

Method and Device for Determining Target Parameters

The invention relates to a method for determining target parameters by directionally selective reception of sound waves of the type mentioned in the preamble of claim 1 and a corresponding device according to the preamble of claim 10.

For determining target parameters, especially for passive determination, sensors based on sonar technology are used for directionally selective reception of sound waves. Here a sensor is understood to mean a hydroacoustic receiving antenna, which is disposed on a carrier vehicle, e.g. a surface ship or a submarine.

In order to determine the range, course and speed of a target, e.g. of a surface ship, submarine or underwater running body, as target parameters, sound waves emitted or transmitted by the target are received with the sonar receiving antenna and the bearing angle to the target is measured. The target parameters of the target are estimated from time-successively measured bearing angles and the carrier vehicle's own positions corresponding to said bearing angles. Here it is assumed that the target is moving uniformly, i.e. with constant course and constant speed.

In DE 34 46 658 C2 e.g. a filter arrangement for determining target parameters is disclosed. The respective measured bearing angle is compared with the estimated bearing angles there and a bearing angle difference is formed. On achieving the minimum, the estimated bearing angle corresponds to the true bearing angle up to a residual error. Said residual error is dependent on a threshold that can be specified. Depending on the current scenario, the respective solution determined as the best solution, i.e. the

optimized solution, converges sooner or later with the actual correct solution.

DE 10 2008 030 053 A1 shows a method for passively
5 determining target parameters for which, in addition to the optimized solution, the reliability of said solution is indicated. For this purpose, during each processing cycle a plurality of different target tracks and a quality measure for each of said assumed target
10 tracks are calculated. A conclusion can be drawn regarding the reliability of the optimized solution from the distribution of the quality measure.

DE 101 29 726 C2 shows a method for determining target
15 parameters with which the received sound waves are subjected to a frequency analysis. The measured receiving frequency together with the measured bearing angle forms the basis of the target data estimation. Target positions and a transmission frequency emitted
20 or transmitted by the target are estimated. The estimated bearing angle associated with said target positions and the associated estimated receiving frequencies resulting from the estimated transmission frequency by a Doppler shift are determined. The
25 differences between the estimated and measured receiving frequencies are then used together with the bearing angle differences, which arise between the estimated and measured bearings, for determining the target parameters. This enables target parameter
30 determination without the carrier vehicle itself having to maneuver.

It follows that the invention is based on the problem of improving the method or the device for determining
35 target parameters.

The invention solves said problem by means of the features of a method for determining target parameters

according to claim 1 and by means of a device with the features of claim 10.

5 Following a target detection, a target position is estimated for each detected target and an estimated bearing angle to the target is determined. A bearing angle difference is then determined between the measured and estimated bearing angles.

10 At least one support value is determined from a set of possible support values by using a decision module and is used to carry out the further method. A support value is understood here as a value for a target parameter to be determined, from which it is assumed
15 that said value corresponds to the true value of the target parameter. A support value can also be a value from which at least one target parameter to be determined can be derived, such as e.g. a radial speed of the target, or other values of target parameters to
20 be determined depending on the waterborne vehicle or on its technical capabilities, such as target range, target course, target speed and/or target transmission frequency, can be derived.

25 A set of possible support values describes those support values that exist at the time of the actual process cycle. Here sources of support values can be various other sensor measurements, such as e.g. a radar measurement, an active measurement, a passive ranging
30 sonar (PRS) measurement and/or an intercept detection and ranging sonar (IDRS) measurement. However, the support values can also be derived from transmitted data, such as e.g. from an Automatic Identification System (AIS), from data via a link or from a torpedo,
35 wherein AIS refers to a radio system that improves the safety and steering of the shipping traffic by means of an exchange of navigation and other data and wherein the data originate via link from a networked operations

management system in which the platforms, sensors and effectors as well as management systems of armed forces are connected together in a common information technology network. Support values specified manually
5 by an operator, e.g. in the form of estimates of range, course or speed by the periscope operator, can be used for the method according to the invention.

It is also conceivable, depending on technical
10 capability, to determine the transmission frequency of a target, e.g. from classification results using a known type of ship, and to use the same as a possible support value for carrying out the method according to the invention.

15 Taking into account at least one of said support values, one or more target tracks are determined in a target track determination unit, each with associated target parameters and each with an associated
20 evaluation quantity, wherein the evaluation quantity is determined from the bearing angle difference associated with each target track and the support value or the support values.

25 An evaluation unit determines a best target track with associated target parameters using the evaluation quantity, wherein the associated target parameters are output as the target parameters to be determined.

30 By the use of support values during the determination of the evaluation quantities, a best target track is advantageously determined faster or if there is a plurality of evaluation quantities a more accurate statement indication of the reliability of the best
35 target track is enabled.

In a preferred embodiment of the invention, data relating to the possible support values are collected

by means of a data acquisition module. Said data specify which support values are available from a quantity of all support values. As described above, there are various sources for the provision of support
5 values. However, not all support values are always available. The quantity of possible support values comprises the currently available values from the quantity of theoretically possible values.

10 Said possible support values are also advantageously provided with data about their reliability. Thus e.g. a range value estimated by the operator using the periscope is less reliable than an additional range value based on a radar measurement that has been
15 carried out.

The data relating to the possible support values that are currently available are transmitted with the data relating to their reliability to a decision module.
20 This advantageously determines therefrom the support value(s) with respective associated weighting factor(s), which are taken into account during implementation of the method according to the invention.

25 In another preferred embodiment of the invention the evaluation quantity of a target track is calculated from the sum of the, especially advantageously weighted, squares of the differences for the assumed bearing angle along the target track and the associated
30 measured bearing angle taking into account at least one, especially advantageously weighted, support value. The evaluation quantity can then be given by the following formula for the exemplary assumption of the
35 use of a range support value:

$$Q(i, j) = \sum_{k=1}^n W_k^2 [B_{meas,k} - B_{est,k}]^2 + W_R^2 [R_{sup} - R_{est}]^2$$

Here $Q(i, j)$ refers to the evaluation quantity for an assumed target track $Z(i, j)$. The index k varies from 1
5 through n , wherein n is the number of the measured bearing angle $B_{\text{meas},k}$ or estimated bearing angle $B_{\text{est},k}$ along the target track. W_k refers to the weighting factors, which e.g. correspond to inverse standard deviations of the measured bearing angle $B_{\text{meas},k}$
10 determined during pre-filtering. R_{sup} refers to the range support value with associated time reference T and R_{est} refers to the target range assumed at time T . Those target tracks $Z(i, j)$ whose target ranges at time T lie close to the range support value R_{sup} thus achieve
15 a better evaluation quantity $Q(i, j)$.

The invention is, however, not limited to the use of a range support value. Rather, other support values can be converted according to previously mentioned formulas
20 by taking into account, during the calculation of the evaluation quantity, a term consisting of an, especially squared, weighting factor associated with the support value as well as an, especially squared, difference of the support value and the associated
25 estimated value.

Likewise the use of a plurality of support values for determining the target parameters is also possible. The previously mentioned formula for the evaluation
30 quantity is hereby expanded by a suitable number of terms, so that for each support value used a term consisting of weighting factors and the difference of the support value and the estimated value is taken into account.

35 According to another preferred embodiment of the invention the sound signals received and directionally selectively processed by the direction generator are

subjected to a frequency analysis, especially a Lofar analysis or a Demon analysis, wherein during the Demon analysis the signals are investigated for the presence of an amplitude modulation and during the Lofar analysis the signals are investigated for conspicuous frequencies. Here the frequency of at least one spectral line is determined as the receiving frequency for a respective bearing angle and together with the measured bearing angle forms the basis of the target parameter estimation. Here the measured frequencies of a plurality of spectral lines can also be combined and form measured values for the receiving frequency for each bearing angle.

A Doppler shift and a transmission frequency emitted or transmitted by the target are estimated from the estimated target position determined using the measured and estimated bearing angles and its change against time. The estimated transmission frequency is frequency shifted according to the estimated Doppler shift and forms the estimated Doppler frequency or the estimated receiving frequency from which the measured receiving frequency is derived. The estimated transmission frequency is, however, largely erroneous and hence also the estimated Doppler frequency. The true transmission frequency of the target can be determined from the difference of the measured receiving frequency and the estimated Doppler frequency, since if said difference is approximately zero the measured receiving frequency corresponds to the estimated Doppler frequency. The underlying transmission frequency approximately corresponds to the true transmission frequency and can be used for target position determination. The evaluation quantity is then determined for one or a plurality of target tracks from the bearing angle differences, the frequency differences and at least one support value, especially a support value of the transmission frequency of the target.

Taking into account the transmission frequency or the Doppler shift has the advantage that a target parameter determination can be carried out without the carrier vehicle itself having to maneuver. Another advantage is the possibility of using a support value for the transmission frequency of the target, because in this case the transmission frequency can be determined better as another target parameter by means of the method according to the invention.

In another preferred embodiment of the invention, during each processing cycle of a series of successive processing cycles, the evaluation quantity is iteratively minimized taking into account at least one support value of at least one target track. For this purpose, positions for the target are calculated and estimated bearing angles are determined therefrom starting from an initial position of the target, which is e.g. randomly selected as the starting position on a first locating beam or is known by other on-board sensors. The respective measured bearing angles are compared with the estimated bearing angles and a bearing angle difference is formed, which forms the evaluation quantity taking into account the support value, which evaluation quantity is iteratively minimized. The advantage is that on achieving the minimum the estimated bearing angle corresponds to the true bearing angle apart from a residual error. The residual error is advantageously dependent on a threshold value that can be specified. Taking into account at least one support value for iteratively minimizing the evaluation quantity leads advantageously to a faster convergence of the method.

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In another preferred embodiment of the invention a plurality of different target tracks are determined, wherein a first locating beam associated with a first

measured bearing angle as well as a last locating beam associated with a last measured bearing angle are determined. The assumed target tracks thus start on the first locating beam at a starting point and end on the last locating beam at an end point. The distances of the assumed starting points or end points from each other on the first or last locating beams advantageously determine the accuracy of the distribution of the evaluation quantity. The first and/or the last locating beams are preferably variable.

For each assumed target track an evaluation quantity is determined from the estimated bearing angles, the measured bearing angles and at least one support value. Using said evaluation quantity, a best target track can be advantageously determined, whose associated target parameters are output as the best solution. The best target track is thereby that target track whose evaluation quantity indicates a best quality or the best possible reliability.

Determining a plurality of different target tracks gives the advantage that from the distribution of the evaluation quantity conclusions are possible regarding the reliability of the best solution, wherein the distribution of the evaluation quantity is advantageously influenced by the support value(s).

According to another advantageous embodiment of the invention, only those target tracks are taken into account for determining the target parameters whose associated evaluation quantity has fallen below at least one predetermined threshold value. Only said target tracks are relevant as potential solutions. By the use of one or a plurality of support values when determining the evaluation quantity, the number of target tracks whose evaluation quantity has fallen

below the threshold value is advantageously limited further.

5 In another embodiment of the invention, during each processing cycle the target parameters of all or a plurality of the target tracks are graphically displayed on display device using one or a plurality of diagrams of quality information derived from the evaluation quantity relating to the target course
10 and/or the target speed and/or the target range. Such a display enables an accurate read-out of the target parameters for a selected quality indication. Especially by selecting a target parameter, all target parameters associated with said solution can be
15 displayed, whereby the operator can directly determine whether a solution is probable or not.

In another embodiment of the invention, during each processing cycle future target positions of the target
20 are determined for all or a plurality of the target tracks. Said future target positions are determined from the target parameters associated with the respective target track, especially target course and target speed, for a predetermined time period. The
25 advantage of said future target positions is that the operator is shown which possible solutions the hitherto available bearings allow and how reliable the best solution is. Taking into account at least one support value advantageously provides that the number of
30 possible permissible solutions is further limited.

A future expected area representing the future target positions, at least one range solution space for indicating the possible solutions for the target range
35 and/or the best target track are advantageously displayed graphically and/or numerically on a display device. The display is preferably carried out in the form of a positional display, especially a PPI display

(Plan Position Indicator display). This has the advantage that the target parameters to be determined with an optimized best solution can be graphically displayed directly in a single display together with
5 the associated evaluation quantity indicating a best quality, preferably in the usual position display, in order to facilitate the operator working with the sonar system.

10 Other advantageous embodiments of the invention arise from the dependent claims as well as from the exemplary embodiments described in detail using the accompanying figures. In the figures:

15 fig. 1 shows a schematic illustration of two locating beams, using which the bearing of a target has been located at two different points in time,

20 fig. 2 shows a scenario with a plurality of locating beams from a carrier vehicle to a target,

fig. 3 shows a schematic illustration of the speed components for illustrating the determination of a radial speed,

25 fig. 4 shows a schematic illustration of two locating beams, using which the bearing of a target has been taken at different points in time with a plurality of possible target tracks,

30 fig. 5 shows a block diagram for illustrating a method and a device for determining target parameters,

35 figs. 6 A-C show three two-dimensional diagrams for illustrating the quality against three target parameters and

fig. 7 shows a position illustration of the solution space shown in figs. 6 A-C.

On board a waterborne vehicle, especially a submarine,
5 there is a plurality of arrangements of waterborne acoustic sensors, especially electroacoustic and/or optoacoustic transducers. Such a transducer arrangement is disposed e.g. as a linear antenna on each side of the waterborne vehicle or as the base of a cylinder in
10 the bow of the waterborne vehicle. Another arrangement of waterborne acoustic sensors can be towed behind the waterborne vehicle as a towed antenna.

Receiver signals of such waterborne acoustic sensors
15 are combined to form group signals of juxtaposed directional characteristics using a direction generator within the sonar receiver system. For this purpose the receiver signals are summed to form group signals with a transition time delay and/or a phase delay according
20 to their disposition.

Depending on the time delay coefficients used, bearing angles are associated with the respective group signals, whose intensity values, especially levels, are
25 determined. The intensity profile resulting therefrom, especially the level profile, provides local maxima, which represent measured bearing angles to targets.

Such a sonar receiver system has an estimation filter
30 for determining target parameters from the measured bearing angles to the target, associated positions of the carrier vehicle itself and at least one support value. Here the bearing angles are measured from the carrier vehicle along its path of motion to the target
35 while the target is moving at constant speed on a target course from a first target position to a second target position. The path of motion of the carrier vehicle preferably consists here of one or a plurality

of so-called Eigen legs, wherein an Eigen leg refers to a section of unaccelerated linear motion, i.e. on which the carrier vehicle moves with approximately a constant course and constant speed.

5

Fig. 1 shows a schematic illustration of two locating beams 2, 4, using which a target bearing is located at two different points in time. A first locating beam 2 relates to a starting bearing location and another, especially last, locating beam 4 relates to a final bearing location carried out at a later point in time. Said locating beams 2, 4 are respectively the first or last locating beams used for determining the target parameters. They are determined automatically or manually by operator intervention.

With the assumption that the target range is unknown, the target can have been found in different positions 6 on the first locating beam 2 as well as likewise in different positions 8 on the last locating beam 4.

A possible target track $Z(i, j)$ is also entered, wherein index i refers to one of the possible positions 6 on the first locating beam 2 and index j refers to one of the possible positions 8 on the last locating beam 4.

Fig. 2 shows a schematic illustration of a possible scenario with a plurality of locating beams from a carrier vehicle to a target. Here the carrier vehicle is travelling with an observing sonar receiver system on its path of motion 10 and records n bearings to a target at various known positions $E_1, E_2, \dots, E_n$, while the target is moving on its target track $Z(i, j)$ from a first locating beam 2 via locating beams 11, 12, 13 etc. to the n th locating beam. In this exemplary embodiment the n th locating beam is specified as the last locating beam 4.

Assuming an orthogonal X-Y coordinate system whose origin is the known position E_0 at time $t_0 = 0$, an initial position of the target is determined either
5 randomly or from additional sensor measurements and is selected as the starting position X_0, Y_0 on the first locating beam 2.

Starting from said starting position of the target, a
10 target position is estimated for the respective measured bearing angle B_{meas} with the addition of estimated speed components V_x and V_y of the target and an associated estimated bearing angle B_{est} is calculated. A sum of weighted squares of bearing angle
15 differences is formed along said target track $Z(i, j)$ between the measured bearing angle B_{meas} and the estimated bearing angle B_{est} and is iteratively minimized. The best target track is determined if said
20 sum is zero or approximately zero, i.e. the associated estimated bearing angle B_{est} approximately corresponds to the true bearing angle B_{true} .

In order to support the iterative minimizing of the bearing angle differences, at least one support value
25 is taken into account when implementing the method so as to assist said method to a faster convergence. A support value is understood here to mean a value that is assumed as correct and which can be used for target position determination. E.g. an already known target
30 parameter, such as e.g. a target range at a specified point in time, a target speed, a target course or a target transmission frequency is specified as a support value. However, any other variable from which a component for target position determination can be
35 obtained can be used as a support value.

Sources for support values to be used are other on-board sensors for transmitting or receiving information

signals and/or measurement signals determined by the operator. However, because all theoretically possible support values are not always available, since e.g. the target is not detected by all sensors, data relating to possible support values are collected in a decision module. Thus it can be determined which support values are currently available.

The decision module selects at least one support value from the possible support values, which is taken into account for carrying out the method according to the invention. The selection is carried out here by means of predefined algorithms or manually by operator intervention.

Additionally the decision module provides the selected support value(s) with respective weighting factors, which correspond to the reliability of the respective support value and specify to what extent the support value is taken into account when implementing the method according to the invention.

For target parameter determination an evaluation quantity is determined for the assumed target track $Z(i, j)$ from the bearing angle difference between the estimated and measured bearing angles while taking into account at least one support value, e.g. a range support value R_{sup} :

$$\sum_{k=1}^n W_k^2 [B_{meas,k} - B_{est,k}]^2 + W_R^2 [R_{sup} - R_{est}]^2 = Q(i, j)$$

Here $Q(i, j)$ refers to the evaluation quantity for an assumed target track $Z(i, j)$. The index k runs from 1 through n , wherein n gives the number of the bearing angle along the target track. W_k refers to weighting factors, $B_{est,k}$ refers to the estimated bearing angle of the k th locating beam, which corresponds to the measured bearing angle $B_{meas,k}$. Furthermore, R_{sup} refers

to the range support value, R_{est} to the assumed range to the target and W_R to a weighting factor.

Fig. 3 shows e.g. a schematic illustration of the speed components V_x , V_y of the target in an X-Y coordinate system. The target has left its position P_0 here with speed V , wherein the speed V comprises the associated speed component V_x in the X direction and the associated speed component V_y in the Y direction. Knowing the bearing angle B , the speed components V_x and V_y of the target are converted into a radial speed component V_{rad} :

$$V_{rad} = V_x \cdot \sin B + V_y \cdot \cos B$$

If measurements for a bearing B and the associated radial speed V_{rad} of the target are available, e.g. by means of an active sonar system, then an estimate for V_{rad} can be determined from the estimated values of the speed components V_x and V_y using the above equation:

$$V_{rad,est} = V_{x,est} \cdot \sin B + V_{y,est} \cdot \cos B$$

When determining the evaluation quantity a support value for the radial speed can be taken into account as follows:

$$\sum_{k=1}^n W_k^2 [B_{meas,k} - B_{est,k}]^2 + W_{V_{rad}}^2 [V_{rad} - V_{rad,est}]^2 = Q(i, j)$$

Said evaluation quantity $Q(i, j)$ is iteratively reduced until it falls below a predefined error limit. The underlying estimated position is recognized as the target position and the associated target parameters are determined.

For the case where the reception signals of the sonar receiver system are subjected to a frequency analysis, e.g. a Lofar analysis or a Demon analysis, an estimated target transmission frequency can be included as a

support value during the target parameter determination.

5 A possible transmission frequency of the target is to be estimated as an initial value from a measured reception frequency and assuming a normal vehicle speed of a waterborne vehicle. A Doppler shift is determined using the estimated bearing angle B_{est} and the related speed components. Together with the assumed
10 transmission frequency of the target, an estimated Doppler frequency F_{est} and a frequency difference of the reception frequency F_{meas} and the estimated Doppler frequency F_{est} are given for each bearing angle.

15 For target parameter determination an evaluation quantity $Q(i, j)$ is determined for the assumed target track $Z(i, j)$ from the bearing angle difference between the estimated and measured bearing angles, the frequency difference and taking into account at least
20 one support value, e.g. a transmission frequency support value:

$$\sum_{k=1}^n \left[W_k^2 [B_{meas,k} - B_{est,k}]^2 + W_{F,k}^2 [F_{meas,k} - F_{est,k}]^2 \right] + W_F^2 (F_{sup} - F_{Sest})^2 = Q(i, j)$$

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A possible source of the transmission frequency support value F_{sup} is e.g. a classification result, with which the target was recognized under a certain type of ship and target specific frequency lines are associated with
30 the target.

Even in the case where the reception frequency or transmission frequency of the target is taken into account, the evaluation quantity $Q(i, j)$ is reduced
35 until it falls below an error limit. The underlying estimated position is recognized as a target position and the associated target parameters are determined.

Taking into account one or a plurality of support values leads to faster convergence of the method.

According to an alternative exemplary embodiment of the method according to the invention, a plurality of different target tracks are determined.

Fig. 4 shows a schematic illustration of a plurality of possible target tracks $Z(i, j)$. Two locating beams 2, 4, are illustrated, using which the bearing to the target has been located at two different points in time. For determining the target parameters a plurality of positions 6 on the first locating beam 2 and a plurality of positions 8 on the last locating beam 4 are selected. Said positions thus correspond to the initial or final positions of possible target tracks $Z(i, j)$, wherein index i refers to a position 6 on the first locating beam 2 and index j refers to a position 8 on the last locating beam 4.

Preferably, those target tracks $Z(i, j)$ that relate to impossible solutions are eliminated during the further course of the method. These can e.g. be target tracks whose solutions lead to positions on land or which would collide with other obstructions to shipping traffic. Those target tracks $Z(i, j)$ can also be excluded whose associated target parameters exceed a maximum value that can be specified.

For each target track $Z(i, j)$ of the remaining solution space, an evaluation quantity $Q(i, j)$ is determined as described above. Preferably, only those target tracks are taken into account whose associated variable has fallen below at least one predetermined threshold value, because only these could be considered as relevant solutions.

From said potential possible target tracks $Z(i, j)$, using the associated evaluation quantity $Q(i, j)$ a best target track Z_{best} is determined for which an evaluation quantity indicates maximum achievable quality. Taking
5 into account at least one support value ensures that the solutions in the vicinity of the support value are given larger weightings.

Fig. 5 shows a device according to the invention for
10 carrying out the method according to the invention for determining the target parameters. Using an arrangement of waterborne acoustic sensors 20, sound waves from a target are received and their reception signals are combined into group signals in a direction
15 generator 22 using transition time delays or phase delays. A measurement circuit 24 then determines measured bearing angle B_{meas} to a target.

Depending on the technical capabilities of the
20 waterborne vehicle, various sources of possible support values are conceivable. A support value for the range to the target can be determined in connection with an associated time reference, e.g. from a radar measurement, an active measurement, a periscope
25 measurement by means of an integrated laser rangefinder, a passive ranging sonar measurement, an intercept and ranging sonar measurement, reception data of the Auto Identification System, information transferred by link, available torpedo measurement in
30 active mode or torpedo estimation or a manual input by the periscope operator.

A support value for the speed can be obtained e.g. from
an estimate of the DEMON analysis, a passive ranging
35 sonar estimate, reception data of the Auto Identification System, information transferred by link, available torpedo measurement, radar estimate or a manual input by the periscope operator.

A support value for the course can e.g. be determined from a passive ranging estimate, reception data of the Auto Identification System, information transferred by link, torpedo estimates, radar estimates or a manual input as a position angle by the periscope operator.

The radial speed of the target as support value can be e.g. determined using an active sonar as a radial component of a Doppler measurement.

The transmission frequency as a support value can be e.g. derived from classification results.

The data relating to the possible support values 27 are recorded using a data acquisition module and passed to a decision module 28. Using data collected via the available sources, the detection module selects at least one support value 29, which is taken into account when carrying out the further process. The selection is carried out separately for each target depending on the detected targets. Furthermore, the decision module 28 determines for the support values 29 a respective associated weighting factor w , which takes into account the reliability of the support value 29.

The method according to the invention includes for one thing a calculation of the entire solution space by determining a plurality of target tracks $Z(i, j)$ with associated evaluation quantities $Q(i, j)$, and for another thing an iterative method for determining a best solution. Preferably, both procedures are carried out in parallel. It is, however, conceivable that only one of the previously mentioned approaches to carrying out the method is used in each case.

For implementing the iterative method, a least mean square method is preferably used (see e.g. DE 34 46 658 C2) that delivers the best solution in an iterative process. For this purpose an assumed initial position
5 X_0 , Y_0 of the target and an assumed target track $Z(i, j)$ are determined in a downstream target track determination unit 30 using the known positions X_E , Y_E . From the measured bearing angles B_{meas} , the estimated bearing angles B_{est} and the support value or support
10 values 29 obtained by the decision module 28, an evaluation quantity is determined for the assumed target track, which is transferred together with the target track to the evaluation unit. The associated evaluation quantity or a variable derived from the
15 evaluation quantity is then compared with a threshold value that can be specified.

If the value falls below said threshold value, said target track is defined as the best target track Z_{best}
20 and is transferred together with the target parameters and the evaluation quantity to a display unit 34.

If the evaluation quantity or a variable derived from the evaluation quantity does not fall below said
25 threshold value, however, for the purpose of iterative minimization of said evaluation quantity position components and/or speed components associated with said target track are adapted and transferred to the target track determination unit 30, which assumes another
30 target track based on the changed position components and/or speed components. Taking into account support values 29 passed to the decision module 28, an associated evaluation quantity is determined and transferred to the evaluation unit 32. A new comparison
35 with the threshold value is carried out in the evaluation unit 32.

The process described above of the iterative minimizing of the evaluation quantity or of a variable derived from the evaluation quantity is repeated until the value falls below the threshold value that can be specified and the associated target track is transferred as the best target track Z_{best} to the display unit 34.

10 For the case in which the entire solution space is calculated, the target track determination unit 30 determines a plurality of target tracks $Z(i, j)$. An associated evaluation quantity $Q(i, j)$ is determined for each target track $Z(i, j)$ from the measured bearing angles B_{meas} , the estimated bearing angles B_{est} and the support values 29 transferred from the decision module 28. The downstream evaluation unit 32 determines a best target track Z_{best} , which has an evaluation quantity indicating best quality, and passes said best target track Z_{best} to the display unit 34 with the associated target parameters together with a plurality of target tracks $Z(i, j)$, whose evaluation quantity $Q(i, j)$ or a variable derived from the evaluation quantity have fallen below a threshold value that can be specified.

25 The distribution of the evaluation quantities $Q(i, j)$ or the distribution of a variable derived from said evaluation quantities $Q(i, j)$ provides information about the reliability of the specified best solution.

30 It is optional for a frequency analysis to be provided for the previously mentioned embodiment of the method according to the invention. The reception signals 21 of the transducer assembly 20 are passed to a frequency analysis circuit 36 after the direction generator 22 for this purpose. Here a reception frequency F_{meas} is measured and an assumed Doppler frequency F_{est} for the bearing angle is determined from an estimated transmission frequency F_{sest} emitted or transmitted by

the target. The target track determination unit 30 determines from the available input data a frequency difference of the measured reception frequency F_{meas} and the assumed Doppler frequency F_{est} as well as a bearing angle difference between the measured bearing angles B_{meas} and the estimated bearing angles B_{est} . An evaluation quantity $Q(i, j)$ is then determined for each assumed target track $Z(i, j)$ from the frequency difference and the bearing angle difference, taking into account the support values 29.

The determination of the best target track Z_{best} takes place analogously to the previous embodiments, wherein however, not only the bearing angle difference are included during iterative minimizing taking account of the support values 29, but the frequency differences are also included.

The target parameters of the optimized solution are processed in a display unit 34 in order to output or display them numerically and/or visually on a display device 38. If the previously mentioned method does not produce a plurality of possible target tracks $Z(i, j)$, but only a best target track Z_{best} with associated target parameters, these are displayed as the target position on the display device 38.

If, however, a plurality of target tracks $Z(i, j)$ with associated evaluation quantities $Q(i, j)$ are determined, the possible target parameters of the entire solution space can be displayed. This enables the display of the target parameters to take place in various ways. The display is explained below using Figs. 6 A-C and Fig. 7.

For the illustration of a quality of the target parameters to be determined, preferably the above specified evaluation quantity $Q(i, j)$ is converted into

an inverse value that is also normalized to the range between 0 and 1, referred to in the following as a quality measure. Thus $Q(i, j)$ is replaced by $Q^*(i, j) = \min(Q) / Q(i, j)$ below.

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Figs. 6A-C show three diagrams, in which the quality measure $Q^*(i, j)$ is plotted against the target range (see Fig. 6A), against the target course (see Fig. 6B) and against the target speed (see Fig. 6C).

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The display of the quality measure Q^* can be improved by using suitable coloring. For this purpose e.g. symbols for values of the quality measure Q^* greater than an upper value 40 are shown in a first color, symbols for values of the quality measure Q^* below a second value 44 in a second color and symbols for values in an intermediate value range 42 in a third color. The number of value ranges 40, 42, 44 is, however, not limited to three. Rather, any number of value ranges, each with a different associated color, is also possible.

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Figs. 6A-C show exemplary diagram representations of the solution spaces of the respective target parameter to be determined. In this case for the determination of the target parameters a speed support value V_{sup} was taken into account. This results in a very narrow solution space for the speed (see Fig. 6C).

25

The diagram in Fig. 6A shows with the two illustrated bell curves two potential solution areas for the target range and Fig. 6B shows an incoming course and an outgoing course, wherein both solutions are apparently approximately the same. Such an arrangement is e.g. possible if the carrier vehicle has a starting position angle of approx. 0 degrees to the target.

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Fig. 7 shows an alternative illustration of the solution space from Figs. 6A-C. The first locating beam 2 and the last locating beam 4 are plotted in a position representation, especially a PPI representation.

Using the target tracks $Z(i, j)$, a range solution space 46 for the locating beams 2,4 is determined by showing for each target track to be displayed a possible target position for an initial range on the first locating beam 2 and a possible target position for a final range on the last locating beam 4 with the respective associated quality measure $Q^*(i, j)$. Preferably, the range solution space 46 comprises an inner region in a first color, which indicates a high quality, an outer region in a second color, which indicates a low quality and a region in the center indicating a medium quality.

Furthermore, a future target position of the target is determined for the target tracks $Z(i, j)$, wherein the future target position is determined from the target parameters associated with the respective target track for a predetermined time period. Said future target positions are displayed with the associated quality indication $Q^*(i, j)$ as the future expected region 48 in the solution space.

Fig. 7 shows the presence of a potential reciprocal course situation, especially for a starting position angle of the carrier vehicle of approx. 0 degrees to the target. In this case the arrowheads of an associated course/speed vector are shown in the position illustration for all target tracks $Z(i, j)$ whose quality measures $Q^*(i, j)$ have exceeded a specified threshold, e.g. $Q^*(i, j) > 0.8$. Many incoming and outgoing solutions can be seen in Fig. 7. The best target track Z_{best} and a possible best reciprocal course solution Z_{gegen} are each also shown in vector form.

Taking into account a speed support value V_{sup} provides a relatively narrow solution space for the speed. The incoming and outgoing solutions in the illustration according to Fig. 7 are therefore well separated. The different starting points 50 of the incoming and outgoing solutions correspond to the two bell curves of the range solution diagram of Fig. 6A.

10 All features mentioned in the previously mentioned figure description, in the claims and in the description introduction can be used both individually and also in any combination with each other. The disclosure of the invention is thus not limited to the described or claimed combinations of features. Rather,
15 all combinations of features are to be considered as having been disclosed.

Claims

1. A method for determining target parameters by directionally selective reception of sound waves,
5 which are emitted or transmitted by a target, with an arrangement (20) of waterborne acoustic sensors of a sonar receiver system, from estimated bearing angles (B_{est}), which are determined from estimated positions of the target, and bearing angles (B_{meas})
10 measured by the arrangement (20), wherein a bearing angle difference is determined between the measured bearing angles (B_{meas}) and the estimated bearing angles (B_{est}),
characterized in that
15 at least one support value (29) is determined from a set of possible support values (27),
one or a plurality of target tracks ($Z(i, j)$) are determined with respective associated target parameters and a respective associated evaluation
20 quantity ($Q(i, j)$), wherein the evaluation quantity ($Q(i, j)$) is determined from the bearing angle difference associated with the respective target track and the support value (29) or the support values (29),
25 a best target track (Z_{best}) is determined with associated target parameters using the associated evaluation quantity, wherein the associated target parameters are output as the target parameters to be determined,
30 a plurality of different target tracks ($Z(i, j)$) are determined, wherein a first locating beam (2) associated with a first measured bearing angle and a last locating beam (4) associated with a last measured bearing angle are determined and each
35 assumed target track starts on the first locating beam (2) at a starting point (6) and ends on the last locating beam (4) at an end point (8), the evaluation quantity ($Q(i, j)$) is determined taking

into account at least one support value (29) for each target track and a best target track (Z_{best}) giving the best solution is determined using said evaluation quantities ($Q(i, j)$) and its associated target parameters are output as the best solution, and

during each processing cycle the target parameters of all or a plurality of the target tracks ($Z(i, j)$) are graphically displayed against the target course and/or against the target speed and/or against the target range on a display device (38) by means of one or more diagrams of a quality measure ($Q^*(i, j)$) arising from the evaluation quantity ($Q(i, j)$).

2. The method according to claim 1, characterized in that data relating to possible support values (27) are collected that specify which support values are available from a quantity of all support values, data relating to the reliability of the possible support values (27) are collected, the data regarding the possible support values (27) are transferred with the data relating to their reliability to a decision module (28), which determines therefrom the support value(s) (29) with respective associated weighting factors that are taken into account during implementation of the method.

3. The method according to claim 1 or 2, characterized in that the evaluation quantity ($Q(i, j)$) of a target track ($Z(i, j)$) is calculated from the sum of the, especially weighted, squares of differences of the estimated bearing angles (B_{est}) and the associated measured bearing angles (B_{meas}) along the target

track ($Z(i, j)$) while taking into account at least one, especially weighted, support value (29).

4. The method according to any one of the preceding
5 claims,
characterized in that
reception signals (21) of the arrangement are
subjected to a frequency analysis, especially a
Lofar analysis or a Demon analysis, and the
10 frequency of at least one spectral line is
determined as the reception frequency (F_{meas}) for
each bearing angle,
a frequency difference of the reception frequency
(F_{meas}) and an estimated Doppler frequency (F_{est}) is
15 determined for each bearing angle, wherein the
estimated Doppler frequency (F_{est}) is determined
from an estimated transmission frequency (F_{sest})
emitted by the target and a Doppler shift and
the evaluation quantity ($Q(i, j)$) is determined
20 from the bearing angle difference, the frequency
differences and at least one support value (29),
especially a frequency support value (F_{sup}), for one
or a plurality of target tracks ($Z(i, j)$).
- 25 5. The method according to any one of the preceding
claims,
characterized in that
during each processing cycle of a series of
successive processing cycles the evaluation
30 quantity ($Q(i, j)$) or a variable derived from the
evaluation quantity is iteratively minimized while
taking into account at least one support value
(29), and on reaching the minimum the target track
(Z_{best}) associated with the minimum evaluation
35 quantity provides the target parameters of the best
solution.

6. The method according to claim 1,
characterized in that
for determining the target parameters only those
target tracks ($Z(i, j)$) are taken into account
5 whose associated evaluation quantity ($Q(i, j)$) has
fallen below at least one predetermined threshold
value.
- 10 7. The method according to any of claims 1 to 6,
characterized in that
during each processing cycle future target
positions of the target are determined for all or a
plurality of the target tracks ($Z(i, j)$) and a
15 solution space containing the possible target
parameters, which comprises a future expected area
(48) representing the future target positions, at
least one range solution space (46) for indicating
the possible solutions for the target range and/or
20 the best target track (Z_{best}), is displayed
graphically and/or numerically on a display device
(38).
- 25 8. A device for determining target parameters by
directionally selective reception of sound waves,
which are emitted or transmitted by a target, with
an arrangement (20) of waterborne acoustic sensors
of a sonar receiver system, wherein the device is
designed so as to determine estimated bearing
30 angles (B_{est}) from estimated positions of the target
and bearing angles (B_{meas}) measured by means of the
arrangement (20), and wherein a bearing angle
difference between measured bearing angles (B_{meas})
and estimated bearing angles (B_{est}) can be
35 determined,
characterized by
a decision module (28) that is designed so as to
determine at least one support value (29) from a

set of possible support values (27), a target track determination unit (30) that is designed to determine one or a plurality of target tracks ($Z(i, j)$) with respective associated target parameters and a respective associated evaluation quantity ($Q(i, j)$), wherein the evaluation quantity ($Q(i, j)$) can be determined from the bearing angle difference associated with each target track and the support value (29) or the support values (29),
5 an evaluation unit (32) that is designed so as to determine a best target track (Z_{best}) with associated target parameters using the associated evaluation quantity, wherein the associated target parameters can be specified as the target parameters to be determined,
10 a design of the target track determination unit (30) such that a plurality of different target tracks ($Z(i, j)$) can be determined, wherein a first locating beam (2) associated with a first measured bearing angle and a last locating beam (4) associated with a last measured bearing angle can be specified and each assumed target track can be displayed such that it starts on the first locating beam (2) at a starting point (6) and ends on the
20 last locating beam (4) at an end point (8),
and that the evaluation quantity ($Q(i, j)$) can be determined while taking into account at least one support value (29) for each target track and a best target track (Z_{best}) giving the best solution can be determined using said evaluation quantity ($Q(i, j)$), wherein its associated target parameters can be displayed as the best solution, and
25 a display unit (34) that is designed so as to graphically display on a display device (38),
30 during each processing cycle, the target parameters of all or a plurality of the target tracks ($Z(i, j)$) using a plurality of diagrams of a quality measure ($Q^*(i, j)$) arising from the evaluation

quantity ($Q(i, j)$) against the target course
and/or against the target speed and/or the target
range, and/or
to determine future target positions of the target
5 for all or a plurality of target tracks ($Z(i, j)$)
and to graphically and/or numerically display on a
display device (38) a solution space containing the
possible target parameters, which comprises an
expected area (48) representing the future target
10 positions, at least one range solution space (46)
for indicating the possible solutions for the
target range and/or the best target track (Z_{best}).

9. The device according to claim 8,
15 characterized by
a data acquisition module that is designed so as to
record data of possible support values (27),
wherein the data comprise indications as to which
support values are available from a quantity of all
20 support values,
a data acquisition of reliabilities of the possible
support values (27),
another design of the decision module (28) so as to
evaluate the data relating to the possible support
25 values (27) with the data relating to their
reliability so as to determine the support value(s)
(29) with (a) respective associated weighting
factor(s).

30 10. The device according to any of claims 8 to 9,
characterized by
a frequency analysis circuit (36) that is designed
to subject the reception signals (21) of the
arrangement to a frequency analysis, especially a
35 Lofar analysis or a Demon analysis, wherein the
frequency of at least one spectral line can be
determined as the reception frequency (F_{meas}) for at
least one bearing angle,

a design of the target track determination unit (30) such that a frequency difference of the reception frequency (F_{meas}) and an estimated Doppler frequency (F_{est}) for each bearing angle can be determined, wherein the estimated Doppler frequency (F_{est}) can be determined from an estimated transmission frequency (F_{sest}) emitted by the target and a Doppler shift, as well as by the evaluation quantity ($Q(i, j)$) being able to be determined for one or a plurality of target tracks ($Z(i, j)$) from the bearing angle difference, the frequency differences and at least one support value (29), especially a frequency support value (F_{sup}).

11. The device according to any of claims 8 to 10, characterized by a design of the target track determination unit (30) such that during each processing cycle of a series of successive processing cycles the evaluation quantity ($Q(i, j)$), or a variable derived from the evaluation quantity, can be iteratively minimized taking into account at least one support value (29) and on reaching the minimum the target parameters of the best solution, which is associated with the minimum evaluation quantity, can be delivered.