MIROS - A microwave remote sensor for the ocean surface.

by

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Abstract: MIROS is a microwave radar system for real time directional measurements of water particle speed, ocean waveheight frequency spectra and surface current. This paper gives a system description including both hardware and software. The theories behind the principles of operation are also reviewed. MIROS has been subjected to extensive field trials, and a selection of data collected during these trials are presented and compared to data collected by conventional instruments. The field trials has demonstrated that microwave remote sensing, as implemented in MIROS is a realistic alternative to conventional techniques. MIROS is now comercially available.

Keywords: *Microwave radar, remote sensor, waveheight, surface current.*

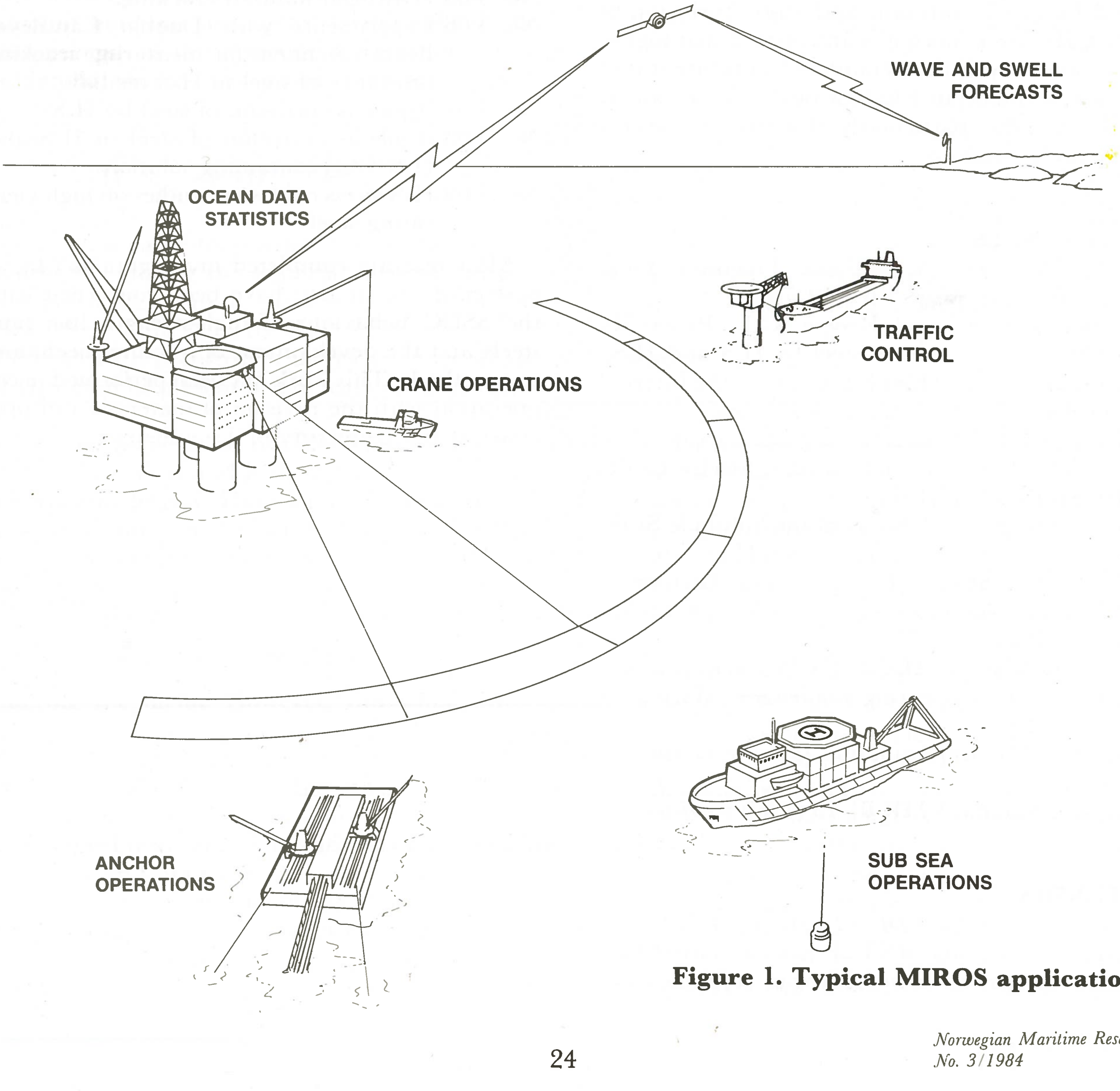

Figure 1. Typical MIROS applications.

1. INTRODUCTION

MIROS is a microwave sensor for real time directional measurements of ocean wave spectra, surface current and water particle speed. It is primarily designed for remote sensing of the ocean surface from stationary offshore installations. Capabilities such as high directional resulution and real time data processing and presentation make the instrument useful for a broad range of applications.

MIROS is developed by A/S Informasjonskontroll, and the project has been sponsored by Statoil and NTNF (The Royal Council for Scientific and Industrial Research). NTNF has also contributed scientifically to the development through the Environmental Surveillance Technology Program-

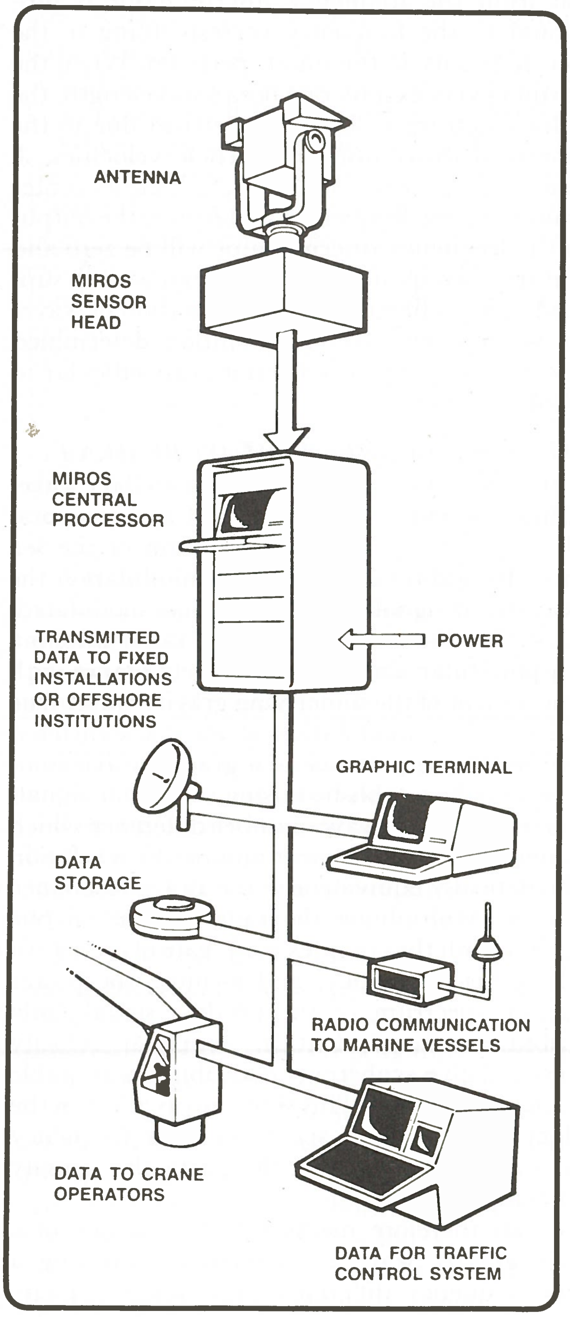

Figure 2. System configuration.

2. MIROS SYSTEM DESCRIPTION

2.1 MIROS HARDWARE

The MIROS hardware, which is shown in figure 2, consists of an outdoor mounted microwave sensor head connected by a cable assembly to an in-door installed central processor cabinet.

The sensor head comprises an antenna assembly, a C-band microwave transceiver and a servo platform.

The central processor cabinet houses

— radar waveform generating and signal processing electronics
— system computer
— tape cassette storage
— graphic terminal

The system computer is interfaced to a graphic printer and an optional second graphic terminal. A telephone modem may also be connected. Thereby measured data and system status information may be transmitted to a remote location and/or the MIROS system itself can be remotely operated.

2.2 MIROS SOFTWARE

The MIROS software is written in extended PASCAL, and with a few timecritical operations implemented in assembly language. The MIROS system software consists of the following elements:

— An operating system kernel controlling the execution of software modules and intercommunication
— Device drivers for the various peripherals used
— The application software, performing all MIROS operations

The application software has the following functions:

— It displays the set-up of the system, and allows the operator to change the parameters he requires.
— It positions the antenna, performs the data sampling and spectral analysis.
— It presents sampled data on a graphic terminal.
— It checks the MIROS operation continuously by monitoring selected test points, and reports any malfunction.

All operator communication at any level are done by menues, providing an easy to use, self explanatory system operation. The data sampling, spectral analysis and sampled data presentation are done in real time, with intermediate measurement results displayed during sampling. Facilities are provided for the connection of an additional terminal, allowing the investigation of previously sampled data while the current sampling is done.

3. A TYPICAL MIROS INSTALLATION AND MEASUREMENT SEQUENCE

MIROS is primarily designed for operation on stationary offshore installations. See figure 1. The sensor head is to be installed on top of the platform building section or roughly 50 to 100 meters above the sea level. The central processor cabinet and peripheral equipemt are located in a control room.

The directional properties of MIROS depends on the actual geometry and the antenna beamwidth in azimuth. The typical geometry gives 30 degrees directional resolution for wind waves up to 200 m wavelength. The resolution is gradually decreasing for longer wind waves. However, the direction of swell can be estimated with high accurancy.

During a typical measurement sequence, observations are taken in 6 directions with an angular increment of 30°. This represents a 180° rotation of the antenna assembly, which is sufficient for a complete directional measurement since the system observes both approaching and receding waves.

A typical observation time per direction is 12 minutes, corresponding to 72 minutes for a complete directional scan. If for any reason a full scan is not required, the operator can easily select between a broad range of angular increments (1,4° to 180°) and observation periods (90 seconds to 72 minutes).

4. PRINCIPLES OF OPERATION

MIROS operates in two different modes, the pulse doppler mode and the dual frequency mode. Directional waveheight-frequency spectra are measured in the pulse-doppler mode, basicly by obtaining water particle velocity information. A wave-model is applied in order to transform the velocity spectrum into a waveheight spectrum.

Surface current information is obtained by measuring the phase velocity of a gravity wave component in the dual frequency mode.

4.1 WAVEHEIGHT MEASUREMENT

The MIROS sensor head is operating in the C-band (5,8 GHz.λ =5 cm). Hence the actual radar target on the sea surface is the capillary wavefield which rides on the underlying gravity waves, forming a large number of uncorrelated radar scatterers all moving with the velocity of the water particles. If the sea surface is illuminated with a radar pulse short compared to the gravity wavelength, all scatterers within the illuminated area (the «footprint») will move with the same velocity. The instantaneous doppler shift is proportional to the radial component of the water particle velocity. If only a single harmonic gravity wave is present, the radar echo will be frequency modulated with a period equal to the wave period. If the echo is frequency-to-voltage converted, the frequency spectrum of the output signal will contain a single line at the wave frequency with amplitude proportional to wave-height.

The sea surface can be described by an infinite sum of plane, harmonic elementary waves. The frequency to voltage converter output signal will therefore have a continuous power frequency spectrum, directly related to the waveheight spectrum.

Directional resolution is achieved by using a footprint of radial dimension small in comparison with the dominant ocean wave-length and azimuth dimension large in comparison with the dominant wavelength. When the antenna is pointed perpendicular to the wavefront, all scatters within the footprint will circulate with the same speed, resulting in a single line doppler spectrum. When the look direction is not perpendicular to the wave-front, the scatters within the footprint will rotate with different radial velocities. Hence, the instantaneous doppler spectrum will be broadened. The output signal from the frequency discriminator is proportional to the frequency corresponding to the center of gravity of the input spectrum. When the footprint covers exactly one ocean wavelength, the doppler spectrum will be symmetrical due to the symmetrical distribution of particle velocities. A symmetrical spectrum has by definition its center of gravity at zero frequency, and hence, the output from the frequency discriminator will be zero and the return corresponding to the ocean wave is suppressed. Thus, directional discrimination of wavefields is obtained, with a resolution determined by the extent (L) of the footprint perpendicular to the look direction.

4.2 SURFACE CURRENT MEASUREMENT

The gravity waves interact with the capillary wavefield and thereby causing a spatial and temporal modulation of the radar cross-section of the sea surface. In addition to amplitude modulation the backscattered signal will also be phasemodulated, because the distance between the radar antenna and a particular scatter varies in accordance with the movement of the underlying gravity wave. Due to this periodic modulation of the backscattered radar signal, the presence of a gravity wave component may be established using two radar signals with a frequency or wave-number difference which is related to the ocean wave-number by a relation mathematically equivalent to the Bragg resonance condition. Multiplying the radar return on one frequency with the complex conjugate of the return on the other frequency, and forming the power frequency spectrum of the product signal, only contributions from identical or equal velocity scatters will give «coherent» contributions or stable spectral components. This shows up as a line in the product signal power spectrum at a frequency equal to the frequency of the particular gravity wave component.

We can therefore measure the frequency of a specific gravity wave component by selecting a proper frequency difference. The phase velocity of the wave is given by the ratio of the angular frequency to the wave-number. The difference between the measured phase velocity and the theoretical given by the dispersion relation is attributed the radial component of the surface current vector in the radar look direction. By making two independant measurements in different directions the total current vector can be calculated.

5. DATA COMPARISON

In the following we present a selection of MIROS data collected from Lindesnes lighthouse, located at the most southern point of Norway, during a field test in January - February 1983.

Nondirectional and directional wave parameters are compared with the corresponding data from a heave, pitch and roll buoy (NORWAVE, ODAS 494). Surface current estimates are compared with data collected by an accoustic current meter (UCM-6). Both instruments were provided by the Continental Shelf Institute (IKU) of Norway.

When comparing data from the different sensors there are several factors that must be kept in mind. Firstly the buoy and the current meter perform point measurements, while MIROS performs area extensive measurements. In order to obtain proper conditions for comparison, the ideal test site should guarantee homogeneous wave- and current fields. When operating close to the shore-line, as at Lindesnes, this is not the case. Secondly, the variable bottom topography of the area covered by the measurements will influence the results. Thirdly, differences in observation intervals and sampling instants can cause problems under non-stationary weather conditions.

A typical MIROS data output is shown in figure 3. As can be seen, the wave-field in this situation was highly directional with a dominant wave component in the fourth direction, and a frequency of the spectral peak equal to 0,09 Hz.

MIROS estimates the heave spectrum by integrating over the six directions.

The significant waveheight (HMO) estimated by MIROS is based on integration of the heave spectrum. A regression line relating the HMO for MIROS and the buoy is shown in figure 4.

The spectral peak direction is defined as the mean direction of the wave components associated with the peak, in the heave spectrum. The temporal progression of the spectral peak direction observed by MIROS and the buoy during February 5., 1983 is shown in figure 5. The wind direction measured by the buoy is also shown. The curves indicate that the wave direction given by the buoy is correlated with the wind even on a short term basis, probably because of the action of the wind on the buoy ifself, while the radar echo cannot be directly affected by the wind. The systematic angular offset of approximately 20° might be due to topographical effects.

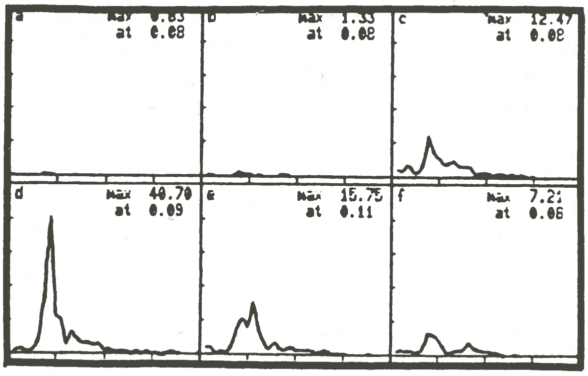

Figure 3. Typical directional frequency spectrum information for 6 wave-directions.

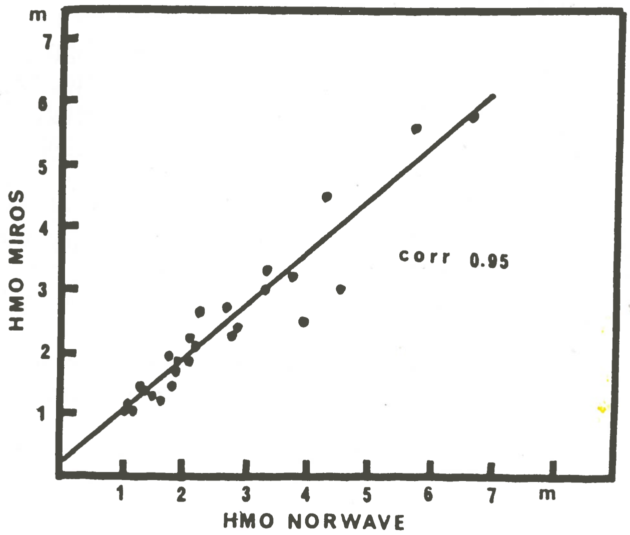

Figure 4. Relation between significant waveheights (HMO) estimated by MIROS and NORWAVE buoy.

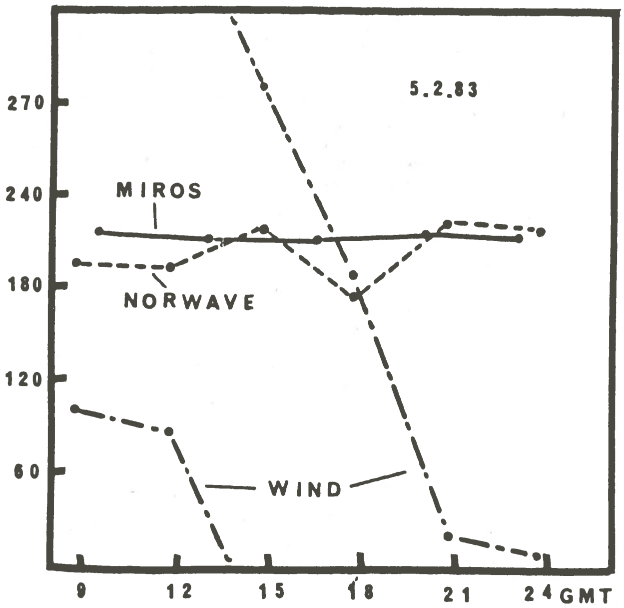

Figure 5. Spectral peak direction and wave-direction.

The spectral peak periods (the period corresponding to the energy maximum in the spectrum) recorded by MIROS and the buoy are also compared. A regression line is shown in figure 6 and displays high correlation.

Figure 7 compares the MIROS current measurements with the component of the current vector measured by the accoustic current meter in the direction of the radar. This data was collected January 29., 1983. The correspondance is good. As expected the radar indicates a higher current speed at the surface than what the current meter measures 2 meters below.

6. CONCLUSION

As a general conclusion the Lindesnes experiment shows that the data collected by the three sensors are highly correlated. This experiment has demonstrated that microwave remote sensing, as implemented in MIROS, is a realistic alternative to conventional techniques.

A major advantage of remote sensing is that the sensor can be taken out of the water and be placed in a less hostile environment. This is of great importance both for the maintenance cost and the system reliability.

At last the MIROS real time capability is very useful both for operational applications and routine measurements.

MIROS is now commercially available.

ACKNOWLEDGEMENT

The authors would like to acknowledge the valuable input to the MIROS project given by Dr. D. Gjessing and his team with the Remote Sensing Technology Programme, Royal Norwegian Council for Scientific and Industrial Research. The MIROS project was initiated at A/S Informasjonskontroll on the basis of their studies. We also would like to thank mr. L. Staveland, Statoil A/S, for his valuable contribution to the system specification and design.

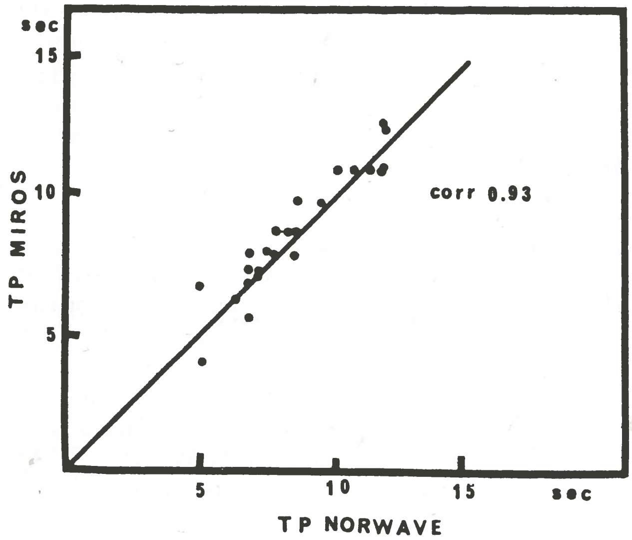

Figure 6. Relation between spectral peak periods (TP) estimated by MIROS and NORWAVE buoy.

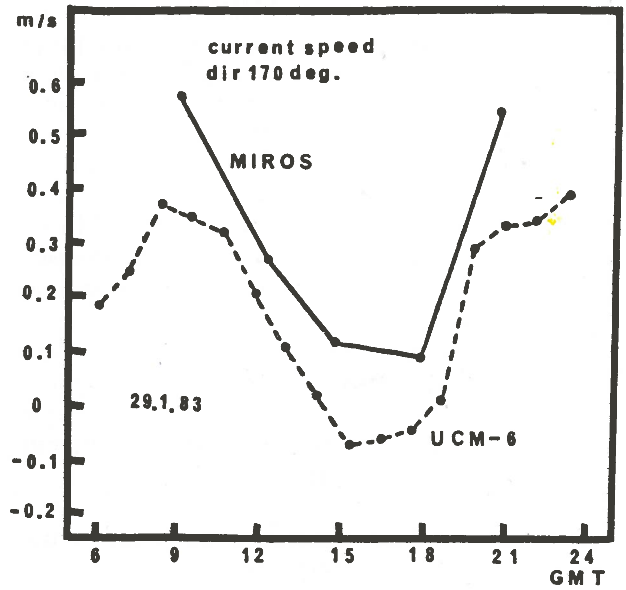

Figure 7. Current speed estimated by MIROS and UCM-6.