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The antenna analysis of insect antennae

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Abstract. Geometric configuration of insect antennae is similar to antennas and their analysis and simulation show the characteristics of them in receiving and sending signals. In this paper, plumose antennae of two kinds of moths are analyzed and simulated in the CST software. In one case, an antenna with high directivity and in the other case one antenna with acceptable bandwidth is obtained.

Keywords: insect antennae, fractal, antenna, directivity, bandwidth

1 Introduction

Nature is full of mysteries which scientists are interested in discovering them. One of these secrets is the communication between insects. This subject involves not only with zoology but also attracts electrical engineers' interest. This is done by the discovery of the electromagnetic communication between insects. Insect antennae play the role of the receiver or transmitter in their electromagnetic communication[4].

American biologist, Philip Callahan, has studied how moths communicate with one another and find their pairs. Callahan concluded that the insect sensory mechanism is both infrared and olfactory; That insects "smell" odors electronically by tuning into the narrow band infrared radiation, emitted by sex, prey, and host-plant scented molecules. In fact, molecules do not need to interact physically with receptors; the interaction can be via electromagnetic field[5–10].

Fig. 1 shows the antennae of male moths. The tentacle is similar to an antenna. In this paper, the tentacles are analyzed as an antenna by CST software.

Some of insects' antennae are similar to fractals. Fractals are created by repeating the same shape many times in smaller and smaller parts that each are copies of entire in the smaller size. These structures are used in the design of broadband antennas[1, 2].

Fig. 2 is related to an insect antenna that is a fractal-like structure. This antenna has been studied in the CST simulation software.

2 Materials and methods

Initially, the pictures of insect antennae were implemented in AUTOCADE software and the shape of antennae was designed with punctuation by tools of this software to be relatively exact. From AutoCAD software was taken dxf-format output and transferred to HFSS software. Again, the SAT format output was taken from HFSS software and geometric design of antennae was transferred to the CST software and was modeled as an antenna

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Fig. 1. The first kind of moth antennae

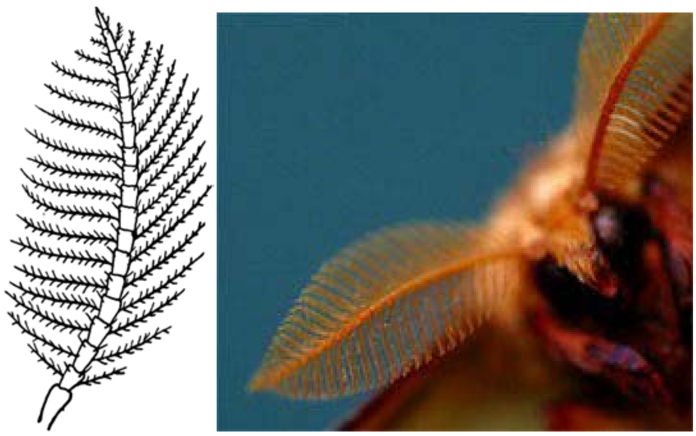


Fig. 2. Second type of plumose antennae of moth, and the geometric design

3 Results and discussion

3.1 Analysis of first kind of moth antennae

Fig. 3 is related to the antenna which is simulated with the first kind of moth antenna pattern.

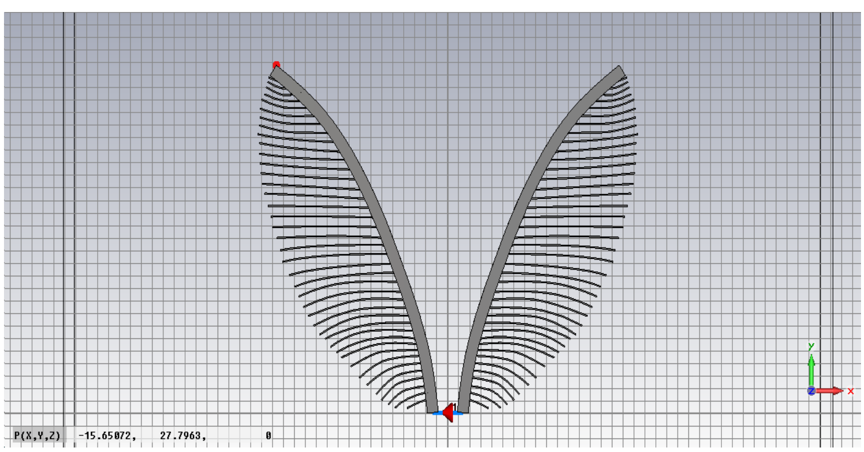


Fig. 3. Antenna design with the first kind of moth antenna ?s pattern

Geometrical and physical specifications of antenna are expressed in Tab. 1:

Table 1. Geometrical and physical specification of the first kind antenna

Quantity	Conversion from Gaussian
Length of antenna	32mm
Diameter of blades of antennae	0.2mm
Material of antenna	PEC

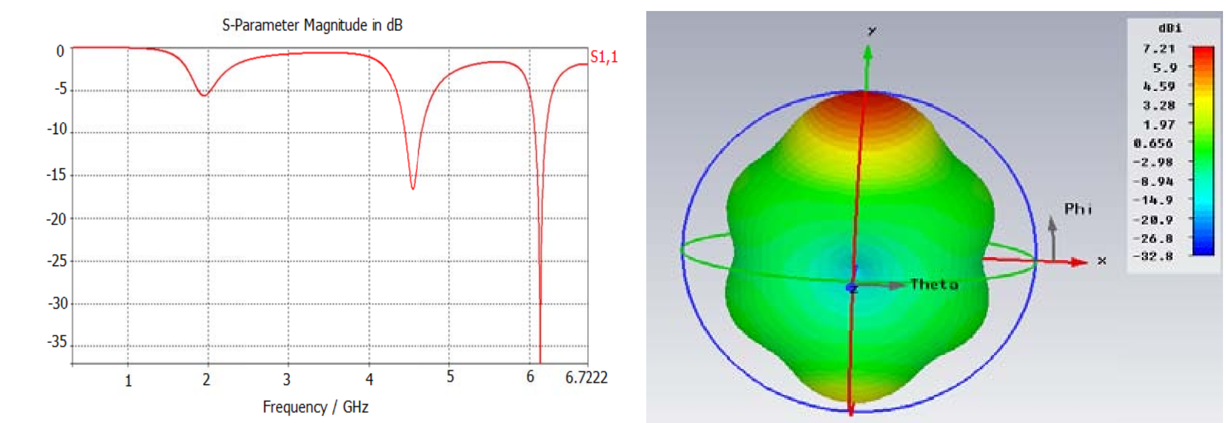
By using CST software, the antenna was fed with DISCRETE PORT and stimulated.

In Fig. 4, the radiation pattern of the antenna and the s_{11} diagram is shown. For a desired design, it can be assumed that the frequency range of the s_{11} diagram which is less than -10 dB, is the bandwidth of the antenna and the minimum of s_{11}, is the main frequency of the antenna[3]. As it can be seen from Fig. 4A, the main frequency of the antenna is $6.1GHz$ and directivity of the antenna is 7.21 dB. Fig. 5 shows the results of a V-shaped dipole antenna in which the length and the angle between the arms are approximately equal to the antenna design. In Tab. 2 these results were compared with each other. In the antenna design with the pattern of moth antenna bandwidth is less and directivity is more in comparison with V-shaped dipole antenna.

Table 2. Comparison of a V-shaped dipole antenna with moth antenna of the first kind

Model antenna	Directivity	Bandwidth	Working frequency
Pattern of moth antenna	7.21 dB	2.5%	6.1 GHz
V-shaped dipole	3.88 dB	8.3%	6.7 GHz

It can be concluded that geometry of moths' antenna is such that it can receive more environment radiation and it is as intense as a radar antenna pattern that the moth can detect the wave transmitter with the movement of its antennae.



(A) **(B)**

Fig. 4. (A) the s_{11} diagram and (B) the radiation pattern of the antenna design with the first kind of moth antenna's pattern

3.2 Analysis of second type of plumose antennae of moth

Fig. 2 is antenna of a moth, which is similar to the three-dimensional fractal tree antennas approximately. Because, the fractals are self-similar, so it is required to repeat of a generator to produce them[6]. For the design of antenna-like moth antenna of Fig. 2, the first was to design the main generator as in Fig. 6 (Type I), then the main generator was placed instead of the blade antenna with the appropriate dimensions (Type II). Fig. 7 shows the approximately case that is designed from the pattern of moth antenna with fewer blades.

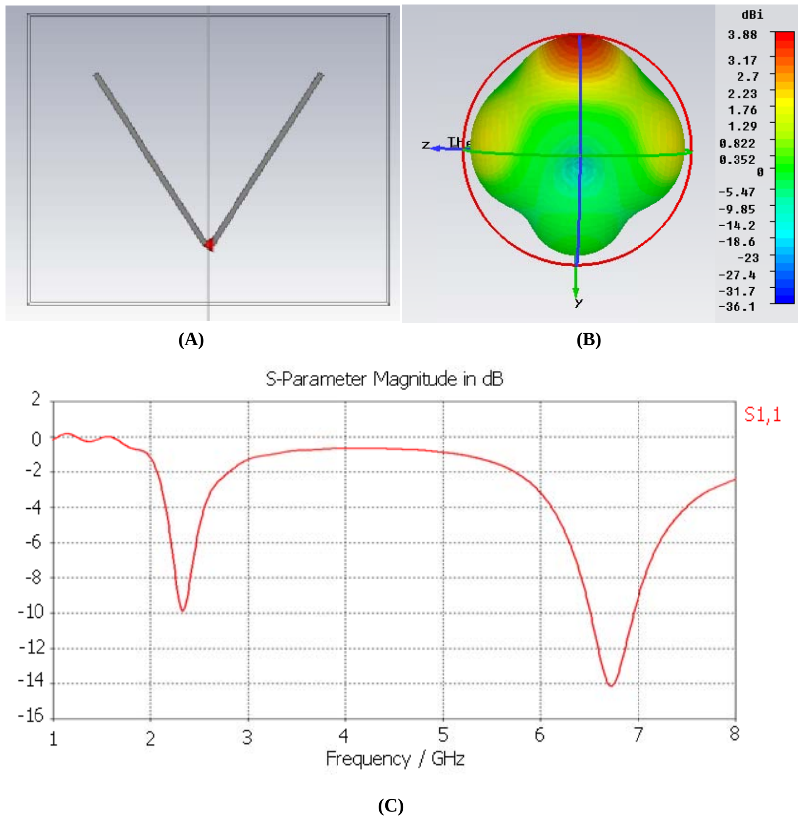


Fig. 5. (A) The V-shaped dipole antenna , (B) the radiation pattern of V-shaped dipole antenna, and (C) the s_{11} diagram of V-shaped dipole antenna

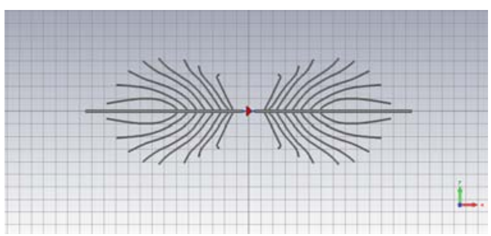


Fig. 6. The main generator antenna(Type I)

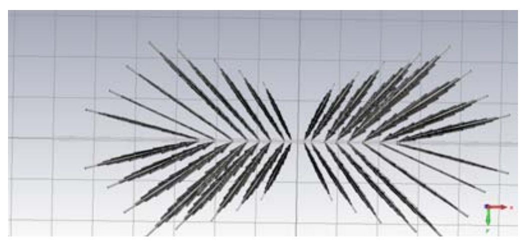


Fig. 7. The antenna is designed with a repetition of generator in the main generator blades (Type II)

Geometrical and physical specifications of the main generator antenna are expressed in Tab. 3:

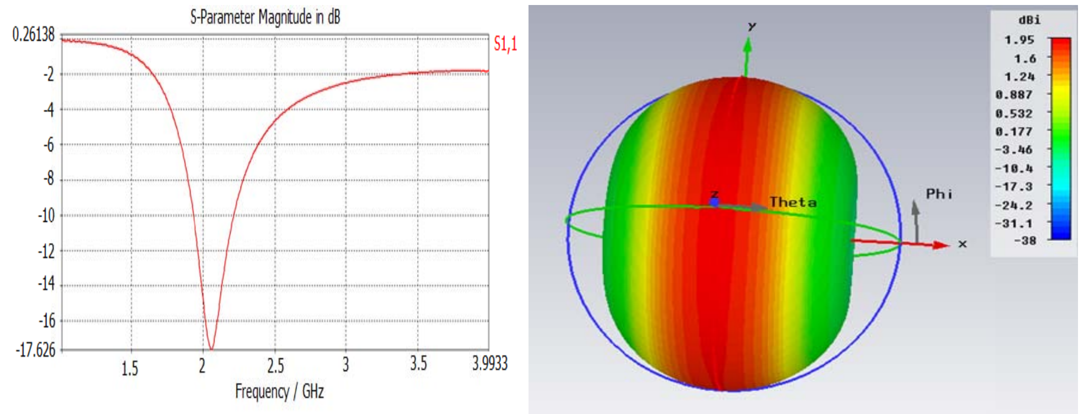
Table 3. Geometrical and physical specification of the main generator antenna

Quantity	Conversion from Gaussian
Length of antenna	24mm
Diameter of blades of antennae	0.2mm
Material of antenna	PEC

Both antennas (Type I and Type II), were stimulated in a similar way with the previous section. Fig. 8 shows the results of main generator antenna (Type I) and Fig. 9 shows the results of a repetition of generator in the main generator blades (Type II).

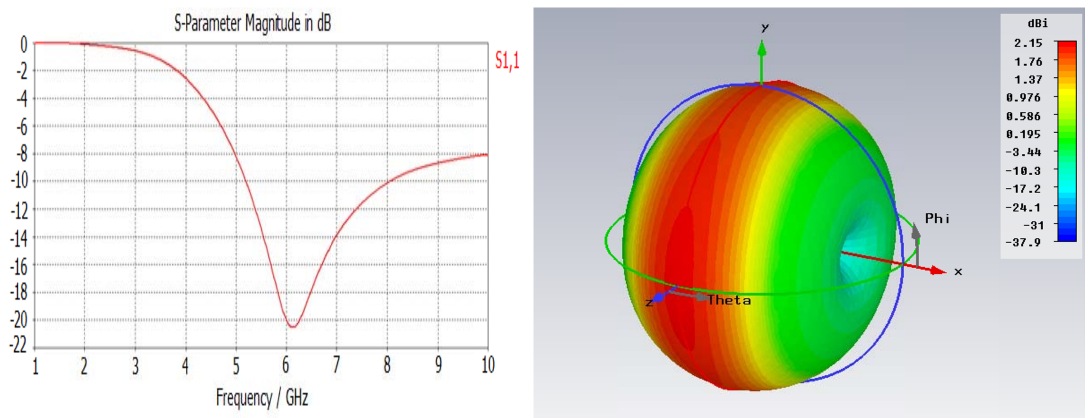
In Tab. 4, the results of comparison of the two antennas can be seen. The bandwidth of the second type of antennas is significantly higher than the first type.

Since fractal antennas have several similar parts in various scales, these antennas radiate in a wide bandwidth.



(A) (B)

Fig. 8. (A) the s_{11} diagram and (B) the radiation pattern of the antenna design (Type I)



(A) **(B)**

Fig. 9. (A) the s_{11} diagram and (B) the radiation pattern of the antenna design (Type II)

Table 4. Comparison of two models of insect antenna

Antenna's model	Directivity	Bandwidth	Working frequency
Type I	2.15 dB	25%	2.1 GHz
Type II	1.98 dB	48%	6.1 GHz

4 Conclusions

In this paper, plumose antennae of two kinds of moths have been analyzed and simulated in the CST software. In one case of antenna with a high directivity and in the other case antenna with acceptable bandwidth is obtained.

We believe that the existing models in nature such as insect antennae are optimal models and our path of work is to evaluate this belief.

Nevertheless, this study can be seen as an initiative for assessment of insect antennas for different applications by the researchers. Study of insect's antennae as a microstrip antenna with metamaterial and ferrite substrate is the next step for investigating this subject.

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