Identification of Oil Spills from offshore installations.

Presentation of methods and preliminary results from the OSIS, ”Oil Spill Identification Sensor” project.

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Abstract

The key driver behind the development of the OSIS sensor system was to pursue implementation of the MARPOL 73/78 annex 1 protocol on offshore installations in line with what is already implemented on vessels. Due to the high number of offshore installations within the "Special Areas" these installations have so far been subject to exemption from the MARPOL 73/78 annex 1 directive. The main reason for this regulative exemption is the lack of surveillance methods capable of monitoring oil spills from offshore installations effectively. The objective for the OSIS project is to develop and demonstrate a sensor system mounted directly on offshore installations performing 24hours a-day surveillance, hereby providing the means to remove the legislative exemption.

A functional model of the OSIS sensor system has been built in 2003 and tests are currently being performed onshore as well as offshore demonstrating the capability of the system to identify and measure volume of oil spills effectively.

The input to the OSIS system is collected by a Sensor Pack based on advanced microwave sensors placed on the offshore installation. The Sensor Pack is continuously monitoring the surrounding waters measuring both area and volume of oil spills. Based on data from the Sensor Pack a rule based pattern recognition system identifies the oil spill. When an oil spill is detected pictures are transmitted to an onshore based Central Server. In the paper various sensor types and oil detection systems are discussed and the resulting components in the OSIS system are presented.

OSIS International

Governmental and non-governmental target groups can have access to the info screens illustrated below via a traditional web interface. The end user is presented relevant information about the location of the rig, status of the sensor measurements and in case of an oil spill, the estimated contamination area and amount spilled. Data is transmitted into an onshore database by a satellite link from a local positioned master unit, gathering data from up to 16 sensors placed on different offshore rigs.

The OSIS sensor system has been tested under controlled input conditions by discharging various amounts and types of oil on a water surface. The paper will present these results and discuss what accuracy can be expected from the oil volume measurements.

The OSIS demonstration project was started in December 2001 after receiving commitment from the Danish Environmental Protection Agency and Danish Energy Agency to build a prototype system. With financial support from LIFE Environment and the Ministry of Science Technology and Innovation, OSIS International pursued the objective of designing a sensor that was able to monitor oil spills from offshore installations.

Keywords

Oil Spill, Water, Surveillance, Detection, Environmental, Monitoring, On-line, Continuous, Real-time, Fixed structures, Offshore installations, Special areas, Remote sensing, Microwave, Radiometer, Radar, OSIS.

Introduction

Ships and offshore installations are the most important sources of the more than 500,000 tons of oil spilled into the marine environment every year. To combat the problem, increasing numbers of national, regional and international protocols have been or are being deployed by authorities.

The International Maritime Organization (IMO) is increasingly facilitating local authorities by declaring a sensitive sea for "Special Area" where allowable oil submissions from ships and offshore installation are lowered from 40ppm to 15ppm. The following “Special Areas” are currently established according to IMO MARPOL 73/78 directive, annex 1: the Mediterranean Sea area, the Black Sea area, the Baltic Sea area, the Red Sea area, the Gulf of Aden area, the Red Sea area, the Gulfs area, the Antarctic area and the North West European waters. The designation as “special Area” is decided upon request from the surrounding authorities due to the environmentally sensitive character of the areas.

In the “Special Areas” there are hundreds of offshore installations already operating and it is questionable if all oil spills are reported correctly. This is evident during several occasions, where airplanes equipped with airborne surveillance equipment have flown over and observed an offshore installation at the time of a significant submission of oil. The differences between the amount observed by the airplane and the amount reported from the offshore installation often results in clean-up actions being based on wrongful or non-objective information, which can lead to incorrect action taken.

Regulatory enforcement, however, requires round the clock surveillance and extending the existing surveillance methods of using airplanes, satellites and establishing inspection teams to achieve these goals are cost prohibitive, unreliable and ineffective. Therefore, proper enforcement requires technical solutions not presently available.

A comprehensive feasibility study carried out by the Danish Environmental Protection Agency (Danish EPA) analysed all proposed methods of surveillance and concluded that the only cost-effective way to observe offshore installations is to mount oil spill identification sensors permanently on the structures. OSIS International began designing the OSIS Environmental Surveillance System after receiving a commitment from LIFE Environment in 2001.

With support from the Danish (Danish EPA), the Danish Energy Authority and the Ministry of Science Technology and Innovation, OSIS International pursued the objective of designing a sensor that was able to monitor area and volume of oil spills from offshore installations.

Sensor type considerations

Several types of sensors were considered before the exact types and characteristics of the sensors in the OSIS Sensor Pack were decided. Some experience with oil slick detection by remote sensing is described in the open literature and most of this is gathered using aerial and satellite systems. Mounting remote sensing equipment on fixed offshore installations requires considerations about limitations and advantages of the different sensor types compared to the results obtained with aerial and satellite systems. Advantages and limitations for the considered sensor types are shown in (Fig. 1).

Sensor Type	Advantages	Limitations
Infrared (IR) and ultraviolet (UV) scanners or multispectral scanner (MSS)	Matured industrial instrument. Widely used for oil spill detection on water. Good spatial resolution.	Gives only limited information about oil layer thickness in IR-channel (thin/thick or only few steps). Requires daylight and clear atmosphere conditions.
Microwave radiometer (MWR)	Quantitative information about oil layer thickness Independent of daylight and weather conditions.	Low spatial resolution. Ambiguity problems require more channels to measure both thin and thick oil layers.
Side-looking radar (SLAR)	Matured industrial instrument. Medium spatial resolution. Independent of daylight.	Requires wind (capillary waves) to detect oil. No information about oil thickness.

LIDAR	Gives information about oil type.	Very costly and physically large sensor type. Can only measure oil layer thickness for thin layers. Only suitable for near nadir measurements

Figure 1: Characteristics for considered sensor types

Based on the characteristics of each sensor type it was decided to design the Sensor Pack with a single-channel MWR and a SLAR primarily due to the independence of daylight and weather conditions and the ability to estimate oil layers thickness and thereby give estimates of total oil volume in the spill.

Geometrical considerations

Remote sensors are very often airborne or space borne, favouring an imaging geometry where a reasonable area is covered without measuring at large incidence angles. On an oil rig it is only possible to obtain measurement positions with relatively low altitude - between 20 and 50 meters - and large incident angles will therefore be necessary to cover a reasonable area. A MWR is traditionally used from nadir to approx. 50° incidence angle. Limiting the incident angle to the usual 50° will not cover a satisfying area and therefore it is of interest to discuss the implications of increased i.e. more shallow incidence. The SLAR is quite different from this point of view as its imaging geometry is well suited for low altitude, shallow incidence, e.g. ship navigation radars. However, there are also in this case subjects to be discussed associated with the short distance to the target and potentially near 90° incidence.

MWR's are generally poorly suited for imaging out to large incident angles as the footprint on the Earth's surface is beam limited and thus will grow dramatically when the incidence angle approach 90°. The situation is illustrated in (Fig. 2), where è is the incidence angle, h the sensor altitude, and R the distance from the nadir point to the footprint being sensed.

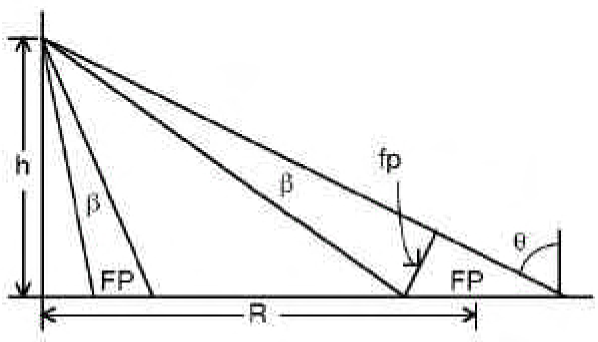

Figure 2: Geometry of the antenna measuring beam from the MWR.

The spatial resolution in the è plane (as illustrated) is FP. In the orthogonal direction it is fp and likewise in a plane orthogonal to the beam direction. It is seen that fp = â·h / cosè, and FP = fp / cosè. Thus we find that FP = â·h / cos^{2}â. The angular resolution (â) for the microwave antenna in the Sensor Pack is 2.0°. If an operating altitude of h = 40 m is assumed, (Fig. 3) can be generated using the formula derived above.

è	fp (m)	FP (m)	R (m)
20°	1.48	1.58	15
50°	2.17	3.37	48
70°	4.07	11.9	110
75°	5.38	20.8	149
80°	8.02	46.2	227

Figure 3: Measurement geometry from the MWR in various incident angles.

The MWR in the OSIS Sensor Pack is covering incidence angles from 40° to 80° as a compromise between area coverage and measurement fidelity.

A SLAR is well suited for wide area coverage from low altitudes with the ship navigation radar being an obvious example of an application with similar characteristics. However, unlike the ship radar that detects hard targets on/above the sea surface, the oil surveillance radar in question here must detect the sea surface itself, which gives a limit to the usable incidence angle. This limit is generally accepted in the range of 85 – 87°. When using 40 m as altitude example as in (Fig. 3), 85° corresponds to 460 m of range, and 87° to 760 m.

Operating environment considerations

The environment on an oil rig is very harsh and the influence from the mixture of salt, water, humidity, dirt and changing temperatures will cause the measurements to deteriorate and ultimately fail in the functionality if the sensible equipment is not protected. An enclosure for the 2 sensors in the OSIS Sensor Pack has been designed and built to protect the remote sensing equipment and move it in a pattern such that it can measure 360° azimuth and between 40° and 80° in elevation. The enclosure can be seen in (Fig. 4).

Figure 4: OSIS Sensor Pack.

Designing the enclosure in such a way that service and operation of the equipment is easy in the difficult environment has been a considerable task. To allow the Sensor Pack to be mounted on an oil rig the Sensor Pack has been tested thoroughly and approved by Norske Veritas (DNV) to the marine EN-60945 standard. The Sensor Pack requires connection for power and all measurements are transferred to a database through a wireless connection, enabling furthermore a simple mounting of the Sensor Pack on the oil rig.

Test program overview

The OSIS Sensor Pack has been tested in an intensive onshore test program. The onshore test program has checked the sensor measurements under controlled conditions and furthermore checked the reliability and compatibility of the equipment. The offshore tests that will be performed in the 2nd and 3rd quarter of 2004 will test the sensor measurements under real operating conditions and accumulated data from the tests will be basis for the algorithms for automatic oil spill detection.

The objective of the onshore tests has been to minimize the risk of failures in the offshore tests and to obtain approval from DNV to mount the Sensor Pack on an offshore oil rig. The onshore tests have included many functionality tests for specific operational features as well as controlled oil spills in harbours and water basins to test the measurement quality in a controlled environment. The preliminary results described below are from one of these controlled oil spills.

Preliminary results from MWR measurement test

To test the output of the MWR in a controlled environment a series of measurements were made where the Sensor Pack was measuring over a water tank with a smaller tub floating on the water containing a well defined volume of oil. The test setup is shown in (Fig. 5).

Figure 5: Test setup for the radiometer measurements.

The tub was submerged in the water so only few cm of the sides were over the surface of the water to limit the effects from the tub in the measurements. The tub was then filled with a mixture of petroleum and a few % of cellulose thinner to help the petroleum to spread homogeneous over the water. The test was made in clear weather with a temperature between 0 and 5 degrees Celsius.

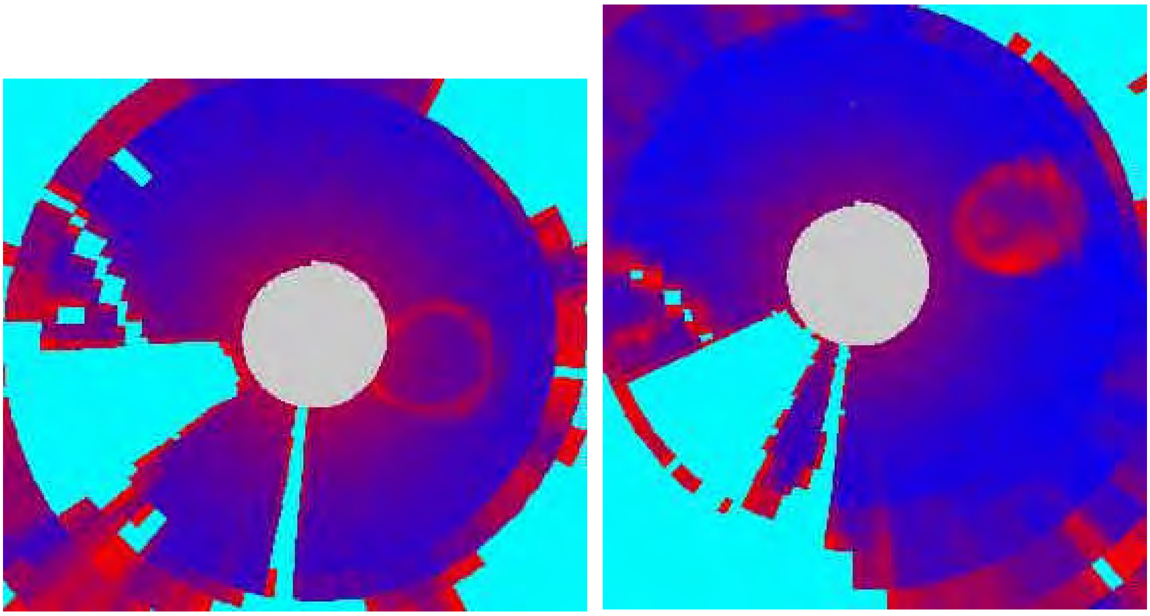

Figure 6: Image from the MWR without petroleum in the tub (left side) and with petroleum in the tub (right side)

Figure 6 shows 2 examples of images from the MWR. The brightness temperatures are translated to a colour scale with red as higher temperatures and blue as lower temperatures. The turquoise colour indicates that the brightness temperature is out of scale.

In left part of (Fig. 6) the tub without oil can be clearly seen as a red ring in the MWR image. The signature from the tub will clearly affect the measurements in the sides of the oil slick as the measured brightness temperatures from the tub corresponds to an oil thickness of 0,4 mm to 0,5 mm. Due to the increased brightness temperature from the tub it is not expected that it will be possible to measure layer thicknesses lower than 0,4 mm to 0,5 mm in the described test setup.

In the right side of (Fig. 6) the tub is again seen as a red ring, but now it is filled with petroleum in a 1,5 mm thick layer, and the area encircled by the tub has higher brightness temperature.

Measuring oil on a water surface with a MWR is a well known method. A more detailed description of the functionality and the physics of measuring oil on water with the MWR can be found in (Skou, 1986).

The resulting brightness temperatures from the MWR are analysed to estimate the brightness temperature for unpolluted water for each frame. This is done by finding the mean temperature in an area where it is known that there is no oil.

When the brightness temperature for unpolluted water is found, this can be used to detect the parts of the frame where oil is present. Finally the measured brightness temperatures in the parts of the frame where oil is present are compared to the transfer function of the radiometer as described in (Skou, 1986) to find the measured oil thickness.

The results from 3 test series are shown in (Fig. 7).

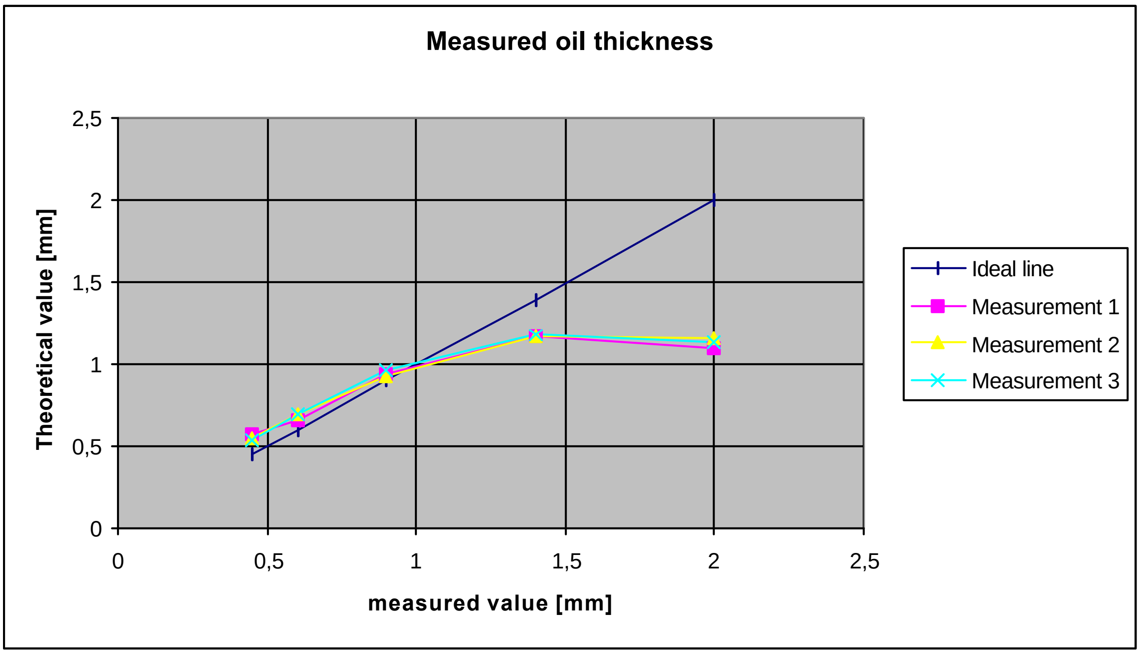

Figure 7: Curve showing the test results from the MWR

It can be seen from the curve that the MWR measures a slightly higher oil thickness than theoretical values prescribe in the low range, and after 1,0 mm – 1,2 mm the measurements are lower than theoretical value.

The higher measurements below 0,8 mm oil thickness is considered to be due to effects from the sides of the tub that add to the brightness temperature close to the border of the slick. The deteriorating measurement accuracy over 1,0 mm – 1,2 mm is due to ambiguity in the transfer function for thicker oil layers, where the brightness temperature has its maximum between 1,5 mm and 2 mm depending on the incident angle.

Conclusion

Although the measurements were slightly affected by the test setup as described above the results from the MWR are very promising. Results from the onshore tests indicates that measurement accuracy in oil volume estimation between 10 and 20 % is possible, which is sufficient for desired environmental monitoring. Measurement accuracy will be further tested when measuring oil spill in open sea during the offshore tests.

During 2nd and 3rd quarter of 2004 the OSIS sensor project will continue and extensive offshore tests will be carried through. The Sensor Pack will be placed on an offshore structure and the equipment will monitor both the accidental spills from the platform as well as controlled spills where the exact oil volume is known.

References

(Skou, 1986)

Skou N. (1986). Microwave Radiometry for Oil Pollution Monitoring, Measurements and Systems. IEEE Trans. on Geoscience and Remote Sensing, Vol. GE-24, No. 3, May 1986, pp 360-367