The Variable Input Coupler for the Fermilab Vertical Cavity Test Facility

Mark Champion, Camille M. Ginsburg, Andrei Lunin, Wolf-Dietrich Moeller, Roger Nehring, and Valeri Poloubotko

***Abstract*— A variable input coupler has been designed for the Fermilab vertical cavity test facility (VCTF), a facility for CW RF vertical testing of bare ILC 1.3 GHz 9-cell SRF cavities at 2K, to provide some flexibility in the test stand RF measurements. The variable coupler allows the cavity to be critically coupled for all RF tests, including all TM010 passband modes, which will simplify or make possible the measurement of those modes with very low end-cell fields, e.g., π/9 mode.**

The variable coupler assembly mounts to the standard input coupler port on the cavity, and uses a cryogenic motor submerged in superfluid helium to control the antenna position. The RF and mechanical design and RF test results are described.

***Index Terms*—Cavities, couplers.**

I. INTRODUCTION

THE Variable Input Coupler (VIC) was developed to provide the possibility to adjust the position of the antenna during the test of 1.3GHz 9-cell RF cavities, allowing us to find the critically-coupled position for each cavity.

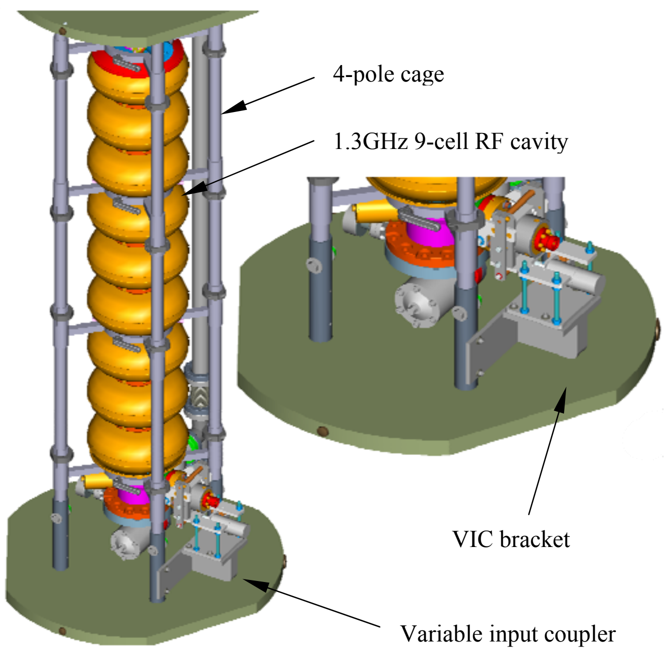

Fig. 1. The test stand insert with mounted VIC.

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Mark Champion, Camille M. Ginsburg, Andrei Lunin, Roger Nehring, and Valeri Poloubotko are with Fermilab, Batavia, IL, USA (phone 630-840-8310, e-mail: polub@fnal.gov). Wolf-Dietrich Moeller is with DESY, Notkestrasse 82, 22607 Hamburg, Germany.

The VIC design can be used for a single or a double cavity version of a test stand insert. Each cavity, having its own coupler, is independently coupled. The antenna's linear drive is rigidly attached to a standard cavity coupler port and a cavity 4-pole cage with an adjustable bracket for the coupler mounting, as shown in Fig. 1. Only the RF and the motor drive system cables penetrate into a superfluid helium bath to provide input RF power to the antenna and complete monitoring of the device.

II. THE VARIABLE INPUT COUPLER DESIGN

The Vertical Test Stand Facility was designed to accommodate two 1.3GHz 9-cell RF cavities [1]. It does not allow the use of the traditional schematic of a variable input coupler used at DESY (Germany) and KEK (Japan) test facilities, when a RF cavity moves relative to a fixed coaxial antenna [3-7].

The Fermilab variable coupler, connected to a cavity perpendicularly to its axis, consists of an antenna housing, a linear drive, and a motor drive system which specifies the displacement of the antenna and control parameters of the stepper motor during operation.

A. RF Design

The RF simulation with Ansoft HFSS was developed to find the coupler requirements. The results are shown in Fig. 2. The antenna motion, R, is perpendicular to the cavity axis in order to conserve vertical space in the cryostat. A 75 Ohm copper antenna is used to minimize the weight and the RF loss. The impedance mismatch simulation shows an 11 dB return loss, but there is no resonance in the antenna itself [8].

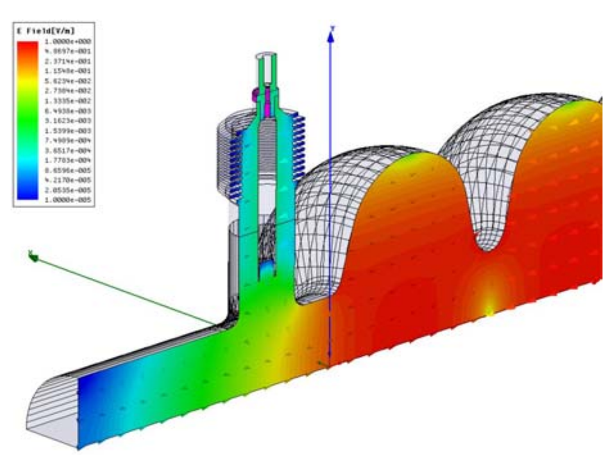

Fig. 2. RF simulation (π-mode) for the VIC design.

The required Qext range was determined from experience at the DESY TTF to be $2\times10^9 < Qext < 4\times10^{10}$. The corresponding required coupler range is shown in Fig. 3 to be about DR=15 mm.

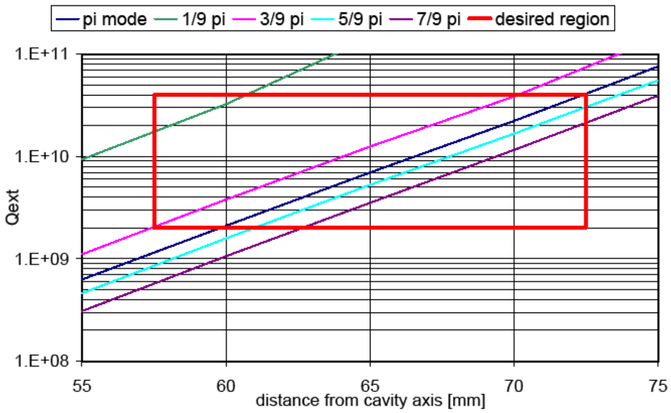

Fig. 3. VCTF variable input coupler Q_{ext} as a function of coupler movement range.

B. *Mechanical Design and Installation*

As noted above, the variable input coupler consists of three main components, i.e., the antenna housing and the linear drive, and two flange holders that prevent a transition of tension/compression forces to the coupler port of a cavity, arising inside the device during its operation, shown in Fig. 4.

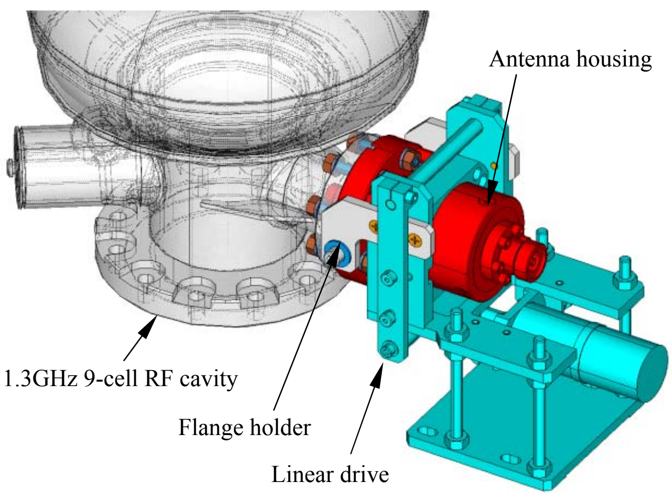

Fig. 4. The components of the Fermilab variable input coupler.

The assembly of the antenna housing and its installation on a cavity are performed in a Class 10 clean room. The bellows, welded between a mini CF flange and a diamond seal flange, is assembled together with a cartridge. Round spacers are placed between the cartridge collar and the flange, as shown in Fig. 5, stabilizing the assembly and preventing its collapse by the vacuum. The RF antenna and META CERAM RF feedthrough previously connected together are mounted in the mini CF flange. Finally, the antenna housing is attached to the cavity. Then the cavity is covered with the 4-pole cage and inserted in the top plate assembly outside of the clean room. This chain of actions allows us to prevent contamination of the cavity.

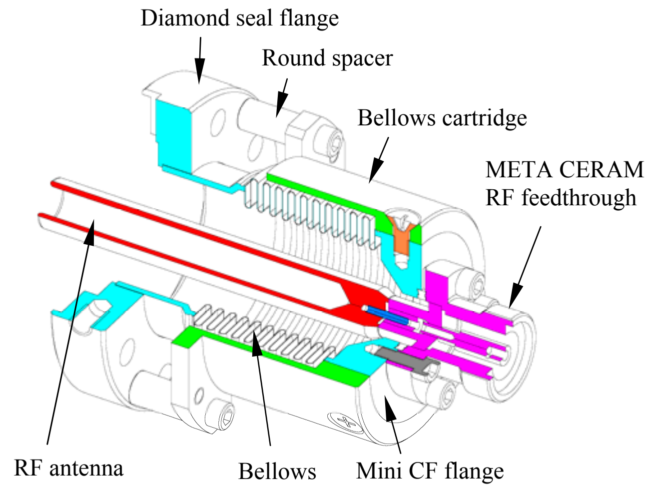

Fig. 5. The antenna housing is ready for the installation on the 1.3GHz 9-cell RF cavity.

The linear drive is a lever mechanism combined with a mechanical actuator which converts a rotary motion of a screw into the lever turning via a motor to which the screw is attached (Fig. 6). The Phytron UHV stepper motor spinning the screw is operated in a liquid or superfluid helium environment. The levers of the mechanism, swinging around the top pivot (fulcrum), push or pull the shoulder screws attached to the guide ring. The linear motion of the guide ring is created in slots with help of the linear bearings.

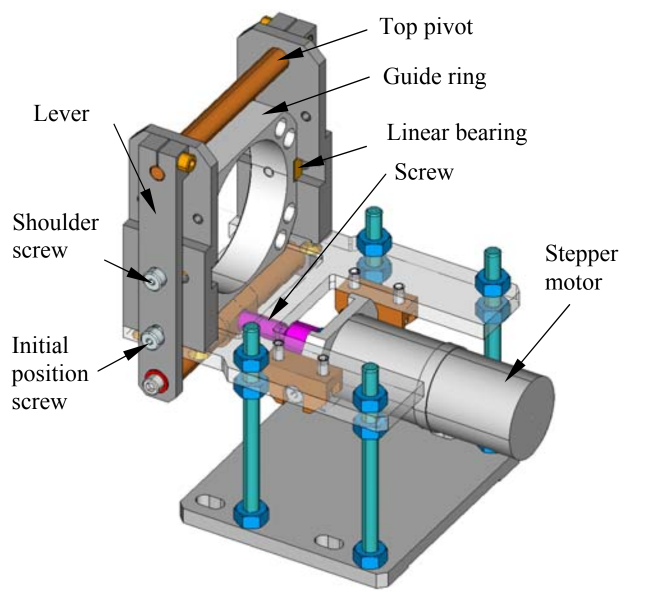

Fig. 6. The linear drive adjusts the position of the RF antenna relative to RF cavity axis.

The lever arms have special holes allowing us to place the guide ring in its initial position, also referred to as the “zero” position. It allows us to begin a test from the same point every time.

Then the level mechanism can be installed in the top plate assembly in the following way:

1) The guide ring is connected to the bellows cartridge.
2) The flange holders are bolted to the level mechanism

frame and the diamond seal flange.

3) A RF cable is attached to the RF feedthrough via the adapter.
4) The round spacers and the initial position screws must be removed from the subassemblies.

The final assembled variable input coupler is shown in Fig. 7.

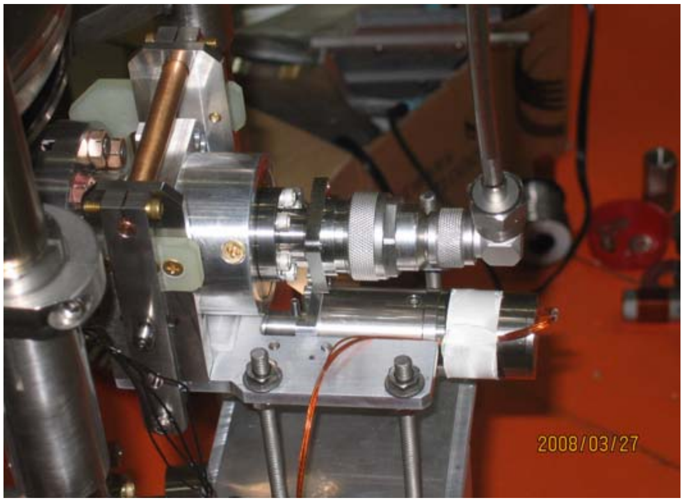

Fig. 7. The variable input coupler is installed on AES3 cavity.

C. Motor Drive System

The variable coupler motor drive system consists of a Phytron mini controller, two power sources, a temperature monitoring device, an emergency stop button and a LABVIEW software program to operate the motor.

The Phytron controller (model MCC-2 32-48) is a low cost, 2-axis "stand-alone" controller designed to be compatible with Phytron's small, low torque stepper motors. Programming/communication with the controller is done through RS232 serial communication. Since there is no "high speed" communication required to operate or monitor the controller, RS232 serial communication seems to be adequate. One important feature the controller has is the capability to programmatically adjust the motor's drive and the holding current. Since the motor requires no holding current while not running, it was determined that it should always remain at "zero". This eliminated some concerns of possible overheating of the motor during the absence of an operator or when the software was not running. The controller also requires a small low cost 48VDC power source to drive the motor and a 24VDC power source for I/O logic. An additional MiniLog-COMM software package came with the controller; however we used this software for preliminary software development and troubleshooting only.

Some concerns arise about motor temperature and possible overheating during the operation. The Omega DP63500T Temperature Monitor Device (TMD) is used to monitor a platinum RTD-100 resistor mounted on the outside casing of the motor. If the temperature exceeds an adjustable set point above the ambient dewar temperature, the limit switch from the TMD which is connected to the controller interrupts power to the motor independent of any software operation. Once the temperature falls below the set point, motor control operations can resume via operator intervention. An emergency switch is also connected to the Phytron controller in the event that an operator feels the need to stop the movement of the motor, once again independent of any software operation.

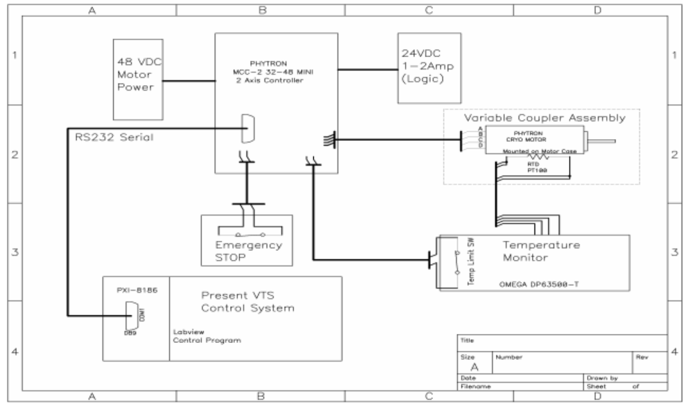

Fig. 8. The block diagram as a schematic representation of the Variable Input Coupler's Motor Drive System.

In order to have a smooth integration of the Variable Input Coupler's Motor Drive software into the present ILCTA_VTS test stand data acquisition system [2] the Phytron controller's commands must be written in LABVIEW 8.2. There was no software driver available from either Phytron or National Instruments so we had to write our software code based on Phytron's list of commands in their programming manual. The VCTF test stand has a NI-PXI-8186 controller presently installed and in use for the VCTF controls so that the LABVIEW software for the motor control is installed on it. Communication with the PXI controllers RS232 port is shown in Fig. 8.

The LABVIEW program has several features that allow for easy motor operation including:

1) It allows the operator to specify antenna travel distance of the coupler in coarse, medium or fine motor steps in and out of the cavity.
2) Several readouts allow the operator to both read and adjust the motor currents as well the pulsing (rotational speed) frequency of the drive signal.
3) Although there is no position feedback on the motor such as an encoder, the program keeps track of the Phytron controller's internal counter. The slide bar and a digital readout give the operator a value of the coupler position in millimeters from a center position that is shown in Fig. 9.
4) If the TMD temperature reading exceeds the set point, both the motor and the last recorded count value are stored in a file. An LED indicator allows the operator to monitor when the limit switch has cleared.
5) If the operator should decide to stop the motor movement by pressing the emergency stop button, once again, the motor will stop and the last recorded position will be stored in a file. Motor movement can resume after a 20 second time out period and the emergency button is cleared.
6) The operator can also store the coupler position in a file and read the last position stored.

7) Different dialog prompts will pop-up at different times to assist the operator with making correct choices.
8) If the coupler should approach the +/- end limits, the slide bar will turn red and will not let the operator jog the motor past a present limit value.

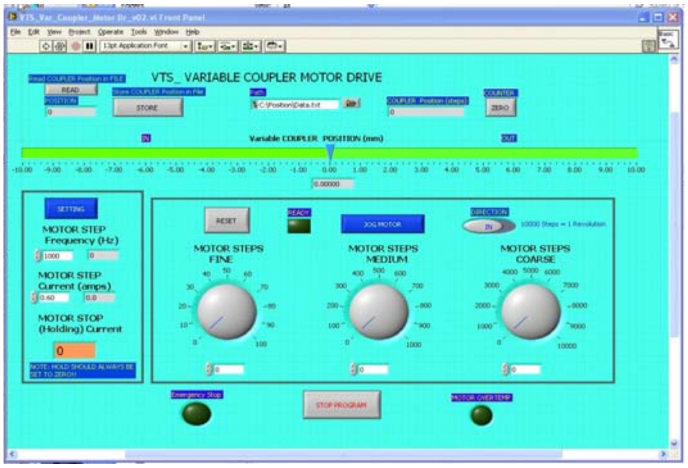

Fig. 9. The LABVIEW user friendly interface to control the Variable Input Coupler's Stepper motor.

D. *Testing of the Coupler*

Two mechanical tests were performed to confirm the functionality of the mechanical components of the antenna housing and the linear drive under such cryogenic conditions. During the first test, the operational reliability of the linear drive was confirmed with help of a limit switch that registered the end position of the lever. Also this test showed the ability of the stepper motor to work in a superfluid helium bath. The second test gave us opportunity to check the quality of the bellows welds. The bellows welded assembly remained leak-tight after more than ninety compression-extension cycles.

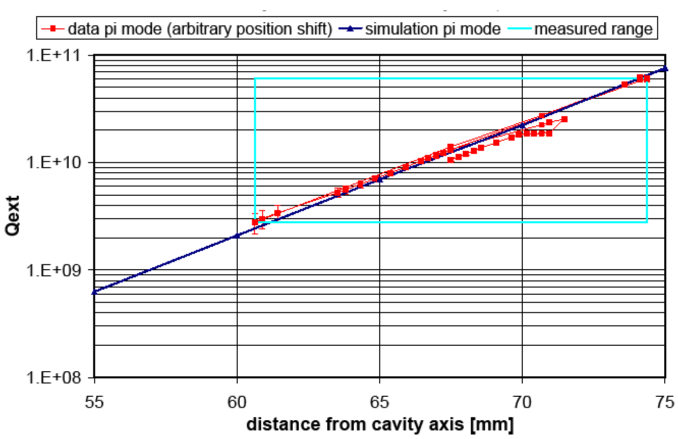

Fig. 10. Variable Coupler Test with AES3 Cavity, April 3, 2008, Fermilab.

The AES03 cavity equipped with the variable coupler was tested at the VCTF in April 2008. The result is shown in Fig. 10. The measured range of external quality factor was $2.8x10^9 < Q_{ext} < 6x10^{10}$ corresponding to a measured antenna movement DR=13.75mm. The shape of the simulation and the actual experimental data agree very well. The various linear trends correspond to forward and backward antenna movements and the minor difference in Q_{ext} values is explained by an uncertainty of absolute antenna position of about 0.5 mm.

III. CONCLUSION

The Fermilab variable input coupler is now being used for the testing of 1.3GHz 9-cell cavities. The first results of the testing confirm reliability of the chosen design of the coupler. The following cavity tests will allow us to find the optimal parameters for the motor drive system and the best procedure for VIC installation.

ACKNOWLEDGMENT

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