Holography support in AIPS++
DRAFT V1.0

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Contents

1 Introduction

This note specifies the requirements for holography support in AIPS++ and provides a discussion of the priorities and implementation schedule for these capabilities.

In keeping with the overall philosophy of AIPS++, it is intended that generic core support for holography be provided using the standard imaging and calibration sub-systems, with instrument-specific additions only where necessary.

2 Holography support

This section enumerates the forms of holography which need to be supported in AIPS++. No software support is planned for non-holographic surface measuring techniques. Instrument-specific requirements for holography are described by Maddalena *et al.* (1991), Emerson (1998), and Masson (1991) for the Green-bank Telescope (GBT), Atacama Large Millimeter Array (ALMA) and the Sub-Millimeter Array (SMA) respectively.

2.1 Single-dish holography

This category encompasses traditional forms of holography employed for single antennas, which are not operating at the time as part of a larger interferometric array. These are divided into two sub-categories:

1. **Phase-sensitive techniques:** In this method, the antenna is scanned across the target source to sample the beam pattern on a grid in the standard manner. The complex pattern is obtained with reference to a auxiliary horn or small antenna, which is used in addition to the main holography receiver, thus providing full phase information (Mayer *et al.* 1983; Godwin *et al.* 1986).

   The technique is suitable if land-based or satellite beacons are used as the target source. Note that near-field corrections may be required when using land-based beacons.

2. **Phase-less techniques:** The complex antenna pattern can be derived from a measurement of the antenna power pattern alone at different axial focus settings, by utilizing phase-retrieval algorithms (Morris 1985). This technique imposes more stringent constraints on the calibration stability than phase-sensitive methods, and is commonly employed using land-based beacons.

2.2 Interferometric holography

In this context, interferometric holography covers techniques used for antennas operating as part of a larger array. The antenna is scanned across the target source to allow the measurement of the complex antenna pattern at a sampled grid of offset positions; a reference antenna in the array is pointed at the boresight position to provide a phase reference (Scott and Ryle 1977).

Astronomical sources of sufficient flux density (e.g. planets and astronomical masers) may be used as target sources in this approach, in addition to satellite beacons.

3 Data reduction requirements

This section considers data reduction capabilities required to support the identified holographic techniques. The techniques share many common elements; there is significant opportunity for common development of data reduction capabilities.

3.1 Data representation

The holography data can be accommodated in the AIPS++ MeasurementSet (MS) format. In the case of phase-sensitive single-dish holography, the reference signal is most easily represented as a separate antenna. Requirements for representing associated single-dish calibration information, and independent antenna-based pointing offsets, are already supported in the data format. Data fillers needs to be able to recognize the external data formats written by specialized, single-dish holography backend devices, and fill the MS appropriately.

3.2 Data display and examination

The standard display and listing utilities can be used to access the recorded holography data, by virtue of their representation in a standard MS format. Some specialized views may be required on top of the standard display utilities to view status information from holography backend devices.

3.3 Holography commissioning tools

Software support is required to assist in the commissioning of holography backend devices. For example, utilities may be required to monitor the calibration stability of the main and reference holography receivers in the case of phase-sensitive single-dish holography, or to allow diverse data manipulation or display in the on-line environment. The AIPS++ command-line interpreter, Glish, and the representation of the data in the standard MS format, already provide the infrastructure to allow these needs to be addressed.

3.4 Gridding and calibration

The sampled data, taken in on-the-fly (OTF) mode or at discrete pointings, need to be gridded in a regular, antenna-based coordinate system. The grid may not necessarily be of dimension 2^N. The data need to be corrected for instrumental drifts in amplitude and phase, possibly derived from periodic boresight measurements.

It is expected that, in the main, this calibration and gridding will proceed using standard OTF capabilities in the single-dish case or synthesis capabilities in the interferometric case.

In addition, the data may need to be corrected for the complex beam response of the reference feed if this is not flat over the sampled field. Phase corrections to the calibrated data are also required to set the antenna reference plane close to the plane of the antenna surface.

3.5 Fourier transform

A Fourier transform (FFT) of the gridded data is required, with optional tapering and padding. Masking may be required to exclude antenna blockage and diffraction effects; this is antenna-specific. A second-order wavefront correction is required for the aperture distribution for the near-field case (Zhang *et al.* 1995). The resultant aperture distribution will be represented as a standard AIPS++ image.

3.6 Offset corrections

Gross pointing and focus offsets are removed by fitting their respective signatures in the aperture phase distribution.

3.7 Surface error map

The calibrated aperture phase map allows a derivation of the surface error distribution. Their translation to panel adjustments is instrument-specific. Display capabilities will follow naturally from the representation of the error maps as AIPS++ images.

3.8 Phase retrieval algorithms

Specialized phase-retrieval algorithms are required for phase-less single-dish holography (Morris 1985; and others).

4 Planning and implementation

This section discusses the current status of holography development in AIPS++, priorities and future directions.

At present an holography application exists for the Westerbork telescope; it will be drawn from, as well as other existing software, to develop generic holography support. Such a capability is expected in the second AIPS++ release later this year. This will cover the core capabilities for phase-sensitive single-dish holography and for interferometric holography; phase-less algorithms will be considered later.

Initial holography commissioning tests are planned for April and July 1999 using the Greenbank 140 ft telescope in preparation for the GBT commissioning later in the year. These test will be supported by developing commissioning tools as required in Glish, and by translating existing UniPOPS capabilities to Glish. OTF single-dish capabilities will be utilized as they become available in this effort. Full support for single-dish holography will be assured before GBT commissioning, as this is a key requirement.

5 References

Emerson, D., and Perfetto, A., 1998, *MMA Project Book, Chapter 11.*

Godwin, M., Schoessow, E., and Grahl, B., 1986, *Astron. Astrophys.*, **167**, 390.

Maddalena, R.J., Norrod, R., and White, S., 1991, *GBT Memo. Series No. 68.*

Masson, C., 1991, *SMA Technical Memo. No. 50.*

Mayer, C., Davis, J., Peters, W., and Vogel, W., 1983, *IEEE Trans. Instrum. Meas.*, **IM-32**, 102.

Morris, D., 1985, *IEEE Trans. Antennas Propagat.*, **AP-33**, 749.

Scott, P. and Ryle, M., 1977, *MNRAS*, **178**, 539.

Zhang, X., 1996, *SMA Technical Memo. No. 86.*