produce these data was an Endeco Model 956 Wave-Track buoy and the experiment was conducted as part of ARSLOE (Atlantic Remote Sensing Land-Ocean Experiment, fall 1980).

While Middleton's technique may provide directional wave spectra, his system does not account for acceleration data noise created when a buoy pitches and rolls. Thus, it remains a requirement in the art to provide a technique for generating a complete wave data spectra while compensating for accelerometer data noise induced by pitch and roll in a buoy, in a manner that is compact and easy to implement in a cost-effective manner.

SUMMARY OF THE INVENTION

The present invention comprises a portable moored system for the real-time measurement of the ocean surface directional wave spectrum. Measurement and reporting of the surface ocean wave spectra with the present invention provides data from the ocean that is essential for marine weather analysis, forecasts, and warnings. Additional applications of the present invention include maritime operations and safety (e.g., marine transportation, offshore operations, etc.), planning and design of coastal structures and processes, information for ocean and coastal zone activities (e.g., boating, fishing, surfing, etc.), validation of remotely sensed surface ocean wave systems and method and numerical ocean wave models, and the use for forensic purpose for at-sea mishaps.

The invention can be used by research organizations (government—Federal, State, etc.), commercial entities, such as Harbor Pilot's Associations, Oil and Gas Exploration Companies, Ship Routing Services or Weather Forecast Services, or the general public to obtain detailed sea state information for safe and efficient maritime operations.

The invention uses a moored buoy floating at the ocean surface and anchored to the seafloor that precisely measures the acceleration, pitch, roll, and Earth's magnetic flux field of the buoy over a limited sampling period. A moored buoy system is essential to the progress of maritime weather forecast and safety by providing a more accurate and precise determination of the surface ocean wave spectra than can be determined from traditional observations from ships or from remote sensing applications. The moored buoy system maintains its position in the face of hazardous maritime conditions that ships would normally avoid and thus can make measurements without hazarding vessels or life. NDBC has developed reliable, cost-effective surface ocean wave spectra measurements that can be integrated into a moored system. An operational network of instrumented, moored buoys making real-time ocean surface spectra measurements has been established off-shore of the United States and on the Great Lakes. In real-time the surface buoy communicates with shoreside processing facility to decode, analyze, and re-distribute the ocean wave spectral data and its derived parameters to national and international maritime weather, safety, and operations.

Until the development of the present invention, at sea ocean wave spectra measurements were limited to a few costly, bulky, expensive, and specialized observing systems. The use of a moored buoy system together with a compact wave measurement system allows the expansion of a network of surface ocean wave spectral measurements co-located with other important maritime environmental observations, such as wind speed and direction, air temperature, and atmospheric pressure.

The Digital Directional Wave Module (DDWM) was developed in support of the National Weather Service and maritime operations interest (e.g., commercial shipping, Coast Guard Search and Rescue, Oil and Gas drilling platforms). The primary goal of the system was to provide accurate, precise, timely, and low-cost surface ocean wave spectra measurements. Additional goals included compatibility with existing NDBC systems and reduced life-cycle costs.

The DDWM was developed and tested as a prototype by NDBC in 2007. Currently the DDWM is operational on more than 18 moored buoys of the NDBC network of 105. NDBC is responsible for all aspects of system maintenance, operation, deployment recovery, documentation, and life-cycle management.

The components of the surface ocean wave spectra measurement system include: 1) A buoy, 2) A mooring system consisting of an anchor on the seafloor, mooring line connecting the anchor and the buoy, 3) An electronic datalogger that controls the communications between the wave measuring system and the on-board remote telecommunications system, 4) an embedded computer including printed circuit board for data input/output, temporary or permanent data storage, and algorithms to convert the measured time series data into surface ocean wave spectra and quality assurance statistics and encode the results for transfer to the datalogger, 5) Sensors include one or three acceleration sensors, three orthogonal angular rate sensors, and three orthogonal magnetometers to measure the Earth's magnetic flux field, 6) A telecommunications system that links the buoy datalogger and a shoreside processing system, and 7) A shoreside processing system that decodes the transmitted data, performs, quality control, and computes derived wave parameters.

The buoy measures vertical acceleration (the up and down) and the tilt of the buoy to get the slope. It takes a combination of accelerometers, magnetometers, and angular rate sensors to determine wave direction with respect to True North. The wave directions are first calculated using accelerometers and angular rate sensors in the buoy frame of reference (fore and aft, starboard and port). The magnetometers are used to tell how the buoy is oriented with respect to the magnetic direction, and the wave direction is rotated, determined in the buoy frame of reference into the magnetic direction. Lastly the directions are rotated using the magnetic declination or variation to get the wave directions with respect to earth True North directions.

The algorithm, which is actually a collection of algorithms, is unique. The noise correction does not use the tilt data. The tilt data causes noise in the acceleration data, but the algorithm of the present invention uses the presence of signals in the very lowest frequencies, which do not contain relevant wave information, to estimate what that noise is.

The algorithm is used shoreside and on the buoy. Shoreside it is used to remove the noise from the vertical acceleration spectrum. On the buoy it used to determine the lowest frequency at which to start the integration of the angular rate measurements to get pitch and roll.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments, features and advantages of the invention described herein will occur to those skilled in the art from the following description of a preferred embodiment and the accompanying drawings, in which:

FIG. **1** shows a typical mooring system used in accordance with the present invention.

FIG. **2** is a flow chart illustrating the steps in the operation of the algorithm portion of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, each surface ocean wave spectra measurement system uses a discus-shaped surface buoy **10** to