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Measurement of Cavity-Loaded Quality Factor in Superconducting Radio-Frequency Systems with Mismatched Source Impedance

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Precise measurements of the cavity-loaded quality factor (QL) is crucial for monitoring the performance of superconducting radio-frequency (SRF) cavities. The conventional “field decay method” cannot be used to measure QL accurately when the impedance is mismatched. This can lead to nonzero forward signals (V_f), which significantly affect the measurement accuracy. To address this limitation, we developed a modified “field decay method” based on the cavity differential equation, enabling precise calibration of QL even with impedance mismatch conditions. This method was validated on the SRF cavities of the Chinese ADS Front-End Demo Linac (CAFe) and further tested at the European Spallation Source (ESS) TS2 facility. TS2 facility which is equipped with a high-power circulator having an adjustable reflection coefficient, provides increased experimental flexibility for validating the proposed algorithm. The results confirmed the effectiveness of our approach in accurately calibrating QL under mismatched conditions, demonstrating the practicality and reliability of the proposed algorithm.

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