INITIAL RESULTS FROM THE GEOSTAR-II LABORATORY DEMONSTRATOR

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ABSTRACT

The Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) team recently concluded its second Earth Science Technology Office (ESTO) IIP-07, "GeoSTAR technology development and risk reduction for PATH". The major accomplishments during this project at JPL were:1) Demonstrate performance and scalability of the 183 GHz receivers 2) Local oscillator phasing architecture and technology 3) Subarray design validation including feedhorns, manifolds and alignment 4) System demonstration of signal distribution topology and measurements. Significant progress has been made to retiring risk of the various subsystems.

Index Terms **—** *Synthetic Aperture Radiometry, Microwave radiometry , MMICs*

1. INTRODUCTION

The Decadal Survey nominally calls for a microwave array spectrometer as the main instrument for the Precipitation and All-Weather Temperature and Humidity (PATH) [1]. The various GeoSTAR developments have been geared towards developing the technology required for such an instrument. The GeoSTAR-I laboratory demonstrator was a 50 GHz microwave array spectrometer that demonstrated the synthetic thinned aperture radiometry concept at the Oxygen line for temperature sounding [2]. The GeoSTAR-II laboratory demonstrator builds on this pedigree by operating at the 183 GHz water vapor line and investigating new array geometries for improved instrument performance [3]. The following summarizes the various key developments that have occurred during the ESTO IIP-07, "GeoSTAR Technology Development and Risk Reduction for PATH."

2. 183 GHZ RECEIVER

The 183 GHz receivers were developed under ACT-05 "Miniature MMIC Low Mass/power Radiometer Modules for the 180 GHz GeoSTAR Array (MIMRAM)" [4] and underwent several improvements for GeoSTAR-II including improved cavity alignment and mechanical strength. Careful on wafer screening of both the LNAs and mixers MMICs was performed, and a total of 50 MIMRAMs were produced at JPL. An issue involving flux flow was discovered during the integration process with the intermediate frequency (IF) boards which led to rework of approximately 25% of the units, Figure 1.

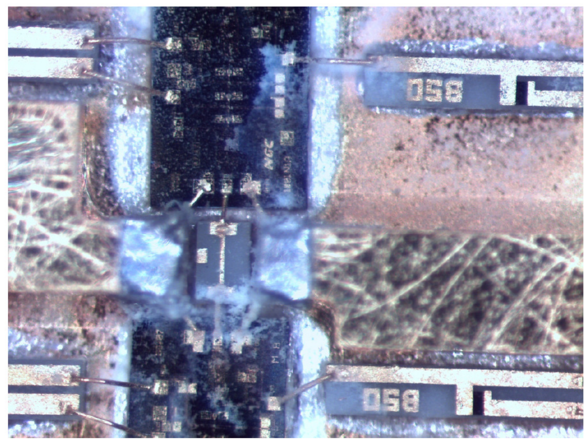

Figure 1. Flux residue lifts up MMICs and substrate

Each individual MIMRAM gate and drain voltages is controlled separately through the use of a digital to analog converter (DAC). This allows for optimization of the gain and noise performance in the system. Nominal measured system noise figures were on the order of 4.0 to 4.5 dB. The best performing MMIC had a 3.5 dB noise figure. Figure 2 shows a 183 GHz receiver integrated with the IF Board.

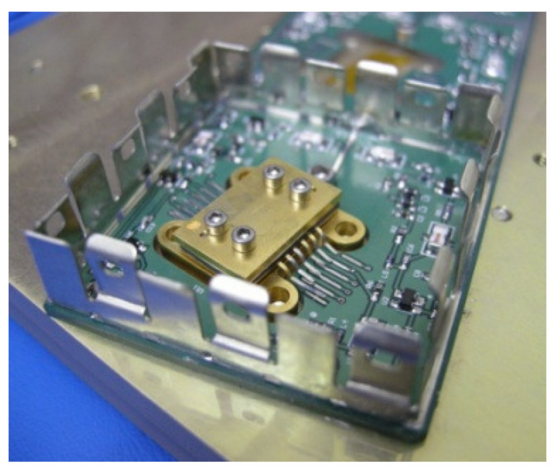

Figure 2. MIMRAM integrated on the IF board

Overall, 75% of the units were functional in the system. Typical failures included: 1. No LNA current draw 2. Low gain at the output 3. Noisy channels. It was not possible to achieve 100% functionality as there were insufficient spare MMICs available from the existing wafers. The lower yield represents the learning curve from the fabrication process. Yield statistics will improve going forward with new procedures and testing in place.

3. LOCAL OSCILLATOR PHASE SWITCHING

Phase shifting of the local oscillator is a crucial component of the calibration methodology of GeoSTAR-II. An LO multiplier unit was developed with a 5-bit phase shift and programmable output leveling. Test results show leveling of LO power of ±0.01 dB vs phase over the pre-multiplier frequency range of 26 to 32 GHz. Figure 3 shows the design, physical hardware and correlation vs phase data measured through the system.

3. SUBARRAY MODULES

The subarray modules are the basic building blocks for the GeoSTAR-II array. Each subarray consists of a LO distribution manifold, integrated receivers with IF boards, feed horns and alignment frame. The full GeoSTAR instrument for PATH will require arms with up to 200 elements. Subarrays allow for ease of fabrication and testing of smaller that can be eventually integrated into larger arrays.

3.1 4x4 Subarray Geometry

The new 4x4 arm geometry is utilized to increase the aperture size of the antenna in order to increase the antenna gain [5]. This new geometry allows us to achieve the challenging 0.3K noise equivalent delta temperature (NEΔT) requirement. Figure 4 shows the physical position of the antennas and the associated visibilities.

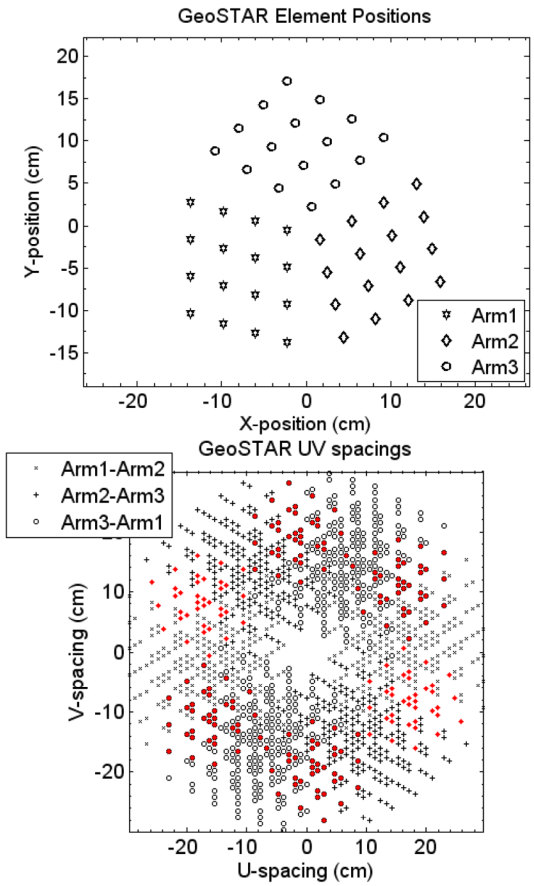

Figure 4. (Top) Physical antenna positions (Bottom) Associated visibility samples

Careful attention must be paid to the antenna design, as the antenna pattern is carefully selected so that it will provide de-aliasing in the image area.

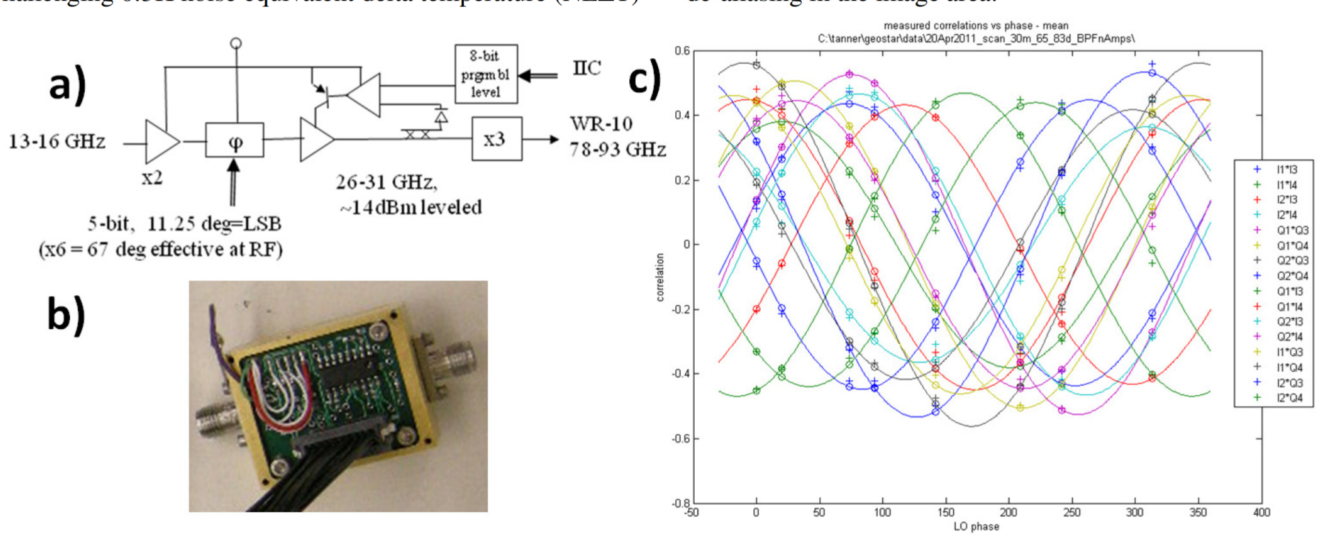

Figure 3. Block diagram of the LO system b) Actual fabricated unit c) Measured correlations vs phase

3.2 Scalability

Figure 5 shows the GeoSTAR-II array with 3 subarray units, showing the new high gain array antenna topology [5]. Each arm can be easily extended by adding additional subarrays allowing for ease in scalability. For a synthetic aperture array, the addition of elements on the end increases the pixel resolution of the imager. The alignment of the antennas is maintained by a lightweight support structure built around the antennas. An alignment tool was developed to ensure correct pointing of the antennas during mechanical assembly.

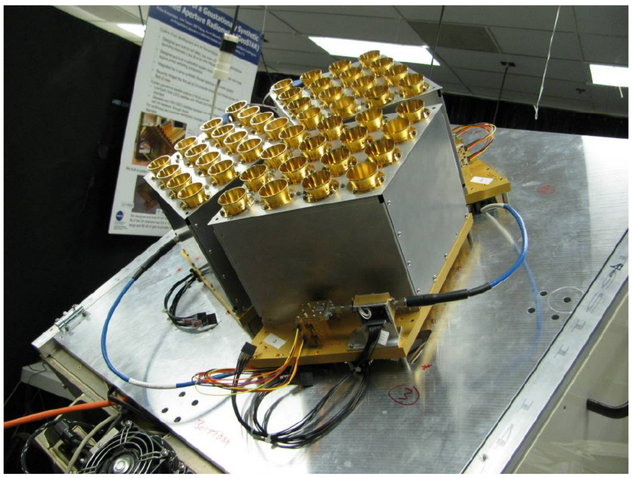

Figure 5. GeoSTAR-II subarrays integrated

4. SYSTEM DEMONSTRATION

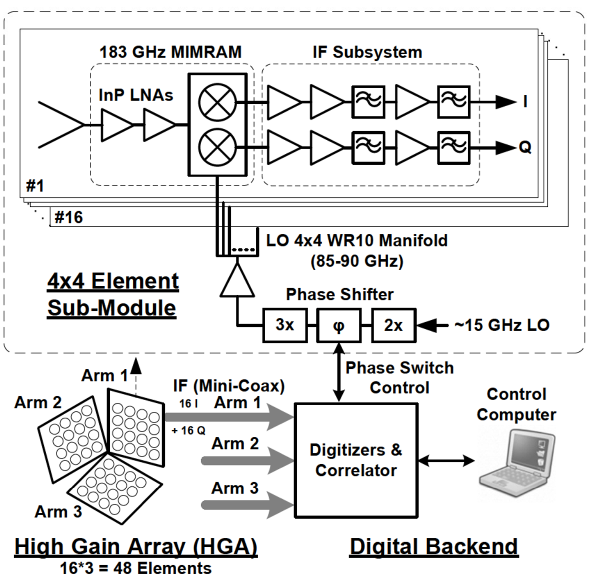

Figure 6. GeoSTAR-II system block diagram

Figure 6 shows the system block diagram for GeoSTAR-II. The fully integrated system was moved outside to view a sun transit to look at correlation magnitudes and fringe measurements. Figure 7 shows the instrument with foam insulation and the normalized correlation magnitudes. The variance in the correlation magnitudes are measured to be less than 1%, giving high confidence in antenna and system.

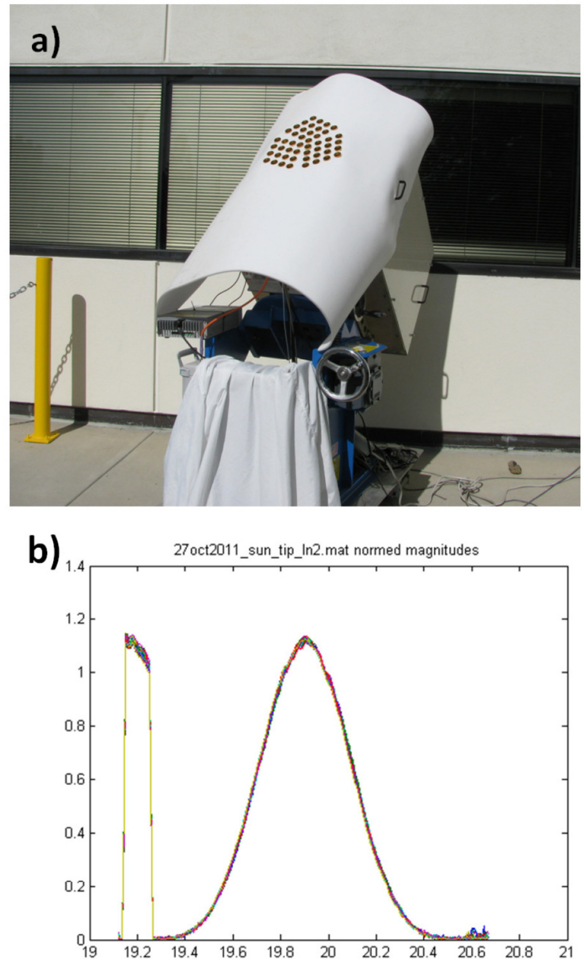

Figure 7. a) GeoSTAR-II observing a sun transit b) Normalized correlation magnitude

The system is shown attached to the GeoSTAR-I digital backend system (FPGA based) due to issues with the new ASIC correlator design. Figure 8 shows the correlations with the quadrature components for elements that are physically close (left) and far (right).

5. CONCLUSION

The initial results from the GeoSTAR-II prototype have demonstrated significant improvements in the technology, allowing for a realizable large scale system in the near future. Processes have been refined to reduce risk as issues have been identified during prototyping. Various aspects of the instrument design have been addressed including the LO distribution, antenna alignment and IF signal distribution.

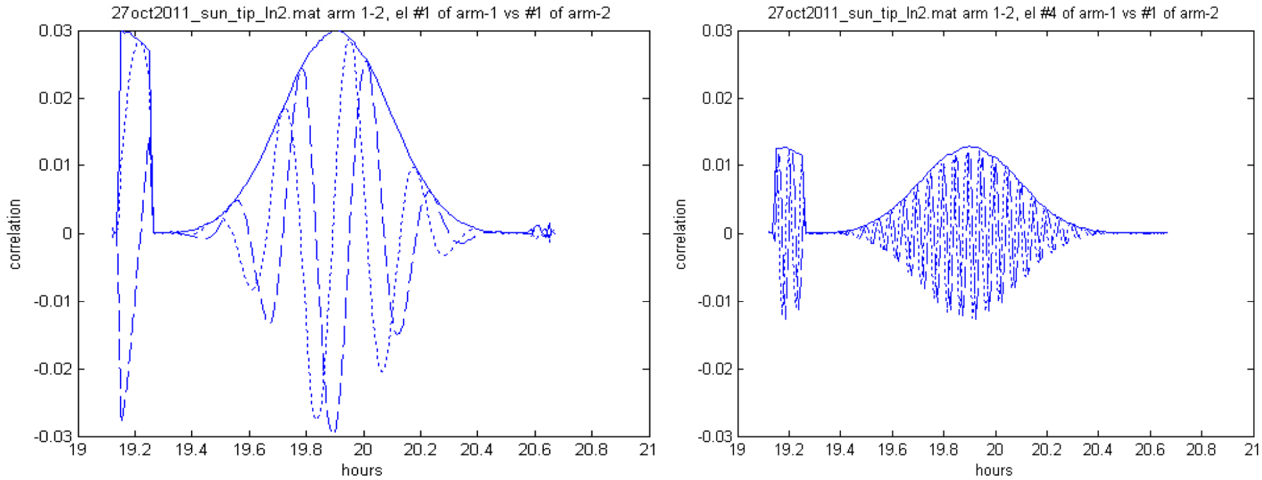

Figure 8. Sample correlations with quadrature components shown

Significant work still remains to be done pertaining to the backend digital correlation system.

6. ACKNOWLEDGEMENTS

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