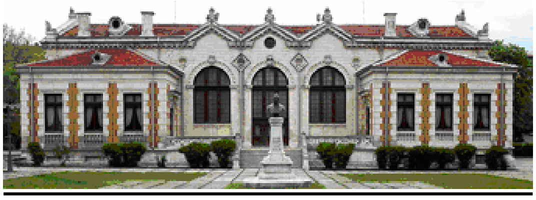

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# МЕТОД ЗА ОПРЕДЕЛЯНЕ МЕСТОПОЛОЖЕНИЕТО НА РАДИОИЗЛЪЧВАЩИ ОБЕКТИ

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# METHOD FOR DETERMINING THE LOCATION OF RADIO-EMITTING OBJECTS

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***Abstract:****The report examines the current state of methods and algorithms for determining the absolute and relative coordinates of radio emitting objects in single station onboard radar systems.*

***Key words:*** *radio-electronic complexes; onboard radar systems; methods for determining*

The main source of information for air and ground environment for aircraft is the onboard radar system. These systems are built using the latest achievements of modern radio-electronic and computing machinery and are complex radio-electronic complexes that have an enormous impact on the effectiveness of aviation. The scope of aviation includes air, land and sea objects. Modern aircraft are required to perform a variety of purposes, which in turn require the installation of multi on-board radar systems, working in "air-air" and "air-land".

One method for determining the location of radio emitting objects is fold direction-finding. It is used in conducting aerial surveillance of ground radars. In direction-finding the stationary radiating source located at point T is determined by two points $P_1$ and $P_2$ ( fig.1) which are apart one from another at a distance L. The coordinates of the source are determined by solving $\Delta P_1TP_2$, taking into account angles $\varphi_1$ and $\varphi_2$ and the base L , which are utilized in relationship [1].

$$R_1 = \frac{L\sin\varphi_2}{\sin(\varphi_2 - \varphi_1)}, \quad (1.1)$$

$$R_2 = \frac{L\sin\varphi_1}{\sin(\varphi_2 - \varphi_1)} \quad (1.2)$$

Where $\varphi_1$ and $\varphi_2$ are the objects in the on-board direction-finding in points $P_1$ and $P_2$ taking into account the relative direction of flight and coinciding with the longitudinal axis of the airplane. L being the base for direction-finding.

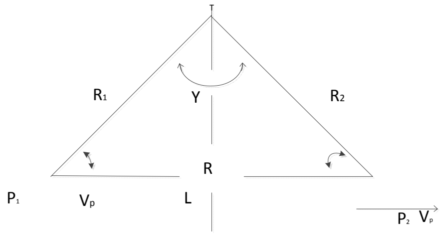

*fig. 1: Determining the location of an object in fold direction-finding in one plane.*

Slight errors in determining the fold symmetric direction-finding are obtained, $\gamma = 70{,}5^0 (\gamma = \varphi_1 - \varphi_2)$, where the angle is equal to the difference in the directions of the direction-findings. In this case the ratio of the length of R to the object under path to the base L is equal to 0.7 . As for the given angle $\gamma$ the value is $109.5^0$. The differences in the numbers value, is explained by the fact that many small errors in the location [2,3,1] using different criteria: in [2,3] The magnitude is very small $\sigma_R / L$, в[1]$-\sigma_R$ / R. In carrying out the assignment with an airplane the error is important in determining the location of the object, relating to the distance of the object taking into into account that the magnitude of the base is variable and can be selected depending on the conditions of its use in [1]. It has been proven, that fold direction-finding on base compared on to the remoteness of the object on the traverza line and accuracy of direction-finding to $1^0$ relative error of the determining the location is about 3-5%._In this case it is assumed that the coordinates of the aircraft, from which direction-finding is carried out determined with significantly greater accuracy, than the coordinates of the object. But because of inaccuracy errors resulting LA may not be taken into account. Another method for determining the location of radio emitting objects is repeated direction-finding . In the process of aerial surveillance is possible straight flight of the aircraft as well as measurement of bearing of radio emitting object at regular intervals. Which in [1] are obtained algorithms for processing measurement results according to the methods of the squares and weight factors. The bearing of the object is measured consequently, according to the approach of the beam line and away from it. In terms of accuracy it is appropriate for such a sequence for processing, two bearings are selected corresponding to one of the measurements, to be symmetrical to the line of the beam. When there is no symmetry the errors regarding the location of the object increase dramatically. With a large number of bearings (more than 10) the optimal angle between the end bearings is about $102.67^0$. The results of modeling show, the potential accuracy of the local determination process by the method of least squares and the method of angular coefficients is the same when the bearings, participating in the weighing procedure are symmetrical to the beam. There is another method for determining the location of radio emitting objects which is based on small angles of direction-finding. Sometimes in aviation it is required a flight to the ground radar-by the shortest path. In this case it is necessary to determine the distance of the object at small angles to the bearing of the object._The bearings of the radar are measured in: point $P_1$ on the initial detection (distance $R_1$) and a point $P_2$ of transmission ($R_2$).

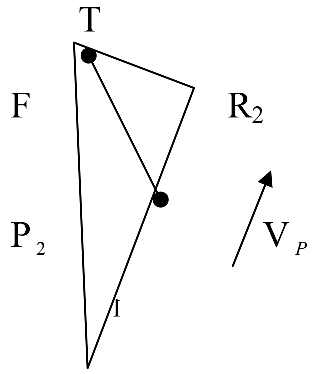

fig.2 Determining the location of a stationary target in the case of small angles for direction-finding.

In [1] is found the dependence of the relative error of determining the relative distance from the course parameter. It shows the ratio of the length of the perpendicular TF spent from the point of object position along the course line to the plane distance $R_2$. When the course parameter is less than 0.3 value and errors of measurement of bearing 1-2 method for fold direction-finding without a special maneuver is inappropriate because the relative error in measuring the distance exceeds 25%. The kinematic method for determining the location of the radio emitting objects in its simplest variation is presented by taking the pattern of relative motion in a plane which is described by the equation: [4].

$$(1.2) \qquad \omega = \frac{V_1}{R}$$

where $\omega$– angular velocity of the line of sight ; V velocity of the aircraft towards the object, the perpendicular line of sight and it's called the tangent; R - distance to the object(since its stationary, then V is the projection of velocity of the aircraft towards the line of sight). If quantities have values they go into formula (1.2), error in calculating the distance is determined by the expression

$$(1.3) \qquad \Delta R = \frac{\Delta V_t \omega - \Delta\omega V_t}{\omega^2},$$

Where:

$\Delta R = R - \widehat{R}; \Delta\omega = \omega - \widehat{\omega}; \Delta V = V_t - \widehat{V}_t;$ and $\widehat{R}, \widehat{\omega}, \widehat{V}_t$ - estimates of relative values. If errors are considered $\Delta\omega$ and $\Delta V_t$ Gaussian and mathematical expectations are equal to zero not correlated among themselves. This mathematical expectation of the error $\Delta R$ and the value of R are equal to zero and the dispersion $D_R$ of the error is found by:

$$(1.4) \qquad D_R = \frac{D_V + D_\omega R^2}{\omega^2} \quad ,$$

where $D_V$ and $D_\omega$ are the dispersions of the errors of evaluation on $V_1$ and $\omega$. From (1.4) follows that the lesser $D_R$ is, the greater $\omega$ is. When R is a constant $\omega$ increases and can reach $V_t$, which is provided at the expense of increasing the rate towards the line of sight representing the speed of the airplane. As a result of this the aircraft is forced to maneuver away from the object. This conflicts with the need to maintain a defined path for targeting. At the same time the single determining of the distance may be insufficient because the targeting process requires periodic adjustment of the coordinates of the object if it is moving. The main conclusion from the information relied is that the use of methods for determining location and to achieve acceptable accuracy is necessary to form a special flight path for the aircraft. The simplified kinematic method for determining the coordinates of radio emitting objects allows determining the distance of the radio emitting object with the onboard radar of the aircraft automatically without searching for data from other indicators. If it is assumed that the object and the aircraft are moving in the same plane. With it is assumed that the object and the aircraft are moving in the same plane. The Radar onboard the plane P (Fig. 2) accepts a signal from the radio-electronic device that is mounted on the plane T and it measures angular position (board bearing) of the object $\varphi_1$ and angular velocity of the line of sight of the object $[4,5]$.

(1.5) $\omega_1 = dE_1/dt_1$ ,

where $E_1$ is the angle of sight at time $t_1$.

Angular velocity of sight is related to the distance $R_1$ to the object and tangent component $V_{tre/1}$ of the linear velocity of the moving object relative to the airplane._This tangent is:

(1.6) $V_{tre/1} = V_T \sin q + V_P \sin\varphi = V_{Tt} + V_{Pt1}$,

where q is the trajectory angle of the object;_$V_1$ - velocity of the object; $V_P$ - the speed of the airplane; $V_{Tt}$ and $V_{Pt1}$ - - tangents, speeds comprising the object and the plane.

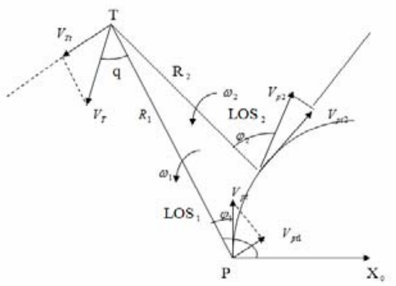

*Fig. 3: Determining the coordinates of the object in a simple kinematic method.*

Under certain values of the velocities $V_T$, $V_P$ and the angles q, $\varphi_1$ the value of the the angular velocity $\omega_1$ makes it possible to Find the distance to the object.

(1.7) $$R_1 = \frac{V_T \sin q + V_P \sin\varphi_1}{\omega_1}$$

But the speed of the object $V_T$ and the angle q are unknown. In this case, the plane P maneuvers in one direction or another depending on the line of sight $LOS_1$ .(Fig. 3) by altering the angular position of the line of sight and thus bearing of the object._Where objects take on a new significance $\varphi_2$. Obviously, this maneuver led to a change in angular velocity of the line of sight, if ignored the change of the course angle q during the maneuver is equal to:

(1.8) $$\omega_2 = \frac{V_T \sin q + V_P \sin\varphi_2}{R_2}$$

The difference in angular velocities $\omega_1$ and $\omega_2$ after the maneuver of the aircraft is determined by the relationship:

(1.9)

$$\Delta\omega = \omega_1 - \omega_2 = \frac{V_T \sin q + V_P \sin\varphi_1}{R_1} - \frac{V_T \sin q + V_P \sin\varphi_2}{R_2} =$$

$$= V_T \sin q\left(\frac{1}{R_1} - \frac{1}{R_2}\right) + \frac{V_P \sin\varphi_1}{R_1} - \frac{V_P \sin\varphi_2}{R_2}$$

With the change of the distance to the object during the measurement can be neglected. Therefore $R_1 = R_2$ which allows to simplify the expression (1.9):

(1.10) $\Delta\omega = \frac{1}{R_2}\left[V_P\left(\sin\varphi_1 - \sin\varphi_2\right)\right]_2$ or

(1.11) $\Delta\omega = \Delta V_{Pt}/R_2$

The magnitude $\Delta V_{Pt} = V_{Pt1} - V_{Pt2}$ characterizes the change of the relative tangent velocity of the object which is determined by the maneuver of the aircraft P. It aircraft. The increase of the angular velocity $\Delta\omega$ is under continuous survey of the angular coordinates of the object by calculating the angular velocities.

(1.12) $\Delta\omega = \omega_1 - \omega_2$

Distance to object $R_2$ is determined by the results of the measurements as the ratio increases $\Delta V_{Pt}$ - the tangential velocity of the aircraft to $\Delta\omega$ - the angular velocity of the line of sight.

(1.13) $R_2 = \Delta V_{Pt}/\Delta\omega$

The analysis of the exact distance to the object shows that the calculation of the distance formula (1.13)_leads to significant errors. For large distances to the object, the error in calculating the distance increases substantially. This is necessary to introduce additional filtration to the parameter distance using the Kalman filter i.e. it is necessary to move to a cinematic method to calculate the spatial coordinates. In this case, sequential amendments to the discrete values $\Delta V_{Pt}$ and $\Delta\omega$ can be performed using a filter assessing the distance of the object and as a result, significantly reduces the error of calculating R.

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