Evaluating GNSS Signals for Passive Local Sea State Monitoring

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I. INTRODUCTION

Passive remote sensing based upon electromagnetic sources of opportunity provides the promise of a useful tool for monitoring natural environments and especially marine environments [1], [2], [3]. In this context, the Global Navigation Satellite Systems GNSS (GPS,...) appear as one of the most relevant solution since the emitted signals (in L-Band) are reliable, available all over the world, deterministic and perfectly known.

In this study, we propose to analyze and to assess the possibility of sensing the sea wave movements using the reflected L-Band signals (see figure 1). Thus, based upon numerical simulations of the electromagnetic scattered field (Method of Moments), we investigate the connections between a time evolving surface and the features in the time-frequency (TF) domain of the signal scattered by this surface (using Wigner-Ville transform). The idea is to take advantage of these representations to extract from Doppler and micro-Doppler signatures the oceanographic parameters of interest.

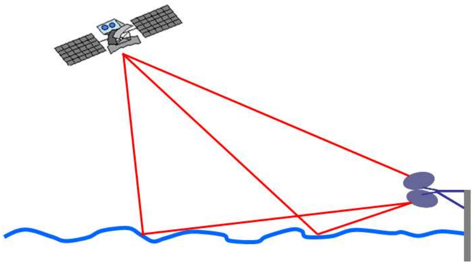

Fig. 1. Experimental setup.

II. TIME-FREQUENCY FEATURE ANALYSIS FOR CANONICAL SURFACES

As first step, our study qualitatively compare the time-frequency features of the signals reflected from different canonical moving sea surfaces (typically a sinusoid or the sum of several sinusoids). From a simple sinusoidal surface, we noted that the obtained time-frequency signatures can be mainly interpreted as the contributions of the Doppler frequency associated with the specular points related to the surface.

In this extended abstract we propose to focus on a particular simulation which consists in considering a surface made of three sinusoids. The sea surface being considered as a dispersive medium, to simulate as closely as possible the sea wave (gravity and capillary waves), the three sinusoids have different wavelength, amplitude and velocity. The first sinusoid (large-scale) uses parameters corresponding to Beaufort scale 3. The two others added sinusoids (small-scale) are fixed so that the wavelength is respectively divided by 3 and 5, the amplitude is divided by 2 and 5 and the velocity is multiplied by 1.25 and 1.6. The Time-Frequency representation (TFR) obtained for the considered configuration is presented in Figure 2.

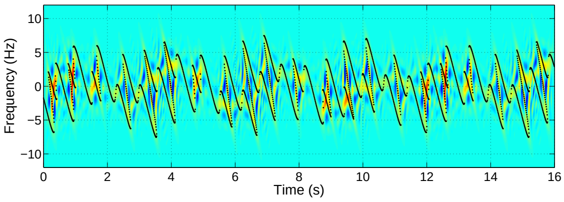

Fig. 2. TF representation of the signal reflected from a surface made of the sum of three sinusoids with different velocities. The Doppler frequency due to the specular points is added (black dots).

It worths to notice that for given moments (Between $t = 2.13$s and $t = 2.39$s for instance), the Doppler curve has a unique contribution. On the opposite, at other moments, Doppler curve is the superposition of several contributions. Figures 3 and 4 show the shape of the sea surface with the corresponding specular points at several successive times within these two periods.

Between $t = 2.13$s and $t = 2.39$s there is only one specular point inducing a Doppler curve that appears to be oscillating. In Figure 3, we can see that in a first step ($t = 2.13$s/2.14s) the specular point moves away from the receiver with a speed greater than the global sea movement. Then Doppler frequency is negative and lower than that obtained for a harmonic sea surface. In a second step ($t = 2.25$s/2.26s) the specular point locally tends to move closer to the receiver. The Doppler frequency increases and even reaches a positive maximum. In the last step ($t = 2.38$s/2.39s), the specular point speeds up the shift to the right, and the Doppler frequency returns to the negative domain. This oscillation cannot be explained by a global translation of the sea surface but must be seen as the consequence of the local sea surface deformations related to dispersion.

Between $t = 6.21$s and $t = 6.26$s, the number of specular points changes over time. Figure 4 shows that there is only one specular point from $t = 6.21$s to $t = 6.22$s. Then, a new specular point appears at $t = 6.23$s. Finally this new point forks into two new specular points. One of them moves closer

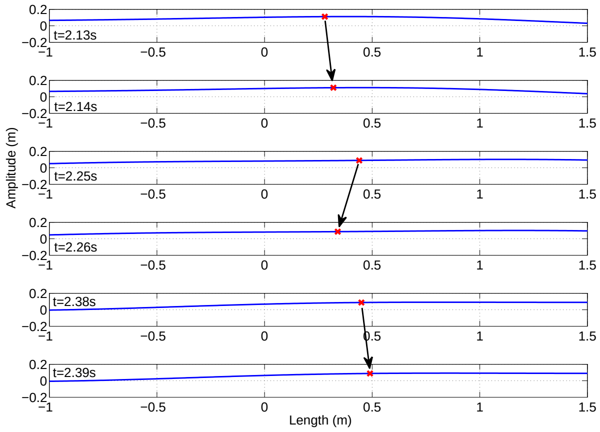

Fig. 3. Three sets of two (zoom) successive surfaces (blue line) and the evolving positions (shown by the black arrows) of the specular point (red star).

(locally) to the observer and the other moves away.

In fact, the dispersion and the local deformations of the sea surface periodically lead to the disappearance of one or more specular points.

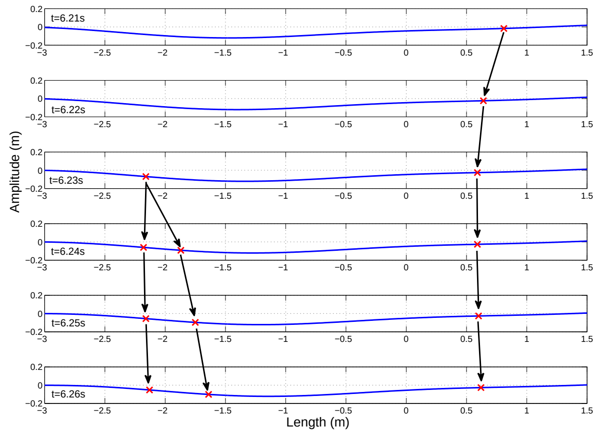

Fig. 4. Example showing (zoom) six successive surface shapes (blue line) and the evolving positions (shown by the black arrow) of the specular points (red star).

III. TF FEATURES FOR REALISTIC SEA SURFACES

Figures 5 shows the TFR obtained from the signal reflected from sea surfaces with respectively Beaufort scale 2, 3 and 4. For the sea surface with Beaufort scale 2, from the receiver point of view, the surface is almost flat which is why the time frequency feature is mainly focused upon the zero-Doppler frequency line: only small oscillations are observed (micro-Doppler phenomena).

For stronger sea states, more complex features appear and can be compared with those obtained for canonical surfaces.

In the same way as for canonical sinusoidal surfaces, we can compute the Doppler evolution of the many specular points related to this realistic sea surface. Figure 6 shows the corresponding TF of the reflected signal (with Beaufort scale= 2.5). It also shows the Doppler evolutions, according to the time, of the specular points.

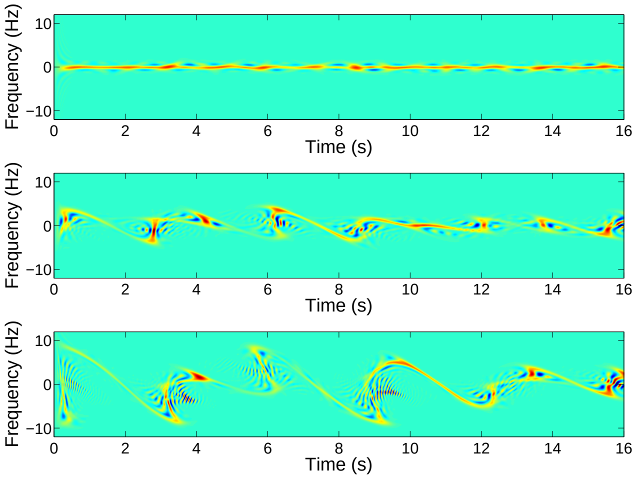

Fig. 5. TF representation of the reflected signals from sea surface with Beaufort scales (top to buttom) 2, 3, 4.

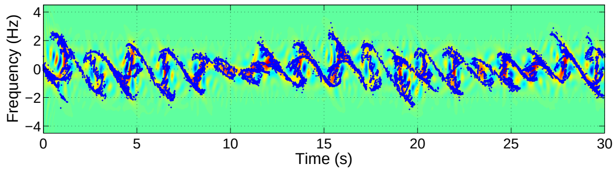

Fig. 6. TF representation of the reflected signal from a sea surface. Superposed with blue dots the Doppler frequency hoghlight the specular points positions according to the time.

IV. CONCLUSION

In this work, the features obtained in the Time-Frequency (TF) domain due to L-band signals reflected from moving sea surfaces are described and interpreted. It has been shown that the signatures in the TF domain are linked to physical phenomena that occur in the considered measurement systems. The main features can be explained by the motion of the specular points. However the multiple interactions also induce some features but with a lower extent. Finally, one can note that future works will deal with the estimation of oceanographic parameters from these TF features.

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