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Study of transient signals propagation. Application to risk assesment

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1. SUMMARY

In order to adapt sonar equation to transient signals, we study the effect of underwater acoustic propagation on that kind of unstationnary signals. In particular the problem is to characterize distortions induced on received signal by multiple paths: temporal spread, attenuation, morphing.

2. INTRODUCTION

To study distortion due to propagation it is first necessary to modelize ocean medium as a linear filter characterized by its impulse response. This approach is well adapted to the case of transient signals.

A propagation model is used to determine transfer function of the medium. Because transient signals present a large spectrum from high to low frequencies, a ray program tracing is used. But this model has been first improved to be able to take into account low frequencies with corrections in caustics area.
The propagated signal is then obtained by a convolution product between the source signal and the impulse response.

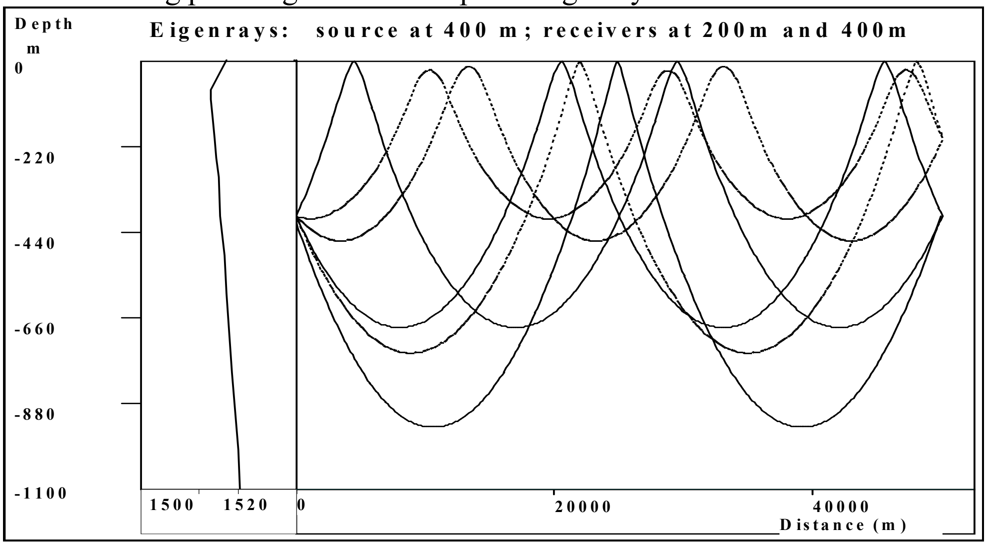
This developed tool is used to conduct a study of the impact of the ocean medium on the impulse response. This parametric study is realized over a set of typical operational configurations and families of measured transient signals. Energy level and temporal spreading of this impulse response which appeared to be interesting criteria to describe distortion are studied in addition to the coherence between propagated and emitted signal.

The synthetized results are used in the transient sonar equation giving more precise information on the detectability of transient noises.

3. METHOD TO DETERMINE IMPULSE RESPONSE OF OCEAN MEDIUM

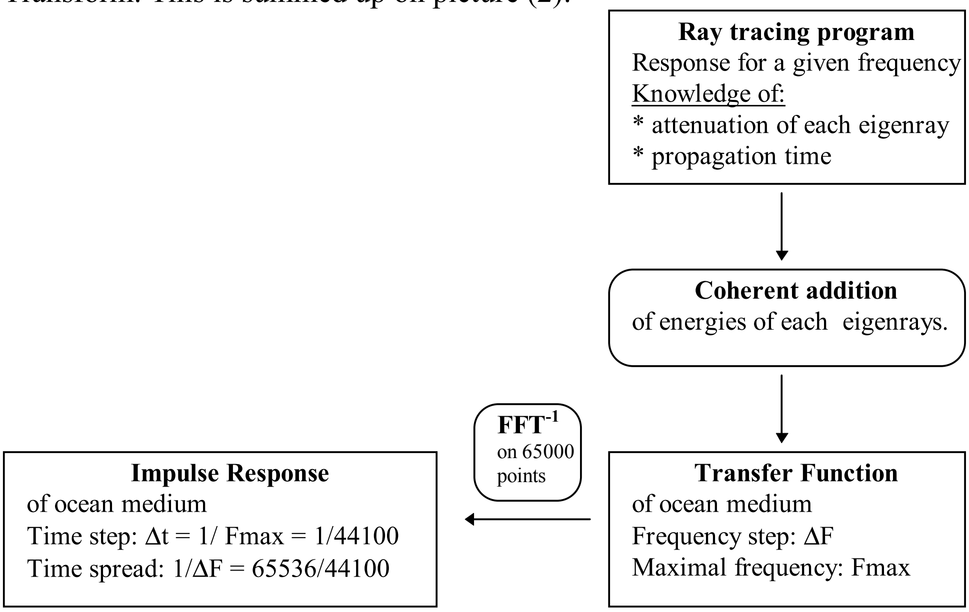
3.1. Ray tracing program and impulse response

A ray tracing program (RAYSON), has been used to evaluate impulse answer. This code is able to determine trajectories, propagation times and intensity of eigenrays (i.e. connecting sound source to a given receiver localized in space by its depth and its propagation distance). The following picture gives an example of eigenrays for two receivers:



Picture (1): Example of eigenrays connecting one source and two receivers.

For each eigenray, propagation time and amplitude can be evaluated for a set of frequencies. Coherent addition of energy of each ray give thus, for each frequency, the transfer function of the medium. From this function, impulse response is obtained via an Inverse Fast Fourier Transform. This is summed up on picture (2):



Picture (2): From eigenrays characteristics to impulse response

This program takes into account 2D sound speed profile description of the medium, which is useful to conduct an impact study of medium effects on transient signals propagation.

3.2. Adaptation to low frequencies

This ray model has been extended to low frequencies by evaluating Airy corrections in the vicinity of caustics, and then constitutes a good tool to acoustic propagation down to 100 Hz if areas near to surface and channel are avoided. [3] [4].

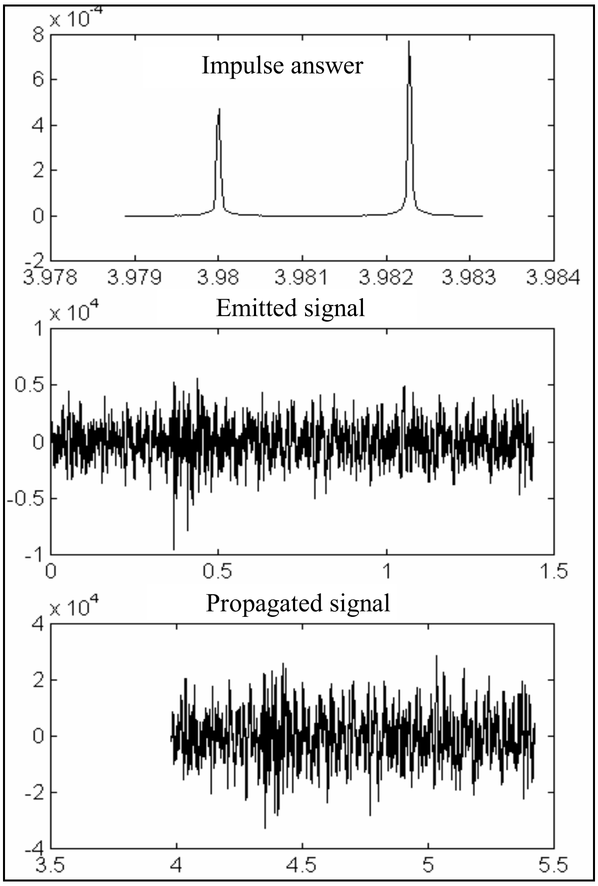
4. CHARACTERIZATION OF DISTORTION OF PROPAGATED SIGNAL

This paragraph deals with the development of a way to evaluate distortion of propagated signal from the knowledge of impulse answer and source signal.

4.1. Impulse response, emitted and propagated signals

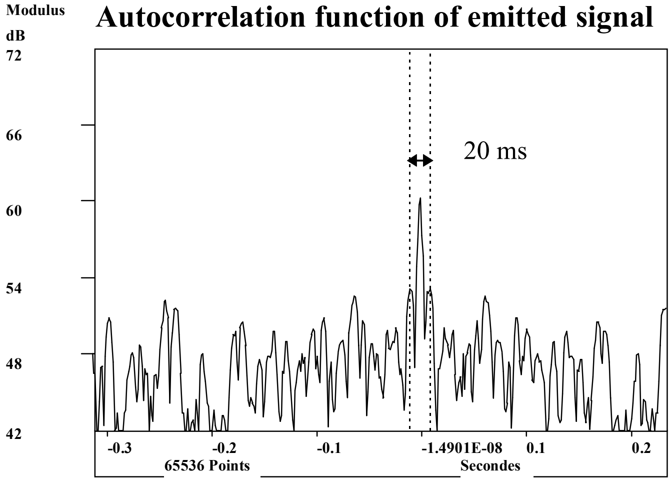
Once impulse response has been determined from results of ray tracing program and previous explained treatment, propagated signal is evaluated by a convolution between impulse answer and emitted signal.

Picture (3) gives an example on an impulse response (upper part of the picture), as a function of time in seconds. Parameters of the present configuration are the following: Depth of source: 100 m; Depth of receiver: 245 m; Propagation distance: 6 km with a Mediterranean sound speed profile.



Picture (3): Example of impulse response, emitted and propagated signals.

Emitted signal may be every noise which can be characterized by its autocorrelation function. In order to clearly present our work, we take the example of a « bang », which belongs to a typical class of transient signal. This signal is also represented on picture (3) as a function of time in the middle of the picture. Picture (4) shows the autocorrelation function of this bang. The width of the autocorrelation function is about 20 ms.

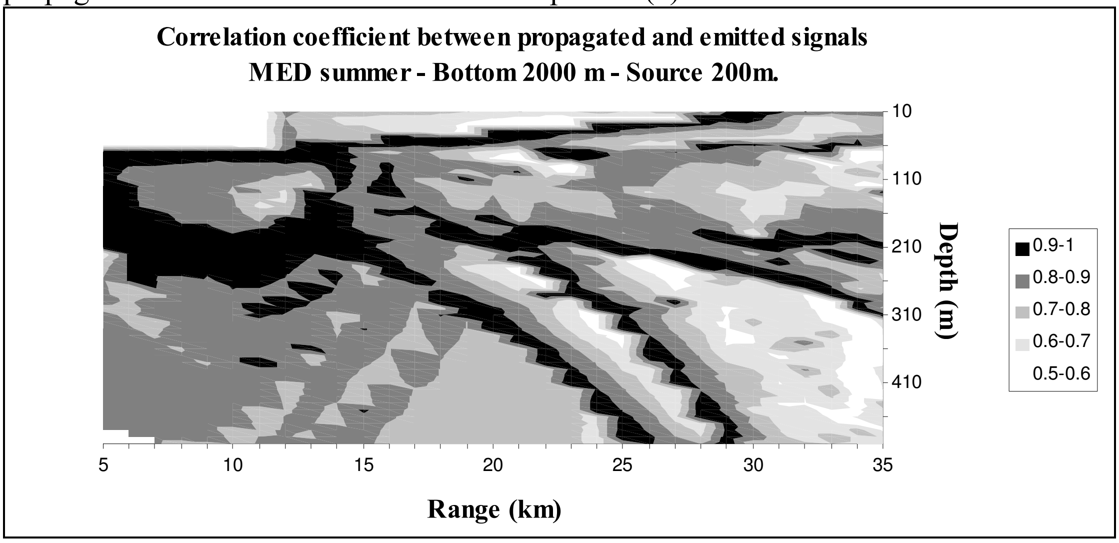


Picture (4): Autocorrelation function of emitted signal.

Then, last line of picture (3) corresponds to propagated signal.

4.2. Coherence between source and receiver signals

In order to evaluate differences between propagated and emitted signals and to try to characterize distorsion by the way of a unique parameter, we have determined coherence between them and evaluated their correlation coefficient as a function of depth and propagation distance. Results are shown on picture (5).

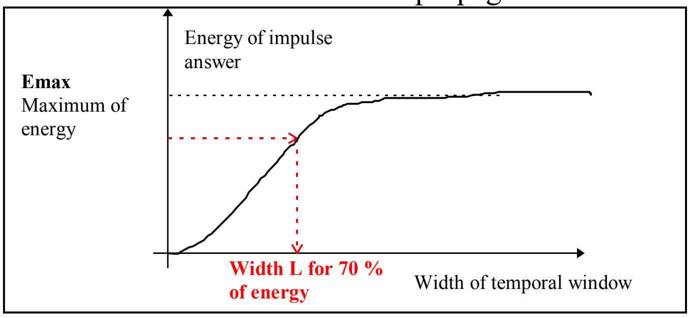


Picture (5): Correlation coefficient between propagated and emitted signals

Propagated signal have been studied with time-frequency analyzer well fitted to transient signals. Conclusions are that signals remain coherent and are not too disturbed in regard to the detectability assesment used by DCN (Navy), when their coefficient is above 0.8.

4.3. Necessity of the definition of a criterion to characterize propagated signal distortion

By the way of calculating propagated signal in each point of space and the correlation coefficient with emitted signal, it is then possible to obtain information about signal distortions due to propagation. But all this calculus are time consuming. So we tried to define a criterion to characterize distortion which doesn't need to evaluate propagated signal. It consists in the determination of the width of the time window which includes a defined percentage of the total amount of energy of impulse response as we can see on picture (6).

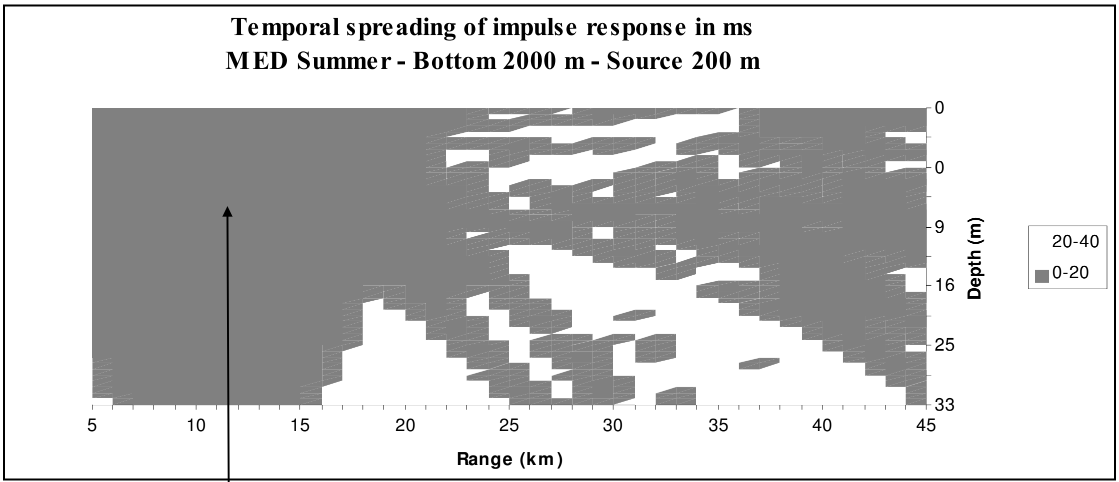


Picture (6): Energy and time width of of impulse response

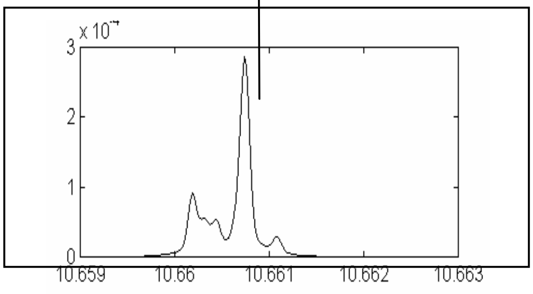
We studied width related to 10 % to 90 % of maximal energy. Finally, the value which is more correlated with coherence coefficient response is those relative to 70 %.

4.4. Time spreading of impulse response

Picture (7) shows results relative to time spreading of impulse response (i.e. width in ms of the time window presenting 70 % of energy) in case of a Mediterranean summer sound speed profile. Black areas are those where the time spreading of impulse response is less than 20 ms.

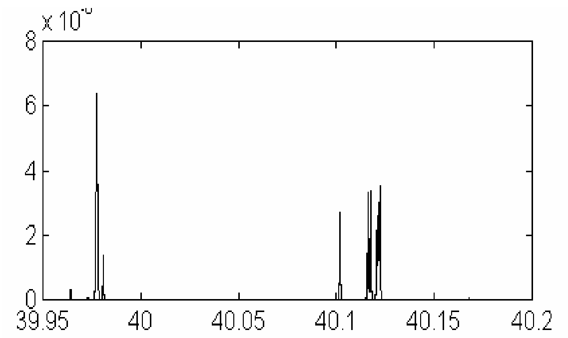


Picture (7): Temporal spreading of impulse response (in ms): less and above 20 ms.



When the width of impulse response is less 20 ms (width of autocorrelation function of emitted signal), the propagated signal remains coherent to emitted signal.
⇐ Energy of impulse response is concentrated.

When the time width of impulse response is higher than that of autocorrelation function of emitted signal, the propagated signal really differs from emitted one ⇒



5. CONCLUSIONS

We have performed calculus of impulse responses in several practical operational configurations [1] and constituted a data basis of impulse responses.
In order to characterize distortion of transient signal, we developped a program for reading this data basis of impulse responses, calculating propagated signal from impulse response and emitted one. Further more, we defined a criterion to evaluate the distortion of the signal. This one is based only on impulse response and is valid for any shape of source signal.
By the way, we can take into account these distorsions in sonar equations devoted to transient signals and give more precise information on the detectability of transient noises.

6. REFERENCES

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