Frequency-switched bandpass calibration at the GMRT

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We have carried out Galactic H I 21cm absorption studies of three bright, compact background sources to test the spectral dynamic range that can be achieved with frequency-switched bandpass calibration at the GMRT. Two approaches were used, each on two sources, switching at the first and fourth LOs, by 5 MHz and 1 MHz respectively. The switching was carried out every five minutes, alternately shifting the band above and below the central observing frequency by the above offsets. We find that switching at the fourth LO yields a complex spectral baseline, with large-scale ripples. While the "local" RMS noise on these spectra gives a high spectral dynamic range ($\gtrsim 1000$) for isolated narrow absorption features, the ripples in the baseline imply a relatively low dynamic range ($\lesssim 300$) for the detection of wide absorption. On the other hand, the spectral baseline obtained by switching at the first LO is quite flat, with RMS values and peak-to-peak spreads consistent with a normal distribution. The resulting spectral dynamic range is $\gtrsim 1000$ for narrow features and $\sim 1000 \times N^{1/2}$ for features that are N channels wide (where N is significantly smaller than the total number of channels). We conclude that GMRT observations that require frequency-switched bandpass calibration should implement this switching at the first LO, to ensure spectral baselines of the highest quality.

The present observations only tested the spectral dynamic range achievable with frequency-switching at a bandwidth of 1 MHz; it would be interesting to test whether the high spectral dynamic range persists for other (especially larger) bandwidths. The amount of time required to switch frequencies at the first LO can be decreased significantly from the ~ 40 seconds of these observations by the use of a new MCM mode (iMCM) which does not wait for feedback about command monitoring; this should allow switching over a time-scale of a few seconds. Finally, each of the present observations was limited by its relatively short span (~ 1 hour of on-frequency time in most cases) as well as problems with antennas and the correlator during the observations, resulting in typically half the baselines being unusable. This limited the dynamic range to $\sim 1000 - 1400$, at the observing resolution. Further, the observed RMS noise was found to be a factor of ~ 2.5 higher than the theoretically-expected value. It would be interesting to carry out a full-synthesis observation of a bright source like 3C48 or 3C286, with switching at the first LO, to test whether the dynamic range continues to improve as expected or whether any systematic effects are observed that might be limiting factors in frequency-switched spectral line observations with the GMRT.

We note, finally, that test observations of the calibrator 0318+164, in GMRT project 11NRb01, obtained a spectral dynamic range of ~ 1400 per ~ 0.4 km/s channel in a seven-hour integration, with switching at the first LO; this is quite close to the theoretical value. While this suggests both that the spectral dynamic range continues to improve as expected for long integrations and that the fudge factor is close to unity for such integrations, further deep observations should be carried out to confirm this result.

Table 1: Summary of the observations and results

Frequency-switching at	First LO		Fourth LO	
Sources	3C286	3C48	3C286	3C295[c]
Frequency increment[a] (MHz)	± 5	± 5	± 1	± 1
Bandwidth (MHz)	1	1	1	1
Spectral resolution (km/s)	0.8	0.8	0.8	0.8
On-frequency time (Hours)	$\sim$1	$\sim$1	$\sim$1	$\sim$2
Number of baselines[b]	467	420	437	120
Continuum flux density (Jy)	15.1	16.0	15.5	23.4
Brightness temperature T_b	3 K	10 K	3 K	2 K
Theoretical RMS (mJy)	$\sim$ 4.6	$\sim$ 5.3	$\sim$ 4.8	$\sim$ 6.5
Single-channel RMS[c] (mJy)	14.8	13.8	13.1	16.7
Dynamic range[d], SDR	$\sim$ 1020	$\sim$ 1160	$\sim$ 1190	$\sim$ 1400
Dynamic range[e], $SDR_{wide}(N)$	$\sim 1020 * N^{1/2}$	$1160 * N^{1/2}$	$\sim$ 270	$\sim$ 240

[a] Alternately above and below the central frequency, every five minutes

[b] Total number of baselines used in the final spectrum, summing the two polarizations. In the case of 3C295, only baselines out to 15 kλ were used.

[c] For switching at the first LO (columns $1-2$), this is the RMS noise across the entire line-free band, excluding edge channels. For switching at the fourth LO (columns $3-4$), this is the "local" RMS noise, from a small, "flat" part of the band.

[d] The spectral dynamic range for the detectability of narrow features, the ratio of continuum flux density to single-channel RMS.

[e] The spectral dynamic range for the detectability of N-channel-wide features.

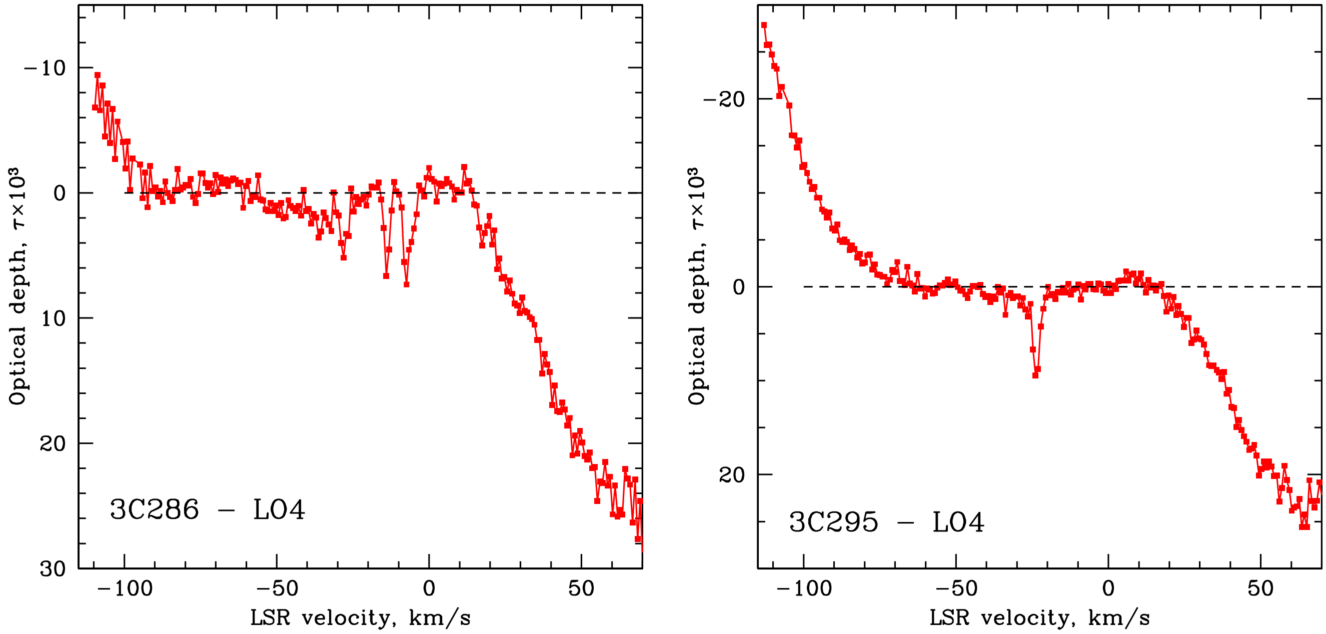

Figure 1: Final GMRT H I 21cm Stokes I spectra towards [A] 3C286 (left panel) and [B] 3C295 (right panel), with switching at the fourth LO; in both cases, optical depth, $10^3 \times \tau$, is plotted against LSR velocity, in km/s.

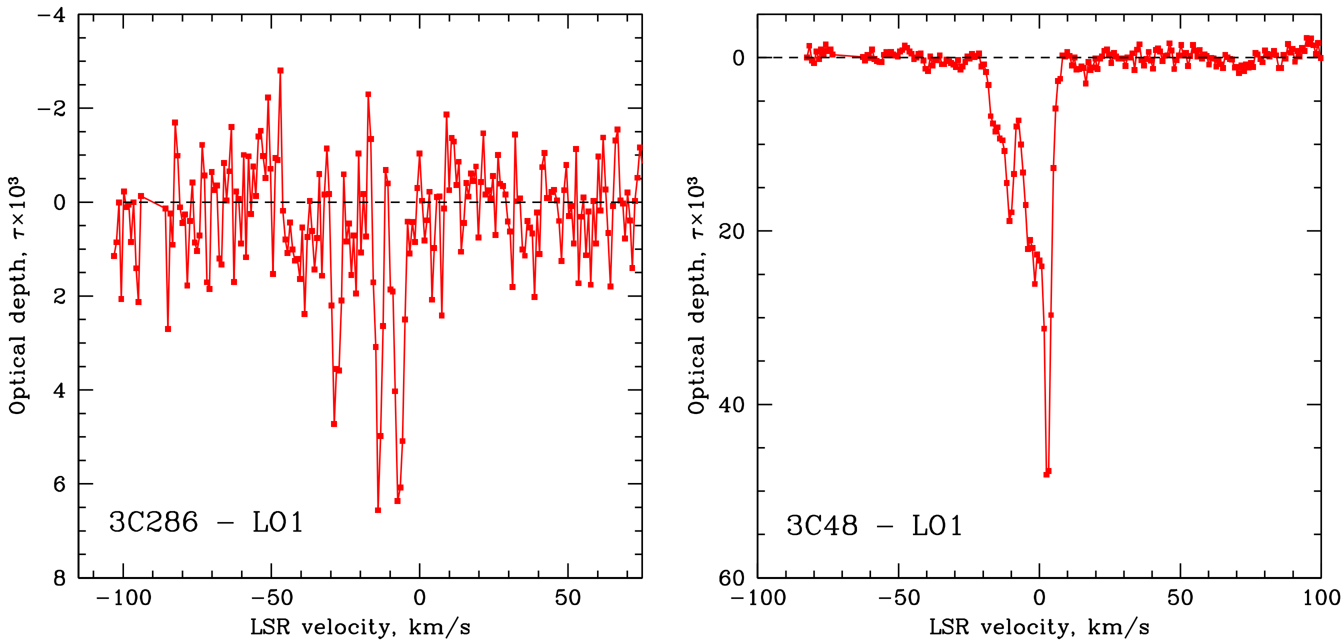

Figure 2: Final GMRT H I 21cm Stokes I spectra towards [A] 3C286 (left panel) and [B] 3C48(right panel), with switching at the first LO; in both cases, optical depth, $10^3 \times \tau$, is plotted against LSR velocity, in km/s.