WIDE BANDWIDTH LOW COST SYSTEM FOR CAVITY MEASUREMENTS

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Abstract

Recently we developed a novel measurement apparatus that simplified the tests of superconducting cavities. A few commercial electronic boards, mounted in a devoted chassis and controlled by a PC, operate most of the functions usually carried out by standard RF instrumentation. The set up allows the measurements of resonators in the 80-700 MHz frequency range and we used it to characterize resonators both in the ALPI vault and in off-line tests.

Upgraded control program carries out all the typical procedures, related to the cavity measurements in classical VCO-PLL system. It allows to adjust and to measure the RF forward power, to find and update the cavity resonant frequency, to calibrate the pick-up signal, to monitor the transmitted power, to adjust the coupler position. The implemented automatic procedures permit to measure the cavity decay time, to trace the Q-curve, to perform CW and pulse RF conditioning, to calibrate cables and measurement instruments.

The same software applies to the other two measurement systems routinely used at Legnaro to test resonators up to 6 GHz frequency.

INTRODUCTION

Our first experience was a PC based measuring system for 160, 1300, 1500 and 6000 MHz cavities [1, 2, 3] now used for the characterization of Tesla type cavities in the Superconductivity Laboratory at LNL.

Some years ago, we developed in house a second similar movable RF system covering 80, 160 and 350 MHz [4]. We extensively used it for the characterization of ALPI superconducting cavities produced by Nb sputtering at LNL and Superconducting RFQs. Both measuring systems showed over time to be reliable and easy to use.

Due to radioprotection access restriction, it was not so easy to move the system in and out the accelerator vault, thus making difficult to share it for Q-measurement in laboratory and on line.

Recently we found the way of setting up another system which consists mainly of old RF equipment already present in laboratory (RF generator, frequency counter, DC amplifier), integrated by a digital scope and by commercially available, low cost, electronic devices which make the functions of phase shifter, phase detector

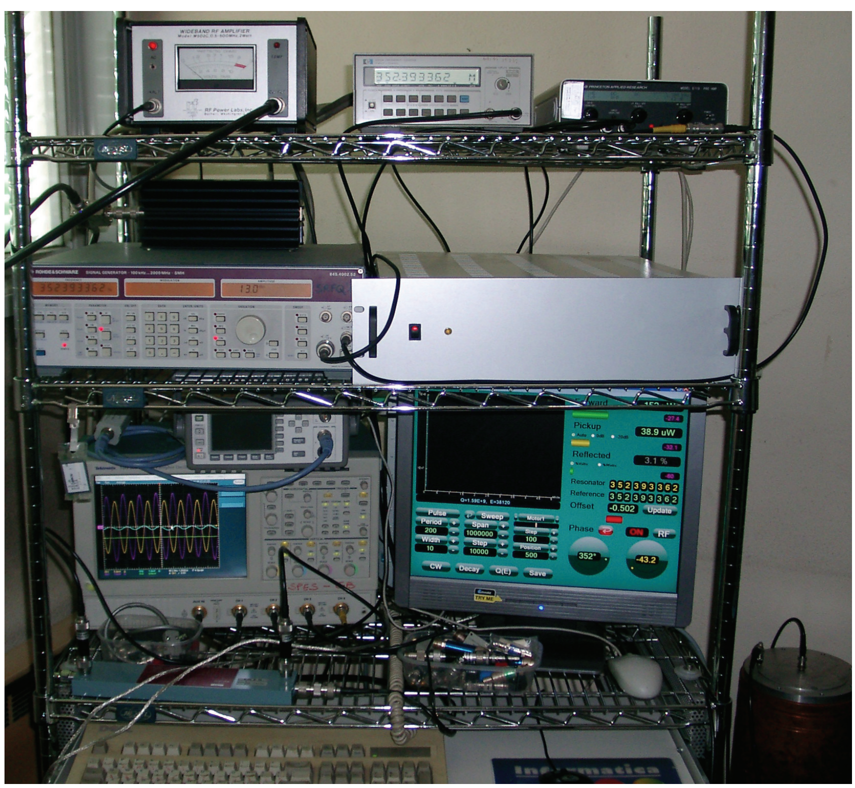

Figure 1: Measurement system for cavity characterization.

and variable gain amplifier and which are also PC controlled. In this way, we could avoid the traditionally used, more expensive RF components.

The set up of the new system gave us also the opportunity to upgrade the control software to improve the measurement accuracy and make it easier to use.

The new apparatus made it possible to repeat the Q-curve measurement of all the sputtered cavities installed in ALPI [6] and to perform recent characterization of the 352 MHz ladder cavity at LNL.

RF MEASURING SYSTEM

The low-level RF resonator testing systems can take advantage of the conventional electronic devices for various cellular phone and wifi applications.

As a matter of fact, the frequency range of many of these devices covers the typical RF cavity frequencies up to 2000 MHz. Other characteristics, such as time and temperature stability, are also at a very good level due to their integrated temperature compensation. Moreover, the differential design brings low noise feature valuable in the generally very noisy accelerator environment. Both the low voltage power supply and reduced power consumption, typical for cellular phone applications, are a further advantage for a movable system.

Fig. 2 presents the new measuring system layout. GPIB and RS232 buses connect the RF Signal Generator, Oscilloscope, Frequency Counter and DC Amplifier to computer.

The operating frequency determines the choice of power amplifier.

A unique chassis includes all the other low power RF components. Computer communicates with it through USB board having 32 digital IO lines for device control and 3 counters/timers that form a pulse generator for cavity conditioning. The chassis houses also the power supply for all the installed devices.

Analog Devices components perform the functions of the phase shifter, phase detector and variable gain amplifier.

Phase Shifter

The combination of Analog Devices AD8345 and AD9761 chips gives us the possibility to create the digitally controlled Phase Shifter. The AD8345 is a low noise, wide dynamic range quadrature modulator with 50 Ω buffered output. To drive it the AD9761 is used that is a dual channel, high speed (40 MSPS), 10-bit DAC. Each DAC provides differential current output with a nominal full-scale current of 10 mA. The I and Q input data are latched to the corresponding registers. Both DACs are then simultaneously updated [5].

The Phase Shifter is quoted to operate from 140 to 1000 MHz, but we found it has still quite acceptable performance down to 50 MHz.

Phase Detector

We have the possibility to use the gain and phase detector AD8302, which integrates two closely matched wideband logarithmic amplifiers, a wideband linear multiplier/phase detector, a precision 1.8 V reference, and analog output scaling circuits. It covers the range from

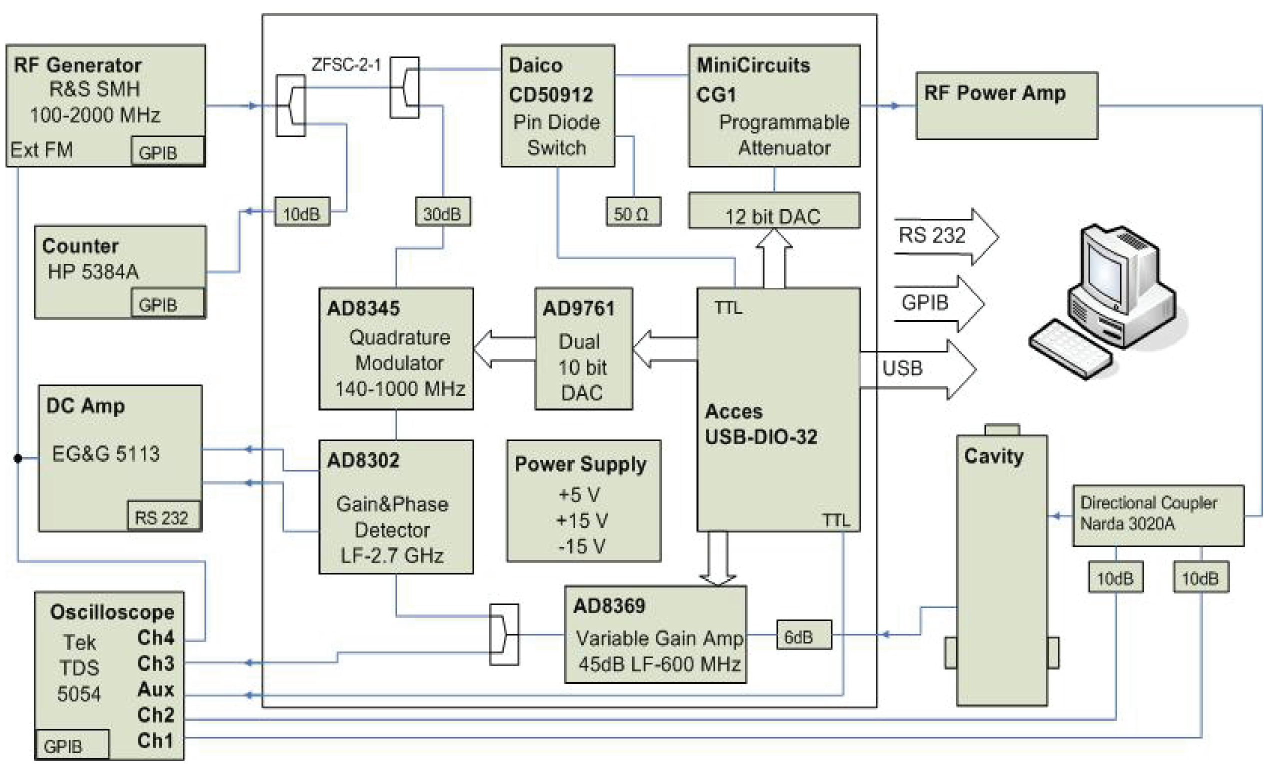

Figure 2: Measurement circuit for cavity characterization.

low frequencies to 2.7 GHz with dynamic range of 60 dB and provides the phase measurement over a 0 to 180 degree range scaled to 10 mV/degree. The applied input signal can range from -60 dBm to 0 dBm (50 Ω) [5].

Variable Gain Amplifier

We chose to use the AD8369 as variable gain amplifier. It is a 600 MHz, 45 dB, Digitally Controlled VGA. Its gain is controlled in 3 dB steps through either parallel or 3 wire serial control. It features high gain stability, flatness and low distortion [5].

SOFTWARE UPGRADE

We upgraded the original control program, developed in Visual Basic, to MS Visual Studio 2005 (Net 2.0). It covers the new apparatus and the previous measurement systems in order to use it for all of them.

The modular structure of the software permits a more flexible hardware configuration in the case of instrumentation substitution or upgrade.

The extended use of mouse wheel facilitates frequency, power and phase adjustment.

The main program window now contains the stepper motor control panel for the antennas and tuner movement.

The new tabbed options window permits to write the measurement diary, to consult and to change setup parameters, to view the acquired data and to visualize the measuring systems hardware configuration. We are finishing the upgrade of the previously developed RF Calculator for computer assisted measurement and data verification and visualization to add it to the options window [4].

Fig. 3 presents the program main panel. There is a chart section to show the behavior of the variables of the activated automatic procedure.

The frequency sweep procedure gives the possibility of determining the cavity resonant frequency easily. It visualizes the phase detector output response that is an indication of the actual phase angle inside the PLL.

From panel menus, one can activate the semiautomatic procedures needed for forward/reflected and pickup RF lines calibration.

The decay procedure for cavity in both cold and warm condition gives the possibility of determining the cavity Q-value (Fig. 3). From it and from the measurements of forward, pickup (transmitted) and reflected power, presented on the panel to the right, it is possible to perform the pickup calibration. We use this procedure in warm condition for adjusting the pickup antenna.

The Q(E) procedure presents the resonator Q-curve as a function of the accelerating field (E_a). The E_a and the

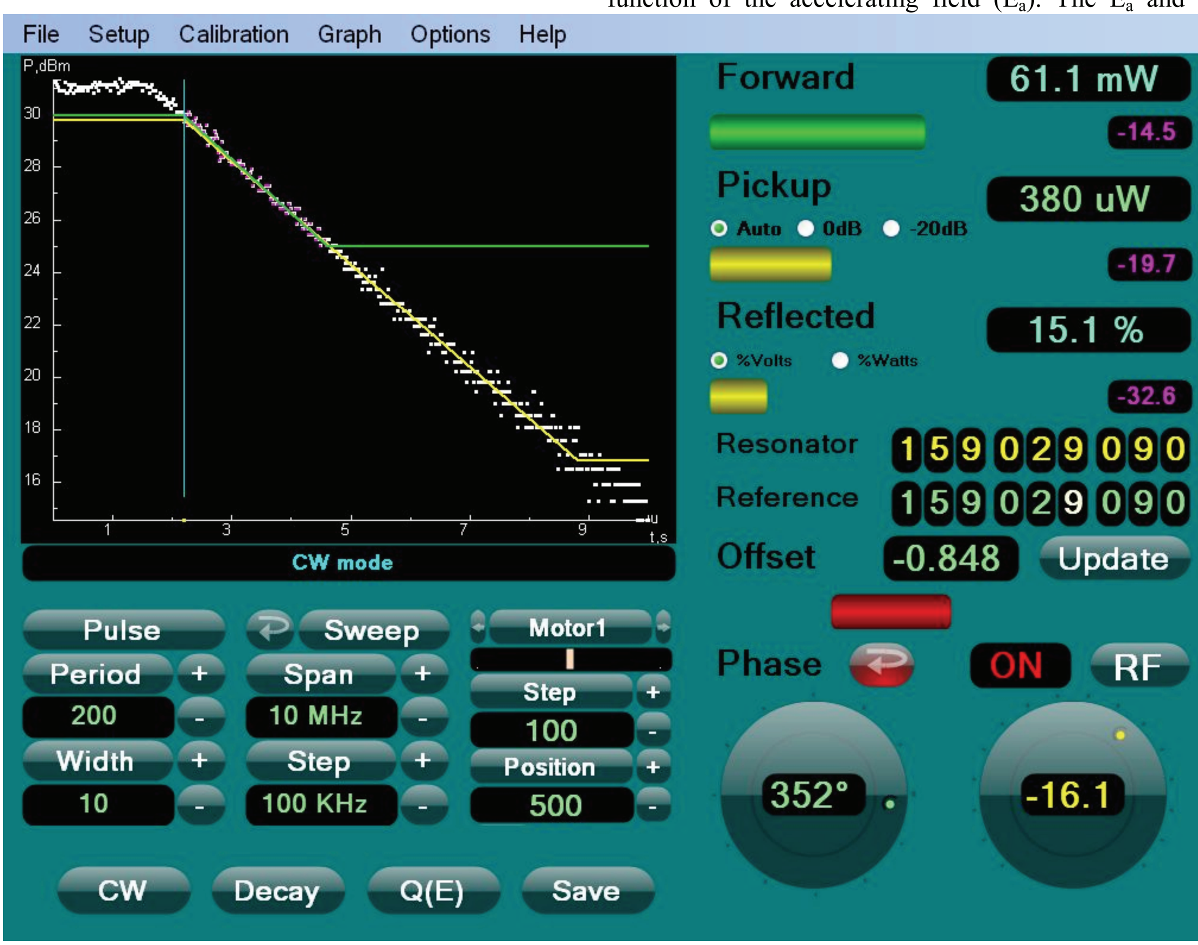

Figure 3: Control panel view during room temperature decay time measurement.

Figure 4. Options Window with RF Calculator panel.

corresponding Q value, as computed from the actual measured power values, are shown in the Q(E) plot and, if the case, saved by the Save button.

It is possible to adjust the coupling condition acting on the coupler stepping motor.

It is also possible to enter in the pulse mode using the Pulse panel on the left. We can choose both the pulse period and width for the cavity conditioning at high pick power. The chart in this case shows the reflected and transmitted power pulse envelopes for easy coupling adjustment.

A voltage-controlled attenuator, set by the knob on the left bottom side of the panel, regulates the forward power. Fast Down – Slow Up feature of this knob limits the risk of power overhead.

The cavity operates in phase lock loop. It is possible to adjust the phase in order to minimize the reflected power by moving the corresponding knob. The Phase button provides switching between the locked/unlocked conditions.

The panel gives the possibility to set the reference frequency manually. The frequency counter reading can also update the reference frequency automatically, thus making the reference frequency to follow the actual frequency of the locked resonator.

Semiautomatic procedure produces calibration tables for oscilloscope channels at different frequencies. The program can load and implement these curves using separate polynomial approximation for every vertical channel range of the scope.

Setup file including all the system parameters for a particular measurement is loaded at the software start. It contains the hardware configuration settings, various measurement constants, calibration data and file references for calibration tables and stepper motors configuration. The panel menus visualize and permit modification of many of these parameters.

CONCLUSIONS

A new computer based mobile measuring system for laboratory and online characterization of superconducting cavities was set into operation at LNL. The system actually covers the frequency range up to 500 MHz with possible expansion to 700-750 MHz.

The use of conventional electronic components makes it possible to create low cost circuitry for laboratory and online cavity testing.

The upgraded software for cavity measurements was tested and put into operation. It smoothly covers three LNL cavity test systems with different frequency ranges and hardware configurations thus making the future development and hardware upgrades easier.

Availability, mobility and ease of use of the system permit the reliable evaluation of the state of ALPI cavities optimizing the conditioning time and consequently the operational performances.

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