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Synthesis of Quasi-Fractal Hemispherical Dielectric Resonator Antennas

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***Abstract* —The paper considers the models quasi-fractal dielectric resonator antenna (DRA) based on a hemispherical. Thus, the influence of the depth of the overlap of the constituent elements in the spatial-frequency characteristics DRA. The interaction of the antennas of non-Euclidean geometry with radio waves is described difficult. It is therefore advisable to perform the synthesis of these antennas by mathematical modelling using the Ansoft HFSS package. To simplify the analysis of the characteristics of the antennas, their arrangement is limited geometrical structure, which has five elements on one horizontal surface. Evaluation and comparison of antennas held by the following characteristics: amplitude-frequency response, beam pattern and voltage standing wave ratio.**

Keywords— amplitude-frequency response, Ansoft HFSS, antenna, beam pattern, dielectric resonator antenna, fractal, quasi-fractal, voltage standing wave ratio.

I. Introduction

As you know, the development of telecommunication equipment is necessary to consider the contradictory requirements. One of them is to reduce the physical size of the antennas while ensuring a wide bandwidth and mode of operation in many ranges. To solve this problem, new approaches are needed in building antenna systems.

Quite convenient and cheap solution to this contradiction may be the use of dielectric resonator antennas (DRA) [1, 2]. Among their advantages it should be noted:

High efficiency at high frequencies.

Easy shaping of elements of the antenna (hemispherical, cylinders, parallelepipeds, cones, etc.) due to dielectric materials.

Compact dimensions.

Application in a wide range of frequencies.

In turn, when designing multi-band antennas with small size, high gain and directivity using a comprehensive fractal approach [3]. Its distinguishing feature is a simple algorithm of forming the antenna geometry and the possibility of reducing the dimensions without significant loss of gain.

II. ANALYSIS OF RECENT STUDIES AND PUBLICATIONS, WHICH DISCUSS THE PROBLEM

A very promising direction is based on the use quasi-fractal. Based on the analysis in this direction should indicate the most successful examples of such geometry of antennas is given in [4]. However, this article is limited to the synthesis and evaluation only chromoscopic 2D antennas.

As a consequence, implementation of the DRA on the basis quasi-fractal structures, including in the form of hemispheres, in theory, still remains to be improved. This shows the relevance given in the research results.

III. THE AIM OF RESEARCH

Thus, the aim of this work is to increase the efficiency of antenna systems by introducing technologies DRA-based quasi-fractal.

IV. Main Results of the Study

According to [5], quasi-fractals do not strictly sequential repetition of elements at each change in scale, or incomplete or inaccurate similarity of structure of its elements.

Features quasi-fractal (fractal) antennas are defined depending on the geometric shape or number of elements, which greatly complicates the prediction results. Therefore, for calculation of such antennas, it is expedient to use methods of numerical analysis [6]. Hence the need to use a program that would provide the above-mentioned processes, and provide a wide range of possibilities. An example implementation of this approach can be a software package electrodynamic modeling Ansoft HFSS [7], which allows designing complex devices of different types, and to

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calculate their characteristics, simulating the conditions of the real world.

To determine the properties of the designed quasi-fractal DRA in the article the estimation of their spatial-frequency characteristics: amplitude-frequency response (AFR), beam pattern (BP) i voltage standing wave ratio (VSWR) [8].

We should pay attention to the fact that in real terms the value of the VSWR significantly depends on the frequency of the received signals, which is easily explained by different conditions of approval of antenna and load in a wide spectral range [7]. The reason for this is not only the presence of the reactance to the internal resistance of the antenna, but also the change of the active component of internal resistance with frequency variation, caused by differences in the conditions of flow of induced currents of different frequencies on the surface of the receiving antenna. The higher the frequency, the less they penetrate deep into the conducting medium, namely the cross-sectional area of a conductor depends, in the end, its conductivity.

Therefore, the value of VSWR is related to one of the methods of determining the bandwidth of the antenna system [9]. Under this approach, the term "bandwidth of an antenna" means the frequency range of the received signal within which the VSWR value does not exceed a predetermined level.

It should also be noted that when calculating the bandwidth in the VSWR as it appears integral value for the whole antenna design [10]. The fact that the value of VSWR is not fixed for all parts of the antenna and may have significant changes, variations of the impedance of the antenna in different locations where the relevant measurements are.

Thus, for modeling the DRA extended the following assumptions.

Peripheral and central elements have the same size and made from homogeneous dielectric.

The number of peripheral elements does not exceed five.

The position of the peripheral elements is changed symmetrically relative to the base element.

Each peripheral element has only one touch point to the central element or the set of such points that form the local area, providing a symmetrical arrangement of the antenna.

Antenna power is provided by a loop of the vibrator, which is located under the lower base of the central element DRA.

Calculations of the parameters of the antenna are performed with a step of 50 MHz.

The DRA agreement with the receiving-transmitting tract on the characteristic impedance and the VSWR is not possible.

The first step of the synthesis of antennas is the process of creating basic components such as: space to ground antenna feed system, a central element in the form of a hemisphere and air box (Fig. 1). In the future, based on the assumptions, it was designed a few options DRA (Fig. 2).

The first design was synthesized on the basis of five hemispheres without overlapping its constituent elements (Fig. 3).

The results of determining the AFR and VSWR of the antenna are explained by figure 4. As can be seen, the frequency response of the antenna has two pronounced resonances at the frequency of 10 GHz.

Other design DRA (Fig. 5) also consists of five hemispheres, but with partial overlap of the peripheral elements 10 mm. The change in placement of the elements had almost no effect on the performance of the antenna, except the gain, which was reduced to 18 dB. As can be seen (Fig. 5.b), in this located element of BP it remained almost unchanged. As for AFR and VSWR (Fig. 6.a, b), the range of operating frequencies is almost unchanged.

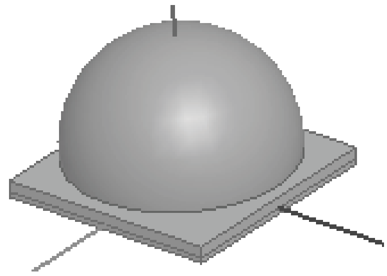


Fig. 1. Basic element of the quasi-fractal DRA

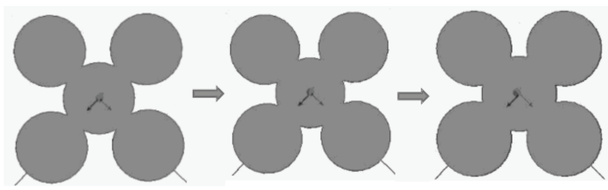
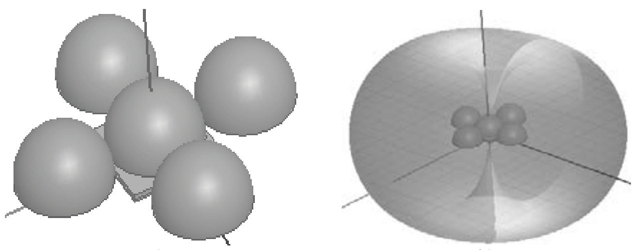


Fig. 2. The introduction of overlapping of constituent elements of the antenna

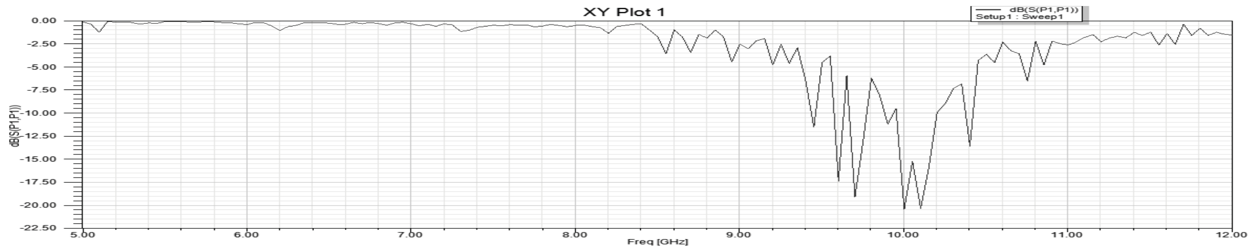


a) b)

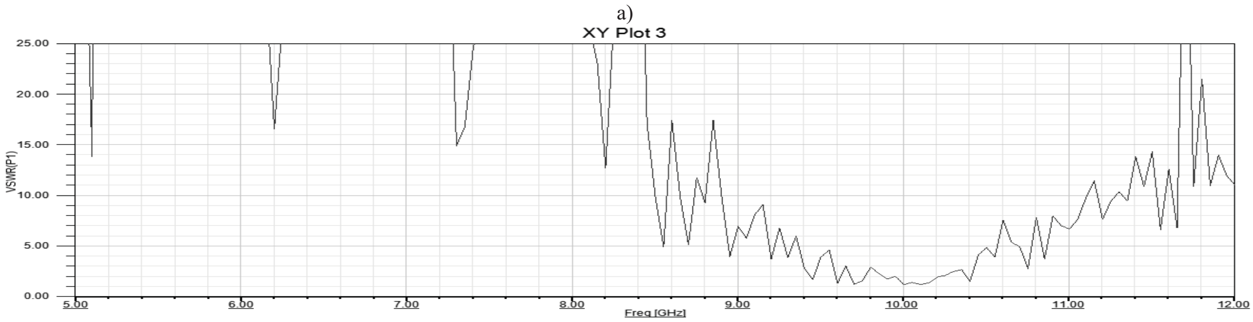
Fig. 3. Quasi-fractal hemispherical DRA without overlap: a) – layout; b) – BP.

In the third design DRA overlap of the peripheral elements had increased to 20 mm (Fig. 7, 8). This version of the antenna you may notice some changes in the characteristics. AFR graphs show that the antenna gain up to 28 dB at the resonance frequency of 10.1 GHz approximately, and the area of the resonance is quite narrow.

This indicates that the antenna design becomes narrowband. As for the VSWR of the antenna, its frequency range within which VSWR does not exceed 2.5, tapers. Thus, the decrease in the overall size of the horizontal section of the antenna design due to the increase of overlapping central and peripheral hemispherical elements leads to a narrowing of the frequency band of the antenna in the range of 10 GHz.

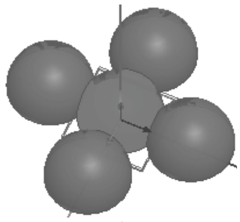


a)



b)

Fig. 4. Features of the quasi-fractal hemispherical DRA without overlap: a) – AFR; b) – VSWR



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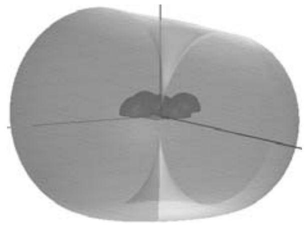
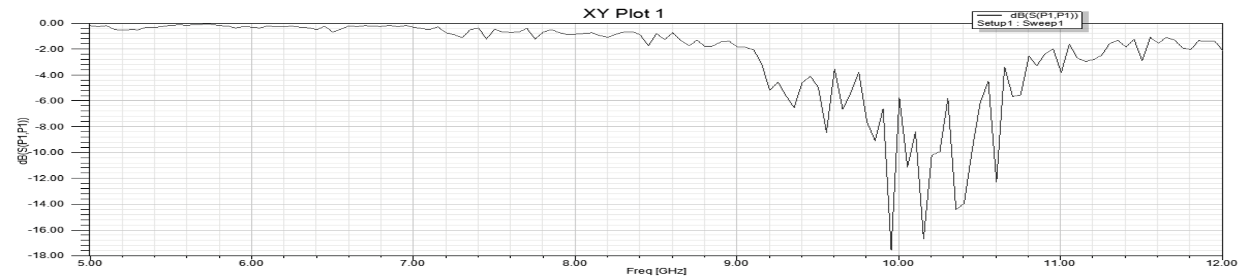


b)

Fig. 5. Quasi-fractal hemispherical DRA with overlapping constituent elements in 10 mm: a) – layout; b) – BP



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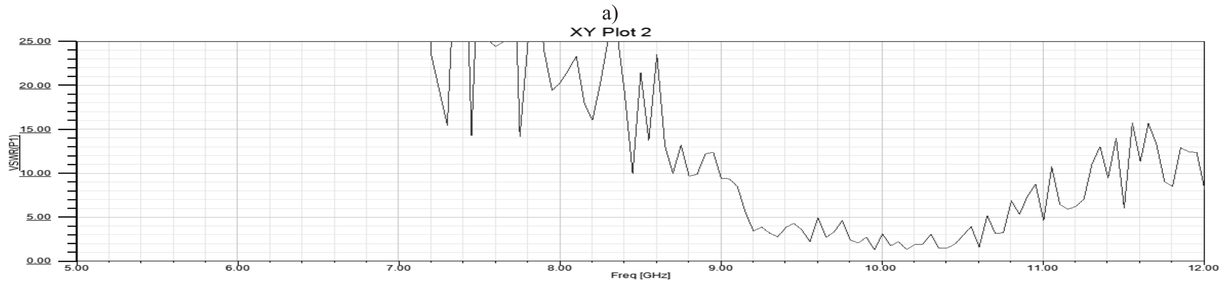
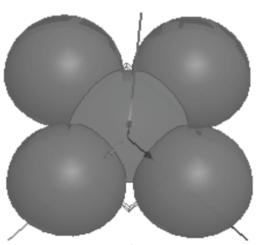
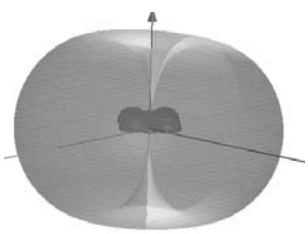


b)

Fig. 6. Features of the quasi-fractal hemispherical DRA with overlapping constituent elements in 10 mm: a) – AFR; b) – VSWR



a)



b)

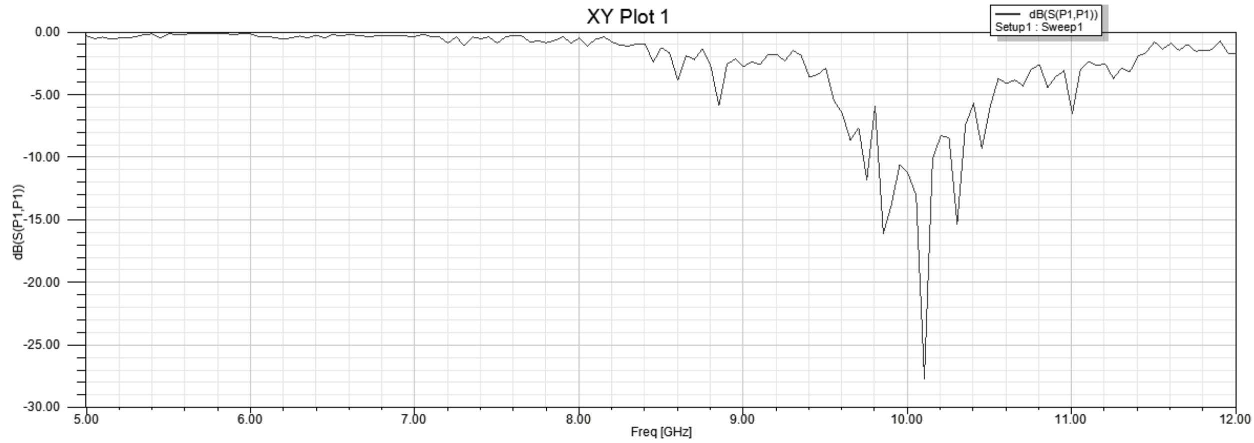
Fig. 7. Quasi-fractal hemispherical DRA with overlapping constituent elements in 20 mm: a) – layout; b) – BP

V. CONCLUSIONS AND PERSPECTIVES OF FURTHER RESEARCH

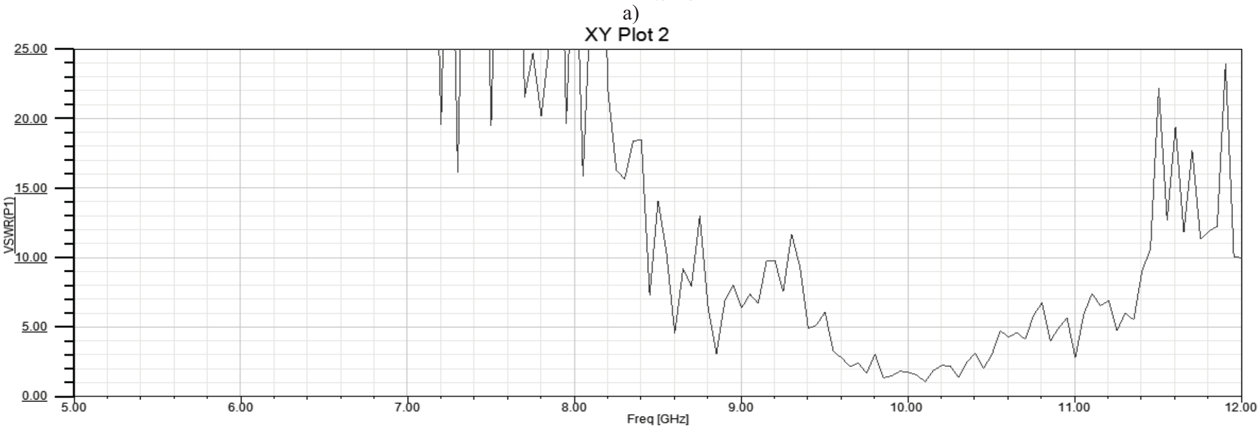
After analyzing all of the models we can conclude that the mutual arrangement of elements of antenna has some effect on its performance. It was also determined that the decrease in the overall size of the structure through the slab leads to the narrowing of the bands in the range of its operating frequencies.

However, quite a large step in frequency (50 MHz) and lack of coordination with DRA receiving and the transmitting tract is not allowed at this stage to obtain a more coherent picture of the distribution of resonances.

Thus, carefully selecting mutual spacing of overlapping items DRA, it is possible to find a compromise solution which will satisfy the requirements to the maximum possible band of operating frequencies. The corresponding optimization problem can be solved analytically but using the HFSS package for this is a much simpler solution.



a)



b)

Fig. 8. Features quasi-fractal hemispherical DRA with overlapping constituent elements in 20 mm: a) – AFR; b) – VSWR

Regarding the considered images BP, it should be noted that in all cases they comply with the limiting boundaries of the investigated frequency range. Overall, further research could be used to define the properties of DRA, which are based on combination of fractal and quasi-fractal geometric structures, as well as incorporating metamaterials

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