TESTS OF THE COMPUTER CONTROLLED ELECTRONICS FOR THE RF SYSTEM OF THE MILAN K800 CYCLOTRON.

A. Bosotti, G. Varisco, F. Zibra, INFN Milano, Italy
C. Pagani, Universita' di Milano and INFN, Italy
M. Di Giacomo, INFN Catania, Italy

Abstract

During the process of moving the cyclotron from LASA, Milan to the LNS lab, Catania, low power tests of the RF system control electronics were performed. Half a RF cavity, without the dee but properly closed, was controlled up to 10 kV, being driven by a 200 W amplifier. One cavity control cabinet, the common electronics and the computer cabinets have been tested together via a PC console. In this paper the whole system performances are described and results are talked over.

System Description

The system under test is shown in figure 1.

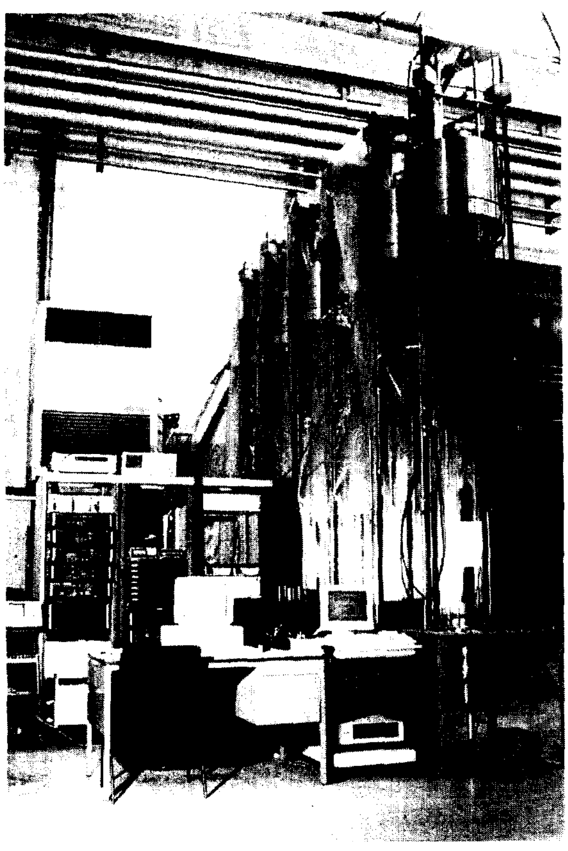


Fig. 1 The system under test.

It is made up of three electronics cabinets, the power amplifier, the cavity and the computer console. One of the cabinets contains all the cavity control racks: tuning, phase and amplitude loops, turn on and protection circuits, sliding shorts and coupler movement controllers. The second cabinet contains instruments and devices shared among the three cavities control circuits such as: the vector analyzer, the RF multiplexer, the delay lines, the control interlock system and the optoisolators of the encoders signals. The Intel intelligent control boards fill the third cabinet. A 200 W, ENI solid state and broad band power amplifier is used to drive the cavity up to 10 kV. Since the BBC power amplifiers are being moved to Catania, power tests were not accomplishable. Though few details have been changed in the cavity structure since the power tests performed in 86[2,3] checking out the improvements would have been of real interest anyway. Since low power tests were performed, no special coaxial transmission line, nor vacuum chamber were needed. Half a cavity is used as resonator. Instead of the dee, a simple plate is used to terminate the inner coaxial, while an enclosure was arranged to terminate the outer one and to support the coupling capacitor. The latter is obtained from a 1 $^5/_8$" transmission line, is manually positioned and the plate dimensions (r=3, d=4÷5 cm) were calculated by conformal mapping. A reflectometer is placed before the coupling capacitor to measure the best matching (SWR <1.5)

Two levels constitute the computer control[4]. The lower one is based on the Intel microcontrolled-boards and operates on the circuits. The 310 Intel Supermicro system is used as development environment for the distributed control module application software. The top one, based on a high performances PC (CPU 80386 - 16 MHz, monotask OS), has supervising functions and interfaces with the operator. Another PC is dedicated to data-acquisition and a program calculating operative parameters, is implemented on it. The two computers are linked together via RS232, so that most significant parameters could be supplied to the RF consol application program environment.

Cavity Simulation and Measurements

Due to the different bottom shape, the new resonance frequency ranges from 17.5 to 90 MHz. Indeed the absence of the dee turns out in less equivalent capacitance and in higher resonance frequency.

Simulation with numerical codes (Superfish) has been carried out to study the Q and field distributions. Theoretical values obtained with Superfish has been checked performing measurements of Q and resonance frequencies related with the sliding short positions. For the sake of accuracy, the quality factor has been measured in two different ways. The first way (Q_1) is normally used in room-temperature cavity Q measurements. Ranges aside resonance are inspected, looking for -3dB frequency values. In this way the equivalent lumped circuit of the cavity at resonance is supposed still valid in the whole inspected range.

Besides, the loaded Q_1 is measured and we resorted to expediens to minimize the coupling of the transmission line. The other way (Q_2) is instead characteristic of superconductive cavities and is based on the discharge time: a pulsed RF is forced in the cavity and the falling transient is inspected. The following relation was calculated:

$$Q = \frac{0.158 \cdot \omega \cdot \Delta t_{90-10}}{\ln 2}, \quad (1)$$

where Δt_{90-10} is the lag between 90% and 10% of the "plateau". In both cases, a great deal of samples was collected, and averaging was performed achieving eventually perfect agreement as shown in figure 2.

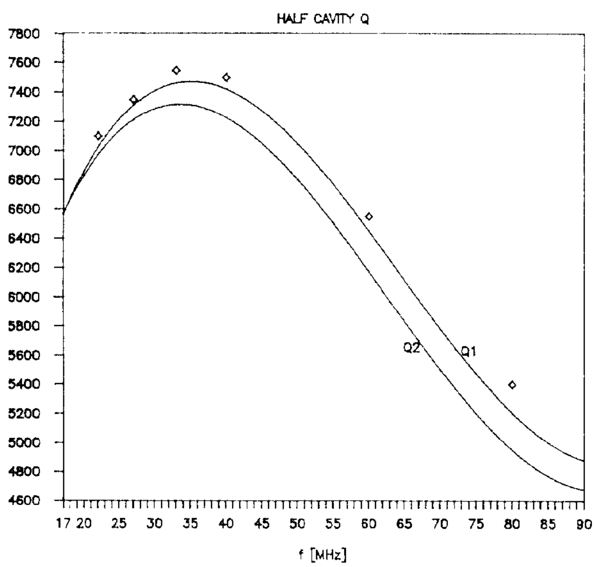


Fig. 2 Half cavity Q values.
Dots are related to Superfish calculations.

Control Features

These tests were also intended to check the interfacing between hardware and the system console via the BitBus[5] level, that is to say the reliability of the computer assistance in parameter settings and monitoring. For this purpose the RF console was simulated with a PC. The application software is described here. It was designed in order to garantee the easiest communication between the system and the operator. To achieve this target, macrofunctions were intensively used separating even involved tasks into few answers required by the system and some outcomes to be verified. Besides, the classical tree menu concept was combined with very powerful facilities and tools in the system architecture.

The choice of the personal computer as development environment for the console software, is due to the reliability and powerful functions it offers together with friendly development and implementation. At first[6], PL/M-86[5] had been chosen as programming language, but it was rejected afterwards, owing to difficulties encountered when implementing it on MS-DOS[7] (memory location and I/O handling). The MS-QuickBasic[7] has been prefered, which offers a structured programming environment, powerful graphic functions, keyboard handling, easy data-base maintenance and good debugging tools.

The BitBus network master board links the MS-DOS environment to the distributed environment. Synchronization between the console software and the distributed controllers network is activated, regulated and ended by message transmission, as described in figure 3.

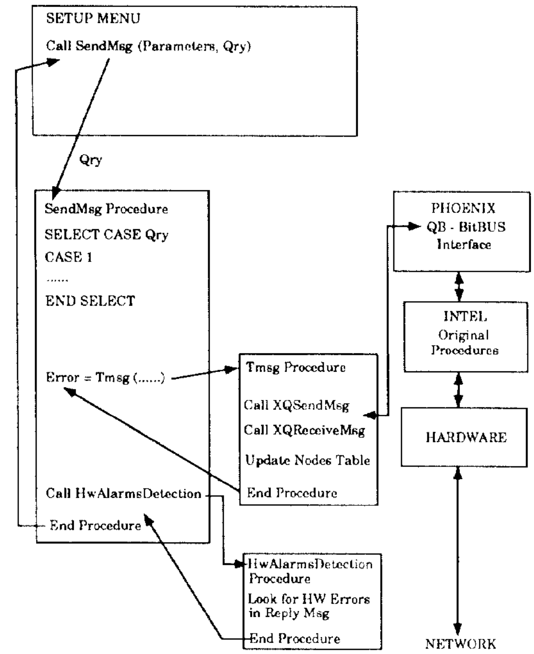
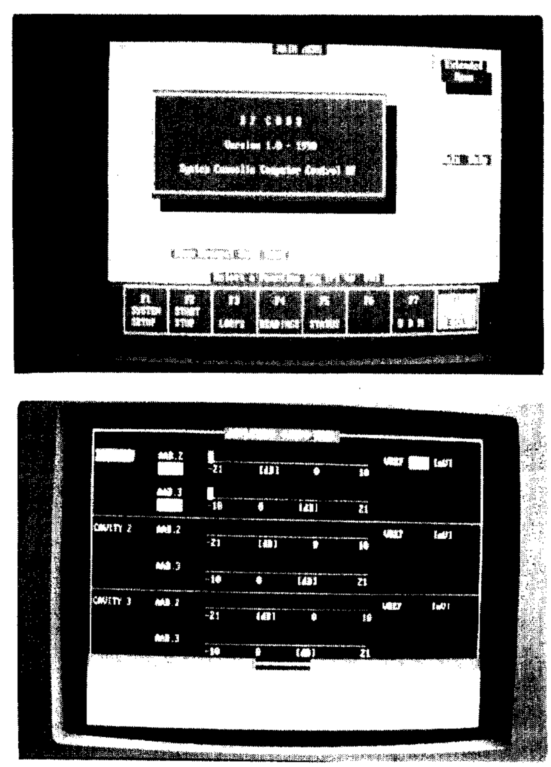


Fig. 3 Block diagram of the interaction between console software and BitBus.

Electronic circuit control calls for device settings depending on the operating frequency and for more general controls on the operating hardware. Consequently, two different kinds of menus are available to the operator: setting and control panels. From setting panels, the operator handles electronic devices of each cavity control chain, while from control panels he turns on and off the system, opens and closes loops, operates instrument monitoring. Both kind of panels are shown in figure 4.



(a)

(b)

Fig. 4 Control (a) and setting (b) panels.

Test Results

Before being arranged in the cabinets, all racks had been bench-tested and loops behaviour had been analyzed, by simulating the dominant poles of the cavity and of the tuned power amplifier with the well known formula[8]:

$$\omega_p = \omega_o / 2Q, \qquad (2)$$

where ω_p is the frequency of the dominant pole and ω_o is the resonance frequency of the cavity.

Results on the cavity were in strict accordance with expectations. Particularly, 20 and 30 dB gains were obtained respectively for the phase and amplitude loops, more than enough to garantee required fixes[8] These values were achieved all over the inspected frequency range (17.5 - 50 MHz), both loops being closed and interacting. Separately, indeed, each loop has higher gain but the interaction makes their performances worse.

Periodic alarm situations were simulated to check out the proper behavior of protection and control interlock systems, together with turn on procedures. Naturally we did not have multipactoring problems as we were working at room-pressure.

A long time was spent on the sliding short moving and monitoring systems to achieve a good sensibility with the fine remote control and precise automatic positioning. In spite of filtering already described[9] we were still troubled by some EMI problems.

New results were expected from long time tests. Reliability of circuits and devices, presence of drifts and problems due to the interaction of several cabinets were successfully checked out. Only the AAB devices[9] gave problems with the relay life-time, but the cause was identified and eliminated. Working points were stable in most of circuits under test and time independence was achieved for circuit performances.

Tests on the console program have checked out the efficiency of the interaction between the monotask DOS system and the multitasking Intel intelligent board environment. Some difficulties were encountered with message transmission, owing to the high frequency of information exchange. Indeed, several functional blocks are involved in this process: PC, distributed boards, operative systems, communication software drivers and application programs. The BitBus operative system (iDCX51) is responsible of the worst problems and we needed not only to reduce its use as much as possible, but also to implement a sophisticated communication control on the PC program.

Friendly interaction between system and operator has been achieved.

Conclusions

The RF system is now ready to be moved to Catania. The cavities will leave by the second week of June while the cabinets will be moved in September. Acceleration is scheduled by the end of next year. This long testing of the cavity, was useful not only for debugging purposes but olso to allow the staff at LNS - Catania, to gain a deeper understanding of the system.

Acknowledgment

The authors would like to thank A. Caruso D. Corti and A. Sparta' for their precious contribution on cabinet assembling and testing and on software development.

References

[1] C. Pagani et al., "Full Power Tests of the First RF Cavity for the Milan K800 Cyclotron", in Proceedings of the XI Int. Conf. on Cyclotr., Tokyo 1986, pp. 271-274.

[2] C. Pagani et al., "Very High Performance Sliding Short for RF Resonators Tuning", in Proceedings of the XI Int.Conf. on Cyclotr., Tokyo 1986, pp. 361-364.

[3] L. Serafini et al., "Electromagnetic Calculations for an Improved Design of the Milan K800 Cyclotron RF Cavities", in Proceedings of the XI Int. Conf. on Cyclotr., Tokyo 1986, pp. 365-369.

[4] A. Bosotti et al., Computer Control for the Milan K800 Cyclotron RF System, in Proceedings of the I EPAC, Rome 1988.

[5] MultiBus and BitBus are trademarks of INTEL Corp.

[6] F. Zibra et al., "The Computer Control for the RF System of the Milan K800 Cyclotron", Proceedings of the XII Int. Conf. on Cyclotr., Berlino 1989.

[7] MS-DOS and QuickBasic are trademark of Microsoft.

[8] A. Bosotti et al., "Accelerating Voltage Amplitude and Phase Stabilization for the Milan Superconducting Cyclotron", in Proceedings of the I EPAC, Rome 1988, pp. 1303-1305.

[9] A. Bosotti et al., "New Developments in the Control Electronics for the Milan Superconducting Cyclotron RF System", in Proceedings of the XII Int. Conf. on Cyclotr., Berlino 1989.