UNIVERSITY OF FLORENCE
Faculty of Engineering
Department of Systems and Informatics

PhD in

Digital processing of the echo received by an Over The Horizon (OTHR) Sky-Wave (SW) Radar System for Geo-Referencing of radar footprint through the identification of Sea/Land transition

PhD Student
Ing. Francesco Sermi

Tutors
Prof. Luca Facheris

Prof. Fabrizio Argenti

January 2013

Acknowledgements

... to Didi.

Abstract

Over-the-horizon radars (OTHRs) are HF-band systems that, via surface propagation (ground-wave or surface-wave) or ionospheric reflection (sky-wave), cover an area that is located well beyond the horizon. Though based on an assessed technology, OTHRs are attracting today much interest, thanks to the relevant improvements in signal processing and data storage techniques. By exploiting the propagation mechanisms of HF waves in the Terrestrial Atmosphere, the OTHR is able to overcome the horizon line, that represents a natural boundary for every ground-based microwave radar. In the case of sky-wave OTHR, the reflection of the signals by the Ionosphere allows the system to achieve range distances up to about 3000 km. Nevertheless, the employment of the Ionosphere as part of the propagation-channel introduces an intrinsic uncertainty about the actual HF wave propagation path and, consequently, about the actual geographic position of the radar footprint. In fact, the non-homogeneous structure and time-dependent behavior of the Ionosphere make the a priori models for the propagation channel absolutely useless for a correct Geo-referencing of the received echo. Therefore, every HF OTHR-SW application must include a process to associated the received signals to unambiguous geographic coordinates. Such a process, referred to as coordinate registration (CR), generally relies on an ionospheric model, based on seasonal and daily ionospheric statistics within the radar operating area. Several current OTHR-SW systems perform a periodic update of the ionospheric model exploiting information gathered by ionosonde networks or directly collected from the OTHR with a dedicated procedure. Both approaches exhibit several limitations, leading to a correct characterization of the ionosphere only when it is in particularly steady conditions.

The present research is focused on the study and development of a new different approach to the CR problem for OTHR-SW systems. This approach, referred to as Sea/Land Transition Identification (SLTI), takes advantage from the *a priori* knowledge of the Geo-morphological structure of the surveillance area in order to compensate for the uncertainties introduced by the Ionosphere. In fact, as

suggested by the name of the method, the shape of the coastline profiles within the surveillance area are employed as position-references for the geo-referencing of the received radar echo. This task is possible through a basic time analysis of the echo, thanks to the marked difference in the values of the HF back-scattering coefficient for sea and land regions. The SLTI method is based on the maximization of the cross-correlation between the received radar echo and the surface mask signatures for the surveillance area. It can be employed in real time by the system, during its typical surveillance routine and besides the collected data can be exploited to estimate some Ionospheric parameters in order to periodically update and correct the employed statistical model.

After a general introduction about the OTHR sensors and a more detailed description of the sky-wave system who we refer to in the present work, the state of the art for the CR procedures actually employed by OTHR-SW is presented. Hence the SLTI method is outlined together with the numerical model of the whole OTHR-SW scenario. The application of the method, in this scenario simulated under simplifying operative hypothesis, is described with the help of some examples for both the CR procedure and the Ionospheric probing task. Within these examples of application of the SLTI method, the minimum requirements in terms of received signal-to-noise ratio (SNR) and differential sea/land back-scattering coefficients necessary to achieve a given accuracy in the range estimate are pointed out. Finally the further developments of the SLTI method and some possible improvement of the simulated OTHR-SW's scenario are pointed out.

Contents