THE FREQUENCY AGILE SOLAR RADIOTELESCOPE

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ABSTRACT

The Frequency Agile Solar Radiotelescope (FASR), a telescope concept currently under study, will be a ground based solar-dedicated radio telescope designed and optimized to produce high resolution, high-fidelity, and high-dynamic-range images over a broad frequency range (~0.1-24 GHz). As such, FASR will address an extremely broad science program, including the nature and evolution of coronal magnetic fields, the physics of flares, drivers of space weather, and the quiet Sun. An important goal is to mainstream solar radio observations by providing a number of standard data products for use by the wider solar physics community. The instrument specifications and the key science elements that FASR will address are briefly discussed, as well as several operational issues.

INTRODUCTION

The Frequency Agile Solar Radiotelescope (FASR) is being designed and optimized to exploit the diagnostic power of emissions at radio wavelengths for studies of solar phenomena. FASR will produce high-resolution, high-fidelity, and high-dynamic-range images over an extremely broad frequency range of ~0.1-24 GHz, or approximately 1 cm to 3 m in wavelength. In other words, FASR will perform broadband imaging spectroscopy, producing a brightness temperature spectrum along each line of sight to the source, with temporal and spectral resolutions commensurate with the phenomenon under study. An important goal is to mainstream the use of solar radio observations by the wider solar physics community, much as the use of X-ray observations were mainstreamed by *Yohkoh*, and EUV observations were by SOHO/EIT and TRACE.

In the following sections, the operational basis of FASR is described and the basic instrument specifications are presented. An overview of the key elements of the FASR science program is then given and operational issues are touched upon.

OPERATIONAL BASIS

FASR is a Fourier synthesis telescope. As such, it will comprise of an array of antennas. The basic element of an imaging array is a pair of antennas, an interferometer. Each interferometer measures a single Fourier component (or complex visibility) of the Fourier transform of the radio brightness distribution (the visibility function) at a given frequency. Many interferometers, composed of pairs of antennas placed at various separations and orientations, sample the two-dimensional visibility function. In this sense, FASR is analogous to RHESSI and an interferometer is analogous to a pair of collimated grids. An image is formed by means of an inverse Fourier transform of the measured visibilities. A variety of deconvolution techniques can be used to remove the instrument sidelobes in the image that result from incomplete sampling in the Fourier domain.

The radio brightness distribution of the Sun is, in general, spatially complex. Furthermore, the Sun's radio brightness distribution changes on a variety of time scales. Hence, the technique of Earth rotation aperture synthesis – used to advantage to map cosmic sources that are essentially unchanging in time (e.g., the continuum emission from a radio galaxy) – cannot be exploited. Instead, a large number of visibility measurements must be made instantaneously, requiring a large number of antennas. For an array composed of N antennas, there are N(N-1)/2 interferometers. FASR will require ~100 antennas, or ~5000 instantaneous visibility measurements.

INSTRUMENT SPECIFICATIONS

The FASR instrument specifications are the result of several meetings involving the international solar physics community, the most recent being a FASR Science Definition Workshop at the National Radio Astronomy Observatory (NRAO) in Green Bank, WV, in May 2002, and a FASR Technical Workshop at the NRAO in Charlottesville, VA, in August 2002. Consideration of key science goals and the relevant radio emission mechanisms yielded the instrument requirements summarized in the table.

FASR Instrument Specifications

Angular resolution	$20/\nu_{GHz}$ arc sec
Frequency range	~0.1-24 GHz
Frequency resolution	<3 GHz: 0.1%
	>3 GHz: 1%
Time resolution	<3 GHz: 10 ms
	>3 GHz: 100 ms
Polarization	Stokes I & V
Number antennas	2-24 GHz: 100
	0.25-3 GHz: 60
	<0.3 GHz: 40
Size antennas	2-24 GHz: 2 m
	0.25-3 GHz: 6 m
	<0.3 GHz: dipoles or similar
Maximum antenna spacing	6 km
Absolute positions	1 arcsec
Absolute flux calibration	<5%
ΔT_B (snapshot)	1000 K

In practice, it is not feasible to use a single antenna/feed/receiver design and array configuration to cover the entire frequency range that has been proposed for FASR. Broadband feeds can currently support roughly a decade of bandwidth while FASR spans more than two decades. The current FASR strawman design therefore calls for three sets of antenna elements: an array of ~100 antennas, 2 m in size, will observe from 2-24 GHz; an array of ~60 antennas, each 6 m in size will observe from 0.25-3 GHz; an array of ~40 antennas – log-periodic dipoles, fat dipoles, or slot Vivaldi-type antennas – will observe below 300 MHz. The antenna sizes represent a compromise between the need for adequate sensitivity for calibration purposes and a large field of view, sufficient to see the entire solar disk at all frequencies up to 18 GHz.

An angular resolution of 1 arcsec is required at a frequency of 20 GHz. To meet this requirement over an hour angle range of ± 3 h requires a maximum antenna baseline of 6 km. For a fixed array configuration, the angular resolution scales linearly with frequency. The angular resolution is therefore ≈ 2 arcsec at 10 GHz, ≈ 4 arcsec at 5 GHz, and so on. This is a good match to the amount of fine structure present in the Sun's radio emission, which varies in a frequency-dependent manner as a result of scattering in the turbulent coronal plasma (e.g., Bastian 1994).

An interesting and important problem is that of the antenna configuration. The configuration must be optimized to provide excellent sampling of the visibility function in order to provide excellent imaging of both compact and diffuse emissions over a broad frequency range. A promising possibility is a self-similar array configuration such as a log-spiral configuration (Bastian et al. 2002). An example illustrating the snapshot imaging fidelity of a 102 element, three-armed, log-spiral array is shown in Figure 1.

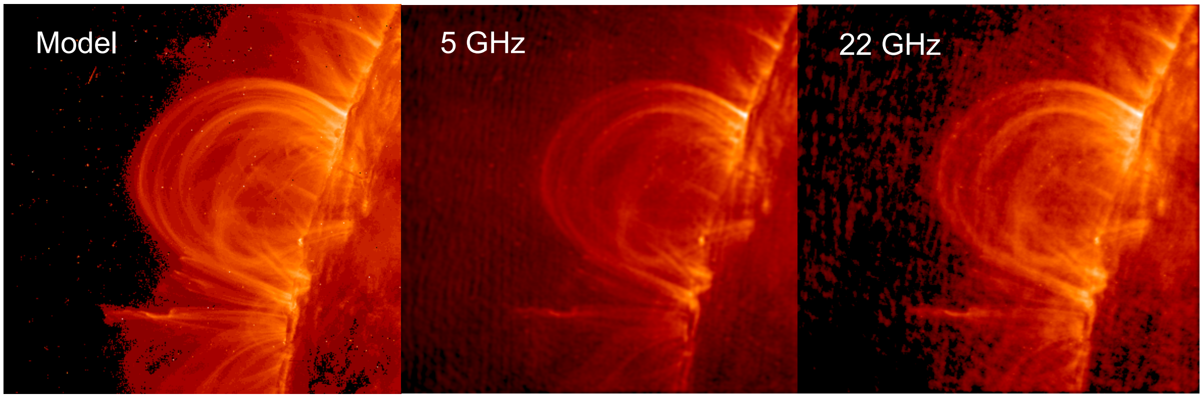

Fig. 1. Simulation of the imaging properties of a log-spiral array. a) model image from TRACE, 6 Nov 1999; b) snapshot image made at 5 GHz; c) snapshot image made by same array at 22 GHz. The instrument response function has not been deconvolved from the snapshot maps.

The requirements on temporal and spectral resolution are based on consideration of the emission mechanisms that can contribute to the observed emission at a given frequency (next section). At frequencies >3 GHz, incoherent thermal and nonthermal mechanisms prevail. At lower frequencies a variety of coherent emission mechanisms are relevant, notably plasma radiation at the first and second harmonics of the local electron plasma frequency although incoherent mechanisms also play a role.

Polarimetry will be supported by FASR, with an emphasis on accurate measurements of the Stokes I and V parameters (see next section). The Stokes I parameter is a measure of the total intensity whereas the Stokes V parameter is a measure of the circularly polarized radiation. The Stokes Q and U parameters are not relevant, in most cases, because strong differential Faraday rotation in the solar corona washes out any intrinsically linearly polarized radiation.

FASR will be calibrated against cosmic standards with secondary calibration against geostationary satellites at selected frequencies. The dynamic range of an image at a given frequency is determined by many factors. It is anticipated that snapshot maps with an rms brightness of 1000 K or less can be made. A modest amount of frequency synthesis will be possible and desirable for many types of programs. These will yield significantly lower rms brightness variations.

FASR SCIENCE

Radio emission originates throughout the solar atmosphere and from every observed phenomenon by a variety of emission mechanisms. The frequency range spanned by FASR will be sensitive to emissions from the middle chromosphere to the mid- to upper corona. The emission mechanisms most commonly encountered are:

- *Thermal free-free emission*: ubiquitous in the solar atmosphere
- *Thermal gyroresonance emission*: gyromagnetic emission at low harmonics of the electron gyro-frequency: s~1,2,3,4
- *Thermal and nonthermal gyrosynchrotron emission* : gyromagnetic radiation from mildly relativistic electrons at harmonics s~10-100 of the electron gyrofrequency
- *Plasma radiation*: radiation at the fundamental and/or harmonic of the electron plasma frequency

These mechanisms offer broad and unique diagnostic tools to address a large number of outstanding problems in solar physics. A comprehensive description of the FASR science program is beyond the scope of this paper. A brief summary of key FASR science goals must suffice. These are: the nature and evolution of coronal magnetic fields, the physics of flares, drivers of space weather, and the quiet Sun. I briefly discuss each in turn.

Nature and Evolution of Coronal Magnetic Fields

The role of magnetic fields in the solar corona is of overriding importance in gaining a detailed understanding of the basic structure of the solar corona, coronal heating, and energetic transient phenomena such as flares and coronal mass ejections (CMEs). While longitudinal and vector magnetic field measurements are possible at photospheric and chromospheric heights, quantitative measurements of coronal magnetic fields have been an elusive goal, one which FASR will confront directly.

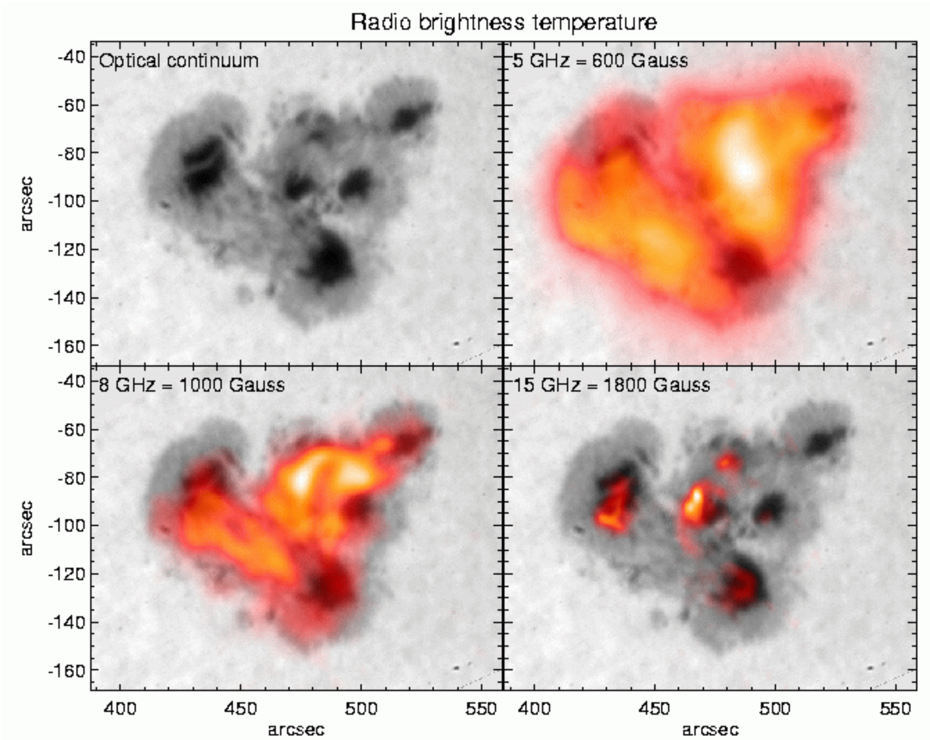

Fig. 2. An example of gyroresonance emission from an active region. The upper left panel shows sunspots in the white light continuum. The remaining three panels repeat the white light continuum image with gyroresonace emission superposed at 5, 8, and 15 GHz, corresponding to emission from isogauss layers of 600, 1000, and 1800 G (assuming emission from the third harmonic layer). From Lee et al. 1998.

An important and unique new capability that FASR will make available to the solar physics community is coronal magnetic field measurements. Several techniques will be brought to bear on the problem. The most straightforward technique is to exploit thermal gyroresonance emission, which occurs in solar active regions wherever the magnetic field is sufficiently strong to render the corona optically thick to gyroresonance absorption. Under typical coronal conditions, this occurs at the second or third harmonic of the electron gyrofrequency, which is linearly propotional to the magnetic field strength B (see White and Kundu 1997). The emission observed at a given frequency then originates from a thin resonance layer in the solar atmosphere. The brightness temperature of the emission corresponds to the kinetic temperature of the resonance layer. A radio map made at a given frequency therefore maps the kinetic temperature of the corona from an isogauss layer. By tuning the observing frequency to higher or lower values, an observer measures the temperature of isogauss layers corresponding to higher or lower magnetic field strengths. Figure 1 shows examples of gyroresonance emission from an active region at three different frequencies observed by the VLA (Lee et al. 1998). FASR will provide high resolution radio images over the frequency range relevant to gyroresonance emission: roughly 1.5-18 GHz, corresponding to magnetic field strengths of B=150-2100 G. Unlike existing instruments such as the VLA, FASR will provide a spectrum along each line of sight through the source with a spectral resolution of 1%.

A coronal magnetogram can be trivially constructed at the base of the corona by noting that, along a given line of sight, the radio spectrum will show a break at the frequency where the resonance layer drops below the corona and the brightness temperature drops precipitously to sub-coronal values. The frequency at which the spectral break occurs corresponds to the magnetic field strength at the base of the corona. By measuring the break frequency along each line of sight through an active region, a magnetogram at the base of the corona is constructed. The data are inherently three-dimensional, and contain information on B in three-dimensions. To extract the vector field in three dimensions using gyroresonance emission is a research problem. Possible approaches include the exploitation of stereoscopic techniques using the Sun's rotation (e.g., Aschwanden et al. 1995) and joint modeling of radio, EUV, and soft X-ray data (e.g., Brosius et al. 2002).

A variety of other techniques will measure or constrain magnetic fields. These include the use of gyrosynchrotron radiation during flares (see below), thermal free-free radiation to measure the mean longitudinal magnetic field along selected lines of sight, and the use of propagation effects (mode coupling) to impose constraints on the vector magnetic field in certain cases. Unlike the use of gyromagnetic diagnostics, the use of thermal free-free and propagation diagnostics offer quantitative constraints on weak magnetic fields in the solar corona.

The applications of, and insights gained from, quantitative measurements of the coronal magnetic field are extremely broad, and cannot be fully anticipated, but include quantitative checks of magnetic field extrapolations, measurements of the magnetic energy density, measurements of the build-up and release of magnetic energy, and the exploitation of coronal seismology; i.e., the use of magnetic oscillations to constrain local properties of the corona.

Physical Processes in Solar Flares

FASR will be a superb instrument to observe solar flares and to gain fundamental new insights into the physics of flares. FASR will make significant new contributions to energy release in flares, the acceleration and transport of electrons, plasma heating, and the origin of energetic particles in the interplanetary medium (see next section).

Progress has been made in recent years on identifying tracers of energy release in the solar corona (see Bastian et al. 1998 for a review). Decimetric type III bursts, due to plasma radiation excited by electron beams, occur most commonly in the 400-800 MHz range, although they are occasionally observed to frequencies as high as several GHz. This frequency range corresponds to densities of $2\text{-}8 \times 10^9$ cm^{-3} and higher, densities where energy release in flares is thought to occur. Multitudes of bursts are released during the course of the impulsive phase of a flare. They are believed to be intimately related to energy release in flares via magnetic reconnection. Type IIIdm bursts are more numerous than metric type IIIs and show positive or negative frequency drifts, indicating upward or downward motion in the corona. Some events show positive *and* negative drifts, indicating the presence of bi-directional electron beams. While type IIIdm bursts have been observed spectroscopically for many years, they have not been imaged. FASR will image the multitudes of type IIIdm radio bursts that accompany the impulsive phase of flares and, because it images across the entire frequency band in which they occur on a 10 ms time scale, it will image the trajectories of the electron beam. Hence, FASR will use type IIIdm bursts to identify and delineate the topology of the energy release regions, as well as measure the electron number density in the energy release region.

At centimeter wavelengths, incoherent gyrosynchrotron radiation from a nonthermal population of energetic electrons is responsible for the bulk of the radio emission in flares. The spectrum and polarization of the radiation is sensitive to the details of the electron distribution function, including the spectral index of the power-law tail, the presence of a high-energy cutoff, and the degree of anisotropy (Ramaty 1969; Fleishman and Melnikov 2002). Imaging spectroscopy of the flaring source can therefore be used to infer the electron distribution function as a function of time and space in the flare source, offering new insights into electron acceleration and transport processes. For example, it should be possible to distinguish between directly precipitating electrons and trapped electrons, and to determine whether electron scattering is dominated by Coulomb collisions or wave-particle interactions (e.g., Lee et al. 2002). In addition, the radiation spectrum depends sensitively on the local vector magnetic field and the ambient plasma density. Hence, in addition, to providing key new insights into the evolution of the electron distribution function, magnetic field measurements will be available in those coronal loops containing nonthermal electrons and the ambient plasma density will also be constrained.

It bears emphasizing that one of the outstanding and unique capabilities of FASR will be to provide an integrated picture of what occurs during a flare from the mid-chromosphere into the corona, thereby allowing energy release, electron acceleration, electron transport, plasma heating, and associated phenomena to be studied as a coupled system.

Drivers of Space Weather

The term “space weather” refers to a vast array of phenomena that can disturb the interplanetary medium and/or affect the Earth and near-earth environment. This includes recurrent structures in the solar wind such as fast solar wind streams, the ionising radiation and hard particle radiations from flares, radio noise from the Sun, coronal mass ejections, and shock-accelerated particles. These drivers result in geomagnetic storms, changes in the ionosphere, and atmospheric heating which can, in turn, result in a large variety of effects that are of practical concern to our technological society: ground-level currents in pipelines and electrical power grids, disruption of civilian and military communication, spacecraft charging, enhanced atmospheric drag on spacecraft, etc. Interest in CMEs has been particularly strong because they are associated with the largest geo-effective events and the largest solar energetic particle (SEP) events. With its ability to perform broadband imaging spectroscopy, FASR will make significant contributions to characterizing and understanding the science of drivers of space weather. In addition, FASR may play a significant programmatic role in forecasting and “now-casting” events of interest to the space weather community.

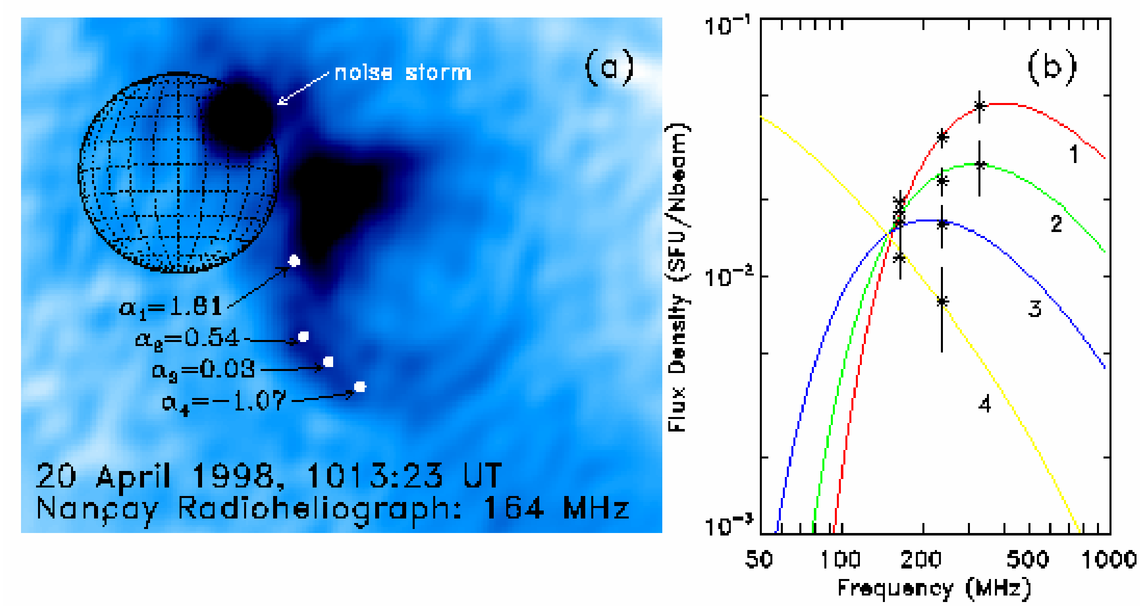

Fig. 3. Example of a radio CME imaged by the Nancay Radioheliograph at a frequency of 164 MHz. The panel to the left shows the expanding CME loops (emission from the background Sun has been subtracted). The panel to the right shows model fits to multi-point spectra and the lines of sight indicated to the left.

With the detection of nonthermal gyrosynchrotron radiation from CMEs (Bastian et al. 2001) a new tool has become available to detect, image, and diagnose the properties of CMEs. An example is shown in Figure 3, where radio emission is shown from relativistic electrons entrained in the expanding CME loops. Multi-frequency data were provided for this event by the Nancay Radioheliograph. Fits of a simple gyrosynchrotron model to two- and three-point spectra at various locations in the source illustrate the potential for full imaging spectroscopy. Such fits yield not only the magnetic field of the CME, but the ambient density of the thermal plasma, too. CMEs, and the response of the solar atmosphere, can be detected by other means. Thermal emission from CMEs (Kathiravan et al. 2002), and coronal dimmings resulting from the launch of a CME (Ramesh and Sastry 2000) have been reported White (priv. comm.. 2002) has detected the radio analog to “EIT waves” at 17 GHz with the Nobeyama Radioheliograph. An advantage to radio imaging of CMEs and associated phenomena is that, unlike coronagraphic observations, no occulting disk obscures the event in its nascent stages. Hence radio observations offer the means of probing the birth and acceleration of CMEs.

FASR will also be an extremely powerful instrument for relating type II radio bursts to flares and CMEs. It is generally accepted that type II radio bursts are a tracer of fast MHD shocks. The shocks that produce coronal type II radio bursts may be driven by fast ejecta (Gopalswamy et al. 1997), by a blast wave (Uchida 1974, Cane & Reames 1988), or by a CME (Cliver et al 1999; Classen & Aurass 2002). Fast ejecta and/or a blast wave are produced by a flare; a CME produces a piston-driven shock wave. The relationship between these shocks, their radio-spectroscopic signature, and other phenomena of interest such as Moreton waves and “EIT waves” remains a matter of considerable controversy, as discussed by Cliver et al. (1999), Gopalswamy (2000), Gopalswamy et al. (2001) and Klassen et al. (2000). The emphasis placed on FASR’s ability to provide an integrated picture of the flare phenomena applies equally to CMEs and associated phenomena (type II radio bursts, EIT and Moreton waves, filament eruptions).

Particle acceleration in flares and shocks has been of fundamental interest for many years. Of particular relevance to space weather studies are solar energetic particle (SEP) events. During the past ~15 years, SEP events have been classified as impulsive or gradual events (e.g., Reames 1988) based on the properties of the associated soft X-ray flare, correlations with radio bursts of type III (impulsive) or types II/IV (gradual), abundances and charge states of the energetic particles, and the presence or absence of a CME. Impulsive SEP events were believed to originate in solar flares while the energetic particles in gradual SEP events were thought to be accelerated in CME-driven coronal and/or interplanetary shocks. Since the largest SEP events are gradual events in this scheme, interest in particle acceleration by CME-driven shocks has remained high.

Several analyses of radio spectroscopic and energetic particle data have called this simple picture into question (Klein et al. 1999; Laitinin et al. 2000; Klein & Trottet 2001), arguing that sustained particle acceleration can occur in the mid-corona. Detailed observations of abundances and charge states by the Advanced Composition Explore (ACE) suggest that at the very least, the impulsive/gradual paradigm requires modification in recognition of complicating realities. As an instrument that images coronal energy release and particle acceleration, tracers of coronal shocks, and the onset and ejection of certain coronal mass ejections, simultaneously, FASR should shed light on the difficult and controversial problem of the origin of SEPs.

The Quiet Sun

The quiet Sun confronts us with a number of outstanding problems, including the structure and heating of the solar atmosphere, the origin of the solar wind, the formation and structure of solar filaments, and more. Radio emission from the quiet solar atmosphere is due to thermal free-free emission. An advantage to radio observations is that they are in Rayleigh-Jeans regime. The source function is Planckian and, consequently, the observed flux is linearly proportional to the kinetic temperature of emitting plasma. At high frequencies, the corona is very optically thin and the bulk of the emission originates in the mid-chromosphere. As the observer tunes to lower frequencies, the emission contribution function shifts to greater heights. At low frequencies, the corona becomes optically thick.

One of the fundamental questions in solar physics is how the solar corona maintains its high temperature of several million Kelvin above a surface with a temperature of 6000 K. The power needed to maintain the corona above an active region against radiation and conduction losses is $>10^{28}$ erg s^{-1}. The leading theoretical ideas for how the corona is heated is either some form of resonant wave heating or ``nanoflares'', although there exist many other models. Wave heating models make specific predictions of where and on what time scales energy deposition occurs in coronal magnetic loops. The FASR will provide a detailed history of the temperature, density, and magnetic field in coronal loops in active regions, from which the rate of energy deposition can be calculated as a function of position and time. The role of ``nanoflares'' – tiny, flare-like releases of energy from small magnetic reconnection events – depends critically on the rate at which such events occur. Numerous studies have shown that X-ray events ranging over as much as five orders of magnitude in energy, from 10^{27} to 10^{32} erg, form a single power law with slope 1.5-1.6. Smaller events cannot be energetically significant relative to the larger events unless the rate distribution at lower energies becomes significantly steeper. It is therefore of critical importance to characterize the distribution and energy content of the smallest energy release events on the Sun. FASR will provide observational inputs with which to test these, and other types of models.

The chromosphere will be a particularly interesting subject for study by FASR. Over the past decade it has become evident that the prevailing semi-empirical chromospheric models, largely based on non-LTE UV/EUV line and IR/submm/mm continuum observations and computed under the assumption of hydrostatic equilibrium, are in stark disagreement with observations in bands of carbon monoxide (CO) and with microwave observations. In particular, observations of the CO molecule near 4.7 μm show that the low-chromosphere contains a substantial amount of cool (3800 K) material leading to the view that the chromosphere is fundamentally bifurcated between cool and hot material (e.g., Ayres and Rabin 1996). Accurate broadband microwave (1–18 GHz) spectroscopy of the quiet Sun (Zirin et al. 1991) convincingly demonstrates that the prevailing semi-empirical models include an over-abundance of warm chromospheric material (Bastian et al. 1996). These developments have caused the solar community to begin to re-think the solar chromosphere. Schematic multi-component models have been proposed which emphasize the pervasive cool component in the solar atmosphere (e.g., Ayres and Rabin 1996). Another approach has recognized that chromospheric dynamics play a critical role in understanding the structure of the chromosphere (Carlsson and Stein 1995). Testing modern chromospheric models requires spatially and temporally resolved observations of the thermal state of the chromosphere on the relevant spatial and temporal scales.

The FASR design will allow us to sample the thermal structure of the chromosphere down to the height where $T_e \approx 8000$ K. The sensitivity of the FASR, as presently conceived, will allow us to study the time variability of the thermal structure of the solar chromosphere in a single frequency band on a time scale ~30 min ($\Delta T_B \approx 100$ K). Over a period of several hours, the FASR will provide high quality maps of the mean thermal state of the chromosphere over its entire frequency range. FASR observations will therefore provide a comprehensive specification of the thermal structure of the chromosphere – in coronal holes, quiet regions, enhanced network, plages – as an input for modern models of the inhomogeneous and dynamic chromosphere.

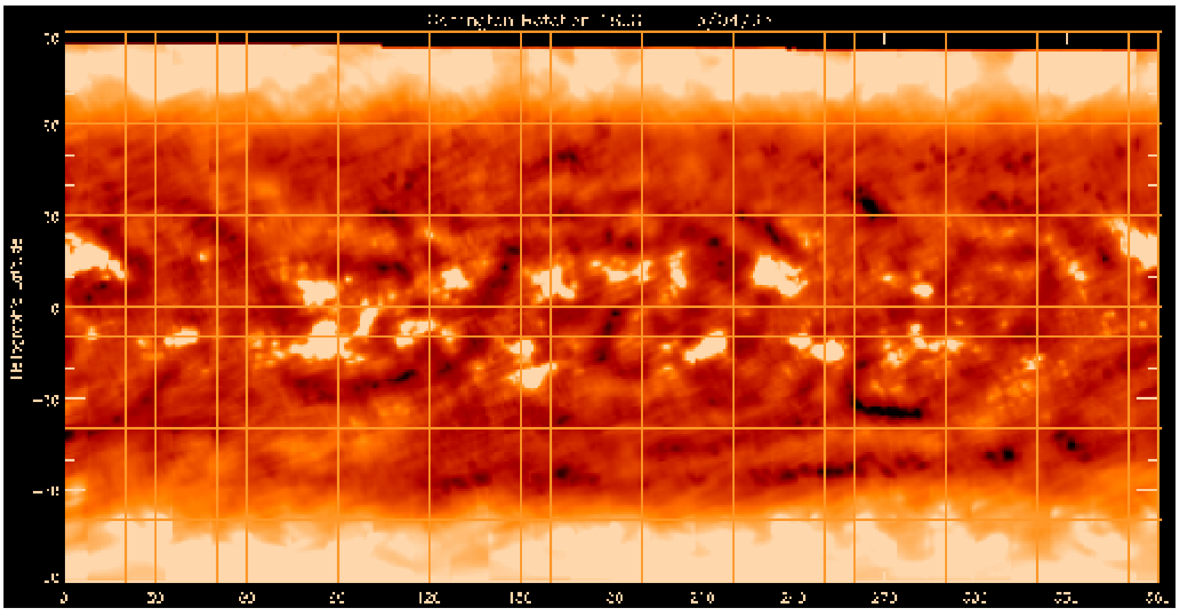

Fig. 4. Example of a synoptic map at 17 GHz (from Shibasaki 1998)

Synoptic Studies

The solar 10.7 cm flux has been used for many years as a proxy indicator of solar activity owing to its close correlation with other activity indicators such as sunspot number and area, the emission in Lyβ, Mg II, and EUV fluxes, and the total solar irradiance. The 10.7 cm flux remains the solar measurement in highest demand amongst the space weather community. However, Schmahl and Kundu (1998) have shown that multi-radio-frequency measurements can be combined to yield superior proxies for both sunspots and irradiance. FASR will provide multifrequency observations suitable for exploiting such diagnostics, but such observations require accurate and stable calibration over long periods of time. FASR will achieve this by calibrating against cosmic standards. One can envision many other synoptic studies with an instrument like the FASR. For example, with high-resolution, spatially resolved maps at each frequency, synoptic studies of the gyroresonance component of the radio emission and hence, the coronal magnetic field, could be performed. Additional examples include statistical studies of parameters associated with flares, CMEs, filaments, coronal holes, and other recurrent phenomena of interest.

OPERATIONAL ISSUES

FASR will be a *frequency agile* instrument. It will not process the entire bandwidth to which it has access simultaneously. It will instead sample a number of sub-bands in parallel. As an example, the bandwidth of the instrument may be divided into four sub-bands – <0.3 GHz, 0.3-3 GHz, 3-12 GHz, 12-24 GHz – and a total of eight data channels (two polarization channels per frequency band). The instrument would sample each frequency sub-band at a rate and with a spectral resolution sufficient to fulfill the instrument requirements outlined in Table 1.

FASR is being designed and optimized to be a basic research instrument that exploits the diagnostic potential of radio emission from the Sun. An important goal of the FASR project is to mainstream the use of radio data by the wider community, much as *Yohkoh* mainstreamed the use of soft- and hard-X-ray observations, SOHO/EIT and TRACE mainstreamed EUV observations, and RHESSI is mainstreaming imaging spectroscopy at hard X-ray wavelengths. To do so requires automating most of the functions of data acquisition, calibration, and reduction and making the data available to the community in a timely way.

FASR will produce roughly 10 Tbytes/day. It will observe the Sun in an uninterrupted fashion during daylight hours. Primary instrument calibration will be determined before and after the observing day. FASR will operate according to a pre-defined observing plan designed to fulfill key science and programmatic objectives. It is anticipated that the data will be recorded to an interim data base with a latency of 24 hrs. Time-independent calibration and excision of radio frequency interference will be applied to the data in real time as the interim data base is populated. A variety of selection criteria will then be applied to the interim data set in order to identify optimum data sets for science, forecasting, and now-casting programs. These data sets will be spectrally and temporally averaged according to problem being addressed and secondary calibration will be applied. These data will then be archived and will represent the primary archive for the community. The production of archived data streams will occur, depending on the nature of the archive (quick look data, flares, quiet Sun, etc.), within minutes up to one day.

Offline data reduction will proceed along two paths. First, a standard suite of data products will be made available to the community. These might include optimally deconvolved images of the Sun across the entire frequency band, synoptic maps at all frequencies, coronal magnetograms, quick-look data on radio bursts, flares, coronal mass ejections, and filament eruptions. Second, because it is not possible to anticipate the myriad ways in which basic research will be conducted using FASR data, the scientific community will have full access to the archival data. Appropriate software will be provided to allow the community to select, reduce, image, deconvolve, and render/visualize the data in as flexible a way as is possible. The FASR project will consult closely with the solar physics and space weather communities to ensure that the FASR data archive, and FASR data reduction and analysis conforms to, and is fully integrated with, common software environments.

CONCLUDING REMARKS

FASR will provide the solar physics community and with a variety of new and unique tools for conducting basic research into a variety of outstanding problems related to coronal magnetic fields, the physics of flares, drivers of space weather, and the quiet Sun. As a solar-dedicated and well-calibrated instrument, FASR will make significant contributions to a variety of synoptic studies. Finally, as a full-disk imager that can provide a variety of data products in near real time, FASR could play an important role in forecasting and "now-casting" solar activity and space weather. The details of the project are evolving rapidly. The most up-to-date information is available at the FASR web site: http://ovsa.njit.edu/fasr.

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