

SRF Cavity Emulator for PIP-II LLRF Lab and Field Testing

ID#44

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Introduction

A system has been developed to emulate expected LLRF signals generated from superconducting RF cavities. The purpose of this simple analog emulator design is to meet the cavity bandwidth requirements, high quality factor and to provide tuning errors for emulating Lorentz force detuning and microphonics for all cavity types.

Objectives and Features

- Frequency 650MHz
- High quality factor $\sim 1.3 \times 10^7$ and bandwidth 77Hz
- Emulates cavity, dual directional coupler at cavity input and cavity transmitted power signals
- Output amplitude is proportional to input RF drive signal level
- Lorentz force detuning and Microphonics proven with simulation-under development
- IQ modulation for upconversion to RF from IF for cleaner output RF



Fig.1 Cavity emulator chassis

Design Details

The crystal filter board is the heart of the emulator design and is developed in ADS to achieve impedance matching and bandwidth.

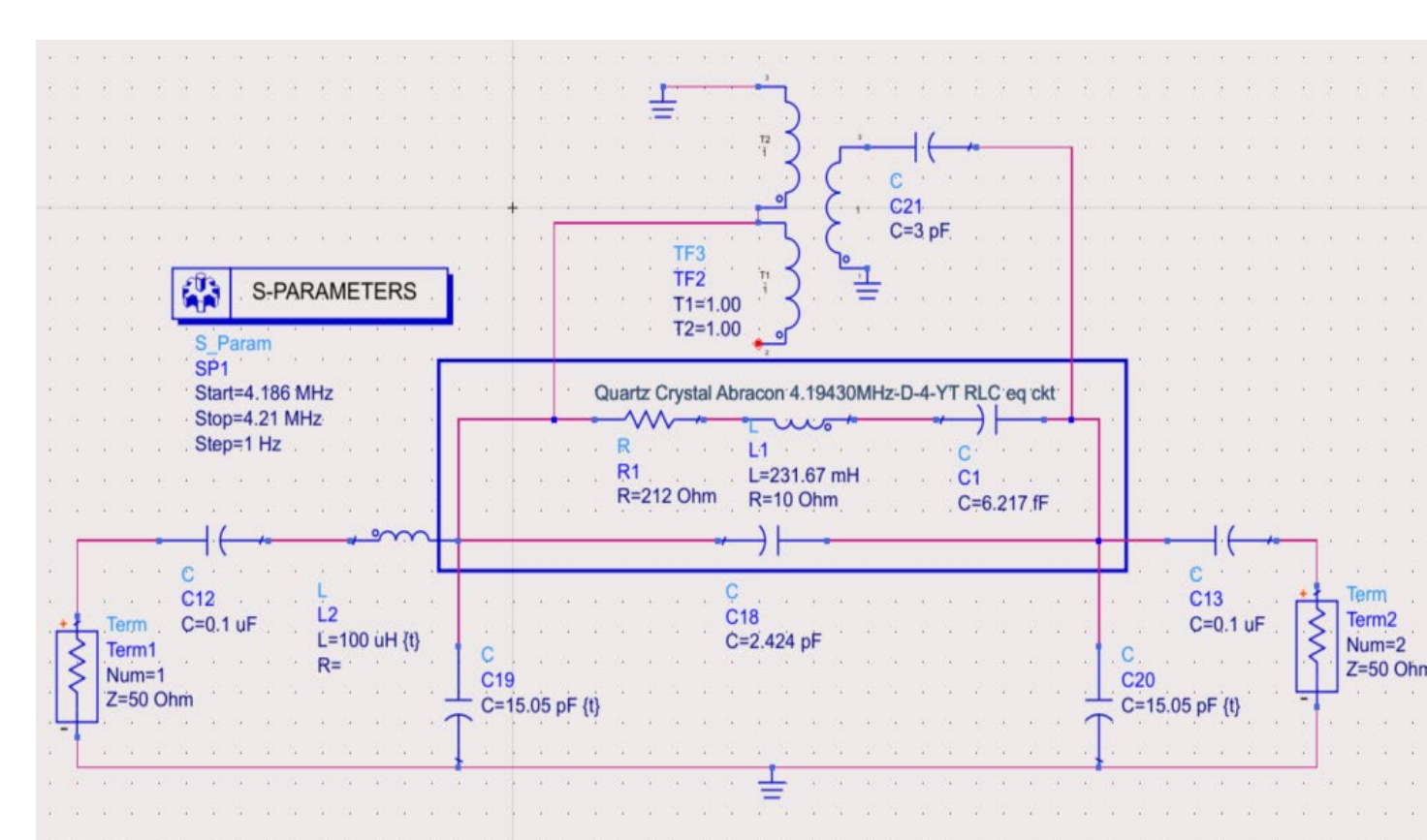
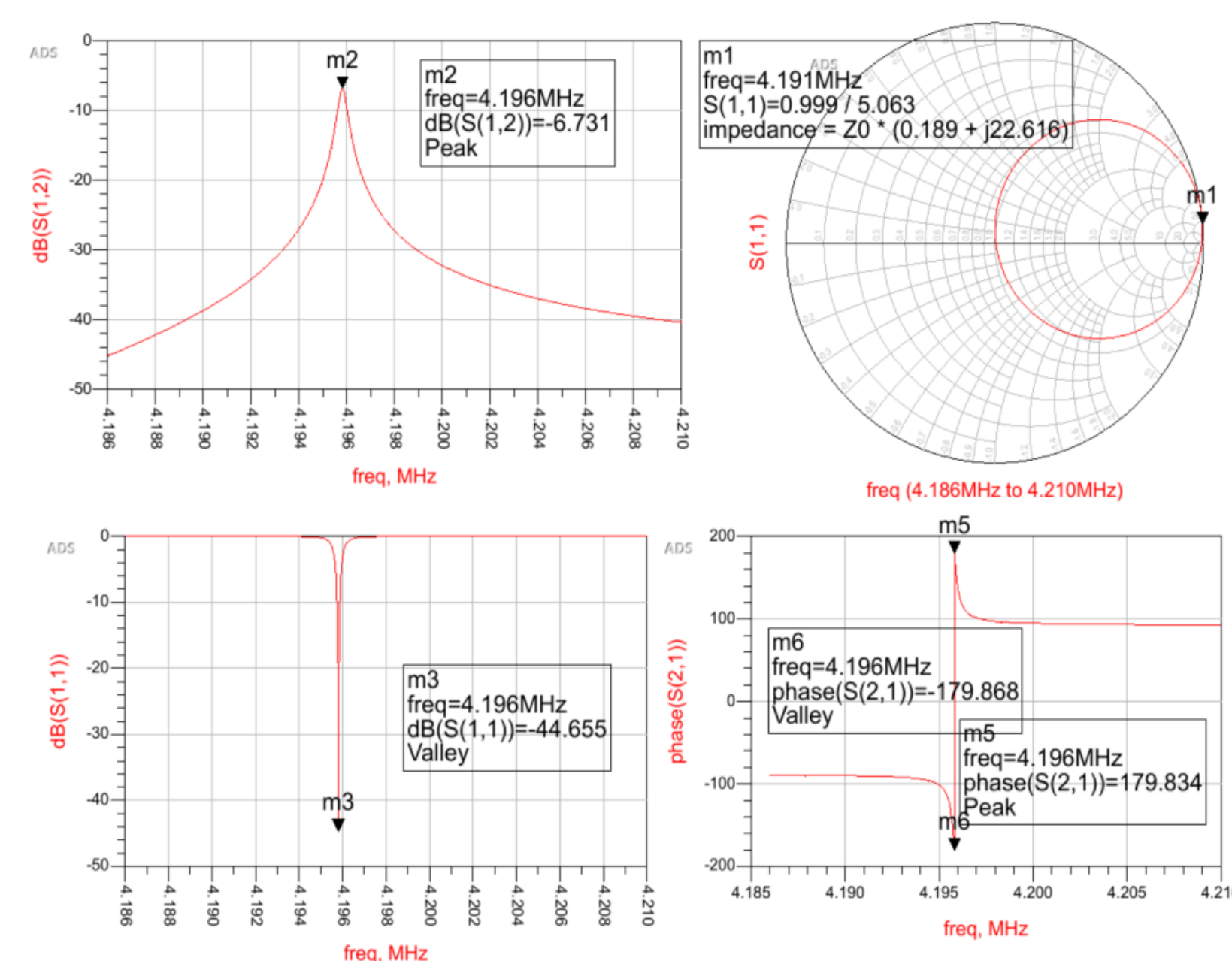


Fig.2 (Top) Circuit schematic for crystal filter board (Left) ADS simulation plots

Microphonics and Lorentz Force Detuning

ADS simulations demonstrate ability to change frequency with varactor diodes by varying bias voltage/ capacitance.

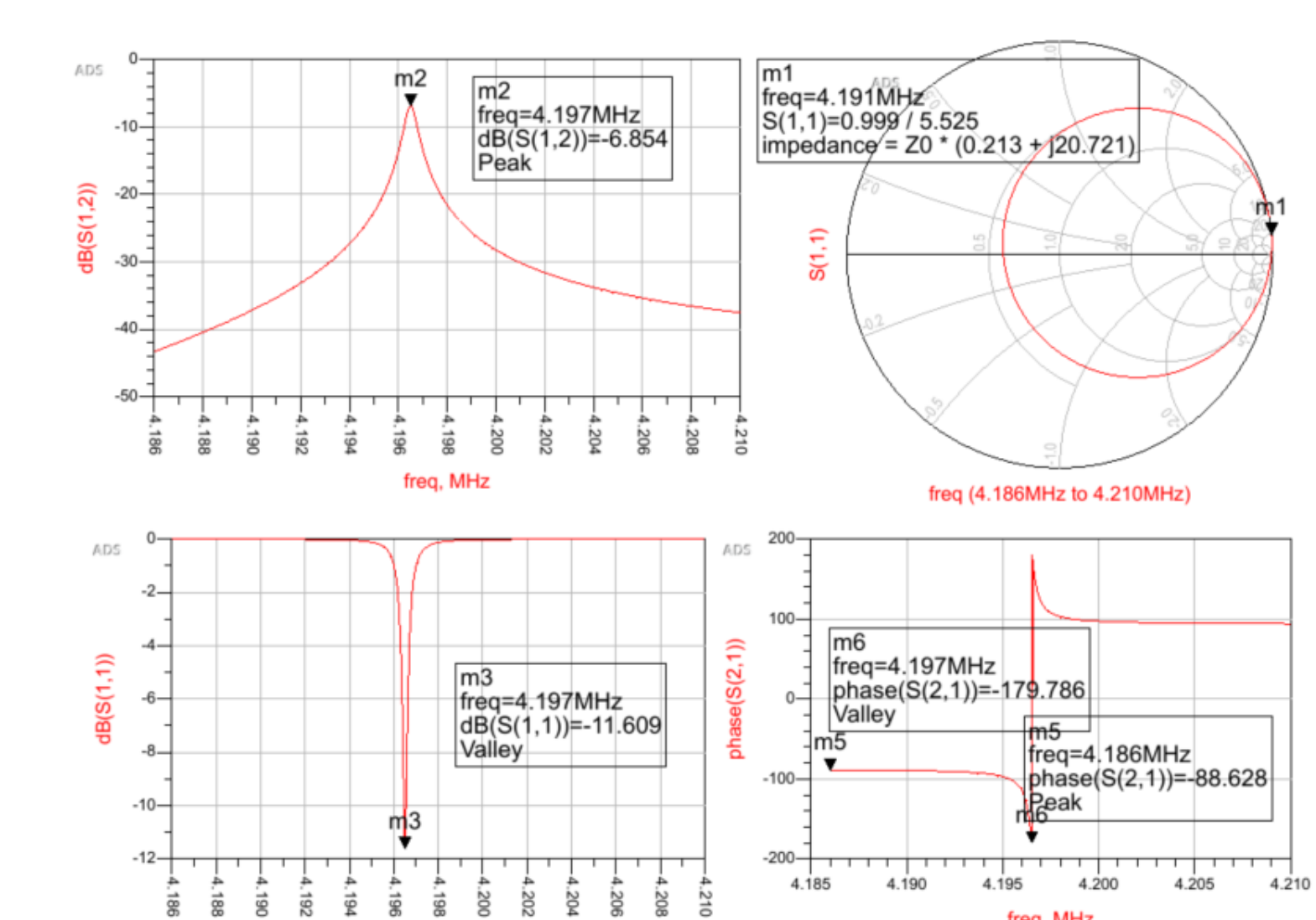


Fig.3 ADS simulations showing frequency shift on varying capacitance C19 and C20

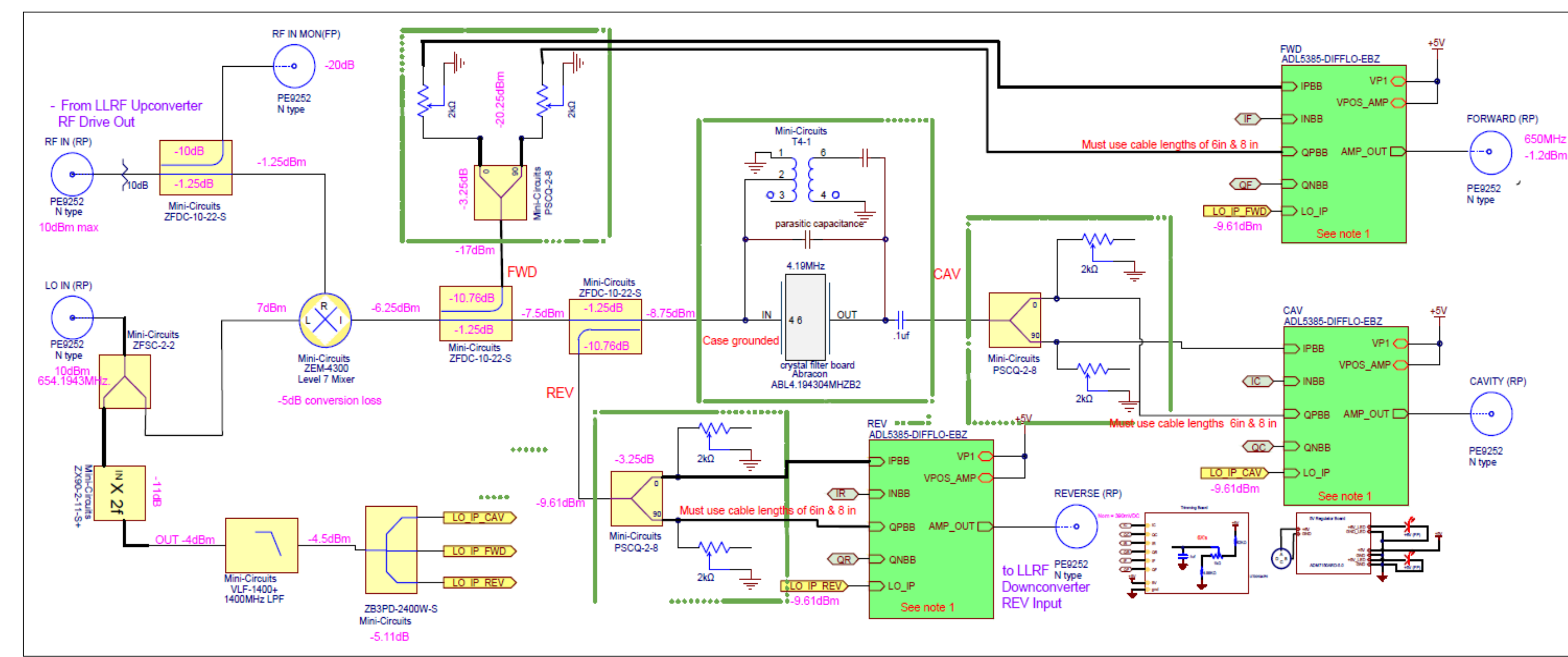
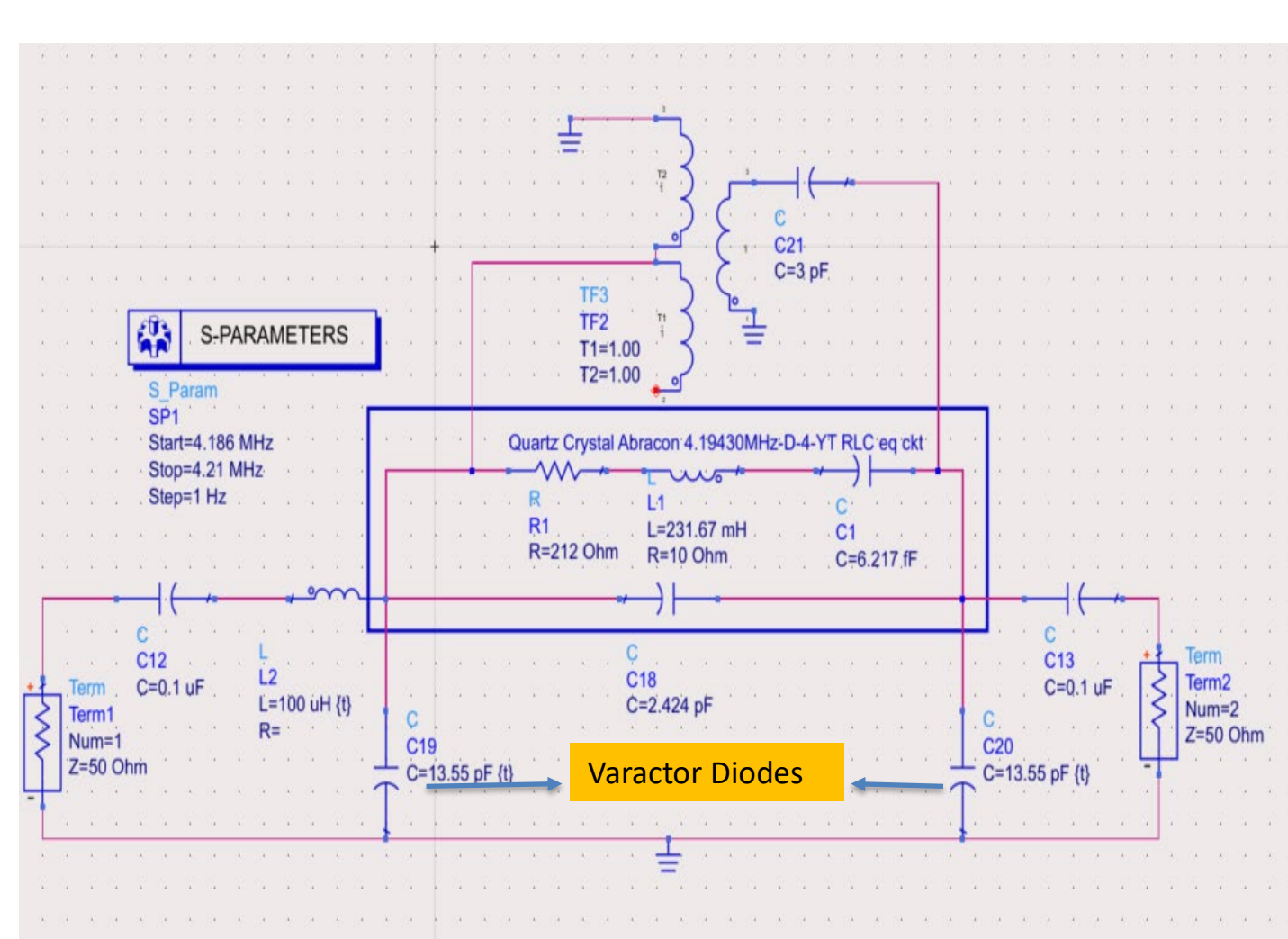


Fig.4 Detailed schematic of cavity emulator design

Test Results

The cavity emulator was tested to benchmark its performance as compared to an RF superconducting cavity.

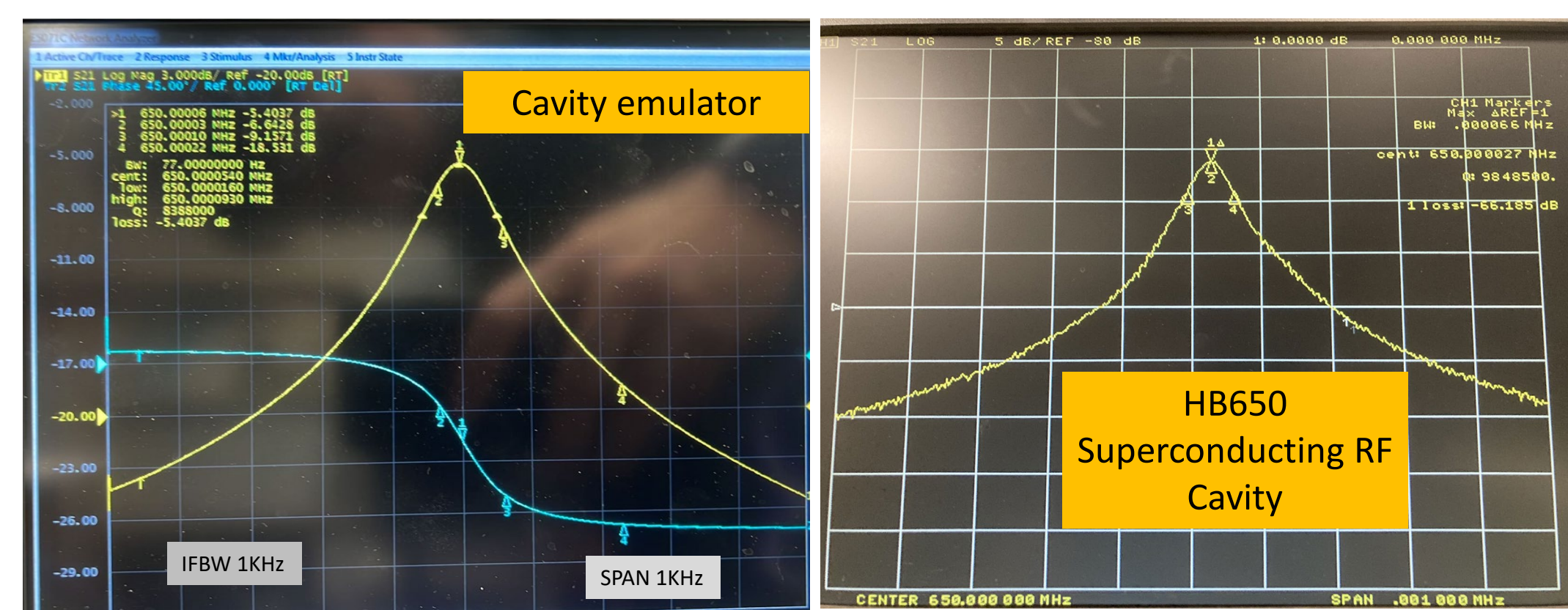


Fig.5 (Left) S21 plot of cavity emulator (Right) S21 plot of an RF superconducting cavity

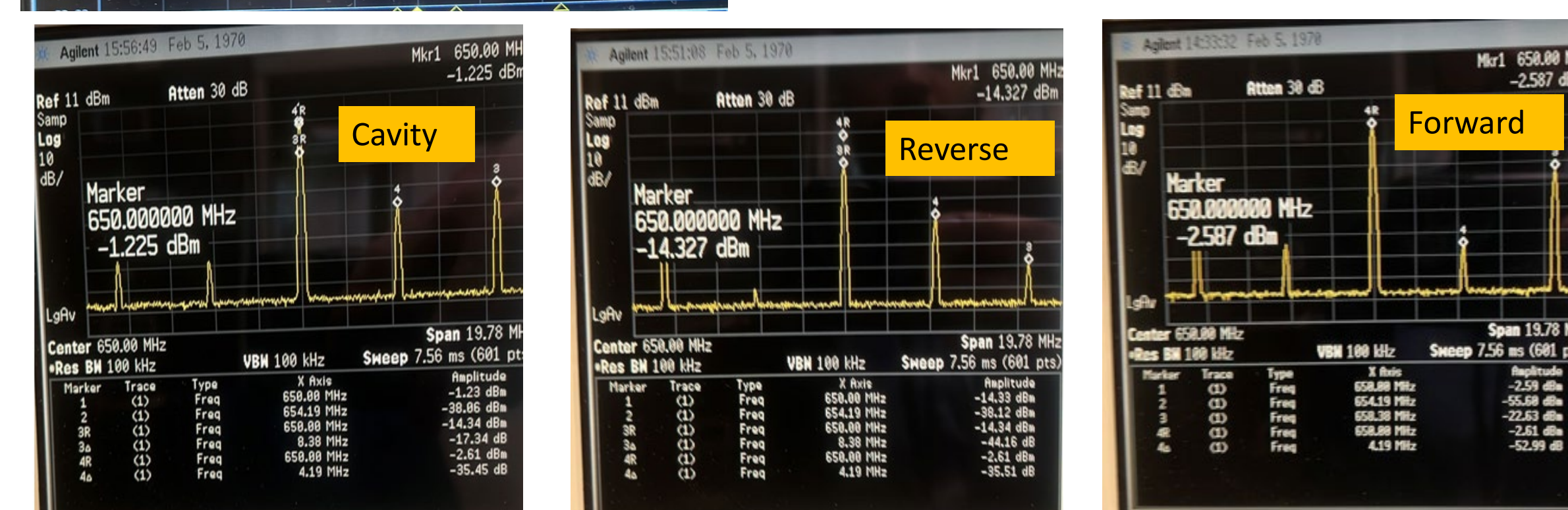


Fig.6 With full scale RF drive 7dBm output power of cavity emulator at 3 channels-cavity, forward and reverse

Application

Cavity emulator has demonstrated its ability to be used in checkout of LLRF hardware, software and firmware at PIP-II Test Facility and at PIP-II Spoke Test Cryostat Test facility at Fermilab.

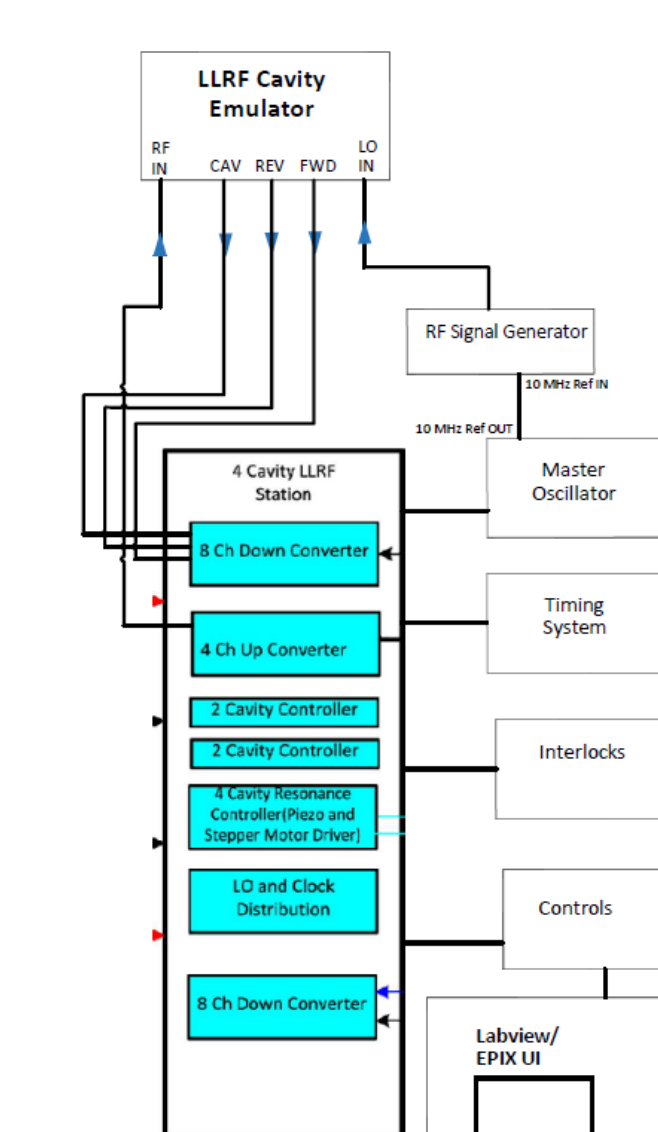


Fig.7 Block diagram of cavity emulator's setup at PIP-II test stand

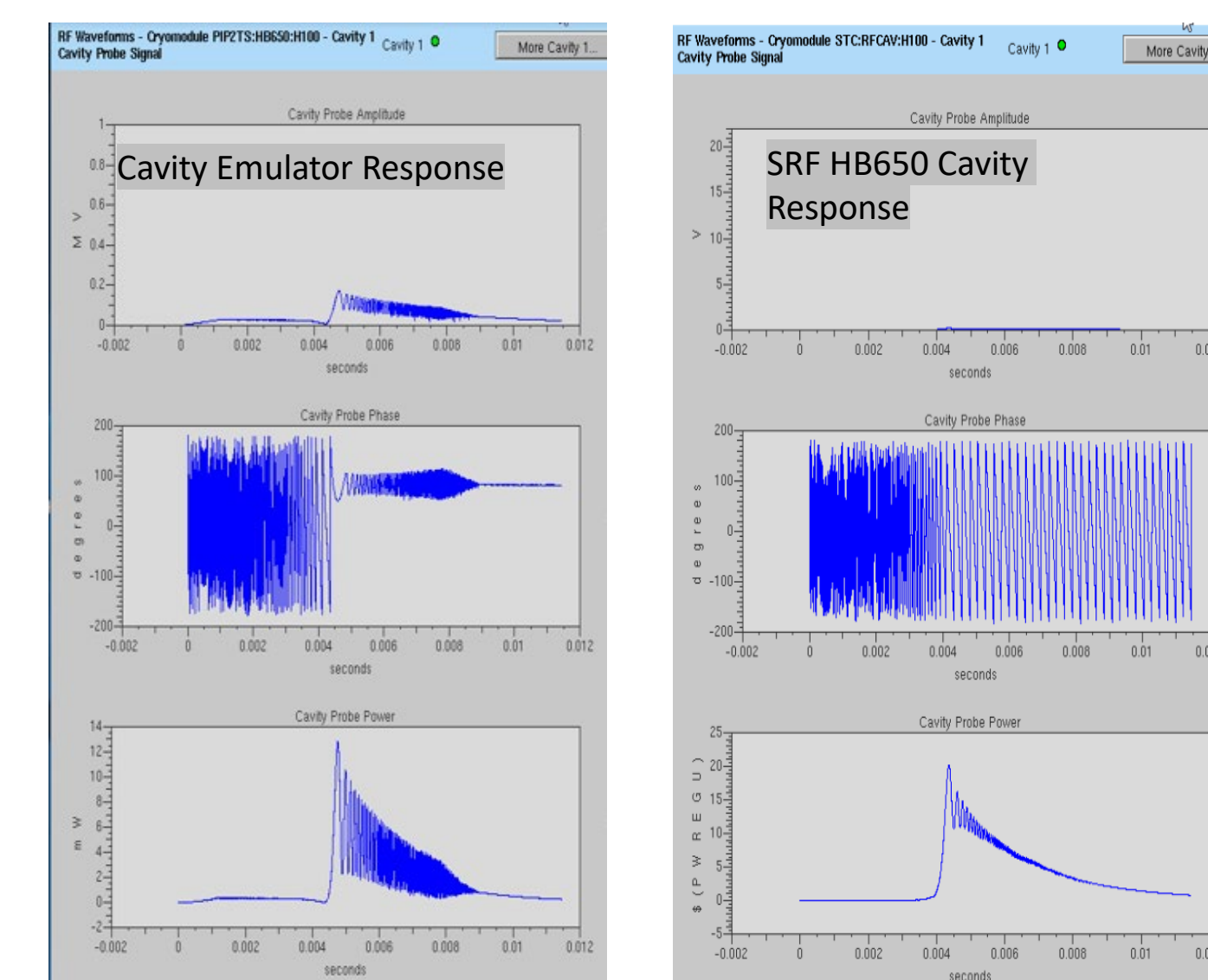


Fig.8 Comparison of cavity emulator and superconducting RF HB650 cavity response to chirp mode signal

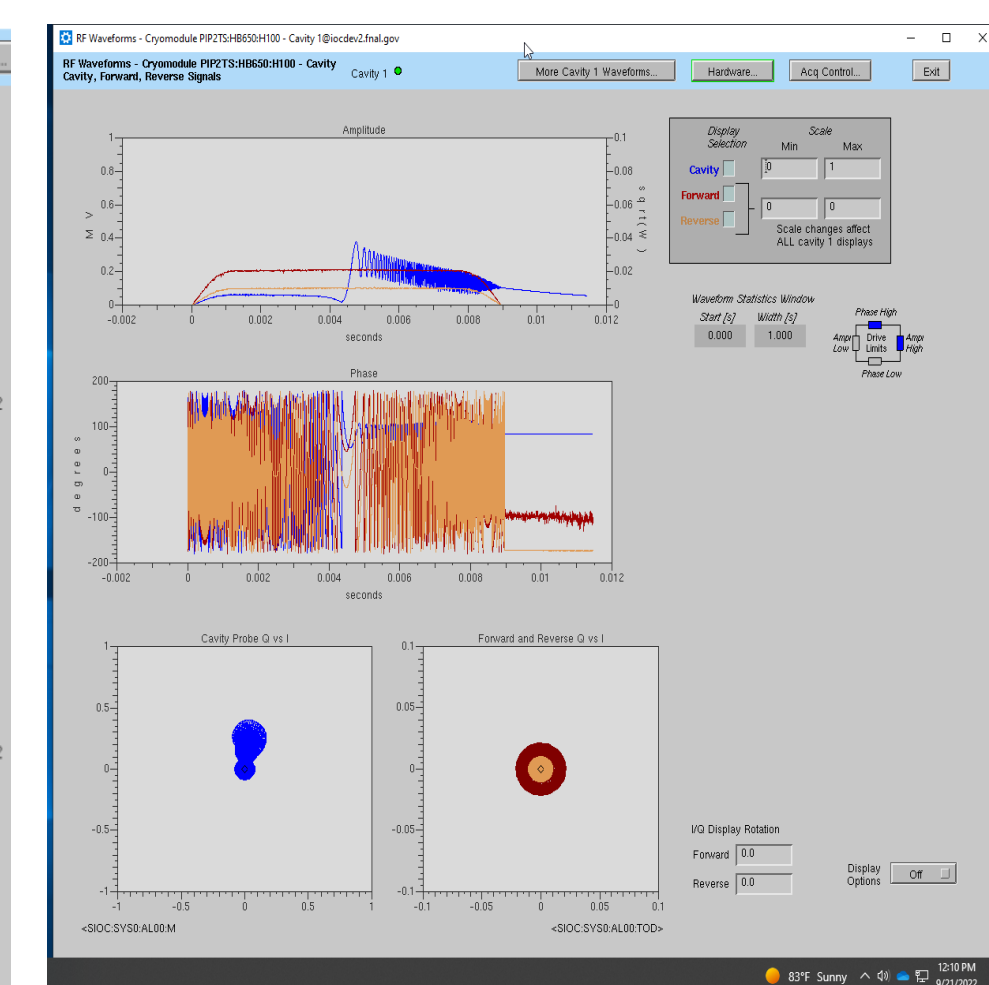


Fig.9 Cavity emulator response to a chirp signal

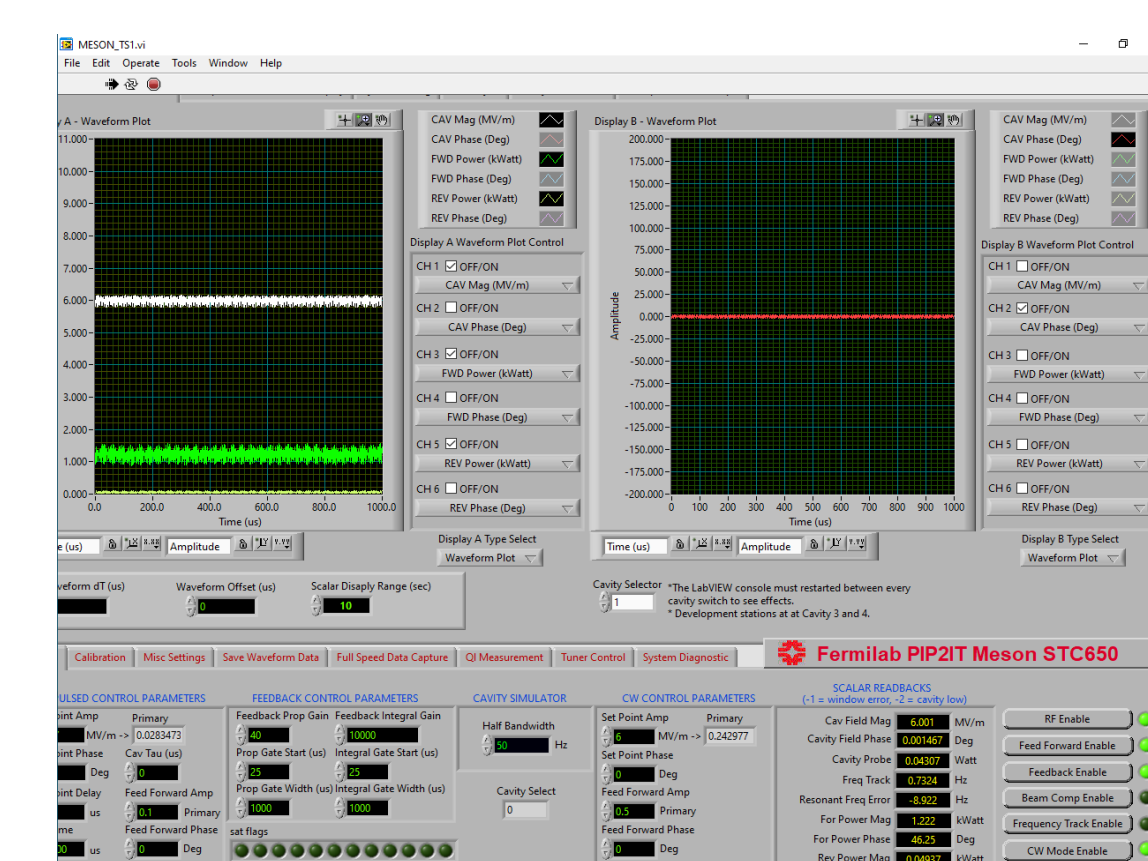


Fig.10 Cavity emulator cavity probe, forward power and reverse power signal magnitudes in GDR mode with feedback

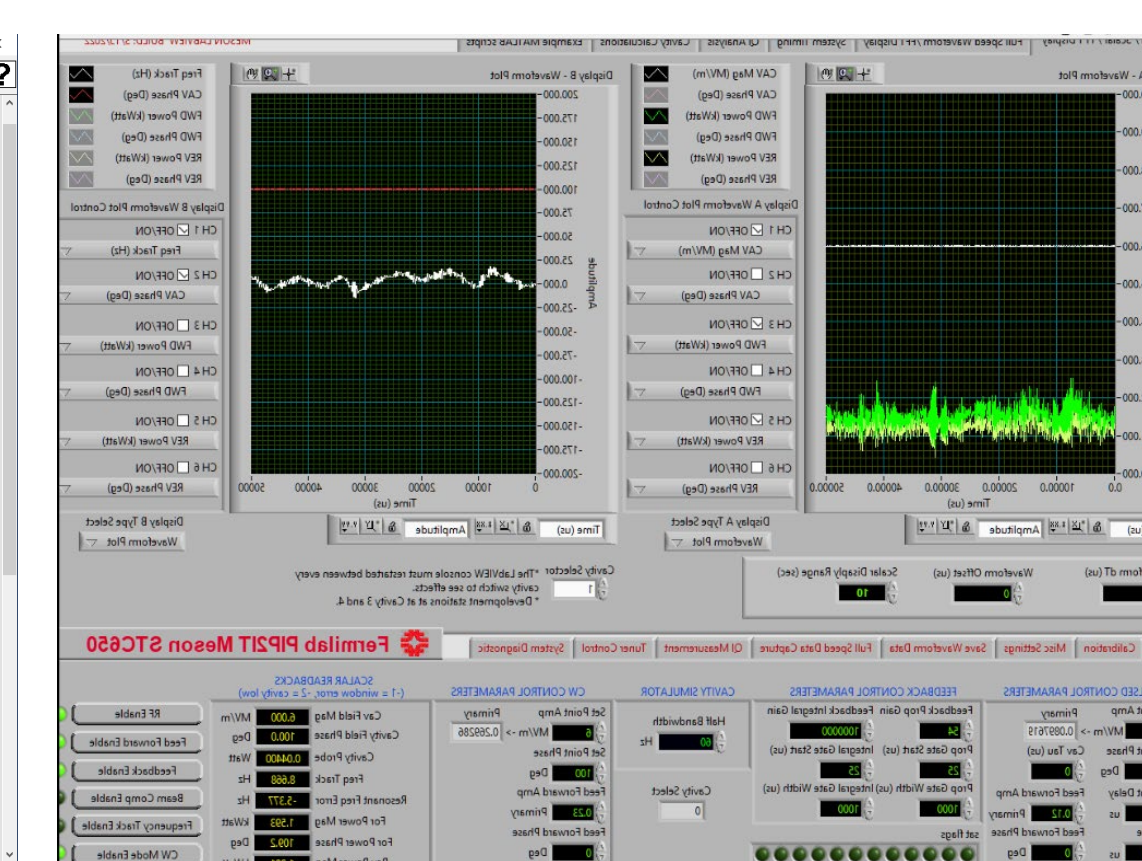


Fig.11 SRF LB650 cavity in GDR mode at 6MV/m



Fig.12 Cavity emulator setup