Raw Data Generation of Maritime Scenes Using MOCEM V4 and PHYS-IQ V1

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Abstract— For many years, DGA MI — expertise center of the French MoD — has developed simulation tools for SAR surveillance applications. The GPU computing has recently opened new efficient ways for raw data simulation. The tools now have the capability to generate complex EM scenes like maritime ones, and therefore can be used for other applications than their initial purpose. The simulation of realistic raw data is crucial for advanced processing, including target imagery modes (SAR/ISAR). This paper focuses on opportunities offered by this set of tools, part of the French DGA simulator named SIROS — Simulation toolset for Imagery Radar and Ocean Surveillance — for studies and for tuning processing.

1. INTRODUCTION

The DGA — Delegate for Armament of French MoD — has been for many years developing [1, 2] and improving a simulator named SIROS — Simulation toolset for Imagery Radar and Ocean Surveillance. This paper presents and illustrates the components of this simulator used for simulation of maritime applications. In maritime scenes, we have to take into account at least:

- one or several ships,
- the sea surface,
- interactions between ship(s) and the sea surface.

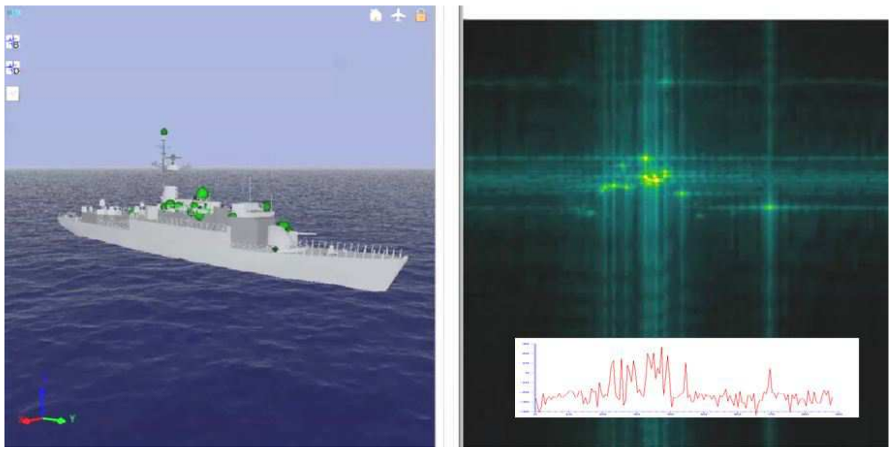
In a first step, we will focus on the main components of the EM modeling considering the interest and the expected use of the simulation. We focus here on the following tools: MOCEM and PHYS-IQ. These applications have been developed under DGA contracts by Alyotech technologies, a French SME.

2. SIMULATION GOALS

Even if the subject is not here to explain and detail the benefits and motivations of simulation, we must not forget that every simulation is built within a particular interest. A simulator has to render adequately a number of radar signal properties. Simulator must be driven by principles and efficient methods in order to produce "realistic enough" products required by the signal processing planned to be use. In SIROS, we focus on coherent radar processing for surveillance systems including SAR and ISAR imagery but not only. As we work in the field of military applications that include small target detection and target classification, we are highly interested in high resolution (1 m or less). We would like also be able to address radar applications in a larger field, from coastal or naval radars to airborne radars.

3. SHIP EM SIGNATURE WITH MOCEM V4

Our need is to be able to produce high resolution and multi-channel signals and images (polarimetry, interferometry). Since the very beginning, we have chosen, for target modeling, an innovative approach consisting of building directly, from an analysis of the geometry, a 3D EM scatterering model. This approach has many advantages, such as an accurate localization of points in 3D and a very fast computation time. The associated tool is MOCEM, whose original principles have been presented in several publications [3, 4]. As illustrated below, from a rough geometry (internet provider) and some improvements in CAD model in order to add common missing parts, such as barriers, we can build a 3D EM model. As we consider several types of effects, the 3D model is not made of isotropic scatterers but points associated to a level and a directivity function corresponding to the nature of the EM effect. A rectangular plate is the product of two sinc directivity function, while a dihedral is only directive across the internal edge and a trihedral is represented as a point with a smooth diagram, quite isotropic. Based on the nearest known canonic configurations, directivity function is obviously approximated. Benefits of such modelisation are great because we get a very compact model in 3D and it is easy also to take into account surfaces less as plane as their CAD model and use a "dielectric and roughness coefficient" to reduce specular effects and enlarge visibility of contributors. We can also easily take into account a diffuse effect of surface in order to generate on complex surfaces, not detailed in CAD model, a skin level and a texture to render a spatial distribution. From this model, it is easy to localize contributors in range and Doppler according to the relative motions between ship and radar. GPU computation is fundamental to do that very efficiently. Details have been explained in [13].



Green spheres of the 3D EM model surimposed on CAD model *range (x-axis)-doppler view and corresponding signal range profile*

4. THE HYDRO SEA MODEL USING MERCUDA

MOCEM and PHYS-IQ share the same model of the sea surface. MERCUDA, a 3D animated model developed by Alyotech. This model is used in MOCEM and PHYS-IQ for radar purposes, but it is also used as presented in [8] for IR applications.

The hydro model is based on:

- a 2D wave power spectrum based on Jonswap formulation and its Elfouhaily [21] improved version;
- spatial frequencies computed from temporal frequencies (ergodic hypothesis) by use of the appropriate dispersion relationship;
- time sample realizations of the mean spectrum, simulated through a complex multiplicative Gaussian noise.

The EM computation requires high resolution on the surface, but another constraint is to handle large area needed for applications in order to cover the intersection of the radar beam and the sea surface.

An FFT approach is used, but using two separated grids:

- a large grid, that can support large scale phenomena such as swell and observation;
- a smaller local grid, that will be used to represent EM contribution of the gravity waves. This scale is sampled at 5λ.

In order to introduce a nonlinear sea that takes into account the dissymmetry of the waves, the model also uses the "Choppy wave Model" [10].

The hydro model is used as a support of all scene computations. It holds:

- Radar signal computation, described more thoroughly in PHYS-IQ model;
- ship motion computation in MOCEM and also in PHYS-IQ.

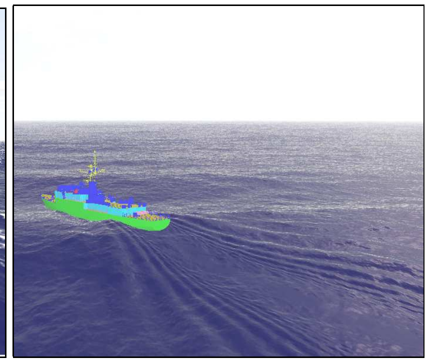
The first use of the hydro model is to compute ship motions which have a great impact on the Doppler properties of the signal and are used on SAR/ISAR focusing process.

The hydro model has other applications:

- Shadowing effects on the ship by the sea surface under the floating line, but also from higher waves, especially when a swell is present and in particular at low-grazing angles;
- MOCEM software computes, with some approximations, the EM coupling between the ship and the sea surface;
- influence of the ship itself on the surface with its wake (kelvin and narrow V included in MOCEM as illustrated above) but also with its stem wave (not yet included).


Wind 5 m/s


Wind 15 m/s


wake behind ship

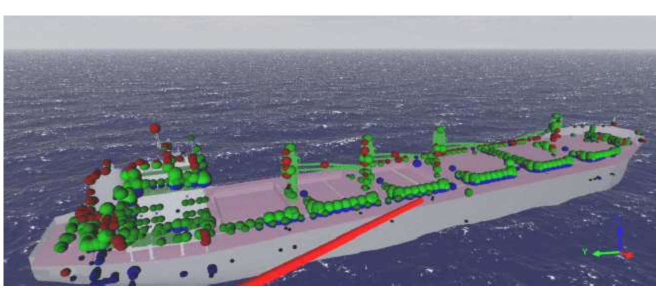
5. THE SEA CLUTTER WITH PHYS-IQ V1

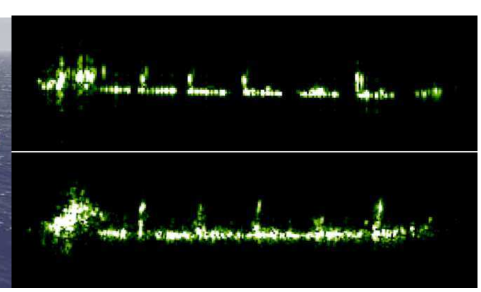
PHYS-IQ [7, 10] is a specific development to compute signal from the dynamic sea model detailled above. It is a great challenge because this computation needs a large sea surface in order to cover the radar antenna beam and a sufficiently fine sampling step to correctly hold the gravity wave spectrum. For capillarity waves, we take into account the slopes, resulting of dynamic sea, to modulate the 5λ patch where Braggs effects are computed. For low sea states ($SS < 4$) and except in very grazing angles, the sigma0 variation is quite similar to GIT [9] and GOSSA model [12]. We can also observe that the Doppler spectrum of the sea clutter is well represented as well as we can observe a K distribution, similar to measurements [17, 18, 20]. We can also render the Doppler shift and its spreading [16]. It remains therefore difficult to validate these points considering the relatively scarce data available for uncertainties on the ground truth associated to available measurements.

PHYS-IQ also takes into account breaking waves that enforce the Bragg contribution and also create discrete events in the signal called "spikes" [19]. PHYS-IQ implements a sophisticated crest detector in order to locate and characterize the breaking phenomenon when it appears (a vertical acceleration is measured on the surface). Spike signatures which have been pre-computed are then added to the signal with Doppler properties associated to the local properties of the surface. Works are still under way under DGA contract with ONERA and THALES to conclude about the representativeness of sea clutter signal for sea state upper 3, and according to the wind direction form the radar.

6. VALIDATION WORKS

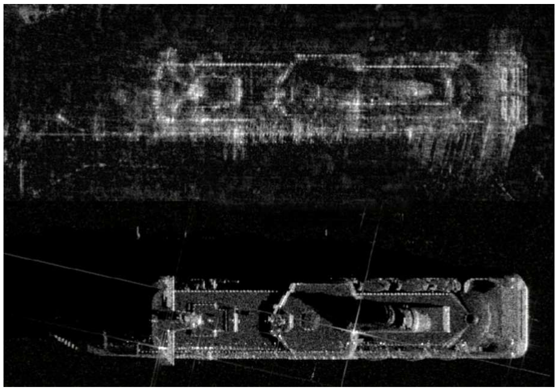
In [11], Alyotech and Thales have compared simulated raw data form MOCEM with some real acquisitions with ship in motion.


3D EM MOCEM MODEL

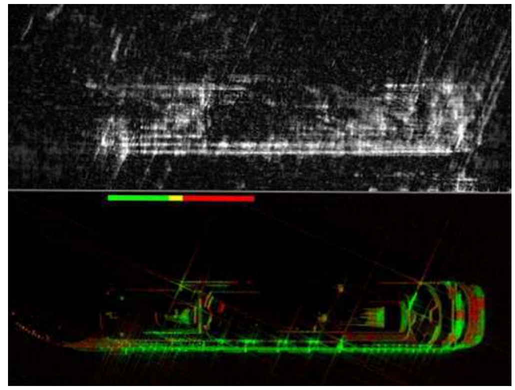

up SAR simulated image , low Thales real

Several validation works have been conducted for each component (target, clutter) but also considering complex scenes. In [5, 6, 14], simulated image of fixed ship has been compared to

FFI (Norway MoD) acquisitions done with SELEX PicoSAR radar, not only visually, but also according to several metrics. The SSIM metric has been adapted by ONERA to radar applications. As illustrated below, its shows promising results that pave the way for target recognition using 3D models of the ships. Conducted works also show that rough EM parameters used in MOCEM are enough for image metrics. Of course a well-proportioned 3D model is needed but with nothing comparable in term of accuracy of the CAD model usually needed by RCS codes and also in terms of computation time.

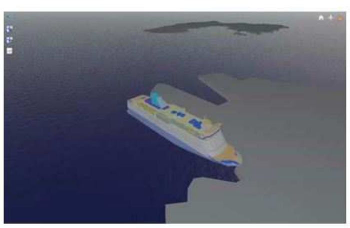


FFI PicoSAR image (up) versus MOCEM (down) On Stena Saga cruise ship

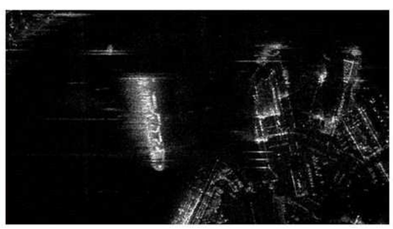


Similarity Indicator applied to compare Crown of Scandinavia ship image with Mocem simulation

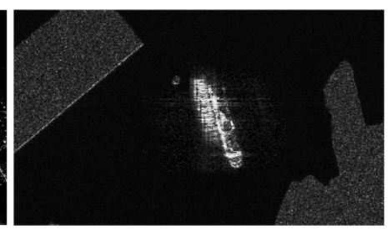
In [15], DGA and FFI have simulated a real scene with a moving ship in Oslo harbor. It is interesting to note that ship motion takes into account in the simulation creates delocalization phenomena as well as seen in SAR measured image. We can also observe that coupling with the sea, create an unfocusing phenomena that is also reproduced in simulation.



Simulation view



FFI PicoSAR image of ship leaving Oslo harbor



simulated image generated with MOCEM

7. APPLICATIONS AND FUTURE WORKS

New applications are also currently developed. A first version of a maritime patrol simulator has been assembled. This simulation, done by ONERA under DGA contract, uses precomputed PHYS-IQ sea clutter, adds, quite in real time MOCEM target and processes detection and tracking of a target in high sea clutter in order to display result on PPI to operator.

Futures works are planned to take into account coastal effect as a multi-parameter function driving a "fetch" value in order to separate the instantaneous effect of the wind on the sea surface and its longer time effect that generates the gravity waves, scales and phenomena that have already been separated in the PHYS-IQ V1 model.

8. CONCLUSION

The presented tools appear to be very helpful for estimating radar detection performances. The signal computation, done in GPU, is a disruptive step. Signal generation opens to apply "real" processing and observe "real" performance on fully control and complex scenes. This is a great progress when considering small targets and high sea states where the signal distribution has a great impact on detection threshold driven by adaptive false alarm regulation. Moreover, the multi-point model for the target also offers a more realistic signal distribution than a Swerling law. Taking into account shadowing of the target in high sea state or swell condition is also a better approach to recreate realistic situations. We have now a toolset that can be used from the global performance prediction to most advanced processing of targets (s.a. ISAR).

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