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| **Qext measurement of weakly a coupled antenna** |
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# Purpose

The purpose of this document is to describe the steps required to measure the Qext of a weakly coupled antenna, such as those used for cryogenic RF testing of SRF cavities. The same procedure can be used to check the Qext of the FPC of a CEBAF cavity in a cavity-pair or cavity-string configuration.

# Scope

This procedure applies to the measurement of the Qext of an antenna mounted to an SRF cavity under vacuum. It relies on knowing the Qext-value of a secondary antenna mounted to the cavity.

# Terms and Definitions

The following terms have specific meanings within this procedure.

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| **Term** | **Definition** |
| VNA | Vector Network Analyzer |
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# Roles and Responsibilities

The following roles have responsibilities described in this document.

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| **Role** | **Responsibility** |
| RF Technician | Performs the measurements and calculations described in this procedure |
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# Procedure

The procedure requires basic knowledge of RF measurements using a VNA. All *S21* measurements are in units of dB. Use the Excel file listed in the References section to easily enter measured quantities and calculate the results.

Connect a series of attenuators to achieve a nominal attenuation of at least ~**70 dB**. Setup the VNA to measure *S21* with a center frequency within 0.5 MHz of the -mode resonant frequency of the cavity being measured and a span of 10 MHz. Use the maximum number of points and IF frequency = 2 kHz. Position a marker at the center frequency.

1. Measure the insertion loss of an RF cable at center frequency, *S21*c1, by connecting it between ports 1 and 2 of the VNA.
2. Connect the attenuator series between port 1 of the VNA and one end of the same cable measured in step 1. The other end of the cable is connected to port 2. Measure *S21*attn+c1 at center frequency. The attenuation of the attenuator series is *Attn* (dB) = *S21*c1 − *S21*attn+c1
3. Set the power output of the VNA to **−10 dBm**. Connect cables, amplifiers and the attenuator series to ports 1 and 2 of the VNA as shown schematically in Fig. 1. Turn on the amplifiers and measure *S21* at center frequency, *S21*tot. The net total gain is given by: *TG* (dB) = *S21*tot + *Attn*.

1

2

VNA

RF Amp, ~35 dB gain

RF Amp, ~35 dB gain

Load

Attenuator series

Circulator

1

2

RF Amp, ~15 dB gain

**Figure 1**. Schematic of the measurement setup to determine the overall net gain.

1. Turn off the amplifiers, disconnect the attenuator series and connect the cable ends 1 and 2 to the field-probe and input antenna feedthroughs on the cavity, respectively, as shown in Fig. 2.

1

2

VNA

RF Amp, ~35 dB gain

RF Amp, ~35 dB gain

Load

Circulator

1

2

RF Amp, ~15 dB gain

Field-probe side

Input antenna side

**Figure 2**. Schematic of the measurement setup to determine S21 through the cavity.

1. Turn on the amplifiers, measure *S21* at the -mode resonant frequency, *S21*cav, with 16 averages. Also measure the *Q*0 of the -mode. Note the *Q*ext2 of the field-probe antenna as measured, for example, during a cryogenic RF test of the cavity. The *Q*ext1 of the input antenna is given by:

$Q\_{ext1}=\frac{4 Q\_{0}^{2}}{Q\_{ext2} 10^{{\left(S21\_{cav}-TG\right)}/{10}}}$ (1)

Eq. (1) is valid only for weakly coupled antennas: *Q*ext1, *Q*ext2 >> *Q*0.

1. Turn off the amplifiers and disconnect the cables.

This procedure can also be used to check *Q*ext2, if *Q*ext1 is known, by reversing the connection of cable ends 1 and 2 in Fig. 2.

This procedure can also be used to check the *Q*ext of the waveguide FPC by mounting a waveguide adapter between the FPC RF window on the cavity and cable end 1.

# Process Flow

<Related Process Outside this Procedure>

<Starting Condition>

<Step 2>

<Related Step 1>

<Step 4>

<Decision>

<Related Step 2>

<Related Step 4>

<Ending Condition>

<Step 1>

YES

NO

<Related Decision>

<Related Step 3>

YES

NO

<Step 3>

# References

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| **Document No.** | **Title** |
| SRF-01-ML-001 | SRF Quality Manual |
| SRF-MSFM-VTA-CAV-LPRF-R1 | [Worksheet to calculate Qext of weakly coupled antenna](https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-277422/Worksheet%20to%20calculate%20Qext%20of%20weakly%20coupled%20antenna.xlsx) |
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# Release and Revision History

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| --- | --- | --- |
| **Rev #** | **Major Changes** | **Effective Date:** |
| 1 | Initial version | DD Mmm YYY |
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# Approvals

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