MMA MEMORANDUM # 69

SIS MIXER & LO OPTIONS FOR THE MILLIMETER ARRAY

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This memorandum is based on a document sent last August to members of the MMA Joint Development Group. Its purpose was to initiate discussion amongst those interested in SIS receiver and local oscillator development for the MMA.

Appendices 1 and 2 list some of the options that might be appropriate for SIS mixer and LO development. The items that seem most promising for further study and development, when MMA funding becomes available, are printed in italics.

In Appendix 3, an initial conservative SIS receiver design is described. It consists of components which we are reasonably confident could be made a few years from now in the quantities needed for the MMA.

MMA receivers for 30-50 GHz, probably 68-90 GHz, and possibly 90-115 GHz, will use transistor amplifiers, whose development will be managed by Marian Pospieszalski. For the present discussion, it will be assumed that SIS receivers will be used at all frequencies above 90 GHz.

The total number of receivers required to give the MMA its intended spectral coverage depends on the outcome of the preliminary SIS mixer and transistor amplifier development efforts. At present we are reasonably confident that amplifiers and SIS mixers will each be able to cover ~20% bandwidths. Each MMA antenna would then need 11 receivers (x 2 polarizations), packaged in 3-5 cryostats, to give full coverage of the desired bands. With additional effort, 30-40% bandwidth (approximately a full waveguide band) may eventually be possible, reducing the required number of receivers to 7 (x 2 polarizations).

For SIS receiver development to proceed at an acceptable rate, substantial sustained funding is needed for junction fabrication. Our only real source of junctions at present is UVA, and their SIS project is almost crippled by insufficient support. Support for SIS junction fabrication should be of the highest priority as we cannot hope to develop wideband SIS mixers without a responsive source of junctions.

Wideband frequency multipliers for the first LO will require considerable development of both circuits and planar diodes. This, too, should be a high priority. At present, NRAO supports no work, internally or elsewhere, on frequency multipliers or other LO sources.

Appendix 1: SIS Mixer Options for the MMA

(Items in italics are initial suggestions for further development.)

- Coupling
  - Quasi-optical
  - *Horn-waveguide*
- Tuning
  - *Fixed*
  - *Adjustable*
    - Mechanical
      - W/g short circuit(s)
      - Other
      - Actuators
        - Lead-screw
        - Cam
        - Piezoelectric
    - Electronic
      - *Varactor*
      - JJ inductor
      - Kinetic inductance
- Junction type
  - *Nb*
  - NbN
  - Pb-alloy
- Mixer type
  - Fundamental
    - *Single-ended*
    - *Balanced* (may be useful for image separation mixers)
  - Harmonic
  - *Image-separation*
  - Single-sideband (i.e., reactive image termination)
  - *High IF* (e.g., 20-40 GHz) vs low IF
- Additional areas needing study:
  - *Multiple bias points in series arrays.*
  - *Suppression of Josephson noise ???-360 GHz in mixers with series arrays.*
  - *Effects of a high IF (e.g., 20-40 GHz) on SIS mixer performance.*
  - *The need for an IF isolator; how does it depend on mixer design?*
  - *Integration of the IF amplifier into the mixer block.*
  - *Optimization (L, T_M, bandwidth) of fixed-tuned mixers.*

Appendix 2: Millimeter Local Oscillator Options for the MMA

(Items in italics are initial suggestions for further development.)

- Fundamental Source (or pump for multiplier)
  - Transistor
    - *YTO*
    - Other
  - *Gunn*
  - Transit-Time (IMPATT, Tunnett, etc.)
  - Quantum-well
  - Solid state vacuum triode
  - Josephson oscillator

  - X-Y Distributed (grid oscillators)
  - Z-Distributed (travelling-wave)

  - Tuning method -- see mixers

- Upconverter
  - Varactor (or varistor) diode
  - Transistor

  - Distributed (travelling wave)

- Multipliers
  - Discrete
    - *Tunable*
    - *Tunerless*
  - X-Y Distributed (grid multipliers)
  - Z-Distributed (travelling wave multipliers)
    - *Nonlinear transmission line (soliton)*

  - Diodes for multipliers
    - Whisker-contacted
    - *Planar diodes*

      - *Schottky*
      - *δ-doped*
      - Quantum-well
      - Other

  - Tuning method -- see mixers

- *Power amplifiers* (to drive multipliers)

- Additional areas needing investigation
  - *Noise (AM, FM, and ϕM) in oscillators, multipliers, power amplifiers.*
  - *Design of broadband multipliers.*
  - *Optimization of diodes for multiplier chains (e.g., δ-doped for low power stages).*

Appendix 3: An Initial Conservative Receiver Configuration

Room temperature optics

Input multiplexer	Martin-Puplett interferometer tuned for 3 dB LO loss while terminating the image in a 4 K load.
Vacuum window	?

Cryogenic optics

I/R filter (50 K)	Grooved teflon or polyethylene.
Lens	Polyethylene.
Horn	Corrugated horn for longer wavelengths. Potter horn for short wavelengths?
Image Cold-Load	?

Mixer

SIS mixer	Single-ended, broadband, waveguide mixer with integrated tuning. No mechanical tuning. Fundamentally pumped. Useable bandwidth not yet clear.

IF Components

Isolator	Probably necessary unless the IF amplifier can be integrated with the mixer. At L-band an isolator would restrict the bandwidth. Prefer, therefore, an IF of 2-3 GHz.
Amplifier	30 dB gain, 3 stages, 30 mW dissipation (+ 20 mW if LED's are required).

Local Oscillator

Fundamental source	ϕ-lockable YIG-tuned oscillator, 30-45 GHz.
Power leveller	(servoed to DC junction current)
Amplifier	30-45 GHz, 100 mW
Doubler(s) Tripler(s)	Output 68-90 GHz Output 90-120 GHz
Amplifier(s)	65-90 GHz, 50 mW
Doubler(s) Tripler(s) Quadrupler(s)	Output 130-170 GHz Output 200-270 GHz Output 270-360 GHz