OPTIMIZATION OF FREQUENCY AND ENERGY CHARACTERISTICS OF DISK MONOPOLE ANTENNA

Mayboroda D.V., Pogarsky S.A., Pshenichnaya S.V., Anikeeva K.S., Smirnova K.O.

V.N.Karazin Kharkiv national university
61022, Kharkiv, sq. Svobody, 4, Kharkiv national universuty
Named after v.N.Karazin, Departmant of Ultra High Frequencies
E-mail: Sergey.A.Pogarsky@univer.kharkov.ua

The results of numerical simulation of frequency characteristics of complex radiating structure based on disk microstrip monopole with 3rd iteration quasi-fractal topology are presented. The structure has been excited in two stages: by coplanar waveguide segment and segment of coaxial waveguide with step change of inner conductor diameter. Simulation has been performed in a free version of CST. The structure has been found to be dual-band, and with operating bands sufficient for ultra-wideband signals processing.

Introduction

Modern telecommunication technologies development causes application of an increasing number of new communication types. The main requirement to devices providing new types of communication is miniaturization without the main technical characteristics worsening. The particular attention is being paid to opportunity of ultra-wideband signals transmission. Today, planar antenna systems with so-called canonical topology (rectangle, disk, ring and their modifications), meeting almost all the modern requirements except high power signals transmission [1], are the most common.

The use of certain topology enables various operating modes realization, formation the specified characteristics of radiated fields. Topologies based on axially-symmetric structures are the most attractive because of their unique properties. The foremost one is the ability to form circularly (elliptically) polarized fields. However, these structures have significant disadvantage – the existence of degenerate modes. There are well-knows ways of removing the degeneracy in these structures [2, 3]. The main idea of them is creation of tortuous paths for currents flowing on the monopole surface. One of the possible implementations is the use of fractal (quasi-fractal) structures. It should be mentioned, that implementation of the so-called physical fractal is almost impossible because real structures have finite dimensions and high iteration order (δ) can not be realized. Besides, the broadbandness effect appears only at low iteration order (δ).

This paper demonstrates one of the ways to optimize the frequency and energy characteristics of a quasi-fractal monopole.

Model under study

There are well-known papers, which consider quasi-fractal structures based on disk monopole [4, 5]. The feature of explored structures is a grounded back side of dielectric plate (excitation type is not important in this case). The structures provide multi-frequency operating mode (in a certain sense, broadbandness could be mentioned). However, relative bandwidth equals from 1 to 3%. In this case ultra-wideband signals processing is impossible. The physical reason of narrowbandness is being explained below. Resonance and energy accumulation occurs between grounded plane and microstrip disk (with all the possible topology variations). This region is limited because dielectric plates, that are thin in comparison with the resonant wavelength, are used for most applications. The dielectric substrate thickness increasing leads to some expansion of operating frequency band, however, the possibility of surface waves excitation increases, which eventually causes antenna efficiency decrease.

One of the possible solutions is a fundamental design change, such as grounded plane removing. Technically, it leads to an increase in resonant volume (dielectric substrate and a free space region), but, at the same time, it causes radiation from the opposite side of the structure.

Therefore, some special type of disk resonator excitation has to be chosen. In this case, the best option is excitation by coplanar transmission line.

Fig. 1 demonstrates the design of quasi-fractal monopole with unshielded coplanar line segment as an exciter.

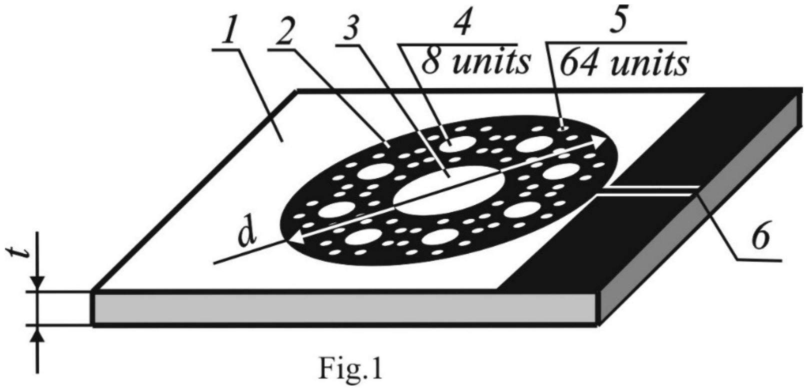

Fig.1

Fig. 1 uses the following notations: 1 – dielectric substrate, 2 – base microstrip disk; 3 – 1st iteration element; 4 – 2nd iteration elements; 5 – 3rd iteration elements; 6 – coplanar transmission line segment elements. Dielectric plate with the standard dimensions 60x48 mm has been used as a substrate. The base microstrip disk diameter is $d = 35$ mm. The dielectric substrate thickness is $t = 0.5$ mm. Permittivity ε_r was being varied in order to determine sensitivity of studied characteristics to this parameter.

The input impedance of microstrip radiator is known to vary within interval from 120 to 240 Ohm and its topology is not very important. The key factor is a ratio between resonant wavelength and the radiating aperture size. Considering ratio between sizes of structure elements, coplanar line segment length can not exceed 12.2…12.4 mm, which is obviously not enough for smooth change from structure input impedance to disk input impedance. For this reason, it is necessary to use an additional matching element, e.g. segment of coaxial line with step change of inner conductor diameter.

This structure characteristics has been numerically analyzed using free version of CST. Initially, the possibility of obtaining optimal matching within the widest possible frequency range has been studied. In fact, it determines total device bandwidth and the ability of ultra-wideband signals processing.

Frequency dependences of $|S_{11}|$ for different ε_r are presented in Fig. 2. Values of ε_r are being varied from 2.4 to 3.9. Obviously, antenna turns out to be dual-band within whole frequency range under consideration. The operating frequency range is determined in accordance to IEEE standard: return loss has to exceed -10 dB ($|S_{11}| \approx 0.396$), which corresponds to $\text{VSWR} \approx 2$. The low-frequency bandwidth is $\Delta F \approx 5.88$ GHz at $\varepsilon_r = 2.4$ and somewhat narrower for other ε_r (about $\Delta F \approx 5.26$ GHz), and lower frequency of the band does not change, which is caused by topology of base disk radiator. The upper frequency of low-frequency band almost does not change as well (for curve 1 it is slightly shifted to high-frequency region, considering significantly smaller ε_r). This frequency depends on the 1st iteration aperture topology. After normolizing by central frequencies, relative bandwidths obtained are equal to 1.387 and 1.338 respectively.

High-frequency bands turn out to be narrower than low-frequency ones (4.9 GHz and 4 GHz, respectively). It should be noted, that both the widest bands of acceptable matching and minimum of $|S_{11}|$ can be realized at $\varepsilon_r = 2.4$. General trend is the operating band narrowing, and when ε_r equals 3.6 and 3.7 the matching quality is high. However, in the narrow band, as ε_r increases to 3.8 and 3.9, the band of acceptable matching significantly widens, but matching quality worsens. Such dependences behavior is caused by 2nd and 3rd iteration slot inhomogeneities, dimensions of which are comparable to resonant wavelengths excited in the structure.

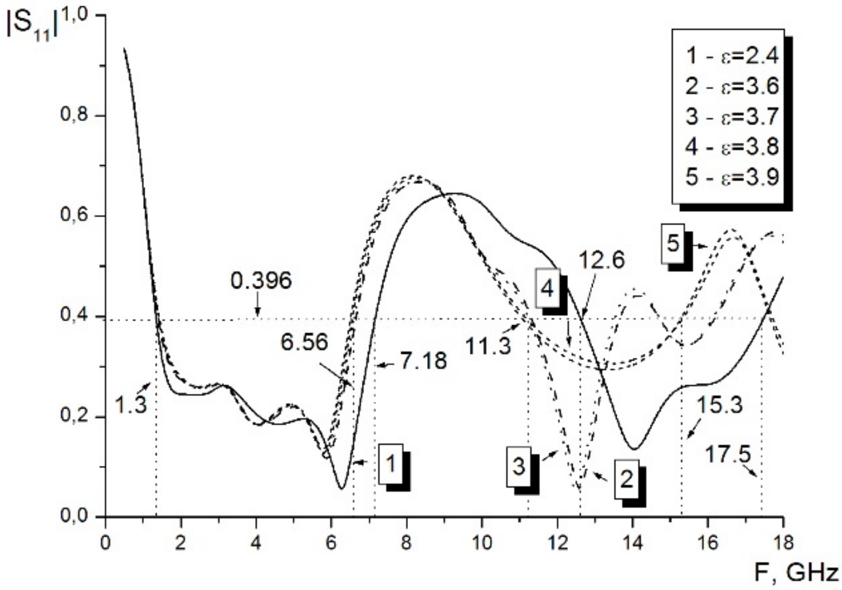

Fig. 2

Conclusions

The numerical experiments have revealed the opportunity of using quasi-fractal microstrip structure as a broadband dual-band radiating antenna. Bandwidth ratio in low-frequency region equals 5.5. In high-frequency region, the operating band is somewhat narrower. The obtained dependences demonstrate rather weak sensitivity of $|S_{11}|$ to small (to 5%) changes of ε_r. Integrated approach to the problem of radiating module matching with external exciting circuits has revealed the opportunity of operating frequency band widening.

References

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