GMRT quasi-simultaneous observations of 7 Extremely Inverted Spectrum Extragalactic Radio Sources (EISERS)

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Abstract: *Even for a perfectly homogeneous radio source, inverted spectrum with a slope α greater than +2.5 cannot arise from self-absorption in synchrotron plasma with the standard (power-law) energy distribution of relativistic electrons. Therefore, any such extreme spectra, if found, would require invoking either a non-standard electron energy distribution (e.g., Maxwellian) or, alternatively, thermal free-free absorption in external medium. As a first step towards checking if such sources exist, we have started a systematic search for extragalactic radio sources having integrated spectrum with α > +2. For 7 candidates previously reported by us (Gopal-Krishna et al. 2014: Paper I) we present here new quasi-simultaneous GMRT observations to define their continuum spectra at sub-GHz frequencies.*

Even for an ideal case of a perfectly homogeneous radio source, synchrotron self-absorption (SSA) can only yield inverted spectrum with a slope (α) of upto +2.5 (e.g., Slish 1963), at least for a power-law electron energy distribution (Rees 1967; de Kool &Begelman. 1989). Hence discovery of extragalactic radio sources having even more steeply inverted spectra would provide the first examples of radio galaxies/quasars whose relativistic electron population is either differs from the standard one (i.e., power-law), or their integrated radio spectra are predominantly determined by free-free absorption in their environments. An opportunity to discover such extremely rare objects is presented by the ongoing TIFR. GMRT. Sky. Survey. (TGSS), given its combination of good sensitivity and angular resolution at a low frequency of 150 MHz (http://tgss.ncra.tifr.res.in/). In an earlier paper, as a first step, we reported a search for sources with α > +2.0, which is a previously unexplored spectral domain. This was done by combining the 5th data release of TGSS (150 MHz) with the Westerbrok Survey (WISH) made at 352 MHz. The comparison revealed seven extragalactic radio sources with α > +2.0. We have used GMRT to make near-simultaneous snapshot observations of these 7 sources at 150, 325, 610 and 1400 MHz. Here we present the results at all these frequencies, except for 150 MHz for which data are taken from the TGSS (hence non simultaneous).

Synchrotron-self absorption (SSA) in milli-arcsecond components of radio galaxies is commonly thought to cause low-frequency turnover in their radio spectra. However, the role of free-free absorption (FFA) in causing the spectral turnover has also been discussed by several authors (e.g. Shklovsky 1965; Kellermann 1966; Bicknell et al. 1997; Kuncic et al. 1998; Kameno et al. 2000; Marr, Taylor & Crawford 2001; Shaffer, Kellermann& Cornwell 1999; Tingay & de Kool 2003; Ostorero et al. 2010). This is done particularly in the context of Gigahertz-Peaked Spectrum (GPS) sources which extend on kpc scale and show a conspicuous spectral turnover at metre wavelengths (e.g. O'Dea 1998; Gopal-Krishna, Patnaik & Steppe 1983; Spoelstra, Patnaik & Gopal-Krishna 1985). The turnover could possibly arise from FFA in the gas clouds of the narrow-line region engulfed by the radio lobes, such that their compressed surface layers are kept photo-ionized by the AGN radiation and the synchrotron UV emission from the lobes (e.g., Bicknell et al. 1997; Stawarz et al. 2008). However, attempts to find inverted spectrum extragalactic radio sources with integrated spectral indices steeper than +2.0 have generally not yielded positive results; clearly, such objects must be very rare (e.g., Murphy et al. 2010; Dallacassa et al. 2000). Recently, seven candidates were reported, albeit based on no-simultaneous flux measurements (Gopal-Krishna et al. 2014). We have followed them up by making quasi-simultaneous GMRT snapshot observations at 4 frequencies in the range 150-1400 MHz (Table 1).

The results of these observations at 325 MHz , 610 and 1400 MHz are presented here together with the TGSS measurement at 150 MHz. Our new GMRT measurements of these sources at 150 MHz are in process of being analysed and will be reported shortly, together with the details of the GMRT observations and analysis procedure at all the 4 frequencies. All these Inverted spectrum sources are found to be point-like at each of the four frequencies.

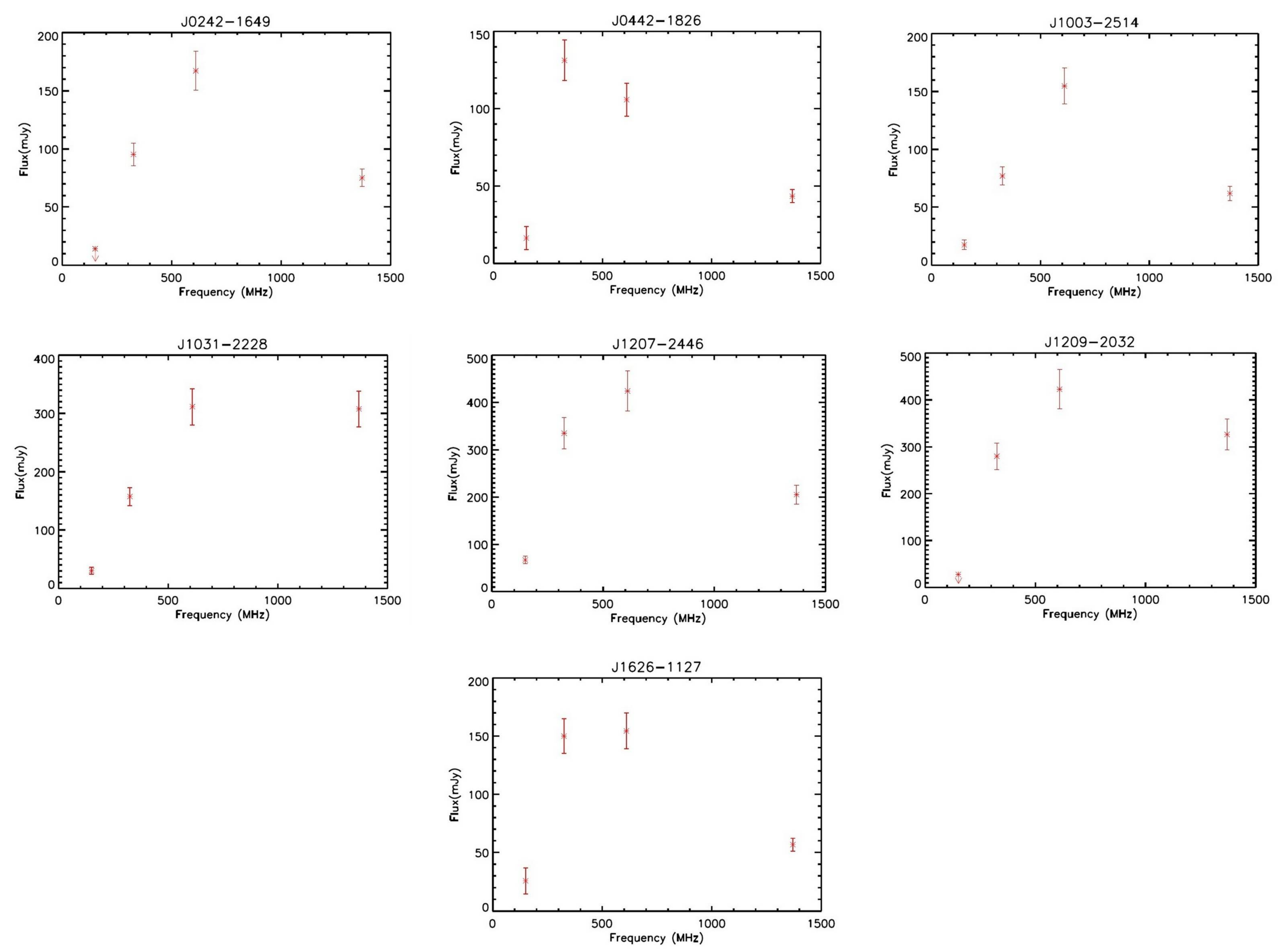
A summary of the radio spectral measurements for the 7 sources is presented in Table 1 and their spectral plots are shown in Figure 1. We have assumed the error in the flux density to be ~10% at all frequencies. The observations at all 4 frequencies were taken within a span of two months (July-August, 2014).

Table 1. Flux densities and spectral indices of the seven EISERS

Source	Flux densities, error & image rms (mJy)*				Spectral Indices ($S_\nu \propto \nu^\alpha$)		
	150 MHz	325 MHz	610 MHz	1.4 GHz	α (150-325 MHz)	α (325-610 MHz)	α (610-1400 MHz)
J0242-1649	< 14.2 -	95.3 ±9.5 σ = 0.8	167.2 ±16.7 σ = 0.4	75.2 ±7.5 σ = 0.2	2.46 ±0.13	0.89 ±0.23	- 0.99 ±0.17
J0442-1826	16.3 ±7.3	131.3 ±13.1 σ = 1.5	105.8 ±10.6 σ = 0.5	43.5 ±4.4 σ = 0.3	2.70 ±0.60	- 0.34 ±0.23	- 1.10 ±0.17
J1003-2514	17.5 ±4.1	77.1 ±7.7 σ = 1.5	154.8 ±15.5 σ = 0.3	62.1 ±6.2 σ = 0.3	1.92 ±0.33	1.11 ±0.23	- 1.13 ±0.17
J1031-2228	30.1 ±5.9	157.5 ±15.8 σ = 1.8	311.6 ±31.2 σ = 0.6	307.7 ±30.8 σ = 0.5	2.14 ±0.29	1.08 ±0.23	- 0.02 ±0.17
J1207-2446	67.1 ±8.2	334.9 ±33.5 σ = 1.3	424.4 ±42.4 σ = 0.5	205.2 ±20.5 σ = 0.4	2.08 ±0.20	0.38 ±0.23	- 0.90 ±0.17
J1209-2032	< 27.7 -	280 ±28 σ = 2.0	422.9 ±42.3 σ = 0.5	326.2 ±32.6 σ = 0.4	2.99 ±0.13	0.65 ±0.23	- 0.32 ±0.17
J1626-1127	25.8 ±11.2	150 ±15 σ = 8.6	154.4 ±15.4 σ = 0.5	56.7 ±5.7 σ = 0.3	2.28 ±0.58	0.05 ±0.23	- 1.24 ±0.17

- The values at 150 MHz are based on TGSS observations, as mentioned in paper-I and those at remaining frequencies are from the present observations.
- The Perley-Butler flux scale was used at all the frequencies during data analysis.

Figure 1: Radio Spectra of the EISERS



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