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Online control of the SPOTLIGHT and integration with the GMRT system

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Abstract

SPOTLIGHT is a real-time multi-beam system to search for Fast Radio Bursts (FRBs) and pulsars in the observing field-of-view of the GMRT in 24 x 7 mode and runs in piggy-back mode with GMRT Wide-band Back-end (GWB). It is a GPU-based compute cluster that generates visibility and post-correlation beam-formed data by fetching digitized samples from the GWB. An HPC (High Performance Computing) and AI (Artificial Intelligence) powered pipeline is used for real-time FRB search. GMRT has a dedicated central control and monitor system that sends appropriate instructions to the GWB to compute and record real-time visibility for imaging of field and beam-formed data for time domain astronomy. We describe an online control and monitor system for the SPOTLIGHT that runs in shadow mode or in parallel with GWB.

1. Introduction

Fast radio bursts (FRBs) are very powerful, millisecond-duration, sporadic, high-energy bursts across the sky, making their detection and follow-up study observationally challenging. The large field of view (FoV) instruments are ideal for survey, however, they do not have sufficient spatial resolution resulting in poor localisation of the detection event. While many of the properties of FRBs can be studied in high-resolution time-domain data, to associate FRBs with their host galaxy and study their properties, the precise localisation of FRBs in the sky is of immense importance. GMRT, being an interferometer, is an ideal telescope that simultaneously offers time-domain and imaging observations. It is in operation in 24x7 mode, carrying targeted observations all across the sky and, hence, offering the opportunity for FRB searches in the observing field with an arc-second localisation accuracy. SPOTLIGHT is a commensal project designed for the real-time search of FRBs and pulsars in the observing field, covering by 2000 phased array beams [1]. It is a GPU-based computing cluster that receives copies of base-band sampled voltages from the GMRT Wide-band Back-end (GWB, [2]) and processes them to produce visibility for imaging and post-correlation beam-formed data for time-domain search [3]. It carries real-time search in time-domain data for FRBs [4] across the field of view in distinctly separated 2000 beams covering the target field that GMRT is observing. Since the GMRT's default back-end, the GWB, is already running for regular GTAC observations, it is crucial to run the SPOTLIGHT correlator in parallel. This involves sharing or operating in shadow mode with the main GMRT control alongside the GWB, without compromising any functionality of the GMRT, thereby supporting commensal operation.

2. Control and monitor system

We have developed a fully automatic operation to control and monitor the SPOTLIGHT in parallel to the existing GWB operation. The Tango-based GMRT Control (TGC, [8]) is the primary control and monitoring system central to all GMRT operations. It supplies metadata information (e.g. frequency of observation, source coordinates, antenna configuration, etc.) for real-time processing of astronomical signals in the GWB. A copy of the metadata is available in shared memory on the master control node of the GWB, which is updated whenever there are operational changes (e.g., source change, observation frequency change, etc.) from the TGC via a chain of software. The SPOTLIGHT control node accesses this information from the GWB master node via socket and takes corresponding actions for the SPOTLIGHT correlator. This includes starting and following all stages of operations in close succession, approximately 10 seconds after the GWB. The SPOTLIGHT operates in phased array mode; hence, it is very central to the operation of the SPOTLIGHT correlator to carry periodic phasing of an array every time the array is observing the phase calibrator. The robust calibration required for real-time imaging for FRB localisation [5] is taken care of by this phasing. Source and calibration code information (e.g., band-pass, phase calibrator, etc.) entered by TGC is transferred along with the metadata from TGC to SPOTLIGHT via the GWB master node. Upon receiving the source calibration code, the SPOTLIGHT controller performs the phasing of the array on a phase calibrator scan. The metadata information (phase center coordinates, frequency, array configuration, etc.) and the list of bad antennas identified by phasing (as shown in Fig. 1) are then sent through the SPOTLIGHT correlator [3] and parsed into a simulation package [6], which synthesizes the 2000 steered directions (RA and Dec) for FRB search. Phased array beams are very sensitive to available antennas which are dynamically updated to multi-beam synthesis [6] on every phasing scan ensuring optimal beam tiling. During the testing phase, when GMRT observations are not running, we have implemented an alternate mode of SPOTLIGHT control. In this mode, metadata information can be sent directly from TGC to SPOTLIGHT, bypassing the GWB.

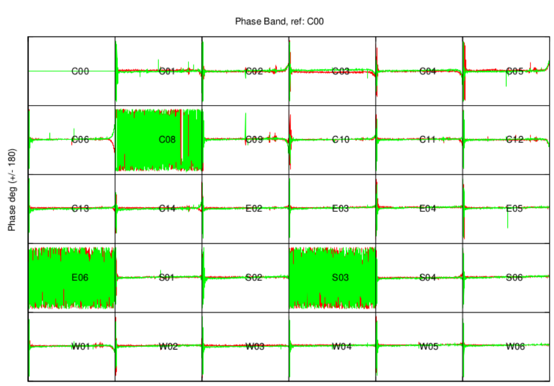

Fig 1. Phases for all baselines after phasing operation.

Along with the high-time resolution visibility and time-domain data, intermediate-resolution (~ second) visibility data is produced by SPOTLIGHT correlator [3] for real-time monitoring of visibility fringes, auto-correlation spectrums etc. For real-time monitoring of visibility and phasing quality checks, we have developed a set of software that shows self- and cross-power spectrum and cross baseline phases. We developed software to fetch real-time self and cross-visibilities (see e.g. Fig. 1 for cross baseline phases) from shared memory on the control master node of SPOTLIGHT that generates visibility (cross-phase, self-amplitude etc.) data for web-based monitor tools [7]. This ensures the proper integration of the SPOTLIGHT system into the observatory's control and monitoring system, aiming to enable fully automated commensal observations.

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