RAYSON : a real time underwater communication simulator and performance estimator

Christophe VIALA - Claire NOEL♠ Gérard LAPIERRE♣
♠ SEMANTIC TS, 39 chemin de la Buge, 83110 SANARY SUR MER, France
♣G.E.S.M.A. (Groupe d'études sous-marines de l'atlantique), BP 42, 29240 BREST NAVAL, France

ABSTRACT .

This paper describes the development of a real time simulation tool to model underwater acoustic communication over time-varying channels. Physical parameters characterize time varying channels by integration of static parameters (kind and form of sea surface or sea bed) and variable ones (celerity, receiver moves…). RAYSON software is suitable for testing all configurations (provided rays propagation is available) and is able to deal with time variant impulse response. Performances of acoustic link could be then evaluated. This tool is particularly useful to design acoustic link, especially in defining necessary powerful and frequency band, and to evaluate environment impact on the transmission.

INTRODUCTION

This paper presents a tool to evaluate the performances of acoustic links. This software called RAYSON is an acoustic propagation model based on rays method. The first part of the article reviews some contributions indexed in the field of simulators of underwater acoustic communication. The second part presents the different functionalities of RAYSON. Finally, interest of using of such a tool in deep sea applications needing underwater communications is presented.

A QUICK REVIEW OF UNDERWATER ACOUSTIC CHANNELS (UWA) MODELING

Underwater Acoustic (UWA) channels are characterized by multipath phenomenon whose characteristics are time-varying. This speed of variation is partly due to the medium (change of celerity, nature of the sea-bed, form of surface) but also to the instruments (movements, immersion depth...). The performance evaluation of a transmission in simulation thus requires taking into account variability in order to estimate the robustness of treatments. Current work in this field thus rests on the characterization of this time and frequency dispersion and on their consequences on transmissions [1], [2].

Whatever the degree of modeling could be, simulation cannot perfectly represent the reality (due to insufficient knowledge of the environment, erroneous modeling...). However, this tool can be of a great utility in the preparation of sea trials (optimization of instrumental positions, comprehension of global phenomena...)as the conception of acoustic links by the evaluation of the impact of environment on transmitted signals. In that case, some important parameters like time guard interval, source level or frequency selectivity could be fixed according expected environment.

A first possible approach to model these disturbances is to let physical phenomena and model the whole transmission link by the discrete equivalent model. The impulse response is modeled in this case by a 2-D random process synthesizing the sum of N contributions shifted in time, out of phase and attenuated in amplitude.

$$h(t,\tau) = \sum_{i=1}^{N} \alpha_i(t).\delta(t - \tau_i(t))$$

Synthetic time–varying channels with certain shapes of fading (Raleigh, Rice channel) can be modeled by the application of laws of variations on amplitudes α_i delays τ_i and phases. A second level of description consists in linking the main characteristics of the channel to the physical phenomena. Then, the application of simple geometrical laws allows to define multipaths and to determine main characteristics of various rays. A first contribution [3] described such a reception. Some modelings are refined by taking into account temporal variations of the medium due to changes of instruments [4]. The modeled channels in this way are often characterized by what one calls the scattering function which allows the visualization of the dispersion of energy both in time and frequency. Interest rests on the integration of realistic order of magnitude in the fluctuations of these models.

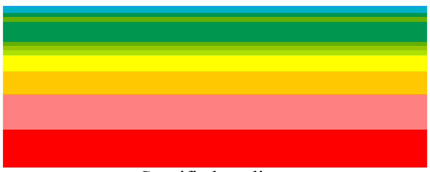
The author's contribution is based on the development of software in order to evaluate performances of underwater acoustic communication. The impulse response is determined by the preliminary definition of configuration of transmission (celerity, nature and form of surface and sea bed, movements of the transmitter and the receiver...). In situ signals and measured noise could also be integrated on any part of the link.

RAYSON : ACOUSTIC RAYS PROGRAM IN OCEAN MEDIUM

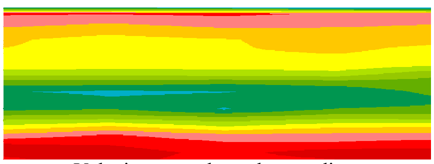
RAYSON [5] program is able to predict acoustic field using a ray method based on a simplification of Helmholtz equation valid in areas of high frequencies. This differential equation defines the trajectory of a ray taking into account local values of sound velocity and its gradients. When the medium is range independent (that means that vertical sound speed profile is the same across the range) this equation presents analytical solutions which are parts of circles. When the medium is range dependent no general analytical solution exists, even in the case of simple profiles of celerity. Ray equation is then solved numerically with a Runge-Kutta scheme of the order 4, moving forward along the range axis. This program has been realized in C++.

RAYSON is able to take into account various realistic environments (CF Fig 1):

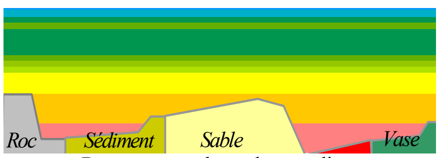
- Range independent medium: horizontally homogeneous
- Range dependent medium (2D description (range, depth) of sound speed field. The number of celerity profiles is just limited by the processor memory.
- Bottom profile and type dependent on range in propagation loss calculations. Type of bottom is chosen among: sediments, sand, mud, rock, fluid bottom, fixed bottom (loss in dB is constant)
- Space-time dependent surface: Propagation times underline temporal dispersion that can reach some hundred milliseconds after some fifty kilometers of propagation. Two rays that have been sent from the source at the same moment will hit the surface in such different places and times that surface cannot be considered as stationary. A dynamic model is then necessary to deal with surface effects on acoustic propagation.



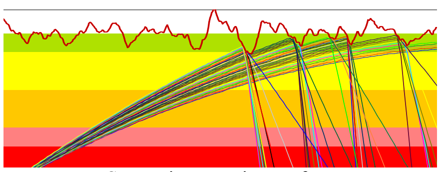
Stratified medium



Velocity range dependent medium



Bottom range dependent medium



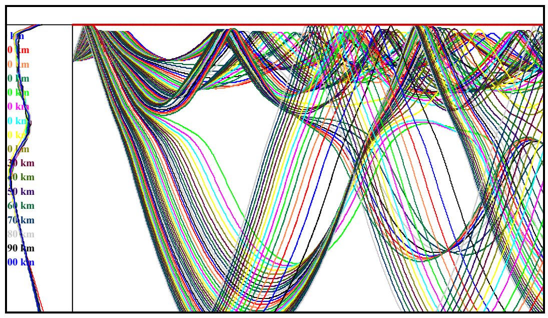
Space-time varying surface

Fig 1: Environments

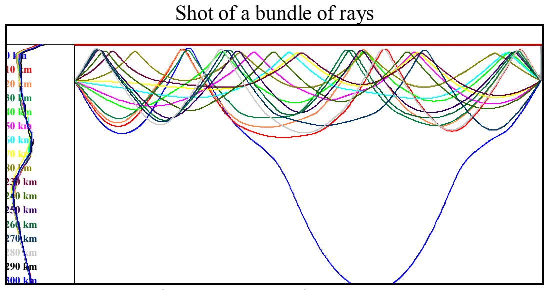
RAYSON offers several functionalities:

- Shot of a bundle of rays devoted rays trajectories studies
- Calculations of eigenrays (connecting source to a (set of) receiver(s)): memorization of trajectories and arrival angles, time and intensity for each eigenray.
- Calculations of propagation loss fields: visualization with 2D map of coherent, incoherent and maximal losses.
- Calculations of propagation losses fields are made through a systematic insonification from the source; calculations area is regularly discretized in range and depth; losses due to divergence and/or surface and bottom reflexion are determined in each mesh.
- Calculations of impulse responses: for a source and a set of receivers.

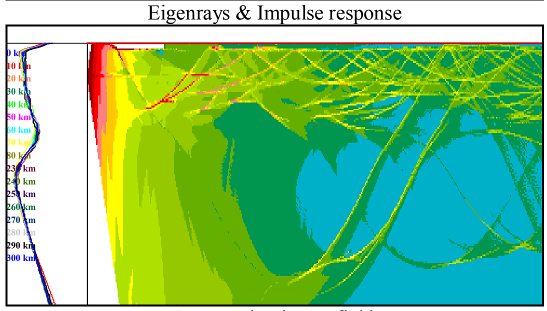
The program has a procedure of Monte-Carlo type that allows automatic and systematic statistical numerical simulations: determination of ray characteristics and their intensity for a set of speed profiles, moving surfaces, or unknown bottoms whose description files are present in a directory. All the characteristics are available in a file of results. Calls for parameters and the processing of files are automatized; human actions and manipulation errors which constitute a real problem when the number of realizations is high are minimized; this authorizes parallelization of calculations and therefore optimization of processor efficiency. The method allows dispatching calculations over a set of data between several processors of a network.



Shot of a bundle of rays



Eigenrays & Impulse response



Propagation losses field

Fig 2: Functionalities

RAYSON has been adapted to take into account source receiver directivity and receiver trajectory. Fig 3 shows the receiver trajectory in the receiving area.
Impulse response is interpolated on the receiver trajectory point as shown on Fig 4 by knowing it in each point of the receiving area.

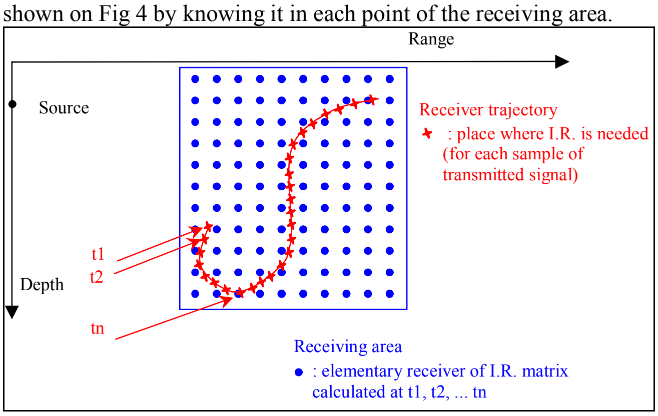


Fig 3: Places where I.R. (Impulse Response) is needed

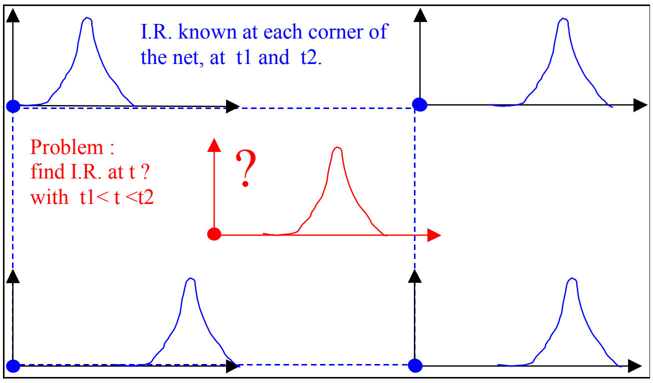


Fig 4: Impulse Response interpolation

Once impulse response is determined for each receiver place RAYSON calculates propagated signal in real time.

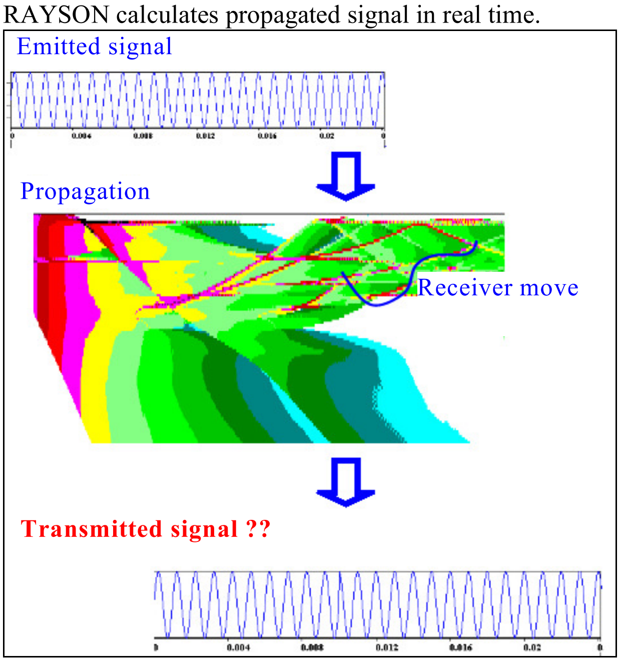


Fig 5: Transmitted signal

Fig 6 shows an example of propagated signal in case of a sinus emitted signal. The multipath structure of the channel implies a temporal spreading of the signal.

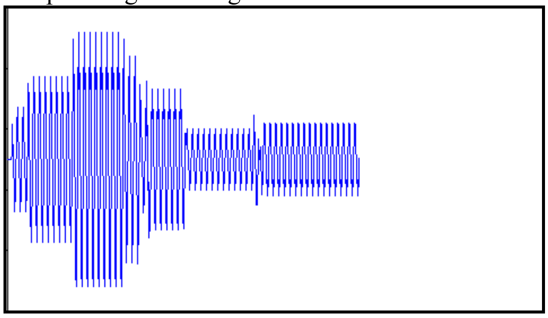


Fig 6: Propagated signal

INTEREST FOR AN USE IN DEEP SEA APPLICATIONS

An acoustic communication simulator is presented. This tool, which now works in real time, could be useful in deep sea applications needing underwater communications like:

- Underwater acoustic rapid environment assessment (REA)
- Underwater tracking and sonar systems
- Acoustic control during drilling (evaluation of the impact of high noise level [6]
- Production set up monitoring (impact of the installations and environment). Investigation, drilling and production are realized in deeper and deeper water depth, more than 3000 m today. As a consequence, current control and command of these systems between bottom and rig by electro-hydraulics umbilicals will reach such a cost that acoustic transmission stand for an interesting solution to be considered. Before using this kind of communication, some specifications have to be realized. Basically, acoustic noise level, impact of installations and environment are the three main problems, a designer have to take into account first.

For that purpose, RAYSON constitutes a useful tool to study feasibility of acoustic transmission in a complex and realistic environment, for help of modem, phone, tracking or sonar systems setting up.

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