RECENT UPGRADE OF ULTRA-BROADBAND RF SYSTEM FOR CAVITY CHARACTERIZATION

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Abstract

The first computer controlled RF system for SC cavity characterization entered into operation at INFN-LNL in 1994. Since then it has been successfully used for testing SC cavities of different shapes and frequencies. Recently we performed an important upgrade on it in order to cover a wider frequency range and to take advantage of the better performance of nowadays electronic devices.

The paper describes the present system layout, dedicated software, sequences of calibration and testing procedures and moreover discusses further upgrading possibilities.

INTRODUCTION

The first, computer based, measuring system, developed at LNL in 1994 for superconducting (SC) cavity testing, covered two frequency bands around 160 and 1300/1500 MHz in order to measure both ALPI QWRs and TESLA type cavities [1]. Later we added the 6 GHz band for a small scale cavity characterization [2, 3]. We added also the possibility of remote measurement in the case of radioprotection restrictions [4]. During all these years the system has been routinely used for the SC cavity studies at LNL Superconductivity Laboratory. The software developed for the cavity measurement was continuously upgraded passing from the original HP IBASIC to VB3, VB6, VB.NET 2.0, and VB.NET 3.5. Most of the original HP RF instruments (Power meters, RF generator, and Frequency counter) were substituted in 2008. Following the approach described in [5], the rest of the system components was upgraded, where possible, by commercially available, low cost, electronic devices from contemporary communication technologies [6]. At present, only the RF power amplifiers, bidirectional couplers and circulators remain frequency dependent.

The broadband solution has the advantage of using practically the same measurement setup, control software and standard procedure sequence for the different types of RF cavities that are tested at LNL. This approach is less error prone and improves the learning curve for the personnel and students involved in cavity testing activities.

Recently we introduced and tested a new calibration procedure. We perform it at a forward power level 10 times higher than in the past in order to reduce the calibration uncertainties in the forward/reflected lines.

Guard-Charts [7] multiple parameters monitoring software helps to keep under control and to register all the auxiliary parameters and conditions during test.

UPGRADE MOTIVATION

The main reasons for upgrade were as follows:

- possibility of old components substitution (20+ years)
- RF circuit simplification and cost reduction
- need for a continuous coverage for low frequency (50 to 500 MHz) cavities including 80, 160, 352 MHz for LNL cavities and RFQs and CERN HIE-ISOLDE prototypes at 101 MHz
- increase in the digital phase shifter granularity (from 9 to 11 bit selectable) for better resonator phase adjustment during test
- latching relay implementation for better temperature stability of RF and DC lines, thus avoiding the heating of the relay coil and contacts

HARDWARE IMPROVEMENTS

The new configuration makes use of the recent wide bandwidth devices, which permitted to cover smoothly, using only two partially different RF signal paths, all the cavity types from 50 to 1500 MHz and from 2 to 6 GHz (Fig.1).

The switching between the two bands is performed automatically using conventional relays. The only one RF relay is used for the pick-up sensitivity selection. All of them are of latching type in order to reduce power consumption and heating effects.

New wide band components for phase detection from 2 to 6 GHz are not yet available, thus we have to use a standard mixer as phase detector.

In the new layout we use a combination of a dual DAC and a quadrature modulator to produce the phase shifting of the RF signal. Based on our experience, the typical previous phase shifters granularity of 8 bits (1.4 degrees per step) is not quite sufficient for phase adjustment during the superconducting cavity measurement. For this reason a dual 14 bit DAC has been chosen to produce a user selectable from 9 to 11 bits of phase control (down to 0.18 degrees per step). The DAC output is switched between two quadrature modulators covering two frequency bands.

The forward signal path from signal generator to power amplifiers remained unchanged with respect to the previous design because there is not yet low cost alternative to controlled PIN Diode attenuators and switches for ultra-broadband operation.

Fig. 2 shows the measuring system for superconducting cavity testing at LNL Superconductivity Laboratory.

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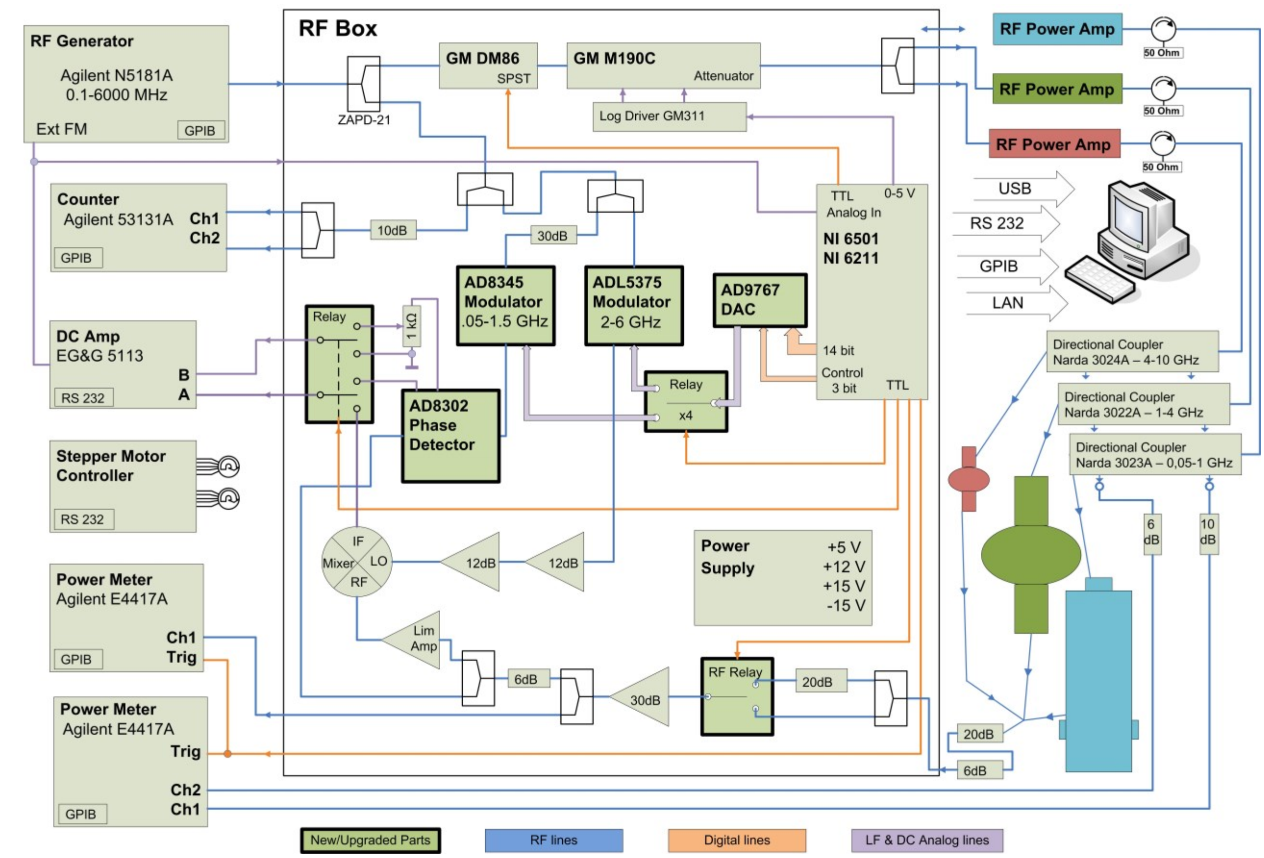

Figure 1: Measuring System layout.

NEW CALIBRATION PROCEDURE

The dynamic range of the cavity measurement system goes from milliwatts to tens of watts. As a consequence, we have to protect the measurement heads by attenuators. On the other hand we are trying to avoid any manual operations with cables, connectors and attenuators, which can compromise the results of the cavity test, especially at 6 GHz. Consequently, the calibration procedure should be optimized to guarantee the maximum precision of attenuations and corrections for all the dynamic range. As a matter of fact, with the additional attenuators, the 10 mW of source power, previously adopted during the calibration procedure, led to a rather low signal at the forward and reflected power heads, thus increasing the measurement error. We now use 100mW of forward power for all the calibration procedures.

The calibration sequence that we used in the past did not foresee the measure of the reflected power during the full transmission step (RF feeding line terminated by a 50 ohm power head). This gave a further contribution to the measurement error.

The updated calibration sequence is illustrated in Fig.3. A zero value for cables and attenuators indicates that they are included automatically into overall attenuation of the corresponding lines during the calibration procedure. In case of subsequent manual modification of line attenuations, the corresponding values have to be inserted into the variables foreseen in the control software.

During the first step, we determine forward and reflected power values at the directional coupler sampling ports while shortening the forward cable in order to produce full reflection.

The second step gives the forward and reflected power measured at directional coupler in case of full transmission, when the forward cable is connected to a third power head through a calibrated 10dB attenuator.

At this point we can calculate both forward and reflected overall attenuations.

Figure 2: Measuring system view.

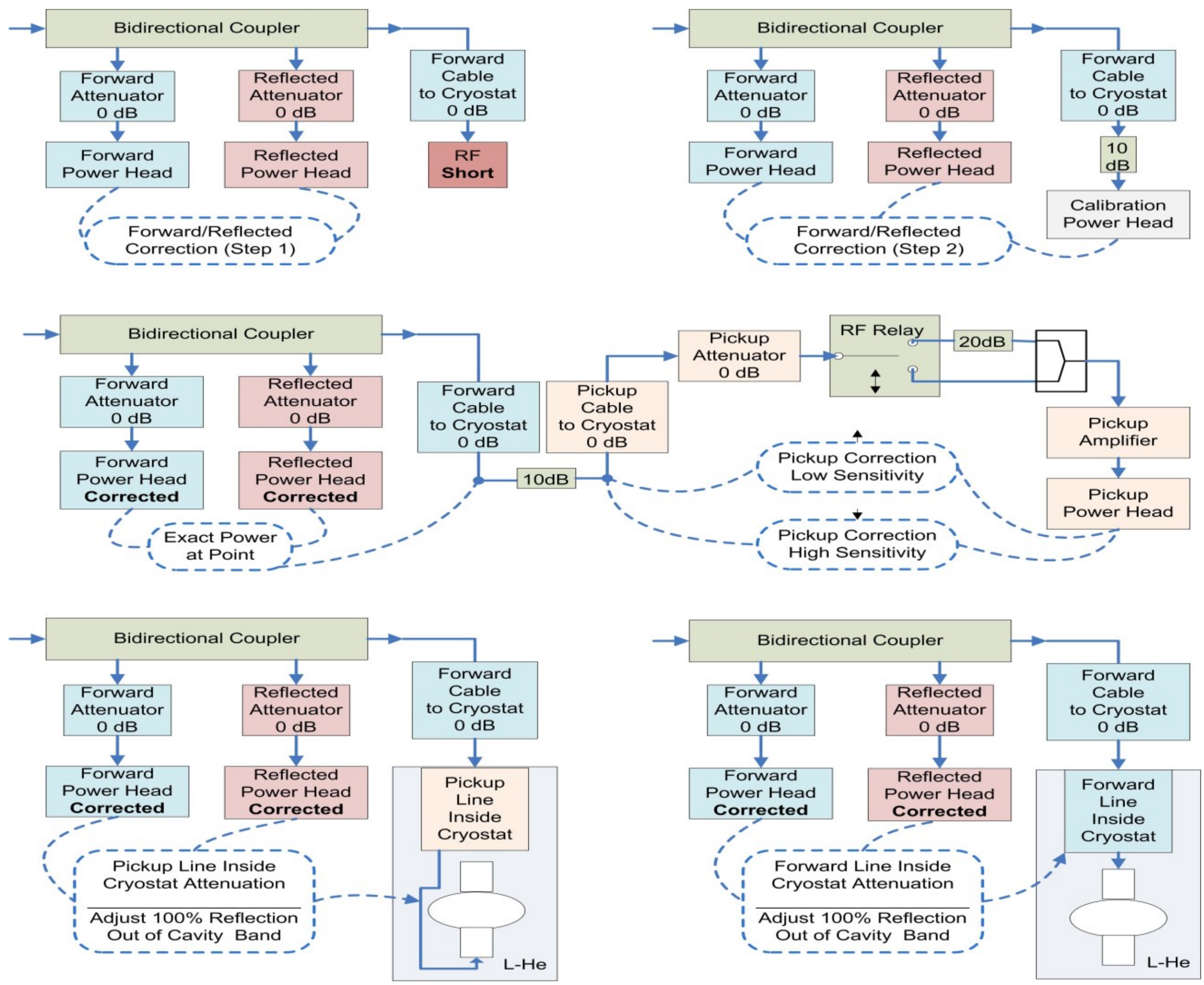

Figure 3: Five steps of the new calibration procedure.

The third step measures and automatically acquires the two attenuation coefficients for the two paths of pickup input lines. In this case the forward cable is used as calibrated power source.

The attenuations of the RF lines inside cryostat are measured at 4.2 K, always using the forward cable as calibrated power source but setting the generator frequency slightly outside the cavity band. For both the lines we find the right attenuation coefficient by trials changing the numbers in the foreseen fields in the control program in order to get full (100%) reflection from the correspondent cavity port.

The next step in the calibration of the system is the determination of the cavity Q at low field cavity in critical coupling. For the types of cavities affected by low field multipacting we condition the levels in advance. We feed the cavity, locked in phase at its resonant frequency and we adjust the coupler position up to minimize cavity reflected power. At equilibrium (stable cavity field), we can start the Q measurement procedure. The latter turns off the power and interpolates the pickup decay data to determine the cavity decay time and the related Q-value. From it and from the measure of the feeding and transmitted power, the program then computes the pickup acceleration field coefficient (known the ratio between stored energy and square of accelerating field). The accelerating field and the correspondent Q-value at higher accelerating fields can be then determined by increasing the feeding power and adjusting the coupling in order to maintain the critical coupling condition. The program automatically plots the values of Q versus accelerating field, allows a fast analysis and recording of data and gives the possibility to print the Q-curve immediately.

The control software maintains the previous structure and the visual interface, but was modified both to support all newly introduced hardware elements and to perform the upgraded calibration sequence. Fig. 4 shows the control program main panel. Acting on it, it is possible to adjust the power level, frequency and phase, to perform frequency sweep, decay time measurement, Q(E) acquisition, to regulate pulse operations, if required, to control the stepping motors for cavity coupler and tuner movement, to visualize the rf signal level and to access other control panels.

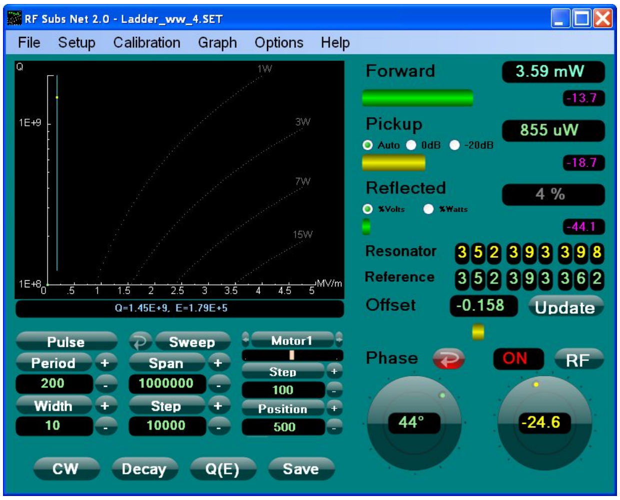

Figure 4: Control software main panel.

CONCLUSIONS

We performed an important upgrade on measuring system for superconducting cavity testing at LNL Superconductivity Laboratory using commercially available, low cost, electronic devices. The system actually covers smoothly the frequency range from 50 to 6000 MHz divided in two bands. Further upgrades are possible with the arrival of new generation telecommunication devices covering higher frequency range.

We developed and tested a new calibration procedure applicable to all three measuring systems operating at LNL that permits more precise and reliable evaluation of cavity characteristics. The upgraded software was tested and put into operation.

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