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The precision of compass error observation using parallel lines option in radar

Dokładność określenia poprawki kompasu przy wykorzystaniu opcji linii równoległych w radarze

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Key words: accuracy, compass correction, radar, parallel lines

Abstract
The article presents a method to determine the gyro correction by utilizing parallel lines used in radar, taking into account the advantages of this method, which are the convenience and ease of use. The accuracy of the method according to the geographical and technical factors was analyzed. The mathematical calculation of the final results accuracy was presented. Situations in which it is recommended to use this method for determining gyrocompass corrections due to the high accuracy were described.

Słowa kluczowe: dokładność, poprawka kompasu, radar, linie równoległe

Abstrakt
W artykule zaprezentowano metodę określenia poprawki żyrokompasu przy wykorzystaniu linii równoległych stosowanych w radarze. Uwzględniono zalety tej metody, którymi są szybkość i łatwość stosowania. Przeanalizowano dokładność metody w zależności od warunków geograficznych i czynników technicznych. Przedstawiono matematyczne wyliczenia dokładności wyników końcowych. Opisano sytuacje, w których rekomendowane jest stosowanie tej metody określania poprawki żyrokompasu ze względu na wysoką dokładność.

Introduction

There is the option “Parallel lines” in the modern radars. The radars “DATA BRIDGE 2000” of NONCONTROL Company, “NUCLEUS” of Kelvin Hughes Company and others have possibility to display 50 parallel lines. There are possibilities of variation changing their angular attitude. These lines can be used for measuring of compass direction between any two object. The observation of compass bearing by means of parallel line is presented at figure 1.

Thus, even if the observer is not on the baseline linking objects, this method can be used to determine the correct direction [1].

This method of determining the compass error does not require any formulas for calculation, except for classical:

$$CE = TB - CB$$

where: CE – compass error, TB – true bearing, CB – compass bearing.

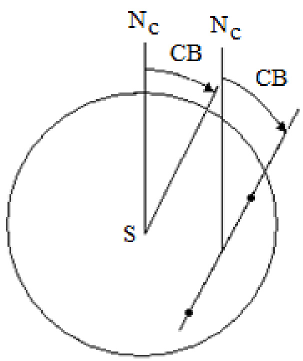

Fig. 1. Observation of compass bearing by baseline on radar
Rys. 1. Obserwacja kompasu z zachowaniem linii bazowej na radarze

The most common such frameworks can be used to isolated marks or outstanding points as beacons, fairway buoys or capes on the coast line.

The observation of compass error by the method of parallel lines may be used in any situation, when in range of radar detection are two objects suitable for observing [2].

It is clear that a final response to a question about the feasibility of any method can be accessed only when the question of accuracy of the proposed method was thoroughly researched.

At using of electronic chart this process can be automated, that would completely eliminate the routine operation from side of navigators.

Analysis of accuracy

The accuracy of compass error measured at using of parallel line depends on the following main factors:

– angular resolution of eye on radar screen,
– the width of diagram of the radar antenna,
– random and systematic errors of objects' relative positions.

The accuracy of compass error depends on the geometric factors (the distance between the objects, relative position of the ship and the resolution of the eye on the radar screen). The connection of geometric factors and accuracy of compass error is shown in figure 2. The angular resolution of eye on radar screen (m_S) at the point *A* and *B* can be expressed in linear extent of about 0.3 mm [3].

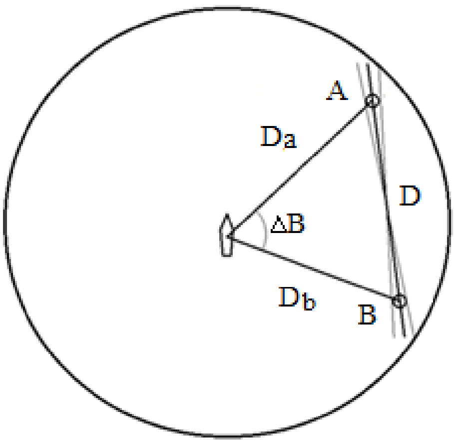

Fig. 2. The accuracy of observation the direction of the baseline
Rys. 2. Dokładność obserwacji kierunku linii bazowej

The accuracy of direction of the baseline can be calculated in this case by the formula:

$$\Delta B = \frac{m_s}{D} = \frac{m_s}{\sqrt{D_A^2 + D_B^2 - 2D_A D_B \cos\Delta B}}$$

At a distance *D* between objects on the radar screen *D* = 10 cm, and sensibility of eyes 0.3 mm. accuracy of determining the direction of the baseline is:

$$\Delta B = 0.17° \approx 0.2°$$

To ensure high accuracy measurement of this direction the navigation charts should be used in appropriate scale, what generally does not constitute problem. The radar adds its own errors, depending on its technical parameters (width of the antenna diagram θ, systematic errors of distance). The errors of antenna are shown in figure 3.

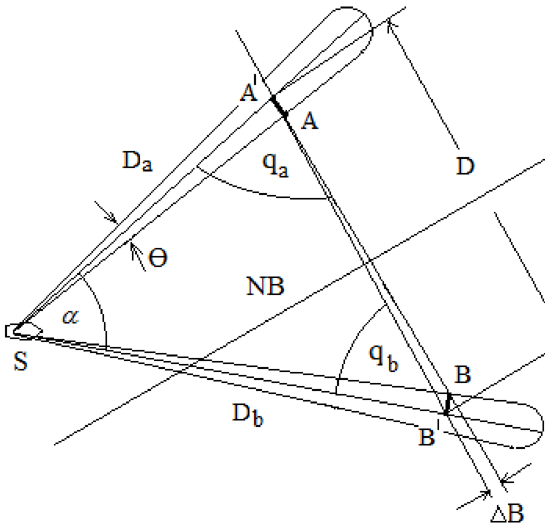

Fig. 3. Impact of the accuracy of the diagram width of the radar antenna on determining the baseline direction
Rys. 3. Wpływ szerokości schematu anteny radaru na określenie kierunku linii bazowej

When the distinctive elements of the coast are used, such as capes and peninsulas, the error of direction, depending on the width of the diagram of the radar antenna is defined by the expression:

$$\Delta B_\theta = \frac{\theta}{2D}\left(D_A \cos q_A - D_B \cos q_B\right) \tag{2}$$

where:

θ – the diagram width of the radar antenna,
D_A – the distance to the object A,
D_B – the distance to the object B,
q_A – the aspect of the object A,
q_B – the aspect of the object B.

The length of leading line *D* can be represented by the equation:

$$D = D_A \cos q_A + D_B \cos q_B \tag{3}$$

From equation (2) and (3) there is:

$$\Delta B_\theta = \left(1 - \frac{2D_B}{2D}\cos q_B\right)\frac{\theta}{2} \tag{4}$$

or otherwise:

$$\Delta B_\theta = -\left(1 - \frac{2D_A}{D}\cos q_A\right)\frac{\theta}{2} \qquad (5)$$

The expressions (4) and (5) present two curves of mirror reflection on the main normal to base line *AB* (normal at the middle point of the segment *AB*).

The accuracy of baseline direction for width of radar diagram 2° is presented in table 1.

Table 1. The error Δ*B* of baseline direction at $\theta = 2°$ depending on the distance of vessel from the normal of the main base
Tabela 1. Błąd Δ*B* kierunku linii bazowej przy $\theta = 2°$ w zależności od odległości statku od normalnej bazy głównej

The length of baseline [Nm]	Distance from the normal to baseline (NB) [Nm]					
	0	1	2	3	4	5
5	0°	0.4°	0.8°	1.2°	1.6°	2.0°
10	0°	0.2°	0.4°	0.6°	0.8°	1.0°
15	0°	0.14°	0.27°	0.4°	0.53°	0.67°
20	0°	0.1°	0.2°	0.3°	0.4°	0.5°

An analysis of the equation (2), as well as the table 1 indicates the proportion depending of accuracy from the length of baseline and from the distance of the ship from the normal to baseline.

Table 1 and figure 4 show that within the limits of the width equal of base line length, linear error value depends on the deviation from the normal line, and the error limit is equal to half of the width of the radar antenna diagram.

From the equation (2) is clear that the error of bearing is absent when the ship is situated at the main normal to the baseline. Hence the first recommendation that objects should be observed when they are nearly the main normal line to baseline. This recommendation allows excluding the antenna from the factors of accuracy.

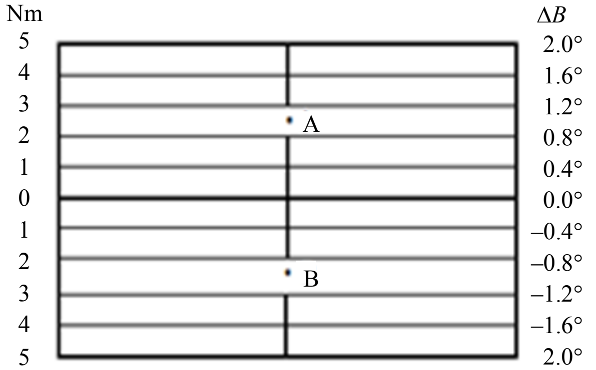

Fig. 4. Lines of equal values of the error to determine the direction of the baseline, depending on the distance of the ship from the normal of the baseline
Rys. 4. Linie równych wartości błędu przy określaniu kierunku linii bazowej w zależności od odległości statku od normalnej linii bazowej

Influence of systematic error of distance to accuracy of registration the compass error

In figure 5 the nature of baseline *AB* distortion due to systematic error of distance Δ*D* was shown.

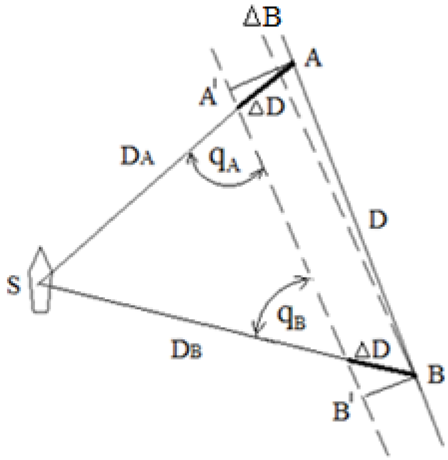

Fig. 5. The error Δ*B* depending on the constant error Δ*D*
Rys. 5. Błąd Δ*B* w zależności od stałego błędu Δ*D*

Table 2. Error of base line direction $\Delta B_{\Delta D}$ [°]
Tabela 2. Błąd kierunku linii bazowej $\Delta B_{\Delta D}$ [°]

q_A°	q_B°									
	0	10	20	30	40	50	60	70	80	90
0	0	–0.05	–0.10	–0.15	–0.20	–0.24	–0.27	–0.29	–0.30	–0.31
10	+0.05	0	–0.05	–0.10	–0.14	–0.18	–0.22	–0.24	–0.25	–0.26
20	+0.10	+0.05	0	–0.05	–0.09	–0.13	–0.16	–0.18	–0.20	–0.20
30	+0.15	+0.10	+0.05	0	–0.04	–0.08	–0.11	–0.14	–0.15	–0.15
40	+0.20	+0.14	+0.09	+0.04	0	–0.04	–0.07	–0.09	–0.11	–0.11
50	+0.24	+0.18	+0.13	+0.08	+0.04	0	–0.03	–0.05	–0.07	–0.07
60	+0.27	+0.22	+0.16	+0.11	+0.07	+0.03	0	–0.02	–0.04	–0.04
70	+0.29	+0.24	+0.18	+0.14	+0.09	+0.05	+0.02	0	–0.01	–0.02
80	+0.30	+0.25	+0.20	+0.15	+0.11	+0.07	+0.04	+0.01	0	–0.01
90	+0.31	+0.26	+0.20	+0.15	+0.11	+0.07	+0.04	+0.02	+0.01	0

The accuracy of determining the baseline direction due to systematic error of distance ΔD is defined by the expression:

$$\Delta B_{\Delta D} = \frac{\Delta D}{D}(\sin q_A - \sin q_B)\, 57.3° \qquad (6)$$

This expression shows that this error of bearing also does not have in case of ships position located nearly the main normal line to baseline. Hence another recommendation. The objects should be observed when the difference of distance to objects is small.

$$\Delta B_{\Delta D} = 0.31°(\sin q_A - \sin q_B) \qquad (7)$$

Error of baseline direction, depending on the heading angles q_A and q_B. Calculations by the formula 7 depending on the angles q_A and q_B at $D = 5$ Nm and $\Delta D = 50$ m are shown in table 2.

The table 2 shows, that the error of base line direction is the less when the difference between q_A and q_B is the smallest. The conclusion is that the minimum error occurred on the main normal to the baseline.

Conclusions

The analysis of baseline direction accuracy has shown the validity of the method to determining the compass error by using parallel lines on the radar screen.

The calculated accuracy indicates the possibility of using this method to navigate due to meet requirements of navigational safety.

Minimum time for manual monitoring and possibility of automatic problem solving by means of electronic charts makes the method very promising for use on ships.

References

1. LUSHNIKOV E.: Use of base leading line for determining of a compass error. 2 Seas and Oceans International Congress, Szczecin-Międzyzdroje, Szczecin 2005, 139–143.
2. LUSHNIKOV E., PLESKACZ K.: Determination of compass error by means of parallel lines at radar. Konferencja “MTE –2011”, Akademia Morska, Szczecin 2011, 297–302.
3. LUSHNIKOV E.: Use of system AIS for maintenance of the navigating safety. International conference “Explo-Ship 2004”, Szczecin – Copenhagen 2004, 263–271.

Other

4. LUSHNIKOV E.: Increase of navigational accuracy at sailing by the leading line. 2 Seas and Oceans International Congress, Szczecin – Międzyzdroje, Szczecin 2005, 129–138.