can lower the radiation efficiency by 20% and the gain by 1.14 dBi. Future directions will include characterizing microstrip antennas suitable for flexible circuit technology, aiming at further reducing tags' weight while optimizing performance.

Acknowledgement

Arno Thielens is a postdoctoral fellow of the Research Foundation Flanders (FWO) under grant agreement no. 12U1417N. This work was funded by the FWO under grant agreement no. G033220N.

References

[1] P. J. Kennedy, S. M. Ford, J. Poidatz, D. Thiéry, and J. L. Osborne, "Searching for nests of the invasive asian hornet (vespa velutina) using radio-telemetry," *Communications biology*, vol. 1, no. 1, pp. 1–8, 2018.

[2] C. Ju and H. I. Son, "Investigation of an autonomous tracking system for localization of radio-tagged flying insects," *IEEE Access*, vol. 10, pp. 4048–4062, 2022.

[3] S. Kim, C. Ju, J. Kim, and H. I. Son, "A tracking method for the invasive asian hornet: A brief review and experiments," *IEEE Access*, vol. 7, pp. 176 998–177 008, 2019.

[4] D. Toribio, W. Joseph, and A. Thielens, "Near field radio frequency electromagnetic field exposure of a western honey bee," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 2, pp. 1320–1327, 2021.

[5] H. Herssens, D. Toribio, E. De Borre, and A. Thielens, "Whole-body averaged absorbed power in insects exposed to far-field radio frequency electromagnetic fields," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 11, pp. 11 070–11 078, 2022.