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ACCURACY EVALUATION OF GUIDANCE OF THE GYROSTABILIZED ANTENNA DIVICE OF A SHIPBASED

Master's Program Automation of design and engineering

The abstract of the Master's Thesis

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The thesis work is done at the Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University»

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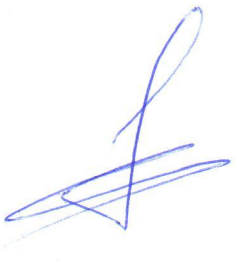


Michail. P. Golovin

GENERAL DESCRIPTION OF THE THESIS WORK.

Significance of the work. An antenna is the device emitting or receiving electromagnetic waves in a radio frequency range (radio waves). Mechanical designs of antenna systems are extremely diverse. Systems of gyroscopic stabilization of different types are applied in navigation devices and control systems of ships and aircrafts, and they are also used in antenna orientation systems, telescopes and other devices installed on moving objects to work out of problems of control, orientation and navigation.

The main requirement of the gyroscopic stabilization system is the accuracy of positioning of its final unit in a standard position concerning the basic axis guided under the action of various dynamic disturbances from the object where it is installed.

Therefore for stable operation of current system, it becomes significant to determine the accuracy of positioning a final unit of the guidance system taking into account balancing of external actions. In addition it's urgent to determine its resonant frequencies on rotation axes in order to ensure the required accuracy of the guidance system.

The aim of master's thesis is to assess the accuracy of guidance of the gyrostabilized antenna device at the design stage, taking into consideration the influence of the disturbance.

Objectives of the research:

1) To carry out the information review of a design and the principle of operation of the gyrostabilized antenna device;

2) To develop a model for calculating the compensation angle of the antenna, with alternate external influence, taking into account various options of design geometry;

3) To develop calculated finite element model for research of constructive rigidity of the antenna;

4) To develop calculated finite element model for an assessment dynamic and stiffness characteristics of the stabilization system taking into account the basic frequency of the system.

Research methods:

The following methods were applied to solve the determined tasks:

- the matrix method of coordinate transformation to define compensation angles;
- the method of logarithmic amplitude characteristics;
- the method of the theory of elasticity for an assessment of the stress-strain state;
- the finite - element modeling in CAE software program in ANSYS Workbench.

Reliability of the data is determined by the selected methods, and also a numerical experiment, and solution of test problems.

Scientific novelty of this work:

1) Designing a mathematical model to define angles of balancing of alternate external influences on the antenna device, taking into account any combination of geometrical parameters of a design;

2) Designing a calculated finite element model considering the dynamic characteristics and non-rigid peculiarities of the design.

The problem is formulated according to the customer requirements of JSC "Radiosvyaz" and the **practical significance of this work**. It can be defined as designing elements of integrated methodology of developing antenna systems based on the service performance.

Work approbation:

Obtained results of dissertation and its separate parts were reported at:

— 51-st International Scientific Student Conference "A student and progress in science and technology" in 2013 (Novosibirsk, distant participation);

— IX All-Russian scientific and technical conference of students and young scientists "Youth and Science ", in the section "Informatics: The system analysis, automation and management" in 2013 (Krasnoyarsk);

— IX All-Russian scientific and technical conference of students and young scientists "Youth and Science ", in the section "English for Specific Purposes" in 2013 (Krasnoyarsk);

— Regional Scientific Conference of Post-graduates "Special engineering education" in 2013 (Krasnoyarsk);

— X All-Russian scientific and technical conference of students and young scientists "Youth and Science", in the section "Informatics: The system analysis, automation and management" in 2014 (Krasnoyarsk, distant participation);

— International Scientific Conference "Research Journal of International Studies XXV" in 2014 (Ekaterinburg, distant participation).

CONTENTS OF WORK

Introduction. Relevance of dissertation work is proved, the purposes and research problems are formulated, objects and subjects of researches are defined.

Chapter 1 is devoted to the information review of a design and the principle of operation of the gyrostabilized antenna device.

The main element of any gyroscopic stabilization system it is gyroscope with two or three degrees of freedom, including freedom degree concerning its main axis.

According to the principle of the gyroscopic stabilization the systems may be classified as:

1) Direct systems – the devices that are used directly stabilizing properties of three-stage gyroscope;

2) Power systems — the electromechanical devices containing besides the gyroscopes, special engines for overcoming of impact on the stabilized object of the external revolting moments;

3) Indicator systems – the systems of automatic control where the gyroscopic devices are installed on stabilized object (for example, a platform), are sensitive or setting the elements that determine the object's position and control the watching systems. Stabilization of an object (a platform) is carried out by means of positioning systems.

In this work the element of positioning system is considered, namely the navigation antenna (the antenna-feeder unit of the ship-based), which uses a gyroscopic system of the indicator type.

The design of an antenna-feeder unit is a double reflector antenna with a diameter of a reflector of 1800 mm (Fig.1).

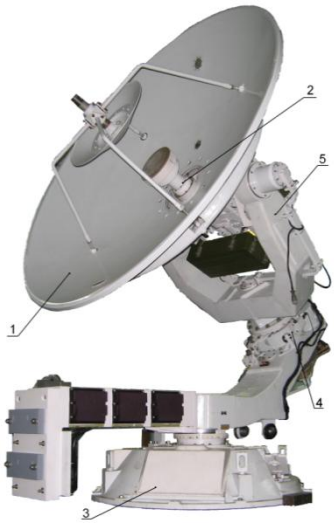


Figure 1 - Antenna-feeder unit

1 –A head of antenna; 2 – a transmitter system; 3 – a mechanism of a horizontal guidance; 4 – a mechanism of vertical guidance; 5 – a mechanism of cross-roll

The device consists of the antenna's head 1 (Figure 1), transmitter system 2 and the mechanisms of rotation on the axes of horizontal guidance 3, vertical guidance 4 and cross roll 5. For weather protection device installed under the radio transparent cover.

Chapter 2 is devoted to the calculation of the compensation angle of the gyrostabilized antenna device.

While considering the problem of determining the compensation angles of the disturbing effect, the Earth's rotation and its curvature aren't taken into account. It is accepted that the ship is moving at a constant speed and a constant course.

Figure 2 shows the angles of yaw and roll, where the arcs of great circles show the corresponding angles of the ship and guided measuring device.

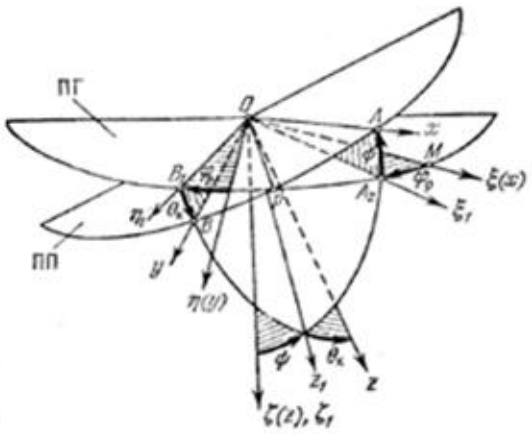


Figure 2 – The angles of yaw and roll

A transfer of a mobile coordinate system from starting position $O\xi\eta\zeta$ to a standard position *Oxyz* is made by consecutive turn of mobile axes on a pitching angle ψ (1), angle of roll θ and yaw angle φ.

$$A_{\psi} = \begin{pmatrix} x \cdot \cos(\psi) - z \cdot \sin(\psi) \\ y \\ z \cdot \cos(\psi) + x \cdot \sin(\psi) \end{pmatrix} \quad (1)$$

where *x*, *y*, *z* - the coordinate position of the object;

ψ - the angle of the ship pitching (trim angle).

Further conducted shift by the length of the construction unit a_3 (2):

$$A_{a3} = \begin{pmatrix} a_3 + x \cdot \cos(\psi) - z \cdot \sin(\psi) \\ y \\ z \cdot \cos(\psi) + x \cdot \sin(\psi) \end{pmatrix} \quad (2)$$

where a_3 - length of the link.

As the antenna system has a spatial construction of the link, in the preparation of the final transformation of coordinate systems it is necessary to take into account the linear shifts caused by length of links and the rotation transformation, moreover it is necessary to take into account the location of the antenna on the platform. Thus, using the principle of superposition, we obtain the final statement of transformation of coordinate systems for each individual constructive variant of the antenna system.

We designed the program module for calculating angles of balancing setting with alternate external influence, taking into account different options of design geometry, by means of MathCad (Fig. 3).

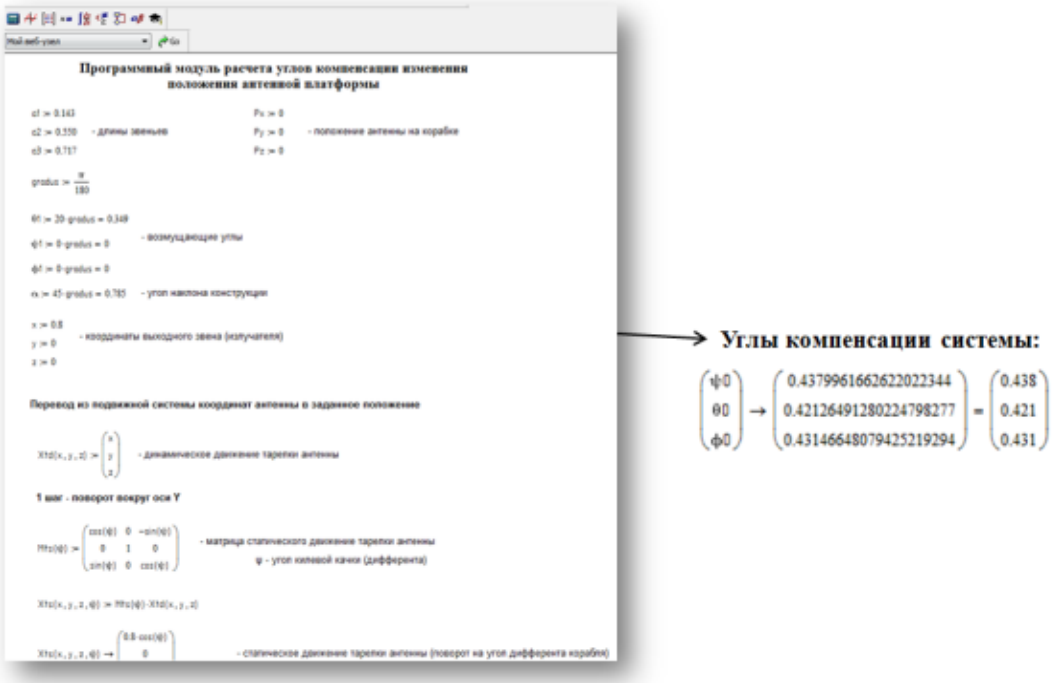


Figure 3 – A program module

The developed computational model allows:

– to consider peculiarities of geometrical and technological parameters of a construction taking into account the length of links, their relative position and the possible range of angles rotation;

– to consider antenna location on the ship;

– to consider coordinates of location of the tracking object.

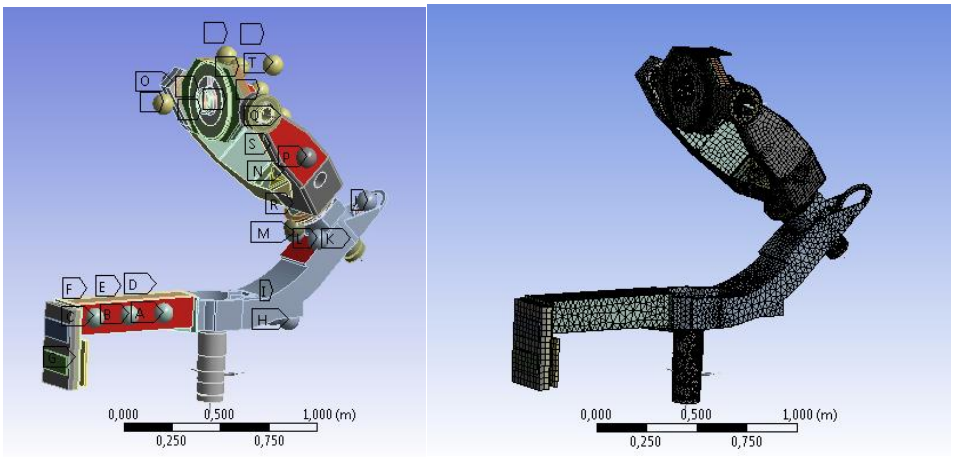
Chapter 3 is devoted to the development of calculated finite element model for research of constructive rigidity of the antenna.

By consideration of dynamics construction the method of logarithmic amplitude characteristics is taken for a basis as one of the most developed methods of engineering synthesis of automatic control systems.

Finding the own frequencies of the system by an analytical method leads to splitting its design into frame primitives, that is incomplete display of all characteristics of the system, and, therefore, leads to inaccurate results of calculation and requires a large amount of time to perform the calculation. For this reason, this problem can't be solved up to the end by the analytical methods and as the decision it is offered to use the finite - element modeling techniques in CAE environment ANSYS Workbench, which will improve the quality of the calculation results and reduce time for solving problem significantly.

Input data, such as the base frequency of the system ($f_0 = 5{,}8$Hz) and the model of antenna constructed by means Solid Edge, are considered to be an allowable minimum of values of frequencies on all axes of rotation of the antenna (have to be $\geq 3 \cdot f_0$, that is $\geq 17.3Hz$), and the geometry of the structure (Fig. 4a). By importing and editing the received design the calculated finite - element model for research of

constructive rigidity of the antenna is constructed by means of ANSYS Workbench (Fig. 4b).



A) geometry B) finite-element mesh

Figure 4 – The finite - element model of the antenna

We conducted the modal analysis (Fig. 6), for finding the own frequencies, and also defined deformations of the construction which have arisen under the influence of operating loads (gravity, inertial influence as a result of antenna movement) (Fig. 5).

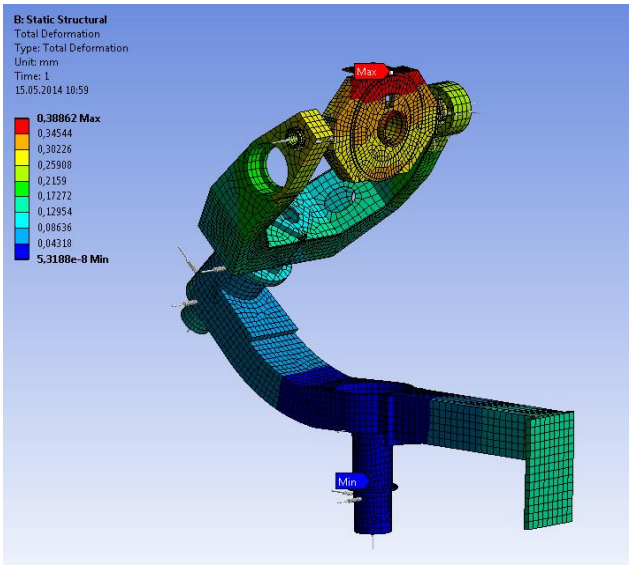


Figure 5 – Structural deformations

According to the obtained data the structural deformation constitutes 0, 02 °; it is accepted in the specified range of the dynamic error 3 - 4min.

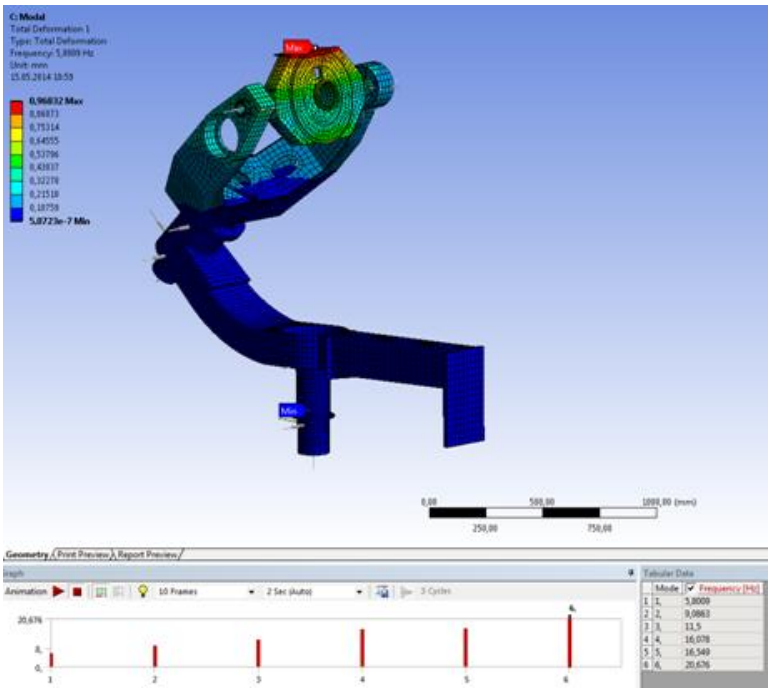


Figure 6 – The modal analysis

From the carried-out modal analysis it is established that own frequencies received as a result of calculation equal to 5,8Hz, aren't accepted in the range of admissible values of own frequencies, that doesn't meet requirements of high-quality work of gyroscopic system, and, therefore, this design must be modified in order to increase its structural rigidity.

Conclusion

Having conducted finite - element analysis we came to conclusion that the antenna design does not correspond its rigidity indicators. It was proved that various parameters of the design (thickness of walls, mass of details, and rigidity of bearings) are influenced on results of calculations that can be used at modernization of the antenna installation to increase its structural rigidity. Is also considered the possible solution this problem, as the replacement antenna design by the offset antenna.

Among other things, the developed program module of the calculation of the compensation angle represents the general method of calculation the position of antenna installation, and can be used for calculation of various options of a design system. As a result of transformations, coordinates of any point of a design of the antenna system is uniquely determined in the global coordinate system of the earth.

Obtained data will be further considered at the complex techniques for the design antenna systems.

The main publications on the theme of the thesis:

Fundamental principles of the thesis are rendered in publications: the total number of works is 7, one paper published in the journal recommended by Higher Attestation Commission, five papers are printed in other publications, one certificate of registration software is obtained.

– A list of the main scientific works:

Papers published in journals recommended by Higher Attestation Commission:

1. Simovich T. E., Kolbasina N. A. Calculation of the compensation angle of the gyrostabilized antenna device // The International Research Journal, ISSN 2303-9868.: Yekaterinburg – 2014, pp. 64-66.

Articles published in other publications:

2. Simovich T. E. The analysis of dynamic characteristics of the gyrostabilized antenna device // The source book of the 51st International scientific student conference "Student and scientific and technical progress": Novosibirsk, 2013.
3. Simovich T. E. The analysis of dynamic characteristics of the gyrostabilized antenna device // The source book of the IX All-Russian scientific and technical conference of students and young scientists "Youth and Science", section "Informatics: The system analysis, automation and management": Krasnoyarsk, 2013.
4. Simovich T. E., Kolbasina N. A. The analysis of the accuracy characteristics of the gyrostabilized antenna device // The source book of the Regional Scientific Conference of Masters "Special engineering education": Krasnoyarsk, 2013.
5. Simovich T. E., Kolbasina N. A., Vonog V. V. The analysis of dynamic characteristics of the gyrostabilized antenna device // The source book of the IX All-Russian scientific and technical conference of students and young scientists "Youth and Science", section "English for Specific Purposes": Krasnoyarsk, 2013.
6. Simovich T. E., Kolbasina N. A. // The source book of the X All-Russian scientific and technical conference of students and young scientists "Youth and Science", section "Informatics: The system analysis, automation and management": Krasnoyarsk, 2014.

Certificates and patents:

7. Certificate of state registration of the computer program "Program module of calculation of the compensation angle reposition the antenna platform".