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Focused antennas for diagnostics of spacecraft antenna systems

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Abstract. The use of a focused radiating system principle opens up additional possibilities for solving a number of technological problems in the development and testing of spacecraft antenna systems. This paper presents the basic properties of antennas focused in the near radiated-field zone and the indicated applications. The paper deals with the tasks of diagnostics of the amplitude-phase distributions of antennas, materials of space antenna construction, cable lines.

1. Introduction

In recent years, antenna systems focused in the near-field zone, both theoretically and due to the possibilities of technical applications, have been the object of close attention [1]. The use of the principle of a focused radiating system opens up additional possibilities when creating new communication systems [2], medical diagnostic equipment [3] and a number of other applications. The principle of focusing can serve as an effective tool for solving a number of technological problems in the development and testing of spacecraft antenna systems. This paper provides a concise form of these applications.

2. Focused antennas

Focusing of antenna radiation in the zone of the near-radiated field is ensured by the choice of the amplitude-phase distribution of currents in its aperture, at which the electric field has the maximum possible value at the given point in space. The main properties of focused antennas, depending on their electrical dimensions, environmental parameters and aperture distribution of radiating currents, are described by the aperture theory of antennas for the specified zone [1]. An important feature of the near-radiated field is the possibility of three-dimensional focusing. This property creates prerequisites for use in a number of diagnostic tasks of antenna systems, including space-based ones.

3. Diagnostics of antenna amplitude-phase distributions

The focusing principle makes it possible to increase the reliability of detecting defects of antenna reflectors or the presence of defective elements in antenna arrays, including the feeds of the hybrid-mirror antennas. Finding the aperture distributions of the surveyed antennas is performed using existing antenna measurement equipment, for example, flat scanners.

The measured values of the field strength in the zone of the near radiated field are subjected to processing consisting in a weighted summation, the corresponding focusing of the reception, respectively, at different points of the aperture.

The measurement result can be considered as the one obtained by means of a virtual focused synthetic aperture array. With a proper choice of weighting factors, the amplitude-phase distributions are measured with an accuracy sufficient for most applications (figure 1) [4-5].

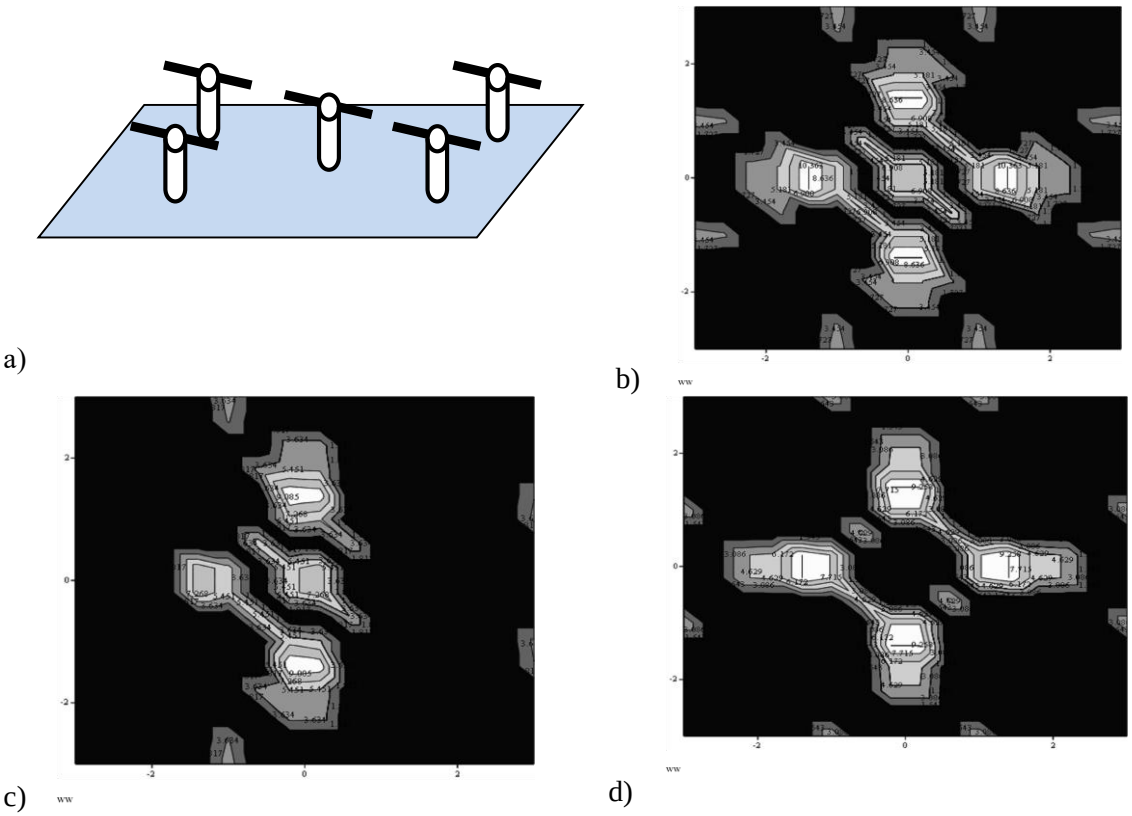


Figure 1. Results of 5-element antenna array diagnostics in the presence and absence of a defective element: a) type of antenna, b) absence of defective elements, c) -, d) presence of a defective element.

4. Material condition diagnostics of antenna reflectors

A number of effective methods have been developed for measuring the reflection coefficient of materials used to create antenna reflectors [5-6]. Using the principle of focusing allows not only to improve the accuracy of measurements, but also to localize the area of the defect. It is based on controlled focusing, which allows to select an element with dimensions of the wavelength order (figure 2) [1].

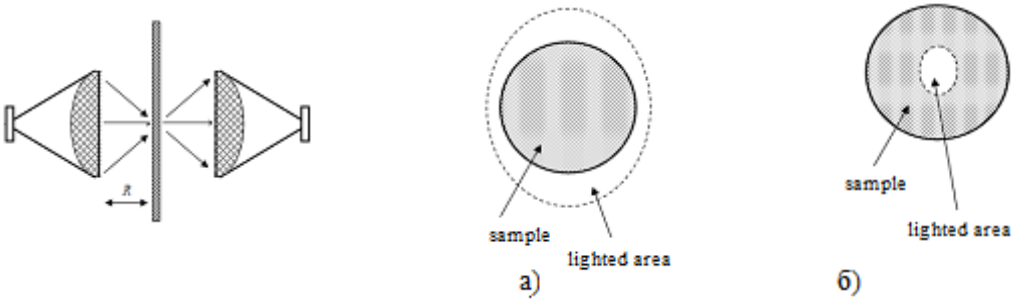
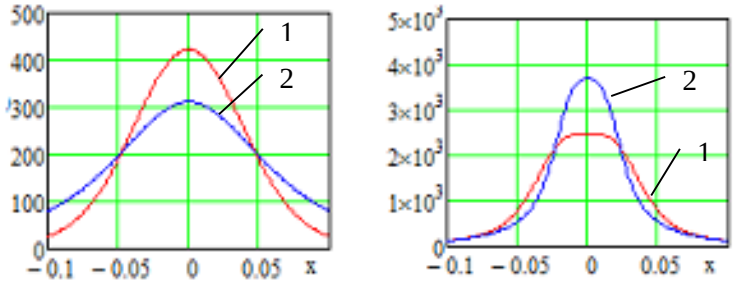


Figure 2. Transmission coefficient measurement a) low directional antenna, б) focused planar antenna.

5. Detection of defects in structures made of composite materials

Methods of radiowave diagnostics are widely used in non-destructive testing of radiotransparent materials. Using the principle of focusing allows not only to increase the accuracy of the spatial localization of the defect, but also to increase the depth of penetration, which expands the possibilities of using radio-wave methods for materials with significant attenuation. Although effective focusing in the direction perpendicular to the aperture is possible only in environments with moderate attenuation $\alpha\lambda<0.1...0.2$ [1], an increased field concentration at the focus point is maintained in environments with high attenuation (figure 3).



a) focal length - 75 мм b) focal length -12.5 мм

Figure 3. The strength of the electric field created in a dissipative medium in the focal plane: Medium ε=50,6=50См\м, f=600 MHz. 1 - half-wave antenna, 2 - focused antenna.

6. Cable diagnostics

The use of focusing principle is effective also in the tasks of reflectometric diagnostics of extended feeders, for example, as part of terrestrial large-aperture antennas. In [7–8] a method of synthesized video pulse was proposed, which can be considered as a variant of processing the reflected signals in accordance with different positions of the "focus point" along the waveguiding structure. When the point of focus coincides with the true position of the defect, a sharp increase in the amplitude of the synthesized signal takes place (figure 4).

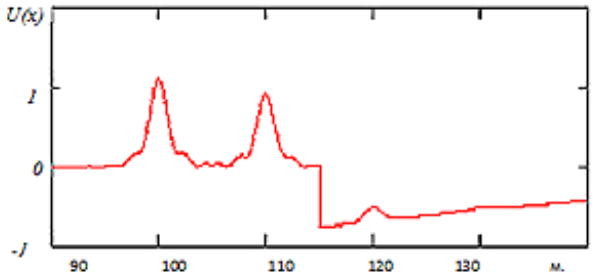


Figure 4. Trace with algorithmic removal of phantom responses for two inhomogeneities located at a distance of 100 m and 110 m from the beginning of the transmission line.

7. Conclusion

The method of focusing in the near-radiated field can be an effective tool for improving the accuracy and reliability of measurements carried out for the purpose of technical diagnostics of antenna systems.

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