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QUASIFFRACTAL DIELECTRIC RESONATOR ANTENNA BASED ON THE SYMMETRIC HEXAGON

In this work proposed dielectric resonator antennas based on quasifractal structures. In order to determine the influence of the geometry of the antenna on its spatial-frequency characteristics, simulation was carried out using a package of electrodynamic modeling Ansoft HFSS. On the basis of the introduced initial assumptions, the dependences of the amplitude frequency characteristic, the beam pattern and the voltage standing wave ratio on the depth of the overlap of the central and peripheral elements were studied. Based on the analysis of antenna geometry models, optimal variants of the layout geometry of dielectric resonator antennas are substantiated.

Key words: AFC, antenna, BP, fractal, Ansoft HFSS, DRA, VSWR.

Introduction

As is well known, the tendency towards miniaturization of telecommunications requires the maintenance of an adequate level of characteristics of antenna systems. In this case, the dielectric resonator antennas (DRAs) are quite promising [1]. At the same time from dielectric materials various volumetric shapes (spheres, semispheres, cylinders, parallelepipeds, cones, intermediate cones, hexagons, etc.) or their combinations can be formed. This approach can provide a fast, reliable, convenient and cost-effective solution to the challenges faced by telecommunication system developers.

At present, for the design of multi-band wideband antennas with high gain, necessary beam pattern (BP) simultaneously with small dimensions it is possible to use geometric fractals [2].

However, in this approach, the analytical description of antenna parameters is rather complicated because their characteristics are determined based on the change in the geometric shape of the antenna or the number of elements with pre-predictably difficult results. The consequence of this is the calculation of fractal antennas, which is carried out mainly by methods of numerical simulation [3].

Thus, the aim of this paper is to develop proposals for the implementation of DRA based on the fractal method and to determine the influence of the geometry and depth of the DRA element overlap on the basis of symmetric hexagons on the characteristics of the antenna.

In order to expand the DRA circuitry, it is proposed to use quasifractal geometry as the basis for which the existence of a recursive ratio of fractal iterations is optional. For completeness of the description of the influence of geometry DRA, in addition to BP, it is expedient to consider the frequency characteristics of the antennas in the form of frequency dependences of the gain factor (Amplitude-Frequency Characteristic, AFC) and Voltage Standing Wave Ratio (VSWR) [4].

The main difference between fractal geometric forms is the fractional dimension, which manifests itself in a recursive repetition, on a reduced or growing scale, output deterministic or random antenna patterns. According to [5], at present, there are over two hundred fractal geometric shapes that are suitable for the construction of antenna technology. Also, their number is steadily increasing.

Another issue of the introduction of quasifractal structures, characterized by the absence of a recursive repetition, in the theoretical plan has not yet been sufficiently worked out.

Therefore, the work proposes the use of a hexagonal as a basic element of a quasifractal DRA.

It will be useful to determine the influence of the geometry of the quasifractal DRA on its spatial-frequency characteristics. For research, in order to simplify the modeling process in Ansoft HFSS [4], the following provisions were admitted.

1. All elements are made of a conditional dielectric material, whose relative permittivity is ε = 50.

2. Dimensions of DRA elements are identical and provide a quasi-fractional structure: a base hexagon with a edge of 14 mm, and a height of 50 mm.

3. Power antenna supply is provided by a conductor of the loop vibrator located below the bottom of the central element of the DRA (the diameter of the conductor is 0.5 mm and the diameter of the loop is 10 mm).

4. Antenna elements do not overlap in space or overlap partially.

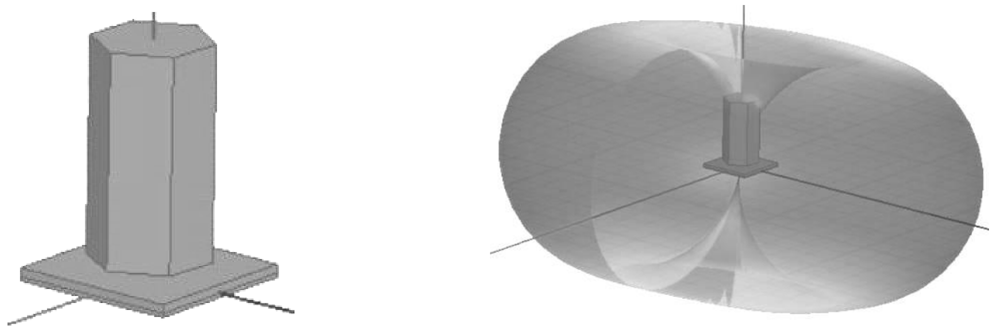
5. Each peripheral element has only one point of contact with a central or multiple of such points that form a local zone, providing a symmetrical antenna arrangement.

6. Calculations of antenna parameters are carried out in a step of 50 MHz. The resulting BP should have a minimum level of return light petals.

7. When synthesizing the antenna layout, it is not expected to rotate the peripheral elements along the long axis.

8. Reconciliation of the DRA with the receive-transmission path over the wave impedance and VSWR is not carried out.

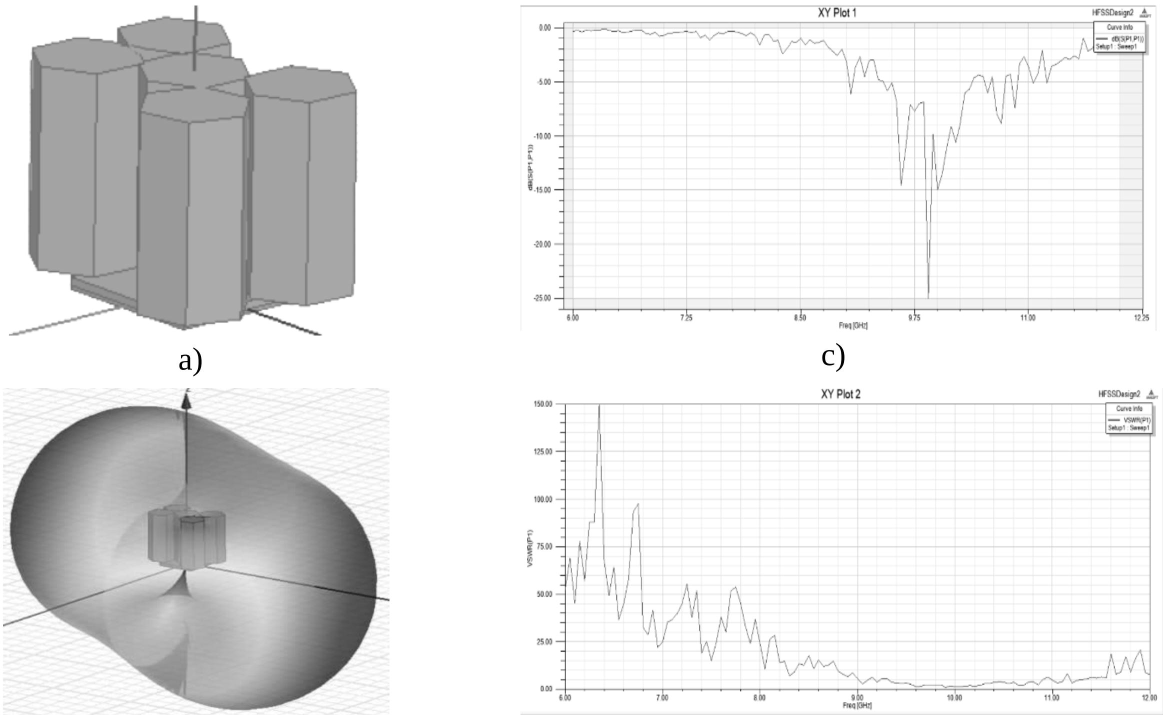
Thus, hexagon is considered as the basic element (Fig. 1). Subsequently, the influence of the number of peripheral elements and their positions relative to the central element on beam pattern and AFC of antennas was analyzed. Based on the implications of assumptions, several versions of the DRA model were investigated.



a) b)

Fig. 1. Basic element DRA based on on a hexagon: a) – power scheme; b) – BP

In the first version (Fig. 2), 4 dielectric peripheral elements touch the faces of the central element. AFC such an antenna (Fig. 2.c) has a pronounced resonance region between 9.5 and 11 GHz in which the antenna bandwidth is rather narrow.



a) c)

b) d)

Fig. 2. The first version of the quasifractal DRA: a) – power scheme; b) – BP; c) – AFC; d) – VSWR

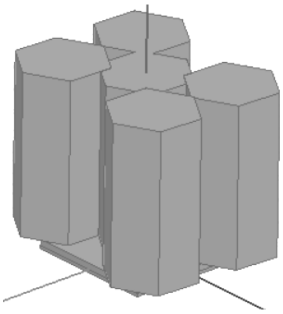
We know that under real conditions, VSWR greatly depends on the frequency of received signals, this is easily explained by different conditions for matching the antenna and the load in a wide spectral range.

The reason for this is not only the presence of the reactive component of the antenna's internal resistance, but also the change in the active component of the internal resistance with the frequency caused by the differences in the course of the currents of the various frequencies on the surface of the receiving antenna. The higher the frequency of currents, the less they penetrate deep into the conductive medium, and in particular from the cross-sectional area of the conductor depends, ultimately, on its conductivity.

Therefore, one of the methods for determining the bandwidth of an antenna system is related to the values of the VSWR. According to this approach, the term "antenna bandwidth" refers to the frequency range of the received signal, within which the value of VSWR does not exceed a predetermined level.

Also, it should be borne in mind that the VSWR in the bandwidth calculations shows its integral value for the entire antenna construction. The fact is that the VSWR value is not fixed for all antenna areas and may have significant changes, in accordance with the variation of antenna impedance at its various points, where appropriate measurements are made.

The second version of the investigated construction (Fig. 3) contains 5 elements - 4 dielectric peripheral elements touching the faces to the central element and overlay it on 5 mm, and two elements touch the faces to each other. The AFC of this antenna (Fig. 3.c) has a pronounced resonance region between 9 and 11 GHz, in which the bandwidth of the antenna is rather narrow.



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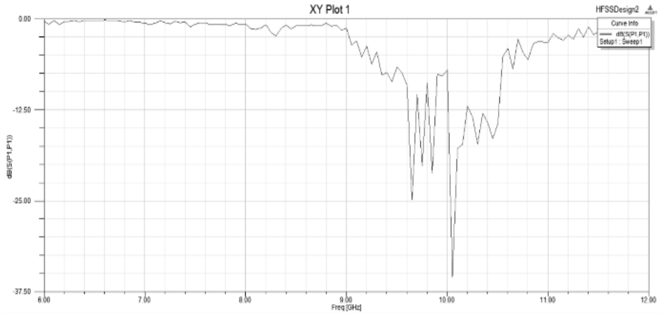
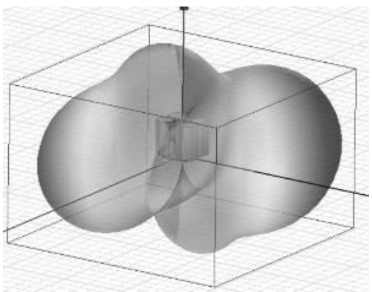
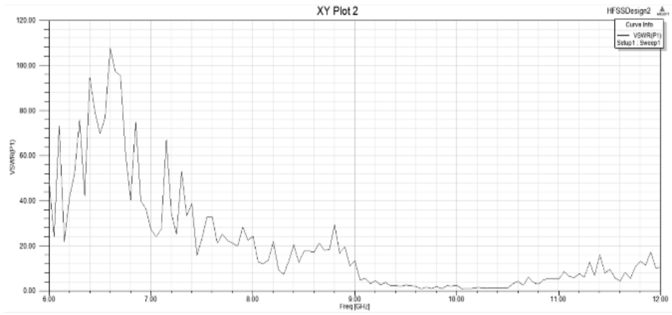


c)



b)



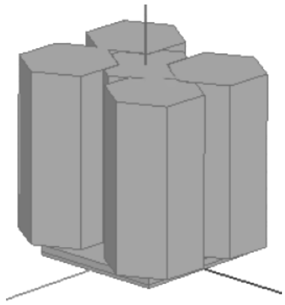
d)

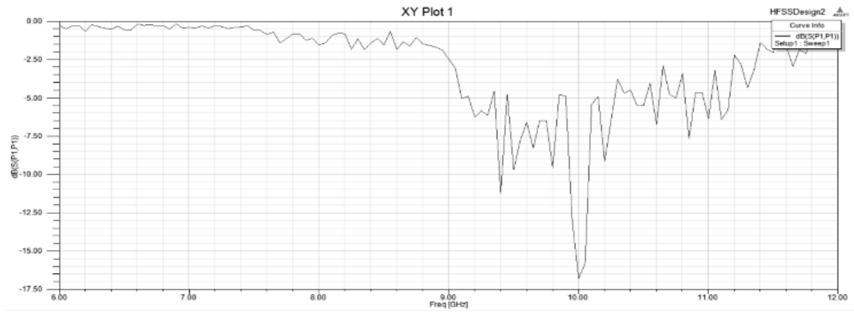
Fig. 3. The second variant of the quasifractal DRA: a) – power scheme; b) – BP;

c) – AFC; d) – VSWR

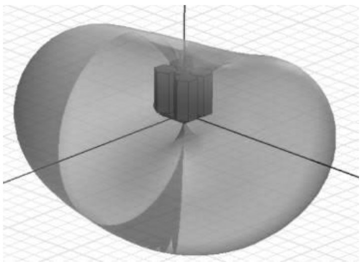
Compared with (Fig. 2.a), the peripheral elements overlap the angles of the central hexagon by 5 mm. Comparing the results obtained, it is not easy to establish that an increase in the immersion of the outer elements of the antenna construction in the central part of the body leads to the expansion of the bandwidth of the antenna due to the appearance of additional resonances. Such an effect is quite consistent with the phenomenon described in [6], for example, a quasifractal printed antenna.

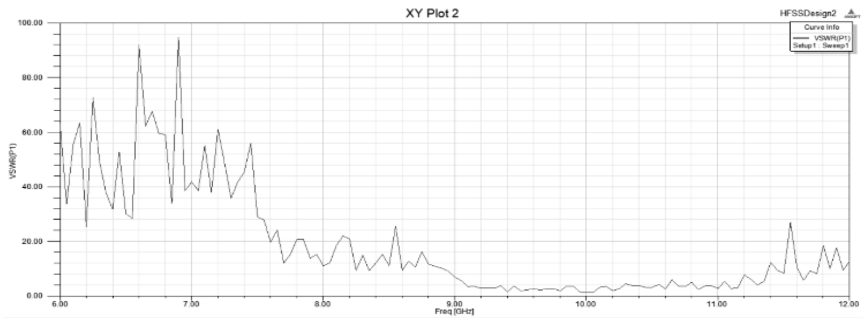
In the 3rd version of the DRA, the central element is overlapped by the side elements by 7 mm (Fig. 4). Compared to the first and second variants, the bandwidth of an antenna is further expanded, as additional resonances diverge over a greater distance by frequency of 9÷11.5 GHz.





a) c)



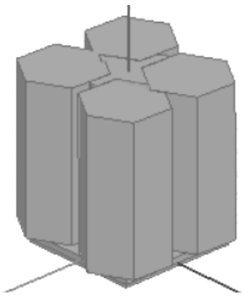


b) d)

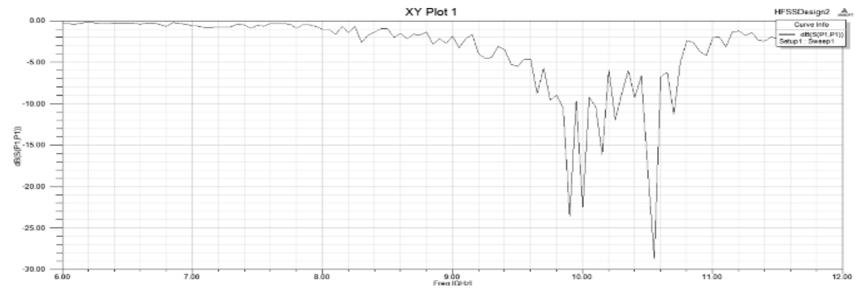
Fig. 4. 3rd variant of quasifractal DRA: a) – power scheme; b) – BP; c) – AFC; d) – VSWR

At the same time, the lack of harmonization of the DRA with the receive-transmission path and a fairly large step in frequency at 50 MHz calculations did not allow at this stage to obtain a more distinct picture of the distribution of resonances. However, in accordance with the interpretation [6], in this case, the additional resonances that are due to the external dimensions of the quasifractal basis of the antenna, formed by lateral elements, are rather closely monitored.

As expected, the bandwidth expansion with increasing hexagonal overlapping elements can not continue monotonously. This is evidenced by the following, the 4th version of the DRA, which is characterized by a deeper overlay of the peripheral hexagons on the central one – 10 mm, and two corner hexagons are superimposed one by one – 1 mm (Fig. 5). The bandwidth of the frequency response of the antenna, however, significantly decreased, as the frequency interval between the additional resonances significantly decreased. In this case, at a level of 25 dB, the operating frequency band exceeds 550 MHz in the range of 9.8÷10.6 GHz. Therefore, carefully selecting the interval of mutual overlapping of DRA elements, it is possible to find a compromise solution that satisfies the requirements for the maximum possible operating frequency band. The corresponding optimization problem can be solved analytically, but the use of the Ansoft HFSS package for this is a simpler solution.



a)



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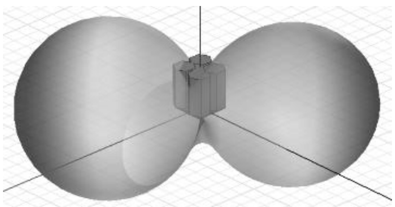

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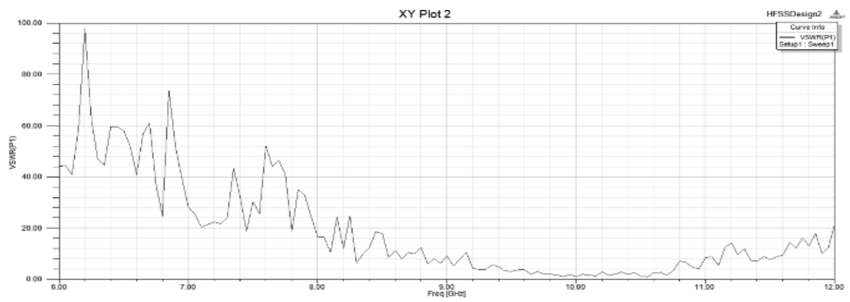


d)

Fig. 5. 4th variant of quasifractal DRA: a) – power circuit; b) – BP; c) – AFC; d) – VSWR

In relation to the above BP images, it should be noted that in all cases considered, they correspond to the limits of the studied frequency range.

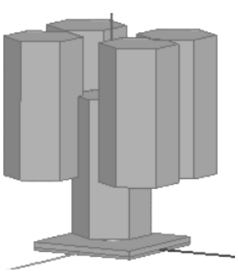
In addition to the analysis of the influence variation of the structural arrangement of parallelepipeds in the horizontal plane, in the framework of the described study, the effect of the vertical shift of peripheral elements relative to the central body antenna was also studied.

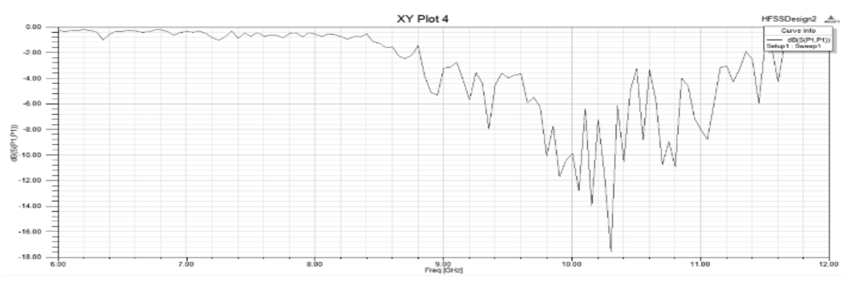
Antenna model in the version given in (Fig. 6) also contains 5 elements, 4 of which are located on top, raised 25 mm and superimposed on the central body of 5 mm. From the charts it is clear that the results are similar to the previous variants of the above models: the band passes AFC is rather narrow, its peak has a second resonance, due to the dimensions of the external elements.

Compared with the previous model, the range of operating frequencies has expanded. Clearly pronounced first and second frequency resonances have almost identical peak values.

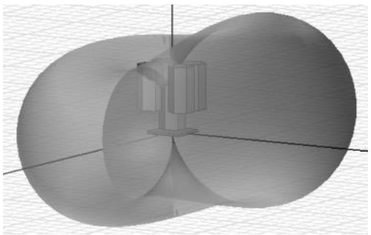
After analyzing the antenna models considered, it is possible to sum up the first: the location of the antenna elements, as expected, has a significant impact on its BP and AFC.

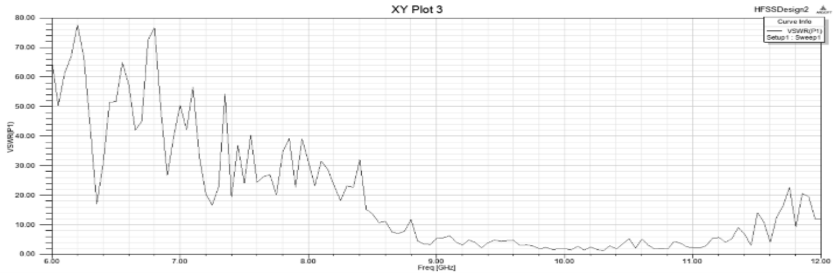
When change the location of elements relative to each other in a vertical plane, the data in the graphs AFC and BP significantly different. The fact that all elements are located in a horizontal plane can be considered justified, which allows obtaining a better result and ensures that the resultant BP approaches the one-beam one.





a) c)





b) d)

Fig. 6. 5th version of quasifractal DRA: a) – power scheme; b) – BP; c) – AFC; d) – VSWR

In general, the results obtained confirm the adequacy of the previously made assumptions and conclusions drawn in [6] for printed antennas. Placing DRAs in a horizontal plane allows for better qualities.

As know, when designing, they tend to shift the resonance frequency of the DRA to the center of the required bandwidth.

As an ideal, the curve of the VSWR value on both sides of the resonance minimum should be symmetric. But in practice, the case of asymmetry of the bandwidth relative to resonance is more widespread. As a consequence, to estimate the frequency properties of the antenna it is expedient to use the concept of relative bandwidth.

Conclusions

Dielectric resonator antennas based on quasifractal structures allow to expand the base of technical solutions for the implementation of mobile applications. Their application allows us to meet broadband and multiband requirements.

In the future, it is necessary to determine the geometric parameters of the DRA for specific frequency ranges of existing standards for wireless telecommunication systems.

But with this, it is advisable to perform an assessment of the proposed layout of the DRA model taking into account the rotation of the peripheral elements along the longitudinal axis, as well as the introduction of asymmetric overlap with the peripheral elements of the central.

It also deserves attention to the use of these quasifractal DRAs based on metamaterials and in the interests of implementing digital beamforming technologies, taking into account the mutual influence of the antenna elements of the smart antennas.

References

1. Slyusar V.I. Dielectric resonator antennas. / Slyusar V.I. // Electronics: science, technology, business. – 2007. – № 2. – P. 28-37.

2. The multi-band antenna based on fractal. / Sliusar I.I., Slyusar V.I., Voloshko S.V., Smolyar V.G. // News of Science and Education. – Sheffield, Science and education Ltd. – № 2, 2018. – P. 32-43.

3. Sliusar I.I. Simulation model of quasifractal 3D antenna. / Sliusar I.I., Slyusar V.I., Mikolenko O.S. // Problems of Informatization: Abstracts of the 5th International NTC, 13-15 November 2017 – Cherkasy – Baku – Bielsko-Biała – Poltava. – P. 80.

4. Bank S.E. Calculation of antennas and microwave structures using HFSS Ansoft. / Bank SE, Kurushin AA - M .: ZAO "NPP" Rodnik ", 2009. – 256 p.

5. Sliusar V.I. Fractal antennas. A fundamentally new type of "broken" antennas. Part 1. / Slyusar V.I. // Electronics: science, technology, business. – 2007. – № 5. – P. 78-83.

6. Babichev D.A. Development and research of microstrip antenna on the basis of fractal approach: dis. Cand. tech Sciences: 05.12.07 / Babichev D.A. – SPb., 2016. – P. 104.

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