Aquarius Instrument Design For Sea Surface Salinity Measurements

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***Abstract*— Sea surface salinity is a key parameter for the study of ocean circulation, global water cycle and hence climate changes. In response to these measurement needs, Aquarius was selected recently for the third NASA Earth System Science Pathfinder (ESSP) Announcement of Opportunity for a planned launch date in September 2008. The characteristics of the Aquarius instrument are provided in this paper.**

Keywords: Sea surface salinity; microwave radiometer; scatterometer

I. INTRODUCTION

The Aquarius mission is dedicated to global measurement of Sea Surface Salinity (SSS). Global measurements of SSS will directly aid in characterizing and understanding the current variations in global ocean circulation. The key scientific objectives of the Aquarius mission are to examine the cycling of water at the ocean's surface, the response of the ocean circulation to buoyancy forcing, and the impact of buoyancy forcing on the thermal feedback of the ocean on the climate. To achieve these objectives, the Aquarius instrument will require an accuracy of 0.2 PSU (Practical Salinity Unit or parts per thousand) in monthly averages at 100 km resolution.

II. INSTRUMENT DESIGN

The Aquarius employs a push-broom antenna with three feedhorns illuminating a 3-m offset parabolic reflector to obtain a swath width of 250 km (Fig. 1). This swath width is required to produce about 8 samples per month for each location in the tropics to achieve 0.2 PSS accuracy by temporal averaging. On each of the antenna feedhorns is an L-band radiometer to accurately measure the microwave emission from the ocean. Each radiometer is a Dicke-switching radiometer, using noise diodes and match load for calibration. A real-aperture L-band scatterometer shares the antenna with the radiometers to provide information to correct for the ocean surface roughness. The radiometer and scatterometer are both polarimetric to enable the correction of Faraday rotation through ionosphere [2]. A summary of the instrument characteristics is given in Table 1.

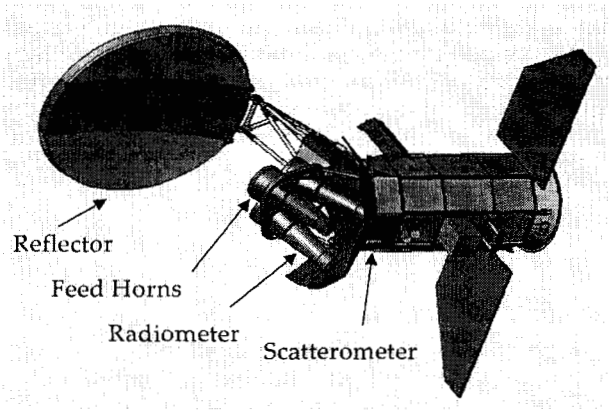

Figure 1. Aquarius instrument on the SAC-D spacecraft

The instrument consists of six functional parts: (1) antenna, (2) radiometer, (3) scatterometer, (4) instrument command and data (ICDS), (5) mechanical and thermal subsystems, and (6) power distribution unit (PDU). Fig. 2 is a block diagram of the instrument.

The *Aquarius* radiometer design is based on three existing instrument designs. The first is the PALS aircraft instrument, in which a precision, stable radiometer has been integrated with a scatterometer for SSS measurements [1]. The second is the AWVR, which is a ground-based instrument used for precision measurements of atmospheric water vapor and has demonstrated radiometer stabilities of 0.05 K over 30-day time scales. The third instrument is the Jason-1 microwave radiometer (JMR) using a similar Dicke-switch radiometer design with noise diode calibration.

The interface between the feedhorn/Ortho-Mode Transducer (OMT) and the radiometer and scatterometer is the diplexer as shown in the block diagram in Fig. 2. The diplexer divides the signal into two passbands using bandpass filters to set the frequency bands and minimize RF interference. The diplexer will provide ≥60 dB isolation between the scatterometer and radiometer.

The directional couplers at the radiometer input are used to inject a calibration noise signal from temperature and current controlled noise diodes for gain calibration. Following the coupler is a Dicke switch operating at 33 Hz to eliminate the amplifier's noise and drift. Several vendors provide space-qualified PIN or Field-effect-transistor (FET) switches with losses ≤ 0.5 dB and ≥40 dB port-to-port isolation. The Dicke load will be a 50 Ω surface mount termination with an integrated temperature sensor. Following the switch is another set of directional couplers and noise diodes to be used for system diagnostics. An isolator with a loss < 0.5 dB and isolation ≥20 dB precedes the low noise amplifier (LNA) to provide a good impedance match for the LNA. The LNA has a noise figure (NF) of 0.4 dB, a gain of 30 dB. This is followed by two more amplifiers (G = 30 dB, NF = 1 dB each) and bandpass filters setting the radiometer passband from 1401 to 1426 MHz, which is within a protected radio astronomy band. Each filter will provide ≥40 dB rejection at the scatterometer frequency of 1260 MHz. The gain distribution provided by three amplifiers together with rejection from the diplexer, switch, and bandpass filters assures that the scatterometer transmitter will not saturate any of the amplifiers or detectors. The radiometer data will also be blanked during the transmit time, to eliminate any spurious signal.

TABLE 1. Aquarius instrument characteristics

Parameter	Radiometer	Scatterometer
Frequency	1.413 GHz, 25 MHz bandwidth	1.26 GHz
Orbit	600 km, sun-synchronous	
Polarization	Vertical, Horizontal, U	VV, HH, HV, VH
Incidence Angle	23.3°, 33.7°, 41.7°	
Antenna Beamwidth	5.2°	
Footprint size	62x68 km, 68x82 km, 75x100km	
Calibration	3-position Dicke-switching	Calibration loop
Pointing accuracy	0.1° (knowledge), 0.5° (control)	
Signal detection sensitivity for 12 second integration	0.05 K for radiometer noise equivalent delta T	0.03 dB
Calibration stability for 8 days	0.12 K	0.15 dB
Radar transmit	NA	200 W peak power, 1 ms pulse length, 4 MHz transmit chirp bandwidth, 100 Hz pulse repetition frequency

With the ~100 K signal from the ocean surfaces, the radiometer system noise will be <350 K. Taking into account the scanning of the footprint from the orbital motion, it has been calculated that it will be possible to integrate for ~12 s to achieve an effective 100-km 3-dB footprint in the outer antenna beam. (The inner antenna beam can be integrated up to 30 s.) The three-position Dicke radiometer has ~20% larger ΔT than the classical Dicke configuration, and with a 25-MHz detection bandwidth, the predicted ΔT is <0.05 K for each 12-s integration period.

Near-simultaneous radiometer and scatterometer operation is achieved with a time-sharing design. The scatterometer transmits 1-ms pulses with an inter-pulse period of 10 ms and sequentially scans through vertical (V) and horizontal (H) polarization channels on three antenna feedhorns for six pulse cycles. Subsequently, the scatterometer transmit is disabled for six pulse cycles to measure system noise level. Between the nominal scatterometer transmit pulse times, the radiometers operate in a three-position Dicke switching sequence. This timing scheme has heritage from the Passive/Active L-/S-band (PALS) microwave instrument design [1] and enables highly collocated radiometer and scatterometer observations.

III. CALIBRATION STABILITY

The key to high accuracy SSS retrieval from *Aquarius* instrument measurements is the stability of instrument or the repeatability of measurements under the same environmental conditions. The requirement for the Aquarius instrument is the radiometric calibration stability of <0.1 K for radiometer and <0.2 dB for scatterometer. To reach this high level of calibration stability, a combined active/passive thermal approach needs to be applied to the OMTs, radiometer and scatterometer front-end electronics with a required temperature stability of ±0.1°C

The required stability of ±0.1°C is achieved through actively controlled heaters dedicated to local control zones. The ICDS and PDU regulate temperature. The temperature sensors are placed in redundant pairs along the OMT structures and front-end electronics baseplates and are connected to the ICDS by cable. Redundant heater strips are co-located with the sensors on the OMT and electronics, and are connected to the PDU by cables. The ICDS temperature sensor board reads the temperature values one at a time and then converts the sensor voltages to digital values. All values are transferred to the ICDS CPU approximately 10 times a second. The CPU translates the digital values to temperature values and compares them with a programmed mean value to activate or de-activate the heaters through the solid-state relays in the PDU. The mean temperature will be kept as low as possible to conserve heater power and will be kept above the unregulated peak value to meet the temperature regulation requirement.

ACKNOWLEDGMENT

The research carried out in this paper is performed by the Jet Propulsion Laboratory under a contract with the National Aeronautics and Space Administration. The authors would like to thank the other Aquarius project team members for the design and drawings.

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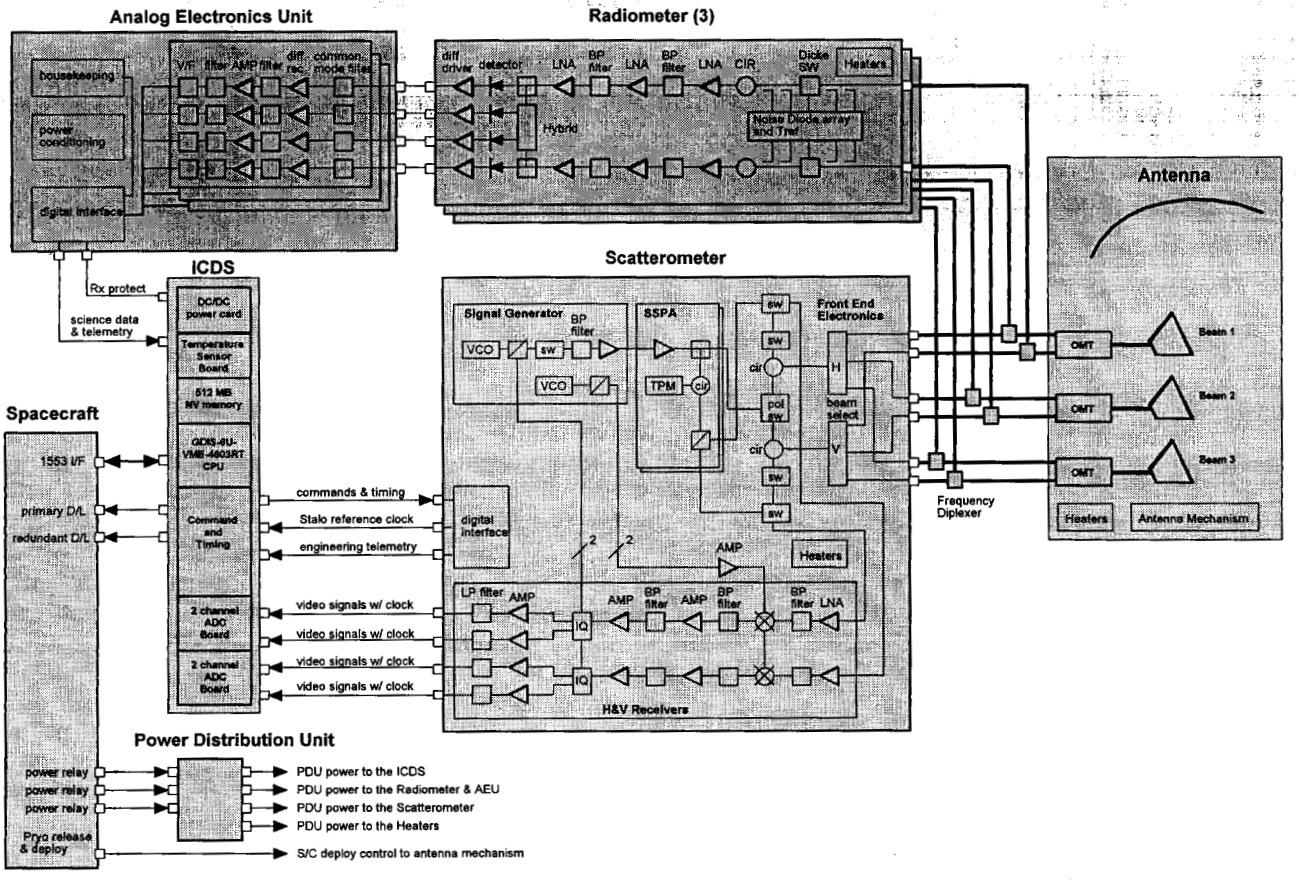

Figure 2. Aquarius instrument block diagram.

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