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Calibration of Ooty Radio Telescope Module Response using Crab Nebula Transit Observations

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Abstract: The Ooty Radio Telescope (ORT) is a large equatorially mounted cylindrical radio telescope operating near 326.5 MHz. Reliable module-to-module response assessment is necessary because gain variations can introduce systematic differences into long-duration transit observations. This study evaluates the relative response of selected ORT modules using repeated Crab Nebula transit measurements acquired over approximately five months. For each observing session, ON-source and OFF-source power sequences were aligned, visually inspected, converted to a logarithmic scale where required, and compared through peak excess and baseline behaviour. Time-series and module-wise plots were generated in GNUPLOT to identify repeatability, anomalous sessions, and relative gain differences. The processed observations consistently exhibited the expected rise–peak–fall transit morphology, while the measured peak excess varied across dates and modules. For the illustrated November subset, Module 21 showed values of approximately 1.59–3.28 dB, indicating measurable session-to-session variability. Because the available dataset does not include a fully documented absolute flux-density transfer, system-temperature measurement, uncertainty budget, or independent reference calibration, the analysis supports relative response normalisation rather than an absolute sensitivity determination in Jy K^{-1} or system-equivalent flux density. The workflow provides a practical screening method for identifying comparatively weak or unstable modules and for selecting observations suitable for subsequent calibration. Future work should incorporate calibrated noise injection, contemporaneous weather and radio-frequency-interference logs, automated baseline fitting, uncertainty propagation, and comparison with a source of traceable flux density.

Keywords: Ooty Radio Telescope, Crab Nebula, Relative Calibration, Module Response, Transit Observation, Radio Astronomy Data Analysis

1. Introduction

Radio astronomy extends astronomical observation beyond the optical window and provides direct access to synchrotron emission, pulsars, active galactic nuclei, the interstellar medium, solar-wind disturbances, and other non-thermal phenomena [1, 2]. The discovery of extraterrestrial radio emission by Jansky and the subsequent development of purpose-built radio telescopes established the observational and engineering foundations of the field [3, 4]. Modern radio instruments therefore depend not only on collecting area, receiver noise, and bandwidth, but also on stable calibration procedures that distinguish true source variations from instrumental response changes [1, 5].

The Ooty Radio Telescope was designed as a 530 m × 30 m cylindrical parabolic reflector installed on a north–south hillside whose slope is close to the local latitude, enabling equatorial tracking by mechanical rotation and electronic phasing [6]. The legacy system operates at a centre frequency of approximately 326.5 MHz and has supported studies of pulsars, interplanetary scintillation, radio sources, and space weather [6 – 8]. Later receiver developments for the Ooty Wide Field Array retained the large collecting area and tracking advantages of the original instrument while introducing a wider digital observing band and a multi-element correlator [8].

Sensitivity calibration in radio astronomy commonly relates measured power to the known flux density of a bright reference source, often through antenna temperature, telescope gain, or system-equivalent flux density [5, 9]. The Crab Nebula (Taurus A) is bright at metre wavelengths and has long been used as a radio calibration source, although its integrated radio flux undergoes a slow secular decline and must not be treated as perfectly time invariant over long intervals [10, 11]. At the timescale of the present five-month dataset, the secular change is negligible relative to the much larger day-to-day instrumental and environmental variations, but it remains relevant for traceable absolute calibration. The present work analyses repeated ORT Crab Nebula transit observations to compare module response, examine ON-source and OFF-source behaviour, and identify relative gain variability. The principal contribution is a reproducible data-screening and normalisation workflow for multi-module observations. The study does not claim an absolute telescope sensitivity because the source flux model, calibration diode response, receiver temperature, effective bandwidth, and full uncertainty budget were not available in the supplied dataset. Accordingly, the term calibration is used here in the restricted sense of relative module-response assessment.

2. Materials and Methods

2.1 Telescope and observational dataset

The analysis used observational files obtained from selected ORT modules during repeated Crab Nebula transit sessions spanning approximately five months. Each session contained measurements representing the source transit and an associated background or OFF-source level. The files were organised by observation date and module identifier. The supplied records did not include a complete metadata table describing integration time, effective bandwidth, pointing offset, calibration-noise temperature, weather, ionospheric conditions, radio-frequency interference (RFI), or receiver maintenance status; these omissions constrain the interpretation of inter-session differences.

2.2 Data preparation and quality control

Processing was performed in a Linux environment. Directory and file checks were used only for data organisation; they were not treated as methodological results. For each observation, the time axis and module identifiers were verified, missing or malformed records were flagged, and ON-source and OFF-source sequences were aligned. Sessions with obvious discontinuities, incomplete transit coverage, severe baseline drift, or impulsive RFI should be excluded or separately labelled before gain estimation.

2.3 Relative response estimation

For a given module m and observing session d, the source-related excess power was represented by the difference between the peak ON-source power and the local OFF-source baseline. Where power was stored on a linear scale, the ON/OFF ratio was expressed in decibels as

$$\Delta P_{m,}{}^{d}\ (dB) = 10 \log_{10}[PON,peak(m,d) / POFF(m,d)].$$

A relative module coefficient can then be defined by normalising each valid module value to a reference response, such as the median of stable modules observed during the same session. This procedure indicates relative gain differences but does not yield absolute sensitivity. Absolute calibration would additionally require a traceable source-flux model or calibrated noise source, effective bandwidth, integration time, system temperature, and propagated measurement uncertainty [5, 9].

2.4 Visualisation and comparison

GNUPLOT was used to display signal power versus time, overlay ON-source and OFF-source sequences, convert power ratios to decibels, and compare module values across dates. Figure 1 presents the long-duration ON/OFF time series used to examine baseline consistency and source-related excursions. Figure 2 compares the date-wise response of Modules 21 and 22 for the illustrated November subset.

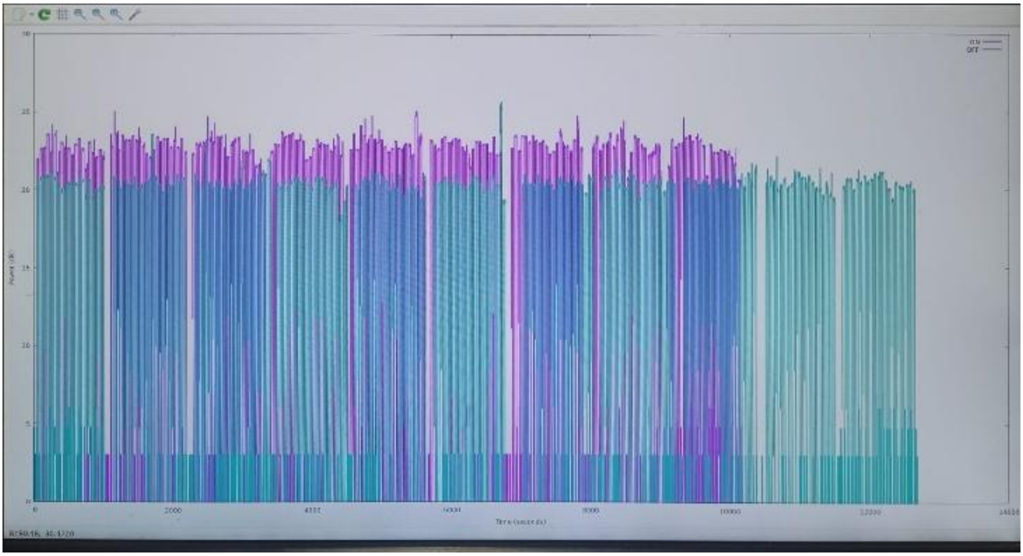

Figure 1. Time variation of the recorded ON-source and OFF-source power sequences used for baseline and transit-response inspection.

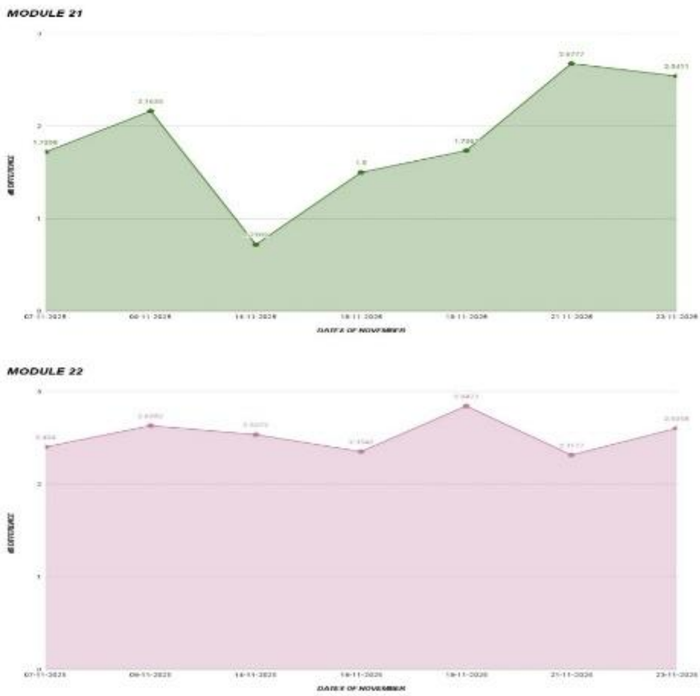

Figure 2. Date-wise relative response of ORT Modules 21 and 22 for the illustrated November observation subset.

3. Results and Discussion

3.1 Transit profile and baseline behaviour

The Crab Nebula observations displayed the expected transit-like increase in recorded power as the source entered the telescope beam, followed by a maximum near beam-centre passage and a decline as the source moved away. This morphology is consistent with a detectable astronomical contribution superposed on the receiver and sky background. As shown in Figure. 1, the ON-source and OFF-source sequences also contain substantial short-timescale fluctuations and baseline structure. These features require robust baseline estimation; a simple single-point subtraction may overestimate or underestimate the source excess when the background is non-stationary.

3.2 Module-to-module and date-to-date variation

The processed module values were not constant across the observing period. In the November subset shown in Figure. 2, Module 21 varied from approximately 1.59 to 3.28 dB. The lower observation does not, by itself, prove a loss of intrinsic module sensitivity. Plausible contributors include RFI, pointing or phasing error, receiver-gain drift, baseline-selection differences, incomplete transit coverage, or changes in data-acquisition settings. Module 22 also exhibited date-dependent variation, reinforcing the need for simultaneous or closely matched comparisons rather than unqualified pooling across sessions.

3.3 Interpretation of the November observations

The original draft identified November as the month with the highest response. The available plots support higher values for some November sessions, but they do not establish that atmospheric conditions were superior or that telescope alignment was better. At 326.5 MHz, ionospheric and RFI conditions can influence observations, while most neutral-atmosphere effects are comparatively small. Without contemporaneous environmental, pointing, phasing, and receiver logs, the physical cause of the November pattern remains indeterminate. The defensible conclusion is therefore that the November dataset contains comparatively high measured peak excesses for the illustrated modules, not that a specific environmental mechanism produced them.

3.4 Relative calibration utility

Normalising valid peak excesses to a stable reference module or to the median response of a module ensemble can reveal channels that are persistently weak or unstable. Such coefficients are useful for quality assurance and preliminary equalisation before scientific analysis. However, modules should not be adjusted solely because one session produces a lower peak. A calibration coefficient should be derived from multiple RFI-screened observations, with uncertainty estimated from repeated measurements. The Crab Nebula is suitable as a bright check source, but its known secular flux decline and frequency-dependent spectrum must be incorporated when an absolute flux scale is required [10, 11].

4. Limitations

The study is limited by incomplete observational metadata and the absence of raw calibration parameters. The number of valid sessions per module, data-sampling interval, effective bandwidth, integration time, beam model, source-flux model at 326.5 MHz, calibration-diode response, receiver temperature, and RFI excision criteria were not documented in the supplied manuscript. No confidence intervals, repeatability statistics, or independent reference measurements were available. Consequently, the reported dB values should be interpreted as relative processed responses, and the present work should not be used to infer absolute ORT sensitivity, system-equivalent flux density, or astrophysical variability of the Crab Nebula.

5. Conclusion

Repeated Crab Nebula transit observations were used to examine the relative response of selected Ooty Radio Telescope modules over an approximately five-month period. The processed data exhibited a reproducible transit morphology and measurable differences among observing dates and modules. The illustrated November records contained comparatively high peak excesses, while Module 21 showed a broader range of approximately 1.59–3.28 dB. These variations demonstrate the importance of baseline control, RFI screening, repeated measurements, and session-matched normalisation when evaluating module performance. The analysis provides a practical workflow for identifying weak, unstable, or atypical module responses and for selecting data suitable for subsequent calibration. Nevertheless, the available records do not support an absolute sensitivity estimate because the required source-flux transfer, system-temperature information, effective bandwidth, and uncertainty budget were not supplied. Future work should automate transit fitting, estimate local baselines robustly, retain complete observing metadata, quantify repeatability, and validate relative coefficients using a calibrated noise source or an established flux-density scale. These additions would convert the present screening procedure into a traceable calibration framework suitable for long-term ORT performance monitoring.

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Conflict of interest

The Author's have no conflicts of interest to declare that they are relevant to the content of this article.

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