Journal of Siberian Federal University. Engineering & Technologies 6 (2014 7) 655-659
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УДК 621.396.663; 621.396.969; 629.78

Direction Finding in Satellite Systems

Vitaly V. Sukhotin*
Siberian Federal University,
79 Svobodny, Krasnoyarsk, 660041, Russia

Received 07.07.2014, received in revised form 14.08.2014, accepted 29.08.2014

In article the method allowing to determine coordinates of a source a radio emission located on a terrestrial surface in satellite systems with use of the geostationary satellite is stated.

Keywords: determination of coordinates, radio emission source, satellite systems, difference of phases

Пеленгация в спутниковых системах

В.В. Сухотин
Сибирский федеральный университет
Россия, 660041, Красноярск, пр. Свободный, 79

В статье описан метод, позволяющий определить координаты источника радиоизлучения, расположенного на земной поверхности, в спутниковых системах с использованием геостационарного спутника.

Ключевые слова: определение координат, источник радиоизлучения, спутниковые системы, разность фаз.

Introduction

In satellite technologies the problem determination of coordinates a source a radio emission (SRE) which can settle down both on Earth surface, and on the aero-space carrier [1] is actual.

Method determination of location SRE

For measurement of coordinates the SRE (corners α and β in topocentric system of coordinates, Fig. 1), B_g located in a point the phase radio direction finder established onboard a communication

* Corresponding author E-mail address: VSuhotin@sfu-kras.ru

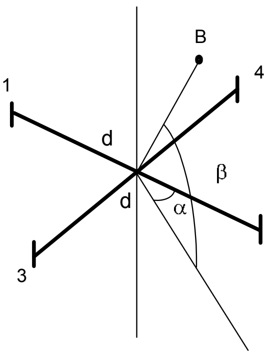

Fig. 1. Antenna arrays

artificial satellite (ASE), has to have two couples antennas 1-2 and 3-4 with mutually perpendicular bases. Shift of phases between E.D.S., induced in antennas 1-2 and 3-4, [2]:

$$\Delta\psi_{1-2} = \frac{2\cdot\pi\cdot d}{\nu}\cdot\sin\alpha\cdot\cos\beta\,, \qquad \Delta\psi_{3-4} = \frac{2\cdot\pi\cdot d}{\nu}\cdot\cos\alpha\cdot\cos\beta \tag{1}$$

Where: d – base of antennas 1-2 and 3-4; – length of a wave an accepted signal.

Corners α and β from (1):

$$\alpha = arctg\frac{\Delta\psi_{1-2}}{\Delta\psi_{3-4}}, \qquad \beta = \arccos\frac{\nu}{2\cdot\pi\cdot d}\cdot\sqrt{\Delta\psi_{1-2}^{2}+\Delta\psi_{3-4}^{2}}\,. \tag{2}$$

Having placed an antenna arrays on a geostationary ASE it is possible to define the direction on SRE concerning an ASE [3 … 6]. For determination of coordinates SRE it is necessary to calculate its coordinates in geocentric system of coordinates taking into account ellipticity of Earth

For calculation of required width and longitude of a source signal we will address to Fig. 2 [7]. Transition to the geocentric demands modification of expressions (2) therefore corners α and β pay off on formulas from topocentric system of coordinates:

$$\alpha = arctg\frac{\Delta\psi_{3-4}}{\Delta\psi_{1-2}}, \quad \beta = \arcsin\frac{\nu}{2\cdot\pi\cdot d}\cdot\sqrt{\Delta\psi_{1-2}^{2}+\Delta\psi_{3-4}^{2}}\,. \tag{3}$$

Here $\alpha = 90 - \alpha_1$; $\beta = 90 - \beta_1$.

The point D_g lies in the plane of the equator and is the projection of a point B_g. The angle φ of the triangle B_gOD_g is the breadth of the signal source. The longitude λ of the signal source is $\lambda = \lambda_{sp} + \lambda_g$, where λ_g – angle triangle C_gOD_g; λ_{sp} – longitude of the satellite. If the satellite is on the Greenwich Meridian, λ_{sp}=0. The point C_g on the line R1 is a projection of a point D_g on the meridional plane. Note that R1=42253,135 km [8].

To determine λ_g refer to the section of the Earth meridional plane (Fig. 3b). In the triangle K_gON_g angle α is calculated according to the formula

Segment K_gN_g is perpendicular to the plane of the equator. Required in this triangle is the n-end. Fig. 3a shows the plane spheroid with minor radius n, at an angle α to the plane of the equator. Semi-minor axis n intersects the plane of a triangle B_gAO at the same angle α to the plane of the equator. In

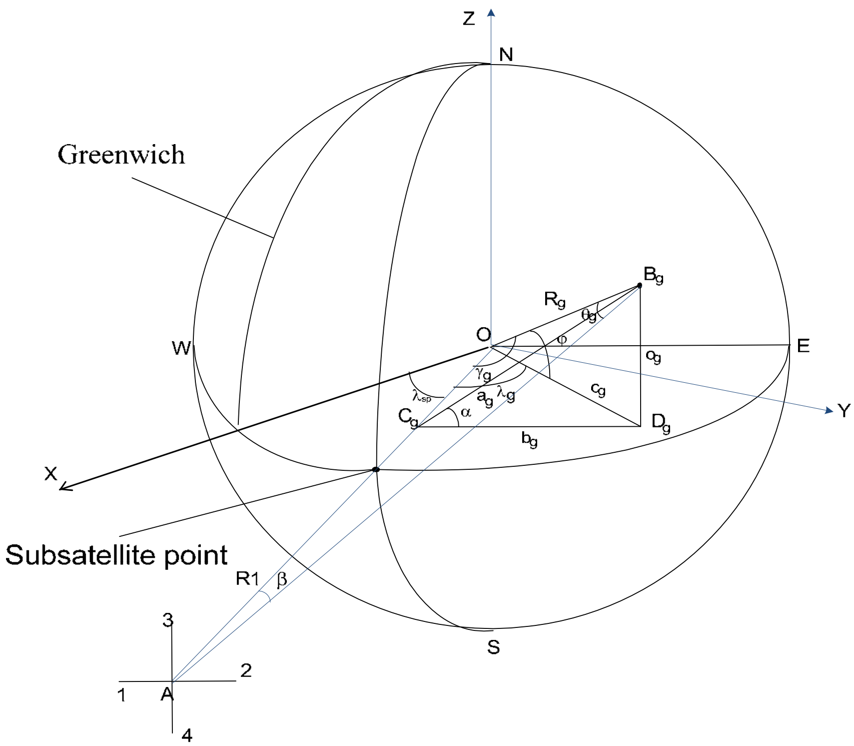

Fig. 2. Geometrical ratios

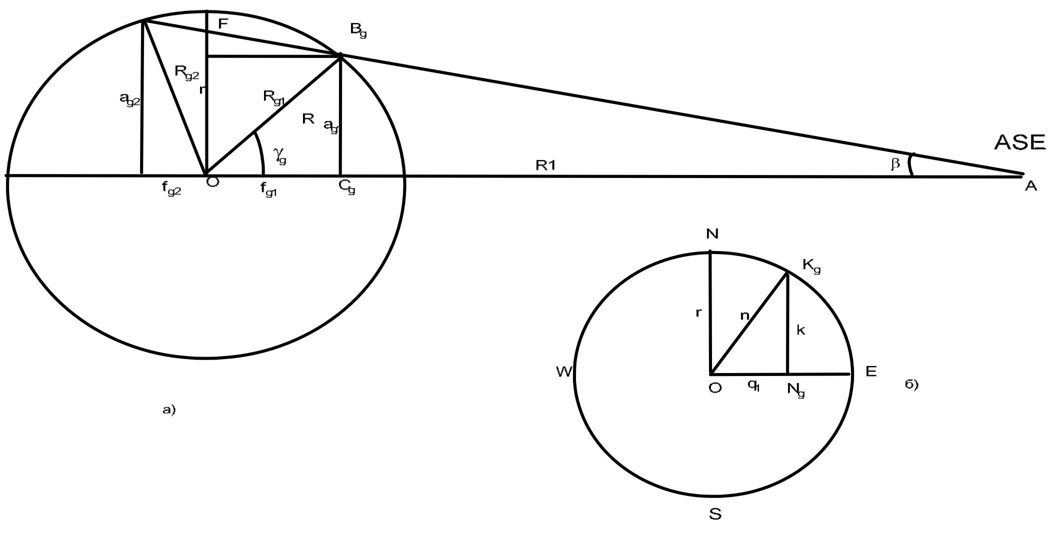

Fig. 3. Additional geometric constructions to calculate the coordinates of SRE with regard to the ellipticity of the Earth

the triangle B_gAO angle β is calculated according to the formula (3). The required Fig. 3a is a R_g party in the triangle B_gAO.

Calculation of latitude φ and longitude λ includes the following 7 stages.

1. Is the point of intersection (Fig. 3b) minor axis n and arc spheroid, the solution of systems of two equations

$$\left.\begin{aligned} k &= q \cdot tg\alpha \\ k &= r \cdot \sqrt{1-\frac{q^2}{R^2}} \end{aligned}\right\}. \tag{4}$$

where the first equation describes the minor axis, and the second is arc of a spheroid.

The solution (4) has two roots

$$q_1 = r \cdot R \cdot \sqrt{\frac{1}{tg^2\alpha \cdot R^2 + r^2}}, q_2 = -r \cdot R \cdot \sqrt{\frac{1}{tg^2\alpha \cdot R^2 + r^2}} \tag{5}$$

Further used only positive root, since a negative value belongs to the opposite part of a spheroid.

Substituted q_1 in any of the equations (4), we obtain the value of K. The semiminor axis n of a right triangle K_gON_g is equal to:

$$n = \sqrt{k^2 + q_1^2}\,. \tag{6}$$

2. Is the point of intersection (Fig. 3a) direct Rl, which is given by the equation $a_g = tg(R_l - f_g)$ and arc spheroid by solving the system of two equations:

$$\left.\begin{aligned} a_g &= tg(R1 - f_g) \\ a_g &= n \cdot \sqrt{1-\frac{f_g^2}{R^2}} \end{aligned}\right\} \tag{7}$$

Solution of the quadratic equation

$$\left(tg^2\beta + \frac{n^2}{R^2}\right) \cdot f_g^2 - 2 \cdot R1 \cdot tg^2\beta \cdot f_g + \left(tg^2\beta \cdot R1^2 - n^2\right) = 0\,, \tag{8}$$

are the two roots f_{g1} и f_{g2}

$$f_{g1} = \frac{2 \cdot R1 \cdot tg^2\beta + \sqrt{D}}{2 \cdot (tg^2\beta + \frac{n^2}{R^2})}, \qquad f_{g2} = \frac{2 \cdot R1 \cdot tg^2\beta - \sqrt{D}}{2 \cdot (tg^2\beta + \frac{n^2}{R^2})}\,, \tag{9}$$

where $D = (2 \cdot R1 \cdot tg^2\beta)^2 - 4 \cdot (tg^2\beta + \frac{n^2}{R^2}) \cdot (tg^2\beta \cdot R1^2 - n^2)$.

From Fig. 3a and (9) follows that, in further calculations will need the root f_{g1} meaning equal side OC_g. Substituting f_{g1} into any equation of system (7), we obtain the value of the side a_{g1}, then from a right-angled triangle B_gOC_g, we find R_{g1}:

$$R_{g1} = \sqrt{a_{g1}^2 + f_{g1}^2}\,. \tag{10}$$

3. From right-angled triangle $B_gC_gD_g$ (Fig. 2) we find o_g:

$$o_g = a_{g1} \cdot \sin\alpha\,. \tag{11}$$

4. From right-angled triangle B_gOD_g we find latitude φ of SRE:

$$\varphi = \arcsin \frac{o_g}{R_{g1}}. \tag{12}$$

5. From right-angled triangle B_gOD_g we find c_g:

$$c_g = \sqrt{R_{g1}^2 - o_g^2}. \tag{13}$$

6. From right-angled triangle B_gOC_g, angle λ_g:

$$\lambda_g = \arccos \frac{f_{g1}}{c_g}. \tag{14}$$

7. Longitude λ of SRE:

$$\lambda = \lambda_{sp} + \lambda_g. \tag{15}$$

In geocentric system of coordinates (Fig. 2):

$$x = c_g\cos\lambda,\ y = c_g\sin\lambda,\ z = o_g. \tag{16}$$

Conclusion

Thus, the described technique relying on use onboard the spacecraft of an antenna arrays, allows to solve a problem determination of coordinates of the Source a radio emission.

Work is performed with financial support of the Ministry of Education and Science of the Russian Federation in the Siberian federal university (Contract No. 02.G25.31.0041).

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