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THE LINEAR POLARIZED HORN ANTENNA WITH DECREASED EFFECTIVE SCATTERING AREA

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Abstract

The linear polarized rectangular horn antenna with decreased effective scattering area construction is offered. The method of the horn antenna excitation by the longitudinal slot is proposed. Reduction of the effective scattering area is achieved by absorption of the higher wave modes excited by a falling wave.

Keywords: Horn antenna, effective scattering area.

1. PROBLEM DEFINITION

1.1. RESEARCH ACTUALITY

The linear polarized horn antennas are required for solving the several tasks of radio-location, radio monitoring and communication. Advantages of such antennas are low level of lateral and back radiations, ability to provide the good direction and gain properties and concordance with a feed-in line in the frequency range with a few times covering [1]. However such aperture antennas are considered to posses high values of effective scattering area up to hundreds of square meters [2, 3]. It causes the signal energy loses when antenna works in receiving mode and degrades electromagnetic compatibility of then radio electronic devices. Thus the researches of decreasing the horn antennas effective scattering area present the actual scientific problem.

1.2. BACKGROUND OF THE RESEARCH

The sources of reradiated electromagnetic field of the horn antennas are [1-5]:

- Surface electric currents flowing on antenna edges, internal and external surfaces;
- The dominant mode wave reflected by horn aperture, mouth and feeding facilities;
- The higher order waves reflected by out-of-limit cross sections in horn aperture and feeding waveguide;

These sources determine the ways of the horn antennas effective scattering area reduction. Now the most efforts are performed to removal the influence of the first two sources [2, 5]. But the influence of the higher order waves is more considerable in wideband horn antennas [6]. There are no designed horn antennas to minimize the influence of the dominant mode waves and higher order waves reflected by out-of-limit cross sections in horn aperture and feeding waveguide simultaneously.

1.3. AIMS AND TASKS OF THE RESEARCH

The basic aim of present work is to design a linear polarized rectangular horn antenna with decreased effective scattering area.

The tasks of the work are:

- The substantiation and description of the developed excitation method and designed feeding facility;
- Explanation of the basic functioning principles;
- Formulation of antenna excitation analysis methods.

The basic scientific results of this work are experimentally confirmed.

2. SOLVING OF THE PROBLEM

The higher order waves reflection in horn antenna is caused of out-of-limit cross sections existence and mismatching of feeding line for this wave modes [6]. One of the possible ways to minimize the higher order waves influence is to absorb its energy into the matched load. This way is also preferred to ensure better matching with the feeder.

2.1. THE HORN ANTENNA AND EXCITATION FACILITY DESIGN

The linear polarized rectangular horn antennas with decreased effective scattering area preliminary drafts are shown in Fig. 1. Antenna is created on the base of extending rectangular waveguide which sizes are chosen for feeding coaxial line concordance and the one-mode wave propagation achievement in examined frequency range.

The novel type of feeding facility is developed and described below. The feeding facility is based on the principles of directed coupler of the dominant wave mode. The higher wave modes are not to be coupled but terminated by matched load. Thus the frequency band of the horn antenna is determined by the frequency band of the directed coupler. The working frequency

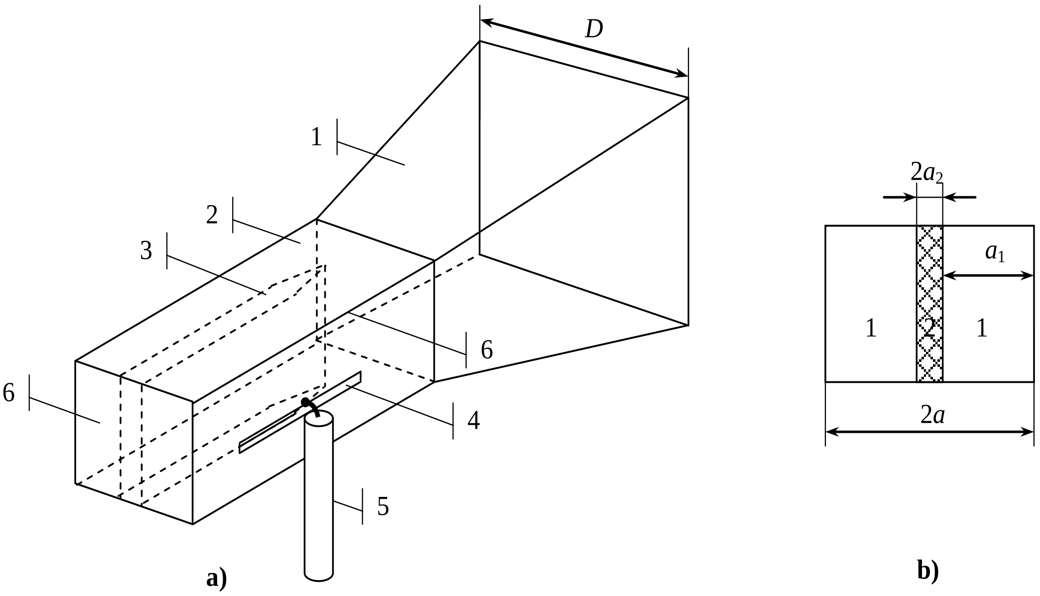

Fig. 1. Linear polarized rectangular horn antenna with decreased effective scattering area construction general view (a) and feeding waveguide cross section (b)

band of the effective scattering area minimization determines of the horn dimensions and matched load parameters and can bee grater then the working frequency band of antenna.

Rectangular aperture 1 of horn antenna appears as extending rectangular waveguide 2. Aperture sizes correspond to provide required directional and gain characteristics over whole frequency range. The rectangular waveguide 2 contains the longitudinal dielectric plate 3 fastened vertically for vertical linear polarization of the electromagnetic wave. The lateral wall of the rectangular waveguide 2 contains the longitudinal thin slot 4 as shown in Fig. 1 a). The slot 4 is loaded to coaxial feeding line 5 which is intended for the output of electromagnetic energy of the dominant wave mode. Thus the directed coupler is formed by the waveguide-slot-coaxial combination. The energy of other higher wave modes excited in the torn is taken in a matched load 6 which terminates the rectangular waveguide 2. The dielectric plate 3 is intended to equalize the phase speeds of the horn mouth rectangular waveguide 2 and the longitudinal slot 4.

The dominant wave mode energy is passed to the feeding line and the higher wave modes energy is taken in a concerted load with minimal influence on total effective scattering area of horn antenna and feeder mismatching.

2.2. Antenna calculations

When designing the following antenna excitation facility dimensions are to be taken:

- The rectangular waveguide 2 and the slot 4 length are much more then the wavelength;
- The slot 4 width is much less then the wavelength;
- The influence of matched load 6 is negligibly small;

Thus the width of dielectric plate 3 is the main parameter to be determined for the horn antenna calculation. The width of dielectric plate 3 could be calculated by solving the dispersion equation for cross section of dielectrically filled rectangular waveguide [7]:

$$\frac{k_{y1}}{k_{y2}} \cdot ctg\ k_{y1}a_1 - tg\ k_{y2}a_2 = 0, \quad (1)$$

where k_{y1} and k_{y2} – the y-axe propagation constants for regions "1" and "2" of feeding rectangular waveguide 2, a_1 – half of dielectric plate width and a_2 – width of unfilled part of waveguide according to Fig. 2 b).

The dispersion equations for environments "1" and "2" are to be represented separately as follows:

$$\begin{aligned} k_1^2 &= k_{x1}^2 + k_{y1}^2 + k_{z1}^2, \\ k_2^2 &= k_{x2}^2 + k_{y2}^2 + k_{z2}^2, \end{aligned} \quad (2)$$

Where k_1 and k_2 – propagation constant for environments "1" and "2" respectively.

If $k_1 = k_{z1}$ the (1) could be represented as follows:

$$\frac{1}{a_1 k \sqrt{\frac{\varepsilon_2}{\varepsilon_0} - 1}} - tg\left(a_2 k \sqrt{\frac{\varepsilon_2}{\varepsilon_0} - 1}\right) = 0 \quad (3)$$

After taking to account $t = 2a/\lambda$ and $a_1 = a(1\text{-}a_2/a)$ the transcendental equation for a_2 is:

$$\frac{1}{\pi\, t \left(1 - \frac{a_2}{a}\right)\sqrt{\frac{\varepsilon_2}{\varepsilon_0} - 1}} = tg\left(\pi\, t\, \frac{a_2}{a}\sqrt{\frac{\varepsilon_2}{\varepsilon_0} - 1}\right) \quad (4)$$

Fig. 2 represents the calculation results according to (4).

For this antenna the scattering characteristics calculations were performed. As shown in [8, 9] the effec-

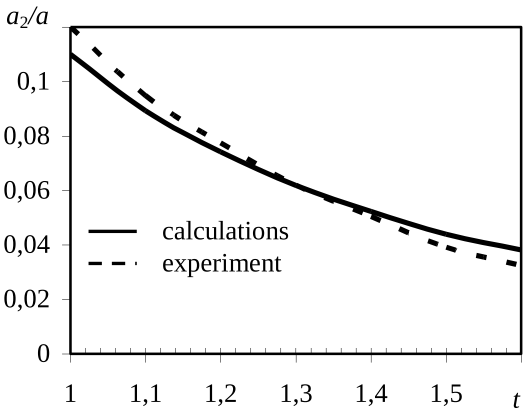

Fig. 2. Graphical representation for calculation the dielectric plate 3 width a_2

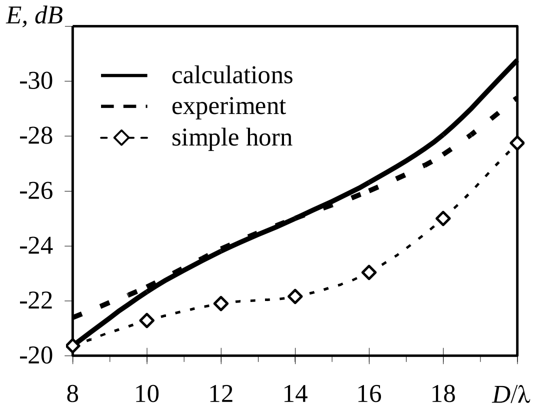

Fig. 3. Linear polarized rectangular horn antenna with decreased effective scattering area construction

tive scattering area influence on antenna efficiency could be estimated by following parameter called as relative efficiency:

$$\mathrm{E} = \frac{G_{eff}}{\sigma_{\Sigma}}, \qquad (5)$$

where G_{eff} – total antenna efficiency and σ_{Σ} – effective scattering area. Fig. 3 represents the calculated and experimental data [10] for the developed horn antenna and the simple horn. As expected the developed horn antenna type provides decreased effective scattering area that respond to increase the relative efficiency about 2-6 dB.

3. Conclusion

The construction of the linear polarized horn antennas with minimized effective scattering area is offered. The method of the horn antenna excitation by the longitudinal slot is proposed. Diminishing of effective scattering area is achieved by absorption of the higher wave modes excited by a falling wave. The developed horn antenna type provides decreased effective scattering area about 2-6 dB

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