Tests for any RFI from the uGMRT Master Control Monitoring system in Band-5 & 3

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1 Introduction

Master Control Monitors (MCMs) are integral part of uGMRT, and is installed to monitor various subsystems. For example, MCMs are installed in Feed positioning system, Front-end, Common Box, Servo, Backend, optical fibre system. These could be used to check if the measured parameters deviate from what is expected at the monitoring points. These could also be used to warn or throw away data affected by system malfunction during astronomical observations. However, these monitoring systems employ various electronic systems, that could generate their own Radio Frequency Interferences (RFIs), which could be picked up by the feeds of nearby antennas and add to the astronomical signals. Here, I describe the results from tests which were carried out in Band-5 and 3 using astronomical observations to detect any extra RFI emitted when MCMs were switched on (as compared to when they were off). I also checked for any significant increase in visibility noise in the data (could occur when out of band RFIs are present) when they were turned on.

2 Observations and data analysis:

Band-5 observation was carried out on 08th November 2022 with a total of 400 MHz bandwidth with default setup. As RFI is local, to avoid time dependent phase change (meant to counteract Earth rotation while observing sources in the sky) by the correlator, North pole was selected as the source. 2202+422 (has quite a flat spectrum and used for bandpass calibration) and 2344+824 were used as secondary calibrators. We observed these sources first with MCM on with about 5 minutes on the calibrators, and 25 minutes on North-pole, and then with MCM off (similar duration of observations towards the sources as before, except that 2202+422 was not observed with MCM off). During data analysis in Aips, dead antennas were edited out. Spectrum visibility amplitudes of all the baselines were plotted in gray scale with time along y-axis. The gray scale plots of all the baselines were visually checked to identify any new line that is absent in a scan with MCMs off, but detectable when MCMs are on.
Time based calibration done using 2202+422 and 2344+824 (their flux values from VLA calibrator manual were inserted with Setjy). After calibration, RFI flagging done using FLGIT. Data between 1450 and 1280 MHz were mostly free from RFI. However, data for RF <1280 MHz were significantly affected. After calibration and flagging, 51 channels were averaged together, yielding 35 frequency channels with a total bandwidth of 348.6 MHz. Among these channels, 3 to 14 channels were averaged while plotting rms. I checked for any enhanced rms for several baselines after channel collapse. This was checked separately for MCM on and off.

Band-3 observation was carried out on 05th May 2023 with a total of 200 MHz bandwidth with default setup. As RFI is local, to avoid time dependent phase change (meant to counteract Earth rotation while observing sources in the sky) by the correlator, North pole was selected as the source. 3C147 was used for bandpass calibration, and 0229+777 was used as secondary calibrator. During data analysis in Aips, dead antennas were edited out. Visibility spectrum of all the baselines were plotted in Gray scale with time along y-axis. The gray scale plots of all the baselines were visually checked to identify any new line that is absent in a scan with MCMs off, but detectable when MCMs are on. Before starting the observations, system gains were adjusted (power equalisation) such that total power on 3C147 remains close to $\sim$150 counts for all the antennas.
Absolute flux density and bandpass calibration were done using 3C147, and 0229+777 was used as a secondary calibrator. After calibration, RFI flagging was done using FLGIT. Data between 394 and 454 MHz were mostly free from strong RFI lines. We averaged over the above part of the band to plot the visibility amplitudes for several baselines as a function of time. This allows to visually check for any systematic difference of rms for the 2 scans plotted. I also checked for any enhanced rms among the various baselines after channel collapse. This was checked separately for MCM on and off.

3 Results & Discussions:

3.1 Band-5

3.1.1 Spectra of cross-correlations for different baselines

Figs. 1 to 3 show the cross-correlation spectra (1848/2048 channels) for baselines C02-C04, C02-C06 and E02-E04 for Stokes 'RR' polarisation towards North Pole. No calibration has been applied. The x-axis shows the band from 1080 to 1440 MHz. The y-axis shows time. The 1-st scan (bottom) is with MCM on, and the next is with MCM off. As can be seen, there are a very large no. of RFI lines across the band. However, no lines could be seen with MCM on only. I also checked for all the other baselines, and the same was repeated for Stokes ‘LL’.

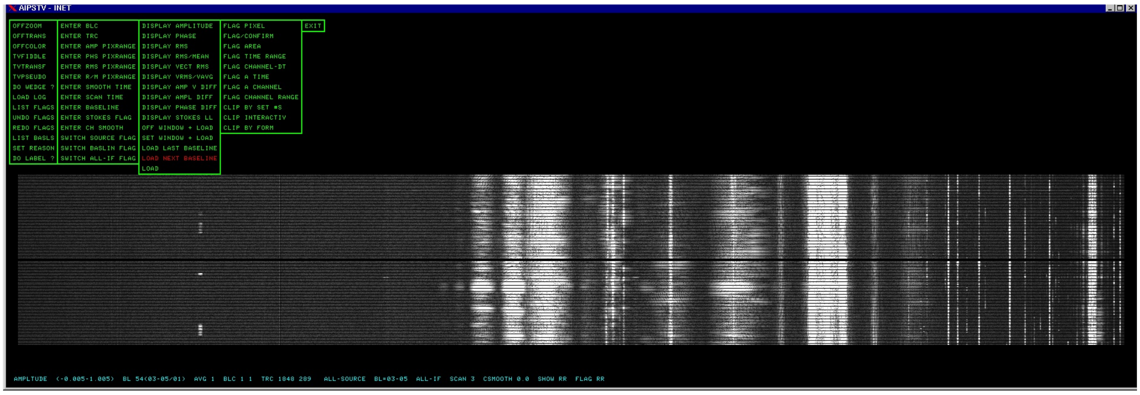

Figure 1. Cross-correlation spectra (with time) for C02-C04 baseline (RR) with MCM on (bottom scan), and MCM off (top scan).

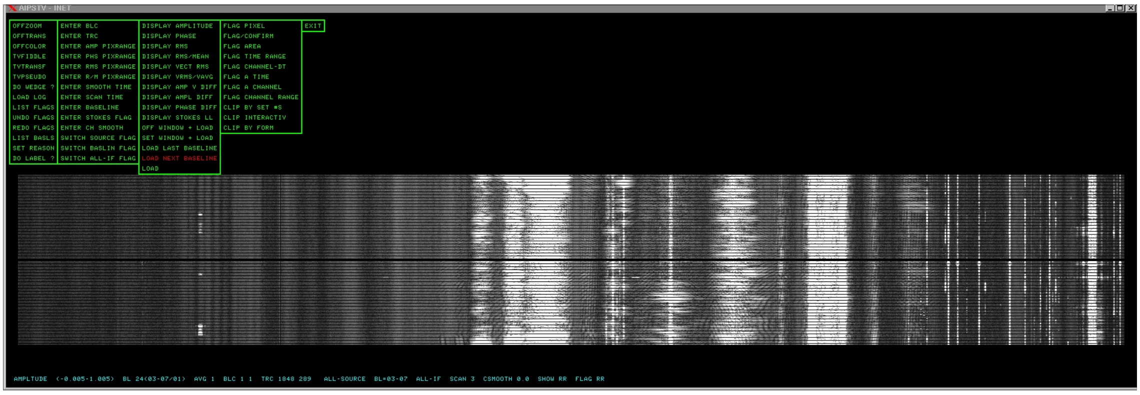

Figure 2. Cross-correlation spectra (with time) for C02-C06 baseline (RR) with MCM on (bottom scan), and MCM off (top scan).

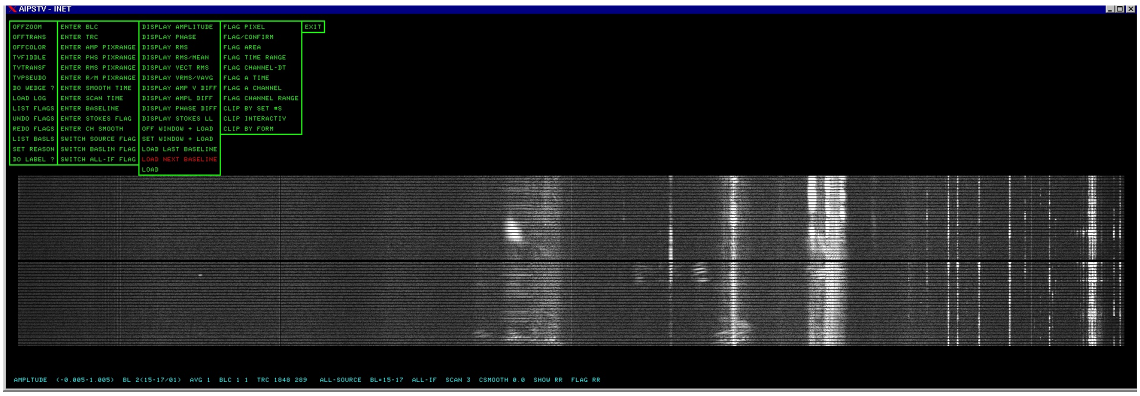

Figure 3. Cross-correlation spectra (with time) for E02-E04 baseline (RR) with MCM on (bottom scan), and MCM off (top scan).

3.1.2 Rms noise after calibration and channel-averaging

Plots for the visibility amplitudes for some the baselines (frequency averaged between 1293 and 1413 MHz) as a function of time are shown below in Figs. 4 to 6.

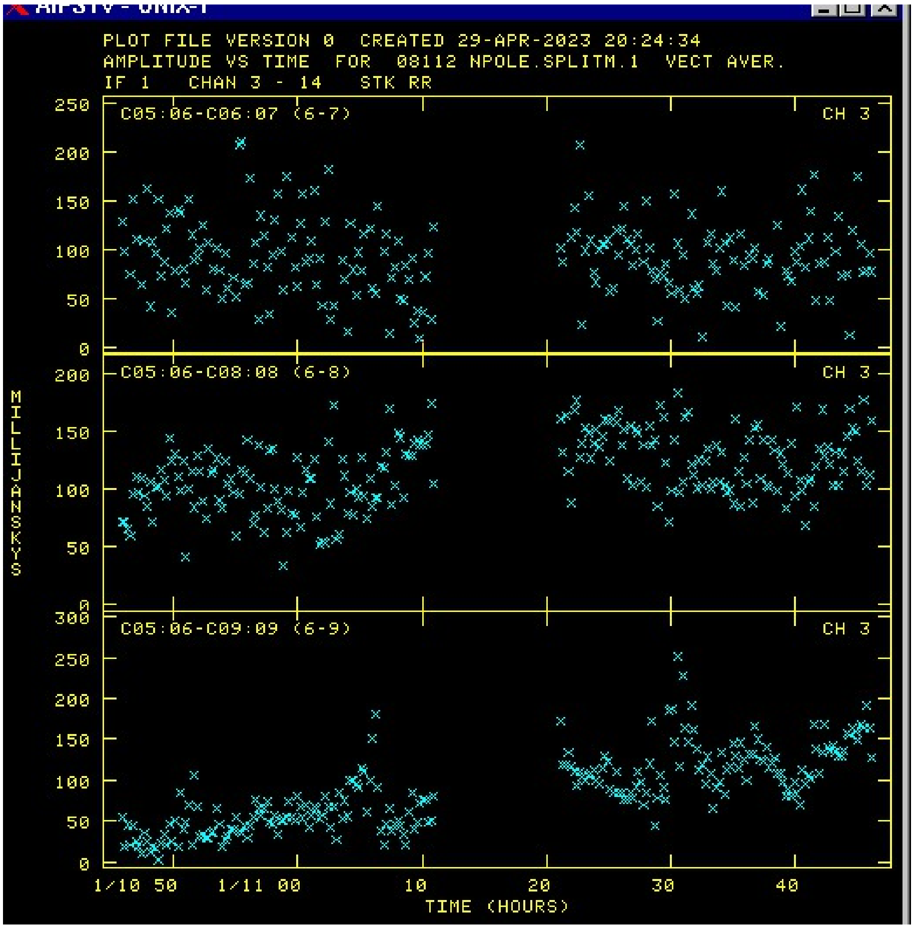

Figure 4. Visibility amplitude as a function of time after collapsing across 120 MHz of edited and calibrated data having C05 antenna. MCM on in 1st-scan and off in the next.

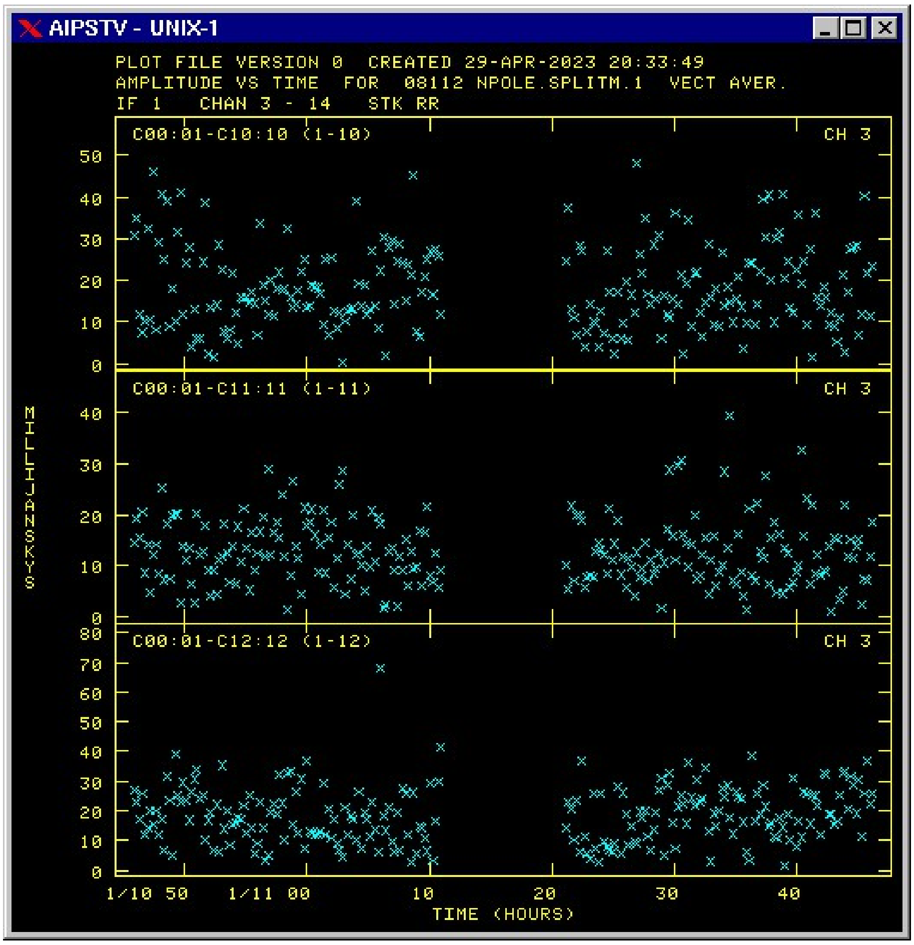

Figure 5. Visibility amplitude as a function of time after collapsing across 120 MHz of edited and calibrated data with a few baselines having C00 antenna. MCM on in 1st-scan and off in the next.

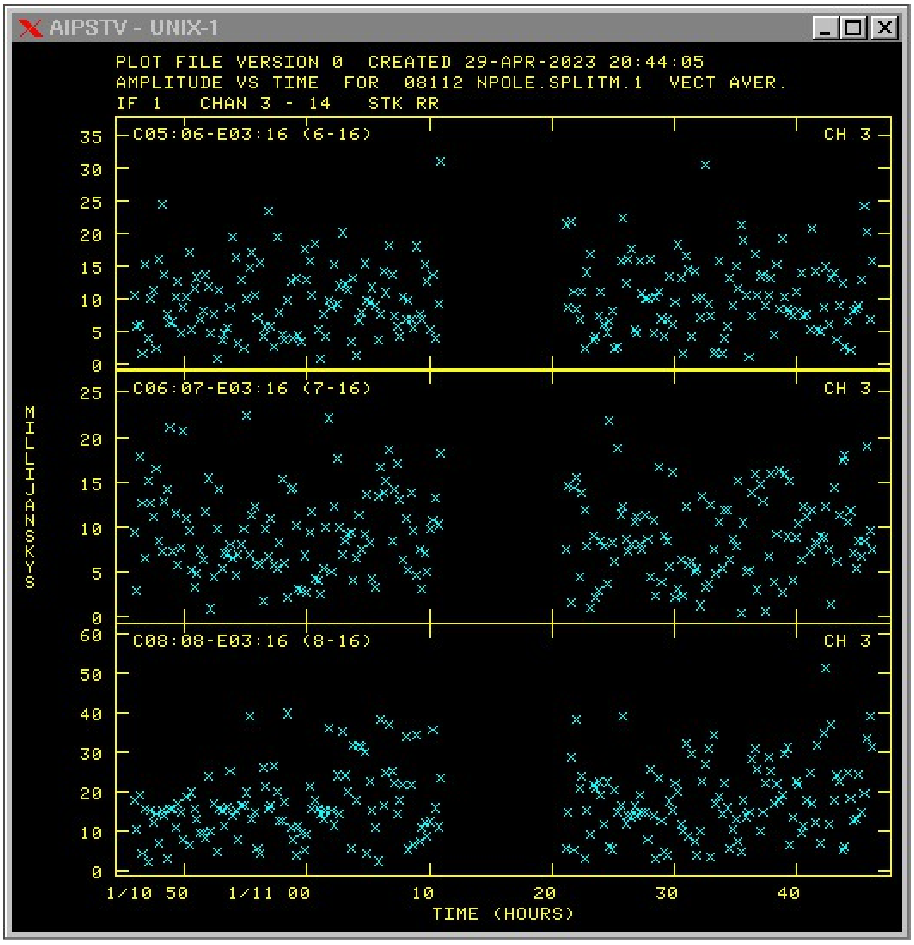

Figure 6. Visibility amplitude as a function of time after collapsing across 120 MHz of edited and calibrated data with a few baselines having E03 antenna. MCM on in 1st-scan and off in the next.

As can be seen from above, the rms noise for all the above baselines after channel-averaging across 120 MHz shows about the same noise (visually) with MCM on (1st scan), and MCM off.

Rms of mean from the average of about 25 data points with MCM on for the baseline C05-C06 is 0.0027 Jy, and with MCM off, rms is 0.0025 Jy. Both of which are close to each other. The same is true for the baselines C00-C11 or C06-E03 (rms noise 6.8×10^{-4} with MCM on, and 6.7×10^{-4} with MCM off).

3.2 Band-3

3.2.1 Spectra of cross-correlations for different baselines

Figs. 7 to 11 show the cross-correlation spectra (977/1024 channels) for baselines C00-C02, C00-C13 for Stokes 'RR' polarisation, and E02-E03 and C05-C06 for Stokes 'LL' polarisation towards North Pole. No calibration has been applied. The x-axis shows the band from 305 to 495 MHz. The y-axis shows time. The 1-st scan (bottom) is with MCM off, and the next with MCM on. As can be seen, there are a very large no. of RFI lines across the band. However, no lines could be seen with MCM on only. I also checked for all the other baselines, and the same was concluded.

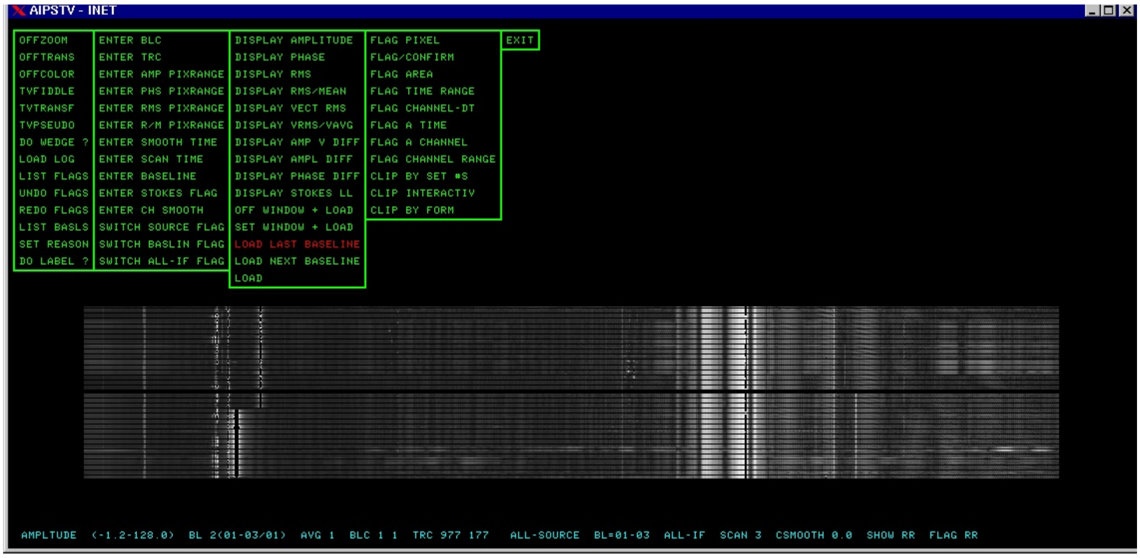

Figure 7. Cross-correlation spectra (with time) for C0-C02 baseline (RR) with MCM off (bottom scan), and MCM on (top scan).

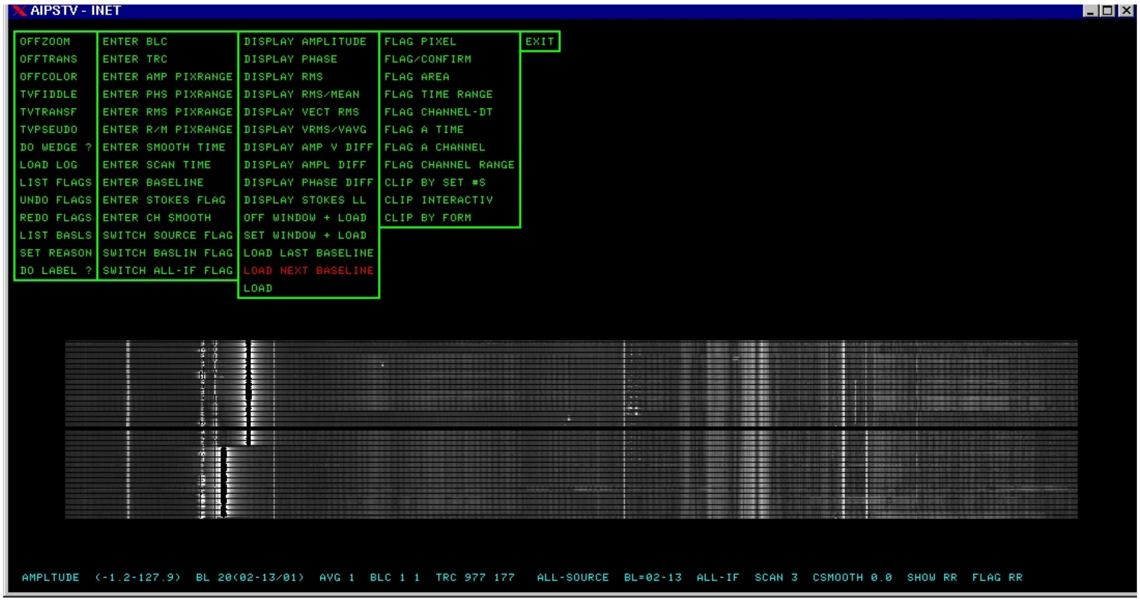

Figure 8. Cross-correlation spectra (with time) for C0-C13 baseline (RR) with MCM off (bottom scan), and MCM on (top scan).

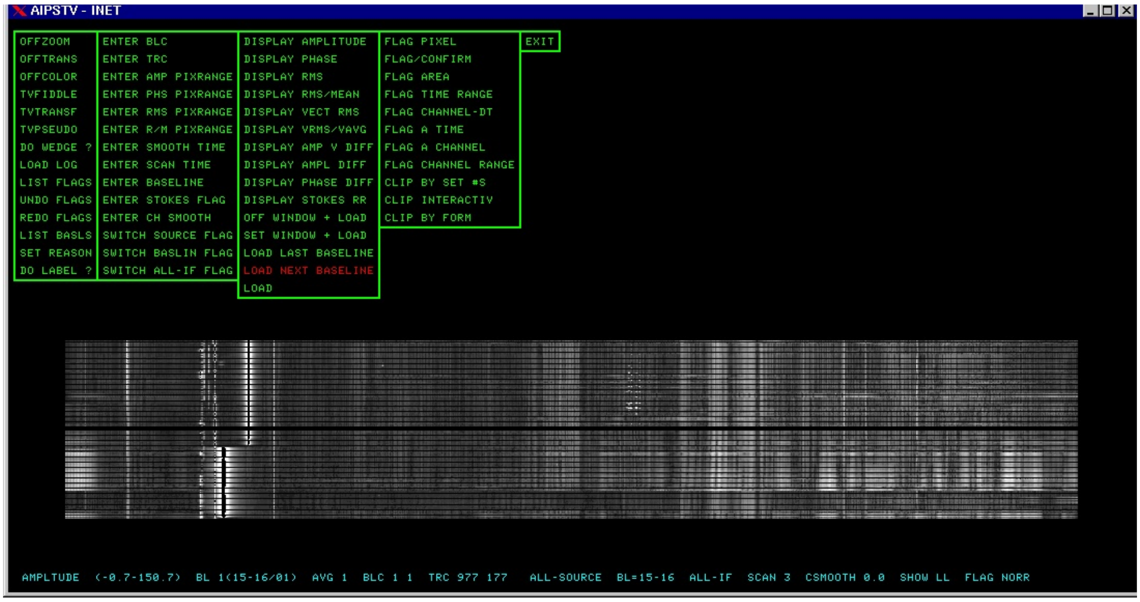

Figure 9. Cross-correlation spectra (with time) for E02-E03 baseline (LL) with MCM off (bottom scan), and MCM on (top scan).

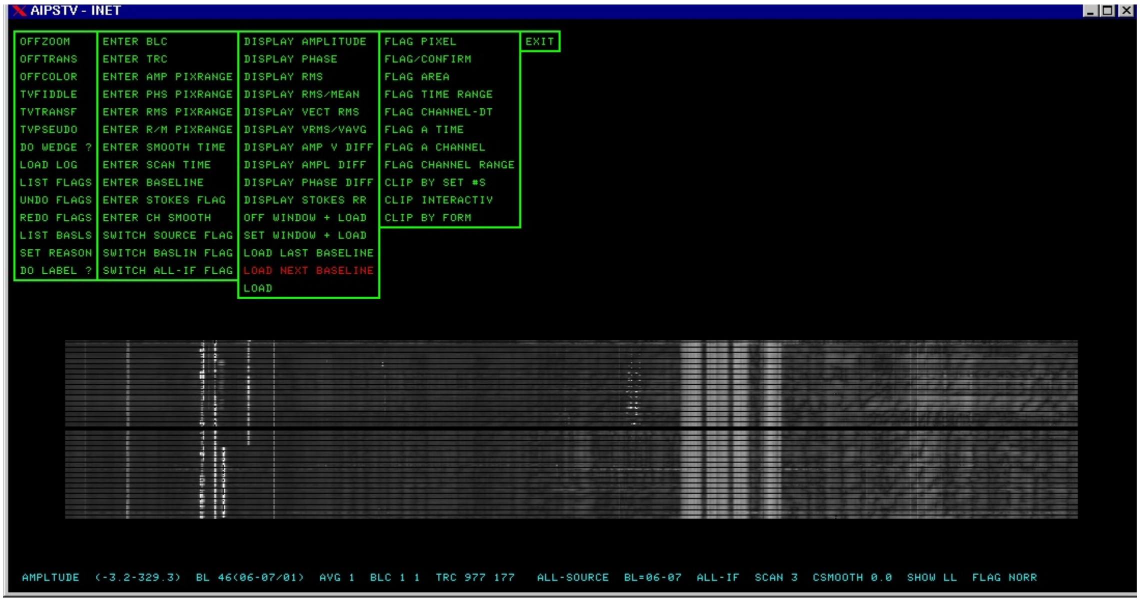

Figure 10. Cross-correlation spectra (with time) for C05-C06 baseline (LL) with MCM off (bottom scan), and MCM on (top scan).

3.2.2 Rms noise after calibration and channel-averaging

Plots for the visibilities amplitudes for some of the baselines (frequency averaged between 394 & 454 MHz) as a function of time are shown below in Figs. 11 & 12.

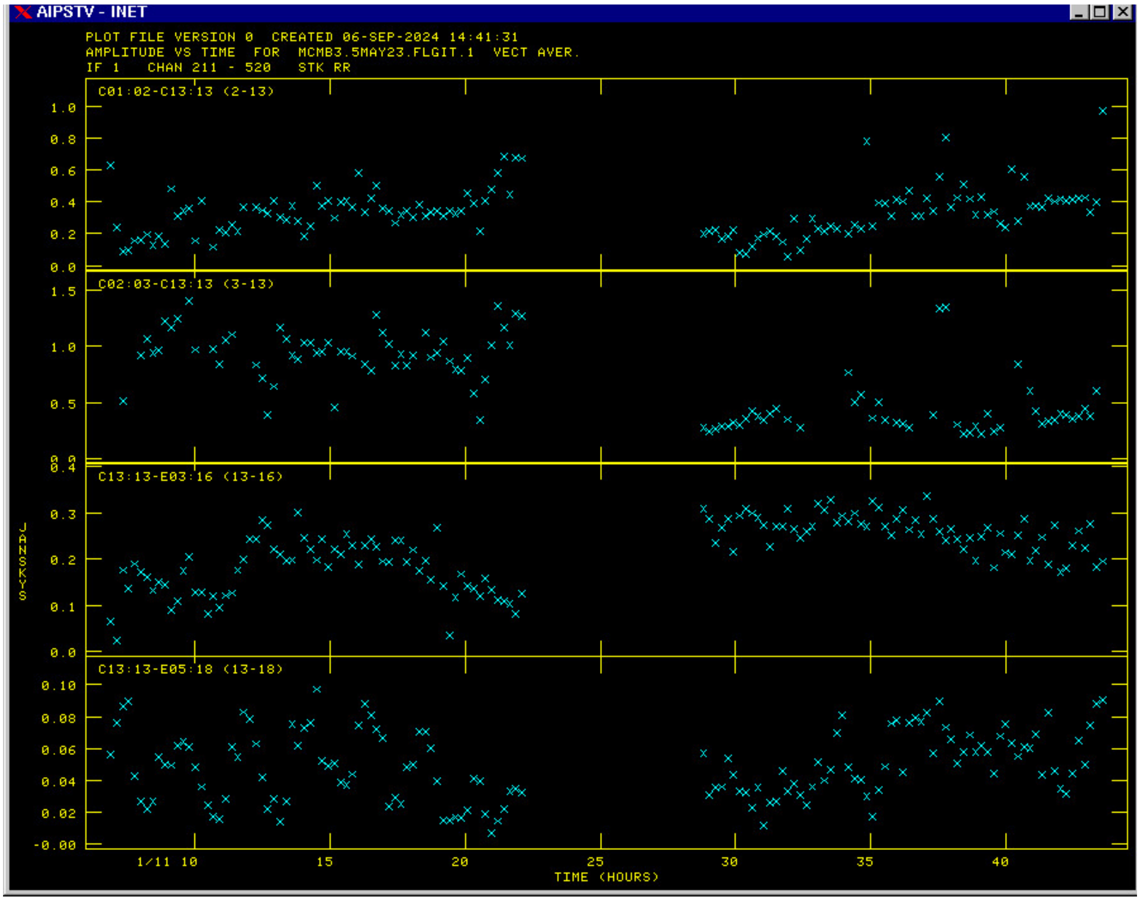

Figure 11. Visibility amplitude as a function of time after collapsing across 60 MHz (394-454 MHz) of edited and calibrated data with a few baselines having C13 antenna. MCM off in 1st-scan and on in the next

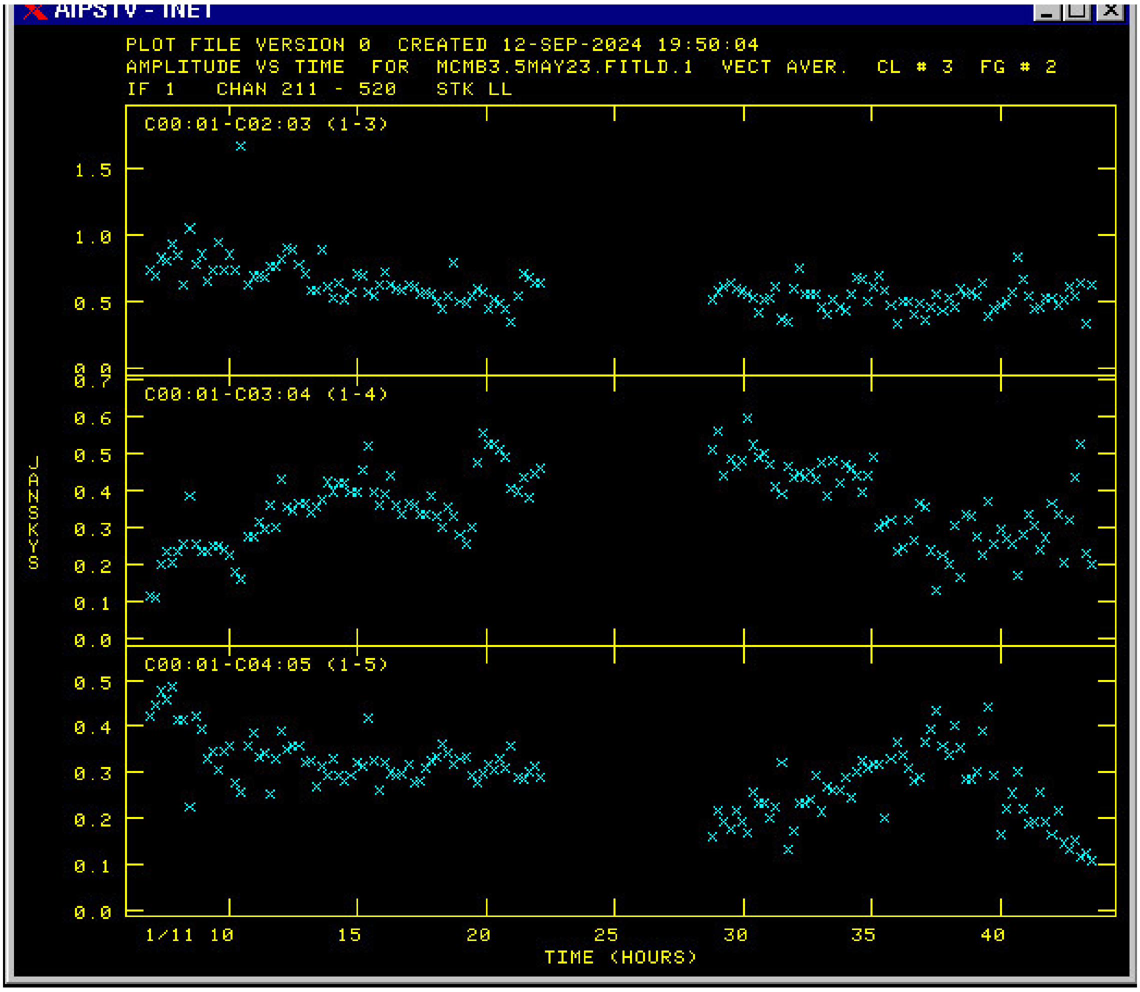

Figure 12. Visibility amplitude as a function of time after collapsing across 60 MHz (394-454 MHz) of edited and calibrated data with a few baselines having C01 antenna. MCM off in 1st-scan and on in the next.

I also checked that the **rms** of mean from ∼16 data points for the baseline C13-E05 (Fig. 11 shows visibility amplitudes without time averaging) is 0.012 Jy with MCM off, and 0.0070 Jy with MCM on.
The same was repeated for the following baselines below.
For C13-E03, rms 0.0052 Jy with MCM off and 0.0037 Jy with MCM on.
For C13-C01, rms 0.027 Jy with MCM off and 0.031 Jy with MCM on.
For C00-C02 (Fig. 12), rms is 0.03 Jy with MCM off and 0.025 Jy with MCM on.
For C00-C03, rms 0.017 Jy with MCM off and 0.019 Jy with MCM on.
For C00-C04, rms 0.011 Jy with MCM off and 0.014 Jy with MCM on.

The above rms noises for the 5 different baselines are comparable, and do not show a systematic increase when MCMs are on.

4 Conclusions

Data acquired with MCM on and off in interferometry mode using Band-5 and 3 were carried out. No new lines could be identified when MCM was on. Also, rms noise in baseline based visibilities after calibration and frequency channel averaging were found to be comparable when MCMs were on vs off. Therefore, MCMs do not appear to generate significant RFIs at GMRT for the bands-5 and 3.