

# An electromagnetic bistatic scattering model for GNSS sea surfactant monitoring

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## BIOGRAPHY

**Ferdinando Nunziata** was born in Italy in 1982. He received the BS and MS degrees (summa cum laude) and the European Ph.D. (Curriculum Electromagnetic fields) in Telecommunications Engineering at the Università degli Studi di Napoli Parthenope, Napoli, Italy in 2003, 2005 and 2008, respectively. He received the Best Remote Sensing Thesis Award by the IEEE GRS South Italy Chapter and the “Premio Sebetia-Ter” (targa d'argento Presidente della Repubblica), in 2003 and 2009, respectively. He has been lecturer at National Oceanography Centre of Southampton (NOCS), Southampton, UK, Université catholique de Louvain (UCL), Louvain-la-Neuve, Belgium, Helsinki University of Technology (TKK), Espoo, Finland, The City College of New York, NY, USA, Politecnico di Torino, Torino, Italy. His main research interests deal with electromagnetic modeling, single and multi-polarization sea surface scattering, radar polarimetry and SAR sea oil slick monitoring. He is chairman of the Università degli Studi di Napoli Parthenope IEEE Student Branch. He was chairman at IEEE IGARSS 2008 Conference, Boston, MA, USA. He is reviewer for IEEE Geoscience and Remote Sensing Letter, Remote Sensing of Environment, Progress in Electromagnetic Research Symposium.

**Maurizio Migliaccio** is full professor of electromagnetic fields at Università degli Studi di Napoli Parthenope. He lectured at international schools and at Italian and international Universities on various topics of microwave remote sensing. His current remote sensing research activities deal with electromagnetic modeling, oil spills SAR monitoring, wind scatterometer data inversion, fire detection, spatial resolution enhancement of radiometric data, optimum sampling of stochastic electromagnetic fields, electromagnetic

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## ABSTRACT

This study is aimed at developing an electromagnetic scattering model to investigate the capability of Global Navigation Satellite System (GNSS) signal as “signal of opportunity” for sea surfactant monitoring. According to the proposed model both the slick-free and slick-covered bistatic Normalized Radar Cross Section (NRCS) are evaluated, which can be used to simulate the GNSS-R received signal due to slick-free and slick-covered sea surfaces.

## INTRODUCTION

The presence of surfactants over the sea surface can be related to both natural phenomena, e.g. oil seepages (which are related to oil deposits), biogenic slicks, and anthropogenic phenomena, e.g. accidental and illegal oil discharges [1].

To provide a synoptic and effective sea surfactant monitoring, satellite microwave remote sensing techniques, due to their wide-area coverage and all-weather day and night capabilities, are widely employed. However, the major drawback of these satellite-based techniques is their low revisit time which does not meet the time-effective requirements of some critical applications such as sea surfactant monitoring [2].

Within this context, the novelty of this study consists of proposing the GNSS for sea surfactant

monitoring. The combination of GNSS transmitter and a delay-doppler receiver with a down-looking antenna can be regarded as a bistatic radar system which can be used for remote sensing of sea surface (GNSS-Reflectometry) [3]. As a matter of fact its peculiarities are:

- all-weather day and night capability (microwave L-band system);
- continuous and global monitoring (several operating: Global Positioning System (GPS), to some extent, GLObal NAVigation Satellite System (GLONASS); and planned satellites: the European Satellite Navigation System (Galileo));
- source of opportunity (only a receiver system with a down-looking antenna and a small delay-doppler receiver, is needed).

## METHODOLOGY

Dealing with navigation purposes, the direct signal, which is simply proportional to the Right Hand Circular (RHC) polarized transmitted one, is considered. In the GNSS classical receiver, the direct signal is basically cross-correlated with a locally-generated replica for various time delays (de-spreading). The maximum correlation indicates the time-delay which makes the two codes aligned and it is related to the range between the transmitter and receiver.

Dealing with GNSS-R purposes, the signal of interest is the one scattered off the sea surface. As a matter of fact, the relatively low power and remoteness of the GNSS transmitters, together with the sea state conditions, make the scattered received signal due to an area around a nominal specular point on the mean sea surface (the so-called glistening zone, see Fig.1) [4].

The quasi-specular reflections, due to the long-scale sea surface waves, are the main scattering mechanism for the near-specular-point area. On the boundary of the glistening zone, the power scattered toward the receiver decreases and the Bragg resonant scattering from small-scale surface components starts playing a role. As a matter of fact, the cross-correlation between the signal scattered off the sea surface and the locally-generated replica would be a complicated function of the time-delay experienced by the scattered signal, the doppler-delay related both to the transmitter/receiver motions and to the long waves orbital motions, the glistening zone, and the antenna footprint.

The glistening zone, which can be considered as the area formed by the local reflection points whose

received power is above the noise floor over the duration of the cross-correlation process, is closely related to the sea surface roughness and to the viewing geometry, see Fig.1 [5].

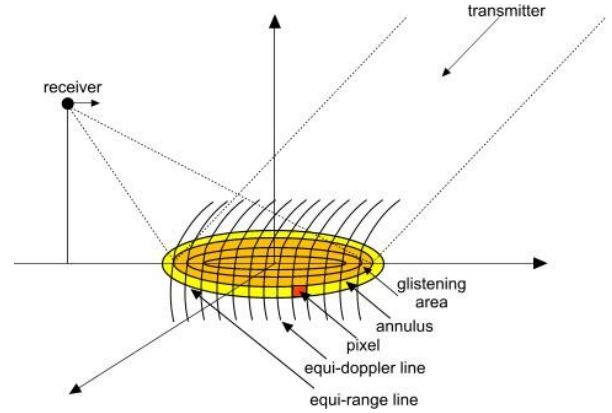


Fig. 1 GNSS-R geometry

Following this rationale and considering that the presence of a surfactant over the sea surface has been shown to affect both the small-scale sea surface, by reducing the short-wave spectral energy, and the long-scale one, by modifying the slope probability density function (pdf) [6], in this study, the capability of GNSS-R for observing sea surfactant will be investigated by developing a proper bistatic electromagnetic scattering model.

Accordingly, the first fundamental step consists of developing an electromagnetic model for understanding the bistatic slick-free and slick-covered sea surface GNSS scattering. As a matter of fact, in this study, an electromagnetic model to evaluate the slick-free and slick-covered Normalized Radar Cross Section (NRCS), is developed. The signal scattered off the slick-free sea surface is evaluated by using the bistatic two-scale Boundary Perturbation Model (BPM) which, being a two-scale model, allows tacking into account also off-specular scattering mechanisms and, therefore, polarization effects [6].

According to BPM, the scattered NRCS is given by the sum of a zero order and a first order term [6]:

$$\sigma_{rt}^o = \sigma_{rt0}^o + \sigma_{rt1}^o \quad (1)$$

where, the zero order term is given by the Physic Optic (PO) solution and takes mainly into account the scattering due to the long wave structure. The first order term, which can be meant as an average of the Small Perturbation Model (SPM) result over the large scale slope, takes into account the scattering due the ripples along the long waves [6].

The sea surface is described by using the Université catholique de Louvain (UCL) sea surface spectrum,  $S$ , which is a three-parameters function able to describe both fully and non-fully developed sea state conditions, which is completely specified once the friction velocity  $u_*$ , the fetch  $x$ , the significant slope  $s$ , and the peak wavenumber  $K_o$ , are provided [7].

To evaluate the signal scattered off the slick-covered sea surface a damping model which, taking into account both the surfactant rheological parameters and the wind speed, is able to describe the effects of a sea surfactant on the whole sea surface spectrum and on the slope probability density function (pdf), has been developed. According to the above described model the slick-covered sea surface spectrum,  $S_c(\cdot)$ , is obtained by the slick-free one by evaluating it at a lower friction velocity ( $u_{*c}$ ) and then reducing it by using the Marangoni damping viscous coefficient,  $C$ , which depends on the rheological slick parameters [6]:

$$S_c(K, x, s, K_o, u_{*c}, |E|, \phi) = \frac{S(K, x, s, K_o, u_*)}{C(K, |E|, \phi)} \quad (2)$$

It must be noted that under fully developed sea state conditions, the presence of a surface slick affects the whole wavenumber spectrum, since the wind dependence of both the peak wavenumber and the significant slope. The surface slick, reducing the sea surface spectrum intensity and the friction velocity, affects also the slope pdf by modifying the slope variances and the skewness coefficients.

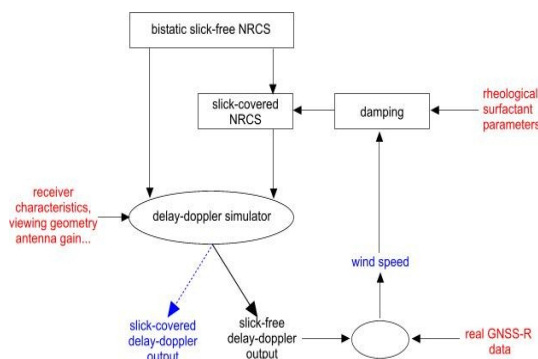


Fig. 2 Processing chain

Once the model to evaluate the slick-free and slick-covered NRCS has been implemented, a more complex block scheme, which allows evaluating the delay-doppler slick-free and slick-covered GNSS-R signal can be implemented according to the

guidelines witnessed in Fig.2.

According to the processing chain described in Fig.2, a delay-doppler signal simulator can be implemented which, by using the previously described scattering model, is able to simulate the GNSS-R received signal in case of slick-free and slick-covered sea surface and for different rheological slick parameters and viewing geometries. An extra output of this processing chain is the wind speed, which can be used, beyond the purposes of this study, for wind retrieval purposes.

## REFERENCES

- [1] A. Delilah, "Marine Oil Pollution: Technologies and Technologies for Detection and Early Warning European Commission JRC report", EUR 20231 EN, 2002.
- [2] M. F. Fingas and C. E. Brown, "Review of oil spill remote sensing," Spill Sci. Technol. Bull., vol. 4, no. 4, pp. 199–208, 1997.
- [3] O. Nogués-Correig, E.C. Galí, J.S. Campderrós, and A. Rius, "A GPS-Reflections Receiver That Computes Doppler/Delay Maps in Real Time," IEEE Trans. Geosci. Remote Sens., vol. 45, no. 1, pp. 156–175, 2007.
- [4] V.U. Zavorotny and A.G. Voronovich, "Scattering of GPS Signals from the Ocean with Wind Remote Sensing Application," IEEE Trans. Geosci. Remote Sens., vol. 38, no. 2, pp. 951–964, Jan. 2000.
- [5] C. Zuffada, A. Fung, J. Parker, M. Okolicanyi, and E. Huang, "Polarization Properties of the GPS Signal Scattered off a Wind-Driven Ocean," IEEE Trans. Geosci. Remote Sens., vol. 52, no. 1, pp. 172–188, 2004.
- [6] F. Nunziata, P. Sobieski and M. Migliaccio, "The Two-Scale BPM Scattering Model for Sea Biogenic Slicks Contrast". IEEE Trans. Geosci. and Remote Sens., vol. 47, n.8, 2009.
- [7] D. Lemaire, P. Sobieski, and A. Guissard, "Full-range Sea Surface Spectrum in Nonfully Developed State for Scattering Calculations," IEEE Transaction on Geoscience and Remote Sensing, vol. 37, no. 2, 1999.