

# Statements of Work for GALFA Spectrometer Development

June 23, 2003

## 1 Introduction

At the GALFA Consortium meeting in Boston, on June 18, 2003, NAIC Director Bob Brown indicated that in view of the importance of being sure of having a dedicated GALFA spectrometer capable of meeting specifications, and available in a timely manner, NAIC would support development of

- A prototype “software FFT” system along the lines developed by Jeff Hagen at NAIC
- A prototype FPGA system as outlined in memo by Stanimirovic, Heiles, Werthimer, & Dexter (June 5, 2003)

The plan is for both groups to move forward to answer remaining technical questions, refine design, and have operating units in the near future. In the following, we give “statements of work” (SOWs) to guide the efforts of both groups in the next few months, in order that a decision about which route to follow can be made by the end of 2003. This will allow a complete, dedicated GALFA spectrometer system to be available at the time the multibeam system comes on line, thus permitting commensal observations and enhancing the efficiency of telescope usage.

## 2 Statement of Work for GALFA Software— FFT Spectrometer System

The development of this system was initiated by requirements of aeronomy research at Arecibo. Thus, the input A/D board, in particular, was chosen with these requirements in mind, which may be significantly different than

those for radio astronomy. In addition, there are signal to noise issues, output data formatting, and overall system design questions that need attention. The items in the SOW are intended to bring this software-FFT approach to the point where a clear determination can be made about its capabilities, and an accurate parts cost and labor requirement for the complete system be known.

### Tasks

1. Continue development of software-FFT spectrometer for GALFA, meeting specifications outlined in document “GALFA Spectrometer Requirements”, particularly 5 MHz bandwidth and inputs for two independent polarizations. Maximum channel spacing to be 610 Hz, with dump time not critical ( $\leq 10$  dumps/s).
2. Investigate choice of optimum A/D board
  - Establish trade-offs in performance (bandwidth, RFI immunity, other) vs. cost, for different numbers of bits
  - Establish value of having down-conversion incorporated into board (Note: while not formally established, it appears likely that Doppler corrections can be handled by first LO, similar to single-pixel receivers)
  - Establish requirement of having filtering incorporated into board (given willingness to operate with a single, fixed bandwidth)
3. Investigate software options for achieving maximum signal to noise ratio
  - It has been pointed out that doing only FFTs on successive data blocks of data may not yield full S/N ratio. One way to get back the full SNR is to also do FFTs on data blocks shifted by fractions of the block length. Preliminary simulations suggest that doing four FFTs with data shifted by 0, 1/4, 1/2, and 3/4 of block length get you close to maximum SNR, and doing eight FFTs gets you very close. If this is borne out, it implies that the computational burden for the direct FFT approach is significantly greater than currently planned. It is not at all clear that the present system could handle doing the shifted FFTs and combining them, to obtain maximum SNR.

- The consortium members need to define more carefully an acceptable filter shape, given desire to keep RFI from spilling into adjacent channels, but not giving up too much resolution.
  - The relationship between the S/N issue and filter shape obtained by weighting data in time series has not been fully investigated, and should be.
  - It has been suggested that the “polyphase filterbank” FFT approach could be implemented in software. This could have the effect of getting close to maximum SNR, while increasing the computational burden by only a modest factor. This appears promising and definitely must be pursued as a significant software effort could be required to get this going.
4. Work with other ALFA engineering staff, and possibly define, data format to be used . This should be done in conjunction with development of other ALFA spectrometers, and with those individuals planning the data reduction pipeline.
  5. Carry out measurements of SNR for realistic integration periods, using noise as the input.
  6. Carry out a test of the spectrometer system using input from the Arecibo telescope and observing a spectral line in standard observing mode (HI in total power would be acceptable).
  7. Develop accurate budget for completion of entire system, including spares, in terms of parts costs and labor. Develop as detailed a schedule as possible.

### **Timescale**

The above tasks should be completed in four months, thus by 1 November 2003.

### **Support**

Purchase of several different A/D boards may be necessary, and possibly a PC chassis dedicated to this project. The total parts cost should not exceed \$10,000.

It is anticipated that Jeff Hagen will spend most of his time on this project during its three month duration. Input from other NAIC staff is also anticipated, and it seems reasonable that in particular Mike Sulzer, Bill Sisk, Mike Nolan, and Avinash Deshpande could contribute significantly to signal processing issues. Other engineers involved with ALFA (Ganesh Rajagopalan, Lisa Wray, Eddie Castro) also should be involved.

### **3 Statement of Work for GALFA FPGA Spectrometer System**

The technical design of this system is given in considerable detail in the aforementioned memo. The purpose of the development phase is to construct a prototype unit and demonstrate its capabilities. In addition, the issue of extension to cover multiple-inputs for radio recombination line work should be addressed.

#### **Tasks**

1. Complete design of GALFA FPGA spectrometer module, meeting specifications outlined in document “GALFA Spectrometer Requirements”, particularly 5 MHz bandwidth and inputs for two independent polarizations. Maximum channel spacing to be 610 Hz, with dump time not critical ( $\leq 10$  dumps/s).
2. Construct a unit for processing signals from one pixel of ALFA system.
3. Define and carry out appropriate array of tests to demonstrate proper functioning of the FPGA spectrometer.
4. Develop accurate budget for completion of entire system, including spares, in terms of parts costs and labor. Develop as detailed a schedule as possible.
5. Develop technical specifications and carry out costing for extending system to include 10 radio recombination line inputs each with  $\simeq 3$  MHz bandwidth, spread over a 300 MHz band.

#### **Timescale**

A functioning spectrometer system shall be completed by the end of 2003. Accelerating this would obviously have advantages in terms of being better synchronized with the software-FFT approach. Demonstration of operation (as well as completion of other tasks) by the end of 2003 is essential for proper consideration at the next GALFA Consortium meeting, currently anticipated to take place in January, 2004.

#### **Support**

NAIC will provide the requested funding to the University of California for \$40,000 during the period of work. The question of what will be the deliverables in terms of hardware (if any) should be worked out in conjunction with appropriate contracts personnel.