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Fractal rectenna for collecting energy in the Wi-Fi range

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Abstract: **Evaluation of the results of modeling a fractal rectenna by the finite element method, with consideration of the central 5 GHz. Directional diagrams are plotted. The simulation results are compared with a sample of a real antenna created on the basis of calculations. The possibility of using the developed fractal rectenna for collecting electromagnetic energy of new generation Wi-Fi networks is shown.**

Keywords: **finite element method, fractal rectenna, RF energy collection**

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Contents

1. INTRODUCTION

A little over 20 years ago, the concept of the Internet of Things (Internet of Things or IoT) was formulated. IoT is a network of physical objects that contain embedded technologies to communicate and recognize or interact with their internal states or external environment [1]. As an example of IoT devices, consider the Wireless Sensor Network (WSN). WSN is a sensor network consisting of many different types of sensors connected to each other using wireless channels capable of collecting and exchanging information [2]. The main requirements for sensor devices included in the WSN include such parameters as low cost, small dimensions, reliability, environmental friendliness and, most importantly, low energy consumption [3]. The last requirement is due to the fact that organizing the power supply of the sensor network (consisting, for example, of hundreds of sensor elements) in the classical way, using wires or using small energy storage devices (batteries), is a technically difficult, economically ineffective task, moreover the same potentially causing significant harm to the environment. The solution to the problem of feeding the sensor elements of such a network is the transition to wireless technologies for power transmission. The modern urbanized environment includes an impressive number of different radio transmitters, cell towers, digital television, Wi-Fi transmitters, repeaters, amplifiers, routers, and other devices operating in the radio frequency and microwave ranges. The ability to collect and store the energy of electromagnetic radiation is a good solution for powering micropower electronic devices that fit into the concept of the Internet of Things. In practice, two options are possible: energy collection from a wide frequency band or at one central frequency. The first case is better suited for urban IoT space, the second for environmental monitoring systems remote from cities, where background radio emission is present only near relay lines. An important parameter in the collection of electromagnetic energy is the efficiency of its conversion into direct current. Microstrip rectennas [4] show high conversion efficiency. The converter is a rectifying antenna or rectenna (rectifiyngantenna), after which a detecting element (rectifier) is installed.

An important stage in the creation of elements of a modern electronic base is the modeling stage. Modern modeling methods make it possible to significantly speed up the process of optimizing the geometric parameters of devices, to select materials and topology to achieve the maximum efficiency of the designed device.

In this paper, we consider the results of finite element modeling of a rectenna based on a geometric fractal *H*-tree (or *T*-branching), with a central frequency of 5 GHz. The fractal has a Hausdorff dimension of 2, and comes arbitrarily close to each point in the rectangle. The H-tree fractal is often used in antenna microstrip arrays so that the radio signal arrives at each individual microstrip antenna with the same propagation delay.

The results obtained are compared with the manufactured experimental rectenna sample.

2. EXPERIMENTAL TECHNIQUE

The rectenna was modeled using the finite element method. Thus, the initial size of the base element of the zero iteration structure was 40×40 mm, while the base element of the fractal of the 1st iteration is already 20×20 mm and, accordingly, of the 2nd iteration, 10×10 mm. Antenna models are also shown in **Fig. 1**. Fig. 1 shows a geometric fractal (*a*), a 3D model of a modeled rectenna built on its basis (*b*) and a mesh used in modeling. The material constants of a standard FR4 glass fiber coated with a thin copper layer were used as the antenna material. The rectenna is connected via a coaxial lead at its base in the center of a metal disk, the diameter and thickness of which are respectively 60 and 1 mm. The ground electrode (copper) was located on the back of the disk. The voltage supplied to the coaxial port located in the center of the disk was 1V.

Based on the simulation results, a fractal rectenna was created. The material used was a double-sided foil glass fiber laminate with a thickness of 1 mm. A disc with a diameter

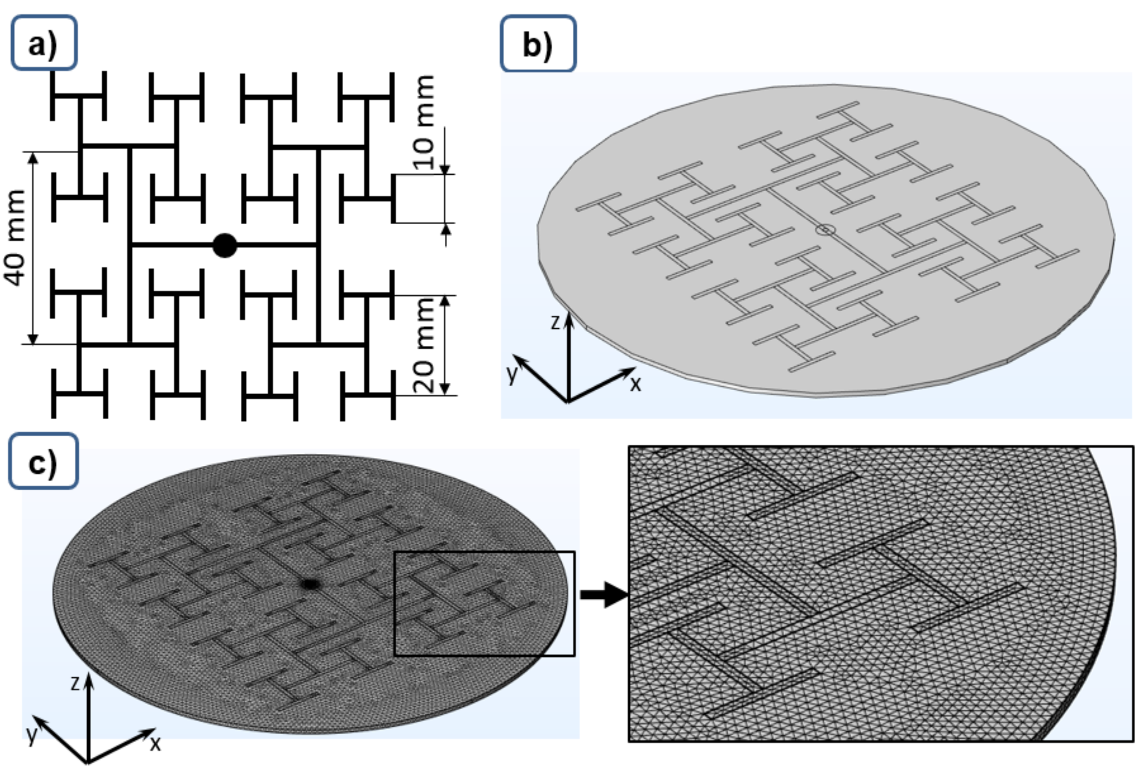

Fig. 1. *Geometric fractal H-tree in the 2nd iteration (a), 3D model of rectenna used for modeling.*

of 60 mm was cut out of a glass fiber plate. On one side of the disk, a 2 μm thick layer of S1813SP15 positive photoresist was applied using a Sawatec SM-180-BT tabletop resist centrifuge (Switzerland). After that, the structure was kept for 30 min at a temperature of 90°*C*, and then a pattern corresponding to the above calculations was created on the photoresist layer using a Smart Print maskless photolithographic setup (Microlight 3*D*, France). Further, the unnecessary part of the photoresist was removed with the P-236A-MF developer, and the excess copper was etched off with ferric chloride. Resist residues were removed with acetone. **Fig. 2***a* shows an image of the front part of the plate with a rectenna formed on it. On the back side of the rectenna, a standard SMA connector was soldered to connect to the device, **Fig. 2***b*. To study the *S* parameters of the rectenna, an Anritsu VectorStar MS4644A vector network analyzer (Japan) was used. The measurements were carried out in a specially prepared anechoic chamber, the interior of which was covered with a MOX 1/50 radio-absorbing material. The rectenna was connected to the measuring device using a phase-stable cable.

3. RESULTS AND DISCUSSION

Fig. 3 shows the graphs of the frequency dependence of the S11 parameters obtained as a result of modeling and as a result of the experiment. **Fig. 4** shows a 3*D* model of the rectenna radiation pattern.

Comparison of the *S*-parameters shows that the considered model adequately reflects the real device.

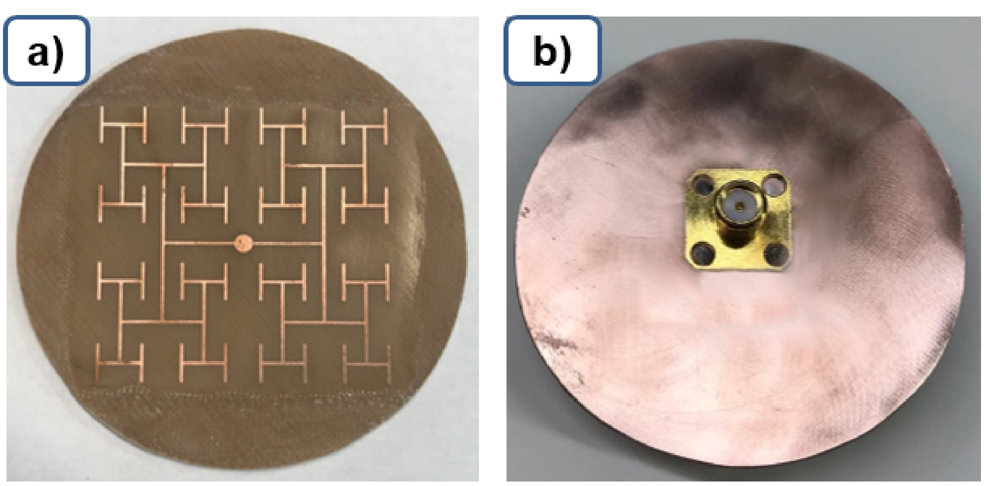

Fig. 2. *Image of the front (a) and back (b) sides of the rectenna sample.*

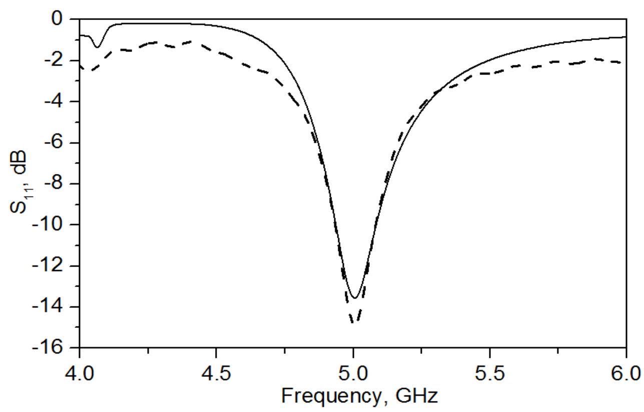

Fig. 3. *Frequency dependence of S11-parameters of the modeled and real rectenna. Solid line – simulation, dashed line – experimental data.*

The directional pattern model allows the rectenna to be positioned in an optimal way if there is information about the real electromagnetic situation on the ground.

4. CONCLUSION

Thus, it is shown that a small-sized rectenna based on a simple fractal with a small filling has a gain of about 14 dB in the main frequency band and can be used as an input antenna in world energy systems [5].

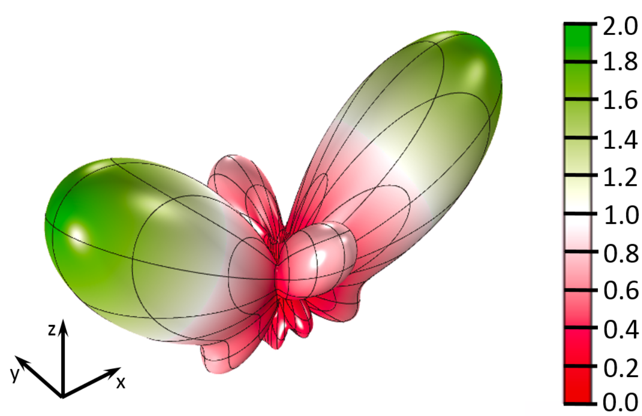

Fig. 4. *3D model of the directional pattern of the rectenna.*

The practical application of rectennas is very wide – from the transmission of electricity by radio waves of the microwave range to the power supply of micropower consumers of various functional purposes. In particular, interest in such devices is caused by the possibility of their application, for example, for wireless transmission of energy to small unmanned aerial vehicles, as well as for providing energy to various sensor systems in microrobotics.

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