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MONITORING SOURCE VARIABILITY WITH THE FAST ALL SKY TELESCOPE

Kenneth J. Johnston and Ralph L. Fiedler
Naval Research Laboratory, Washington, D.C. 20375-5000

Richard S. Simon
Interferometrics Inc., 8150 Leesburg Pike, Vienna, VA 22182

ABSTRACT The proposed Fast All Sky Telescope (FAST) is an interferometer which is intended to monitor the northern four-fifths of the celestial sphere every two days at 8.1 GHz and daily at 2.7 GHz. The design goal is to have a rms sensitivity of 10 mJy/beam at both frequencies. The array is planned to comprise 20 3-meter diameter antennas with a maximum baseline of 0.7 km. FAST will provide a valuable database that may be used to study time variability in a sensitivity limited sample of radio sources. This will significantly impact on the understanding of active Galactic and extragalactic radio sources, as well as on the understanding of radio wave scattering in the interstellar medium.

Introduction

The need for frequent flux density monitoring over an extended time interval has long been recognized in the study of variability. For sources which display intense short-lived radio emission at irregular intervals, this kind of monitoring program is essential in capturing the onset of a flare and then resolving it in time. Flare time-scales for the Galactic sources Cyg-X3 and SS433 are on the order of a few weeks, however, the rise times are as short as a few days (eg. Johnston *et al.* 1981a and Johnston *et al.* 1981b). Equally important is the ability to trigger observations in other wavelength and resolution domains so that the evolution of a flare may be traced from onset to completion. Alternatively, longer time-scale variations don't require as frequent monitoring, but do need to be observed over many decorrelation time-scales. For active extragalactic radio sources, this would involve many years of observations. See, for example, Aller *et al.* (1985) and Fiedler *et al.* (1987).

A third important characteristic to variability is the affect the interstellar medium (ISM) has on the observed flux densities from Galactic and extragalactic objects. Although the time scales for normal refractive interstellar scintillation (RISS) can occur over a broad range in time-scales, days to months, and persist over many years, it is of great interest to determine the dependence of the strength and time-scale of RISS on Galactic longitude and latitude. See, for example, the review article by Rickett (1990). Since the component of the ISM responsible for RISS has not been clearly identified, an all-sky monitoring program should prove invaluable towards understanding the origins of RISS.

The importance of monitoring the entire sky is readily apparent. Instead of relying on circumstances and luck to find sources, or lines-of-sight, producing significant flux density variations, an all-sky instrument will observe them all, not just those that have become well known or popular. Unexpected benefits, such as obtained by the Green Bank interferometer monitoring program regarding Extreme Scattering Events (Fiedler *et al.* 1991), may also occur as the domain of monitoring is expanded.

The need for quasi-continuous monitoring at radio frequencies combined with recent developments in receiver and computing technology has provided the impetus to seriously consider building an instrument such as FAST.

INSTRUMENT DESCRIPTION

Table 1 outlines a straw-man design for FAST. The array is planned to consist of 20 3-meter diameter antennas distributed over an area 0.7 km across. To maximize the antenna aperture and feed efficiencies, the antennas are envisioned to be offset Cassegrain fed parabolas, thereby avoiding aperture blockage.

The desired sensitivity of ≤1% rms for sources with flux densities greater than 1 Jansky requires a total system temperature of 20°K, or better. This constraint may be satisfied by using HEMT (hi-electron mobility transistor) receivers, which have noise temperatures less 5°K between 1 and 10 GHz. Noise contributions from the sky background, atmosphere, and scattering from support structures will add another 10 to 15°K, giving a total system temperature near 20°K. We also plan to use off-the-shelf broadband feeds that operate in the 2 to 18 GHz range, rather than the older concentric feed design.

Significant technical challenges associated with FAST include the design of a special purpose correlator and an automated data processing pipeline. The correlator will be required to handle a continuous data rate of roughly 40 gigabytes/day, or half a megabyte per second, and will probably be of an XF or XF-hybrid design. The visibility data will be archived. An intriguing possibility, given the current advancements in parallel architecture computing, would be to build the correlator in software.

Since the FAST array is a scanning interferometer (see the next section) the data reduction scheme requires the development of a special purpose CLEAN-based mosaiking algorithm. For example, a small number of scan centers would be deconvolved jointly to produce point source flux density estimates. The final estimate would be formed from an average of all the values thus estimated for any given source.

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TABLE I. Straw man design parameters for FAST

Number of antennas	20
Diameter of Antennas	3.0 m
Maximum Baseline	0.7 km
Declination Range	-40° to 90°
Average Declination Scan Speed	47.1 degrees / minute

Frequency	8.1 GHz	2.7 GHz
System Temperature	20°K	15°K
Bandwidth	448 MHz	64 MHz
Number of channels	96	42
Aperture efficiency	70%	70%
Primary Beam FWHM	1.08°	3.23°
Useable Primary Beam Size	1.7 FWHM	1.7 FWHM
Synthesized Beam FWHM	10.9"	32.7"
Average Sampling Rate	0.7 seconds	2.1 seconds
Timescale to cover sky	48 hours	24 hours
Integration Efficiency	90%	90%
Effective Integration Time	4.0 seconds	18.2 seconds
Quantum Efficiency	95%	95%
Sensitivity	10.0 mJy/beam	9.4 mJy/beam

OBSERVING PLAN

FAST will be a meridian scanning instrument, scanning from the horizon to the North Pole and back again every six minutes. As the Earth rotates, successive north and south bound strips on the sky will be observed. The scan speed will be varied continuously to achieve a roughly uniform effective integration time across the sky.

To obtain the desired sampling of one-half beam width in the direction of right ascension, the stripes will be offset by one-half the 8.1 GHz beam width on the second day of each pair of days of observation. Since the 2.7 GHz primary beam is three times that for 8.1 GHz, the northern four-fifths of the sky will be sampled every day at 2.7 GHz.

CONCLUSIONS

The FAST array can be expected to monitor the roughly 1230 sources stronger than 1 Jy at 2.7 GHz in full polarization and an additional 38,000 sources in total intensity above 100 mJy. The corresponding source counts for 8.1 GHz are approximately 330 and 10,000. The planned 10 mJy/beam rms sensitivity is approximately two orders of magnitude above the confusion limit at 8.1 GHz.

A substantial data base will result that should prove invaluable for the study of variability in Galactic and extragalactic radio sources and for the study of radio wave scattering in the interstellar medium. Using archived visibility data it will also be possible to produce an all sky map to a sensitivity better than 0.5 mJy.

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