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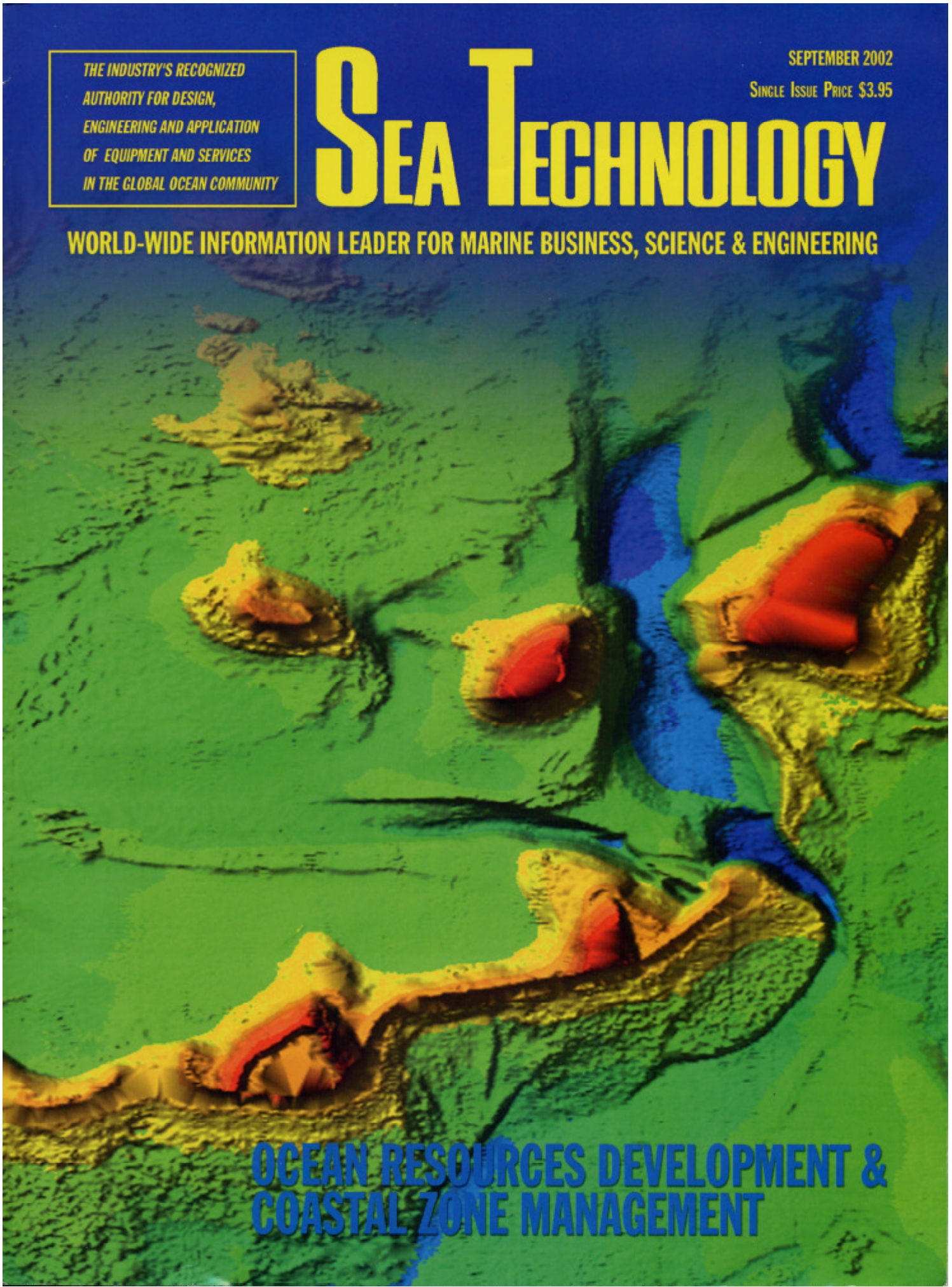

OCEAN RESOURCES DEVELOPMENT & COASTAL ZONE MANAGEMENT

Electromagnetic Sensor Measures Water Level

Simple and Inexpensive System May Provide High Quality Data; Versatile Sensor Suitable for a Wide Range of Applications

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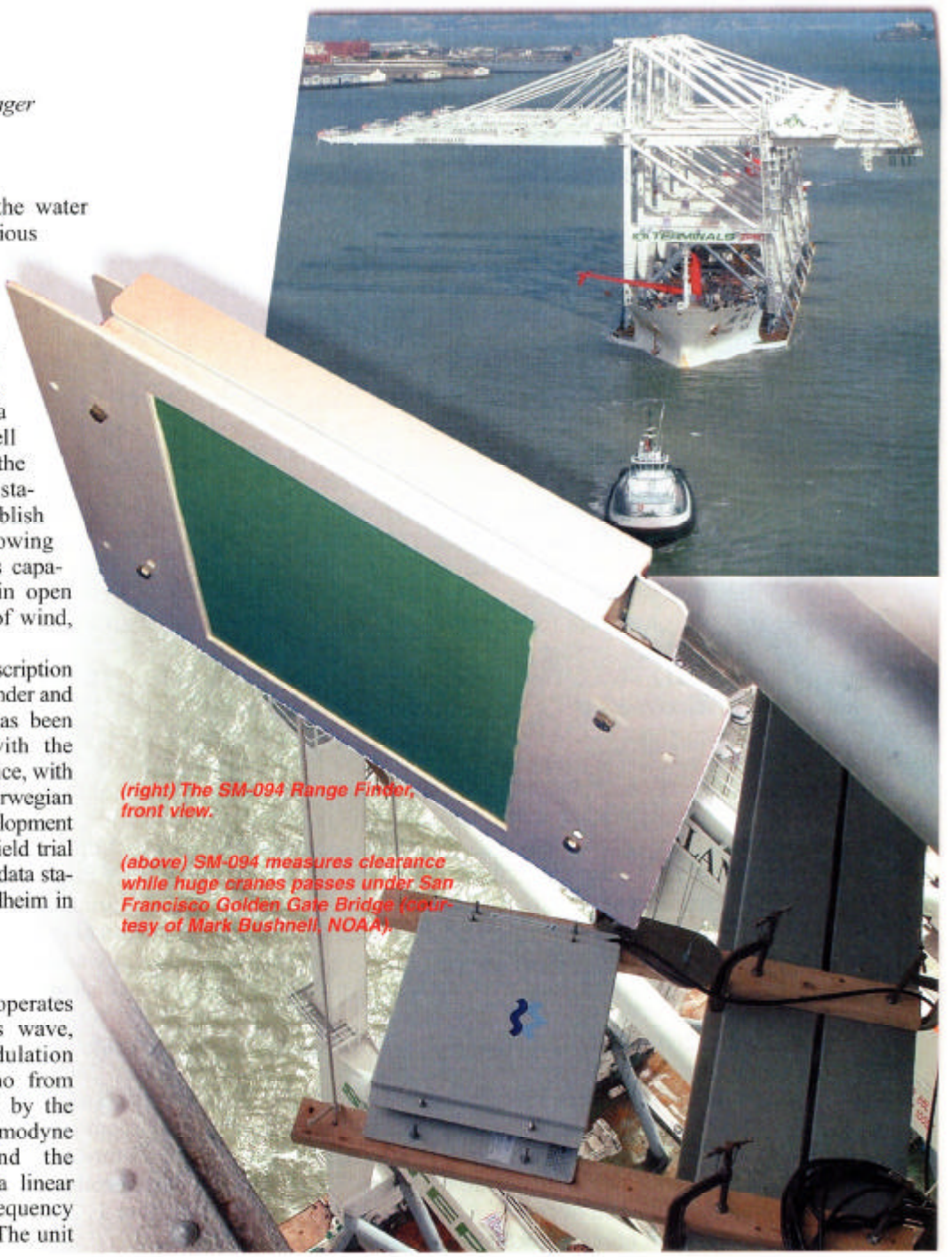
Precise measurements of the water level are important for various activities in the coastal zone. In Norway, the Norwegian Hydrographic Service operates a number of environment data stations equipped with mechanical tide gauges. These are based on a float in a stilling well. The stilling well quiets the water surface in the vicinity of the float. These stations are quite costly to establish and run and there is a growing interest in alternative sensors capable of measuring sea level in open waters (i.e., in the presence of wind, waves and current).

This paper gives a brief description of the Miros SM-094 Range Finder and its applications. The sensor has been developed in cooperation with the Norwegian Hydrographic Service, with additional funding from the Norwegian Industrial and Regional Development Fund (SND). Results from a field trial carried out at the environment data station at St. Olav's Pier in Trondheim in 2001 are also presented.



(right) The SM-094 Range Finder, front view.

(above) SM-094 measures clearance while huge cranes passes under San Francisco Golden Gate Bridge (courtesy of Mark Bushnell, NOAA).

SM-094 Range Finder

The SM-094 Range Finder operates according to the continuous wave, swept frequency modulation (CWFM) principle. The echo from the sea surface is multiplied by the transmitted signal in the homodyne microwave transceiver, and the resulting beat frequency is a linear function of the range. The frequency of operation is 9.4-9.8 GHz. The unit

(left) The MDS in Trondheim.

(right) SM-094 Range Finder measures water level at the MDS in Trondheim.

is designed with linearity and long term stability in mind. The CWFM transceiver uses a crystal-controlled digital frequency synthesizer. The FM sweep is controlled by the built-in micro controller and perfect linearity is ensured. The Range Finder antenna is a printed circuit patch antenna with a physical aperture of about 33 by 33 centimetres.

In order to optimize measurement performance with respect to accuracy, range and data update rate, the sensor has been made available in five different versions, antenna beamwidths may be either 5° or 10°, and the measurement range from 10 up to a maximum of 85 metres. All versions are packaged into the same housing made from welded seawater-proof aluminium sheet metal.

Applications

The SM-094 Range Finder is designed primarily to meet the needs for a microwave water level gauge. A field trial has been carried out at the environment data station of the Norwegian Hydrographic Service at St. Olav's Pier in Trondheim to assess its performance as a water level gauge.

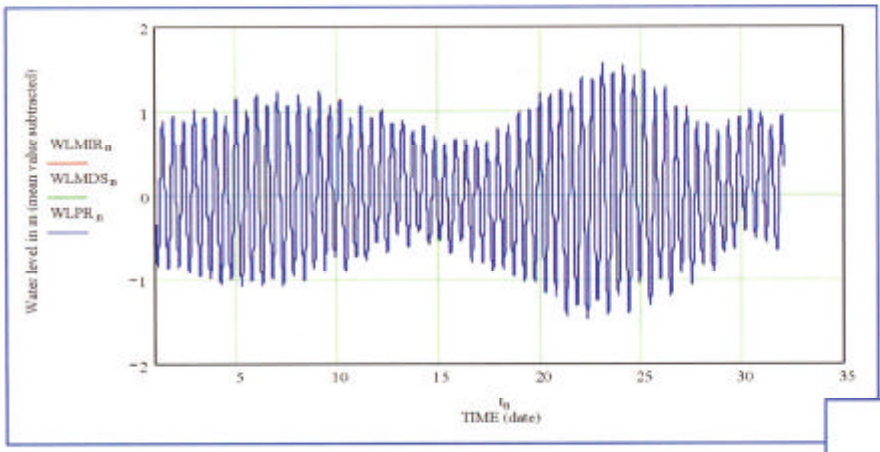
The sensor is also suitable for medium range offshore applications like air-gap and wave measurements, or for monitoring sailing clearances under bridges where both dynamic behaviour of the bridge structure and water level influences the clearance height for vessel passages.

Water Level Field Trial

The purpose of the trial at the environment data station (MDS) of the Norwegian Hydrographic Service in Trondheim in 2000/2001 was to make an assessment of the performance of the SM-094 as a water level gauge. An SM-094/10 (beamwidth 10°, range limited to 10 metres) Range Finder was installed on a mounting bracket about 4.3 metres above mean sea level. A laptop PC was used for data logging. Two Hz time series were stored in addition to statistical 10 minute averages. The collected data were downloaded to Miros facilities in Asker for control and post processing via a telephone line.

The MDS is equipped with a traditional tide gauge, level switch and a barometric pressure sensor. The tide gauge is based on a float in a stilling well. The pressure sensor tide gauge used in this project is a WLR7 (water level recorder) from Aanderaa Instruments.

The WLR7 is specially designed to measure water levels at sea. Placed on



the seabed, the recorder records pressure, temperature and conductivity (optional sensor) at regular intervals. Variations in water level are calculated on the basis of these data and the atmospheric pressure.[2]

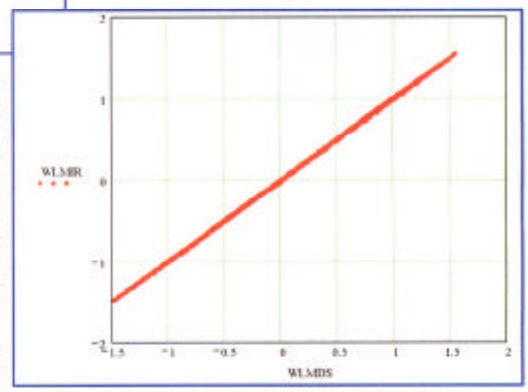
The MDS and WLR7 pressure sensor data has been post-processed by the Norwegian Hydrographic Service. Processing and quality control of the MDS and the pressure sensor data was performed by the Norwegian Hydrographic Service.[2]

Data Comparison

The SM-094 data used in the comparison were based on the 10 minute mean values calculated by the logging software. Three months of data were included in the analyses. The MDS and SM-094 data files include one data set every 10 minutes, while the pressure data files include one set every five minutes.

SM-094 and pressure sensor data have been interpolated using cubic spline interpolation and then time shifted and re-sampled to correct for sampling clock differences and to obtain the same number of data sets. The MDS data represent sea level relative to the chart datum. The position of the SM-094 and the WLR7 sensors relative to the chart datum were not known precisely, the mean value has therefore, been subtracted.

The Miros, MDS and WLR7 pressure data have been compared by plotting the tide time series and by plotting simultaneous values in scatter diagrams. Standard linear regression analysis has been used to calculate correlation as well as slope and offset



Tide in Trondheim in July 2001, as measured by SM-094, MDS and pressure tide gauges.

Simultaneous SM-094 Range Finder and MDS tide gauge measurements in Trondheim, July 2001.

of the regression line. For each set of data, the following variables were calculated: mean value of raw data, time shift for minimum standard deviation, correlation coefficient, slope and offset.[1]

From the sea level time series, the general impression is that all three sensors agree very well. However, zooming in on the highest and lowest tide one may notice a difference. The pressure sensor, in particular, seems to be in less agreement with the MDS than the SM-094. A standard way of comparing large amounts of measurements from two different sensors is to plot simultaneous data in a scatter diagram. SM-094 and MDS data are well concentrated along a 45° line. Using standard regression analysis, this means that the correlation between the two sensors is high (i.e., correlation equals 0.999963).

All available data have been included and no outliers can be observed. The slope of the regression line is 0.998638, which means that the gain of the two sensors (change in measured distance over true distance) is very close. Offset magnitude is 0.0000 millimetres.

"The results from the trial prove that the SM-094, under the environmental conditions encountered, is capable of providing sea level data of high quality."

The absolute deviation between the SM-094 and the MDS tide gauge varies between +/- 20 millimetres, with a standard deviation of 6.1824 millimetres. There are several sources of the measurement error. The most important contribution is likely to be due to sampling clock differences and instabilities. Other errors specific to SM-094 are caused by variation in footprint size due to antenna beam dispersion and interpolation between range resolution cells. In high waves, asymmetry in the wave profile introduces a sea-state dependant error.

Conclusion

The results from the trial prove that the SM-094, under the environmental conditions encountered, is capable of providing sea level data of high quality. Further tests are required, however, to conclude that the requirements of the Norwegian Hydrographic Service, with respect to accuracy and reliability, are met under all environmental conditions.

The trial also proves that the WLR7 pressure sensor is not suited for reference unless it is properly fixed in location. If further tests are to be carried out, data from all sensors involved must be recorded by a data logging system using a common time reference. During the trial in Trondheim the SM-094 was mounted in a rather sheltered location at the inside of the pier. Miros intends to carry out future trials in a more open environment where the sensors are exposed to wind and waves and to incorporate algorithms and sensor processing capacity to achieve satisfactory high accuracy and system dependability without the construction and maintenance of costly enclosures presently required for tide monitoring. */st/*

Øistein Grønlie received his masters degree in electrical engineering from NTNU in Trondheim (formerly NTH) in 1971 and his Ph.D. in communication theory in 1980. He has taken additional courses in radar theory and project management. Since Miros A/S was established in 1984, he has held positions as technical manager, sensor department manager and, since 1999, technology department manager. He has been deeply involved in the development of the Miros wave radar, the Miros altimeter, Wavex marine radar wave monitor and the Miros personnel registration system.

References

1. Miros Document 1201/TE/001/01, "Sea Level Measurements with Miros SM-094 Microwave Range Finder," Miros A/S December 17, 2001.
2. Hodnesdal, Hanne, "Sea Level Measurements with MDS and Pressure Sensor Tide Gauge 04.10.00 - 24.08.01," Norwegian Hydrographic Service, December 4, 2001 (this reference can also be found as Appendix 2 within reference 1).