THE DETECTION AND MITIGATION OF RFI WITH THE AQUARIUS L-BAND SCATTEROMETER

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1. INTRODUCTION

The Aquarius sea-surface salinity mission includes both an L-band radiometer and scatterometer. The scatterometer senses sea-surface roughness to provide a radiometric correction to the radiometer’s measurement of ocean surface brightness temperature, thus allowing the estimation of salinity from the corrected brightness temperature [1]. Both RF sensors are subject to radio-frequency interference (RFI) in their respective L-band wavelengths (1400-1427 MHz for the radiometer, 1258-1262 MHz for the scatterometer). Both instruments require highly sensitive measurements of received power, such that the existing RFI environment at L-band poses significant challenges. The mitigation of the RFI environment for the radiometer has been documented elsewhere [2,3].

This paper describes the results of a study evaluating the severity of terrestrial RFI sources on the operation of the Aquarius scatterometer radar, and the design of a scheme to both detect and remove problematic RFI signals in the ocean backscatter measurements. We will also examine implications of the growing world of global navigation satellite systems, generating space-based L-band RFI, for the Aquarius scatterometer, scheduled to launch in 2010 with a 3-year lifetime.

2. EXPECTED RFI ENVIRONMENT

In 2004, the Aquarius and Hydros [4] projects commissioned, with the NASA Earth Science Spectrum Management Office, an RFI environmental study to understand, quantify, and mitigate RFI generated by ground radars on the two orbiting instrument systems. Realistic beam patterns, orbit geometry, and instrument characteristics were used for modeling the Aquarius Instrument, both radiometer and scatterometer subsystems. A large sampling of non-classified North American radars that transmit at L-band were included in the analysis as RFI sources. This yielded about 180 RFI sources, mostly air traffic control and air defense radars, with a wide variety of peak powers, pulse rates, scan rates, beam widths, and frequency-hopping characteristics. Although all these sources are located on land, they can be seen by the Aquarius Instrument as soon as they pop over the horizon as observed from the satellite (approximately 3000 km distant). Although no main-beam to main-beam viewing occurs, the main beam of the RFI sources pass through the side-lobes of the three Aquarius antenna beams (oriented in a fixed, pushbroom configuration forming a ~370 km-wide swath on the ocean surface). The Aquarius main beams view the side-lobes of the ground radars, but this always occurs over land, thus not affecting the ocean salinity measurements.

Unlike the radiometer, which operates in a nominally protected RF band where no RFI should appear, the scatterometer operates in a radar band full of terrestrial sources. The RFI study indicated that certain sources would create serious problems for the scatterometer operation. In order to correct for roughness-induced brightness temperature errors to the required level of 0.05 K, the scatterometer has to detect backscatter power to a level better than -150 dBW. The RFI study indicated that the scatterometer would see nearly continuous fluctuations of RFI power ranging from <-180 dBW up to -125 dBW, with frequent peaks in the open ocean up to -105 dBW. We would therefore need a scheme to detect and remove radar data contaminated by the stronger RFI peaks, and somehow reduce or mitigate the effects of the continuous fluctuations by up to 25 dB. (We have assumed that the RFI environment elsewhere around the globe is not substantially worse than in radar-rich North America, but we remain aware that this assumption may not be valid everywhere.)
3. RFI MITIGATION AND INSTRUMENT DESIGN

Several approaches are being used to mitigate and remove the RFI from the scatterometer data. The first is the simple time-averaging of the measurement data on the ground. Both the radiometer and scatterometer teams will be averaging data collected at the instrument pulse interval of 10 ms (PRF of 100 Hz) down to intervals of 5.76 seconds in order to reduce thermal noise and scintillation. This averaging by itself tends to reduce the mean RFI power of the continuous fluctuations noted above by about 10 dB.

Based on the above analysis, we determined that if we could directly sense RFI peaks exceeding -130 dBW, roughly the noise floor of the instrument, and exclude them from the time averaging, we could bring the mean RFI power level down to about -145 dBW. This is approximately the accuracy level for which we must measure strong backscatter signals, but still 5-10 dB above the desired accuracy level for weak backscatter signals. However, we found no better solution at reasonable cost to implement.

We do not have the bandwidth to downlink measurement data at the digital sampling rate of 16 MHz, which would give us tremendous flexibility in detecting and removing RFI using ground algorithms. We are instead averaging the received power over ~2 ms receive windows onboard, and downlinking these values. Yet the digital sampling implementation allows a simple method of flagging those 2-ms pulses for RFI contamination. We have implemented a programmable threshold detection system in onboard logic [5] that can sense RFI peaks within a “noise-only” (no transmit) measurement and flag that measurement as contaminated. This system allows us to specify both the power level of RFI and the length of the RFI pulse to flag; as long as these two parameters do not allow expected thermal noise to generate false positives, we can detect most of the RFI sources indicated as problematic in the North American RFI study. No data are actually removed onboard, so all radar data can be reexamined on the ground for consistency with the flagging and characterization of the RFI signal. In addition to providing flags to eliminate or mitigate the contribution of RFI to the radar backscatter measurements, we have the ability to essentially map RFI sources with diverse characteristics at 1260 MHz around the globe.

4. SPACE-BASED RFI

Although it is not expected to pose a serious problem to our instrument, there is a growing constellation of global navigation satellites, some of which have transmit frequencies quite close to the scatterometer operational band [6]. Although all these signals enter through the back-lobes of the antenna, there are some higher-gain “plateaus” in the back-lobe beam pattern. In addition, space-based RFI is not limited to near-land locations and is nearly continuously visible by Aquarius. We will evaluate what effect these RFI sources will have during the expected 3-year life of the Aquarius Instrument.

11. REFERENCES


