INTEGRATED ANTENNA SYNTHESIS OF THE OBJECTS MONITORING SYSTEMS IN THE MICROWAVE BAND

Prudyus I. N., Zubkov A. M., Zakharia Y. A. and Mymrikov D. O.

Lviv Polytechnic National University, Lviv, Ukraine
E-mail: comer@inbox.ru

Abstract

The paper presents the principle of the integrated antenna synthesis of the objects monitoring systems in the microwave band. The main attention is paid to the selection of allocation and geometrical sizes of feed horns for providing identical beamwidth in mutually perpendicular planes.

Keywords: Reflector antennas, microwave antennas, aperture antennas, objects monitoring.

1. INTRODUCTION

Monitoring of objects in the microwave band is vital for navigation, military purposes, agriculture, geology etc. Slow attenuation at microwave frequencies of 35 GHz and 94 GHz allows to realize systems of effective objects monitoring. At the same time, in the microwave band, it is also possible to form narrow radiation patterns using reflector antennas with acceptable geometrical sizes. The systems of the IR-band and optical band do not have such advantages [1].

2. PROBLEM DEFINITION

The article proposes to realize the objects monitoring system antenna on the basis of a paraboloidal reflector, which will ensure functioning of both the radar channel at a wavelength of $\lambda_1 = 3{,}191$ mm ($f = 94$ GHz), and the radiometric channel at a wavelength of $\lambda_2 = 8{,}571$ mm ($f = 35$ GHz). In the radiometric channel 16 horn subantennas serve as feeds of a paraboloidal reflector and provide radiometric information in the altitude plane (H plane) in a passive mode (a reception mode). The feed horn of each channel receives information in a narrow sector of H plane, thereby localizing this information. Radiation pattern of each feed has different direction of maximum radiation, i.e. a different α_0 angle, which is determined relative to the antenna axis. In the azimuth angle plane (E plane) the common scanning of all 16 channels is carried out. On the basis of the received signal, which is subjected to processing, the observation zone is defined. Then, by turning the whole antenna of the objects monitoring system, probing of the observation zone (with predefined solid angle) by the radar channel is performed. At this, horn feed of the radar channel works alternately, either in active or passive modes.

For realisation of the antenna of the objects monitoring system, 16 radiometric feed horns are foreseen. Radiation patterns of these radiometric feed horns overlap an $30°$ angle between maximums of extreme feed horns radiation pattern in H plane. This means that directions of radiation pattern maximums for radiometric feeds in altitude plane α_0 are: $\pm 1°$; $\pm 3°$; $\pm 5°$; $\pm 7°$; $\pm 9°$; $\pm 11°$; $\pm 13°$; $\pm 15°$ with the beamwidth of every radiation pattern in H plane being at level – 3dB: $2\theta_{0,5} = 2°$. Restrictions are also imposed on the beamwidth in an azimuth plane (at the level of -3dB) and on the level of lateral radiation.

The radar channel radiates and receives in the direction of the paraboloidal reflector axis, providing the beamwidth of 40 angular minutes in an altitude plane, and the beamwidth of 20 angular minutes in an azimuth plane.

It is proposed to realize this integrated antenna on a paraboloidal reflector with the radius of $R_0 = 0{,}45$ m, and the focal length of $F = 1{,}2$ m.

The millimetric wave band restricts constructive modifications of feed horns, though such modifications are possible already in a centimetric wave band. Therefore, feed horns are considered here in the simplest pyramidal design.

3. SYNTHESIS OF THE INTEGRATED ANTENNA

The method of aperture radiation analysis was used to calculate radiation pattern of the objects monitoring systems antenna with a feed defocus. This calculation method allows to take account of the shadowing effect, location of the feed as well as to calculate all other necessary parameters of an objects monitoring system antenna.

For choosing the rectangular aperture sizes A and B ($A > B$) of radiometric channel horn feed, fig. 1

and fig. 2 present dependence of the objects monitoring system antenna beamwidth ($2\theta_{0.5}$) on the horn aperture size in E-plane B, for different values of the relation $k = \frac{A}{B}$, and the radiometric feed horn is displaced in the H plane by an angle of $\alpha_0 = 3^\circ$ with the top in the centre of paraboloidal reflector and determined relative to the reflector axis.

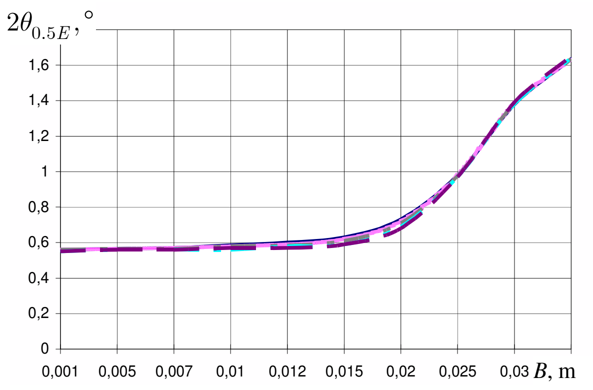

Fig. 1. Beamwidth in the E plane ($2\theta_{0.5E}$) depends on the aperture size B, for different *k*=1,25; 1,5; 1,75; 2; 2,25.

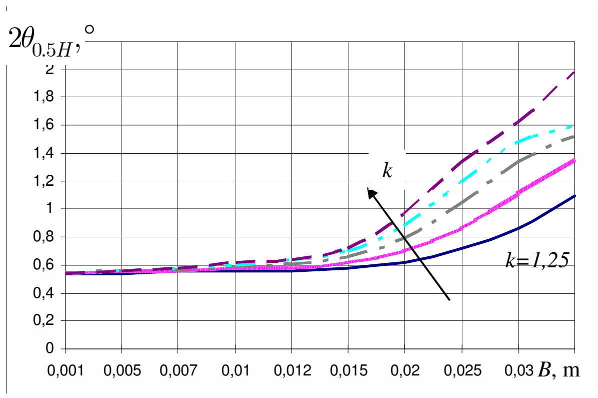

Fig. 2. Beamwidth in the H plane ($2\theta_{0.5H}$) depends on the aperture size B, for different *k*=1,25; 1,5; 1,75; 2; 2,25.

As can be seen in fig. 1, the beamwidth in the E plane practically does not depend on *k*. The depends fig. 1 and fig. 2 are given for a wavelength of λ_1=8,57mm. This curves allow to choose *B* and *A* for a given k and for different $2\theta_{0.5E}$ and $2\theta_{0.5H}$, i.e. the beamwidths of the integrated antenna of the objects monitoring system in orthogonal E and H planes for a given angle α_0.

The maximum level of a radiation field, and the deviation of the beam, i.e. a declination of a direction of the maximum level of a radiated field (angle α) from the set direction a_O, depend on the chosen aperture area of the feed horn. The choice of feed horn aperture sizes separately for each channel ensures identical beamwidth of all channels. Dependence of reception intensity on B for different k (Fig.3), and the influence of angle α_0 value, must be balanced by amplification of signal in each channel.

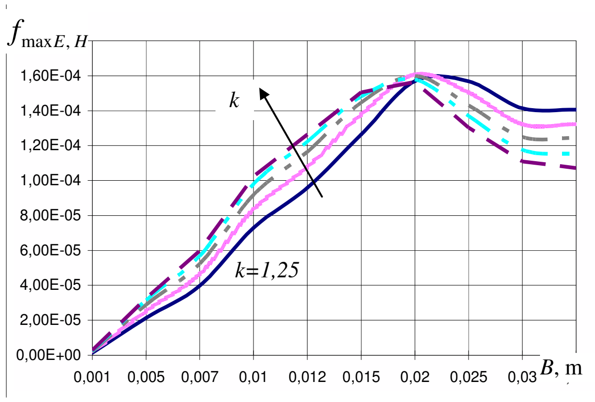

Fig. 3. Maximum level of a radiated field depends on the aperture size B, for different *k*=1,25; 1,5; 1,75; 2; 2,25 .

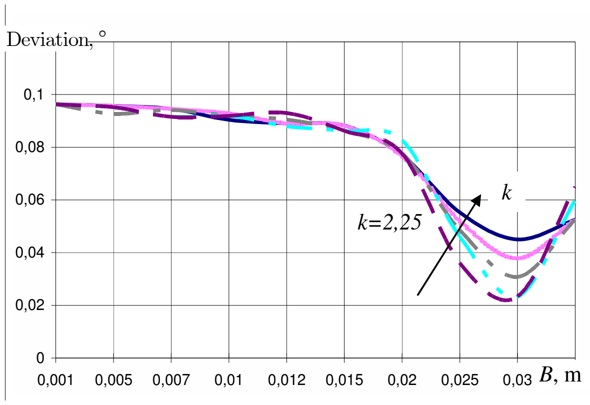

Fig. 4. Deviation of a beam ($\alpha - \alpha_0$) depends on the aperture size B for different *k*=1,25; 1,5; 1,75; 2; 2,25 .

It is also necessary to take account of the character of the radiation pattern change with increasing lateral defocus of the feed:

- increase of the beamwidth ($2\theta_{0.5}$);
- deviation of a beam (α - α_0);
- the larger the α_0 angle, the more the fall of the maximum level;
- asymmetric increase of the lateral lobe level.

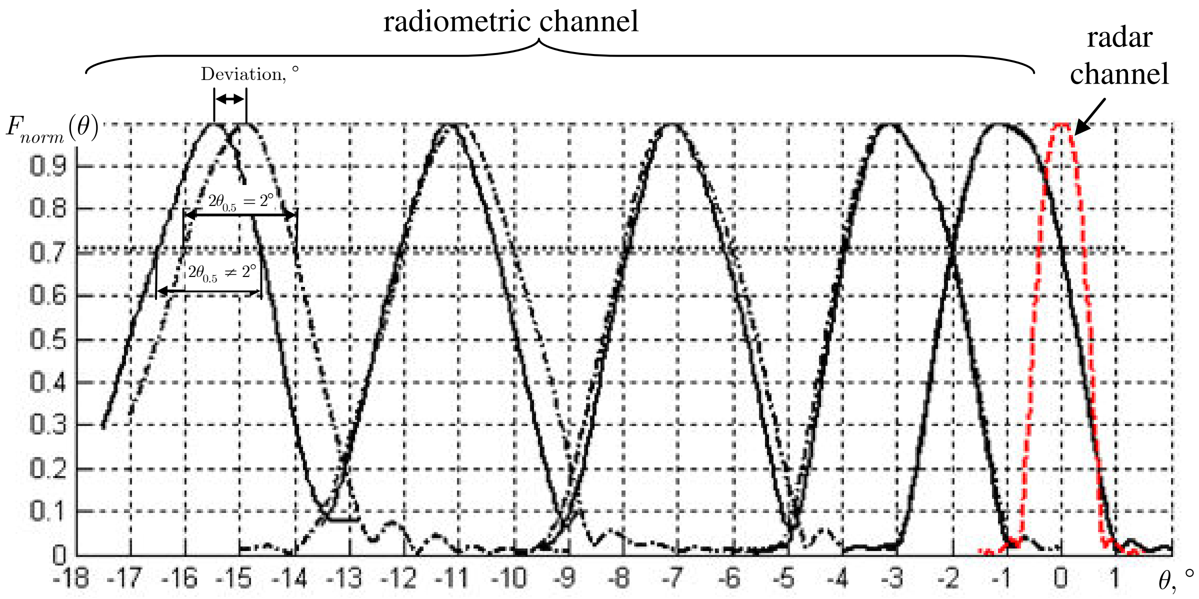

Fig. 5. Normalized radiation patterns of the integrated antenna of the objects monitoring system in the H plane for lateral defocus of the feed for α_0: 1°; 3°; 7°; 11°; 15° (without correction of beam deviation and beamwidth) – solid curves; and with correction of beam deviation and horn aperture sizes – dash-and-dot curves.

On the basis of above principles, parameters of feed horns for each lateral defocus α_0 have been considered. The correction of an allocation of the radiation field maximum (α) (fig. 4) has been accounted, so that a direction of the middle of beamwidth at level $\pm\theta_{0.5}$ coincided with a preset α_0. The sizes of the aperture (*A, B*) have been determined. The lengths of a horn in E and H planes (R_E, R_H) for phase distortions $\varphi_E = \frac{\pi}{8}$ have been calculated. At the same time, the radiation pattern of the integrated antenna of the objects monitoring system in E plane for $\alpha > 0$ has been calculated.

For the case when the H plane of a radiated field coincides with a vertical plane (a plane of altitude), and, accordingly, the E plane is horizontal, there were built radiation patterns of the integrated antenna of the objects monitoring system (fig. 5) with correction of beam deviation and beamwidth at lateral defocus of the feed – dash-and-dot curves; and for comparison: for angular lateral defocus of the feed α_0: 1°; 3°; 7°; 11°; 15° (without deviation correction) and constant sizes of the horns apertures in each case (without correction of beamwidth) – solid curves. Thus, during the correction, there were chosen such sizes and allocations of feed horns, whose radiation patterns satisfy the set requirements of radiometric channels and a radar channel.

4. Conclusions

The paper presents calculation algorithm of the objects monitoring system integrated antenna in the millimetric wave band. Such monitoring systems allow to obtain the radiometric images of object allocation, and simultaneously his allocation coordinate. Therefore the antenna calculation algorithm principally differs from calculation algorithm of classical paraboloidal reflector antenna. The providing of the necessary beamwidth and direction of antenna radiation maximum by choice of horn feed aperture sizes and allocation is proposed. But in calculation process arise the problem of shadowing, the problem of beam deviation correction, the elimination problem of signal interaction between channels, and the diffraction problem. The first two of recount above problems are solve in this article

References

1. Bystrov R.P., Zagorin G.K., Sokolov A.V., Fedorova L.V. 2008 ‘Passive radar: method of detection of objects’. – Moscow: Radio engineering. – 320p.
2. Jacob W.M. Baars. 2007, ‘The paraboloidal reflector antenna in radio astronomy and communication. Theory and Practice.’, *European Southern Observatory Swisttal / Bonn, Germany. Springer Science+Business Media, LLC.* – 253p.