MILLIMETER ARRAY
MEMO NO. 36

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An Interim mmλ Astronomy Instrument

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I. WHY THINK OF INTERIM mmλ ASTRONOMY PROJECTS?

The current planning for the NRAO Millimeter Array project assumes no significant funding and construction until VLBA construction is completed, and this may not occur until the mid-1990's. Because of this there are three reasons why it is useful to discuss possible projects that may be built before, or as a preliminary part of, the full Millimeter Array: (1) the usefulness of new mmλ astronomy capabilities; (2) the need to proto-type possible equipment for the Millimeter Array project; and (3) the need to maintain NRAO's millimeter astronomy capabilities for future Millimeter Array construction and operation.

II. SOME OPTIONS FOR INTERIM mmλ PROJECTS

One version of an interim mmλ project that has been discussed is building an initial sub-set of the large (~10 meter) antennas which would operate as a limited array until the full Millimeter Array can be built. This option has been presented to the MMA Technical Advisory Committee, which recommended that it not be considered because it would be a direct duplication of the current efforts of the California millimeter arrays.

Another option that has been discussed is the construction of the part of the MMA that complements, rather than duplicates, the California millimeter arrays: the "central element" or Multi-Telescope array. This would be a $10M to $15M project, and would provide a major instrument for imaging fields of view that are larger, and resolutions that are smaller, than those that are the emphasis of most major US and foreign mmλ instruments.

A more moderate version of an interim instrument, with some of the advantages and capabilities of the M-T array, is the main topic of this memo. This interim project is a combination of the current NRAO 12m telescope equipped with a 3×3 (or 4×4) focal plane array, and an array of ~9 4m (or 3m) antennas of the type discussed for the M-T array. The 12m + focal plane array would instantaneously sample the same field of view as the array of smaller antennas.

III. AN ARRAY OF SMALL ANTENNAS PLUS THE NRAO 12m WITH A FOCAL PLANE ARRAY

For the sake of specificity let us discuss the characteristics of nine 4m antennas used in an array with the NRAO 12m antenna (equipped with a 3×3 focal place array with over-lapping half-power beam widths). Using this 10 antenna array in aperture synthesis mode would give one an instrument with the collecting area of a 17m antenna, the field of view of the 4m antennas ($56''\lambda_{mm}$), and a resolution of $5.5''\lambda_{mm}$ for an array size scale of 36m. The individual 4m antennas and the 12m antenna, when used to map a source in total power/beam switching mode, would provide the "zero" and intermediate spacing data for size scales of $56''\lambda_{mm}$ and $18''\lambda_{mm}$, respectively.

This multi-purpose instrument would preserve all the basic capabilities of the 12m telescope, but would add: (1) an instrumental mode to do single dish imaging for size scales that are larger by a factor of three; and (2) an instrumental mode for higher resolution aperture synthesis. One of the main purposes of this instrument would be use of $M = n^2$ mosaic elements of $\sim 1'\lambda_{mm}$ size scale used in mosaicking or tesselating images $\sim 1'n\lambda_{mm}$ in size. Figure 1 shows the matching of the smallest fields of view, which are obtain for observing with the 12m antenna (both single dish imaging and for the visibilities obtained when the 12m antenna is correlated with each 4m antenna) and the larger field of view obtained when observing with the 4 m antennas (both single dish observing and for the visibilities obtained when the 4m antennas are correlated with other 4m antennas). Table 1 summarizes the major parameters of this instrument.

Table 1

Field of View	Instrument Mode	Image Size	Resolution	# Pixels
n^2 4m Fields	Single Dish	$(56''\times n\lambda_{mm})^2$	$56''\lambda_{mm}$	$(2n)^2$
n^2 12m/FP Fields	Single Dish	$(56''\times n\lambda_{mm})^2$	$18.3''\lambda_{mm}$	$(6n)^2$
n^2 12m/FP+4m Fields	Aperture Synthesis	$(56''\times n\lambda_{mm})^2$	$5.5''\lambda_{mm}$	$(20n)^2$

While the ideal way to achieve the above-mentioned purposes would be construction of the full M-T array of the Millimeter Array project, this concept of an interim array would attack some of the same scientific goals with a cost of the order of $3M.

Advantages are:

- it would fill a scientific niche not well filled by other instruments;
- it would not duplicate, but rather complement, the California mm Arrays; and
- it would build on current NRAO mmλ efforts.

Use of the 12m antenna in the array doubles the collecting area of the 9 4m antennas, making it equivalent to a 17m antenna, almost equal to the 18.3m equivalent of the M-T with 21 4m antennas. There are two main disadvantages relative to the full M-T array: (1) poorer u-v coverage, particularly for snapshot observations, and hence more reliance on earth-rotation tracking for good u-v coverage; and (2) the need to image the 4m fields with both visibilities "seeing" the entire field and visibilities "seeing" only ~1/9 of each field. The latter imaging problem requires a special kind of mocaicking or tesselation algorithm.

Figure 2a shows one configuration of 9 4m antennas placed south of the NRAO 12m telescope, and Figure 2b shows the resulting u-v coverage for a source at a declination of -30°. Figure 3 shows the beam profiles for this case for both uniform and natural weighting. The imaging characteristics for this array are relatively good because of the 20×20 gridding of the u-v plane containing all the data. The configuration in Figure 2 is too elongated in the N-S direction, but reveals the basic aperture characteristics of the array. Many other configurations can be adopted, but let us defer such a discussion until the concept of this interim instrument is known to be of interest to the US mmλ astronomy community.

The added equipment needed to make this interim 12m + 9 4m instrument would initially be made operational on the current 12m site at Kitt Peak. If deemed worthwhile it could then be moved to a better (higher) site. One of the least expensive new sites, because it is close to another major NRAO site (the VLA), is on South Baldy, a 10,600 ft peak that is already a "scientific preserve" with power and road access.

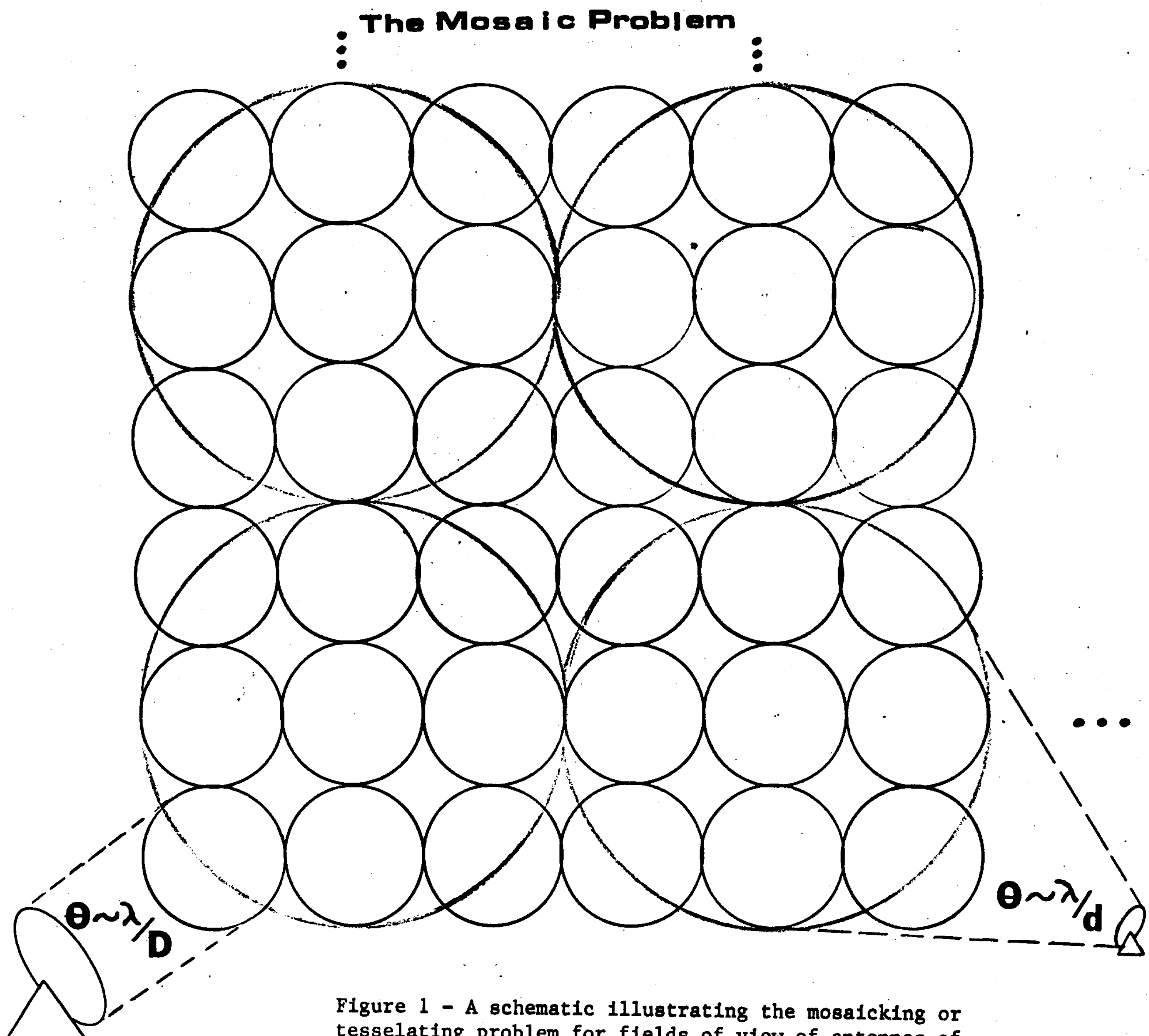


Figure 1 - A schematic illustrating the mosaicking or tesselating problem for fields of view of antennas of diameters D and d, where D/d = 3.

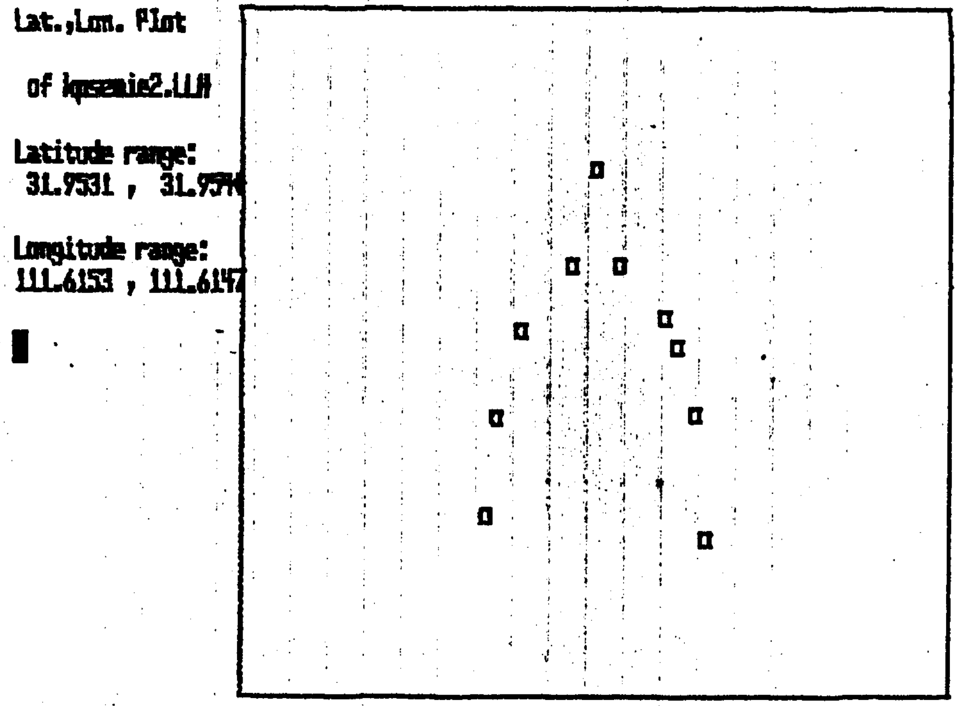


Fig. 2a - An arrangement of a semi-circle of nine antennas located south of the NRAO 12m antenna.

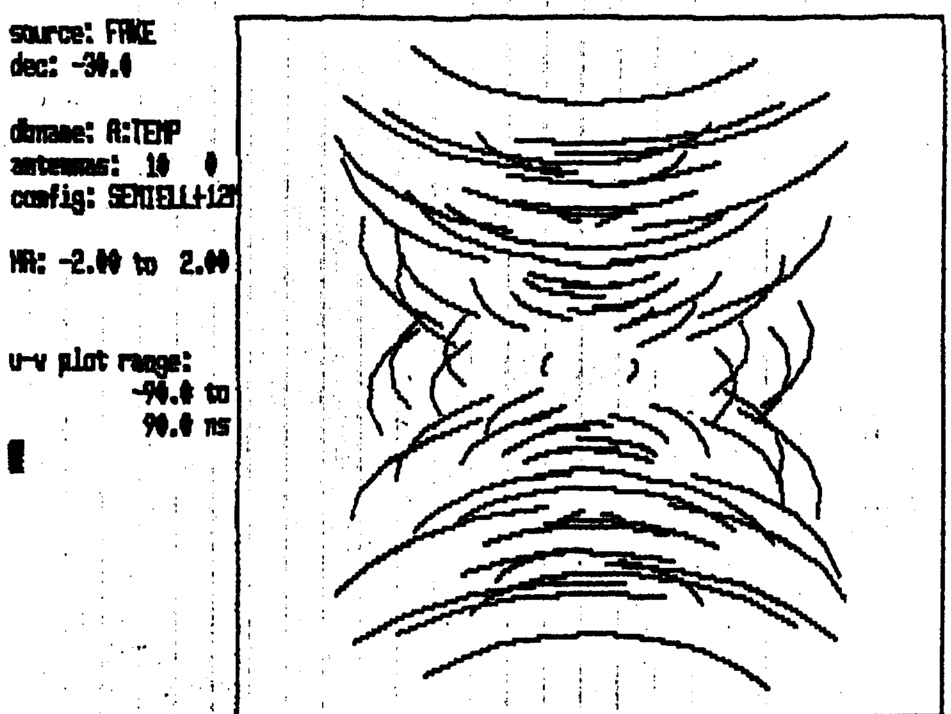
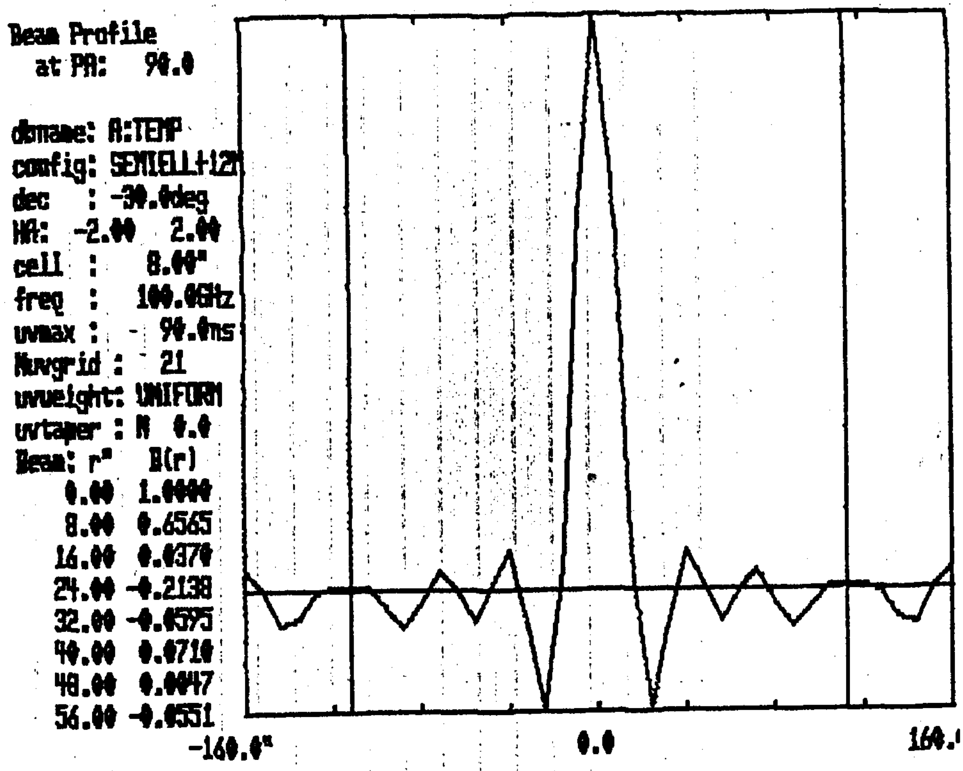
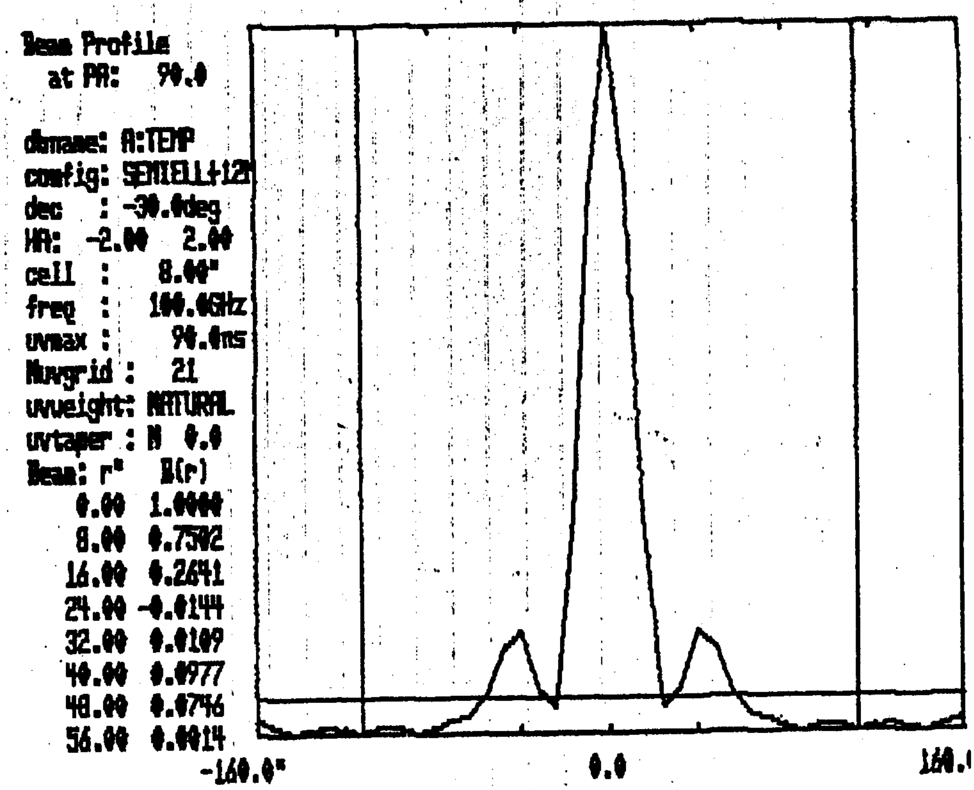


Fig. 2b- The u-v coverage for a four hour observation of a source at declination -30^{o} with the array in Fig. 2a.



(a) Uniform weight



(b) Natural weight

Figure 3 - The beam profiles (with uniform and natural weighting) for the 12m/FP + 9 4m antennas for declination -30° and the configuration in Fig. 2a.