Summary of the Frequency-Agile Solar Radiotelescope (FASR) Project

Science Goals

The Frequency-Agile Solar Radiotelescope is a multi-frequency (~0.3-30 GHz) imaging array composed of many (~100) antennas. It is designed specifically for observing the Sun. It will produce high-quality images of the Sun with high spatial resolution (1" at 20 GHz), high spectral resolution ($\Delta\nu/\nu \sim 0.01$), and high time resolution (<1 s), across two decades in frequency. In so doing, it will produce a continuous, three-dimensional record of the solar atmosphere from the chromosphere up into the mid-corona.

These qualities represent a quantum leap beyond existing solar radio instruments, yet are well within reach of emerging technologies. The range of science that can be addressed by such an instrument is as broad as solar physics itself. Virtually every solar feature from within a few hundred km of the visible surface of the Sun to high up in the solar corona can be studied in detail with the unique diagnostics available in the radio regime. Particular diagnostics include measuring the properties of both thermal and nonthermal electrons accelerated in solar flares from the largest events to the tiniest microflares/nanoflares, measuring coronal magnetic field strengths in active regions and elsewhere (coronal magnetography), and mapping kinetic electron temperatures throughout the chromosphere and corona. The major science goals of the project include understanding

- Transient energetic phenomena
    - Energy release
    - Plasma heating and electron acceleration
    - Electron transport
    - Formation and destabilization of large scale structures
- The nature and evolution of coronal magnetic fields
    - Measurement of coronal magnetic fields
    - Temporal evolution of coronal magnetic fields
    - The role of coronal currents
    - The storage and release of magnetic energy
- The solar atmosphere
    - Coronal heating
    - Structure of the quiet solar atmosphere
    - Origin of the solar wind
    - Formation and structure of filaments

In addition, FASR's far-reaching exploration of the Sun in the radio regime gives the instrument tremendous potential for new discoveries beyond those that we can now anticipate.

Unique Science to be Addressed

The spatially resolved microwave and decimetric spectrum contains unique information about the solar atmosphere and the acceleration of energetic particles that cannot be studied in any other way. These include

- spatial, temporal, and spectral characteristics of the site of energy release, over a broad range of coronal heights;

- measurement of magnetic field strength at coronal heights in flares and active regions;
- determination of the electron energy distribution, including effects of transport, modification by wave-particle interactions, and decay or escape;
- detection of coronal mass ejections, both off the limb and on the solar disk;
- elucidation of possible causes of coronal heating, whether due to the tiniest flare events (nanoflares) or destabilization of coronal currents;
- characterization of the 3D thermal structure of the solar atmosphere;
- synoptic measurement of coronal magnetic fields, and sensitive full-disk monitoring of both thermal and non-thermal activity.

The FASR is highly complementary to instruments working in other regimes, especially optical magnetographs and hard and soft X-ray imagers. Combining data from such instruments with the results from FASR is essential to fully address these science questions.

Current Status

The basic concept for FASR was discussed in detail, and a broad consensus was reached among the more than 40 participants at an international meeting in San Juan Capistrano in 1995, that *it is possible, highly desirable, and timely* to construct an advanced, solar-dedicated radiotelescope. This consensus is reflected by the broader community in the report of the NRC/SSB Task Group on Groundbased Solar Research, which recommended "*exploratory development of a high-resolution frequency-agile solar radiotelescope (FASR)*". Institutional involvement, with the recent addition of Lucent Technologies, also includes New Jersey Institute of Technology and National Radio Astronomy Observatory, with additional involvement by individuals at University of Maryland and UC Berkeley. Technological development in key areas of low-cost antennas, broadband RF, fiberoptic transmission, and digital signal processing (including construction of large correlators that can handle many antennas with good frequency resolution over a broad band), will proceed at these institutions in consultation with a number of other groups who are trying to solve similar technological problems.

Design Summary

The combination of high spatial resolution, combined with unprecedented spectral bandwidth and image quality, is essential to the successful achievement of the science goals. The Sun's unique combination of spatial scales, rapid flux variations, and relevant emission mechanisms drive the need for a particular set of instrument characteristics that cannot be met without a solar-specific design. The baseline characteristics required of the FASR are given in the following table.

FASR Specification

Frequency range	0.3-30 GHz
Frequency resolution	~3%, 3-30 GHz
	1%, 0.3-3 GHz
Time resolution	≤ 1 sec, 3-30 GHz
	≤ 0.1 sec, 0.3-3 GHz
Antenna size	D = 2–5 m
Number of antennas	~ 100
Number of baselines	~ 5000
Polarization	Dual
Number IFs pairs	4 – 8
Angular resolution	$\theta \approx (20/\nu_9)$ arcsec
Field of view	FOV ≈ $1125/(\nu_9 D)$ arcmin

The design to meet most of the instrument specifications has not been finalized, but in each case conservative options exist that make the design goal attainable. Technology innovations will be sought that allow increased capability and/or decreased cost in each of the major design areas.

To Obtain the Full Report

The full report to accompany this summary, along with other relevant information concerning FASR can be obtained from the web site at http://solar.njit.edu/fasr/. The report can be downloaded in a variety of formats. Please be sure to view some of the movies available by clicking on the Images/Movies button on that page.