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Advanced Underwater Technology with Emphasis on Acoustic Modelling and Systems

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Abstract

The Sonar Performance Prediction System (SPPS) will be introduced. The SPPS is an integrated ocean-acoustic propagation model coupled with a sonar performance prediction model. A stationary sea surveillance sonar consisting of a horizontally nested hydrophone array and a vertical transmitting/ receiving array may be used to detect, localise and track surface and subsurface contacts within its coverage area.

The performance of the sea surveillance sonar has been investigated with the SPPS. Results of that performance prediction will be presented.

Introduction

The Sonar Performance Prediction System is a mathematical/physical description of the acoustical behaviour of the sea and their influence to a given active or passive sonar system mounted on arbitrary platforms. The goal is to simulate the sonar-signal with the aim of measurable realistic oceanographic parameters and to give a prediction of the acoustical behaviour of the sea-area of interest.

On the other hand the SPPS enables the sonar system designer to optimise a given sonar system on a PC. This fact reduces the costs (ship-time) for an optimal design of a sonar system tremendously.

The sea surveillance sonar is able to detect and track all surface and subsurface contacts (like submarines, divers and diver delivery vehicles) within the assigned coverage area in the active and/or passive mode of operation.

The sea surveillance sonar is extremely beneficial in countering illegal activities that can strain a nation's economy. These activities include pirating, terrorism, smuggling, illegal immigration.

The SONAR Performance Prediction System (SPPS)

SPPS is a ***user-friendly*** software package, running on a *PC* under *WINDOWS 95.*

Applications of the SPPS:

- Performance evaluation of different sonar systems
- Evaluation of naval warfare scenarios
- Sonar system design
- Oceanographic studies

The Sonar Performance Prediction System (SPPS) [see fig. 1] consists of a Sonar Performance Prediction Model (SPPM), an Integrated Ocean-Acoustic Propagation Model, several data bases and a noise- and reverberation model.

The SONAR Performance Prediction Model (SPPM)

The SPPM has the following features:

It handles active and passive sonar detection problems, broadband and narrowband signals.

All types of sonar antennas are included like

- Towed array (nested)
- Bottom moored line array (nested)
- Flank array (line and planar)
- Conformal array
- Hull-mounted arrays (active, passive)
- Passive ranging arrays
- Variable depth arrays
- Active towed array
- Vertical array
- Bistatical transmitting/receiving arrays
- ROV-arrays

The directivity patterns of the antennas are variable (including side lobe level, horizontal beamwidth, horizontal direction, vertical beamwidth and tilt angle).

Coherent and noncoherent signal processing algorithms. Threshold system.

Examination of environmental effects on the sonar system and the naval warfare scenario.

Integrated Ocean-Acoustic Propagation Model

A *PE*, a *CM* and a *Ray* propagation model are integrated under one umbrella, the ***expert system***.
In this way, the ***expert system*** will help and guide the operator in selecting and using the propagation models.

The objective of this hybrid model system is to provide accurate, valid and user-friendly 2 D, N x 2 D and 3 D model capable of realistically predicting the propagation of sound in the sea.

The frequency ranges of the hybrid model system covers the ranges from 10 Hz to 1 MHz. The hybrid model system will be able to incorporate

- shallow water propagation
- compressional and shear waves
- coupling between wave types at interfaces and boundaries
- depth dependence in the elastic properties
- wide propagation angles

Data Bases

Geographic Information System (GIS)

The large size and the diversity of spatial data in environmental problems makes it difficult to manage them with the traditional data based tools. This is true for both land and sea based spatial data. DBMS have advanced dramatically in the last years with the introduction of the relational systems, but still cannot handle easily information related to space location.

To address this problem the technology of Geographic Information Systems (GIS) has been developed in the last few years. A GIS is a system for storage, display, management and analysis of spatial data.

In a GIS, each piece of spatial information has an associated co-ordinate that explicitly specifies where it is located. For example, when storing sea temperature and/or salinity data, there are x, y, z-co-ordinates that specify the location and depth of each particular measurement.

A GIS, therefore, consists of different layers and coverages of information that are interrelated through the co-ordinate system. Because of these interrelationships, data on different layers (i.e. temperature, salinity etc.) can be analysed and potential relationships explored.

Finally, a very important characteristic of a GIS is that it permits visualisation of spatial data.

A GIS system that stores data related to the sea could include layers related to:
- bathymetry
- hydrographic measurements (e.g. CTD, XBT data)
- bottom stratification

and could be „tied" to interpolation routines that estimate temperature, salinity etc. between measurement points and display thematic maps.

In such an integrated system, the potential user may define any section of interest. The GIS will then extract all data associated to this section, which in turn can be either displayed or used as input for the SPPS. The result of the acoustic calculations can then be fed back to the GIS for storage, display and reference. For such system the geographic size of the units will be a grid.

All other data bases will be due to customer's demands.

Reverberation Model

The reverberation models will predict the single reverberation components:

- Volume (water column, sediment)
- Surface
- Bottom (for range dependent and range independent environments)

Noise Model

This model will predict :

- Ambient noise
- Flow noise
- Thermal noise of the sea
- Self noise (sonar platform and sonar system)

Visualisation of the Results of the SPPS, the Various Sub-Models and the Contents of the Data Bases

The results of the SPPS and the tactical situation will be presented in 3 D, the results of the sub-models and the contents of the data bases in 2 D.

The Sea Surveillance Sonar

The sea surveillance sonar [see fig. 2] is able to detect and track all surface and subsurface contacts (like submarines, divers and diver delivery vehicles) within its assigned coverage area in the active and/or passive mode of operation. The underwater part (wet end) consists of a nested steerable horizontal hydrophone array (256 hydrophones) and a vertical steerable transducer array (64 transducers).

The system is tailored to the local needs and requirements. Illegal immigration might be conducted with small freighters. For smuggling activities and pirating a frequently used craft is a high speed boat. Terrorism might be conducted with submerged vehicles.

To detect these different targets passively, the emitted propeller noise spectrum of the targets will be measured. That of the freighter in the low frequency and that of the high speed boat in the high frequency spectrum.

The sonar system consists of the arrays, the transmitter, receiver, wet end control unit and the surface control and processing unit.

a) Transmitters

64 transducers are working in a frequency range from 2 to 4 kHz. Each transducer will be used as a receiver and will possess its own power amplifier (few hundred watts) and pre-amplifier.

b) Receivers

A fixed nested horizontal receiving array will be used (in addition to the 64 channels vertical array). It consists of an array of about 300 metres (256 hydrophones) that will be suitably arranged in order to cover a very wide frequency range.

In addition, a vertical array of few elements will be moored together with a pinger at a short distance from the arrays in order to continuously monitor the data quality.

c) Wet End Control Unit

The wet end control unit will be in charge of all the dialogue with the surface control unit. It will generate pre-computed signals (or any new signal loaded from the surface) and transmits acoustic data to the surface. It also controls the power

amplifiers. The wet end control unit is connected to the surface control unit by a special purpose cable including power as well as several optical fibre links.

d) Surface Control and Processing Unit

The surface unit constitutes the interface between the user and the underwater part. It will be installed in a land based unit and will be in charge of data collection conditioning, processing and storage.

Sonar Performance Prediction System

(SPPS)

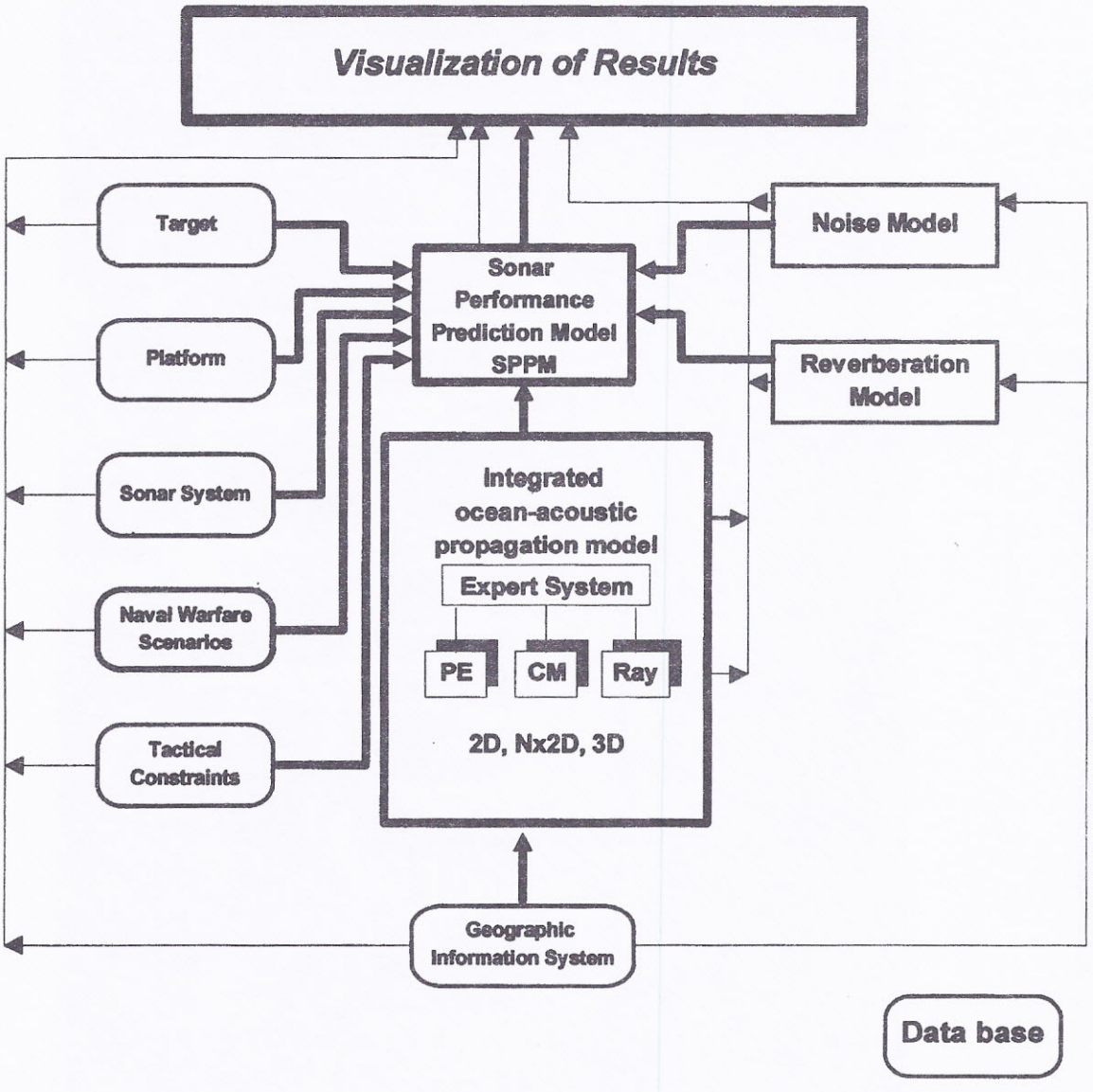

Fig.1: Blockdiagram of the Sonar Performance Prediction System

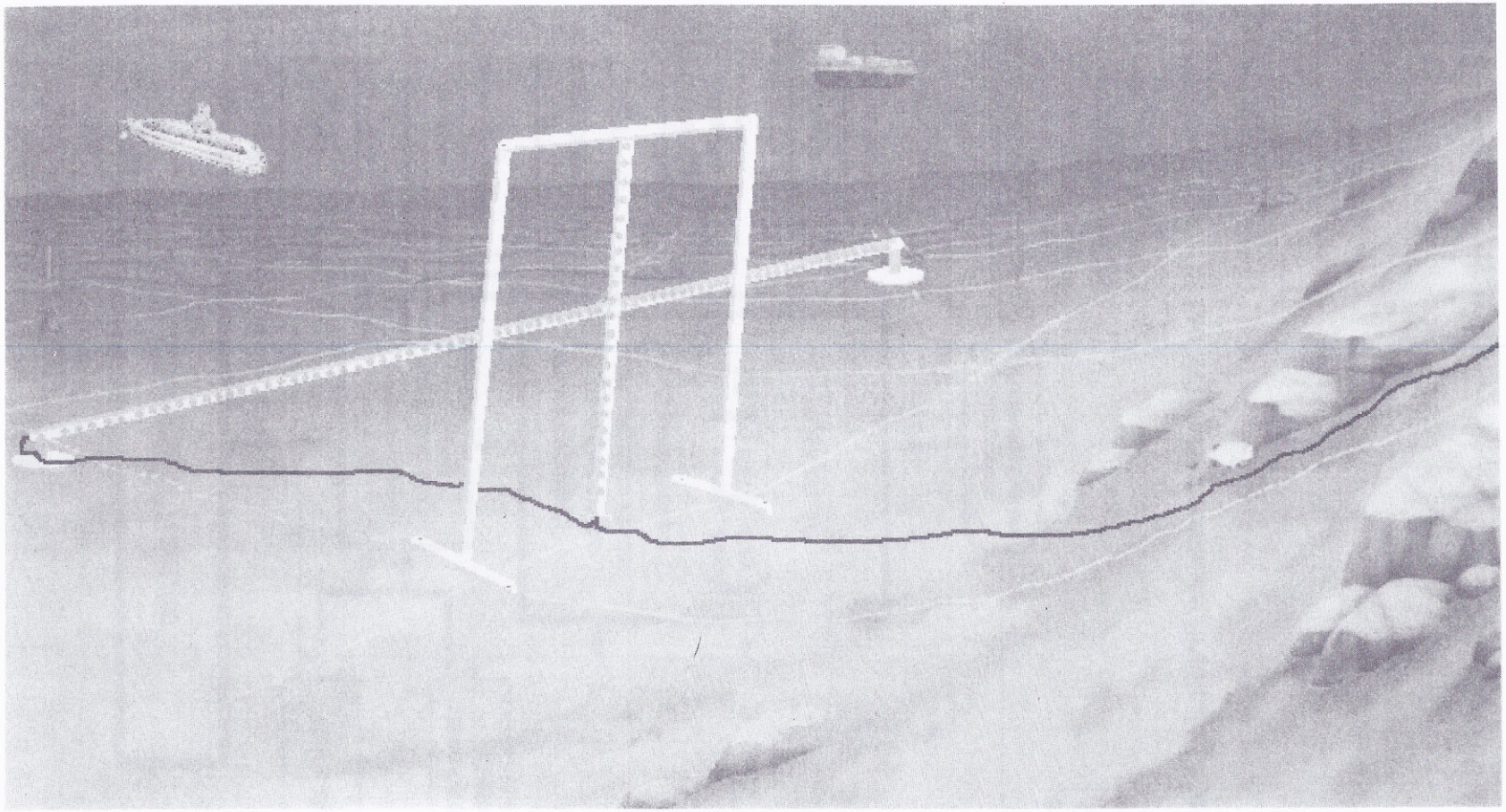

Fig. 2: The sea surveillance sonar (array configuration)