Technical Brief of
"High Frequency Doppler Radar Scatterometer"

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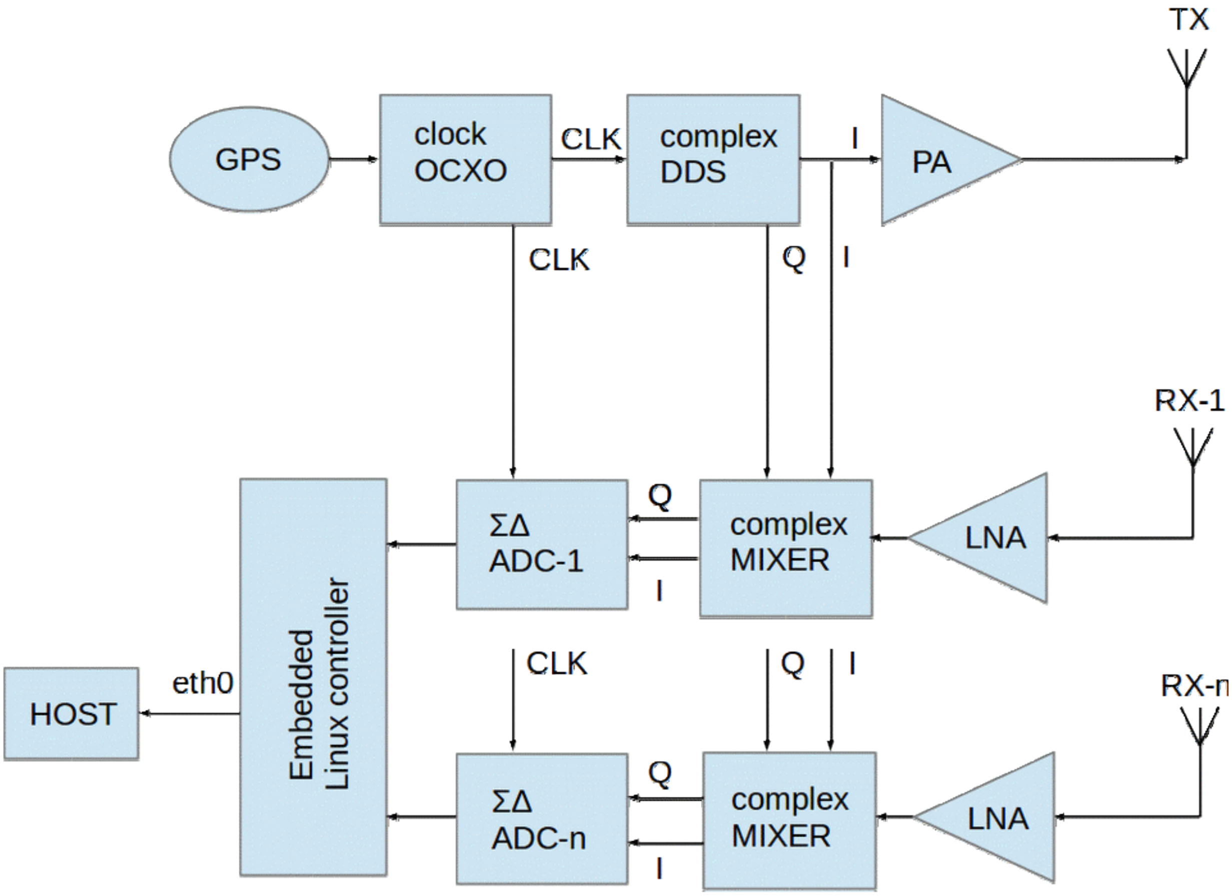
Acronym: HFDRS (High Frequency Doppler Radar Scatterometer)

Design: schematics published by the Radio Oceanography Laboratory, School of Ocean and Earth Science and Technology, University of Hawaii, USA; the design and plans are in the public domain.

Production: subcontracted to a consortium of companies: ParMetal (New Jersey, USA), Novatech Instruments (Washington, USA), Advanced Ciruits (Colorado, USA), Aode electronics and Bresto/Iltom (both in Brest, France), D-Tacq Solutions (Glasgow, Scotland) and Tomco Technologies (South Australia).

Physical principle: The operation of the HFDRS consists of sending radio waves, channeled on the surface of the conducting ocean as a ground wave, in the wavelength range of 10 to 100 m (frequency 3 to 30 MHz). These radio waves are coherently backscattered by the surface gravity waves at half the wavelength (5 to 50 m), and captured by an array of antennas. The back-scattered radio waves are shifted in frequency by the Doppler effect due to the sum of the wave velocities and the surface current. The measurement of this Doppler shift makes it possible to estimate the velocity of the radial current in the direction of the HFDRS.

Diagram:



Principle of operation: the signal generator is programmed to emit a repetition of ramps (chirp), typically of a duration of 0.2 to 1 s and a bandwidth of 30 to 300 kHz determined by the frequency allocation obtained from the national agencies, resulting in a frequency modulated continuous wave (FMCW mode).

For each ramp, a first Fourier transform of the orthogonal demodulated signals at the output of the receivers results in a sampling of the complex backscattering coefficient as a function of the radial distance, with a resolution inversely proportional to the bandwidth (from 5km to 0.5km), and a range inversely proportional to the frequency. The ramps are repeated for a minimum of 10 to 20 min, necessary to obtain a sufficient signal-to-noise ratio and Doppler resolution. HF radar scatterometers typically have a range of 300 km at 5 MHz.

A second Fourier transform of the complex time series for each radial distance, provides the Doppler spectrum at this distance, with a resolution inversely proportional to the averaging time, typically of the order of 1 mHz for 15 min. Beam-forming algorithms are then used to extract the Doppler shift as a function of azimuth from the receiving antenna array, and hence provide a mapping of the radial currents, with a typical resolution of the order of 2 cm / s.

Description of the scatterometer: The following subsystems are integrated to form the HFDRS:

1. an oven-controlled crystal oscillator (OCXO) with a thermal-inertia bell provides the synchronous clock signal (CLK) to both signal generator, and to the analog-to-digital converters; optionally, the oscillator can be slaved to a GPS receiver. Features: 100 MHz frequency, single sideband phase noise equal to or better than -150dBc / Hz.

2. an orthogonal signal generator (sin, cos) frequency-modulated by direct digital synthesis (DDS). Characteristics: clock frequency (after multiplication of the OCXO clock) 250MHz, 48-bit phase register, 12-bit digital-to-analog converter, 30MHz output low-pass filters resulting in a frequency operating band extending from 3 to 30 MHz. Period of repetition of the linear modulation of arbitrary frequencies, between 0.001 and 1000 s. Active Electronic Components (DDS): Analog Devices model AD9854.

3. a solid state power amplifier (PA). Features: Typical 47dB gain for an input signal of 0dBm (1mW), maximum power output signal 50W, frequency operating band ranging from 3 to 150 MHz.

4. a network of 8 channels of homodyne receivers (LNA-MIXER) carrying out a complex demodulation of the return signal of each receiving antenna, by a copy of the transmission signal at 0 ° and 90 ° of phase shifts. Features: -44dBm maximum high frequency input signal, 1MHz limited input bandwidth, 5Vpp maximum demodulated signal, 0-1kHz audio bandwidth with AC output coupling. Options to use as antennas passive monopoles of λ / 4 height, compact active monopoles of λ / 12 height (supplied), or inductive antennas (not supplied). The DC injectors for the power supply of the preamplifiers at the antenna base are incorporated in the receivers. Active electronic components: Gallium arsenide low-noise monolithic amplifiers, GALI-74 and GALI-84, and ADE-1H+ diode ring mixers, all by Mini-Circuits.

5. a sigma-delta analog / digital converter network ($\Sigma\Delta$-ADC). Characteristics: 512x oversampling, 24.6 MHz input sampling, 48kHz output for 16 or 32 synchronous channels digitized at 24 bits (19.5 effective number of bits), with constant delay digital anti-aliasing filter. Active electronic components: Texas Instruments model ADS1278.

6. an embedded processor, combining on the same integrated circuit, a programmable logic gate array (FPGA), digital signal processor cores (DSP) and a dual-core sequential processor operating under Linux (ARM Cortex-A9). FPGA and DSP configuration: decimation / 128

preceded by a digital constant delay anti-aliasing filter, 375 Hz final sampling at 24 effective bits. Active electronic components: Xilinx model Zynq-7000.

7. power supplies, transformers, circuit breakers and various electronic cards

8. Intel NUC7I5DNHE single-board computer running the Debian / Ubuntu operating system, with 32 GB of RAM and 2 TB of hard disk, under the Linux operating system, allowing the recording in continuous raw data for a period of 5 years, as well as real-time processing for transmission to the control center and data management of advanced products. Operation of radar requires a valid matlab licence, to be provided by the end user.

9. watertight enclosures (1 or 2 receivers, transmitter and power supplies) in white lacquered aluminum 20x60x75 cm weighing 28 kg each, protecting all electronic subsystems from weather and electromagnetic interference. These enclosures are custom built. The final installation by the end user can be done either in a standard 10’ container, or directly in the open air under a simple awning. The radar operates without an active cooling device up to an ambient temperature of 30C.

The software provided allows all programming operations of the signal generator, acquisition of raw data, calibration, recording data decimated to 375 Hz, Fourier transforms and beam formation.

High frequency radar scatterometer designed and built by the Radio Oceanography Laboratory, School of Ocean and Earth Science and Technology, University of Hawaii. On the left, receiver box, signal generator and analogue-digital converter in the upper compartment; reception cards and bandpass filters in the lower compartment. On the right, power supply box with circuit breakers, relays, power supplies, isolation transformer in the lower compartment; mounting plate for the control computer in the upper compartment.