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Lab and In Situ Calibration Techniques for a Balanced Correlation Receiver

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Extended Abstract

Recent low-frequency radio astronomy experiments, especially those requiring absolute calibration, high-accuracy and high-precision measurements, have highlighted the need for non traditional calibration methods. Particularly affected are single dipole or single dish experiments operating at VHF frequencies (30-300 MHz) such as for global 21-cm cosmology or absolute calibrated sky mapping observations. A major challenge of these experiments is due to the large beam widths of low-frequency dipole feeds making astrophysical and blackbody calibrators used for calibrating the combined feed and receiver system impractical. Thus, current experiments typically rely on switching between a variety of internal loads for calibration that require further corrections to account for the match between the feed and receiver.

To address this challenge, we propose a more comprehensive radiometer calibration approach that incorporates physical circuit modeling, receiver state tracking, lab characterization of the feed and receiver, wideband noise sources and pilot tones. Using physical circuit models constrained by lab measurements taken over a range of physical instrument states (e.g. temperatures, voltages, and currents) we aim to compensate for the impedance mismatch and differences in signal path between the built-in noise sources and the antenna. These physical parameters are monitored during the operation of the receiver to estimate the instantaneous state of the instrument. Knowledge of the instrument state is then used to compensate the internal broadband noise sources and high-dynamic range tones that provide Y-Factor measurements to derive the receiver transducer gain and noise temperature. This combined approach is expected to provide a more rigorous and physically motivated absolute calibration compared to traditional methods used such as Dicke-switching or noise-injection. These methods are also motivated by the ongoing development for our new Balanced Correlation Receiver design used by the GBT 310 MHz Absolute Sky Mapping receiver (GBT310), the Cosmic Twilight Polarimeter (CTP) , and the Dark Ages Polarimeter PathfindER (DAPPER) mission concept.