Calibration Challenges for Low Frequency Radio Astronomy

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Abstract

A major challenge for all high resolution low frequency radio astronomy is measuring and removing the effects of the ionosphere. The isoplanatic patch size for frequencies below a few hundred MHz is generally much smaller than the field of view. In addition, aperture arrays have beams on the sky which vary dramatically with observing geometry. These beams require careful calibration to be stable and known in order to allow imaging. Various approaches to these problems will be discussed.

1. Introduction

High resolution interferometry at frequencies below a few hundred MHz encounters a number of difficulties in addition to those encountered at higher frequencies. The most serious of these are the direction dependent gain effects imposed by the ionosphere and the usage of aperture arrays to form beams on the sky.

2. Ionospheric Phase Correction

The phase delay introduced by the ionosphere is proportional to the inverse square of the observing frequency and can become very large at low frequencies. In addition, time variable inhomogeneities in the ionosphere cause large variations in the propagation delays in both time and space. The beams of interferometer elements operating at low frequencies are generally quite large, of order degrees, and can be significantly larger than the size of a coherent region on the sky, known as the isoplanatic patch size.

These large beam sizes always include numerous relatively bright sources which may be viewed through differing phase screens. In order to image any but the brightest sources, the phase screen across the array must be measured and corrections applied.

Two approaches to spatially variant ionospheric phase calibration are Field Based Calibration [1] and SPAM [2]. Field Based Calibration is applicable when the ionosphere over the array can be approximated by a bi-linear refractive wedge in a given direction in the beam. SPAM uses iterative peeling to obtain estimates of the phase screen over each interferometer element.

3. Beam shape Calibration

It is frequently cost effective to build low frequency interferometer elements from aperture arrays such as arrays of dipoles. Individual elements of the aperture array are phased together to form the beams of the interferometer elements. Since these arrays are generally fixed to the ground, the synthesized beams on the sky depend strongly on the observing geometry. Instrumental effects such as mutual coupling among the aperture array elements limit the accuracy to which the beam shape can be calculated. Accurate determination of the sky brightness distribution requires detailed knowledge of the beam shapes which must be calibrated using observations of celestial sources.

4. References

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