Optimizing of target detection and tracking processes realized on consoles of passive sonar with linear towed antenna

Aleksandra RAGANOWICZ[1], Kamil SADOWSKI[2], Michał DOLOT[1], Lech KILIAN[1]

[1]Gdansk University of Technology
Faculty of Electronics, Telecommunications and Informatics
Narutowicza 11/12, 80-233 Gdańsk, Poland
ragola@eti.pg.gda.pl
[2]Combat Ship Squadron, 3rd Ship Flotilla in Gdynia
Rondo Bitwy pod Oliwą, 81-103 Gdynia, Poland
kamilsa@interia.pl

The long-range passive towed sonar was first modernised a few years ago. Building on operator experience over that period, a concept was developed of optimising the tasks performed by sonar operators, and improving forms of imaging to inform about object detection and support object tracking. The concept was implemented and successfully tested during ships' manoeuvres. The optimisation of operator tasks was designed to keep listening for signals from an object separate from object tracking. Operator tasks have been made easier by rearranging the imaging, improving interaction between monitors, extending the navigation imagery module, adding new tools for building an acoustic database of potential targets; and improving the recording, browsing and playback of key recorded data. The article gives a more detailed account of the project and its results.

Keywords: passive ASW sonar, imaging, detection, tracking

1. Introduction

Transferred from the US Navy to the Polish Navy, two Oliver Hazard Perry frigates are equipped with passive sonars. Long linear antennas of sonars are towed with sophisticated winches. Both underwent a major overhaul and modernization a few years ago [1],[2],[3],[4],[5],[6], carried out by the staff of the Department of Marine Electronic Systems, part of the Department of Hydroacoustics of the Maritime Military Technologies Centre TUG. The basic objective of the upgrade was to recreate the sonar's functional structure and software using modern-day technology, while keeping the disruption to the existing structure and other ship's systems to a minimum. As a result, the new solutions were installed in the shortest possible time to ensure that the ship remained fully operational. The second objective of the upgrade was to improve the sonar's tactical and technical parameters; ensure that it is easy to operate, improve its reliability, and reduce its size by using modern technology for the hardware and software. The project has successfully:

- improved the parameters of analogue to digital conversion of signals received by elements of the towed array,
- increased angular resolution by generating more receiving beams,
- applied effective algorithms of digital beamforming,
- applied high resolution methods for identifying the direction of oncoming waves (methods of spatial spectrum estimation),
- applied a system for automatic tracking of selected targets,
- introduced a computer higher resolution display using two colour monitors with a wide range of types of imaging, controls, external data, messages, cursors, etc.,
- improved data transmission between parts of the station,
- improved computer methods for signal and image recording,
- introduced modern digital methods for testing and checking the station's components.

The upgrade made it possible to:

- keep the excellent winches, cable lines, absorbers and motion stabilisers when towing the modules of the acoustic arrays;
- keep the same number and geometry of hydrophones arranged into single rows in the array's modules.

2. Objectives of the optimisation

Optimisation was exclusively designed to enhance the imaging software, with no changes to the physical conditions of sonar operation or signal processing.

The main objectives of the optimisation were to:

- keep sonar operator tasks separate from each other;
- change how the images are organised, and the interaction between the monitors;
- introduce a new form of tactical imaging with bearing lines to the target being tracked, and the possibility of graphic target motion analysis (TMA);
- build tools for creating a database of target acoustic signatures;
- improve the recording and playback of return signals and images.

3. Implementation

In the first phase of quest, after the sonar's array is deployed, the body of water is scanned and searched for interesting signals using available tools. Next, a decision is taken to get the bearing of one of the signals, the probable target. While both operators act independently and can make different choices, they should eventually decide to choose one target, and track it.

Phase two is when the operators perform different tasks. Operator number one uses a previously filtered image LOFAR (waterfall with spectral analysis) and histogram (waterfall) of the levels of signal distributions filtered from several neighbouring sonar beams (true bearing time display TBTD), puts markers (or deletes wrong ones) that show target bearings, while trying not to lose the target listening results; a difficult task, especially as the ship (array) turns.

In that same phase, operator number two uses imaging from listening and a new form of imaging, so-called tactical imaging, which is a panorama. Just as in radar, it reproduces ergonomically the view of the sea surface with traces (markers) of echoes of objects from the ship's ARPA system, and bearing lines of the underwater target being tracked.

With sufficient skill and concentration and using bearing markers the operator is now able to track targets fairly accurately by using graphic target motion analysis (TMA). They can also optimise how their ship is moving to improve or maintain target tracking.

The other changes in how the images are displayed involve improved ergonomic tools for displaying signals; and the operations performed with them, such as filtering using different criteria or highlighting specific elements. The tools include:

- waterfall type images (histograms) of actual spectral distributions and/or slightly averaged distributions of signal spectra from listening;
- distributions of (both actual, and/or slightly averaged) signal levels from the particular beams – all of them, or selected beams;
- bearings of surface targets received from ARPA – on bearing waterfalls;
- database of ships' acoustic signatures – those available and added on an on-going basis;
- filtering of redundant signals according to a variety of criteria;
- putting and removing markers of different meanings.

The target signature database is made using ergonomic tools, for quick access to a specific signature, and the ability to create new signatures of different structural properties without the risk of losing contact with the signal by concentrating on another operation.

By changing how return signals are recorded, retrieved and displayed, operators are now able to record the simple images (before the changes), and changed images after they have worked on them. As a result, archiving of the operations is not only simple, but is also a perfect option for training sonar operators.

The examples of listening signals imaging before filtration, and filtering efficiency, are shown below (figures 1 ÷ 5). The colours in the images are different (mostly brighter) than on the monitors – because of editorial reasons.

4. Conclusion

It will not be until operators have gained more experience with target detection and tracking, that an objective evaluation of the optimised software will be possible, following the new and easier training phase. While the operation of passive sonars with a long towed array is generally difficult and complicated, the authors believe that operators will welcome the improved tools. Already recognised in international maritime exercises, the operators will now be able to perform even better in upcoming drills.

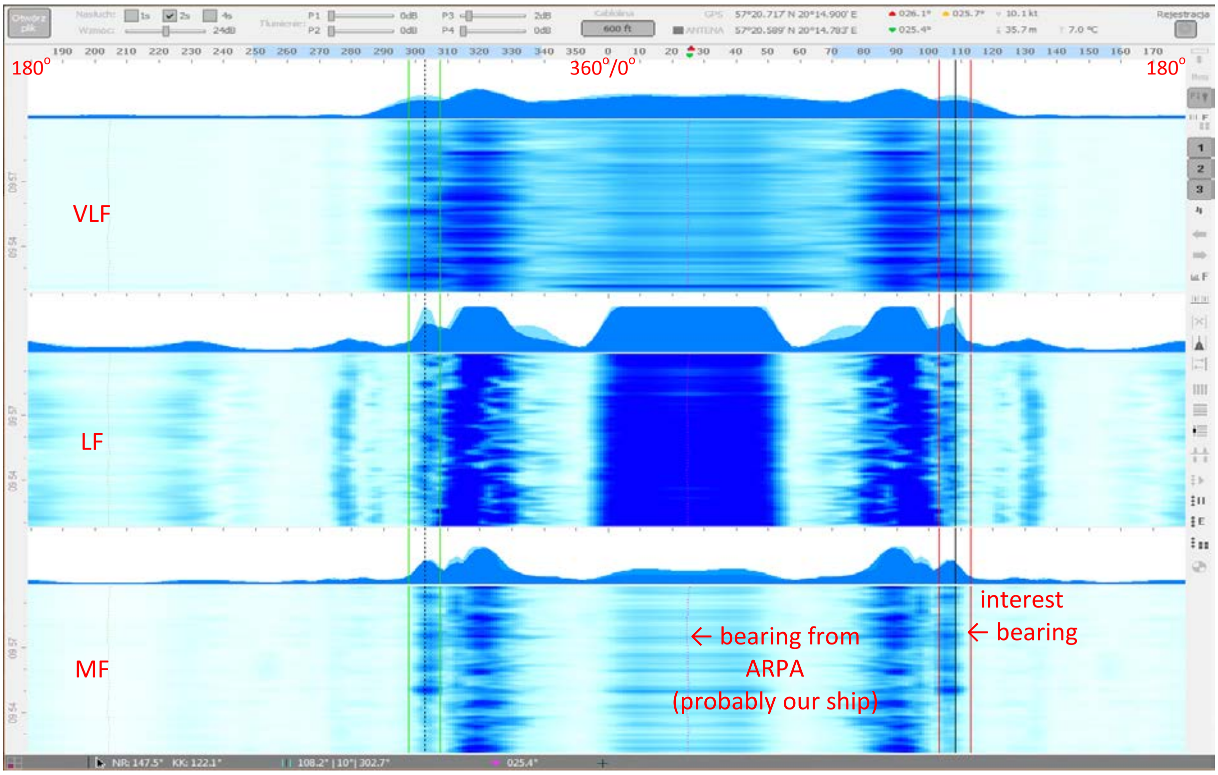

Fig. 1. Waterfalls of VLF (0÷175Hz), LF (175÷350Hz), MF (350÷700Hz) band – unfiltered signal level **from all bearings** (true bearing time display TBTD). HF band (700÷1500Hz) usually empty – not exposed.

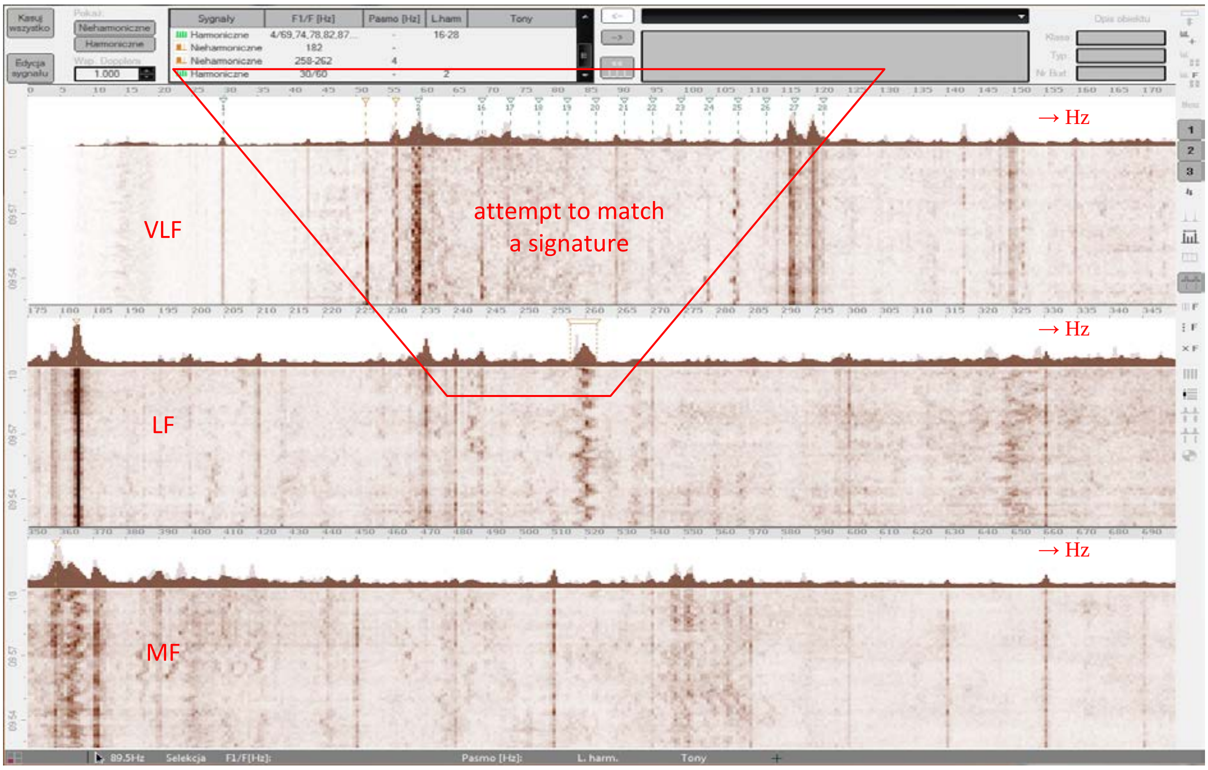

Fig. 2. Waterfalls of VLF, LF, MF band - spectral distributions **from all bearings**.

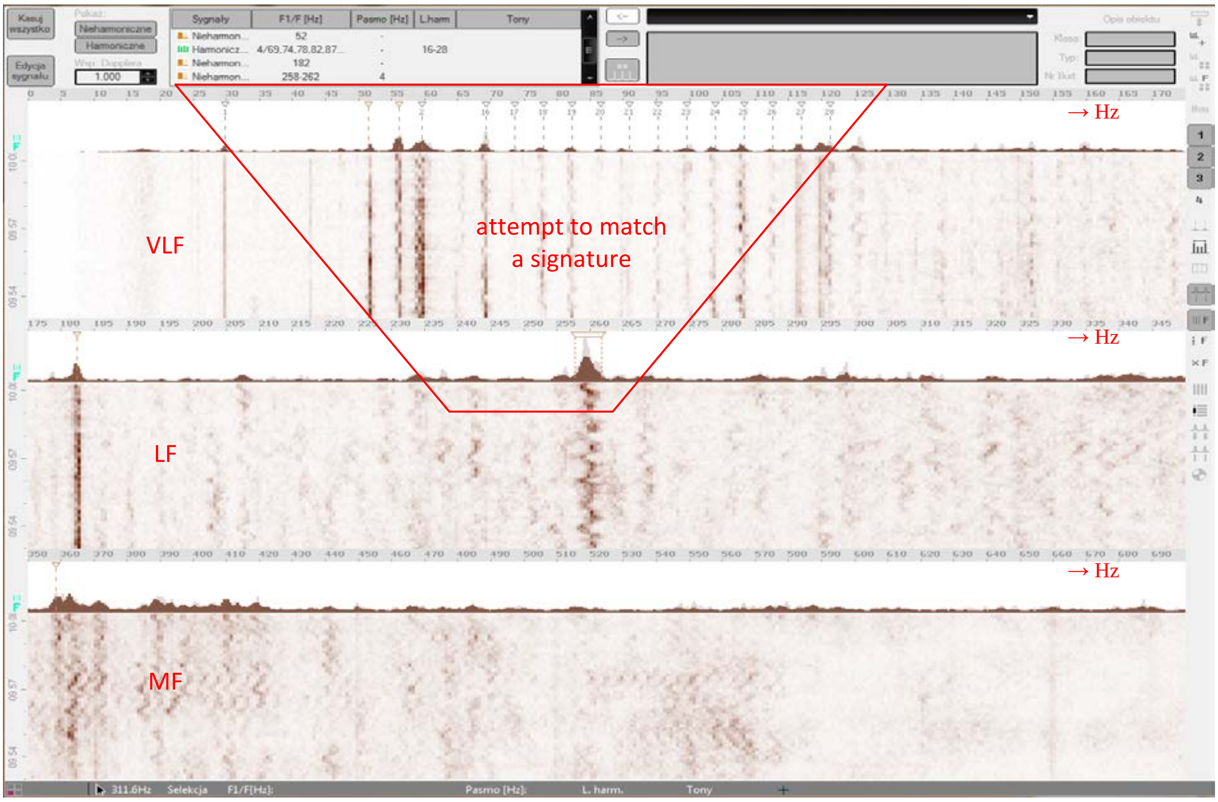

Fig. 3. Waterfalls of VLF, LF, MF band - spectral distributions from one interest, selected bearing (see fig. 1).

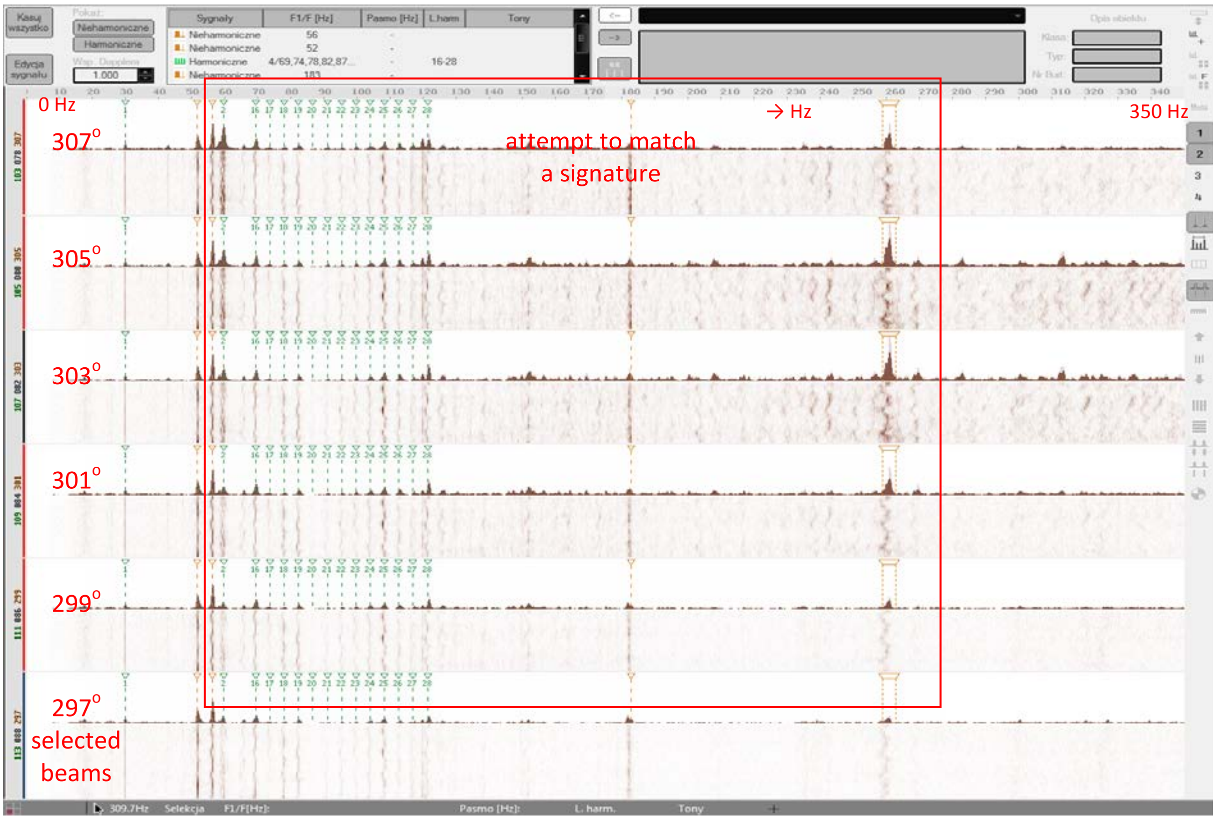

Fig. 4. Spectral distributions from six selected bearing. VLF and LF bands together.

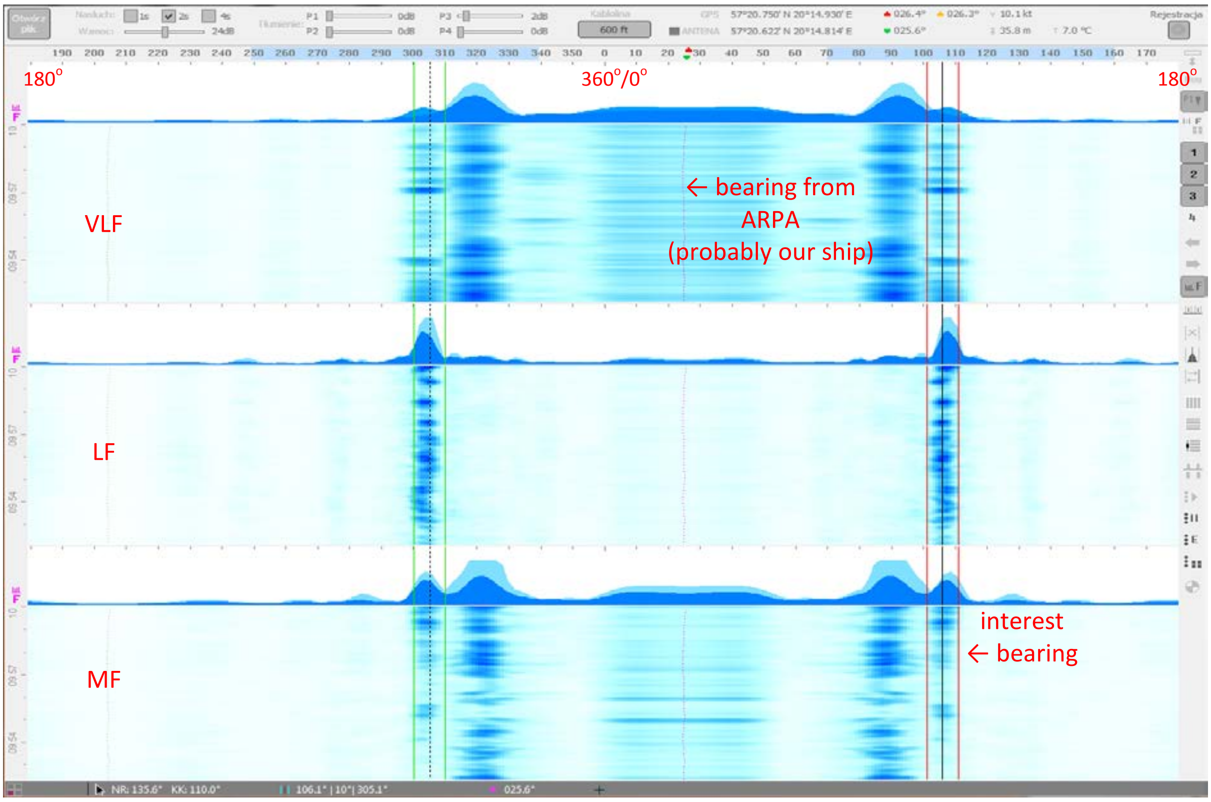

Fig. 4. Signal level from all bearings "filtered by signature" (compare with Fig. 1).

References

[1] Kilian L., Marszal J., Raganowicz A., Salamon R. Organizacja zobrazowania wyników sondażu, nastaw i funkcji pomocniczych w modernizowanych stacjach hydrolokacyjnych. Materiały VI Symp. Wojskowej Techniki Morskiej, 1997, str. 89-96.

[2] Marszal J., Salamon R., Stepnowski A. Military sonar upgrading methods developed at Gdansk Univ. of Technology, Proc. IEEE Oceans '05 Europe Conf., Brest 2005, p. 1-6.

[3] Salamon R., Marszal J., Raganowicz A., Rudnicki M., Application of Fourier Transformation in a Passive Sonar with Gradient Hydrophones, Proc. of the 5th European Conference on Underwater Acoustics. ECUA 2000, Lyon, p. 1115 –1120.

[4] Salamon R., Marszal J., Kilian L., Jedel A., New Signal Processing in a Passive Sonar with Gradient Antenna. Hydroacoustics 2000, Vol. 3., p. 129-134.
Raganowicz A., Kilian L., Marszal J., Ostrowski Z., Schmidt A., Visualisation Forms in Passive Sonar with Towed Array, Archives of Acoustics, Vol. 31, 2006, No 4 (Sup.), p. 373 – 378.

[5] Marszal J., Implementation of Contemporary Technologies in the Modernization of Naval Sonars, Hydroacoustics 2013, Vol. 16, p. 167-180.

[6] Marszal J. Digital signal processing Methods Implemented in Polish Navy Sonar Modernization, Polish Maritime Research, Vol.21, 2014, No2, p.65-75.

[7] Sadowski K., Stacje hydroakustyczne przeciw okrętom podwodnym - część 1, Przegląd Sił Zbrojnych nr 6/2014, str.120-129.

[8] Sadowski K., Stacje hydroakustyczne przeciw okrętom podwodnym - część 2, Przegląd Sił Zbrojnych nr 2/2015, str.129-139.

[9] Sadowski K., Systemy hydroakustyczne – zwalczanie okrętów, Przegląd Sił Zbrojnych nr 1/2016, str. 114-129.