

Galactic plane observations with uGMRT

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1 Introduction

Galactic plane observations with a radio telescope at low radio frequencies poses a special challenge. This is due to high brightness temperature of the Galactic plane which varies significantly depending on the Galactic longitude and latitude being observed. High brightness temperature of extended emission causes corresponding rise in system temperature and it could be ~ 10 higher than observing the typical sky $>10^\circ$ away from the Galactic plane. Therefore, suitable arrangements are necessary to prevent any non-linearity in the telescope observing chain.

For a radio telescope to work in the linear range of operation, the output power must lie within certain range. Quite often, an automatic level control (ALC) is employed to provide negative feedback to the amplifier gains when output power increases. However, the new analogue backend system of the uGMRT has no ALC (this is done to have higher dynamic range). Therefore, when observations are done in parts of the sky where the sky temperature is a significant fraction of the total system temperature (T_{sys}), variation of sky temperatures cause a source position dependent change in total power. This not only causes a calibration problem and correlation efficiency of the digital correlator, but as mentioned above, push certain system parameter beyond the linear regime of operation. Therefore, it is important that users get proper control on the total output power from the antennas.

In interferometry, the amplitude of unnormalised cross correlation measured by the correlator is related to visibility amplitude through a scaling factor called ‘**gain**’. In general, the gain is a function of antenna (could vary with temperature) and is independent of system temperature (T_{sys}). Therefore, if the gains do not change during observations, the flux densities of sources can be established with observations of a single flux density calibrator along with phase calibrator and target sources. The above is often used at GMRT for interferometric observations. However, as mentioned above, it encounters serious problem for observations near the Galactic plane at lower frequency bands (below 600 MHz), where the source is on the Galactic plane, but calibrators away from the Galactic plane.

In the past, this problem has been ‘partially’ addressed by keeping the ALC off which keeps the gain unchanged, and adjust the system gain at the start of the observations such that the source with maximum sky temperature produce the highest tolerable total power (Roy 2006). However, this causes the input operating point of the correlator to change as source changes and this changes the correlation efficiency of the correlator resulting in amplitude calibration error that could be $\sim 10\%$ for a reduction in total power by ~ 5 from its standard operating point. However, the flux density scale at low radio frequencies is now believed to be accurate to $\sim 2\%$ (e.g., consistency of primary calibrator flux densities among Scaife & Heald (2012) vs. Perley & Butler (2017) vs. Baars et al. 1977). One would like to have the same accuracy in uGMRT flux density measurements, which would drastically reduce the error in spectral indices of sources measured from flux densities obtained from different frequency bands. In this report, I describe an approach that could achieve the above by suitably changing the attenuations of the high dynamic range attenuators connected to the broadband radio frequency (RF) signal chain while one observes different parts of the sky.

2 Procedure to keep input power to correlator constant during observations

The upgraded electronic system of the uGMRT features a variable attenuator (HMC472LP4) which supports 0–31.5 dB variable attenuation in steps of 0.5 dB (accuracy 0.25 dB \pm 1.5%) in the RF chain of the antennas (see 'http://www.gmrt.ncra.tifr.res.in/gmrt_hpage/Upgrade/GAB_blockdiag.pdf'). To keep the input power to correlator constant, one changes the attenuation values of the above following the procedures below. The variable attenuators have been tested quite extensively in the Lab and their gains do remain within \sim 10% to what is expected from the Gains being set in the lower frequency bands (below 500 MHz). As the error in gains for the antennas are random, the overall error from changes made in attenuation values would therefore be $(10/\sqrt{N})\%$, where N is the no. of antennas. Therefore, absolute gain error of the system could go down to \sim 2% by using the attenuation values of the variable attenuators.

The following procedure uses the legacy Online system to control the total power of the antennas. While observing a source for the first time in an observing run, a script (`power_eq.new.run`) [uses '`power_eq`' program by Raskar et al. 2014] is to be executed from the user's Command file in the Online computer with the Source name, Start channel (default value 300), End channel (default value 1700) and Power level (default value 150) as its arguments. Using the existing attenuation, the script uses the median value of total power as observed at time '`t`' within the beginning and end channels and computes the attenuation required so that the output power equals the given Power level. The estimated new attenuations are then set using another command [`stgblev('src_name')`] from the user's command file. When the same source is observed afterwards, only loading the right attenuation table for the source is done [`stgblev('src_name')`]. The procedure to load the attenuation is typically repeated once more from the User's Command file to ensure the command gets executed by the corresponding antenna. A schematic block diagram of the procedure is shown below (Fig. 1).

In the above case, the attenuation will increase when T_{sky} increases and vice-versa in a way such that the output power will remain the same despite change in T_{sky} . The attenuation values are recorded for all the antennas for each source. The attenuation files for sources are stored in '`/home/gpuuser/GWB/PowerEq/`' area in the GWB computer (`gwbh6`). The naming convention of the files are '`gab_attn.src_name`' (where '`src_name`' indicates the sources for which the script was run). After the observing run, the operator needs to copy the files produced during the observing run and mail to the user. User can find the attenuation differences between calibrator and target source for the antennas by using a shell script '`attenuation.difference.gwb`'. This allows one to correct the data during analysis for different antenna based gains for different sources by modifying the antenna gains for each sources (e.g., by using AIPS Task SNCOR).

The above procedure for observations towards the Galactic plane at frequencies <1 GHz could be incorporated into the Command file generated by the Astronomers either by themselves or by the On duty Operator on request well before the observation.

One could also plot median value of total power from the antennas (running a script '`plot.total.power`', which needs Nilesh's '`gwbmp`' programme also to run in '`gwbh6`') as a function of time continuously during observation and can detect significant change in total power due to unexpected change in gain or T_{sys} of an antenna immediately during observations.

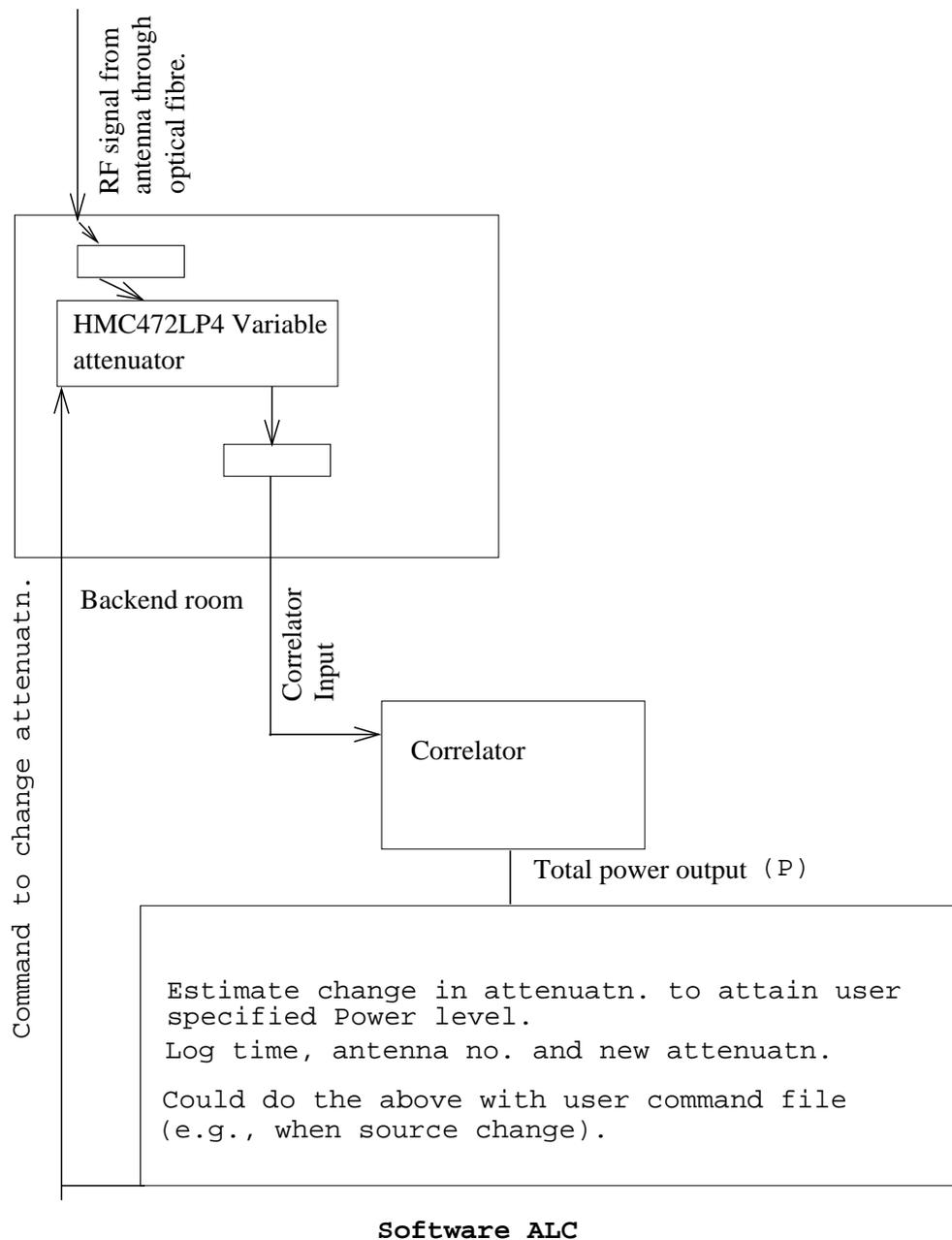


Figure 1. Flowchart of an user controlled ALC to keep the input power to the correlator constant during observations with sources seen through high sky temperature.

3 References:

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