Low Frequency Towed Active Sonar (LFTAS) in Multistatic Applications

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Abstract: The performance potential of multistatic sonar operations has been investigated by several research institutes and proven in numerous international sea trials during the last years. The characteristics of multistatic sonar operation are the use of one or more spatially separated transmitters and receivers, the exchange of the contact or track information as well as the appropriate combination of all available data in order to optimize the detection performance.

In this context, the Low Frequency Towed Active Sonar (LFTAS) from ATLAS Elektronik is described, which is well suitable for multistatic operations because of its high detection ranges. Multistatic scenarios may be realised in numerous variations, e.g. two or more LFTAS-systems may work together or a submarine sonar system may act as an additional receiver.

Multistatic operation provides some well known advantages like enlarged detection areas and increased probability of detection. Submerged operating submarines even can use the active transmission of other cooperative or non-cooperative operating platforms to get information of the underwater situation.

The system configuration and some aspects of signal processing, communication and data fusion in multistatic operation are outlined.

1 Introduction

The characteristics of multistatic sonar operation are the use of one or more spatially separated transmitters and receivers, the exchange of contact or track data, and the appropriate fusion of all available data to achieve the optimal detection performance.

Multistatic operation may be realised in numerous variations, e.g. two or more low frequency active sonar systems may work together, a submarine sonar system may passively receive and analyse the acoustic transmissions of other platforms, dipping sonar and sonar buoys may be included, or a land based transmitter or receiver may be used. An artistic impression of a multistatic sonar scenario is shown in Figure 1.

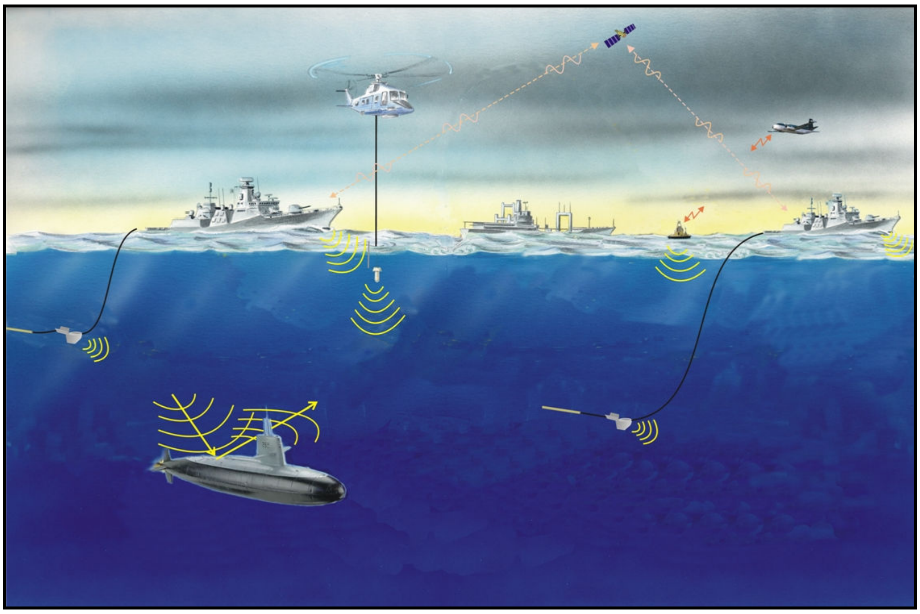

Figure 1: Artist impression of multistatic scenarios

One advantage of multistatic systems is the increased detection area compared to monostatic systems, e.g. a ship equipped with just a towed array, operating in the vicinity of a low frequency active transmitter is able to detect targets in its surrounding area even at large distances to the transmitter. The capability of the transmitter itself would not allow covering the corresponding area.

An important feature of multistatic systems compared to monostatic systems is the growth of detection opportunity due to diverse pulses of the engaged platforms. The chance that a target will be detected at all increases with the number of sonar systems involved because every system faces e.g. a different target strength, reverberation, and noise situation. This property of multistatic systems improves system track holding. Gaps in the detection sequence of one platform might be filled with detections of other platforms.

All bistatic systems have the added advantage that targets cannot choose an optimum course to reduce their target strength, since the targets usually cannot be aware of the receiving position of the bistatic system. A target not knowing the receiver position will not even recognise that it is detected. Sonar performance programs used by targets and for calculating counter detection ranges are useless in multistatic scenarios.

The multistatic systems presented in this paper are based on the use of low frequency towed array sonar systems, which are suitable for multistatic operation in particular due to their high detection range. This leads to an overlap of the detection areas of separated platforms and therefore enables the suitable fusion of detections for the multistatic operation.

In this paper surface ship based systems and submarine based systems are discussed. In this case surface ship based systems are build up by two or more Low Frequency Towed Active Sonar (LFTAS) which are equipped with a transmitter and / or a receiver. In submarine based systems, the submarine uses the sonar pulses emitted by other platforms, e.g. LFTAS, which prevents the submarine from transmitting active sonar pulses on its own.

2 „Low Frequency Towed Active Sonar“ (LFTAS)

The German LFTAS (Low Frequency Towed Active Sonar) is an active and passive operating sonar towed behind the ship. Because of the good sound propagation in the low frequency band, the capability to operate in an optimized depth, e.g. below acoustical layers, and the low self noise level far behind the ship, this system provides an excellent performance up to very long ranges. The wet-end of this system with its main parts

- towed body containing the active transmitter,
- tow cable, offering distance from ships and body induced noise and
- receiving twin array for reception

is displayed in Figure 2. Based on several trials and demonstrations during the 1990s, the German navy decided for the development of an active towed array sonar fitting into the frigate F123.

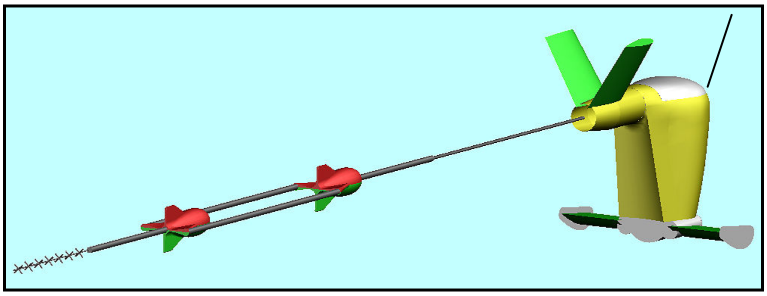

Figure 2: Wet-End of the LFTAS-System with the transmitter and the twin receiving array

3 Surface Ship based Systems

Surface ship based configurations are given by two or more surface ships which are equipped with transmitter and / or receiver. Figure 3 depicts the basic bistatic situation with two LFTAS platforms. In this case both systems are transmitting and receiving signals in monostatic and bistatic operation mode. This configuration can be expanded by further platforms. Alternative configurations are given if some of the involved platforms are equipped only with a transmitter or a receiver, e.g. a containerized transmitter or receiver might be installed on relatively small ships.

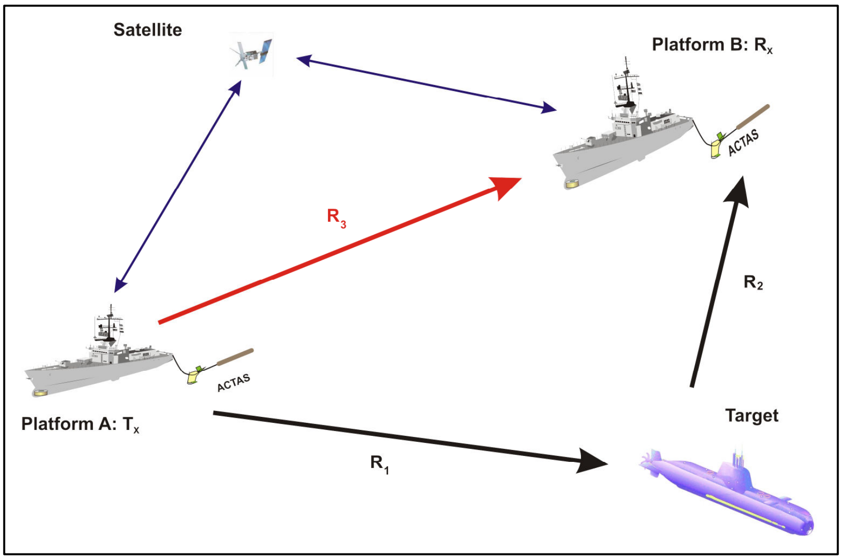

Figure 3: Multistatic scenario with two surface ships

In general, a configuration can consist of M transmitting and N receiving units. As it is not practicable to exchange the received raw data, the signal processing for detection of active echoes (contacts, alarms) of all transmitted pulses has to be done on each of the receiving platforms. This means that each receiving platform needs a separate active signal processing branch for each transmitter. Therefore, an exchange of all relevant information like

- the description of the transmitted pulses,
- the time of transmission and
- the geographic position, heading, and speed of the transmitters at the time of transmission

between the participating units is required.

One main advantage of a multistatic system over a monostatic one is, of course, the diversity of available sound sources and pulse forms. A target poorly illuminated by one active source may be detected due to its reflection of another platform's sounding. To draw the maximum profit from these advantages, it is necessary to combine all the information available from different sources, sensors, and signals into a unified general view of the underwater situation.

It is a tempting idea to do this data fusion at the lowest possible level, for example somewhere after the active preprocessing, using low level data of different processing branches or even different platforms to verify or deny contact suspicions at the very beginning. But the enormous computing and communication capacity necessary to work at this level forbid such an approach.

The data fusion can be achieved with a more reasonable computational and communication complexity, if done at contact or track level. We can separate three levels of data (contact or track) fusion:

1. Fusion of data detected on the basis of different pulses emitted by one platform as a pulse series.

2. Fusion of data extracted from signals received by the same sensor but transmitted by different sources.

3. Fusion of data independently identified by different platforms and exchanged over radio data links.

Due to the fact that systematic errors, e.g. because of an inaccurately known sound velocity or because of the imprecise heading sensor in the receiving array, seemed to be unavoidable in any case, we propose to do the contact fusion only for the first fusion level and to do a track fusion, which is rather robust to systematic measurement errors, for the second and third fusion level.

This means that the contacts detected on basis of different pulses emitted by one platform as a pulse series will be fused in the active signal processing. The fused contacts provide the input of a tracker. In this case each combination of transmitter and receiver uses its own separate tracking unit. Finally a track fusion will be used to achieve a common picture.

The basic architecture for data fusion is given in Figure 4. On the left hand side, the various transmitters are sketched. In the middle of the figure, the different acoustic reception and processing nodes are shown. Each of the nodes obtains its own tracker. On the right hand side, the fusion nodes are presented. If e.g. different assets are involved in an operation, more than one fusion node will be available. Each of the fusion units performs a track-to-track fusion taking account and compensating possible systematic errors of the platform tracks.

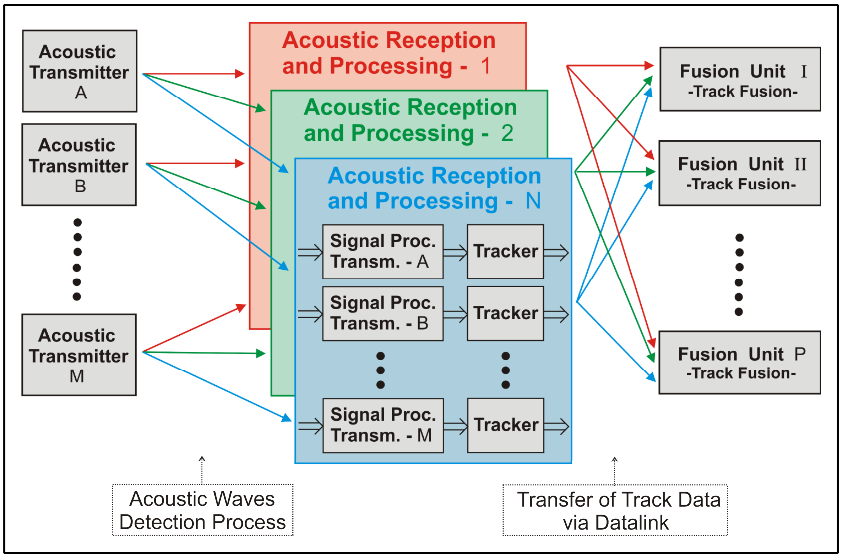

Figure 4: Signal Processing and Data Fusion Concept

4 Bi / Multistatic Operation with Submarines

In general, submarines wish to keep their presence a secret and therefore avoid emitting any noise as far as possible. As a rule, they make use of the sounds emitted by their targets to detect them. When the target noise level is very low, however, the target must be illuminated to achieve useful detection ranges.

However, in bi- or multistatic operation it is not necessary for the submarine itself to transmit sonar pulses in order to illuminate silent targets. If the sonar pulses emitted by other platforms illuminate the water volume adequately, these pulses can be used for detection, if the submarine is suitably equipped. The sonar pulse is thus emitted by a source (often very far away), reflected from the target and received by the submarine sonar (see Figure 5).

In this case, the detection probability and the quality of the target track data (bearing, range, course and speed) depend strongly on the submarine crew's knowledge of the transmitter parameters, such as pulse type and position. Two operational modes have to be distinguished.

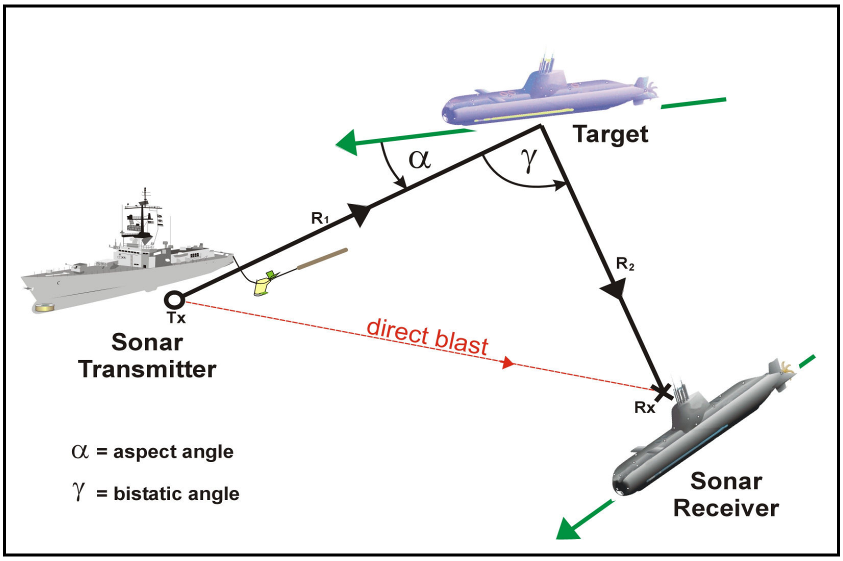

Figure 5: Principle of bistatic active detection

For operations with submarines, the so-called non-cooperative mode of operation is of special interest. In this case, the submarine and the transmitting platform work independent. The time of transmission and the pulse parameters are unknown and have to be estimated. To adapt the signal processing, the pulse parameters have to be determined from the direct blast. In most cases, its high signal-to-noise ratio (S/N) makes it possible to determine the pulse parameters of the incoming signal with sufficient accuracy. Various procedures can be applied to estimate the distance to the transmitter, but appreciable errors can be expected for this non-cooperative case which will lead to strong inaccuracy in the target distance. To overcome this problem, known fixed targets like wrecks or rocks on the sea floor can be tracked and by this, a sufficient accuracy for the distance to the transmitter can be achieved.

In the non-cooperative operation, it is of particular importance that the bistatic operation is successful even if the own submarine is outside of the detection range of the transmitting LFAS system. This is illustrated by the results shown in Figure 6, which are based on detection range calculations for a scenario consisting of a LFTAS system and a submarine. The position of the LFTAS is marked by the black cross and the position of the submarine by the red one. Only the LFAS-transmitter of the frigate illuminates the water volume with its sonar pulses; the frigate is therefore operating in the monostatic mode and the submarine in the bistatic mode. Assuming a standard propagation of the sonar pulses in seawater, the LFAS system has an active monostatic detection range against the submarine of approx. 50 km. This corresponds to the red and blue depicted areas in Figure 6. In this scenario, the submarine always remains outside the detection range of the frigate.

The detection areas of the submarine in bistatic mode, which are described by the green and blue areas, depend drastically on the distance between illuminator and receiver. A typical feature of bistatic detection is the elliptic shape of the detection area and the lack of detection on and near the line connecting the transmitter and receiver. It is especially interesting to see that the frigate illuminates its surroundings. This gives the submarine good chances to detect and localize platforms that may be escorted by the frigate.

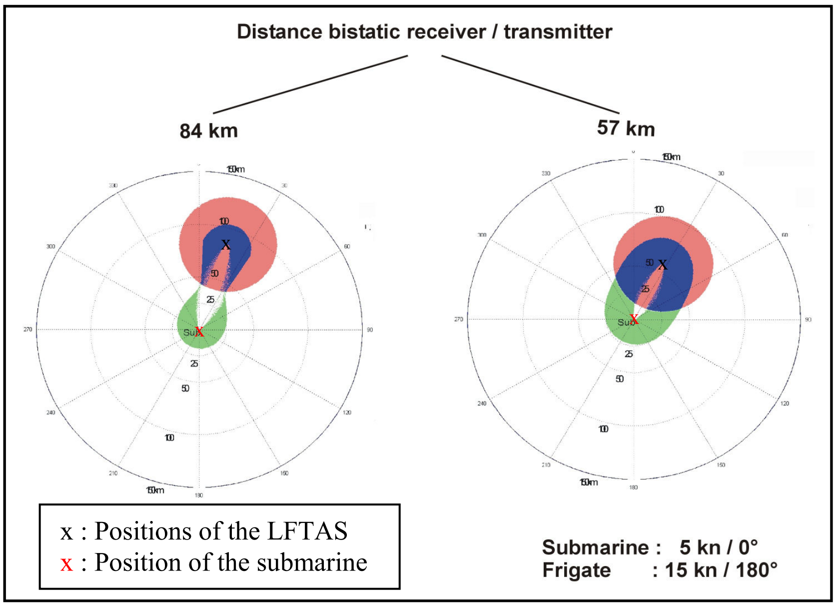

Figure 6: Monostatic (LFAS) and bistatic (submarine) detection ranges for 2 different distances

In the following it is shown for an assumed scenario using simulated bistatic data, how sonar operations can take place in a comparable manner to that of monostatic active detection with appropriate processing of the sonar data received in the bistatic mode. Figure 7 shows the “preprocessed Echos” in a PPI-display with a range setting of 64 km and a superimposed map.

Automatic trackers indicate the target tracks of moving targets and fixed targets. The tracks of target 1 (changing course) and target 2 (moving away) can be seen clearly. Even fixed targets (yellow dots) can be recognized. The illuminator is shown as a red track at 30°.

It can be seen that the quality of the data in bistatic mode is comparable to that of the conventional monostatic mode; at least as far as detection probability is concerned. As described above, a range uncertainty to the illuminator generally has no effect on the target detection, but rather on the localization accuracy.

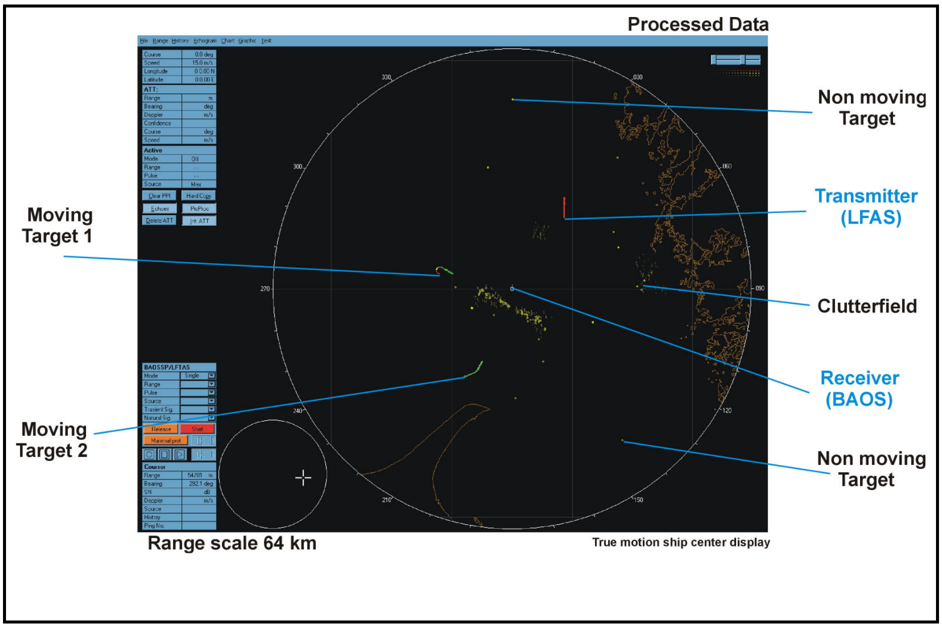

Figure 7: PPI-Display, Processed data presentation

5. Conclusions

Multistatic sonar systems provide several advantages in comparison to monostatic systems. To draw the maximum profit from these advantages, it is necessary to combine all the information available in an adequate way. A track fusion, which is rather robust to systematic measurement errors, seems to be a reasonable choice.

The increasing use of submerged low-frequency active-sonar systems increase the risk for a submarine of being detected, but at the same time enables an enhanced bistatic operating capability for the submarine.