

Direction-Dependent Ionospheric RM/FR Modelling for GMRT

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Abstract: Ionospheric electron density and geomagnetic field geometry introduce direction, time, and frequency dependent polarization changes in low frequency radio observations. These effects are particularly relevant to the Giant Metrewave Radio Telescope (GMRT) (latitude: 19.10°N, longitude: 74.05°E, geographic; dip: 23°N magnetic), situated between the magnetic equator and the northern crest of the Equatorial Ionization Anomaly (EIA). We present a framework for characterizing slant total electron content (STEC), ionospheric rotation measure (RM), and Faraday rotation (FR) across the visible GMRT sky using the International Reference Ionosphere (IRI) and the International Geomagnetic Reference Field data to develop a model to calculate RM along line of sight. FR is subsequently derived using its wavelength squared dependence. Mapped vertical total electron content (VTEC) is compared with IRI VTEC at ionospheric pierce points, while satellite resolved GNSS measurements provide an independent observational benchmark.

For the magnetically quiet reference day, 7 January 2022, modelled STEC spans approximately 5–140 TECU for elevations above 20°, with maximum ionization around 10:00 UTC. Mapped VTEC ranges from approximately 5–80 TECU. Agreement with IRI VTEC improves at higher elevations, whereas residuals reach approximately 5 TECU near 30° elevation. GNSS observations show enhanced STEC toward lower elevations, particularly in the southern sky. Modelled RM varies substantially with direction and time, spanning approximately -2.9 to $+8.5$ rad/m² over the day. At 150 MHz, the RM distribution produces FR between approximately -2.4 and $+3.2$ rad at 00:01 UTC.

These results demonstrate the importance of accounting for both electron content and magnetic field geometry when estimating ionospheric polarization rotation, and establish a basis for direction dependent, time resolved corrections for sensitive GMRT polarimetric observations across its different observing bands.