NATIONAL RADIO ASTRONOMY OBSERVATORY

3 June 1988

MEMORANDUM

TO: M. Balister & D. Emerson

FROM: A. R. Kerr, J. W. Lamb, & J. M. Payne

SUBJECT: SIS RECEIVER PLANS

In recent months it has become clear that we need to review our plans for new SIS receivers on the 12-m telescope. After considerable discussion we have decided that the most expedient way of upgrading the receiver complement to give full frequency coverage is to develop a modular cryogenic system based on a closed-cycle 4K refrigerator. This approach should also pave the way to receiver development for the Millimeter Array which will clearly depend on SIS receivers with closed-cycle refrigeration. The main points of our discussions are summarized in the following notes.

I. MAJOR FACTORS

SIS Mixers:

We now have junctions that should allow us to make tolerable SIS mixers for the whole frequency range from 70-230 GHz. ("Tolerable" here means at least as good as the best Schottky mixer.) In the near future we expect to have junctions usable to 360 GHz.

70-90 GHz	We expect some of the existing 90-116 GHz mixers to operate satisfactorily in this band with a minor modification.
90-116 GHz	In hand.
130-170 GHz	It is likely that some of the 100 GHz devices will work tolerably here. The present 230 GHz mixer block can be scaled for operation at 150 GHz.
200-260 GHz	We have tested one mixer using an old (unshunted) Hypres 100 GHz junction: T_m < 180 K SSB and L ~ 10 dB with image rejection > 20 dB. This should give T_r ~ 250-300 K SSB on the telescope, better than any Schottky

receiver. Much better results should come with more appropriate junctions.

260-320 GHz	It is likely that some 230 GHz junctions will be usable here. The mixer will be scaled from 230 GHz.
320-360 GHz	It may be possible to operate with 230 GHz junctions until appropriate ones are available. The mount will be scaled from 230 GHz.

The Supply of Junctions:

We have just received, but not yet tested, a new batch of Hypres devices, nominally for 100 and 230 GHz. As our work with Hypres has been supported indirectly by Navy and Airforce contracts which are now complete, we cannot rely on any future free junction fabrication from them. Their foundry service costs ~ $50,000 per run.

We have a few IBM 100 GHz junctions left. IBM is now working on a new lot of devices, nominally for 100 and 230 GHz. Delivery could be 2 months to 2 years based on past experience. Our collaboration with IBM is through a Joint Study Agreement which is at no cost to us. This means we have to fit in with their schedule and the limited space available on their wafers.

When the present lithography problems at UVa are sorted out, we should get junctions for 100 and 230 GHz. Since UVa will be a responsive source of SIS junctions with a turnaround time of only a few months, it is critical to the receiver program outlined below that they be given appropriate support.

Proposed Receivers:

The aim of the receiver program is to end up with a set of receivers cooled with closed-cycle refrigerators, giving complete frequency coverage and, at some frequencies, multi-beam capabilities. After looking at the technicalities of receiver construction we have concluded that the receivers fall naturally into four groups, as follows:

90-116 GHz. This receiver package would comprise two dual polarization receivers covering (approximately) 70-90 GHz and 90-116 GHz. It would feature single sideband mixers as currently used in the 90-115 GHz SIS receiver, waveguide LO injection, and cooled optics. It replaces the present SIS receiver which has incomplete frequency coverage of the 3-mm band and requires twice weekly helium fills.

130-170 GHz. As mentioned above, the mixers will probably be scaled versions of the 230 GHz mixers. This receiver will have waveguide LO injection, a cooled feed horn and lens, and quasioptical image dumping.

200-360 GHz. This whole band will be covered by a single receiver package as with the current Schottky system. It will be implemented as a modular receiver with up to four minidewars each containing two orthogonally polarized channels. LO injection and image dumping will be will be done with Martin Puplett interferometers as in the attached drawing. A single quasioptical package will rotate above the minidewars to select the required frequency range. (Note that for wide bandwidths, i.e. greater than 200 MHz, the image rejection of a simple interferometric diplexer is not sufficient and would need to be supplemented by image smearing to achieve more than 20 dB of image rejection)

230-GHz 8-Beam Array Receiver. The array receiver will use the same minidewar cryostat modules as used for the 200-360 GHz receiver but these will be stacked together. LO injection will be quasioptical, and image dumping may be added at a later stage.

Refrigerators:

As SIS mixers are sensitive to temperature variation, we are concerned about the suitability of closed-cycle refrigerators for use with actual telescope receivers. Consultation with Craig Moore regarding the performance of the NRAO closed-cycle refrigerators used with masers suggests that we should face no major problems. Other observatories have successfully used closed-cycle refrigerators with SIS receivers (even with lead junctions). Although it is not known whether their system performance is ultimately limited by refrigerator temperature fluctuations, the best way to determine this appears to be by using such a receiver for astronomical observations.

It seems is clear that in the future closed-cycle refrigerators will be essential, given the proposed number of receivers. Therefore JT coolers will be used from the start, and no plans will be made for additional hybrid systems. Tucson needs to make an immediate start in gaining experience with closed-cycle systems.

II. PLANS

200-360 GHz Modular Receiver

Phase 1. The first phase of construction will be aimed at producing a 230 GHz telescope receiver as quickly as possible. The initial version will have a mother dewar and a single mini dewar, but will not have the quasioptical LO injection and image dumping described above. Some preliminary work will be done on the optics to ensure that diplexers can be added later with no mechanical or optical incompatibilities.

Tony will be responsible for mixer development, John will design the mother dewar (and any heat switches etc.), and James will design the minidewars and do the preliminary optics calculations based on Tony's proposed layout (see attached drawing).

Phase 1 time scale: A bare-bones receiver to be ready for telescope tests in February, 1989.

Phase 2. The next phase will be to design the quasioptical LO diplexer, usable over the whole 200-360 GHz band, to be added to the Phase I receiver. By this time the minidewar concept should have been verified and any bugs ironed out. Further minidewars may then be added to the mother dewar as mixers for the different parts of the band become available.

Phase 2 time scale: Mid 1989.

8-Beam 230-GHz Receiver

Another mother dewar will be constructed to take a stack of minidewars on one side to make up the array receiver. This will require the development of a quasioptical LO splitter based on John's design for the Schottky 8-beam receiver but including some form of active LO leveller in each channel, and an LO diplexer based on the design for the 200-360 GHz receiver.

Time scale: End of 1989.

90-116 & 130-170 GHz Receivers

The receiver packages for the 90-116 GHz and 130-170 GHz bands will be developed based on the experience gained with the 200-360 GHz system. They could, for example, use the same mother dewar but have larger minidewars, each containing a single polarization channel.

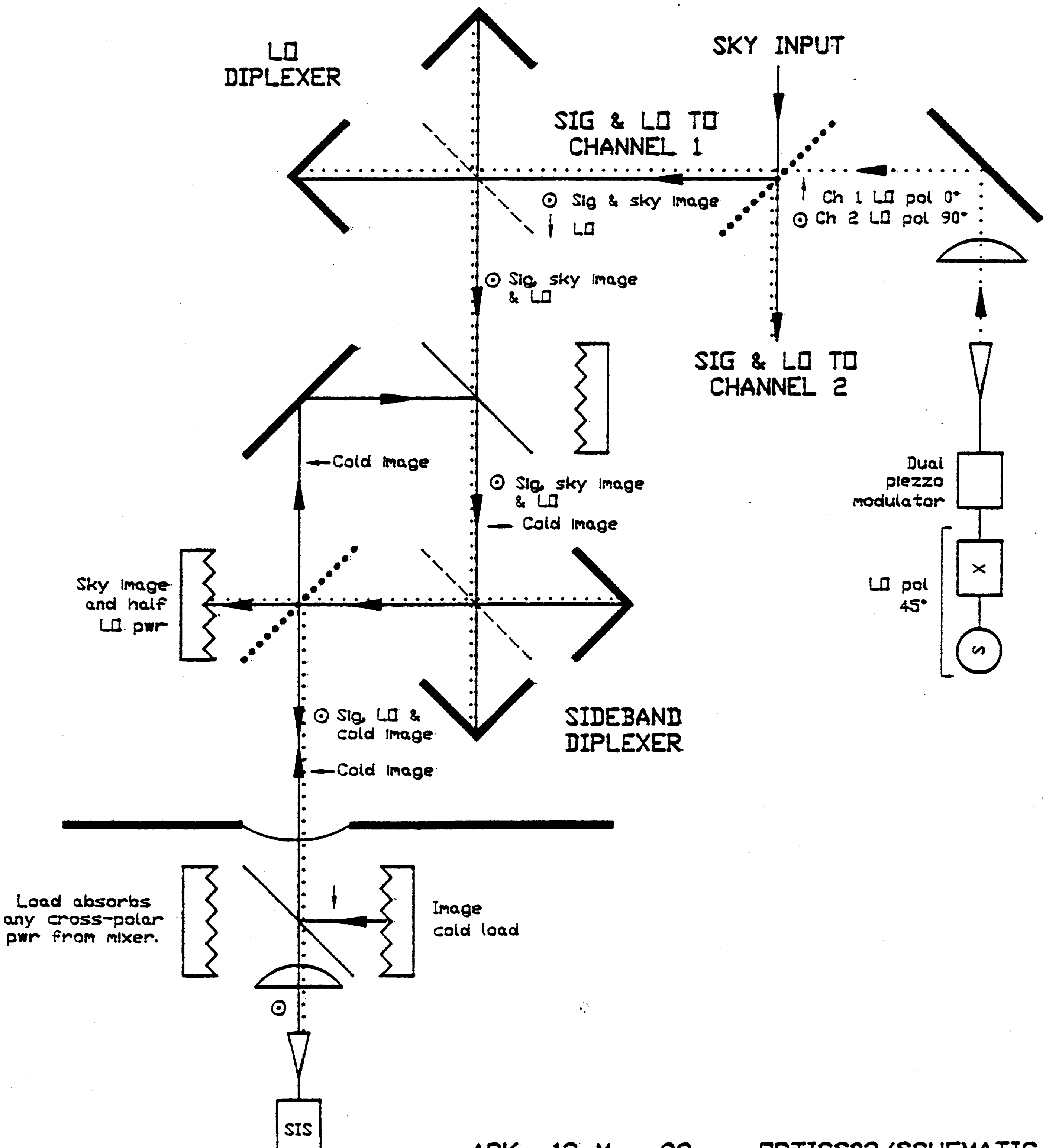
III CONCLUSIONS

The above proposal is aimed at giving the 12-m telescope complete frequency coverage using SIS receivers. The plan calls for a working 230-GHz receiver by early 1989 with expansion to higher frequencies as mixers become available. Outlines are made for coverage at lower frequencies and for multi-beam receivers. The key points in the program are the design and production of mixers in Charlottesville (Tony), construction and testing of JT closed-cycle refrigerators (John), evolution of a mother dewar/mini dewar cryogenic system (John, James), and development of the optical systems (James).

If these proposals are carried out, the competitiveness of the 12-m telescope should be assured well into the future.

Attachments: 1 drawing

cc.: Vanden Bout
Brown
Weinreb
Pan
Bailey
Jewell



ARK 12 May 88 OPTICS02/SCHEMATIC