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TECHNICAL SCIENCE

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INVESTIGATION OF THE OVERLAPPING EFFECT OF DIELECTRIC RESONATOR ANTENNAS ELEMENTS ON THE BASIS OF A CYLINDER

In this paper presented results of a study of quasifractal 3D antennas in which a cylinder used as the base element. Direction of research: the effect of the degree of overlap of antenna elements on the radiation pattern and amplitude-frequency response. Studies were conducted in the Ansoft HFSS software package.

Key words: antenna, AFC, beam pattern (BP), DRA, fractal, Ansoft HFSS.

Introduction

Under conditions of rapid development of communication technology, fractal antennas, particularly quasifractical 3D antennas based on dielectric resonators, are becoming increasingly popular. This is due to the fact that with the development of technology there was a demand for miniature antennas that would fit into the case of small devices. Antennas of classical design no longer meet the requirements that are put forward to them, so now, a lot of resources are aimed at studying and researching fractal and quasifractal antenna designs. Since it is necessary to reduce the size of antennas without deteriorating their characteristics, highly effective dielectric resonator antennas (DRAs) are quite promising in this sense, characterized by a compact size, an omnidirectional radiation pattern and the possibility of application in a wide spectrum of frequencies [1]. These antennas use dielectric which can be formed as a half-spheres, cylinders, parallelepipeds etc.

Consequently, the actual task is to develop compact antennas that are suitable for use in small-scale wireless equipments and have the necessary gain and ability to operate in a wide frequency range. In order to implement multi-bandwidth in DRA a fractal approach is used [2]. As a result of simulation and experiments, it has been established that fractal antennas allow for practically the same gain as ordinary ones, but with smaller dimensions, which is important for mobile applications [3].

Thus, the aim of this paper is to develop proposals for the implementation of DRA on the basis of a fractal approach.

MAIN PART

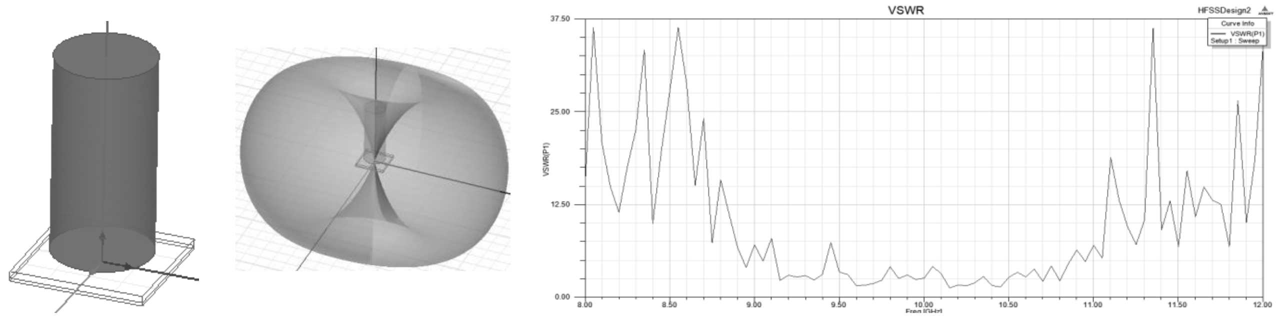
Two main characteristics of the antennas are considered in this paper: the beam pattern (BP) and the amplitude-frequency characteristic (AFC) as the dependence on the frequency of the antenna gain or the standing wave ratio (SWR). The analytical description of the DRA parameters is very complex, so for the calculation of fractal antennas give preference to numerical simulation methods [4].

This is due to the fact that the characteristics of such antennas depend on the geometric shapes of elements, their number, the placement of elements one relative to each other, as well as the depth and the presence of overlapping antenna elements. Actually, the last point will be researched in this paper [5].

Let’s consider the antennas that have 5 elements located on one horizontal surface, the base element of which is the cylinder. The purpose of the research was to determine the influence of the level of overlap of the antenna elements on the achievement of the required BP and AFC [6]. First, we will examine an antenna in which there are no peripheral elements (Fig. 1.a).

This cylindrical antenna is powered by a looped conductor located under the DRA element and has the following parameters: the diameter of the loop is 10 mm; diameter of the conductor – 0.5 mm. The antenna element is made of a homogeneous dielectric, whose relative permittivity is $\varepsilon = 50$. The cylinder has a height $h = 30$ mm and a diameter $d = 15$ mm. This antenna is taken as the standard and we will compare its results with the results of the study of the next variants of antennas.

Fig. 1.b shows the BP of the investigated cylindrical antenna. In its form, it approaches the vibrators BP and is non-directional in the horizontal plane. On the graph of the AFC [7], which is depicted in Fig. 1.c, we see that the SWR of such DRA does not exceed 2.5 in the frequency range from about 9.5 GHz to 10.5 GHz. The small emissions in the SWR at this interval beyond 2.5 are due to the lack of the antenna matching with the power loop, since the goal of optimizing the feeder line in this study was not raised. Thus, the relative bandwidth of the operating frequency of the antenna is about 10 %. Let's proceed to the analysis of quasifractal modifications of this design.



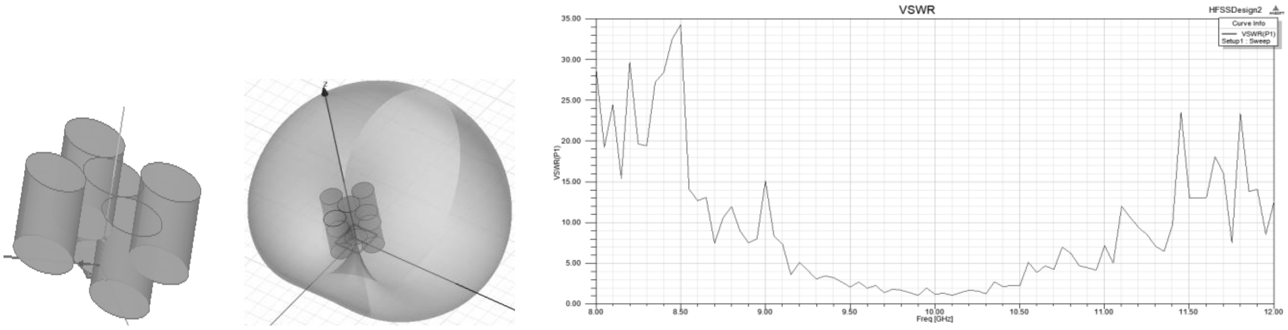
a) b) c)

Fig. 1. Basic element of the DRA on the basis of a cylinder: a) – power circuit; b) – BP; c) – frequency dependence of a SWR

Consider an antenna with symmetrically located peripheral elements (Fig. 2) that do not overlap, but only have a line of contact with each other. Such construction of the antenna consists of the central and peripheral elements, which, in turn, have the shape of a cylinder. As in the previous antenna, the peripheral and central elements are made of a homogeneous dielectric, whose relative permittivity is ε = 50. In addition, it should be noted that in all subsequent cases the power is brought to the bottom of the central element.

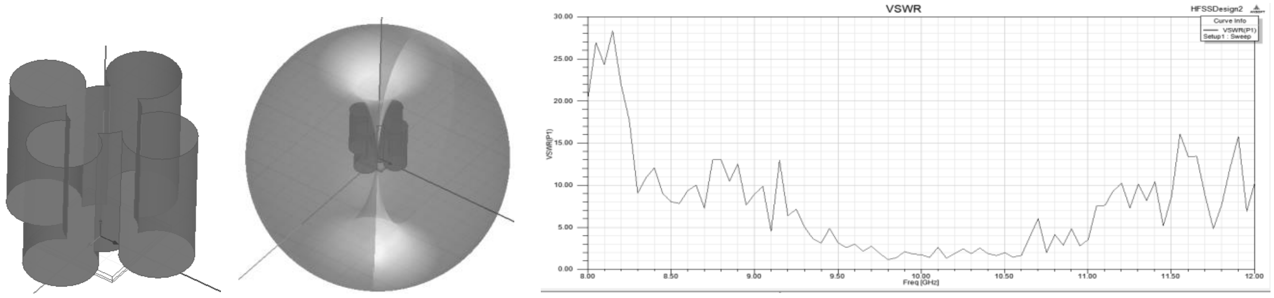
From the frequency dependence of SWR, which is depicted in Fig. 2 it is easy to notice the improvement of the matching of the aggregate antenna construction with the feeder, since the unevenness of the values of SWR in the frequency range from 9.5 GHz to 10.5 GHz has decreased. The interval, within which the SWR does not exceed 2.5, has insignificantly expanded towards the lower frequencies (approximately 50 MHz). BP, which is depicted in Fig. 2.b, is unevenly omnidirectional. From the analysis of graphs of SWR Fig.1.c and 2.c we can make the conclusion that this antenna operates in the same, quite wide frequency range.

The next step will be the modification of the antenna due to the partial overlap of the peripheral elements, which is set at 3 mm (Figure 3.a), which is 20 % of the diameter of the cylinder. As a result, in Fig. 3.b we see that the BP has not changed much, and in the graph of the frequency dependence of the SWR (Fig. 3.c) there was a shift of the operating frequency band by about 100 MHz as compared to the graph of Fig. 1.c.



a) b) c)

Fig. 2. The first version of quasifractal DRA: a) – power circuit; b) – BP; c) – frequency dependence of a SWR

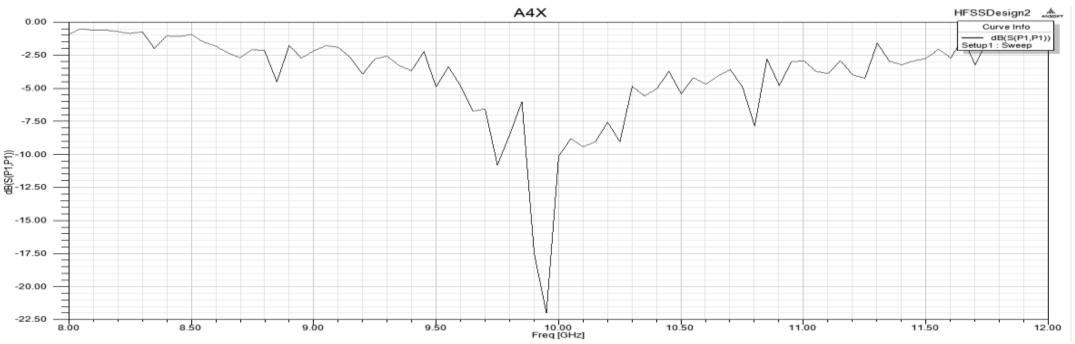


a) b) c)

Fig. 3. The second version of quasifractal DRA: a) – power circuit; b) – BP; c) – frequency dependence of a SWR

The next version of the antenna has the overlapping cylinders that form it, at 6 mm (Fig. 4.a). This is 40% of the diameter of the central element. In addition to the above types of charts, in Fig. 4c shows the AFC of the antenna as a dependence on the frequency of its scattering factor. The results show that the gain of the antenna reaches 22 dB at the resonance frequency of about 9.95 GHz, and the resonance region itself is rather narrow. This indicates that the antenna design becomes narrowband. The frequency range narrowed almost by half (up to 550 MHz), within which the SWR does not exceed 2.5 (Fig. 4.d). Thus, a decrease in the overall dimensions in the horizontal antenna construction intersection due to an increase in the mutual overlap of the central and peripheral cylindrical elements leads to a narrowing of the band of the antenna frequencies in the range of 10 GHz.

a) b)



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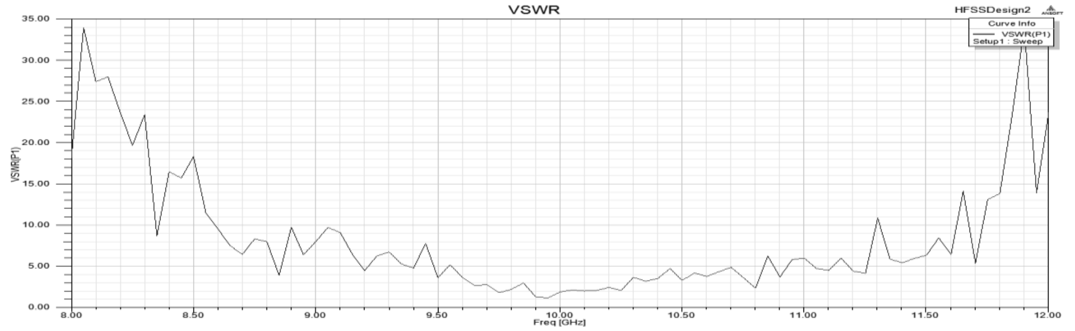
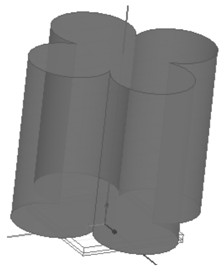
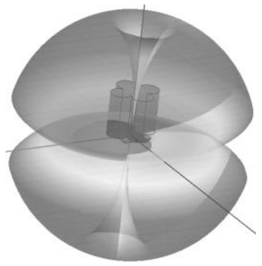


d)

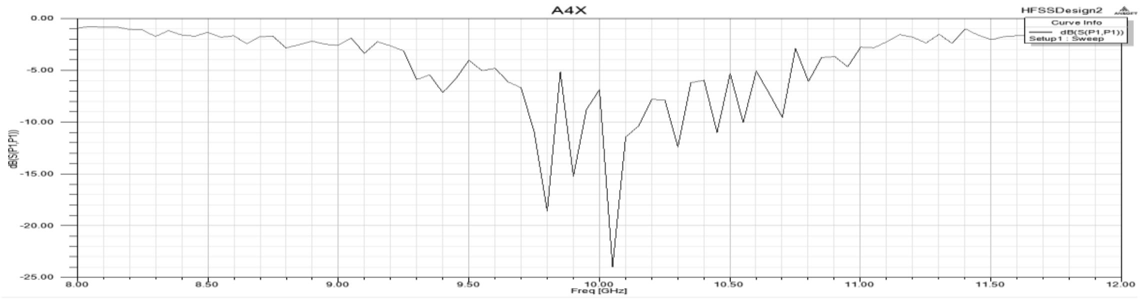
Fig. 4. Third version of quasifractal DRA: a) – power circuit; b) – BP; c) – AFC; d) – SWR

Further deepening of peripheral cylinders in the central element in the third variant of the quasifractal antenna leads to undesirable effects. For example, with the increase of the mutual superimposition to 9 mm (Fig. 5.a), which is 60 % of the diameter of the central element, the results allow to record significant changes in the BP (Fig. 5.b), which now has two distinct basic directions of radiation. In addition, the frequency dependence of the scattering coefficient has three distinct dominant resonances, which indicate the transformation of the antenna construction into a multi-frequency antenna. The same effect is also observed in the graph of the frequency characteristic of the SWR, where the achievement of the graphical dependence of level 2.5 occurs only in three localized zones: from 9.7 to 9.82 GHz, from 9.87 to 10 GHz and from 10.0 to 10.3 GHz. In this case, the radiation conditions of the signals in the specified frequency segments are more favorable than in the previous designs, since within these specified intervals the SWR becomes less than 2.





a) b)



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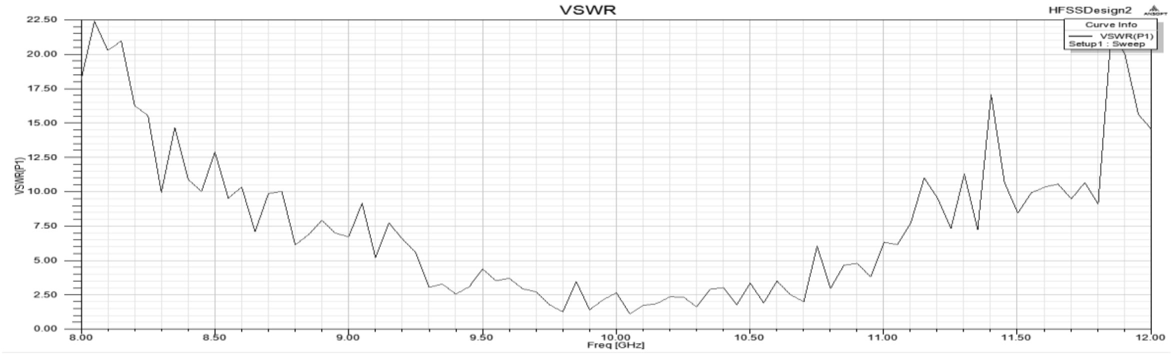

d)

Fig. 5. Fourth variant of quasifractal DRA: a) – power circuit; b) – BP; c) – AFC; d) – SWR

Thus, according to the results of the research, it should be concluded that for the selected variants of the constructive execution of the antennas, the assumption that the bandwidth can be expanded by increasing the peripheral element overlay on the central cylinder was not correct. There are certain limits when such overlap improves the characteristics of the antenna, but there are no significant motivations to increase it by more than 20 %.

Conclusions

In this paper, the characteristics of quasi-fractal antennas based on a cylinder, depending on the degree of overlap of peripheral and central elements were analyzed. As a result, it turned out that despite the acceptable compact antenna sizes, the main problem of insufficient antenna gain was not solved. Among the positive features of this antenna, it should be noted that at the design stage it is possible to control its BP as it depends on the degree of overlay of the elements. Further research will focus on the study of the properties of similar antennas, but with different size of their elements, using different materials and solving the problem of expanding the band of working frequencies.

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