

DESCRIPTION

Title of the invention: Method for improving the time coverage of a beamforming sonar

Technical field

[0001] The invention relates to a method for improving the time coverage of a beamforming sonar, as well as to a system capable of implementing the method. The invention is particularly, but not exclusively, suitable for sonars mounted in autonomous drones, in the context of mine warfare.

[0002] Underwater imaging systems mostly use synthetic antenna (or "synthetic aperture") processing in order to benefit from high longitudinal resolution. The antenna is fixed to a lateral face of a sonar 1 (for example an underwater drone; cf. Figure 1). Given that the sonar 1 (more precisely the carrier of the sonar) moves in a longitudinal direction of movement 2, the same point is illuminated several times (swath 3), this allowing a series of data to be obtained for each point under the sonar. By combining the variation in amplitude and in phase of these returns, the synthetic antenna processing makes it possible to obtain images of the observed zones as if a large antenna with very high resolution were used.

[0003] The time coverage may be defined as being the area covered by the sonar over a given time. Figure 2 illustrates an area 4 (a seabed) covered by a sonar 1. The path of the sonar is segmented into a plurality of predetermined corridors 5 (or tracks), in order to map the entire area 4.

[0004] A drawback of synthetic antenna processing is that it imposes a physical limit on the forward movement of the carrier. Specifically, for an antenna of length L, the carrier cannot move more than L/2 between two pings (sonar pulses). The following demonstrates that the time coverage depends almost exclusively on the length of the physical antenna, for synthetic antenna processing.

[0005] Typically, and as illustrated in Figure 3, for an SAS (Synthetic Aperture Antenna) sonar 1 having two sides, that is to say illuminating both sides of the longitudinal direction of movement, with overlapping of the coverage gap under the sonar, the ACR (Area Coverage Rate) time coverage equals:

[0006] $ACR = (3P - A - m) \cdot V / 2$

[0007] A corresponds to the altitude of the sonar; P corresponds to the range of the sonar; m corresponds to the overlap margin for taking account of positioning errors; V corresponds to the forward speed of the carrier.

[0008] SAS processing imposes a limit on the forward speed of the carrier. As a first approximation, it may be considered that this speed equals:

$$[0009] V_{\max \text{SAS}} = L / (2 \cdot \text{Tr})$$

[0010] L corresponds to the length of the receiving antenna; Tr corresponds to the inter-ping time, related to the range P by the following relationship: $P = c \cdot \text{Tr} / 2$ (and c, speed of sound in water).

[0011] The time coverage is written as follows:

$$[0012] \quad ACR = \left(3 \cdot \frac{c \cdot \text{Tr}}{2} - A - m \right) \frac{L}{4 \cdot \text{Tr}}$$

[0013] Ignoring the margin, as well as the altitude (very grazing and/or long range case), gives the following:

$$[0014] \quad ACR = \frac{3 \cdot c \cdot L}{8}$$

[0015] This simplified formula shows that the time coverage, in the case of conventional synthetic antenna processing, is exclusively dependent on the length of the physical receiving antenna. Without modifying the sonar, it is therefore not possible to increase the time coverage (or very marginally).

[0016] Several solutions exist for increasing the time coverage.

[0017] A first solution consists in increasing the number of carriers in order to mechanically increase the time coverage, but this comes with a proportional increase in the cost of the solution. Moreover, this solution requires handling a substantial number of sonars, as well as complex management of interference between sonars.

[0018] A second solution consists in applying so-called "Fast SAS" processing, such as those described in [1] or [2]. This algorithm is also called "under-sampled SAS data" or else "sparse SAS data". It consists in increasing the speed of movement of the sonar beyond the limit speed $V_{\max \text{SAS}}$; the synthetic antenna becomes under-sampled, causing the appearance of grating lobes which degrade the quality of the image. The "Fast SAS" algorithms therefore aim to reduce these grating lobes. However, in the solutions of the prior art, the reduction in the grating lobes is not sufficiently effective.

[0019] Thus, no software solution is working correctly. Only hardware solutions would make it possible to solve the problem related to exceeding the limit speed $V_{\max SAS}$. However, these solutions are not compatible with existing sonars, are expensive and are bulky. Their compatibility with underwater drones having a small carrying volume is very doubtful.

[0020] Thus, there is a need to provide a method for improving the time coverage of a beamforming sonar, which does not require any hardware being arranged on existing sonars, and which overcomes the physical limit of the forward speed of the carrier.

Summary of the invention

[0021] One object of the invention is therefore a method for improving the time coverage of a beamforming sonar configured to be mounted on a carrier in an area to be imaged in order to characterize at least one target, the method comprising the steps of:

- providing imaging, by coherent synthetic antenna aperture processing, of a seabed of the area, along a lateral line of sight which is substantially perpendicular to the direction of movement of the carrier;
- providing an early assessment of the seabed, along a line of sight that is off-boresight with respect to the lateral line of sight;
- selecting a command from among:
 - reducing the speed of the carrier below a threshold value that is specific to the coherent synthetic antenna aperture processing, on the basis of the early assessment of the seabed, in order to maintain the coherent synthetic antenna aperture processing, or
 - switching from the coherent processing to antenna processing that is insensitive to the speed of the carrier, without reducing the speed below the threshold value that is specific to the coherent synthetic antenna aperture processing.

[0022] Advantageously, the antenna processing that is insensitive to the speed of the carrier comprises so-called incoherent processing, the incoherent processing comprising:

- estimation of the movement of the carrier by a positioning module;

- compensation for each reconstructed image on the basis of the movement of the carrier, so as to obtain compensated images;
- summation in amplitude of the compensated images.

[0023] Advantageously, the switching from the coherent processing to incoherent processing is determined by a correlation coefficient dropping below a threshold value, the correlation coefficient being obtained by the correlation of the antenna signals from one ping to the other.

[0024] Advantageously, the provision of an early assessment of the seabed comprises the steps of:

- acquiring measurements along the line of sight that is off-boresight with respect to the lateral line of sight, so as to obtain a so-called off-boresight image;
- detecting the target in the off-boresight image;
- classifying the target according to at least one classification criterion, in order to determine whether the target is an object of interest;

and wherein, if the classification is considered to be of good quality, the coherent processing switches to the antenna processing that is insensitive to the speed of the carrier, and if the classification is considered to be of poor quality, the speed of the carrier is reduced below the threshold value that is specific to the coherent synthetic antenna aperture processing.

[0025] Advantageously, the classification of the object comprises assigning a quality score, the quality score being calculated by the product of a first probability and of a second probability, the first probability being specific to the algorithm used for the classification, the second probability depending on the resolution of the off-boresight image and on the dimensions of the target.

[0026] Advantageously, the method comprises calculating a merger of quality scores, for a plurality of targets detected during the early assessment of the seabed, the command being selected on the basis of the result of the merger.

[0027] Advantageously, the antenna processing that is insensitive to the speed of the carrier is executed with the proviso that the early assessment of the seabed determines that a target is located at a distance of less than the resolution of the coherent synthetic antenna aperture processing.

[0028] Advantageously, the antenna processing that is insensitive to the speed of the carrier is executed if the early assessment of the seabed comprises the detection of a target which has already been imaged by coherent synthetic antenna aperture processing in a track distinct from the current track in which the carrier is located.

[0029] Advantageously, the method comprises the steps of:

- receiving a mission plan defining at least a first track and a second track to be taken by the carrier;
- the early assessment comprising determining the distance between the sonar and the target;
- the command being executed in the first track on the basis of the distance between the sonar and the target in the first track and in the second track.

[0030] The invention also relates to a system configured to improve the time coverage of a beamforming sonar configured to be mounted on a carrier in an area to be imaged in order to characterize at least one target, the system comprising:

- a device for imaging, by coherent synthetic antenna aperture processing, a seabed of the area, along a lateral line of sight which is substantially perpendicular to the direction of movement of the carrier;
- a device for early assessment of the seabed, along a line of sight that is off-boresight with respect to the lateral line of sight;
- a device for selecting a command from among:

- reducing the speed of the carrier below a threshold value that is specific to the coherent synthetic antenna aperture processing, on the basis of the early assessment of the seabed, in order to maintain the coherent synthetic antenna aperture processing, or

- switching from the coherent processing to antenna processing that is insensitive to the speed of the carrier, without reducing the speed below the threshold value that is specific to the coherent synthetic antenna aperture processing.

Description of the figures

[0031] Other features, details and advantages of the invention will become apparent on reading the description provided with reference to the appended drawings, which are given by way of example.

[0032] Figure 1, already described, illustrates the movement and the swath of a synthetic antenna aperture sonar.

[0033] Figure 2, already described, illustrates the trajectory of a synthetic antenna aperture sonar in a predetermined area.

[0034] Figure 3, already described, illustrates a geometric representation of the range and the altitude of the sonar.

[0035] Figure 4 illustrates the lateral line of sight and the off-boresight line of sight of the sonar.

[0036] Figure 5 illustrates various embodiments for providing an early assessment of the seabed.

[0037] Figure 6 illustrates the system according to the invention.

[0038] Figure 7 illustrates an embodiment for classifying the target.

[0039] Figures 8 to 11 illustrate various embodiments for implementing antenna processing that is insensitive to the speed of the carrier.

[0040] In Figure 4, a lateral synthetic antenna sonar 1 is mounted on an underwater carrier. In addition to its conventional lateral SAS imaging capability 6, the sonar is capable of providing a forward or "early" view 7 of the seabed that will be seen later by the lateral imaging. Thus, the sonar is capable of providing imaging, by coherent synthetic antenna aperture processing, of a seabed of the area, along a lateral line of sight 8 which is substantially perpendicular to the direction of movement 10 of the carrier 1. In addition, it can provide an early assessment of the seabed, along a line of sight 9 that is off-boresight with respect to the lateral line of sight.

[0041] In Figure 4, the sonar is of the "single-side" type (the antenna is located only on one side of the carrier); preferably, the sonar may be of the "two-side" type (one antenna on each side of the carrier), this making it possible to increase the time coverage of the area.

[0042] On the basis of the result of the forward view 7, the method provides either a reduction in the speed of the carrier below the limit speed $V_{\max\text{SAS}}$ (characteristic of the coherent processing), this making it possible to maintain the coherent synthetic antenna aperture processing, or a switch from the coherent processing to antenna processing that is insensitive to the speed of the carrier, without reducing the speed below the limit speed $V_{\max\text{SAS}}$.

[0043] Thus, the method makes it possible to optimize the time coverage, by automatically adjusting the speed of the sonar.

[0044] As illustrated in Figure 5, the early assessment of the environment may be carried out using one or more forward-pointing sonar beams. A number of embodiments are possible for achieving this front view.

[0045] According to a first embodiment, illustrated in the left-hand part of Figure 5, a single transmitter 16 having an electronic off-boresight capability may be used. This embodiment has the advantage of being compatible with the electronic scanning sonars available on the market. As a variant, illustrated by the central part of Figure 5, the sonar comprises an additional transmitter 12 that is mechanically off-boresight in the forward direction (fixed off-boresight angle). According to another variant, illustrated by the right-hand part of Figure 5, a transmitter 13 having a very wide transmission area may be used. A first sub-sector 14 perpendicular to the direction of movement of the carrier is used for imaging by coherent processing, and a second sub-sector 15, directed toward the front of the carrier, is used for the early assessment of the seabed.

[0046] In Figure 4, the off-boresight angle, which corresponds to the angle between the lateral line of sight 8 and the off-boresight line of sight 9, may be adjustable. A large angle makes it possible to better anticipate detections and to have more reaction time. On the other hand, the image will be of lower quality. An angle of between 30° and 45° is a good compromise for good anticipation of detections and good image quality.

[0047] Figure 6 illustrates the system according to the invention. The system capable of implementing the method according to the invention comprises a beamforming sonar block 17, which comprises a "conventional" SAS beam-processing unit 18, and an imaging unit 19, which makes it possible to estimate the environment in front in real time.

[0048] The "conventional" SAS beam-processing unit 18 may be configured, for example, to carry out a mission of detecting and classifying targets of interest, in particular in the context of mine warfare.

[0049] The beamforming block 17 is capable of providing two solutions which are not or are not very sensitive to speed.

[0050] The first solution consists in carrying out so-called "natural" beam processing, which utilizes only the length of the physical antenna.

[0051] Natural processing is conventional beamforming. This forming is performed for each desired observation direction (i.e. for each beam) by summing the signals received by the sensors/hydrophones. The signals are previously delayed depending on their position in space in order to phase them before summation in the desired listening direction.

[0052] A second solution consists in applying so-called incoherent processing, for the "broadside" sector (substantially perpendicular to the line of movement) and/or for the sector seen in front.

[0053] A positioning module 21 estimates the movement of the carrier 1 for this purpose. Advantageously, the positioning module 21 may be an inertial unit. Inertial units are capable of providing measurements without depending on external sources, and with a high refresh rate.

[0054] The beamforming sonar block 17 compensates for each reconstructed image on the basis of the movement of the carrier, so as to obtain compensated images.

[0055] For the incoherent SAS processing, the images acquired by the sensor 23 are integrated in amplitude. These images must therefore be readjusted with a precision close to the resolution of the images (generally set by the frequency band). In order to estimate the movements allowing this readjustment, the beamforming block 17 may use the information extracted from the positioning module 21, as described in particular in [3]. Thus, the positioning module 21 is used to estimate the movements necessary for readjusting the incoherent processing.

[0056] The "incoherent SAS" processing is particularly advantageous because, in addition to its performance, it is almost native to the "conventional" SAS processing,

that is to say that it is sufficient to replace a sum of complex images (coherent SAS) with a sum of images in amplitude (incoherent SAS).

[0057] The switching from the coherent processing to incoherent processing may advantageously be determined by a correlation coefficient μ dropping below a threshold value, the correlation coefficient being obtained by the correlation of the antenna signals from one ping to the other. The correlation coefficient μ is therefore calculated by calculating the cross-correlation between a ping and the next ping. Specifically, when the speed of the carrier increases beyond the limit speed $V_{\max\text{SAS}}$, no sensor correlates with the other sensors any more, and the correlation coefficient μ decreases markedly. In this case, the images are summed in amplitude.

[0058] As a reminder, for coherent SAS processing, the images must be integrated (summed) in phase. This means that it is necessary to readjust the images extremely accurately with respect to each other. For example, for a sonar at 300 kHz, the wavelength equals 5 mm. In order to readjust the images in phase, it is necessary to compensate for the movement with a precision which is equal to a fraction of this wavelength, for example 0.5 mm ($1/10^{\text{th}}$ of the wavelength). This readjustment is performed by a ping-to-ping cross-correlation (or P2C2) method.

[0059] Thus, it is sufficient to rely on the correlation coefficient to switch from one mode to the other. Beamforming processing will automatically and systematically place itself in the best possible mode (coherent or incoherent). Thus, an imaging mode that is robust with respect to speed is advantageously created.

[0060] One example of an early assessment of the seabed is illustrated in Figure 7. Detection processing is then carried out on this "front" image 25. The objective of this detection processing may be, for example, to detect all the mine-sized objects 26. This detection may be carried out by artificial intelligence processing, or else by shadow detection processing, as illustrated by Figure 7. The dimensions of these shadows provide direct information about the width l and the height h of the object, this making it possible to then verify that these dimensions are compatible with the type of object that is being searched for.

[0061] The detections then pass into a classification stage, using algorithms of the ATR (Automatic Target Recognition) or AuDC (Automatic Detection and Classification) type, which are well known to the person skilled in the art. The classification stage,

implemented by the beamforming block 17, associates the classification (for example mine/non-mine) with the position of the detection, obtained by virtue of the positioning module 21, and the sonar beam boresight information calculated in the beamforming block 17.

[0062] The system according to the invention, illustrated by Figure 6, also comprises an autonomous decision-making block 20, which has, at its input, detection/classification information provided by the beamforming block 17, and mission plan and/or mission instruction information, provided by a command, control and communications system 22 (a so-called "C3" system). At its output, the autonomous decision-making block 20 provides the carrier with a speed setpoint, a time of application of the setpoint (to manage the acceleration/deceleration constraints of the vehicle), and a duration of application of the setpoint.

[0063] To simplify the description, two possible speed setpoints are defined:

- V_{high} : speed setpoint greater than the limit V_{maxSAS} imposed by the coherent SAS processing. The actual speed depends on the capabilities of the vehicle and on the limits imposed by the aperture of the lobe at transmission.
- V_{low} : speed setpoint lower than the limit V_{maxSAS} imposed by the coherent SAS processing.

[0064] According to one embodiment, the autonomous decision-making block 20 determines whether the classification is considered to be of "good" or "bad" quality. The "good" or "bad" character may advantageously be set on the basis of a quality score n_q which is calculated by the product of a first probability $P1$ and of a second probability $P2$. The first probability is specific to the algorithm used for the classification. Thus, the first probability $P1$ depends on the algorithm used for the classification (signal-to-noise contrast, complexity of the shape of the object, size of the object, statistical approach, etc.).

[0065] The second probability $P2$ depends on the resolution of the off-boresight image and on the dimensions of the target. Thus, a cylinder that is two meters long which would be seen from the broadside does not need a very fine resolution in order to be correctly classified. According to one embodiment, the second probability $P2$ may be based on the Johnson criteria, described in more detail in [4].

[0066] Thus, using the second probability P_2 in the calculation of the quality score n_q makes it possible to take into account the "physical" characteristics of the target, as seen in the early assessment of the seabed.

[0067] The quality score n_q may be compared to a threshold s_q :

- if $n_q > s_q$, then speed setpoint = V_{high}
- else, speed setpoint = V_{low}

[0068] When making a decision about the speed setpoint, the autonomous decision-making block 20 may also take into account the mission instructions coming from the C3 system 22.

[0069] In particular, the C3 system 22 may transmit, to the autonomous decision-making block 20, an instruction DirA to minimize the duration of the mission, at the cost of a greater risk (this possibly being useful in a well-known area, for example a bay of a harbor where it is certain that there are no mines), or an instruction DirB to minimize the risk, at the cost of a longer mission duration (this possibly being useful in a war zone).

[0070] Thus, two thresholds may be defined: a first threshold s_A associated with the instruction DirA, and a second threshold s_B associated with the instruction DirB, with the following condition: $s_A < s_B$.

[0071] The time coverage is therefore greater in the case of instruction DirA compared to instruction DirB.

[0072] Figures 8 to 11 illustrate various embodiments of the invention.

[0073] According to a first embodiment, illustrated by Figure 8, the antenna processing that is insensitive to the speed of the carrier is executed with the proviso that the early assessment of the seabed determines that a target is located at a distance of less than the resolution of the coherent synthetic antenna aperture processing.

[0074] Specifically, depending on the dimensioning of the sonar, it is possible for the resolution of the incoherent SAS processing, or of the natural SAS processing, to be equal to the resolution of the coherent SAS processing at the beginning of the range. This occurs when a single ping is used at the beginning of the range. On the seabed portion 27, which corresponds to a distance d_{1ping} between the sonar 1 and the seabed, the coherent SAS processing does not offer any gain in resolution. Thus, for any

detection which occurs at a distance of less than $d_{1\text{ping}}$, the speed setpoint may be the higher speed setpoint V_{high} , higher than the limit V_{maxSAS} .

[0075] According to another embodiment, illustrated by Figure 9, the antenna processing that is insensitive to the speed of the carrier is executed if the early assessment of the seabed comprises the detection of a target which has already been imaged by coherent synthetic antenna aperture processing in a track distinct from the current track in which the carrier is located.

[0076] Specifically, the path provided for the sonar, composed of tracks that are generally parallel to each other, provides overlaps between the tracks, in order to fill coverage gaps. Since the autonomous decision-making block 20 has knowledge of the mission plan via the C3 block 22, it is possible to utilize this plan in order to improve the time coverage.

[0077] Thus, the embodiment consists in not taking into account a detection that has already been processed during a previous track. In Figure 9, if the target 28 has already been observed on the track 1, it is not necessary to slow down during the track 2. Thus, even if it is established that a target 28 is located in the track 1, and requires coherent SAS processing, the autonomous decision-making block 20 may transmit a command to switch from the coherent processing to antenna processing that is insensitive to the speed of the carrier, without reducing the speed below the threshold value that is specific to the coherent synthetic antenna aperture processing.

[0078] Figure 10 illustrates another embodiment. Assuming that, with the early assessment of the seabed, the target 28 has been detected at the end of the range during a first pass (first track 29) with insufficient quality ($n_q < s_q$), it would therefore be necessary to slow down the vehicle (speed setpoint = V_{low}), in order to provide imaging by coherent SAS processing.

[0079] However, the autonomous decision-making block 20, which has the mission plan information transmitted by the C3 block 22, may determine that the target 28 will be reviewed at the beginning of the range during the following pass (2nd pass 30), and therefore that it will be faster to perform imaging by coherent SAS processing there. Thus, during the first pass, the autonomous decision-making block 20 may decide not to slow down, and to keep the speed setpoint at the maximum V_{high} , higher than the limit speed V_{maxSAS} .

[0080] Thus, receiving a mission plan defining at least two tracks, and determining the distance between the sonar and the target during the early assessment, makes it possible to increase the time coverage of the sonar.

[0081] Figure 11 illustrates another embodiment of the method according to the invention. In this figure, the targets 31-35 are detected and classified as being of good quality, and the target 36 is detected and classified as being of poor quality.

[0082] The method advantageously comprises calculating a merger of quality scores, for the plurality of targets detected during the early assessment of the seabed. The command (reduction in the speed or switch from the coherent processing to antenna processing that is insensitive to the speed of the carrier) is then selected on the basis of the result of the merger. The merger of scores thus corresponds to a risk associated with the group of targets seen in a time slot by the early assessment of the seabed.

[0083] This embodiment is more "risky" because it is not necessarily the lower speed setpoint V_{low} which prevails over the higher speed setpoint V_{high} . Nevertheless, the embodiment does make it possible to increase the time coverage.

[0084] With N detections (targets 31-36 in Figure 11), the overall quality is expressed by the following relationship:

[0085]
$$\sqrt[N]{\prod_{x \in [1, N]} n_q(x)}$$

[0086] $n_q(x)$ corresponds to the quality score n_q for the detection "x", which is calculated by the product of a first probability P1 and of a second probability P2, as described above.

[0087] The command selection is thus expressed as:

[0088] if
$$\sqrt[N]{\prod_{x \in [1, N]} n_q(x)} > s_\pi, \text{ then speed setpoint} = V_{high}$$

[0089] else, speed setpoint = V_{low}

[0090] s_π is a predefined threshold.

[0091] The above-mentioned embodiments may be combined in order to increase the time coverage of the sonar.

[0092] The method as described makes it possible to optimize the time coverage of an existing system by means of autonomous decision-making, while controlling the overall

performance. The method has the advantage that it does not require the development of a new, specific, expensive and complex sonar system.

References cited:

[0093][1] A Putney, "Reconstruction of Under-sampled SAS Data Using the WIPE Algorithm", OCEANS 2005

[0094][2] Shi YI, "A Method of SAS with Sparse Aperture Based on Compressive Sensing", IEEE 2020

[0095][3] Michael P. Hayes et al., Synthetic Aperture Sonar: A Review of Current Status

[0096][4] F. Langner et al., "Side Scan Sonar Image Resolution and Automatic Object Detection, Classification and Identification", OCEANS 2009-EUROPE

CLAIMS

1. Method for improving the time coverage of a beamforming sonar (1) configured to be mounted on a carrier in an area to be imaged in order to characterize at least one target, the method comprising the steps of:

- providing imaging, by coherent synthetic antenna aperture processing, of a seabed of the area, along a lateral line of sight (8) which is substantially perpendicular to the direction of movement (10) of the carrier;
- providing an early assessment of the seabed, along a line of sight (9) that is off-boresight with respect to the lateral line of sight (8);
- selecting a command from among:
 - reducing the speed of the carrier (24) below a threshold value ($V_{\max\text{SAS}}$) that is specific to the coherent synthetic antenna aperture processing, on the basis of the early assessment of the seabed, in order to maintain the coherent synthetic antenna aperture processing, or
 - switching from coherent processing to antenna processing that is insensitive to the speed of the carrier, without reducing the speed below the threshold value ($V_{\max\text{SAS}}$) that is specific to the coherent synthetic antenna aperture processing.

2. Method according to Claim 1, wherein the antenna processing that is insensitive to the speed of the carrier comprises so-called incoherent processing, the incoherent processing comprising:

- estimation of the movement of the carrier by a positioning module (21);
- compensation for each reconstructed image on the basis of the movement of the carrier (24), so as to obtain compensated images;
- summation in amplitude of the compensated images.

3. Method according to either of the preceding claims, wherein the switching from the coherent processing to incoherent processing is determined by a correlation coefficient dropping below a threshold value, the correlation coefficient being obtained by the correlation of the antenna signals from one ping to the other.

4. Method according to one of the preceding claims, wherein the provision of an early assessment of the seabed comprises the steps of:

- acquiring measurements along the line of sight (9) that is off-boresight with respect to the lateral line of sight, so as to obtain a so-called off-boresight image;
 - detecting the target in the off-boresight image;
 - classifying the target according to at least one classification criterion, in order to determine whether the target is an object of interest;
- and wherein, if the classification is considered to be of good quality, the coherent processing switches to the antenna processing that is insensitive to the speed of the carrier, and if the classification is considered to be of poor quality, the speed of the carrier is reduced below the threshold value that is specific to the coherent synthetic antenna aperture processing.

5. Method according to Claim 4, wherein the classification of the object comprises assigning a quality score (n_q), the quality score being calculated by the product of a first probability (P1) and of a second probability (P2), the first probability (P1) being specific to the algorithm used for the classification, the second probability (P2) depending on the resolution of the off-boresight image and on the dimensions of the target.

6. Method according to either of Claims 4 and 5, comprising calculating a merger of quality scores (n_q), for a plurality of targets (31-36) detected during the early assessment of the seabed, the command being selected on the basis of the result of the merger.

7. Method according to one of the preceding claims, wherein the antenna processing that is insensitive to the speed of the carrier is executed with the proviso that the early assessment of the seabed determines that a target is located at a distance of less than the resolution of the coherent synthetic antenna aperture processing ($d_{1\text{ping}}$).

8. Method according to one of the preceding claims, wherein the antenna processing that is insensitive to the speed of the carrier is executed if the early assessment of the seabed comprises the detection of a target which has already been imaged by coherent synthetic antenna aperture processing in a track distinct from the current track in which the carrier is located.

9. Method according to one of the preceding claims, comprising the steps of:

- receiving a mission plan defining at least a first track (R1) and a second track (R2) to be taken by the carrier;

- the early assessment comprising determining the distance between the sonar and the target;

the command being executed in the first track (R1) on the basis of the distance between the sonar and the target in the first track (R1) and in the second track (R2).

10. System configured to improve the time coverage of a beamforming sonar configured to be mounted on a carrier in an area to be imaged in order to characterize at least one target, the system comprising:

- a device (18) for imaging, by coherent synthetic antenna aperture processing, a seabed of the area, along a lateral line of sight which is substantially perpendicular to the direction of movement of the carrier;

- a device (19) for early assessment of the seabed, along a line of sight that is off-boresight with respect to the lateral line of sight;

- a device (20) for selecting a command from among:

- reducing the speed of the carrier below a threshold value that is specific to the coherent synthetic antenna aperture processing, on the basis of the early assessment of the seabed, in order to maintain the coherent synthetic antenna aperture processing, or

- switching from the coherent processing to antenna processing that is insensitive to the speed of the carrier, without reducing the speed below the threshold value that is specific to the coherent synthetic antenna aperture processing.