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THE OWENS VALLEY SOLAR ARRAY

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INTRODUCTION

* Solar microwave emission contains essential information for the study of the coronal magnetic structure of active regions and of thermal and nonthermal flare electrons.

* To exploit this potential requires BOTH imaging and spectroscopy with sufficient resolution to resolve spatial and spectral features.

* The VLA provides excellent solar imaging (when in the C and D configurations) but inadequate spectral coverage. The existing Owens Valley system has excellent spectral coverage but imaging that is adequate only for very simple sources.

* The Owens Valley system is currently undergoing an expansion, which when completed in October 1990 will provide a SOLAR-DEDICATED 5 antenna array (10 baselines). By using frequency-synthesis, this will provide a significant imaging capability in addition to its current spectral coverage.

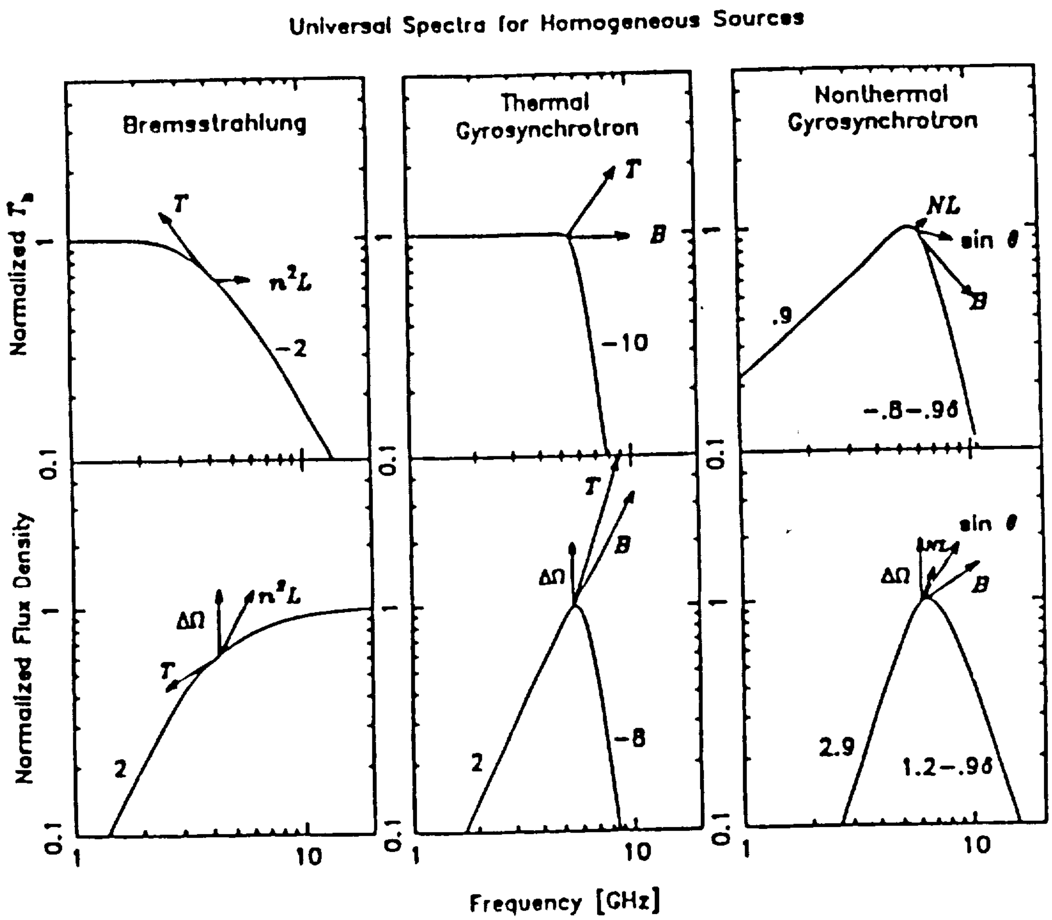
* At present, the application of microwave diagnostics is limited to spatially simple sources. The expanded array will permit their application to most flares and active regions.

SCIENTIFIC MOTIVATION

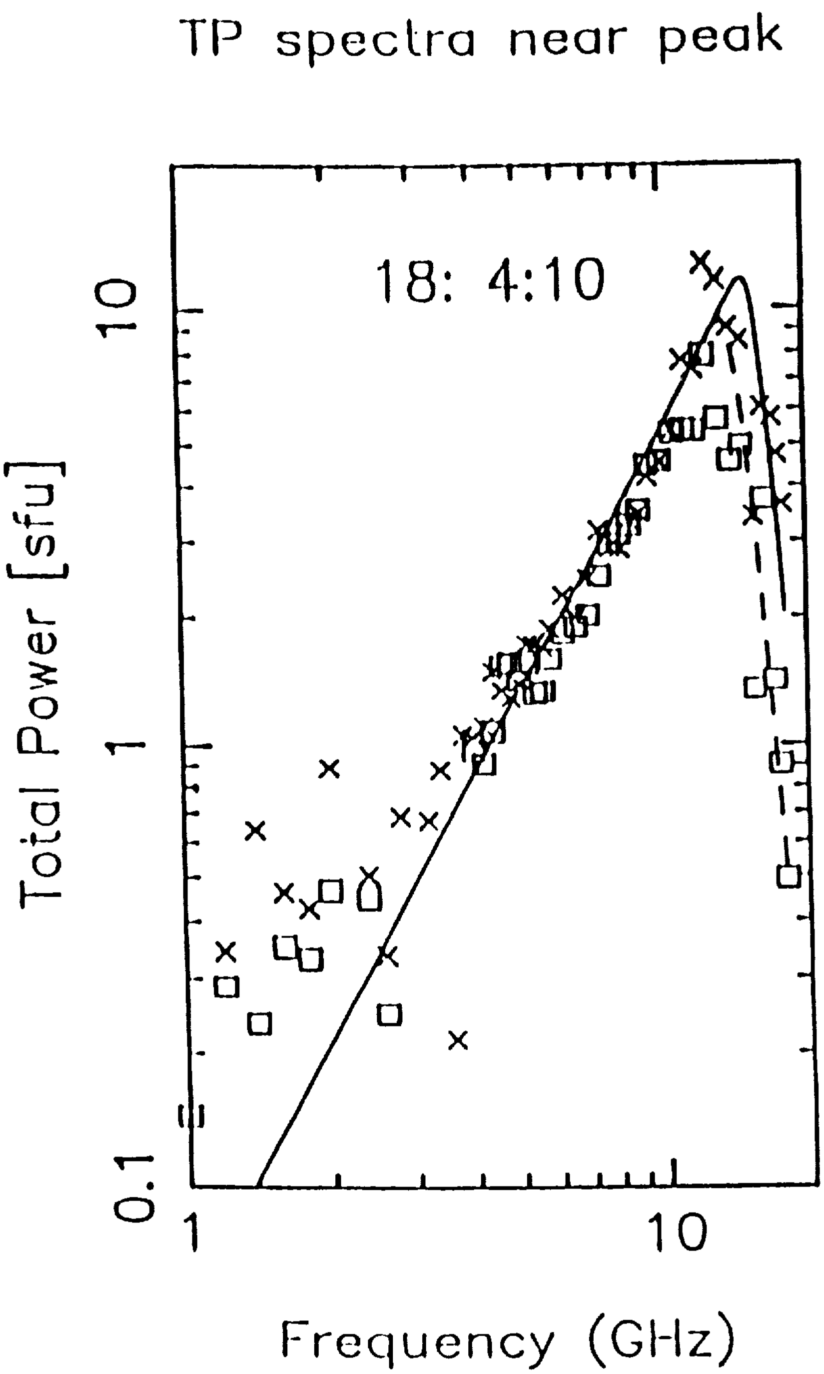
* Microwave imaging and spectroscopy have two primary roles to play in the study of solar activity:

    * In active regions, gyroresonance opacity provides a unique sensitivity to the strength of coronal magnetic fields. The combination of imaging and spectroscopy provides the capability for quantitative magnetograms at the base of the corona.

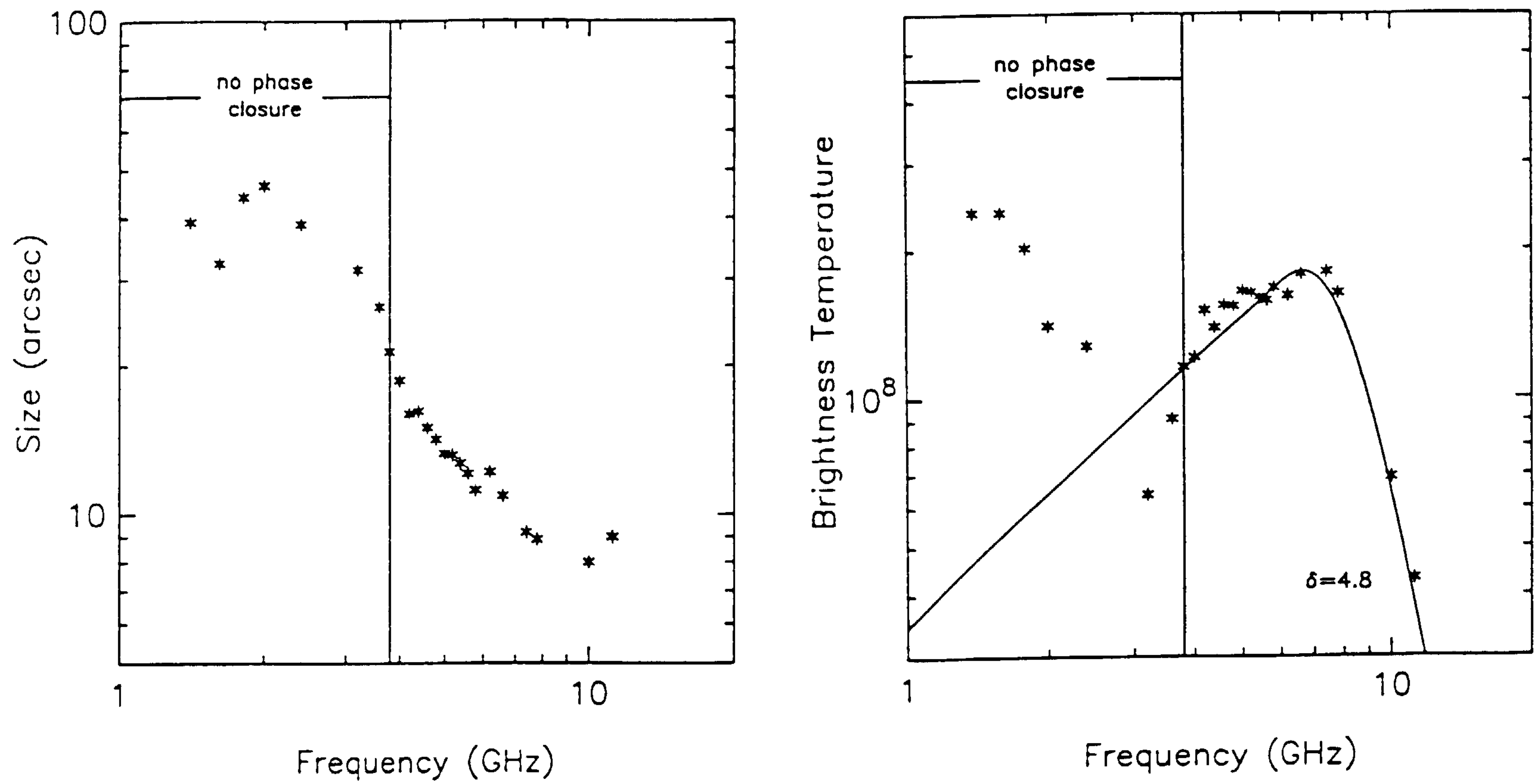
* For flares, the shape of the microwave spectrum indicates whether the electron spectrum is thermal or nonthermal. while the peak flux/frequency provides plasma/field and/or energetic electron parameters. Theoretical spectra and examples of observed thermal and nonthermal spectra are illustrated below.



Theoretical spectra for emission from a homogeneous source by the mechanisms indicated. Note that each mechanism is characterized by a distinct shape that remains invariant over a wide range of parameter space. The arrows indicate the direction and magnitude that the spectrum would shift for a factor of 2 increase in the indicated parameter.



Microwave spectra in right- and left-circular polarization for a demonstrably simple burst. The overlaid curves are for THERMAL gyrosynchrotron spectra of the form illustrated above.



Impulsive-phase spectra for an event observed with three antennas on August 2, 1988. Closure phase data indicates that above 3.8 GHz, the emission was dominated by a single source whose size and brightness temperature is shown. The shape of the brightness temperature spectrum unambiguously implies a NONTHERMAL electron distribution.

FREQUENCY-SYNTHESIS IMAGING

* An interferometric observation at a single frequency with a single antenna pair measures one Fourier component of the source distribution. The relevant parameter is the antenna separation in units of wavelength.

* Conventional aperture synthesis at a single frequency uses many antenna pairs (36 to 351 at VLA, depending on the number of subarrays) to measure many Fourier components from which a map is derived.

* Alternatively, a single antenna pair observing at many wavelengths (eg 45 at OVRO) can measure many Fourier components. In this case the derived "frequency-synthesis" map represents an average over a frequency band.

* The observed spectral shape provides a reliable guide as to what frequency range is reasonable so that the resultant image does not represent an unwelcome average of diverse sources.

* In practice, the images are not sensitive to spectral assumptions or weighting.

* The expanded array typically will observe at 450 baseline/frequency combinations, which can be divided a posteriori among an appropriate number of maps in different spectral bands.

* Examples of frequency-synthsis imaging are given below.

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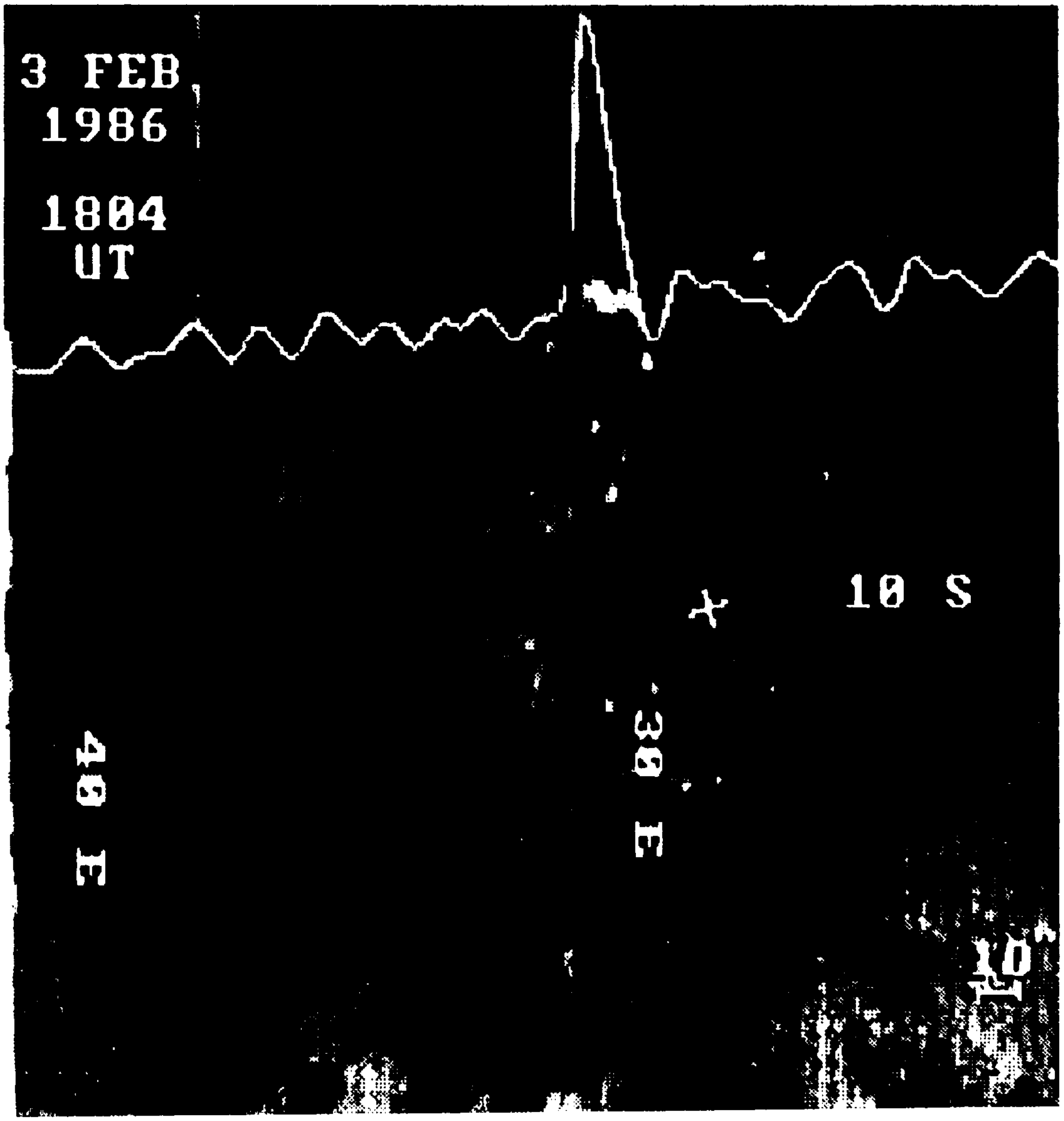

One antenna pair was used to make a 1-dimensional frequency-synthesis map of a flare. The microwave emission is dominated by a single source coincident with the H-alpha emission.

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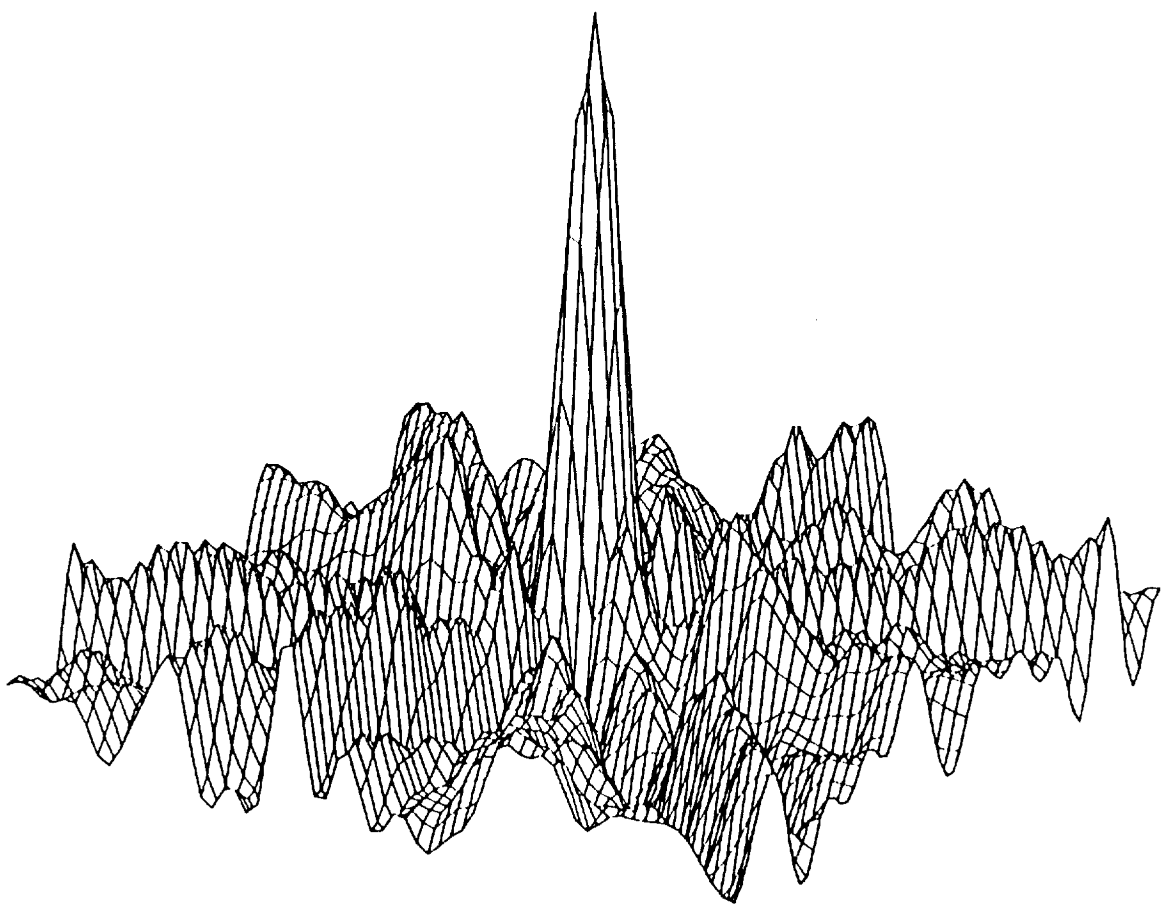
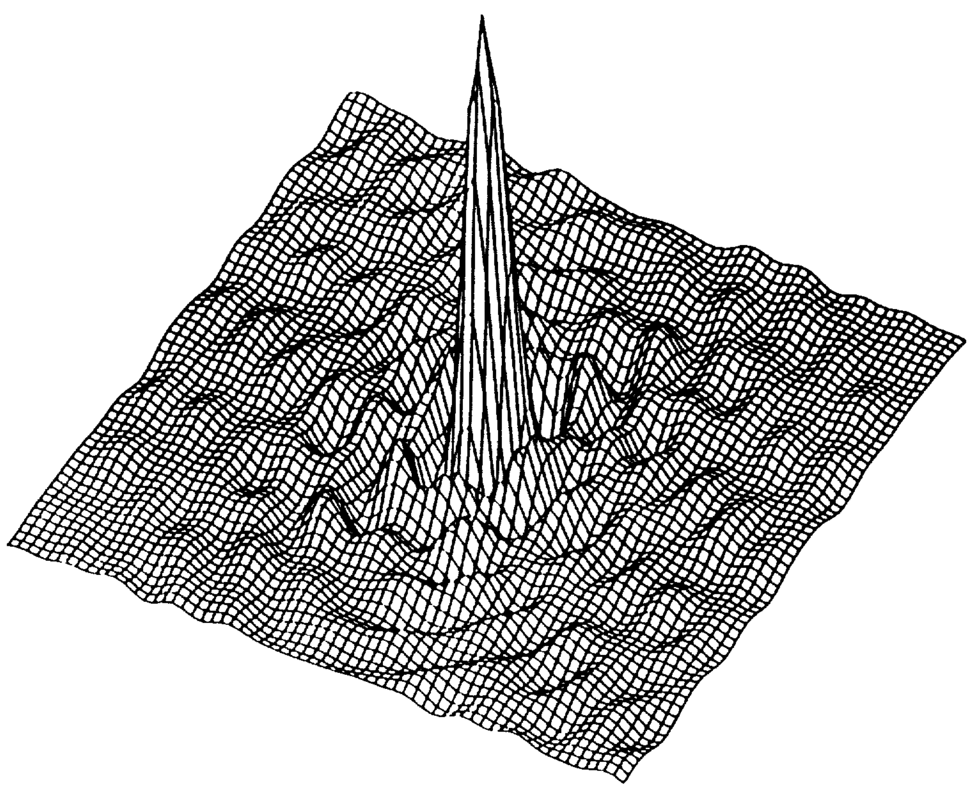
Frequency synthesis maps

Two baselines were used to make two 1-D frequency-synthesis maps with different orientations from which the 2-D flare source locations (crosses) could be determined. This was done in both right-circular polarization (black) and left-circular polarization (blue). Note that the LCP emission came from two widely separated locations while the RCP emission was found to be restricted to the position near the H-alpha kernel.



The ten baselines in the completed array will provide a substantial improvement in imaging capability. Shown above is a snapshot beam (applicable to flares) using 20 frequencies from 4 to 12 GHz. The highest sidelobe is at the 24% level. Extrapolating from our current experience, we expect that in the cleaned maps, sidelobe levels will be below 5% in most cases. The spatial grid is 2 x 2 arcseconds.



Illustrated above is the synthesised beam for an 8-hour synthesis map using 12 frequencies from 5 to 10 GHz. Using such beams at different frequency bands, it will be possible to produce sets of high-quality active region maps on a daily basis in support of SOLAR-A.

IMPLEMENTATION

* The present Owens Valley interferometer is based on two 27-m parabolic antennas, occasionally supplemented by the use of a third 40-m antenna. All antennas are equipped with frequency-agile receivers which can observe at up to 86 frequencies from 1 to 18 GHz in rapid succession (10-30 frequencies/second).

* The array expansion consists of adding three small 2-m antennas (also equipped with frequency-agile receivers) to work with the two 27-m antennas.

* Note that for solar work, large antennas are needed for calibration on cosmic sources and to restrict the field of view to a single active region. Large collecting areas are NOT needed for solar sensitivity. The combination of large and small antennas will still permit calibration on cosmic sources and the restricted field of view.

* The expanded array will NOT require additional delay lines, correlators, etc. Instead, provision has been made to rapidly time-multiplex existing systems which can handle 3 baselines simultaneously. In typical operation, the system will spend 100 milliseconds at a single frequency. This time will be divided into 5 successive 20 millisecond intervals as follows:
    1. Changing to the new frequency and reacquiring phaselock.
    2. Correlating antennas A, B and C.
    3. Correlating antennas A, B and D.
    4. Correlating antennas A, B and E.
    5. Correlating antennas C, D and E.

  Successive 100 millisecond periods would be devoted to different frequencies, so that 10 different frequencies per second would be sampled with all baselines. As at present, 45 frequencies in both right- and left-circular polarization could be measured every 10 seconds.

* Note that the critical design simplifications (and cost savings afforded by) the use of small antennas and time-multiplexing are made possible by the high signal levels provided by the sun.

* The first 2-m antenna is currently being assembled, and will see see first light this summer. Test observations in a 4-element configuration with the 40 m telescope are planned for the 4th quarter of this year. The 5 element array is expected to be complete by October 1990.

* A SIGNIFICANT EFFORT IS BEING MOUNTED TO ENSURE THAT BOTH OPERATIONS AND ANALYSIS ARE HIGHLY AUTOMATED AND USER FRIENDLY.

* OUTSIDE USERS OF THE ARRAY AND ITS DATA ARE WARMLY WELCOMED.

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