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EXACTNESS ESTIMATION OF MAGNETIC COMPASS DEVIATION ACCOUNTING

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Exactness of the known formula of description of remaining magnetic deviation is examined. It is shown that at a roll and different of ship a formula gives considerable errors. Examples of estimations of error are made for the different angles of ship position and different geographical location. The calculation of magnetic deviation is offered on other formula, containing the components of magnetic field of object, described by the model of Poisson. This formula gives a more accurate estimate of the deviation, which depends only on the accuracy of determining the parameters of the magnetic field of the vessel.

***Keywords**: magnetic compass, magnetic deviation, magnetic parameters of Poisson.*

Introduction

There is magnetic or induction compass on any of modern ships. Not only magnetic field of the Earth acts on it, but also magnetic field of ship does, which leads to an error, called magnetic deviation.

Compass deviation is eliminated by special methods. Remaining deviation is accounted by known formula [1]. Exactness of magnetic deviation accounting determines an exactness of magnetic or induction compass. The questions of exactness estimation of deviation calculation and possibility of using other formula to improve the exactness of magnetic deviation accounting are covered in the article.

Problem statement

Full magnetic field of the object described by the model of Poisson:

$$\begin{aligned} X' &= X + aX + bY + cZ + P; \\ Y' &= Y + dX + eY + fZ + Q; \\ Z' &= Z + gX + hY + kZ + R; \end{aligned} \tag{1}$$

where X', Y', Z' - are projections of the total magnetic field strength vector on the axes associated with the object; *X,Y,Z* – are components of the magnetic field of the Earth strength vector; ; *a, b, c, ..., k* – are Poisson's parameters, which characterize influence of soft magnetic iron; *P, Q, R* - are hard magnetic iron strength projections.

Remaining magnetic compass deviation is calculated by formula:

$$\delta = A + B\sin K_K + C\cos K_K + D\sin 2K_K + E\cos 2K_K, \tag{2}$$

where $\delta = K_K - K_M$, K_K - is compass heading, K_M - magnetic heading; *A, B, C, D, E* – are deviation coefficients. Usually remaining deviation is not more then 5°.It is calculated for horizontal orientation of the object at small values of roll and different. For accounting of deviation coefficients by known methods [1] swell must not be more then 2 points.

There are relation between model (1) and deviation coefficients, which is described by approximate formulas [1] :

$$A=\frac{d-b}{2\lambda}, B=\frac{cZ+P}{\lambda H}, C=\frac{fZ+Q}{\lambda H}, D=\frac{a-e}{2\lambda}, E=\frac{d+b}{2\lambda}, \lambda=1+\frac{a+e}{2}, \tag{3}$$

where H and Z – are horizontal and vertical components of magnetic field of the Earth strength vector.

Deviation coefficients from (2), received after eliminating of deviation, and coefficients (3), received using the magnetic field of the ship parameters from (1) and components H and Z of the magnetic field of the Earth, are in good agreement for horizontal orientation of the object.

Purpose of the work is exactness estimation of deviation accounting by formulas (2), (3) for big values of the ship's inclination, which can reach 22° for different and 45° for roll [1], according to compass specification.

Exact magnetic compass deviation accounted by using compass heading calculation by formulas [2]:

$$K_{K1}=arctg\frac{-(X'\cos\gamma+Z'\sin\gamma)}{(X'\sin\gamma-Z'\cos\gamma)\sin\theta+Y'\cos\theta}, \tag{4}$$

where θ, γ - are angles of different and roll. Exact deviation is:

$$\delta=K_K-K_M. \tag{5}$$

Results of the estimation

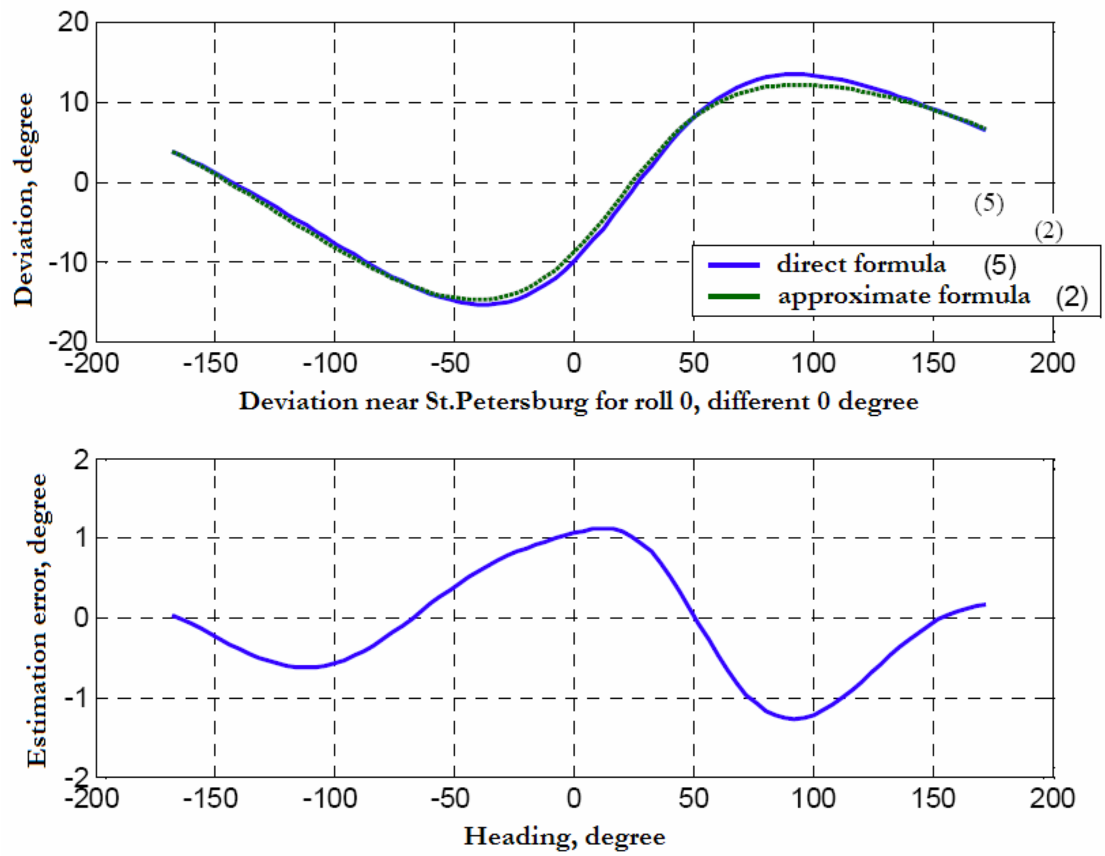
Let's examine case for object orientation in horizontal plane, i.e. θ=0° and γ=0°, while it is situated on latitude of St.Petersburg with relevant components of the magnetic field of the Earth. Let's calculate magnetic compass deviation by formulas (2) and (5) for heading values in the range from -180° to +180°. Plots of deviation are shown on img.1. Deviation estimations by approximated formula (2) and exact formula (5) show, that estimation error can reach one degree even for horizontal orientation of the object (img.1). Error increases significantly for inclination of the object or of the compass card (img.2).

Deviation accounting error remains significant after compensation of component R of hard magnetic iron.

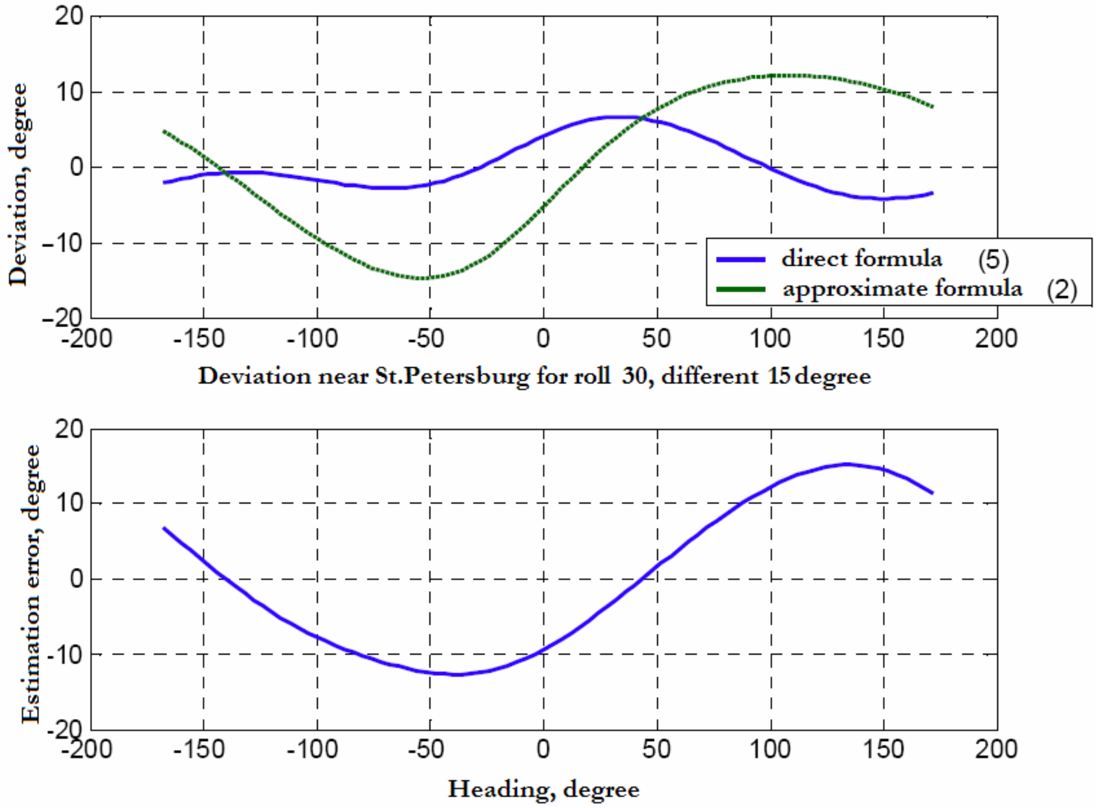
Exactness estimation of deviation depends not only on values of roll and different of the object, but also on its geographical location, and more specifically on components of magnetic field of the Earth, which act on magnetic compass arrow at a given geographical point. Let's use mean-squared error (MNE) for estimation of deviation error calculating. MNE formula:

$$s=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(\delta_i-\delta_{1i})^2},$$

where n – is number of measuring headings.

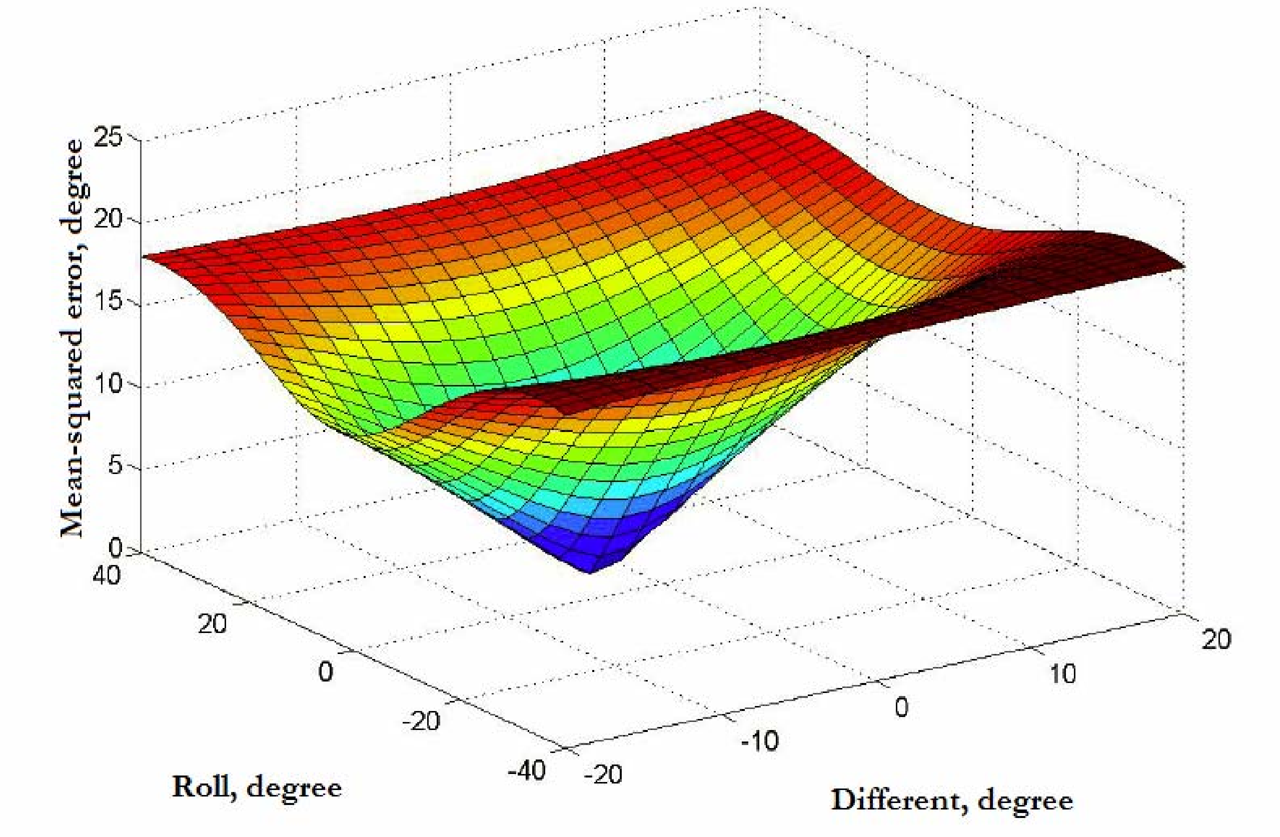


Img.1. Deviation calculation error for horizontal orientation



Img.2. Deviation calculation error for roll and different

Mean-squared error of magnetic compass deviation calculation dependence on angles of roll and different of the object is shown in three dimensions (img.3). Angles of roll (from -20° to +20°) and different (from -40° to +40°) of the object are shown on horizontal axes. The surface is constructed based on data of modeling process for object's location on geographical latitude of Kyiv. Components of magnetic field of the Earth are: H = 15.523 A/m, Z= 36.823 A/m. There may be significant values of angles for case of using three-ax flux-gate magnetometer rigidly connected with the object as magnetic compass. According to preliminary estimate angle of magnetic compass arrow inclination does not exceed 5°. In that case errors reach values of 10°.



Img.3. Deviation calculation error dependence on angles of roll and different

Conclusion

The comparison of calculated deviations showed, that error of deviation calculation by known formula (2) may reach significant values (tens of degrees). It depends on inclination angles of meter, heading and latitude. Deviation calculations made by formulas (4) and (5) are more exact. Formulas (4) and (5) give opportunity to calculate compass heading not only for horizontal orientation of the object, like in case of using formula (2), but for different angels of its position too. Parameters of magnetic field of ship in Poisson's model (1) must be known for using formula (4).

References

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