Simulations of the Altimetric Signal Intensity from *3D*-Layered Air/Snow/Sea-Ice Rough Interfaces

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Abstract

Remote sensing of the sea-ice thickness is one of the main objectives of the Ku-band radar altimeter SIRAL - CRYOSAT II mission. On the one hand, sea-ice thickness is derived from the measurement of the height of the freeboard of the floes, and based on isostasy, assuming that the density of the water, the ice, as well as the snow, are known. On the other hand even if the snow load is known, the penetration of the electromagnetic waves into the snow strongly depends on the electrical and geophysical characteristics of the snow layer (density, temperature, permittivity, roughness). The remote sensing of the snow layer thickness (SLT) remains a real challenge and will be useful to correct the snow load for converting freeboard measurements from satellite altimetry into sea-ice thickness. If the dual frequency radar altimetry data show a good potential for remote sensing of snow and more generally of penetrating media [1], providing the SLT from Ku band data alone is highly motivated by the orbit of CRYOSAT designed to cover the entire Arctic.

In this framework, a theoretical study, based on a *3D* modelling of the scattering of electromagnetic waves by a stratified medium at normal incidence has been carried out in order to investigate and quantify the capacity of snow and ice penetration of Ku-band waves.

The stratified medium is modelled as a snow layer considered as a stack of 2 sub-layers and the boundary layer at the bottom represented by a semi-infinite layer of ice-sea as shown on the figure 1.

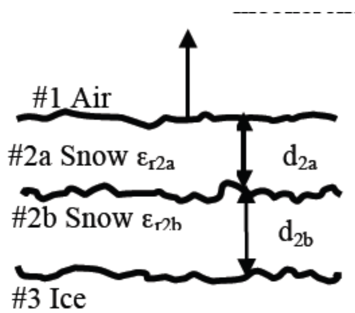

Figure 1 : structure of the stratified medium. The bottom is represented by a semi-infinite layer of sea-ice

The roughness of each interface is taken into account and the small slope approximation (SSA) is used to determine the coherent and incoherent components of the scattered intensity [2-4]. It is demonstrated that the coherent intensity is the the specular direction but it depends on the rms-roughness heights and does not depends on the shape of the correlation function. The incoherent intensity depends even on the rms-roughness heights, but also on the shape of the correlation function.

Several simulations have been conducted by varying the permittivity, thickness and roughness of each interface [5-6]. The 3 interfaces are random processes with Gaussian autocorrelation functions with zero mean values.

The main conclusion is that the backscattered signal from the stratified medium is strongly related to the dielectric characteristics. It can vary significantly even if the variations of the stratified medium are small. This is an important result to be kept in mind when attempting the signal inversion.

In addition , another similar study based on a *2D* modelling of the scattering of electromagnetic waves by the same stratified medium at normal incidence and simulations in the same conditions have been previously conducted [7]. The roughness of each interface was also taken into account and the first-order small perturbation method (SPM) was used to determine the coherent and incoherent components of the scattered intensity. Results from those two studies are also compared at the end.

References

1. Legresy B., F. Papa, F. Rémy, G. Vinay, M. Van den Bosch and O.Z. Zanife (2005) “ENVISAT Radar Altimeter measurements over continental surfaces and ice caps using the Ice2 retracking algorithm” *Remote Sensing of the Environment.* 95. 150-163.

2. R.T. Tonboe, L.T.Pedersen and C. Haas.(2009)"Tonboe et al, Simulation of satellite radar altimeter sea ice thickness retrieval uncertainty," *The Cryosphere Discuss. 3, 513–559*.

3. F.T. Ulaby, R.K. Moore and A.K. Fung, (1986).“Microwave dielectric properties of natural earth materials”, *Microwave Remote Sensing, vol. III, from Theory to Applications*, 2017-2027, Artech House, Norwood.

4. Z.A. Hussein, Y. Kuga, A. Ishimaru, S. Jaruwatanadilok, K. Pak, (2004). "Angular and frequency correlation for sea-ice thickness retrieval" *Geoscience and Remote Sensing Symposium Proceedings IGARSS'04 Anchorage, USA*, vol. 5, 3012-3017.

5. Voronovich, G., *Wave Scattering from Rough Surfaces*, Springer, Berlin, 1994.

6. Berrouk A., Dusséaux R., Afifi S., "Electromagnetic wave scattering from rough layered interfaces: analysis with the small perturbation method and the small slope approximation" *Progress In Electromagnetics Research B*, Vol. 57, 177-190, 2014.

7. Dusséaux R., Afifi S., Dechambre M., Legresy B., « Simulations of the altimetric signal intensity from 2D layered air/snow/sea-ice rough interfaces » *Proceedings of '20 Years of Progress in Radar Altimetry'. ESA SP-710*, Venice, Italy , 2012.