> UNDERWATER ACOUSTIC MODEL FOR PROPAGATION AND RANGE PREDICTION

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# **TNO** innovation for life

## **TNO.NL**

### TNO

TNO is an independent innovation organisation that connects people and knowledge in order to create the innovations that sustainably boost the competitiveness of industry and wellbeing of society.

TNO focuses its efforts on seven themes including Defence, Safety and Security: TNO works on a safe and secure society by creating innovations for people working in defence organisations, the police, emergency services and industry.

### CONTACT

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ALMOST is an underwater acoustic model for propagation and range prediction that is able to assess detection performance for fully specified passive and active sonars. The model runs on PC's under WindowsXP and higher. The detection performance model can be applied to a wide range of active and passive sonars, like low frequency towed array sonars, hull mounted sonars, buoys and dipping sonars, and mine hunting sonars.

ALMOST can be used interactively, or as a calculation object that can be used in other programs. This option makes ALMOST very flexible. Applications for this calculation object range from a real time sonar performance indicator on board a mine hunter, a torpedo defence testbed with realistic sonar performance, an operator support tool to optimise the sonar settings for the environment, to an operator support tool to help prevent harm to marine mammals.

### **PROPAGATION MODEL**

The propagation model is based on ray theory, extended for low frequency using a.o. an initial smoothing of the input sound speed profile. From the resulting profile the main propagation paths are determined, that consist of Upper and Deep Channels, Surface- and Bottom Ducts, Bottom Surface Path, and Short range Path. Contributions from propagation paths are summed for application in passive range prediction, while for active sonar range prediction the propagation paths are applied individually together with travel time and grazing angle, particularly for the reverberation and echo level calculation. Doppler shift and vertical receiver- and source directivity patterns are taken into account in the propagation calculation.

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Propagation loss and detection probability (REPAS)

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# Show Actual Historica Result Depth Sound 10 1512 28 1511 34 1510 46 1507 75 1503 312 1502 424 1502 Month: may2 💌 Area: 8218 💌 Merging Depth % © 30 © 50 © 70 Curve for temp/sal C Extended actual G Sour Q Undo zoom ✓ OK X Cancel Load Save as

Sound speed profiles

### **ENVIRONMENTAL INPUT**

The model uses the Sound Speed Profiles of the water column and the sediment. An actual (measured) profile can be used, which can be merged with a historical profile from a database. Water profiles can be either sound speeds, or temperature combined with salinity. The Bottom Profile describes the generally varying water depth and bottom properties; input of sediment parameters is optional.

### **DETECTION PROBABILITY**

Detection probability for active and passive sonars is the main output of the sonar performance model, which is modelled based on the active c.q. passive sonar equation. Separate (ambient) noise and reverberation models are available based on propagation calculations, and databases from literature.

### **NOISE MODEL**

The calculation of the noise term in the sonar equation is based on noise sources just below the sea surface representing the sea- and distant shipping noise. These sources, which propagate in the actual environment, are calibrated in strength (per m) according to a deep reference environment. This is done in a way that in this reference environment at 100m receiver depth the Knudsen spectrum is formed for the given wind speed and shipping intensity. In the actual environment the calculated spectral level may differ significantly from the Knudsen spectra, as a result of actual propagation conditions.

### REVERBERATION

The reverberation calculation is based on scattering data from literature. The model allows a variety of bottom types for bottom reverberation. Surface reverberation is dependent on wind speed, and volume reverberation is based on mean data for the Deep Scattering Layer. The data is combined with propagation modelling. Propagation loss, travel time and grazing angle per propagation path, are calculated between sonar and scatterers, yielding reverberation versus time results. Particularly bottom reverberation for a varying water depth requires extensive propagation calculations.

### **SIGNAL TO NOISE RATIO** (ACTIVE / PASSIVE)

For active sonars the Signal to Noise ratio is calculated, versus time, by calculating the echo level (signal) for a target of given Target Strength and optional directivity, while the Background level (noise), is calculated from reverberation and ambient noise contributions, after signal processing of the receiver. For practical use the time scale is converted into active range scale, simulating the physical screen of an active sonar. For passive sonars the SNR is calculated versus passive target range. Detection probability is calculated versus range, using the SNR together with the given signal processing type in the receiver, for the general statistical behaviour of signal and noise cq background and the given Pfalse alarm. Active sonars are usually based on either correlation ("matched filter") or energy detection. Passive sonars can be either narrow band (correlator/doppler type) or broad band (energy) detectors. For the energy- and correlator detectors the (different) formulas are used, taken from literature.



ALMOST as tool to predict the performance of a minehunting sonar.

### TACTICAL DECISION AID

The calculation result of detection probability for a number of sonar- and target depths includes all relevant information of detection for a given environment. By running a strategy model on these detection probabilities, obtained at each target range, the optimum sonar depth setting can be determined, as well as the most stealthy target depth setting. The final result for all target ranges are two depth range curves, for optimum sonar and most stealthy target depth, and a third curve of the corresponding detection probabilities, all versus range, thus providing a quick overall picture of the detection performance of a specified passive or active sonar system in a given environment.

CALCULATION MODULE The development of ALMOST was started to fulfill the need to predict the range of the sonars for ASW purposes, taking environmental information into account. The first versions were delivered as stand alone programs with a limited user interface. The possibility to predict the performance of a sonar in real time, using environmental information measured in the area or from a large database was developed later. Currently the ALMOST calculation object can be called with the relevant parameters, the output can be visualised to obtain a predicted sonar display.



Reverberation from sea surface, volume and bottom: versus active sonar range