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SPARC Edge Scanning Reflectometry Overview

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SPARC is a compact, high-field, D-T tokamak that is presently under construction and will be used to de-risk the high-field path to commercial fusion energy. Diagnostic systems are entering the final design stage and will be used for real-time control and to close science gaps needed to design ARC. An Edge Scanning Reflectometry (ESRL) system for SPARC is included in the Campaign #1 diagnostic set, integrated into one of SPARC's midplane port plugs. The engineering challenges for this reflectometry system include space constraints and high thermal and electromagnetic loads, mainly in the port area, long transmission lines from the port towards the laboratory (approximately 20 m), and the necessity for radiation protection of signal processing equipment. Given limited in-vessel access due to activation, developing in-situ diagnostic calibration techniques is crucial for success and to plan for reflectometry on ARC.

The ESRL system aims to determine the edge density profile through measurements in both O-mode and X-mode, utilizing probing frequencies in the K, Ka, U and E bands, corresponding to the 18-90 GHz range. ESRL is being designed to measure the electron density profile from 3x10^18/m^3 to 4x10^20/m^3, corresponding to 0.004 - 0.5 of the Greenwald density limit for Ip = 8.7 MA, the highest plasma current at SPARC.

The ESRL system is being designed to decrease the signal loss while optimizing for cost and manufacturing time. This design overview includes electromagnetic simulations to identify the optimal distance from the plasma, optimization of the horn and waveguide geometries, tolerance analysis for inner surface roughness, development of manufacturing options for the antenna box, simulations of vacuum windows and design of waveguide bends for the wall penetration across multiple frequency bands.

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