MMA Memo No 179:

Compatibility Issues for Joint Operation of the LMSA and MMA

M. Ishiguro (NRO) and P. Napier (NRAO)

2 July, 1997

Summary

If the LMSA and the MMA are to be capable of operating together to form a larger array, it will be necessary that their designs be compatible in a number of areas. Additionally, compatibility of design or operation may make it possible for the two instruments to save capital or operating cost by sharing infrastructure. In this report we present a list of compatibility issues which should be investigated before either instrument freezes its design. Inclusion of an item on the list does not necessarily mean that compatibility is essential, simply that the advantages and disadvantages of achieving compatibility must be understood.

1. Introduction

It is possible that the LMSA and MMA will be built on adjacent sites in Northern Chile, in which case it has been proposed that the two instruments operate together, on occasions, in a large array 10 km in diameter. This combined instrument has become known as the Atacama Array (Ishiguro and Kawabe, 1997). To make the Atacama Array possible it will be necessary to design the two instruments so that they are compatible. Compatibility could be of two kinds. First, and most important for the Atacama Array, are those compatibilities which are required or desirable in order to achieve the science goals of the combined instrument. A second kind of compatibility are those which, if they are achieved, would result in a savings of capital or operations costs due to sharing of infrastructure and other costs. In this report we present a reasonably comprehensive list of compatibility issues of both types. Inclusion of an issue on this list does not necessarily mean that the item is considered to be an essential compatibility, simply that it is possible and probably desirable and the advantages and disadvantages of providing the compatibility should be considered before either instrument freezes its design.

In general, maintaining compatibility between the two arrays will require a significant amount of effort to negotiate acceptable designs and will often cost one instrument or the other more to design a piece of equipment in a way that it is different to its own natural requirements. As a matter of general philosophy therefore, we suggest that we plan to provide only those compatibilities that are clearly necessary to achieve the science goals of the joint array or provide a significant cost saving for the two instruments. This philosophy will provide each instrument with the maximum flexibility to make its own decisions, which is desirable because the two projects may well be designed on different schedules and their equipment will be built by different commercial companies.

The model that we have in mind at present for joint operation of the two instruments in a combined array is the following. Each antenna will receive its local oscillator reference signal and command information from the central control building of its own array and will return its IF data to its own correlator located in that same control building. Its IF data will also be sent to the correlator of the other array on a wide bandwidth transmission link which will run between the LMSA control building and MMA control building.

Below we list compatibility issues for various areas of the instruments. In general the issues are listed without comment. However, where some consensus has developed in the discussions carried out so far, comments are made about the necessity of a particular compatibility or ways of achieving the desired compatibility. Compatibility issues that are considered to be essential, in the sense that they have the potential to prevent the measurement of accurate visibilities on interferometer baselines between the two arrays, are identified by an *.

2. Compatibility Issues For Antenna and Transporter

*(2.1) Rotation of the linear polarization vector and primary beam on the sky. If different optics geometries (e.g Cassegrain vs Naysmith) or antenna mounts (e.g. Az/El vs Slantaxis) are used the beam and polarization vectors will rotate on the sky in different ways. One possible solution would be to rotate the receiver and feed. The polarization problem could also be solved by producing all polarization products in the correlator or by observing in circular polarization.

(2.2) Reflector diameter. This involves issues of primary beam size and single dish or single interferometer sensitivity.

(2.3) Primary beam shape and sidelobe structure. This involves issues of aperture illumination and orientation and size of aperture blocking structure.

(2.4 Antenna slew rates and fast switching ability.

(2.5) Azimuth and elevation limits and compatible sizes and locations of any zones in the sky which cannot be accessed for tracking.

(2.6) Ability for either antenna to use either antenna pad. This becomes a consideration primarily if one wishes to keep open the possibility of also combining the arrays in configurations smaller than the 10 km array. Note that, as well as requiring correct structural design of the pads, this implies power (voltage and frequency) and communication system compatibility. Assuming that the LMSA antennas are larger than the MMA antennas, adequate compatibility is probably provided if the MMA antennas can use the LMSA pads. It is probably not necessary for the LMSA antennas to be able to use the MMA pads.

(2.7) Ability for either antenna to be carried on either transporter. There does not seem to be any strong need for this, unless it is required to place MMA antennas on LMSA pads, as suggested in 2.6 above. In this case adequate compatibility is probably provided by ensuring that an MMA antenna can be carried by an LMSA transporter.

(2.8) Ability for either transporter to travel on the transporter roads of either array.

(2.9) Shadowing of adjacent antennas in compact arrays or clusters. If dissimilar antennas are located very close together in the most compact array or in clusters in the larger arrays, the amount of signal blockage caused by one antenna on an adjacent antenna could be larger than expected. However, there does not seem to be any strong reason why dissimilar antennas should be used very close to each other, so this is probably not a problem.

(2.10) Selection of a holography frequency so that a single mountain-top holography beacon can serve both instruments.

(2.11) Subreflector focusing schemes. If elevation dependent subreflector movements are implemented in different ways, phase jumps could be produced on inter-array baselines.

3. Compatibility Issues For Receivers and Local Oscillator

*(3.1) Type of polarization (linear or circular) and orientation of polarization for each receiver should be the same on the two arrays.

*(3.2) A common master LO reference signal for both instruments. This is needed so that signals received by the two arrays can be cross correlated.

*(3.3) Phase switching, sideband separation and fringe rotation schemes. For example, it would be inconvenient if one array implemented some of these functions in the RF or IF, but the other array relied on implementation in the correlator.

*(3.4) Ability to achieve identical signed-sum of the LO's on both instruments for a given observing frequency. This ensures that astronomical signals are converted to identical baseband frequencies on both arrays, which is required if signals are to be cross-correlated between the two arrays.

*(3.5) Real time atmospheric phase measurement methods and methods for applying the phase corrections to the data.

(3.6) Band edge frequencies for the various receivers. It would be inconvenient if an important group of spectral lines, for which simultaneous observations are desired, were all in one receiver on one array but spread between two receivers on the other instrument.

(3.7) Band pairs for dual-band observations. If a simultaneous dual-band observing capability is provided, the band pairs should be the same for the two arrays.

(3.8) Time to change observing frequency. For timeshared observations in which the observing frequency is rapidly changed it would be desirable for the two arrays to have compatible specifications for such parameters as LO settling time and time to change observing bands.

4. Compatibility Issues for the IF, Transmission and Correlator Systems

*(4.1) Compatible data format at input to correlator (sample rates, number of digitization levels, etc).

(4.2) IF frequencies and bandwidths. Common choice of these parameters will make it easier to input data from both arrays into both correlators.

(4.3) Compatible fiber optics system (desirable if antenna pads are shared). This includes, for example, choice of transmitter/receiver types, connector types, analog vs digital data transmission, etc.

(4.4) Choice of correlator type (FX vs Lag).

(4.5) Correlator dump time.

(4.6) Compatible phasing system and sum ports for VLBI. For the most sensitive VLBI experiments it may be desirable to add the summed signals from the two arrays together.

5. Monitor, Control and Computer System

*(5.1) Synchronization of control events (e.g. phase switching) between the two instruments. Time critical control events will need to be synchronized in time between the two arrays.

(5.2) Designation of a master/slave control computer. In order to achieve item 5.1 above , experience suggests that it will be necessary to designate one of the arrays as the master and the other the slave rather than having the two instruments running asynchronously.

(5.3) Use of UT or sidereal time for array control and scheduling.

(5.4) Antenna/pad bookkeeping system and coordinate system.

(5.5) Error flags.

(5.6) Observing modes and schedule files. Observers using the Atacama Array should have to prepare only one schedule file.

(5.7) Correlator output data format.

(5.8) Data reduction computer system and software.

(5.9) Mass storage system.

6. High Site Infrastructure

(6.1) Shared power transmission line or power generation facility.

(6.2) Choice of supply voltage and frequency in the site buildings (possibilities: USA 110v/60Hz, Japan 100v/60Hz, Chile 220v/50Hz).

(6.3) Shared communication link to San Pedro.

(6.4) Shared antenna assembly facilities.

(6.5) Shared heavy equipment (e.g. cranes, cherry pickers, backhoes).

(6.6) Shared access road, road maintenance, snow removal.

(6.7) Which side of the road do vehicles drive on when using roads shared by both arrays (US is righthand side, Japan is lefthand side)? Since public highways in Chile are righthand drive, this is probably the correct choice for the site

(6.8) Shared emergency services (e.g. fire, medical etc).

(6.9) Shared water and sewerage systems.

(6.10) Shared fuel supply for vehicles.

7. Operations Support Base Infrastructure

(7.1) Shared Internet connection to outside world.

(7.2) Shared dormitory, cafeteria, recreation facilities.

(7.3) Shared specialty laboratory facilities (e.g. cryogenics, lasers) and machine shop.

(7.4) Shared specialty technical experts (e.g. cryogenics, SIS, high voltage electrician).

(7.5) Shared personnel transportation (e.g. shuttles to high site, Calama, Antofagasta).

(7.6) Shared antenna assembly facilities.

(7.7) Choice of supply voltage and frequency (same question as 6.2 above).

(7.8) Shared special purpose antenna transporter vehicle to carry assembled antennas up the access road from the OSB to the high site. This may be necessary if it turns out that it is not feasible to use the antenna reconfiguration transporter on the public highway for reasons of width or speed.

8. Conclusions

We have presented a list of compatibility issues which should be jointly studied by the MMA and

LMSA projects before either instrument settles on a final design. In the event that it is jointly decided that it is essential to maintain compatibility in any of these areas, the two projects will have to negotiate a compatible design which is acceptable to both instruments.

Acknowledgments

The list of compatibility issues presented here comes from suggestions by a number of people. In particular we acknowledge the work of the MMA Systems Working Group, led by Dick Thompson, and all of the attendees of the Technical Discussion held at the Atacama Array Workshop in Tokyo in March, 1997. We also acknowledge valuable discussions with R. Brown, F. Owen, M. Holdaway, N. Ukita and N. Satoh.

References

M.Ishiguro and R. Kawabe, Millimeter and Submillimeter Astronomy at 10 Milli-arcseconds Resolution, Abstracts of papers of a workshop held in Tokyo, 16-19 March, 1997, published by Nobeyama Radio Observatory.