Modeling and simulating GNSS signal for sea transport and maritime environment.

Arnaud Coatanhay and Ali Khenchaf Laboratoire E3I2- EA 3876,
Ecole Nationale Supérieure des Ingénieurs des Etudes et Techniques d'Armement
29806 Brest Cedex 09, France
Email: arnaud.coatanhay@ensieta.fr
Telephone: (33) 2 98 34 88 09
Fax: (33) 2 98 34 87 50

I. Introduction

In maritime environments, the GNSS systems (GPS, GALILEO,...) are well known to be increasingly important for military and commercial ship positionning. As a matter of fact, the main challenge consists in providing a precise, accurate and reliable positioning system for real time sea traffic surveillance, for shipping containers management, for maritime safety (avoiding shipwreck system), for search and rescue,... However, due the multiple electromagnetic reflection from the sea surface, the maritime environement is very hostile to signal propagation and the GNSS signal received above the sea surface could be significantly perturbated with the electromagnetic contributions from the sea, see figures 1 and 2.

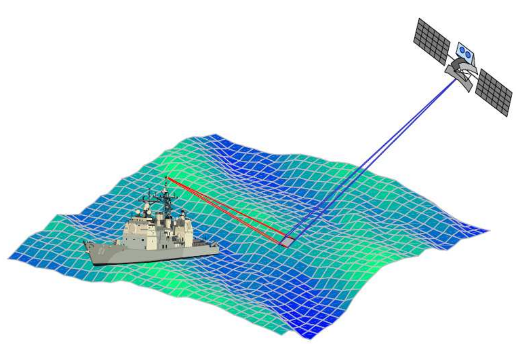


Fig. 1. Influence of the GNSS signal from the sea surface upon sea transport.

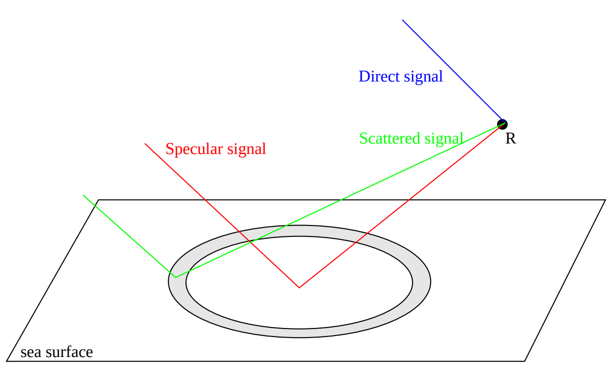
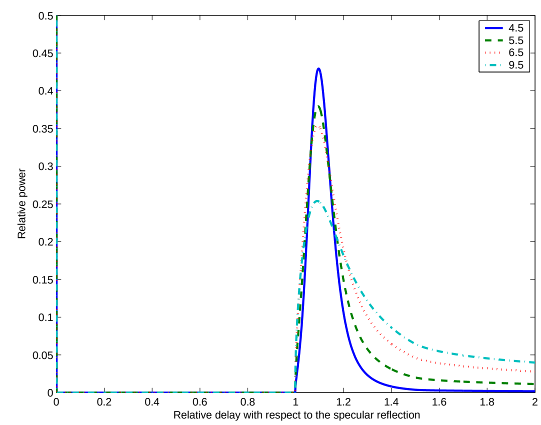


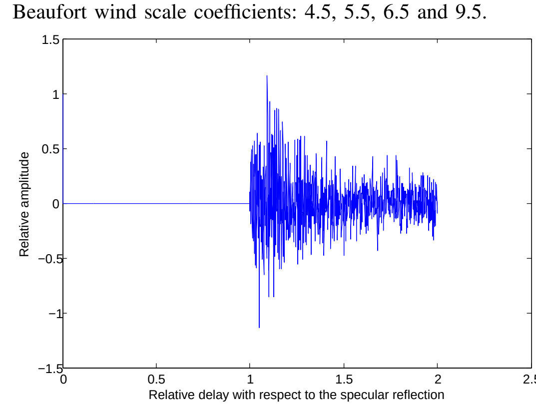
Fig. 2. Different delay associated to each contribution from the sea surface.

II. State of art

For several years, the influence of the ocean surface upon the GNSS signals has been profusely studied by various scientific teams in the world [1], [2], [3], [4]. Actually, these scientific publications highlight the fact that the GNSS signal scattered from the sea, which is considered as a random rough surface, is greatly influenced by the state of the sea and the wind direction, see figure 3. In a way, a GNSS receiver could be considered as a remote sensing device for ocean monitoring.



(a) Power density (incoherent summation) with different Beaufort wind scale coefficients: 4.5, 5.5, 6.5 and 9.5.



(b) Amplitude distribution (summation of elementary contribution with random phase)

Fig. 3. Numerical simulation of the GPS signal (impulse response) received above sea surface at 5km height.

Nevertheless, the most part of the scientific literature concerning the GNSS signals in maritime environments is dedicated to airborne or satellite GNSS reveiver systems. The observers are hardly ever supposed to be in the vicinity of the ocean surface. In these conditions, the electromagnetic interactions with the ocean surface can be modeled using an asymptotic approach, for intance the Kirchhoff approximation, and the ocean is then only described by stationary statistical properties (slope probability density function,...). Anyway, this kind of approach is not really adapted to the sea transport and common maritime activity.

III. Current research

Very recently, we develop a reliable algorithm to estimate the signal scattered (in bistatic configurations) by a deterministic sea surface generated from a realistic sea spectrum (see figure 4) [5].

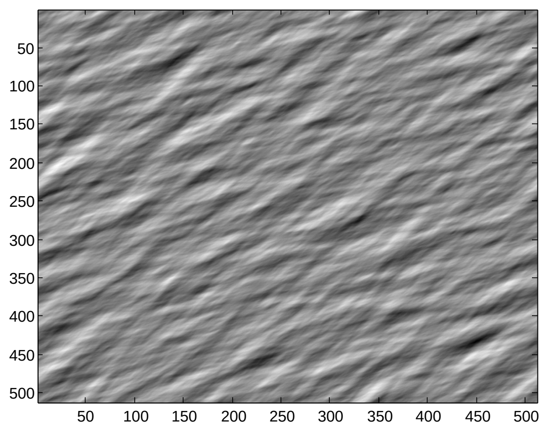


Fig. 4. Deterministic sea surface obtained by a numerical simulation based on the Elfouhaily sea spectrum.

Using this approach, we can simulate the GNSS signals where the observer is a few dozen meters above the ocean surface. With these assumptions, the roughness of the ocean surface cannot be reduced to a simple statistical model and the actual movement of the sea must be taken into account, see figures 5 and 6.

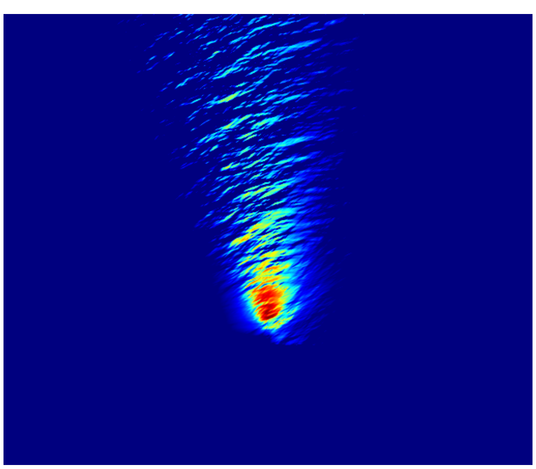


Fig. 5. Scattering of a GPS signal by the deterministic sea surface at 10 m height.

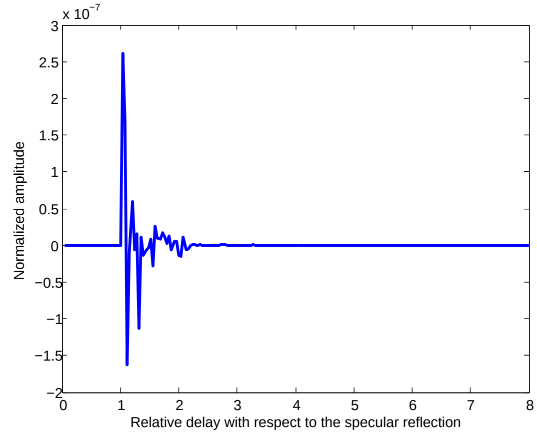


Fig. 6. Simulation of a GPS signal received at 10 m aboce the deterministic sea surface.

Our numerical results point out the influence of the sea movement upon the scattered GNSS signals quite near above the surface. And, our algorithm could be of a great interest to evaluate the reliability of GNSS (GPS and GALILEO) receiver systems in a maritime environment with various sea states and wind conditions.

IV. Challenges and prospects

Anyway, modeling and simulating GNSS signal for sea transport and maritime environment remains a challenging issue for our research laboratory. Indeed, for small ship (fishing, sailing,...) or for search and rescue, the GNSS receiver cannot be supposed a dozen meters above the ocean surface. So, in many cases, modelling the GNSS signal still requires new theoretical approaches to estimate the influence of the sea very near the surface.

In the same way, coastal or shore environments (with portainer cranes for example) could lead to very complex scattering problems that require specific developments.

As a conclusion, we must mention that our laboratory is an active member of the “GALILEOCEAN” project. This project, recognized by the “Pôle de compétitivité mer Bretagne”, is dedicated to the evaluatation of the future european positioning system (GALILEO) in maritime environment.

References

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