

Novel Broadband Frequency and Amplitude Measurement System for 263 GHz Gyro-TWT Amplifiers

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ABSTRACT

Gyro-traveling wave tube (gyro-TWT) amplifiers are promising sources for generating sequenced microwave pulses in dynamic nuclear polarization nuclear magnetic resonance (DNP-NMR) spectroscopy. During their development, accurate and broadband spectrum diagnostic tools are essential to verify performance and ensure reliable operation. This work presents a novel, modular, and real-time-capable diagnostics system based on a heterodyne receiver architecture, enabling simultaneous frequency and amplitude characterization of a 263 GHz gyro-TWT amplifier.

The system incorporates an external front-end module with a sub-harmonic mixer, which can be flexibly positioned and exchanged to accommodate different frequency ranges through the use of mixers with varying waveguide dimensions. This modular design allows the characterization of gyro-TWT amplifiers across multiple frequency bands through different front-end modules. After down-conversion, the system utilizes two complementary measurement approaches. The first employs a filter bank with parallel detector diodes for real-time frequency and RF power measurement. Due to its low latency, this path can also serve as a trigger for rapid shutdowns in the event of amplifier malfunctions. The second approach uses a high-speed oscilloscope to capture the down-converted signal and perform short-time Fourier transform (STFT) analysis, enabling flexible adjustment of temporal and spectral resolution during post-processing.

By combining these methods, the system enables redundant power level measurement and achieves a real-time bandwidth of 38 GHz through ambiguous mixing over a frequency range of 160-288 GHz. The system delivers a frequency resolution of up to 10 kHz, a dynamic range of 40 dB, and a power measurement uncertainty within ± 21 % for the given gyro-TWT amplifier. In addition, pulse durations as short as 250 ns can be reliably resolved.

Future extensions include amplifier gain and phase characterization, for which concepts have already been developed and validated in preliminary experiments, increasing its future flexibility and use-cases.