MICROPHONICS TESTING OF THE CEBAF UPGRADE 7-CELL CAVITY*

G. Davis†, J. Delayen, M. Drury, T. Hiatt, C. Hovater, T. Powers, J. Preble,
TJNAF, Newport News, VA 23606, USA

Abstract

An upgrade cryomodule is being developed for CEBAF at Jefferson Lab. In support of this effort, vibration testing was performed on a single SRF cavity at cryogenic temperature in a Horizontal Test Bed. The tests included response to excitation from background vibration, swept sinusoids, high-power RF pulses, and mechanical impulses. Test procedures, apparatus, and results are presented, along with a description of planned follow-up tests.

1 INTRODUCTION

The CEBAF upgrade cryomodule assembly was tested in a Horizontal Test Bed (HTB) [1] to characterize the effects of vibrations on the cavity resonant frequency. Cavity vibrations cause small dynamic changes in cavity dimensions. When the cavity is locked on-resonance via a phase locked loop (PLL), the RF becomes frequency modulated (FM) by the vibrations (microphonics). The upgrade cryomodule design requires that the modulation due to microphonics be less than 3.5 Hz rms [2].

2 INSTRUMENTATION

The instantaneous frequency was measured in two ways. One method was via the PLL error signal, a voltage proportional to the difference in frequency between the cavity transmitted power feedback signal and the PLL output. The second method used the cavity resonance monitor (CRM) (Figure 1), a custom instrument which uses quadrature detection to produce a voltage output proportional to the instantaneous difference in frequency between the PLL-cavity system and a reference local oscillator.

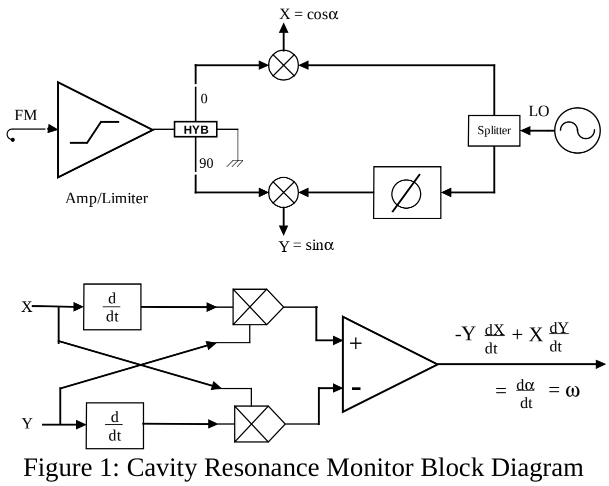

Figure 1: Cavity Resonance Monitor Block Diagram

3 BACKGROUND VIBRATION RESPONSE

The CRM was used to measure the cavity response to background (ambient) vibrations. The RMS spectrum of the CRM output was measured using a Stanford Research Systems SRS 760 FFT Network Analyzer. The results are plotted in Figure 2. The prominent spectral line at 33.7 Hz corresponds to a mechanical resonance (see section 4) which appears in many of the other vibration tests. The peak at 54.7 Hz corresponded to a vibration present in the HTB foundation, as measured with a geophone.

In order to estimate the rms frequency deviation, this frequency domain data was integrated, giving a 2.5 Hz rms frequency deviation, which is below the 3.5 Hz design limit. This value correlates well with a subsequent oscilloscope estimate of 15 Hz pp or 2.5 Hz rms (a common rule-of-thumb divides peak-to-peak by 6 to give rms [3]).

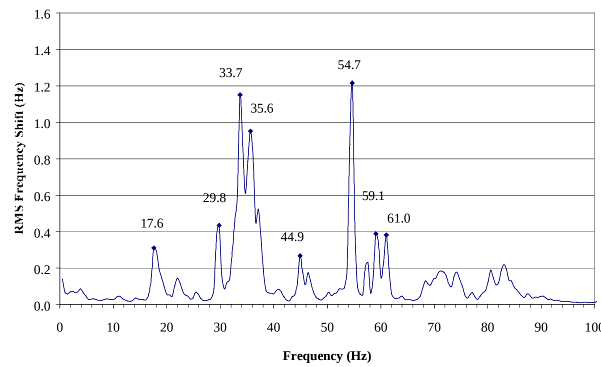

Figure 2: Cryomodule Response, Background Vibration.

4 SWEPT-SINE RESPONSE

A signal generator and amplifier provided sinusoidal drive to a loudspeaker attached to the fundamental power coupler waveguide, thereby coupling vibrations into the cryomodule. This test setup is shown in Figure 3. The signal generator output frequency was manually swept from 0.1 to 100 Hz. An accelerometer attached to the waveguide provided a reference signal, while the PLL error signal provided the system response signal that was fed into an FFT analyzer. The only prominent peak in the response occurred at about 34 Hz. Signals were recorded at 32, 34, and 36 Hz. While the input remained constant within 10%, the output increased by almost an order of magnitude at 34 Hz (Figure 4).

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†kdavis@jlab.org

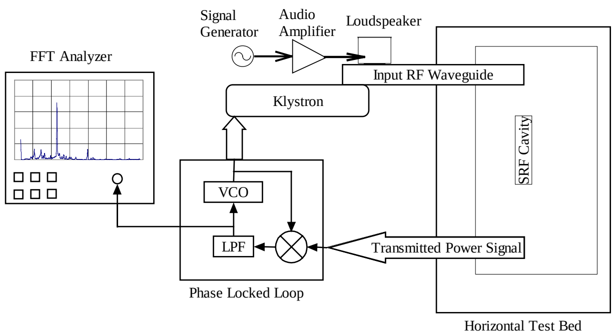

Figure 3: Swept Sine Test Setup.

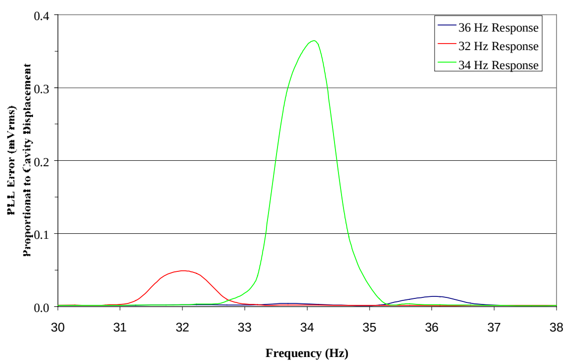

Figure 4: Swept Sine Responses, 32, 34, 36 Hz Vibration.

5 RF PULSE RESPONSE

While pulsing the superconducting cavity with high-power RF, the PLL error signal was recorded. A 50% duty cycle pulse train was generated at various frequencies from 5 to 25 Hz. A frequency shift due to Lorentz force detuning [4] was noted, as expected (Figure 5). Any pulse-induced microphonics would cause deviation from the expected square wave response. No microphonic effects were noted.

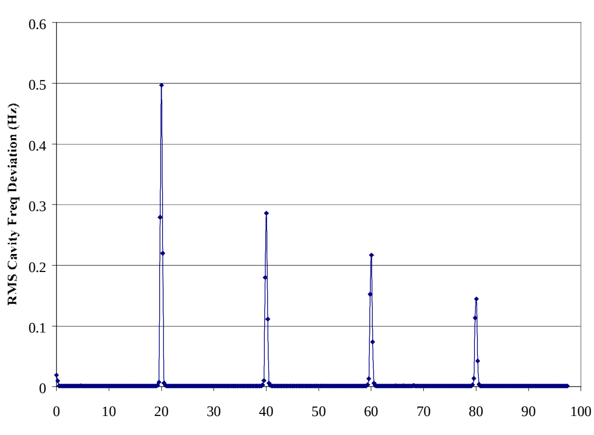

Figure 5: RF Pulse Response, 20Hz.

6 IMPULSE RESPONSE

The cryostat response to mechanical impulse was measured. A PCB model 086C05 modally tuned hammer was used to strike the cryostat in forty different locations. The reason for performing so many impulse responses was to attempt to correlate particular vibration modes with the locations that excited them most strongly. This would provide information on which frequencies would couple in through various cryostat connection points from the outside world. The output of the CRM was processed using the FFT analyzer. Four peaks in the output response suggest mechanical resonance modes at 22, 34, 89, and 162 Hz. The relative response of these modes varied from one input blow location to another. The response from the cryostat foot (return end, tuner side) is shown in Figure 6. This particular response is presented here because all four modes are visible. This situation was seldom the case; most locations excited only two or three of the modes. This location is also significant because the support is a likely path for ground-borne vibrations to couple into the cryostat. Note that the 60 Hz peak shown in Figure 6 is due to background electrical noise, rather than mechanical vibration. Once again (see section 4), the 34 Hz mode dominates the response.

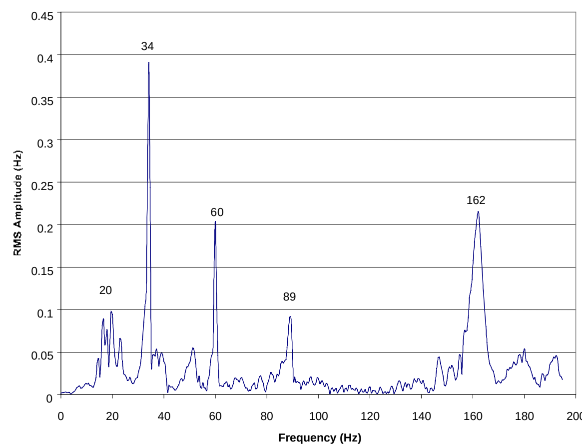

Figure 6: Cryomodule Impulse Response.

7 FUTURE TESTING

Improvements to Jefferson Lab's infrastructure for vibration testing are underway. A four-channel dynamic signal analyzer has been procured, allowing muti-channel measurements such as correlation between excitation and cavity response. Furthermore, a modal test shaker is now available to excite the structure under test.

Using this new equipment, room-temperature vibration testing of the cavity-tuner assembly using accelerometers is planned in order to understand and, if necessary, control the upgrade cavity-tuner vibration modes. Furthermore, a detailed understanding of the frequency response function for each vibration entry point into the cryostat will be measured.

A planned upgrade to the HTB cryogenic system should stabilize pressure fluctuations to allow more accurate measurements to be performed. For example: long-term histograms of microphonic frequency shifts, and overall improvement in S/N ratio.

Finite element models of SRF cavities are being developed, which will be compared to test results.

Accurate simulations will be used to shorten design cycle time.

The methods used to perform cold testing of the cavity are indirect. Research is planned that will test commercial off the shelf accelerometers at cryogenic temperatures. This will allow more direct methods of measuring specific components, rather than the overall system response.

8 CONCLUSIONS

The CEBAF upgrade 7-cell cavity and tuner assembly, as tested in the HTB, exhibits rms frequency swings of 2.5 Hz, which is below the 3.5 Hz rms design limit. This value meets the requirements, assuming that ambient vibrations in the HTB are similar to those in the CEBAF machine. Some comparison tests are planned to evaluate this issue. A resonant mode at 34 Hz that dominates the system response was identified. Further testing is planned that will determine the source of this resonance.

9 ACKNOWLEDGEMENT

Thanks to Mark Wissman at Jefferson Lab for fabrication and testing of the Cavity Resonance Monitor instrument.

10 REFERENCES

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