METHODS TO IMPROVE THE ACCURACY OF GUIDANCE OF TERRESTRIAL ANTENNA STATION

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Abstract: The analysis of factors influencing accuracy of guidance of terrestrial antenna complexes and ways of improvement of a signal reception quality are considered. The above considerations are the result of authors many years practical experience in the AS ground stations setting and monitoring.

Keywords: *AS guidance, instalaton accuracy, surface control, control system*

1.Introduction

The design of high-precision control systems for massive objects in order to guide them to the specified coordinates, tracking on specified trajectories or tracking moving objects is relevant for the a terrestrial stations for the reception of information coming from a spacecraft.The technical problems, arising in providing an accuracy AS tracking are largely due to the precision of installation of work nodes and the antenna in overall [1]-[7]. The accuracy estimations of antenna tracking based on data on the precise geostationary orbit of the satellite are proposed in [8]. Antenna correct orientation with the given accuracy is also of great significance, taking into account the reflector's large weight and the requirements for dynamic characteristics of tracking process. In some AS constructions a correction in the separate regions of elevation angle setting are calculated by a special formula, taking into account the slope angle of the vertical axis [9]. However, the following study will be useful to make general recommendations to improve the quality of signal' reception.. Further the results of authors's practical experience in AS setting and monitoring, allowable deviations of installation parameters, their influence on the signal reception quality are presented.

2.Sources of Errors and Methods to minimize them

A. General classification of errors sources

The total error in the orientation of the antenna system is formed under the influence of many factors due to both design features and the influence of the external environment, systematic and random. Among the reasons of their occurrence it is possible to allocate methodical - due to astronomical coordinates determination inaccuracy – and instrumental, caused by angles measurement, influences of mechanisms angle sensors fastening, Support-Rotary-Device constructions influences, influence of the reflector construction. Behavior of them is unchangeable during a large period of time or changes according to the certain law. The most significant sources of errors in control system are: varyation of the inertia moments of modules with the angles of the reflector and with the ratio of positions of the antenna modules for different axes, change in stiffness of mechanical gear, changes in friction resistance, backlash, instability characteristics of electric drives. Systematic errors are caused by factors that are presented during a AS operating by a constant value or are changed with a time according to some law. Their influence on the AS control can be predicted due to mathematical modeling and neutralized to some extent in a constructive way.

.Random errors are due to the effect on the system of random processes. In a broad sense, all errors in the AS guidance are random with different correlation intervals.

The average value of the errors during the communication session are accepted as the systematic error of this cycle, the average value for a number of cycles - the systematic error of steering. The error random component is characterized by the value of standard deviation from the mean value.

Specific estimates of some the most influential errors arising in the AS setup and operation are given below, also an allowable deviations of installation parameters, their influence on the signal reception quality are presented.

B. Control of a AS installation accuracy

An inaccurate direction of initial AS platform setting cause to decreasing of antenna pattern effective area S:

$$S \sim S_{max} \exp(-(1.7 \frac{\theta}{\delta_{0.5}})),$$

where $\theta -$ the deviation angle of the maximum of the directional chart from the direction to the signal source;

$\delta_{0.5} -$ the diagram width at half power level.

The antenna axis will deviate on the angle from the position adopted as correct at the given azimuth and the elevation angles when the platform inclination on abscissa axis angle φ and ordinate axis σ take place. And

$$\delta = \cos^{-1}(\cos\varphi \cos\sigma).$$

The dependence of antenna pattern axis angle inclination on the abscissa axis angle φ and ordinate axis σ of platform inclination is shown in Fig.2 as the region in the values φ, σ (minutes), corresponding to the permitted values of platform angles inclination, in which the antenna axis deviation does not exceed an admitted level, in the problem under consideration $\delta_{max} = 6'$.

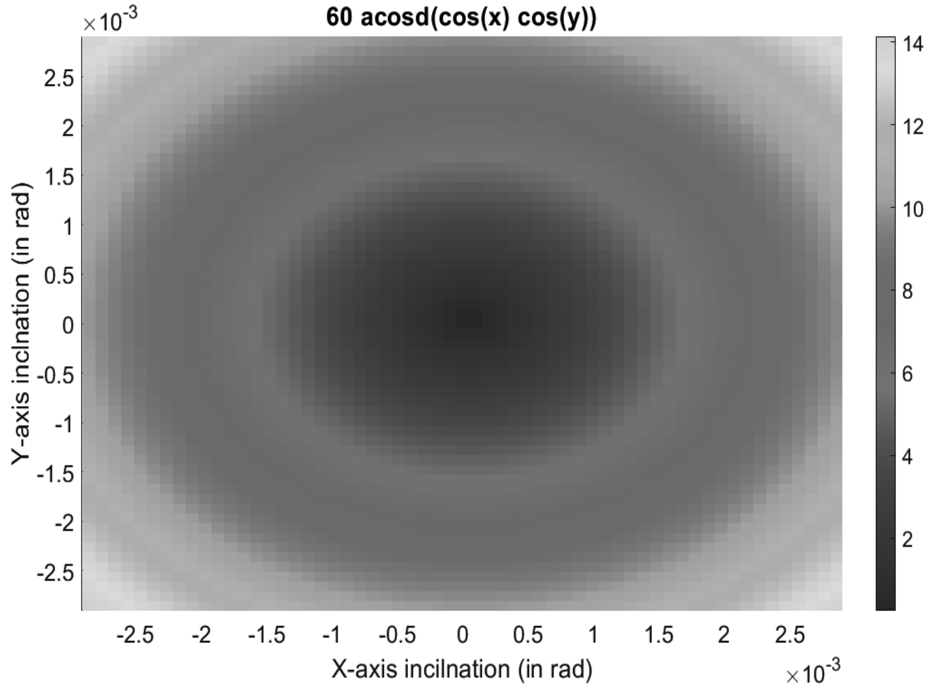

Figure 1. The antenna axis drift (in min), coursed by platform X-axis and Y-axis inclination on angles φ and σ

The method considered and the software developed have been used to simulate the influence of the platform deviation on the antenna setting, and thus, to improve the process of antennas installation and their maintenance.

C. AS properties as a dynamic object and their influence on control system accuracy

Construction of high-precision control systems for mass objects, , tracking of specified trajectories is actual for the synthesis of a control system for antenna systems in which the supporting structure of a turntable with large reflectors weighs from one to tens of tons. The main factors provided the accuracy of ground-based station are determined by:
a) the accuracy and rigidity of OPP design and guidance mechanisms as a whole and their individual parts, including the mirror system;
b) the accuracy of software control signals (targets) for guidance of the AS by means of the drives in accordance with the requirements of spacecraft support;

c) the accuracy with which the angular position of the executive axes can be determined at any time, ie the accuracy of the feedback sensors;
d) the dynamic accuracy provided by the power tracking drive in the conditions of perturbations and various kinds of noise acting on the system in the process of observing the spacecraft.

The increased accuracy of ground antenna stations (AS) with reflectors of large diameters (3-12 m) up to angular minutes units is desirable. To improve the quality of signal reception the following recommendations should be taken into account. A high dynamic accuracy of the antenna rays in the unit of angular minute at large angular velocities at several coordinates (up to 10 bps / sec) should be provided:

a) to ensure the required satellites pointing and tracking accuracy, to increase the reliability and to reduce the cost of AS control system the usage of asynchronous motors in conjunction with frequency speed regulation electronic devices are expedient.

b) the results of simulation and experimental researches show that the control system of AS with frequency-controlled asynchronous electric drive allowed to achieve the needed control accuracy on harmonic trajectories. Shortcomings of regulation during acceleration testing on a special test trajectory with more abrupt speeds change were found

c) the vector control method for asynchronous motors provides the smaller dynamic errors and better quality regulation. However, current consumption significant increasing at the low angular speeds during long-term operation may cause to motor overheat.

d) a frequency AM regulation based on the law U/f = const using RsIs - correction for torque support low turn based on the right parameters choice also can be used for pointing and tracking of AS on a lower dynamic ranges.

e) The frequency regulation can be also used for pointing and tracking of geostationary satellites or in AS with

In details the AS properties modelling as a dynamic management object allowed to synthesize the control system and to investigate the functionality and influence of regulation parameters quality of the AS control without using complex object was studied in [11,12].

The results of the experimental adjustment of the proportional and differential coefficient of feedback are shown in Fig. 2.

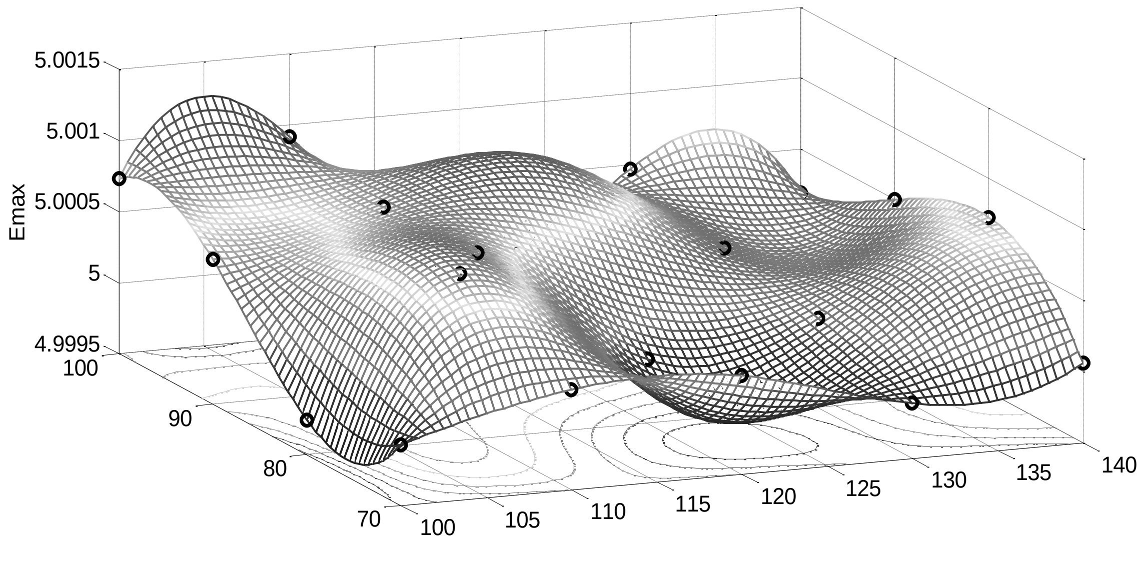

Figure 2. Spline approximation of control errors in the space of feedback coefficients kp=(70:10:100); and kd=(100:10:140);

By the spline approximation of control errors values in the space of feedback coefficients the map for optimal selection of feedback mode was constructed as is shown in Fig. 3.

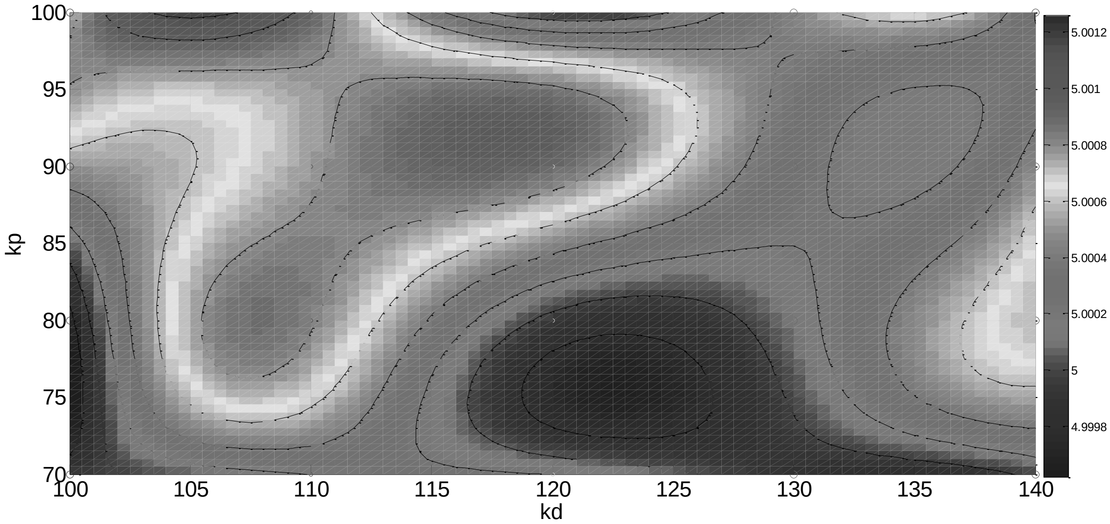

Figure 3. Errors map in the space of kp and kd for the feedback setting

D. Profile errors estimations

Manufacturing defects, inaccuracies in the assembly of the reflector surface elements, its weight and wind deformations cause a phase distortions of the antenna wave front and as a result the deterioration of electrical characteristics of the antenna, such as radiation pattern, directional coefficient, etc., influencing the guidance accuracy. If the mirror antenna operates in the range of centimeter wavelengths, it is necessary to control the deviation of the reflector surface with an accuracy of not less then ±0.9 mm for operating wave $\lambda = 3$ cm, or not less then ±0.3 mm for a wave of 1 cm. the case of less stringent requirements for the quality of the antenna, phase changes in $\Delta\varphi<\pi/2$ are allowed. The corresponding permissible deviation of the surface from the parabolic will be less then $\lambda/16$.

To control the reflector deviation from the theoretical one due to the influence of meteorological and operating conditions, it is important to optimize the reflector surface measuring procedure. These requirements are met by information systems for specialized measuring equipments or remote measurement of spatial coordinates, which in addition to the measuring device are outfited with means for automatic processing of measured data and visualization of the results for prompt decision-making, based on the total estimation of standard deviation of reflector surface displacements from theoretical profile. The map of reflector surface deviations from a test pattern on indications of the sensors placed in the specified positions is shown in Fig. 4.

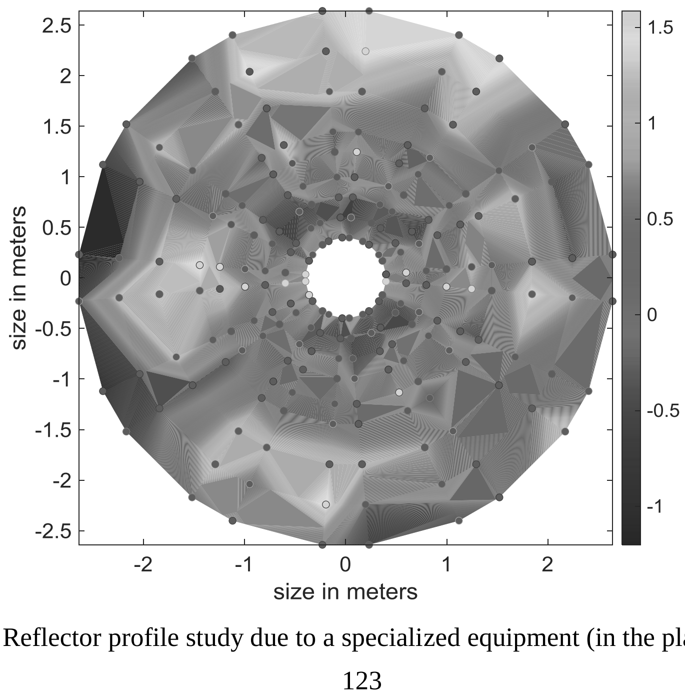

Figure 4. Reflector profile study due to a specialized equipment (in the places pointed)

When scanning the large sizes objects, the measuring device is placed from the object studied at the distances of several orders of magnitude greater than the profile deviation values, it is complicate to use the previous method. The peculiarity of research proposed in [13-17] is the application of a methodology that will allow to estimate the work surface profile displacement against reference sample due to its remote scanning, as shown in Fig.5.

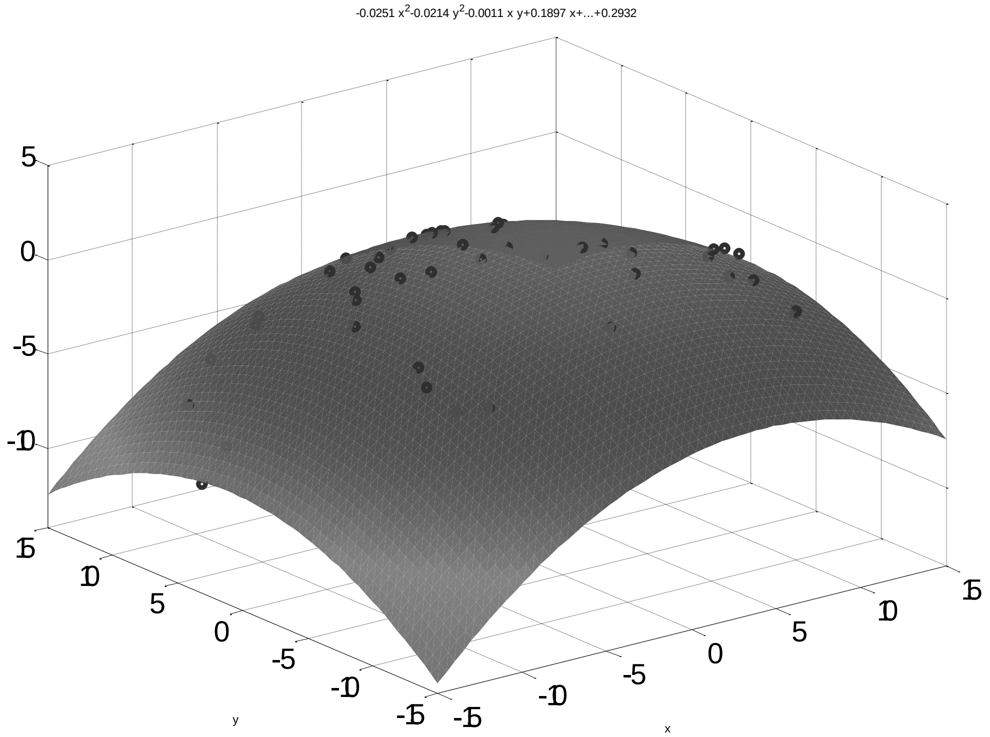

Figure 5. The reflector surface approximation by the least squares method according to remote measurement in separate points (distances in meters)

At first the surface studied measured coordinates are transformed into coordinates of pattern canonical system than real surface is approximated by least square method to pattern. The standard deviation of measured data errors is taken as a criterion for compliance the surface investigated with the design requirements. A similar approach ss proposed in [18].

E. The impact of meteorological factors on the guidance accuracy

As shown in [19,20], as a result of static wind load caused by wind flow with speed *V* AS is under the action of the moment

$$M = a\frac{\rho V^2}{2}S$$

where *p* -wind flow density; *V*- average wind velocity; *S* - the area of the reflecting surface of AS; *a*- aerodynamic coefficient, depending on *S*.

The aerodynamic coefficient wind load separate values, was obtained from the experimentally study in [21] in the process of purging the AS model with a mirror diameter of 32 m in the wind tunnel. Due to obtained data spline approximation in the space of elevation and azimuth and their visualization, as shown in Fig. 4, a wind moment map was reconstructed.

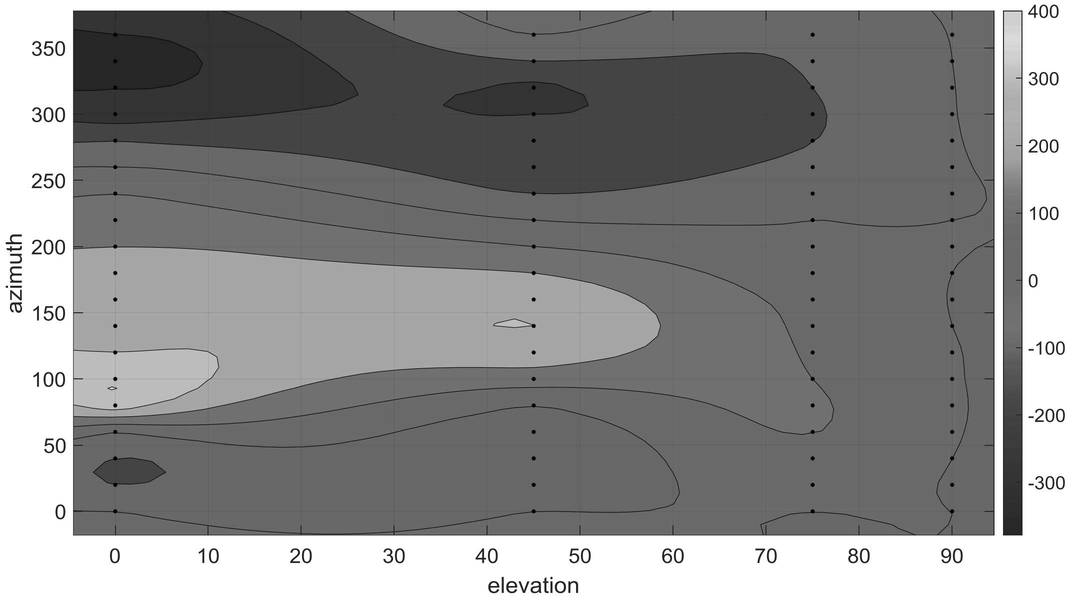

Figure 4 Distribution of aerodynamic coefficient of wind load for the antenna mirror with diameter of 32 m depending on its spatial orientation (in the coordinates of the angle of place and azimuth)

In the general case the nature of the terrain (open, with separate topographic fluctuations, built-up area or rough terrain), as well as the speed profile (location of the AS above ground level) should be taken into account

3.Conclusions

The error reducing methods based of constructive ways often are complicate mechanical parts of SRD and lead to increase costs for their projecting, adjustment and maintenance. To prevent additional correction of AS settings during its operation it is necessary to carry out a preliminary assessment of the limits of possible errors at the goal guidance process

The antenna axis drift when mounting causes the errors in installation of azimuth and of elevation angles. It may cause the communication session weakening. According to the estimates given, it is established deviations of the carrier platform at which the deviation of antenna pattern axis is within acceptable limits.

The vector control method for asynchronous motors provides the smaller dynamic errors and better quality regulation. However, current consumption significantly increase of AM in the low angular speeds during long-term operation may cause to motor overheat. A frequency AM regulation based on the law U/f = const using R_sI_s - correction for torque support low turn based on the right parameters choice also can be used for pointing and tracking of AS on a smaller dynamic ranges.

It is also important to correctly set the coefficients of the PID controller in the feedback line of the control system. Spline approximation of error values in the space of discrete tested values kp and kd allows us to select settings with minimal error for a particular system.

The reception quality is also affected by the possible deviation of the antenna profile from the theoretically calculated one. The profile control in the operating mode can be carried out periodically by means of remote measuring devises completed with the corresponding software for deviations calculation of the measured surface from the profile stated.

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