Hydroacoustic Research at WTD 71

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Introduction

WTD 71, the Bundeswehr Technical center for ships and naval weapons, maritime technology and research, is active in all phases of the procurement process and the in-service support of maritime equipment.

This process starts in the so-called pre-phase where self-conducted and contracted research is undertaken to make the Bundeswehr a smart buyer to provide the German armed forces with the best possible material. That means to build and to keep the capability to give advice to the procurement agency in Koblenz and our Navy.

WTD 71 has dedicated test and research facilities all over 8 sites distributed over Schleswig-Holstein. 610 people are working at WTD 71.

WTD 71 is a federal institution with research tasks which means that we are subject to the continuous evaluation process of the science council of Germany.

It is the scientific council who stated that WTD 71 maintains a unique position in Germany in the field of underwater acoustics, and that we are doing good to very good research in this special area.

In this paper an overview on the topics of hydroacoustical research at WTD 71, especially those with a dual use application, is given.

Research Program

Our research activities are organized in 5 core areas:

- Maritime Environment
- Modeling
- Low Frequency Sonar Applications (ASW)
- High Frequency Sonar Applications (MCM)
- Signatures

The program for 2017 comprises 19 projects of which 12 are dedicated to hydroacoustic.

The first two research areas, Maritime Environment and Modeling, are more or less universal in the sense that knowledge about the maritime environment or our modeling efforts are applied to solve problems related to ASW (Anti-Submarine Warfare), MCM (Mine Counter Measures) or the signature theme.

This paper provides an overview on selected hydroacoustic projects. More details from these and other projects at WTD 71 can be found in dedicated presentations at the DAGA.

Maritime Environment

There are three projects within this core area of which one is dedicated directly to hydroacoustic. The task of the “Seafloor Characterization” project is to find methods to classify the sea bottom using Side Scan Sonar (SSS) measurements.

A typical SSS picture is shown at Figure 1 left. The sonar normally towed by a ship insonifies the area left and right of the track and the backscattered acoustic signal is recorded. Here two tracks have been combined. Track length is about 1 km; radial distance 75 m, f = 100 kHz.

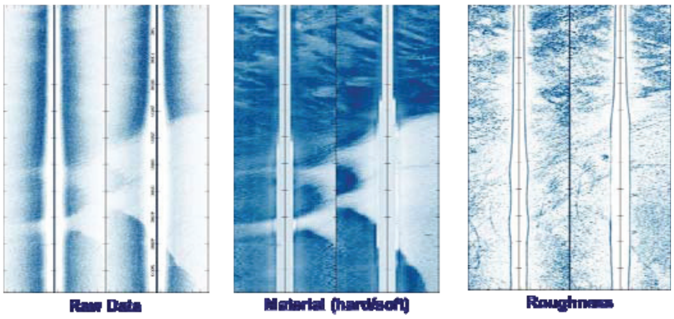

Figure 1: Left: Typical Sidescan Sonar Image (SSS). Middle: Bottom Stiffness (bright: soft, dark: hard), Right: Roughness (bright: low, dark: high roughness)

Using these raw data we are investigating how to analyze the backscatter on order to derive a characterization of the material. Two results are shown in Figure 1, middle and right.

In the area where the sea bottom is soft the roughness is low. In the area above this is as hard as the area below you find different roughnesses. The reason for the high roughness on top is that the sea floor there is covered with a lot of stones.

Modeling

Main efforts of our acoustic modeling activities are dedicated to sound propagation and target echo strength modeling.

Motivated by latest sonar concepts which propose a benefit of using bi- and multistatic approaches there is a need for the development of a 3D Transmission Loss (TL) model. Such a model has to take into account the sound propagation from the transducer to the target and back to the receiver located at a different position as the transducer.

In our concept of a 3D calculation first the TL to each point of a grid describing the area of interest has to be calculated, and afterwards the TL from each of these points back the receiver. The main problem is a three dimensional modeling of the reverberation, i.e. means reflections from the bottom and the sea surface as well as the angle dependency of the target echo strength. At the end all acoustic energy has to be summarized in a correct way. Figure 2 shows the calculation of a bistatic scenario.

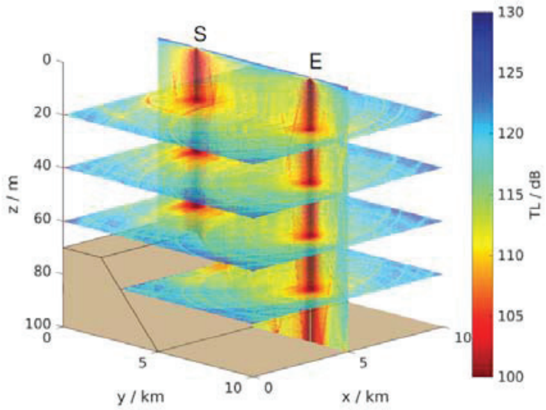

Figure 2: Bistatic calculation of the transmission loss in a scenario with a bottom slope. Source S and receiver E

The target echo strength (TES) modeling has the goal to develop calculation methods for backscattering of the acoustic wave from underwater objects, especially from submarines. The outcome of the application of these calculation models to real objects is classified. On the other hand there is a need to validate the methods. One possibility here is to do benchmark tests against the methods of other institutes or groups. Together with the Netherlands and Canada, WTD 71 conducted the BeTTSi workshops. BeTSSi stands for Benchmark on Target Strength Simulation. Over 25 participating groups from Universities, labs and industry compared their calculations of some more or less simple structures and also a generic submarine. Figure 3 shows our calculation results for this generic submarine.

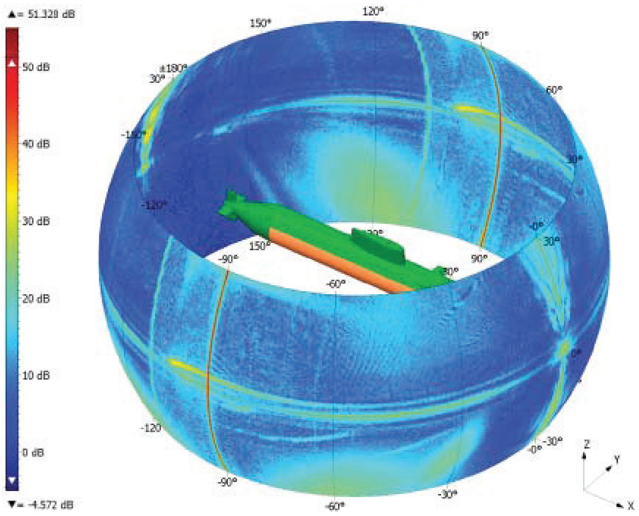

Figure 3: Calculation of the monostatic TES for the "BeTTSi boat". Reflected acoustic energy is projected onto a sphere around the object.

Low Frequency Sonar Applications (ASW)

In the core area Low Frequency Sonar Applications we are investigating new detection methods for both, submarine and submarine hunting sonar systems.

There are four ongoing projects within this core area of which all deal with hydroacoustic applications.

Our workhorse for the development of new ASW concepts is our Low Frequency Towed Active Sonar System (LFTASS). Figure 4 shows a typical PPI display in a deep water scenario.

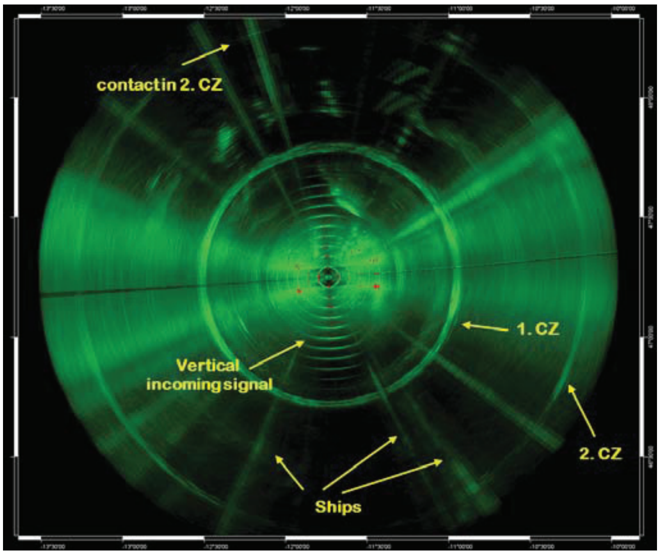

Figure 4: PPI of a deep water scenario. Incoming sound from ships, the noise from the convergence zones and the vertical incoming signal are marked.

The sonar system is located in the middle. The acoustic energy received by the antenna is coded according to its intensity. In this situation we have deep water and the conditions allow convergence zone detection.

High Frequency Sonar Applications (MCM)

Conventional mines, or underwater improvised explosive devices (UWIEDS) and adherence mines are a particular threat. Mine hunting is an important method to detect and to destroy or neutralize them.

There are two problem fields related to the deployment of traditional mine hunting sonars:

- Detection and classification of buried mines
- Sufficiently fast and reliable classification of detected mines

The classification of proud mines needs a high sonar resolution. State of the art is to use high resolution sonar systems like Synthetic Aperture Sonar (SAS). To get a reasonable resolution of approximately 2 cm x 2 cm normally an antenna with a large aperture is required. Such a system is difficult to handle and it is not possible to install it on an AUV. So the solution is to coherently sum up the incoming sound from several pings taking into account the position of the moving antenna, to create an antenna with a synthetic aperture. The challenge is the exact assessment of the position of the antenna (several mm error over several meters of motion of the AUV). Such systems are commercially available and they work often very well. Improvement measures are interferometric approaches and especially multi frequency approaches.

Low frequencies transmit into the sediment which allows getting reflections from buried, flush buried or at least half buried objects. The upper two images of Figure 5 show the SAS picture of a test target insonified at two different frequencies. Both pictures differ and the idea is to combine them in a way shown at the bottom where the backscatter of the two frequencies is colour coded [1].

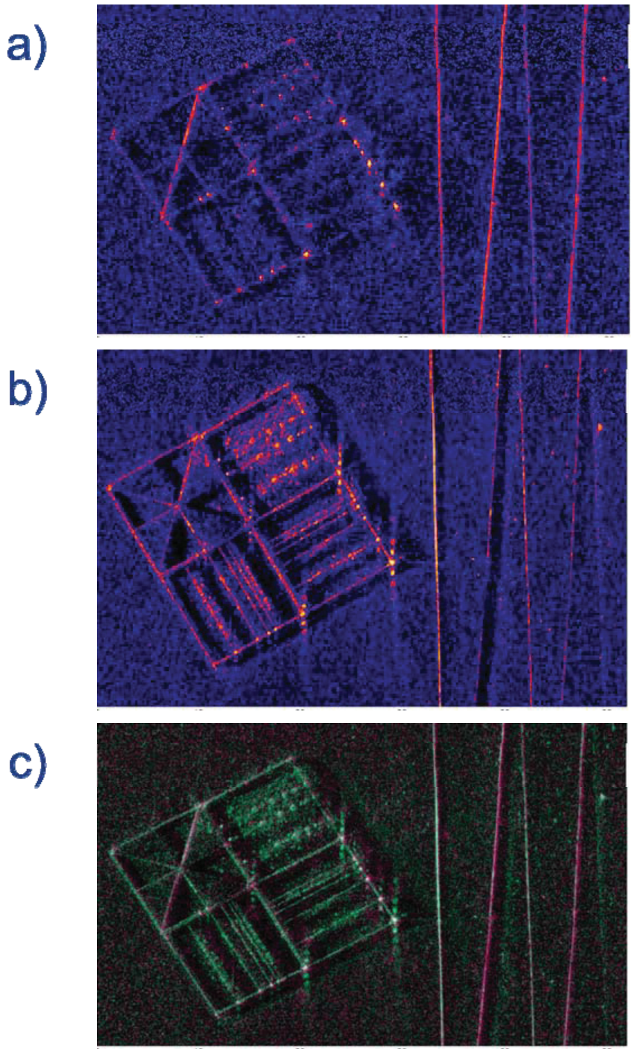

Figure 5: SAS image of a test target insonified with a) LF (f = 22.5 kHz) and b) with MF (f = 75 kHz) and c) their colour coded combination.

Due to the limited communication channels of an MCM AUV and to enforce the autonomy of the vehicle, computer aided detection and a computer aided classification have to be further developed to enable an automated target recognition system.

One approach is illustrated in Figure 6. On the left the SAS image of a cylindrical mine is shown. The ATR approach is to define three areas, the object, the shadow and the sea floor. Using for example a so-called snake algorithm and taking into account the geometry of the scenario, one can find out the shape of the object which helps you to classify the object. Another way is a comparison with it so-called templates.

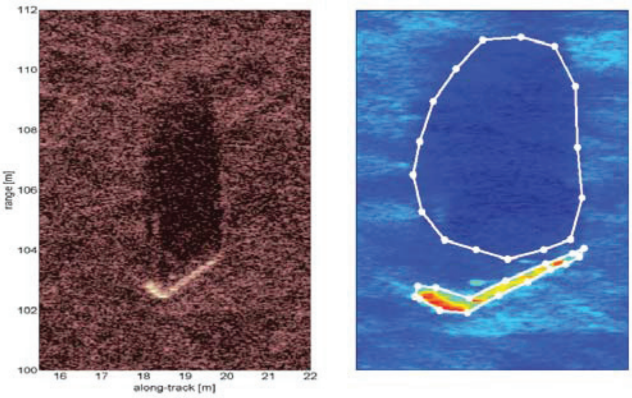

Figure 6: Example for an ATR approach. Left: SAS image off a cylindrical mine, right: Discrimination into object, shadow and bottom using a snake algorithm.

The above mentioned methods are not only usable for military applications but also for the civilian application of detecting old ammunition displaced in the sea after World War II.

Figure 7 shows a SAS image of 70 anchor mines, obtained with the HISAS on board of our HUGIN AUV in an area of the Kiel Bay.

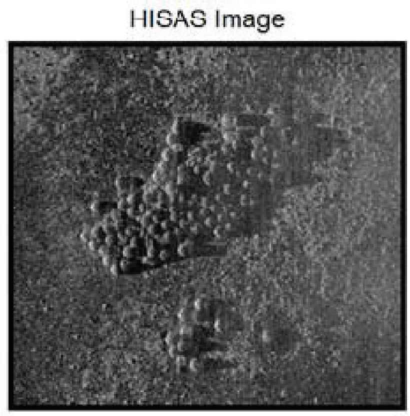

Figure 7: 70 anchor mines from WW II obtained with the HISAS system onboard of a HUGIN AUV

Signatures

Within the research area of signatures there are two ongoing projects dealing with hydroacoustic issues.

The first deals with the measurement of the already mentioned TES of real submarines in deep water conditions. These data are important for both the validation of our TES modeling efforts and to have these data as an input for our sonar performance models. Such an experiment is a tremendous effort. The measurements have to be conducted in the open ocean with water depths larger than 2000 m. The submarine has to sail a precise course 1000 m away from the vertical array. The principal setup is shown in Figure 8.

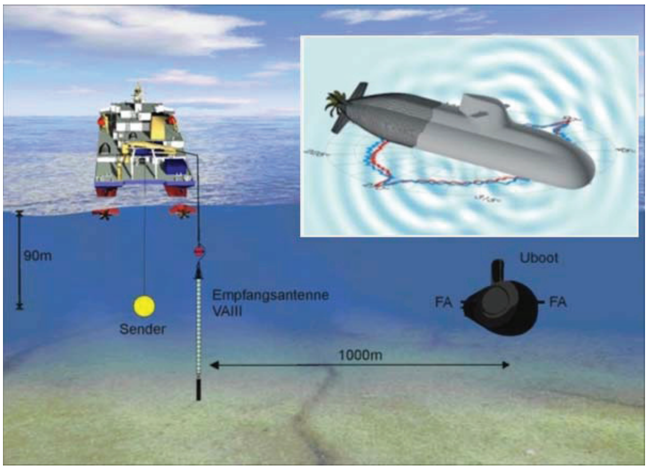

Figure 8: Sketch of the TES measurement principle.

The second project is dedicated to acoustic coatings. As it is well known, low frequency active sonar systems are able to detect submarines over long distances which may be larger than the weapon range of a submarine. The only possibility to overcome this is to minimize its target strength. One approach to achieve this may be to use coatings. Figure 9 shows a coated sphere from which we derive by comparison with an uncoated sphere its stealth capabilities.

Figure 9: Coated steel sphere for the investigation of the stealth capabilities of the material.

Literatur

[1] Groen, J., Schmaljohann, H., Leier, S., Jans, W.: Synthetic aperture sonar fusion for images with dissimilar physical content due to differences in acoustic frequency, Underwater Acoustics Conference and Exhibition, 2015, pp. 121-128