measure heave, pitch, and roll of the buoy's hull **13**, as the waves pass beneath. Within discus-shaped surface buoy **10** is a Digital Directional Wave Module (DDWM) **12**, a datalogger **20**, a power system **15**, and a communications system **40**. Surface buoy **10** follows wave motions (both water surface elevation and wave slopes) as closely as possible so ocean wave information can be determined from the buoy motion (buoy's heave and tilt motion). Thus, a discus-shaped surface buoy **10**, which can follow wave height and slopes better than other shapes, is usually used for directional wave measurement. Buoy tilt data may be used to determine wave slope, an important component of the overall wave spectra.

A mooring system **50** keeps discus-shaped surface buoy **10** within a general vicinity but sufficient slack or scope is provided to allow discus-shaped surface buoy **10** to respond to the waves for better directional wave measurement. A typical mooring system, from the ocean bottom to the surface, may comprise an anchor **131**, a length of chain **130**, shackles **127**, nylon rope **128** and syntactic floats **129**, shackles, another section of chain **126**, swivel and shackles **125** that connect to the buoy bridle **34**. Size and length of the components vary depending on the ocean depth and bottom surface characteristics.

The DDWM consists of sensors **60**, an embedded computer **70**, connections to the sensors **71**, and a serial communication link **72** to the datalogger **20**. Sensors **60** comprise at least one and up to three orthogonal acceleration sensors (**61**,**62**,**63**), three orthogonal magnetometers (**64**,**65**,**66**), and three angular rate sensors (**67**,**68**,**69**).

All sensors **60** are sampled at the same rate to make a cotemporaneous times series of the measurements. Sampling is controlled by the embedded computer **70** of the wave processing system and its associated processing algorithm. DDWM **12** controls and regulates the power to the sensors used to measure buoy hull motion and the earth's magnetic field.

Sensors **60** on discus-shaped surface buoy **10** measure vertical acceleration (the up and down) and the tilt of discus-shaped surface buoy **10** to get the slope. It takes a combination of accelerometers (**61**,**62**,**63**), magnetometers (**64**,**65**,**66**), and angular rate sensors (**67**,**68**,**69**) to determine wave direction with respect to True North. The wave directions are first calculated in computer **70** using accelerometers (**61**,**62**,**63**) and angular rate sensors (**67**,**68**,**69**) in the buoy frame of reference (fore and aft, starboard and port). Magnetometers (**64**,**65**,**66**) 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 shown in the attached appendices, 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 discus-shaped surface buoy **10**. Shoreside it is used to remove the noise from the vertical acceleration spectrum. On discus-shaped surface buoy **10** it used to determine the lowest frequency at which to start the integration of the angular rate measurements to get pitch and roll.

The buoy electronics use a +12V (nominal), solar recharged battery system. Primary batteries (non-rechargeable) are switched on by a power system controller if the secondary (re-chargeable) system fails. Datalogger **20** controls operation of the wave system by applying the battery power to the DDWM **12** and may send control parameters via a serial communications link. Once the DDWM **12** has acquired the raw sensor data and the wave processing algorithm has completed, the data are sent to the datalogger **20** via a serial communications link **72**. The datalogger **20** then includes this data in its environmental data telemetry to shoreside processing system **103** in near real-time via the communication system **40**.

The embedded computer **70** contains the processing code to use Fast Fourier Transforms (FFTs) to transform the data from the time domain into the frequency domain (that is, spectrum) that provides Fourier coefficients at discrete frequencies. The Fourier coefficients of adjacent discrete frequencies are averaged (known as band-averaging) to smooth the spectrum and reduce the amount of data that needs to be transmitted to the shoreside processing system **103**. The embedded computer **70** then transforms the band-averaged Fourier coefficients into a set of directional wave parameters in terms of spectral density, directions, and spreading functions of the waves via a unique NDBC-developed algorithm. The embedded computer **70** also computes statistics (mean, maximum, minimum, and standard deviation) of the time series measurements and other quality control parameters, which are very useful for monitoring wave data quality and for assisting in troubleshooting system malfunctions.

The embedded computer **70** finally encodes the directional wave spectral data and the statistics into an efficient format for relay to the datalogger **20** when the datalogger **20** requests the message from the wave processing system at scheduled times.

The primary measurement is the heave or the acceleration of the buoy perpendicular to the normal surface of the ocean. The accelerometer is fixed to be aligned perpendicular to the buoy's horizontal deck. The intent is to measure the accelerations with respect to perpendicular of the undisturbed steady state sea surface, but in reality the pitch and roll of the buoy cause the accelerometer to tilt from the true vertical. Several previous studies conducted by NDBC show some level of low-frequency noise could be present due to the tilt effect on fixed accelerometers. In addition, other noise (e.g., electronic noise) could also exist, especially at low frequencies. Accelerations or acceleration spectra measured by an accelerometer need to be converted into displacements (or displacement spectra) via an integration algorithm. To remove noise that can be amplified by the integrations, NDBC developed a unique algorithm to determine a cut-off frequency and to remove/correct low-frequency noise.

The angular rate sensors measure the buoys rotation about three orthogonal axes and can be integrated using Fast Fourier Transforms (FFT) and inverse FFT (IFFT) to compute the time-dependent portion, time-series of pitch and roll following the method of Steele et al., 1998. The forward and inverse FFTs are performed until the algorithm converges on a solution. Another algorithm was developed and is used to determine the mean pitch and roll to be added to the time-dependent pitch and roll calculations.

Once pitch and roll time series are determined, in conjunction with the acceleration time series the co-spectra and quadrature spectra are computed from FFTs and directional wave spectra with respect to the buoy's coordinates system are determined following the method of Longuet-Higgins et al., 1963.

The orientation of the buoy with respect to True North is determined from the measurements of the horizontal and vertical Earth's flux made by the three orthogonal magnetom-