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TESTING OF SSR1 PRODUCTION TUNER FOR PIP-II*

J. P. Holzbauer†, D. Passarelli, Yu. Pischalnikov, Fermilab, Batavia, IL 60510, USA

Abstract

The PIP-II project at Fermilab is a proton driver linac calling for the use of five different, novel cavity geometries. Prototyping at Fermilab is in the advanced stages for the low-beta single-spoke resonator (SSR1) and associated technologies. A production tuner design has been fabricated and tested, both warm and cold in the Spoke Test Cryostat (STC). This paper will present the detailed studies on this tuner, including slow motor/piezoelectric tuner range and hysteresis as well as dynamic mechanical system characterization.

INTRODUCTION

Integrated testing of an SSR1 cavity included prototype high power RF coupler and mechanical tuner was successfully completed in 2014 [1,2]. Lessons learned in this test were applied to the tuner design including new piezo encapsulations and cavity tuner interface improvements.

This tuner was fabricated, then tested, first warm then cold, to verify performance in the Spoke Test Cryostat at Fermilab [3].

Tuner performance was found to meet specifications including, range, sensitivity, and hysteresis.

The tuner assembled during warm testing can be seen in Figure 1. Tuner design includes an electromagnetic actuator designed and piezoelectric actuators that act on the cavity in series. The first is meant for long-range slow tuning, and the second is to be used for fast, fine tuning.

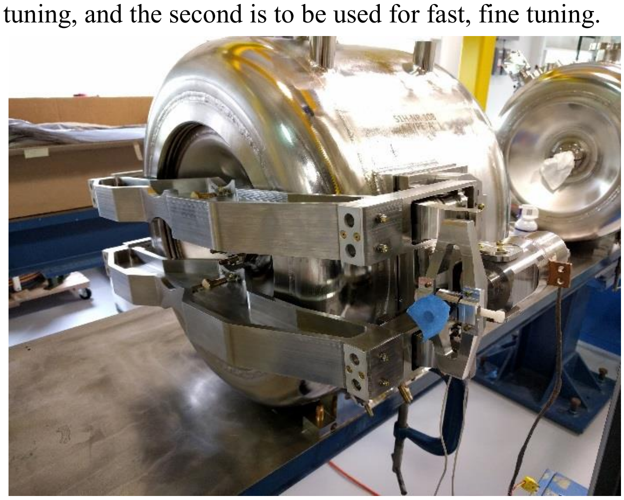

Figure 1: First article of the prototype SSR1 tuner assembled on a cavity.

WARM TESTING

The first article was mocked up on an SSR1 cavity warm and tested for tuning sensitivity and stiffness by RF measurement, direct movement with micrometer, and load cell.

Setup of the tuner includes mounting first the tuner arms to the cavity helium vessel as well as the assembled actuator package on the opposite end of the helium vessel (right in Figure 1). Fine adjustment on the arm mounting is then used to align the two sections for final attachment. The tuner actuators are then tensioned via preload screws on each piezoelectric actuator. The final adjustment is setting the gap between the tuner arms and the cavity vessel. This is done with screw adjustments on either arm, contacting the cavity on either side of the beamline flange.

Slow Tuner Measurement - Warm

In preparations for cold testing, the gap between tuner and cavity flange is set at 1.15 mm to compensate for differential thermal contractions in the tuner/cavity system. This procedure is critical to avoid the overload of cavity and tuner due to the vessel made of stainless steel shrinking more than the niobium cavity during cooldown. Also, this allows the tuner to start in the neutral position, allowing maximal tuning range.

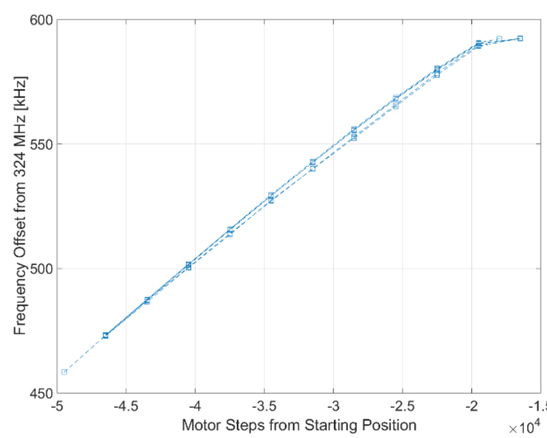

Figure 2: Tuning sensitivity with the slow tuner. Contact with the cavity and loading are visible on the right.

The cavity tuning sensitivity was measured at ~4.4 Hz/step, with a slight slope in sensitivity based on loading. Long range hysteresis was observed, but short range scans showed significantly less hysteresis, below the measurement sensitivity of the warm RF measurements (100-200 Hz). This measurement was repeated with solid metal blanks in place of the piezo tuners to determine if they were the source of the hysteresis, but the measured curve was within measurement errors of the curve with piezos.

Fast Tuner Measurements - Warm

Two encapsulations are used for the piezo tuners, each containing two piezoelectric stacks. This encapsulation was developed in collaboration with PI [4] with many

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†jeremiah@fnal.gov

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features to improve tuning performance, including internal preloading and mechanical features to reduce sheer forces on the piezo ceramic. Each stack measured ~6.5 uF, and is rated to 0-120 V applied differential voltage when operating cold. Warm, the applied voltage is limited to 0-60 V.

The piezo voltage was scanned from 0 to +60V by 20V increments several times at three different slow tuner positions (-5, -65, and -125 kHz). These scans were done energizing both encapsulations together, and each encapsulation individually. These results can be seen in Table 1.

Table 1: Piezo Tuner Sensitivities in [Hz/V] as Energized in Different Configurations

Loading [kHz]	Both Piezos	Piezo 1	Piezo 2
-5	-36.7	-18.1	-18.4
-65	-41.5	-20.3	-20.9
-125	-43.2	-21.7	-21.7

These measurements show the slight increase in sensitivity at higher loading, but still give most of the stroke even at the bare minimum of loading. Additionally, the piezos are mounted so as to give nearly linear addition of the two piezo encapsulation strokes. Measurement bares out this performance. An example of the piezo hysteresis can be seen in Figure 3.

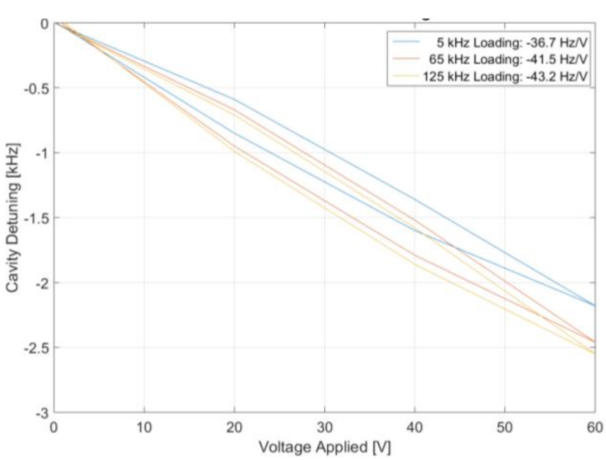

Figure 3: Production tuner hysteresis scans with all piezos energized at various cavity loadings.

Course Tuning Efficiency Measurement

Direct measurement of the course tuner efficiency was done with a micrometer measurement of relative motion of the tuner while operated on the cavity.

The micrometer measurement setup can be seen in Figure 4, one on the beam pipe and one on the motor traveling nut. Using the motor to actuate the tuner, arm motion was compared cavity flange motion. This gave a course tuning efficiency of:

$$\frac{X_{BPc}}{X_C} = 8.8\%.$$

This measured value is lower than the requirement of 37%.

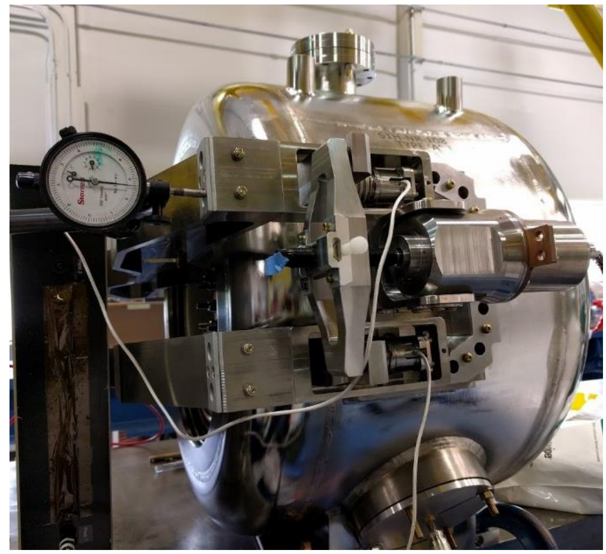

Figure 4: Stiffness measurement as measured with relative tuner component motion.

COLD TESTING

The first-article production tuner was assembled on SSR1-S112, a dressed SSR1 cavity to be tested in STC. The tuner was assembled as intended for a standard cold test, with the relaxed tuner set with a 1.15 mm gap between tuner probes and cavity beam-line flanges.

Slow Tuner Measurement - Cold

Thermal contraction of the cavity/tuner system reduces the gap between the cavity and tuner probes. Previous cold tests have shown that this reduces the set gap by ~0.75 mm. The remaining gap of ~400 µm translated to 23 kSteps of motion until contact was made with the cavity, in line with previous cold testing.

Figure 6 shows the full range scan from cold landing position to high loading. The full tuning range of this tuner is 0 to -135 kHz, and the cold landing frequency of 325.105 MHz, meaning that this cavity could be successfully tuned to the design frequency: 325 MHz.

The tuning sensitivity was measured at low loading, the mid-range of the tuner, and full loading. The measured tuning sensitivities matched warm results as well: [-4.3, -4.4, -4.5 Hz/step]. Not only is the actual sensitivity well matched with warm measurements, the excellent tuner function at low loading and small dependence on loading see in the warm piezo measurements is repeated. As is traditional to this motor design [5], the measured back lash is ~30 steps, or ~125 Hz in this application. This number was consistent at the various loadings.

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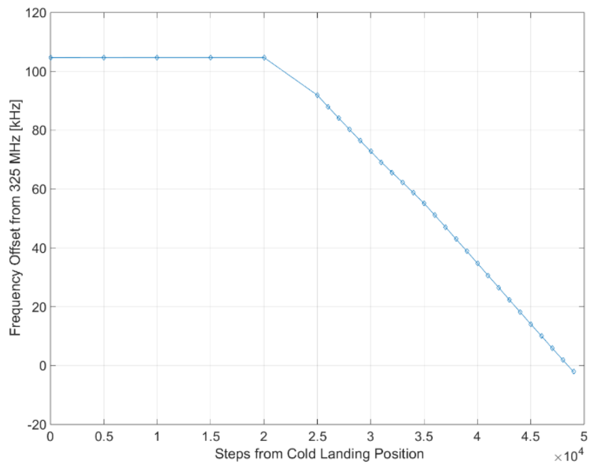

Figure 5: Full range scan of the cold cavity using slow tuner. Cold landing position can be seen on the left.

Fast Tuner Measurement – Cold

Piezo tuner performance was verified cold, including range and sensitivity at various loadings. Linearity of the two piezos together was also verified. The tuning sensitivity at low, moderate, and full loading was: [-13.8, -13.8, -13.0 Hz/V]. The drop in sensitivity from warm to cold is commensurate with the significant drop in capacitance of the piezo electric stacks.

CONCLUSION

The first article of the production SSR1 cavity mechanical tuner was fabricated and tested at FNAL for the PIP-II project. This tuner was measured warm and verified assembly procedures, tuning sensitivity, and tuning efficiency. Cold testing of this tuner on a dressed SSR1 cavity was able to demonstrate tuning range and sensitivity of the slow tuner and fast piezoelectric tuner. This tuner design is considered validated.

REFERENCES

[1] A. Sukhanov *et al.*, "Result of Cold Tests of the Fermilab SSR1 Cavities", in *Proc. of the 2014 LINAC Conf. (LINAC'14)*, Geneva, Switzerland, August 2014, THPP057.

[2] D. Passarelli *et al.*, "SSR1 Tuner Mechanism: Passive and Active Device", in *Proc. of the 2014 LINAC Conf. (LINAC'14)*, Geneva, Switzerland, August 2014, TUPP052.

[3] D. Passarelli *et al.*, "Performance of the Tuner Mechanism for SSR1 Resonators during Fully Integrated Testing at Fermilab", in *Proc. of the SRF2015*, Whistler, BC, Canada, THPB061.

[4] Y. Pischalnikov *et al.*, "Reliability of the LCLS-II SRF Cavity Tuner", in *Proc. of the SRF2015*, Whistler, BC, Canada, THPB065.

[5] J.P. Holzbauer *et al.*, "Performance of the SRF Cavity Tuners at LCLS-II Prototype Cryomodule at FNAL", in *Proc. of the LINAC2016*, East Lansing, MI, USA, THRPC017.