THE DUAL FREQUENCY SCATTEROMETER INSTRUMENT CONCEPT

Robert W. Gaston, Steven L. Durden, Chialin Wu, Richard C. Hughes, Yahya Rahmat-Samii,*
Larry W. Epp and John B. Burt

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109
* University of California, Los Angeles, Los Angeles, CA

1. INTRODUCTION

The Jet Propulsion Laboratory is developing a Dual Frequency Scatterometer (DFS) instrument concept designed to be an operational follow-on to the SeaWinds instrument that operated on the QuikSCAT spacecraft from June 1999 through November 2009. The DFS instrument is planned for flight on the JAXA Global Climate Observation Mission W2 (GCOM-W2) in the 2016 timeframe and will measure wind speed and direction over the ocean surface using radar scatterometers operating at Ku and C-band frequencies. The GCOM-W2 spacecraft will also host the Advanced Microwave Scanning Radiometer generation 3 (AMSR3).

Operational forecasters at NOAA have specified improvements for an operational system over QuikSCAT that are quite demanding [1]. The key objectives are to: 1) measure high winds found in hurricanes, 2) improve performance in rain, and 3) if possible, improve spatial resolution for coastal applications. The evolving partnership between JAXA, NOAA and NASA on the GCOM-W2 mission has enabled a DFS instrument concept to emerge that achieves many of the desired improvements. The partnership has thus far focused on establishing 1) operational user support for and 2) feasibility of the DFS and GCOM-W2 implementation approach.

This paper discusses methodology used by the JPL study team to evaluate feasibility. The DFS instrument concept draws from many features of the SeaWinds instrument design. Special attention is paid to those areas where the DFS concept differs from the proven SeaWinds instrument design. Key differences include 1) use of a single reflector to form four antennal beams, 2) use of a four-channel RF rotary joint, 3) addition of C-band RF electronics including a C-band transmitter power source, 4) cancellation of the angular momentum of the DFS rotating components, and 5) use of an RF shield to attenuate DFS transmit signals that might interfere with the sensitive AMSR3 instrument. Identifying feasible design concepts and evaluating system trades for each of these elements has been the subject of the pre-phase A concept studies that are reported in this paper.

2. DESCRIPTION OF THE DFS INSTRUMENT CONCEPT

Figure 1 is a block diagram of the DFS instrument with the primary differences relative to SeaWinds shown in red. The SeaWinds Ku-band scatterometer flown on QuikSCAT used a dual pencil beam conically scanned (relative to nadir) antenna to form an 1800 km wide measurement swath. The proposed DFS scatterometer instrument will be based on the same architecture and scanning approach as the SeaWinds instrument but will add the capability to measure normalized radar backscatter coefficient, σ0, at C-band. These additional σ0 measurements will enable the DFS system to achieve better performance in high wind and rainy conditions.

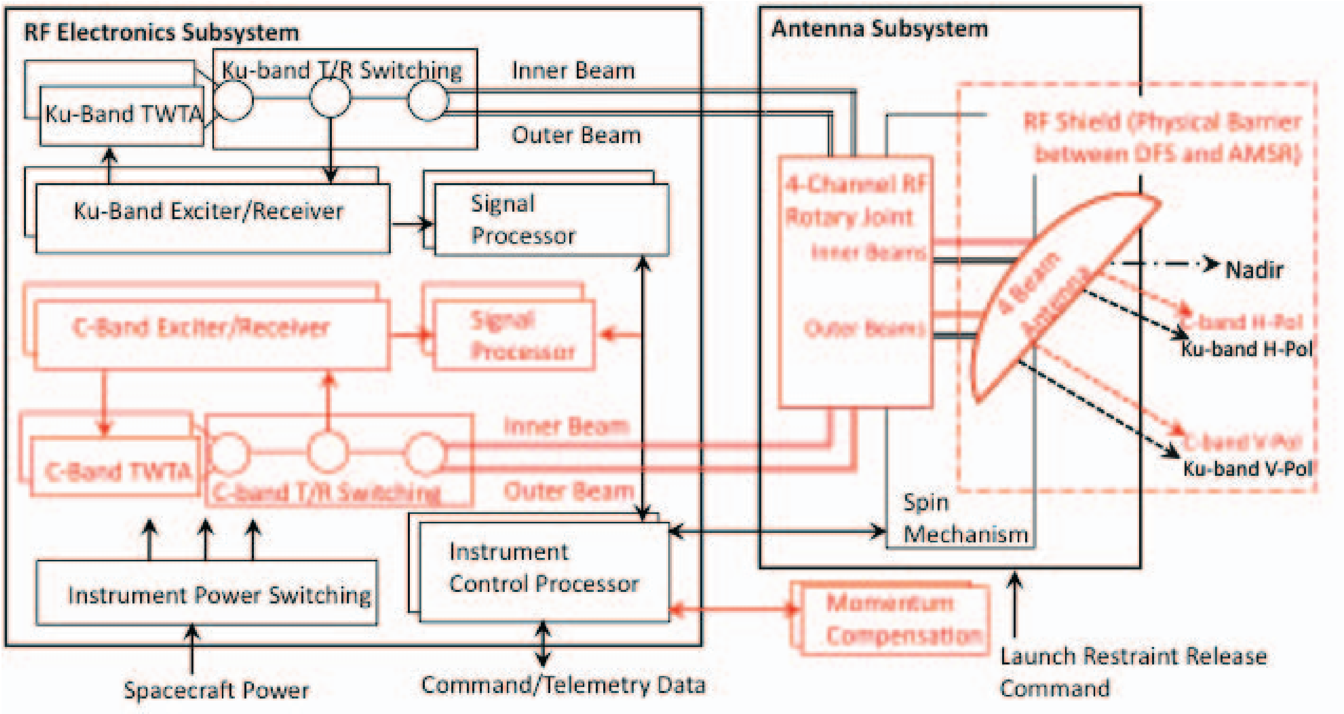

Figure 1: DFS Block Diagram With Differences Relative to SeaWinds Shown in Red

2.1 RF Electronics Subsystem

The C-band scatterometer capability to be incorporated in the RF Electronics Subsystem mirrors that of the SeaWinds Ku-band electronics and the applications and modifications of the heritage SeaWinds designs are straightforward. The C-band traveling wave tube amplifier (TWTA) is the most challenging of the new designs within the RF Electronics Subsystem. The DFS study team has worked with TWTA vendors who have delivered and flown pulsed Ku-band TWTAs to establish the feasibility of a design approach where an existing C-band TWTA for CW operation is modified to accommodate the pulsed radar performance required by the scatterometer. Solid-state power amplifier technology is also considered to be feasible for the C-band power levels that are likely to be required by DFS.

2.2 Antenna Subsystem

Other changes to the SeaWinds heritage design are driven primarily by the need to keep mass and volume within constraints that are consistent with the GCOM-W2 spacecraft capabilities. This drives the design of the antenna subsystem toward sharing a common antenna reflector and spin mechanism for all four beams. The largest rigid reflector that can be accommodated within the launch fairing without a potentially complex stowing concept is 1.9 m. Since that is roughly the same size as the available on-orbit operational volume there is no obvious benefit to developing a stowed antenna design. A feasible 1.9 m diameter antenna concept has been established analytically and will be prototyped during phase A. The antenna can be launched in a fully deployed configuration and satisfies antenna performance parameters specified for both scatterometer frequencies used by DFS.

In keeping with the SeaWinds architecture, the study team has focused on determining whether the DFS instrument can be implemented without need for slip ring electrical interfaces that could be costly and reduce overall system reliability. The key is to establish feasibility of a four-channel RF rotary joint for passing transmit and receive signals for each of the four beams across the rotating interface. This eliminates the need for active electronics on the spun platform. Two qualified suppliers of space flight RF rotary joints have completed studies and are ready to develop prototypes during phase A. Alternative instrument architectures have been explored including implementations using a SeaWinds style two-channel rotary joint in place of the four-channel device. A two-channel approach can be employed at the expense of adding active spun side electronics in the event the four channel approach becomes problematic.

Perhaps the most challenging aspect of the DFS concept is the need to establish RF compatibility with the AMSR3 instrument. The AMSR3 radiometer receivers require very high isolation from the DFS RF transmissions. Analysis has been completed, but because there are many uncertainties in the models that are used, it isn't possible to assure compatibility with AMSR3 by analysis alone. For this reason a comprehensive approach to testing is being developed. Hardware tests will be completed in early 2010 using frequency scaled test articles to establish whether the analysis approaches that have been used are reliable. Other tests using prototype hardware will be completed during phase A. The DFS concept includes an RF shield that surrounds the antenna subsystem to improve isolation. Testing of the materials used in the RF shield as well as treatments applied to the edges of the shield and antenna reflector to reduce diffraction effects is also a priority to be completed early in Phase A. As an on-orbit back-up plan, an operational option that is capable of eliminating interference during flight operations has been identified. By reducing the nominal DFS transmit pulse duration, the interference (if observed on-orbit) can be reduced. This would adversely affect DFS system performance but would enable both AMSR3 and DFS to continue simultaneous operations. Other antenna design concepts that have potential to improve isolation are being studied and will continue to be included in the system design trade space during phase A concept development.

3. CONCLUSION

The DFS pre-phase A studies have established feasible solutions and alternatives for all of the primary differences relative to the proven SeaWinds instrument design.

6. REFERENCES

[1] P. Chang and Z. Jelenak, “NOAA operational ocean surface vector winds requirements workshop,” workshop report, NOAA National Hurricane Center, Miami, FL, June 2006.