

Equalization of Bearing Errors Caused by the Presence of Horizontal Ionosphere Irregularity

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Abstract – Methods of equalization bearing errors caused by horizontal ionosphere irregularities are viewed. Estimation of equalization efficiency while determining coordinates of the source is done.

Keywords – Bearing taking, ionosphere, radio emission source, coordinates determination.

When taking bearings to radio signals reflected from ionosphere in decameter wave band the effect of transversal deviations paths (TDP) of waves' is observed, when projections of the path of wave propagation to the earth surface don't match the plane of great-circle arc. TDP are caused by the presence of horizontal gradients of the reflection layer, more often appearing in the morning and evening time at the meridian radio paths as a result of unequal ionosphere heating by the rising or the setting Sun.

Also longitude gradients caused by seasonal phenomena are observed. Irregularities can reach several hundreds of kilometres in size. Bearing error RMS caused by TDP is about 4° [1] and exceeds all other types of errors, occurring when taking bearings to the radio emission source (RES) in the decameter band that is why recording of these errors is to be paid primary attention.

There is a method of introducing corrections to the bearings measured; these corrections are calculated by the formulas obtained empirically [2]. Corrections calculating formulas contain the length of radio path, the latitude of the reflection point of the signal and coordinates of the Sun (declination, zenithal distance and hour angle). By means of static simulation it is demonstrated that mean error of coordinates determination using corrections is decreased by 3.8km. Such decrease is not enough efficient.

Also there exists equation [1] that binds error $\Delta\Theta$, caused by TDP, with gradient size of reflection layer a , the rotation axis angle of the layer y relative to the plane of wave front:

$$\Delta\Theta = \arctg\left(\frac{2h}{D} \operatorname{tg}(a \cdot \sin(\Theta - y))\right). \quad (1)$$

where: h - the height of reflection layer, D - length of radio path, Θ - measured bearing. The process of coordinates' determination of RES with recording for bearing errors caused by TDP using Eq. (1) can be done as follows:

1) obtained preliminary coordinates are determined using bearings and paths' lengths of all bearing posts (BP) are calculated;

2) using for example widely known IRI (International Reference Ionosphere) [3] model heights of reflection points h are determined for each path with preset date and time;

3) using Eq. (1) substitute corrected bearing values to the known equations of navigation isoline:

$$\Theta_i - \Delta\Theta_i = f(a, y, j_i, l_i, j_0, l_0), \quad (2)$$

where: j_i, l_i - known coordinates of direction finders, j_0, l_0 - unknown coordinates of source, $i = 1 \dots N$, N - number of BP.

Obtained in this way system of equations Eq. (2) contains four unknowns: a, y, j_0, l_0 and with a number of direction finders not less than four it can be solved using for example least square method. In this way corrected RES coordinates are determined.

Simulation of direction finding process of RES is conducted in order to check efficiency of this method. In the simulator 5 BP arranged on the surface at the distance of 1000 km from RES are used. To the real bearings were entered errors caused by TDP with the typical gradient size of reflection ionosphere layer equal to 3° , and also random values according to normal distributing law with zero mean value and RMS equal to 2° . RES coordinates were calculated twice – without bearing corrections and with bearing corrections. In the first case, mean error of coordinates' determination of RES comprised 39.8km, in the second – 27.4km. During simulation 10000 tests were carried out. On Fig. 1 errors distribution histograms of coordinates' determination are demonstrated.

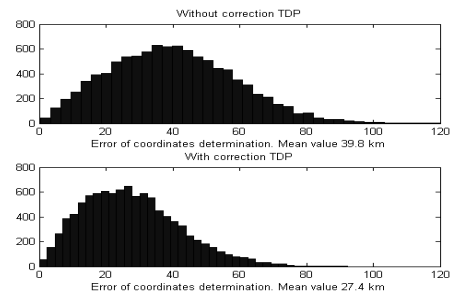


Fig. 1 Simulation results

Thereby simulation has demonstrated that proposed method of equalization bearing errors allows decreasing of mean error of RES coordinates determination approximately by 1.5 time.

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