Marine Information Services associated with HF radar observing networks

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Abstract

The expansion of ocean observing networks, both in situ platforms (buoys, mareographs, etc.) and remote observing technologies, such as coastal HF radars and satellites, together with the increasing ocean modelling capabilities are resulting in a huge growth of data and information on the ocean.

Marine information services associated with HF Radar are experiencing a strong increase in recent years. This paper presents firstly a review of the latest significant advances regarding the technology itself, which have contributed to make its integration into operational ocean observing networks possible; secondly, a snapshot of the recent development that HF Radar observing networks are undergoing in the Iberian Peninsula. We focus then on the information services based on HF Radar data and additional measured and modelled data that are currently being provided.

Keywords:

HF radar, Oil Spill, PORTUS, Ocean Remote Sensing, SeaSonde

1. Key advances around SeaSonde HF Radar technology

1.1. Large antenna arrays evolve into a single antenna solution

One critical issue when planning an HF radar installation is to minimise land occupation in order to keep both ecological and visual impacts to the feasible minimum. This requirement is an absolute must if considering installations on oil platforms, small islands or piers.

The first HF radar to demonstrate and validate current and wave measurement capability was built between 1969-1973 in a program led by DARPA and NOAA, in cooperation with Scripps Institution of Oceanography and Stanford University. Designed by Donald Barrick (nowadays President of CODAR Ocean Sensors, Ltd.) at NOAA Environmental Research Laboratories (ERL), the radar with its original 500-meter long phased-array antenna was bulky and inconvenient for deployment, but proved the point that HF radar is a viable tool for measurement of ocean current and wave parameters.

In 1972, management at NOAA decided to develop an alternative to the large, costly phased-array technology for current and wave mapping. This led to the compact CODAR approach that replaces large phased arrays with single mast direction-finding (DF) antenna units.

The technology has evolved from the original 1972 CODAR radar and is now the SeaSonde®, which latest version has all transmit and receive elements colocated atop a single mast and occupies as little as one square meter for its deployment.

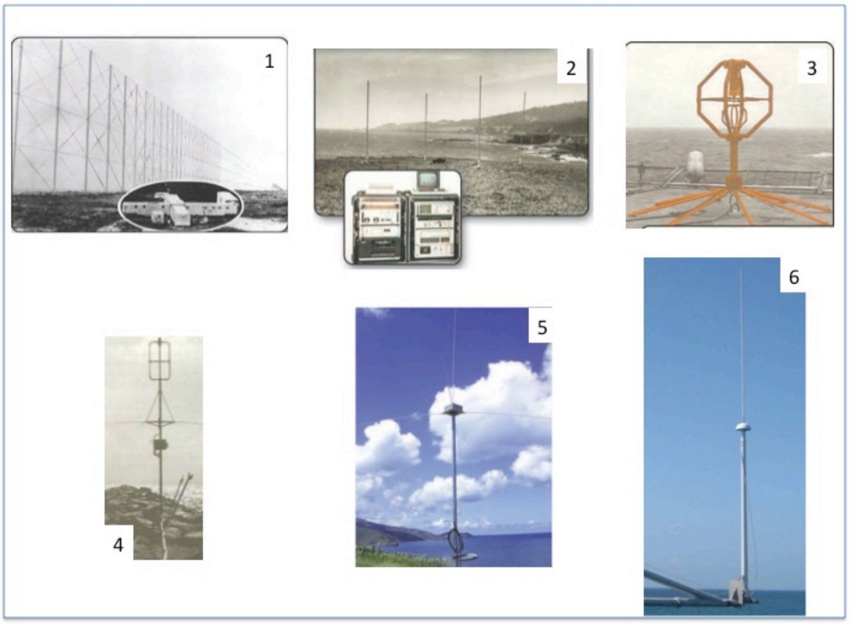

Figure 1: Current mapping HF radar antenna evolution in the last 40 years

1.2. Frequency sharing capability by multiple radars

Because the MF/HF/VHF bands have not been used for most radar applications up to now, there have been no frequency bands designated for radar below 430 MHz by the ITU (International Telecommunications Union). Thus, users must apply for "secondary licenses", meaning they cannot interfere with "primary" users. To avoid interference, each user would like a frequency separate from all other HF radar users (as well as from the conventional radio users of these bands). The problem is exacerbated by the wide signal bandwidths needed for radar operation in contrast with radio communications. To achieve a 1 km range cell, one needs 150 kHz bandwidth, for example. Typical radio channels occupy 5 kHz bandwidth or less. This means that one radar user monopolizes 30 potential radio channels. Finally, a given fixed bandwidth (like 150 kHz) occupies a much larger fractional bandwidth percentage-wise at HF (e.g., 5 MHz) than at microwave (e.g., 5 GHz). All of this makes it clear that each new user will not receive a separate frequency for his own use; multiple users must share the same frequency in a manner that does not cause mutual interference.

CODAR invented and patented a methodology based on GPS timing along with FMCW (frequency-modulated continuous wave) gated signals to control the exact sweep time of multiple transmitters down to nanoseconds so all transmitters can occupy the exact same frequency channel [1]. This enables a single receive antenna to process unambiguously scattered signals from multiple transmitters as described in the next point. The signals from various transmitters are identified and separated in the demodulation phase.

1.3. Multistatic processing for the enhancement of coverage and data quality

The normal mode of radar operation is backscatter (or monostatic). In this mode, transmitter and receiver are collocated, sometimes sharing the same antenna, while in others the transmit and receive antennas may be separated a small distance. Together with the patented frequency sharing method explained in the previous point, CODAR also came up with an inexpensive solution that allowed bistatic operation [1]. This enables a single receive antenna to process unambiguously scattered signals from multiple transmitters. Thus not only mutual interferences are eliminated, but the use of other station's signals is possible. In fact, a single coastal station can simultaneously operate in a backscatter mode (using its own transmitted signal's sea echoes), but also using the echoes from several adjacent coastal SeaSondes transmissions. This gives rise to the term multistatic instead of bistatic.

There are two advantages of extending an existing backscatter network to multi-static

- It extends the area of coverage
- It adds redundancy in the backscatter region, thereby increasing current measurement accuracy and robustness.

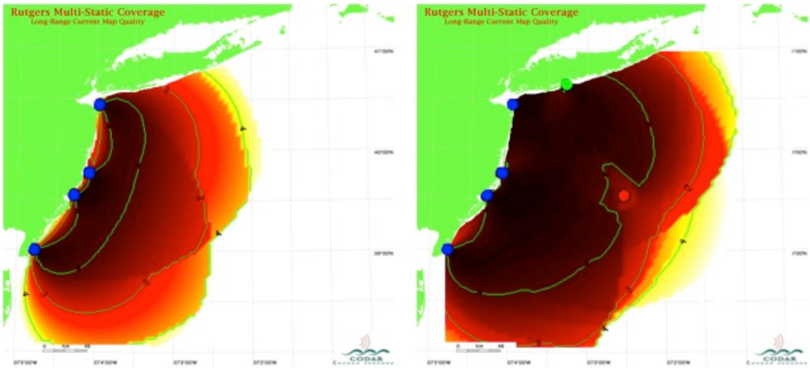

Figure 2: Example of 50% coverage extension using an additional multistatic transmitter on a buoy (red point)

2. Iberian Peninsula SeaSonde HF Radar network

In 2002, the Prestige oil spill disaster off the northwestern coast of Spain acted as a wake up call highlighting the importance of preparing for such a crisis. It led to Spanish Institutions prioritizing the improvement of maritime protection related activities, operational oceanography and oil spill response preparedness.

Back in 2005 a cooperation agreement aimed to increase marine safety and efficiency in navigation and harbour management was signed between Puertos del Estado, the General Directorate of the Merchant Marine of the Spanish Ministry of Public Works and the Galician Government (Xunta de Galicia). One of the primary focuses of the agreement involved the development of advanced ocean observing infrastructures and, as an essential element, the installation of an HF coastal Radar network.

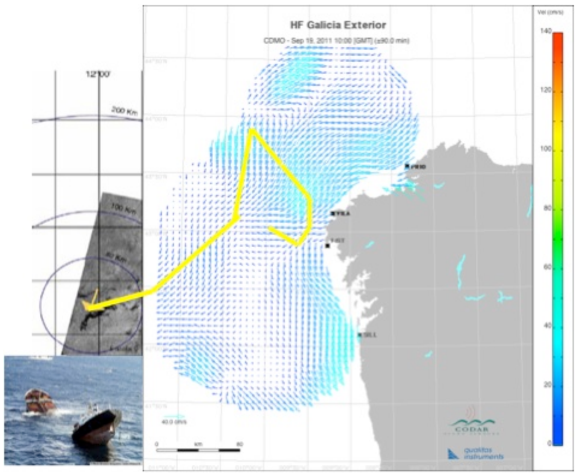

Figure 3: The yellow line represents the trajectory followed by the Prestige ship, most of it now inside the radar coverage area

A successful initial installation led by Puertos del Estado was the beginning of HF radar implementation in the Iberian Peninsula that will count with 20 radars by the end of 2012. We introduce below some of these systems together with their associated operational services and research areas.

2.1. Galicia HF radar network

Today, in 2011, the Galician HF radar network is made up of four SeaSonde long range 5-MHz radars that provide real time surface currents and wave information along the coast from Silleiro in the south close to the boarder to Portugal to Prior in the North (280 km or 75 % of Galicia coast) and with a range of up to 200 km from the coast**.** The operational-scientific exploitation of data corresponds to Puertos del Estado and the Galician Regional Government. Puertos del Estado runs an online validation and quality control of the radar observations from the very initial project layout and system start up. In addition to the long range HF Radar network, the Physical Oceanography Group of University of Vigo in Galicia (GOFUVI) has implemented a high-resolution HF radar system in the Ría de Vigo.

The areas of application of Galicia HF radar collected data are very wide. Real-time surface currents information is openly available online with a special focus on its use by Spanish Port Authorities in order to improve safety in navigation. The use of these data has also resulted in a continuous improvement of oil spill trajectory forecast and backtracking models [2] and the increase in the quality of both ocean models and observations in the area. As a principal result of all these efforts over the years, Galicia has turned to be one of the most advanced science and knowledge development platforms around HF Radar technology in Europe.

2.2. Portugal HF radar network

The first HF radar network in Portugal was deployed in the Sines area by the Hydrographic Institute (IH is the Portuguese Navy's Laboratory for Ocean Sciences), which is a principal operational oceanography institution in Portugal. The system consists of 2 standard-range SeaSonde radars with a spatial resolution of about 1 km. This system is part of the SIMOC (Operational Surface Currents Monitoring System) project. The Sines area, positioned halfway between Lisbon and Algarve, was chosen as the first permanent HF Radar deployment area since it is one of the most sensible locations of the Portuguese coast, having a major petrochemical harbor, and directly to the south, a natural reserve (Natural Park of the Southwest of Alentejo). Environmental monitoring by means of HF radar in this area is understood as a preventive action to improve safety along one of the heaviest ship traffic corridors in the world. The data series obtained will also contribute to the IH modelling activities in currents and oil spill models.

The Portuguese network will be expanded inside the period 2011 to 2012 by the TRADE initiative (Trans-regional RADars for Environmental applications that is being implemented in partnership by the Spanish Puertos del Estado, the Portuguese Hydrographic Institutue and the Cadiz University) along the Iberian Algarve and Andalucía coasts including as part of it also the monitoring of the Gibraltar Strait. Five HF radars will be installed along the coast covering a large part of the area between Cape San Vicente and Gibraltar Strait. This sensitive area, which has several natural parks along the coast and is one important touristic destination in Europe, is the scenario of one of the world's largest vessel concentration and traffic areas in the world. The TRADE project is aimed to contribute significantly to the ocean observing infrastructure required by the region for safe navigation and, at the same time, to help the decision makers in order to improve the coastal management of this area. It is envisioned that additional scientific groups join the original TRADE partners creating a strong permanent environmental applications oriented knowledge base and work team around coastal HF Radar.

2.3. Additional projects and ongoing initiatives

The Basque Government in cooperation with AZTI (a Technological Centre specialised in Marine and Food Research) along the Gulf of Biscay, SOCIB (a Coastal Ocean Observing and Forecasting System located in the Balearic Islands) in the Ibiza Channel and the Spanish Ministry of Environment, Rural and Marine Affairs in the Ebro River Delta have also implemented multipurpose ocean observing networks giving thus life to the largest HF Radar observing infrastructure in Europe.

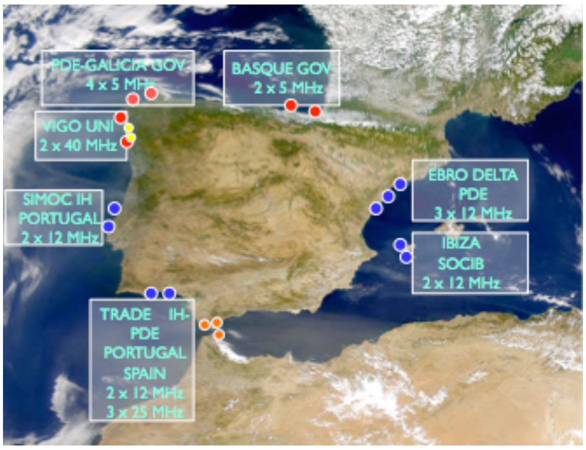

Figure 4: Iberian multipurpose HF Radar network

3. Marine Information Services and Tools related to HF Radar

3.1. Rapid deployable HF Radar currents information

In January 2009, The Norwegian Clean Seas Association for Operating Companies (NOFO) and the Norwegian Coastal Administration (NCA) announced 18 defined technological challenges concerning oil spill response, seeking new ideas and proposals for solutions. Almost 180 ideas were submitted by private enterprises in Norway and abroad. Following rounds of evaluations, 20 projects were approved with funding from NOFO. "Rapid Deployable HF Radar for Emergency Spill Operations" was one of the most successful projects among these 20. The Norwegian company CODARNOR lead the project in which CODAR Ocean Sensors, the Norwegian Meteorological Institute (met.no) and

QUALITAS were partners. The objectives that were reached in this the project were:

- To develop a Mobile SeaSonde HF radar unit that can be rapidly deployed to the coast of Norway to aid in effective and efficient oil spill response
- To develop of a data service that provides high quality SeaSonde-derived 2-D current fields using OMA (Open Mode Analysis) technique[3] to The Norwegian Meteorological Institute in near real time for spill drift model input and operations planning
- To demonstrate that SeaSonde-derived 2-D current fields can improve operational oil spill drift model results

By supplementing models with real time data, calculation of oil drift trajectory and spreading in coastal waters were significantly improved. This is more and more important as oil exploration and production activities move closer to the Norwegian coast. As a future extension, it is envisioned that forecasters from Norwegian Meteorological Office will be able to use the OMA surface currents to blend with modelled currents to improve their operational 24h emergency oil spill service.

3.2. Tsunami Detection

It was over 32 years ago that Barrick first described how an approaching tsunami could be measured from its HF radar-observed current pattern in a 1979 Remote Sensing of Environment article [5]. With few HF radars operating at that time and sizable tsunamis being a rare or infrequent occurrence, this research went largely unnoticed for many years. Following the 2004 Indian Ocean tsunami, Lipa and Barrick revisited the topic by developing a tsunami pattern recognition algorithm that worked against the ambient background flows. The methods described in their 2006 paper [6] formed the basis for the first and only commercial HF radar tsunami detection software package available on the market. The radar measures the velocity of the particle-like Bragg waves arrayed over the surface of the tsunami wave. While the tsunami height increases slowly as depth decreases, the particle/Bragg velocity increases much faster: as the inverse three-quarters power of the depth. Therefore as the water gets shallower, the velocity seen by the radar begins to stand out from the background circulation in that region.

The last Japan catastrophic earthquake and tsunami confirmed the validity of these methods. Two Seasondes installed in Hokkaido (Japan) observed the Tsunami signature and nine hours later SeaSondes installed in the West Coast of the Continental U.S. could also identify this signature.

3.3. PORTUS Marine Information System

The PORTUS concept was initially developed by Puertos del Estado as the Oceanographic Information System to manage and make observations (more than 200 measurement devices) as well as forecasting information available to its stakeholders and the general public.

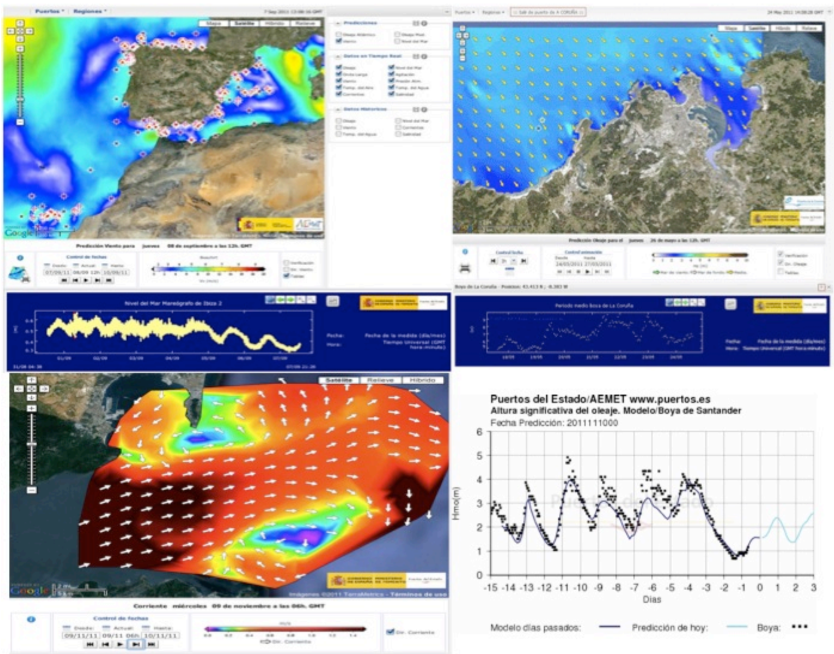

Figure 5: Puertos del Estado general Oceanographic Information System. (www.puertos.es)

PORTUS is an edge web-based Marine Information System. Its main aim is to make all available marine data & information easily available through a single geographical interface to favour its use and integration.

Some of PORTUS features are:

- Flexible Marine Information System with special focus on SeaSonde HF Radar
- Friendly multisource data visualization interface
- Secure data storage and management (historic, real-time, forecast)
- Multilayer web based secured access through Internet
- Specialised tools to take the most out of HF Radar (QA/QC, data fusion and forecast products…)
- Powerful export capabilities in a wide range of standard and non-standard formats and data serving to other systems

Today multiple added value advanced applications related to coastal HF Radar operation are nested in this tool providing daily benefits to a large variety of interested users and society in general.

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