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## TECHNICZNE NAUKI

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# ANALYSIS OF SPACE-FREQUENCY CHARACTERISTICS OF A QUASI-FRACTAL DRA BASED ON A CUBE AND TRUNCATED PYRAMID

*In paper considered, models of quasi-fractal dielectric resonator antennas (DRA) based on a cube and truncated pyramid. Ansoft HFSS package used for their synthesis. For the purpose of evaluation influence of antenna geometry on its space-frequency characteristics, variants for DRA composition defined which differ in location of elements and depth of their overlap. Analysis of the results performed based on comparison frequency response, radiation pattern and standing wave ratio.*

***Keywords:*** *antenna, frequency response, standing wave ratio, Ansoft HFSS, directivity pattern, DRA, fractal.*

## Introduction

Significant development of telecommunication systems and their distribution for today accompanied by certain needs and requirements. One such requirement is to reduce the physical size of the antennas while ensuring wide bandwidth and multiband mode. To solve this problem, new approaches needed to construct the antenna systems. A promising direction is development of dielectric resonator antennas (DRA) with using a fractal approach [1]. Advantages of this solution:

– Simple algorithm for forming the antennas geometry [2];

– Diversity of three-dimensional shapes, which can used when synthesizing an antenna design from dielectric materials (spheres, hemispheres, cylinders, parallelepipeds, cones, truncated cones, etc.) [3];

– Possibility of forming all directed radiation pattern (RP) and influence on the form RP by changing the mutual position of the central and peripheral antenna's elements [4];

– Providing the required gain with simultaneous implementation multiband at smaller size than in ordinary antennas [5].

Calculation of the proposed fractal DRA carried out mainly by methods of numerical analysis, since the analytical description of the antenna parameters of non-Euclidean geometry is rather complicated [4, 5].

**Main**

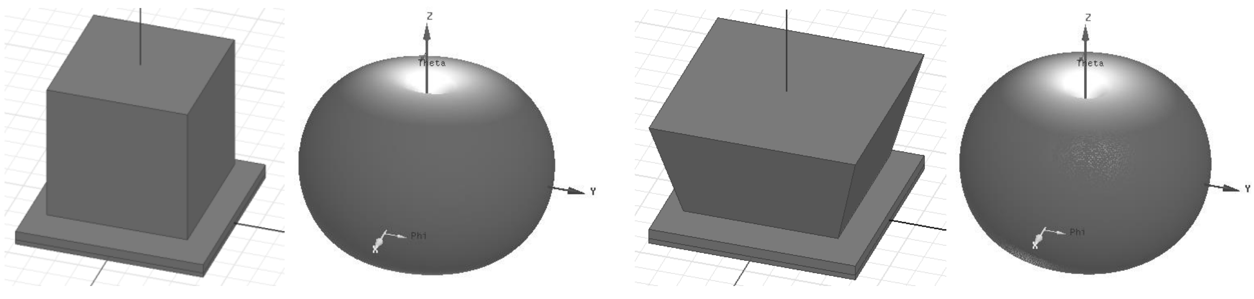
To achieve this goal, in this paper considered models of quasi-fractal DRAs based on a cube and truncated pyramid, which is oriented on a smaller base to the bottom. To design such antennas, electrodynamic modeling package Ansoft HFSS was used [4, 5].

The choice of quasi-fractal structures explained by insufficient research on theory of fractal antennas, and also, unlike fractal approach, providing a recursive ratio of fractal iterations is optional, which simplifies the calculations [1].

As assumptions, the following thesis put forward:

1. Peripherals and central elements are made of a homogeneous dielectric with a relative permittivity ε = 50%.

2. Dimensions of DRA elements are the same and provide a quasi-fractal structure which are based on cube with a 30 mm edge and truncated pyramid which has a smaller base 30 mm, bigger base 40 mm, height 20 mm. Size of a substrate: square with sides 40 mm and height 3 mm (Fig. 1).




a) b)

**Fig. 1. Base elements of DRA and their RP: a) – cube; b) – truncated pyramid**

3. Antenna powered by conductor loop vibrator, which is located below the

bottom of the central element of the DRA. Diameter of conductor 0.5 mm and loop diameter is 10 mm.

4. Each peripheral element has only one point of contact with central elements or set of points forming a local zone, providing a symmetrical composition of the antenna.

5. Estimated parameters of antenna made in increments of 50 MHz.

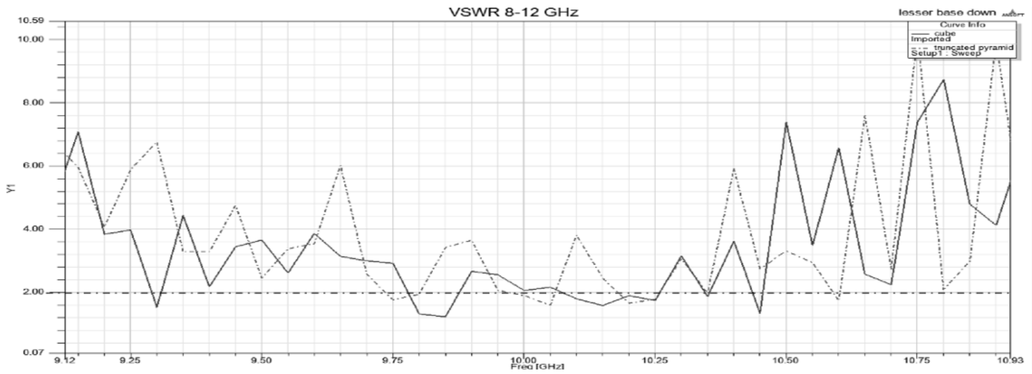
6. The adjustment of DRA with the transceiver path for wave impedance and the standing wave ratio (SWR) not performed.

Analysis of antennas characteristics and their comparison in this research evaluated by parameters such as radiation pattern, frequency response (FR) and standing wave ratio [6, 7]. For example, let us consider the RP of the basic elements of the DRA (for greater clarity, the RP will be used on the plane at a value of φ at 0 degrees), from Fig. 1 can see that RP truncated pyramid has a higher value of power gain and width of a lobes. Note that, RP of these and most of the antenna composition presented in the paper, similar in shape to a single-beam RP of a half-wave dipole antenna (the axis of symmetry does not match to the antenna axis).

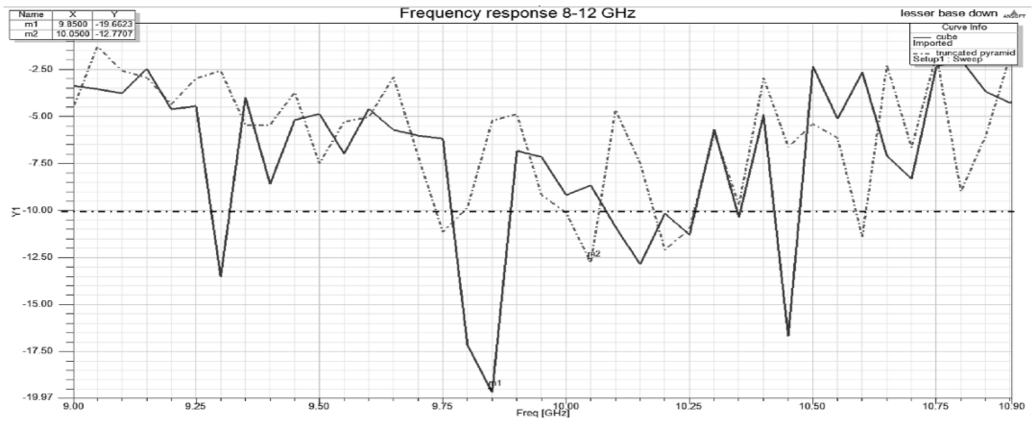
FR and SWR considered at intervals of 8 to 12 GHz, because on this range all the antenna variants have the strongest resonance region. For greater clarity, on interval of 8-12 GHz, will be used the area with only the necessary data for research

In paper used method for determining bandwidth antenna system, which is to find the frequency range of the signal, within which value of SWR does not exceed the permissible value, which is equal to two [6, 7]. As can see from the Fig. 2.a, under such conditions, bandwidth of the base element of DRA based on a cube (solid line) larger than the DRA based on a truncated pyramid (dotted line). Should also take into account, the integral value of SWR for the whole construction used for calculating bandwidth. The point is that the value of SWR is not constant for all sections of the antenna and may have significant changes, according to the variation of antenna impedance at its various points, where appropriate measurements made.

FR analysis makes it possible to explore the resonance area and the level of gain in these areas. For example, according to Fig. 2.a, a peak resonance value of basic element of DRA based on a cube, equals 19.66 dB and is at 9.85 GHz. The peak resonance value of basic element of DRA based on a truncated pyramid equals 12.77 dB and is at 10.05 GHz. Also, if compare the graph of FR with the graph of SWR is noticeable, that the gain in 10 dB corresponds to the permissible value of SWR.




a)



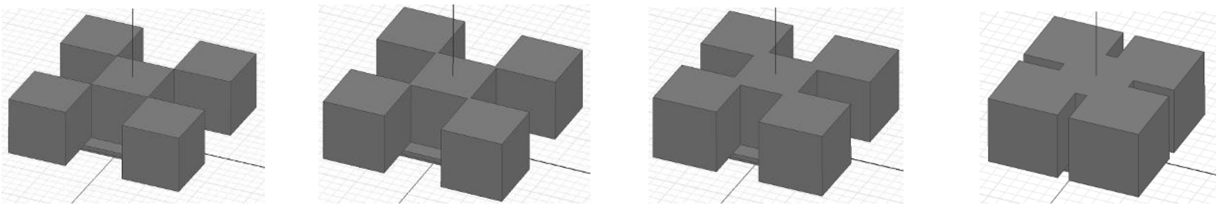

b)

**Fig. 2. Frequency characteristics of basic elements of DRA: a) – SWR; b) – FR**

Consider the effect of the composition with five peripheral elements in the horizontal plane with overlap of the central element and without overlapping, according to these options: without overlapping, overlap to the depth on 1, 5 i 12.5 mm (Fig. 3 and 4) [1].

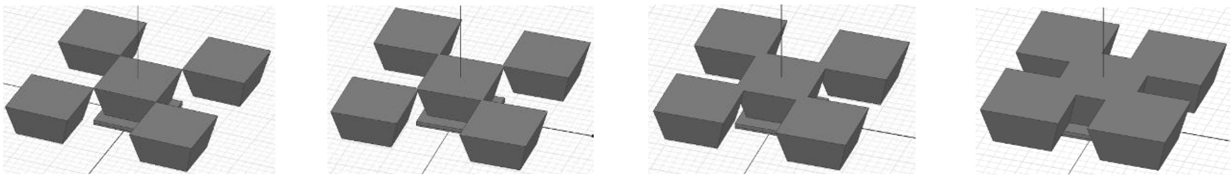
As can see from Fig. 5, DRA based on a cube at low values of overlap has a distortion and a small width of lobes, and for large ones – RPs have the greatest value of power gain, width of lobes and similar in shape to a single-beam RP of a half-wave dipole antenna. In case of DRA based on a truncated pyramid (Fig. 6), the value of overlap does not significantly effect on power gain, width of the lobes and their shape.

DRA bandwidth without overlap much larger in case of a truncated pyramid (Fig. 7.a). As can see from Fig. 7.b, a peak value of resonance equals 18.85 dB at a frequency of 9.75 GHz for cube and 23 dB at a frequency of 10.15 GHz for truncated pyramid. Therefore, in case of DRA without overlap, truncated pyramid wins by all parameters.



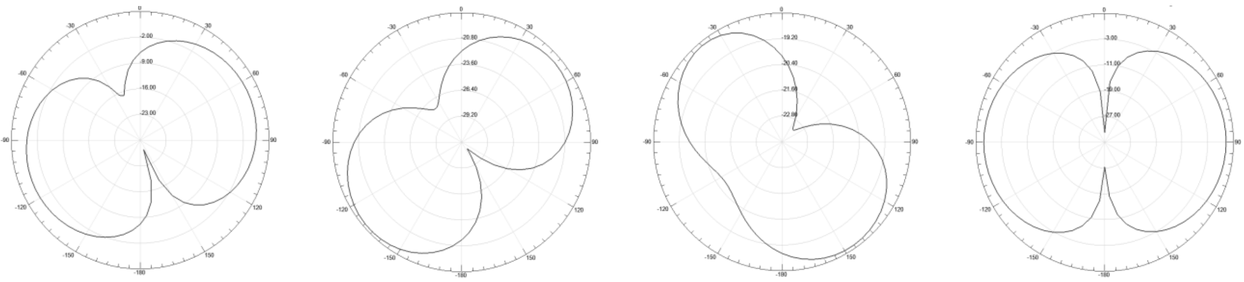
a) b) c) d)

**Fig. 3. Composition of quasi-fractal DRA based on a cube with overlap: a) – without; b) – 1 mm; c) – 5 mm; d) – 12.5 mm**



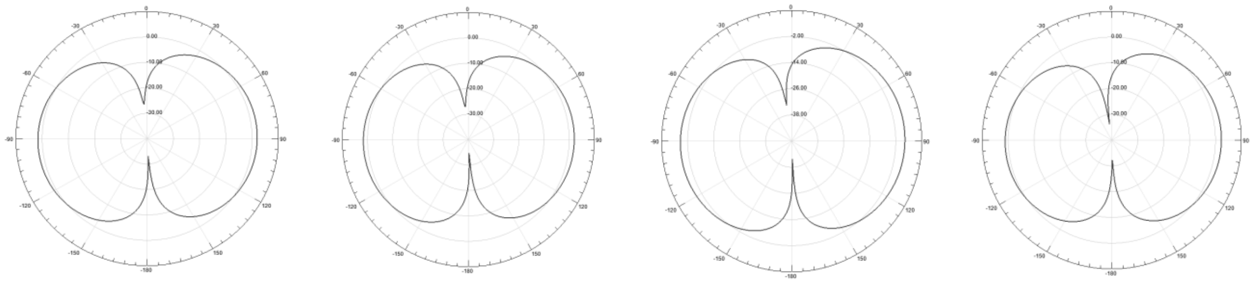
a) b) c) d)

**Fig. 4. Composition of quasi-fractal DRA based on a truncated pyramid with overlap: a) – without; b) – 1 mm; c) – 5 mm; d) – 12.5 mm**



a) b) c) d)

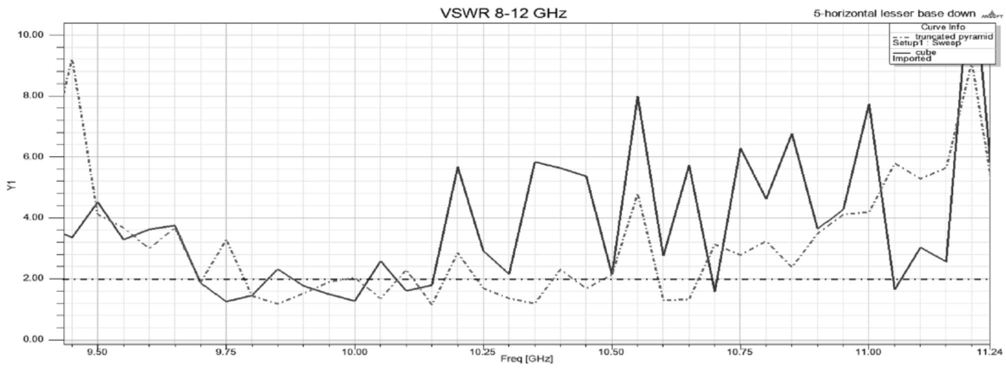
**Fig. 5. RP of quasi-fractal DRA based on a cube with overlap: a) – without; b) – 1 mm; c) – 5 mm; d) – 12.5 mm**



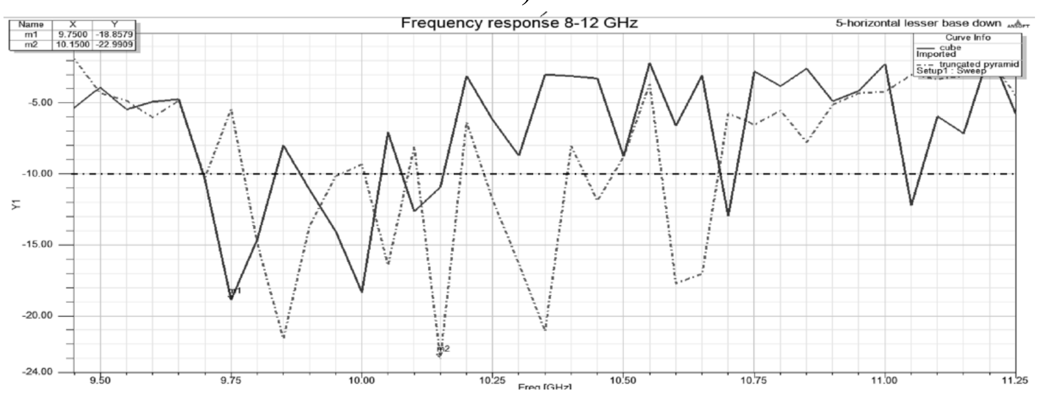
a) b) c) d)

**Fig. 6. RP of quasi-fractal DRA based on a truncated pyramid with overlap:**
**a) – without; b) – 1 mm; c) – 5 mm; d) – 12.5 mm**

For DRA with overlap in 1 mm bandwidth is much larger in an antenna based on the cube (Fig. 8.a). On Fig. 8.b, noticeably that is peak gain equals 31.93 dB at a frequency of 10.05 GHz for cube and 17.93 dB at a frequency of 9.95 GHz for truncated pyramid. That is, in case of DRA with overlapping 1 mm, truncated pyramid loses significantly in frequency parameters.

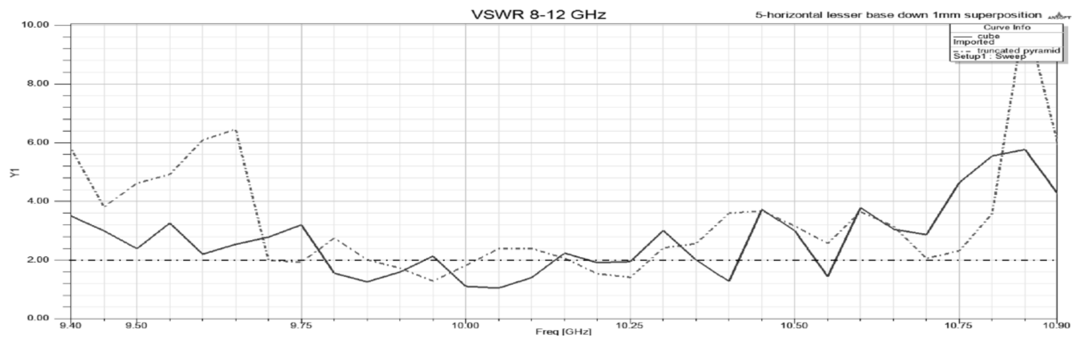



a)

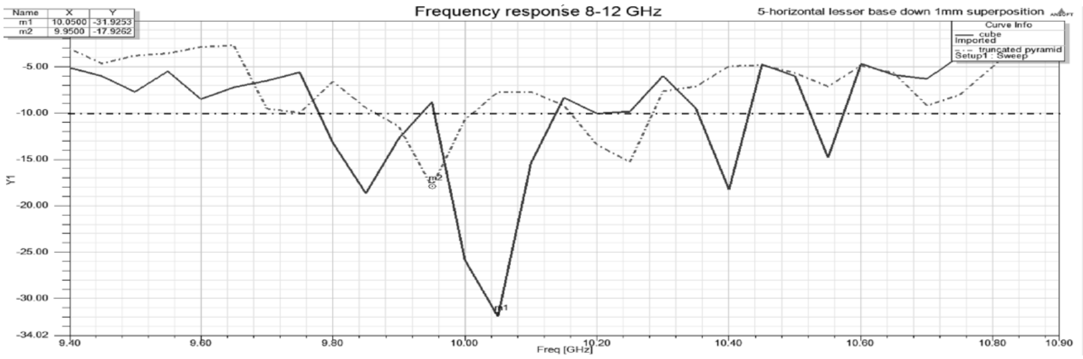



b)

**Fig. 7. Frequency characteristics of quasi-fractal DRA based on a cube and truncated pyramid: a) – SWR; b) – FR**




a)

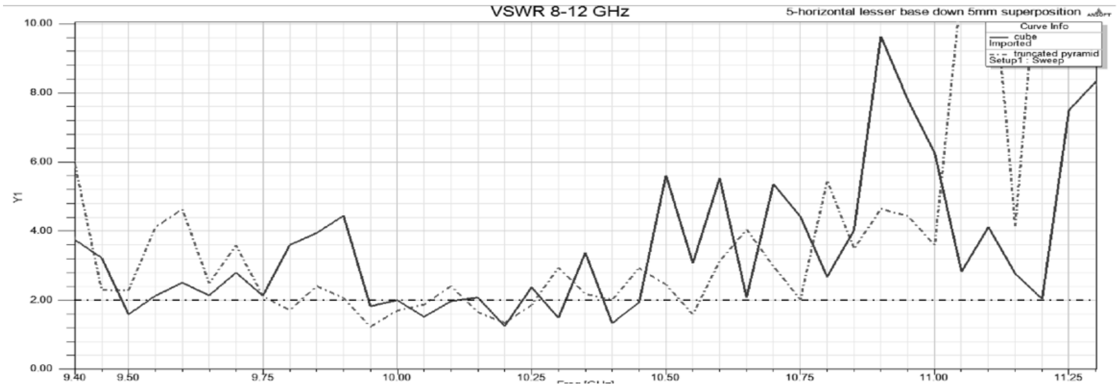



b)

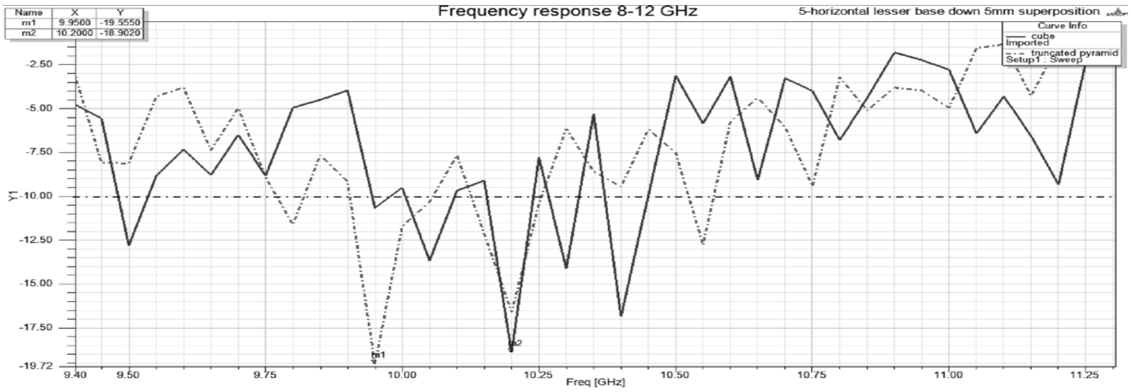
**Fig. 8. Frequency characteristics of quasi-fractal DRA with overlap in 1 mm based on a cube and truncated pyramid: a) – SWR; b) – FR**

For overlap in 5 mm bandwidth not significantly larger in an antenna based on the cube (Fig. 9.a). The peak gain of 18.9 dB is at frequency of 10.2 GHz for cube and 19.55 dB is at frequency of 9.95 GHz for truncated pyramid (Fig. 9.b). Consequently, truncated pyramid has significant advantages by the power gain and antenna directivity, but has a lower bandwidth.

For overlap in 12.5 mm bandwidth significantly larger in an antenna based on the cube (Fig. 10.a). As can see from Fig. 10.b, the peak gain of 37.17 dB is at frequency of 9.7 GHz for cube and 18.16 dB is at frequency of 10 GHz for truncated pyramid. As a result, for DRA with 12.5 mm, truncated pyramid loses by all parameters.




a)

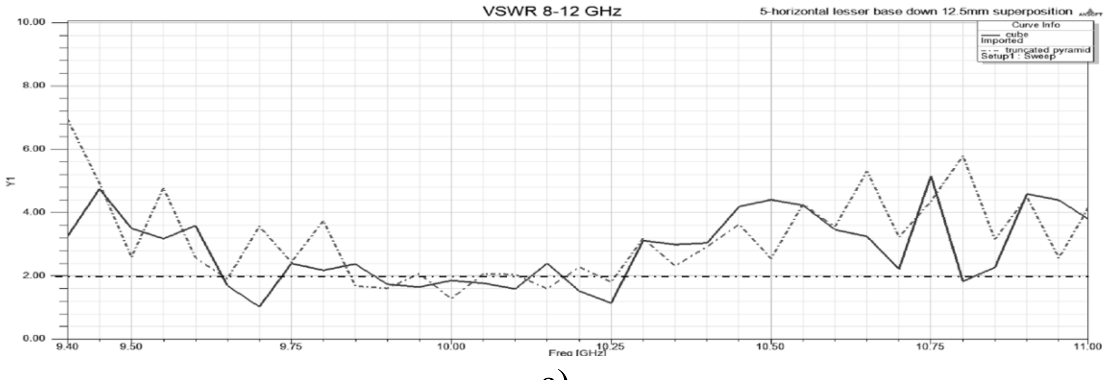



b)

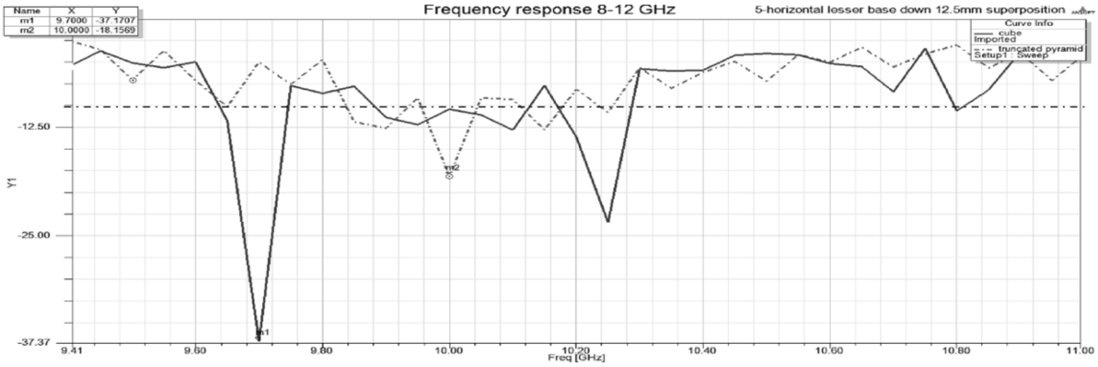
**Fig. 9. Frequency characteristics of quasi-fractal DRA with overlap in 5 mm based on a cube and truncated pyramid: a) – SWR; b) – FR**

The results show, that in general, the most bandwidth and power gain has quasi-fractal DRA with five peripheral elements in the horizontal plane based on a cube, and antenna gain significantly exceeds, reaching over 30 dB in some cases.

DRA based on truncated pyramid generally have better RP, keeping shape, width of lobes at a high level regardless of the geometric location of the elements.




a)




b)

**Fig. 10. Frequency characteristics of quasi-fractal DRA with overlap in 12.5 mm based on a cube and truncated pyramid: a) – SWR; b) – FR**

## Conclusions

Based on the results of study of an obtained models quasi-fractal DRA it is possible to confirm the assumption that the overlapping of peripheral elements substantially effects on space-frequency characteristics of antennas. Thus, the increase in bandwidth is due to the presence of additional resonances. Therefore, obtained variants of DRA in which the bandwidth increase, in comparison with DRA based on one element, more than 2 times. In addition, significant increase in the antenna gain. For example, power gain of composition with overlapping 12.5 mm ten times more than the base element. RP depending on the size of overlap of a central element have both negative changes (small depth of overlap) and positive ones (deep overlap) in case of DRA based on a cube and without change in case of a truncated pyramid.

Further research is advisable to direct to search for DRA models, which will be able to work in multiple ranges, standardized for mobile applications and IoT. Also needs more attention the question of determining the impact on the DRA parameters, variation in size, variation in number of peripheral elements and application of metamaterials.

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