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ALMA SIS Mixer Development

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Considerable effort was expended within the US MMA project on goals for receiver performance before integration of the MMA into the ALMA project. These goals and principles need to be reviewed in the ALMA context so that a clear set of objectives is agreed upon. This document summarizes the MMA receiver items which specifically affect SIS mixer design; these fall into three broad categories:

- General specifications and goals
- MMA adopted specifications and design principles
- Criteria for acceptability to ALMA

General Specifications and Goals

1. Highest practical sensitivity for spectral line work

   - Low receiver noise—always a prime objective
   - Single sideband operation—to reduce atmospheric contribution to receiver noise
   - Instantaneous bandwidth of at least 2 GHz for extragalactic observations and searches

2. Highest practical sensitivity for continuum work

   - Lowest possible value for receiver noise/sqrt(bandwidth)
   - High dynamic range (hard to saturate) to support solar observations

3. Availability and reliability

   - Receiver should have the highest possible reliability consistent with cost—it should be achieved through good design, reliability testing, and quality control

4. Manufacturability and cost

   - Cost should be as low as possible consistent with the performance objectives—this means taking into account the effects of mixer design on other parts of the receiver, such as the optics, LO requirements, cryogenic loads, etc., which could result in some performance compromises
   - Components should be designed for ease of large quantity manufacture and test—it should be acknowledged that this could result in some performance compromises

MMA Adopted Specifications & Design Principles

1. Bandwidth:

   8 GHz instantaneous bandwidth per polarization (the maximum allowed by the IF system and correlator, another design compromise), to be achieved by a target IF bandwidth of 4-

12 GHz with a fallback to a smaller bandwidth within 4-12 GHz if good performance over 4-12 GHz cannot be achieved

2. Noise:

   Single sideband receiver noise of 4-8 photons, depending on band; goal is to be at least as good as typical mm and submm receivers which represent the present state of the art for practical receivers used in interferometer arrays

3. Single sideband operation:

   SSB operation is required for all bands at which it is practical. The preferred implementation is via a sideband separating mixer, so that both sidebands are available simultaneously at separate IF ports. The fallback implementation is a single-sideband mixer via methods TBD, and the second fallback is a double-sideband mixer.

4. Balanced configuration:

   Balanced mixers are required for all bands for which they are practical.

   A balanced mixer configuration will:
   - reduce LO power requirement
   - reduce contribution of LO noise to IF noise
   - eliminate the need for a lossy LO diplexer ahead of the mixer

5. Tunerless operation:

   Operation without mechanical tuners is desired in order to reduce the complexity of the receiver and increase reliability—this must be weighed against any performance gains which might be achieved using mechanical tuners

6. Integrated design approach

   - Up to 275 or 370 GHz, MMIC chip approach, fabrication by photolithography and/or electron beam lithography
   - Above 275 or 370 GHz, if MMIC approach does not work well, use of waveguide structures fabricated in mixer block—allows balanced and perhaps sideband-separating operation
   - Close collaboration with SIS wafer fabricators in order to optimize designs for both performance and manufacturability
   - Avoid separation of development and production for SIS wafers

Criteria for acceptability to ALMA

1. Performance

- Sensitivity for interferometric and single-dish spectroscopic observations in typical atmospheric conditions at the array site

- Sensitivity for interferometric and single-dish continuum observations in typical atmospheric conditions at the array site

2. Reliability

- Demonstrated reliability in long-term operation with multiple cooldowns
- Estimated maintenance requirements and costs

3. System factors

- LO power requirement
- LO noise requirement
- LO injection complexity and cost
- Optics requirements
- Other requirements

4. Manufacturing factors

- Likelihood of successfully fabricating the required number of units, including evaluation of the degree of involvement of the designers in the manufacturing process
- Cost of mixer fabrication
- Cost of mixer test
- Cost of required LO and optics
- Other costs