Analysis of radar sea clutter data acquired during the MARLENE measurement campaign

Jean-Baptiste Poisson, Vincent Fabbro, Laurent Castanet, Jean-Paul Marcellin, Xavier Boulanger, Jörg Förster, Christian Onno Böhler, Michael Gallus, Andreas Ulland, Gregor Biegel, et al.

Jean-Baptiste Poisson, Vincent Fabbro, Laurent Castanet, Jean-Paul Marcellin, Xavier Boulanger, et al.. Analysis of radar sea clutter data acquired during the MARLENE measurement campaign. Joint 2016 IEEE International Symposium on Antennas and Propagation/USNC-URSI National Radio Science meeting (APS/URSI 2016), Jun 2016, FAJARDO, Puerto Rico. 10.1109/APS.2016.7696738 . hal-01408967

Analysis of radar sea clutter data acquired during the MARLENE measurement campaign

Jean-Baptiste Poisson,
Vincent Fabbro, Laurent
Castanet, Jean-Paul
Marcellin, Xavier
Boulanger,

DEMR/ONERA
Toulouse, France
Jean-Baptiste.poisson@onera.fr

Jörg Förster, Christian
Onno Böhler, Michael
Gallus, Andreas Ulland

Bundeswehr Technical
Centre for Ships and Naval
Weapons, Naval
Technology and Research
(WTD 71), Eckernförde,
Germany

Gregor Biegel, Thorsten
Brehm, Andreas
Danklmayer

Fraunhofer Institute for
High Frequency Physics
and Radar Techniques
FHR, Wachtberg, Germany

Yvonick Hurtaud

DGA, Maîtrise de
l'Information CGN2/SDO,
Bruz, France

***Abstract*—Maritime environment, and in particular the sea clutter, has a significant impact on the detection efficiency. Therefore the physical properties of the radar sea clutter must be well mastered. In this paper, we focus on sea clutter data acquired during an experiment called MARLENE, which was held in the Mediterranean Sea region of Toulon, France, in 2014. The aim of this experiment was to characterize the sea environment influence on radar propagation and backscattering for Refractivity From Clutter (RFC) and radar Doppler detection. Three coastal radars, MARSIG (WTD 71), MEMPHIS (FHR) and MEDYCIS (ONERA) were used to acquire sea clutter measurements simultaneously. During the radar measurements, the *in-situ* oceanic and meteorological conditions were characterized on board of the RV PLANET meteorological ship deployed by WTD 71 and by WAVEWATCH III and SWAN wave models. The paper gives an overview of the MARLENE experiment, presents the radar data and the first results on sea clutter reflectivity and Doppler.**

Keywords—radar, sea clutter, maritime environment, Doppler, reflectivity.

I. INTRODUCTION

Maritime environment has a great influence on radar detection efficiency. Therefore, it is essential to study the returns from radar sea clutter for developing future generations of radar sensors. In this paper, we focus on sea clutter data acquired during a coastal experiment called MARLENE (for MediterraneAn Rfc and sea cLutter ENvironment Experiment [1]), which was performed within the framework of the French German technical cooperation [2]. This experiment aims at characterizing sea clutter level and fluctuation of the coastal environment for different sea states, radar bands, polarizations and grazing angles, analyzing the impact of ducting conditions on propagation and improving RFC systems. This paper is organized as follows. In section II, an overview of the MARLENE experiment is proposed. In section III, the radar data and the first results on sea clutter reflectivity and Doppler are presented.

II. MARLENE EXPERIMENT MAIN OVERVIEW

The MARLENE campaign was conducted from SESDA site (Site d'Expérimentation de Systèmes de Défense Aérienne) of DGA-TN, in the Saint-Mandrier-Sur-Mer peninsula near Toulon, France, from May 26th to June 4th, 2014. The radar data were acquired with three different coastal radars called MEMPHIS, MEDYCIS and MARSIG, deployed by FHR, ONERA and WTD 71, respectively. The C band was covered by the MEDYCIS radar, the X and Ku band by the MARSIG radar and the two millimeter wave bands Ka and W by the MEMPHIS radar. The radars operate at different polarizations (HH, VV). The main characteristics of the three sensors are summarized in the Table I. Different acquisition modes were defined for the MARLENE campaign, see [1] for more details. In this paper, we focus on the sea clutter data, corresponding to acquisitions with high PRF (1 kHz and more) of the clutter with a significant spatial and temporal variability.

TABLE I. RADAR MAIN CHARACTERISTICS

System	MARSIG	MEDYCIS	MEMPHIS
Radar Band	X, Ku	C	Ka, W
Freq. GHz	8, 11, 14, 17	5.65	35, 94
Polarization	HH	HH	HH,VV

A. *Maritime environment characterisation*

As mentioned above, the oceanic and meteorological conditions were evaluated by the RV PLANET ship during the MARLENE campaign. This ship allows oceanographic and atmospheric sensors to be deployed, and a lot of atmospheric and sea characteristics to be measured using meteorological sensors onboard the ship. In parallel, SESDA performed coastal meteorological measurements and radio soundings. Two fixed buoys were deployed by the RV PLANET ship for the whole experiment at two different distances from the coast (see Fig. 1 for the buoys positions), enabling measurements of significant wave heights and their evolution over time.

These measurements have been compared to simulations performed by SHOM (Service Hydrographique et Océanographique de la Marine), using the PREVAG tool which emulate the two sea wave models $WW3^R$ and $SWAN^R$ [3]. Fig. 1 shows an example of $SWAN^R$ simulation of significant wave heights (left part), considering wind data given every 12 hours by Météo France (right part). These reanalysis have been compared to the buoys measurements and the results are shown in Fig. 2. Similar values and trends of the wave heights have been obtained, with slightly better results for the south buoy probably due to the effect of bathymetry on measurements.

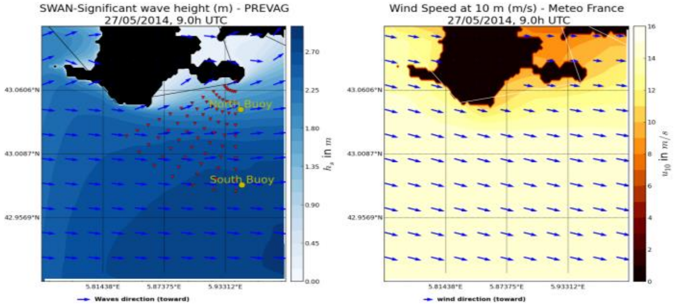

Fig. 1 : example of modeling of environmental conditions during MARLENE experiment. Left: SWAN modelling results. Right: Météo France wind flux inputs. The red triangles represent the positions of the sea clutter measurements, and the yellow dots represent the buoys positions.

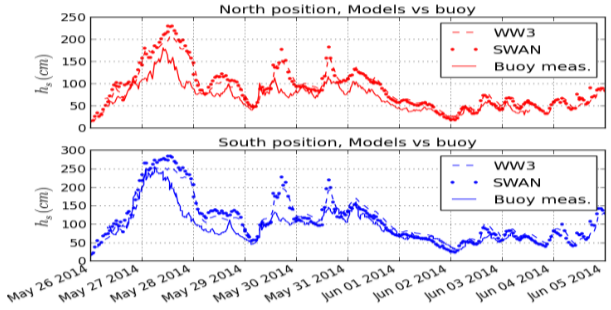

Fig. 2 : significant wave height measurements and modelling during MARLENE experiment. Up: comparison between the North buoy and modelling. Down: comparison between South buoy and modelling.

III. FIRST RESULTS ON RADAR DATA

A. *Reflectivity*

The whole MARLENE database is made up of more than 1000 clutter range-time maps (see example Fig. 3, left image). The sea clutter NRCS has been computed for each map as follows: firstly, the RCS is computed for each range cell and time; secondly, for each range cell the RCS values have been divided by the size of the sea surface illuminated by the radar beam. Then, a threshhold was applied to delete low values (due to sidelobe or filtering effects). An illustration of NRCS range-time map is proposed in Fig. 3, left part.

B. *Doppler*

The mean Doppler spectra have been computed for each map as follows: first, we compute the Doppler spectrum for each range cell; second, the mean Doppler spectrum has been estimated by averaging all the Doppler spectra over range, and normalized (see Fig. 3, right part). Finally, we apply a threshold to remove the spectrum low values to ensure that the Doppler velocity estimation is not biased by the noise. Then Doppler centroid has been estimated with the first moment of the Doppler spectrum:

$$f_c = \frac{\int f\, S(f) df}{\int S(f) df},$$

which leads to the mean Doppler velocity $V_c = f_c\, \lambda/2$, where λ is the carrier wavelength.

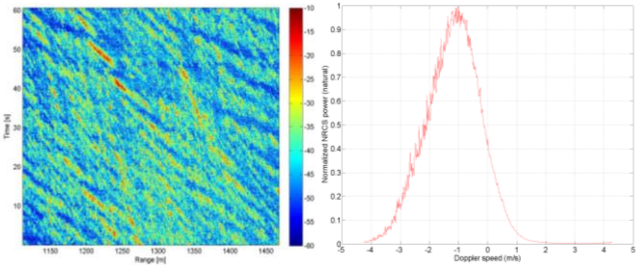

Fig. 3 : example of MARLENE MEMPHIS clutter data (Ka Band, HH polarization). Left: NRCS clutter map. Right: normalized mean Doppler spectrum (natural scale). We found an average velocity of about -1m/s (negative values corresponding to approach velocities).

IV. CONCLUSION

This paper is about a complex maritime measurement campaign called MARLENE, which has been carried out in the South of France in 2014, involving three different coastal radar sensors. This experiment has allowed characterization of propagation and sea clutter. A lot of data have been acquired, covering different sea conditions, illumination angles and frequency bands. Sea clutter Doppler spectrum and reflectivity are in particular studied. In parallel, comparison between measurements of weather conditions and PREVAG simulations yielded good results, which leads to a complete database. Further work should be done to compare these measurements to the existing sea clutter models.

ACKNOWLEDGMENT

This work was performed within the framework of the French German Technical Agreement TA 119 “Modelling and measurements of sea clutter at centimeter and millimeter bands; application to atmospheric refractivity assessment”, involving FHR, WTD71, DGA-MI, and ONERA. The authors would like to thank the French MoD for its financial support and SHOM for the simulations using the PREVAG model.

REFERENCES

[1] V. Fabbro, J. Forster, G. Biegel, C. Bohler, M. Gallus, A. Ulland, T. Brehm, J. Marcellin, X. Boulanger, L. Castanet, A. Danklmayer et Y. Hurtaud, «MARLENE: Mediterranean RFC and sea clutter environmental experiment,» *9th European Conference on Antennas and Propagation (EuCAP)*, Lisbon, 2015.

[2] H. Essen, A. Danklmayer, J. Förster, M. Behn, Y. Hurtaud, V. Fabbro et L. Castanet, «Joint French-German Radar Measurements for the Determination of the Refractive Atmospheric Index in the Maaritime Boundary Layer,» *Proc. SPIE 8535, Optics in Atmospheric Propagation and Adaptivve Systems XV, 853505*, vol. 8535, 2012.

[3] H. Tolman, User Manual and System Documentation of WAVEWATCH II TM, version 4.18, March 2014.