NEW DEVELOPMENTS IN THE CONTROL ELECTRONICS FOR THE MILAN SUPERCONDUCTING CYCLOTRON RF SYSTEM.

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ABSTRACT

A computer controlled electronics is used to operate the three RF cavities of the Milan Superconducting Cyclotron and to control the amplitude and phase of the accelerating voltage. The final optimized version of the control electronics has been assembled inside five cabinets, one of which contains the computer control hardware. Each subsystem is assembled in a 19" unit including few aluminum boxes to shield circuits. Each unit has been internally organized in order to ensure high flexibility and to simplify maintenance procedures, while a mimic diagram is engraved on the front panel.

Since the main features of the system have been already described elsewhere[1,2,5], in this paper we present the new improvements and the final construction details, mainly dictated by the computer assisted operation.

INTRODUCTION

The control electronic system used to operate the three RF cavities of the Milan Superconducting Cyclotron (M.S.C.) is conceptually the same that was used to test the first λ/4 cavity resonator at high power[1]. Nevertheless, since the first version was mostly manual, we decided to implement a new design, fully computer assisted.

One of the three chains of the control electronics is shown in Fig. 1, the other two

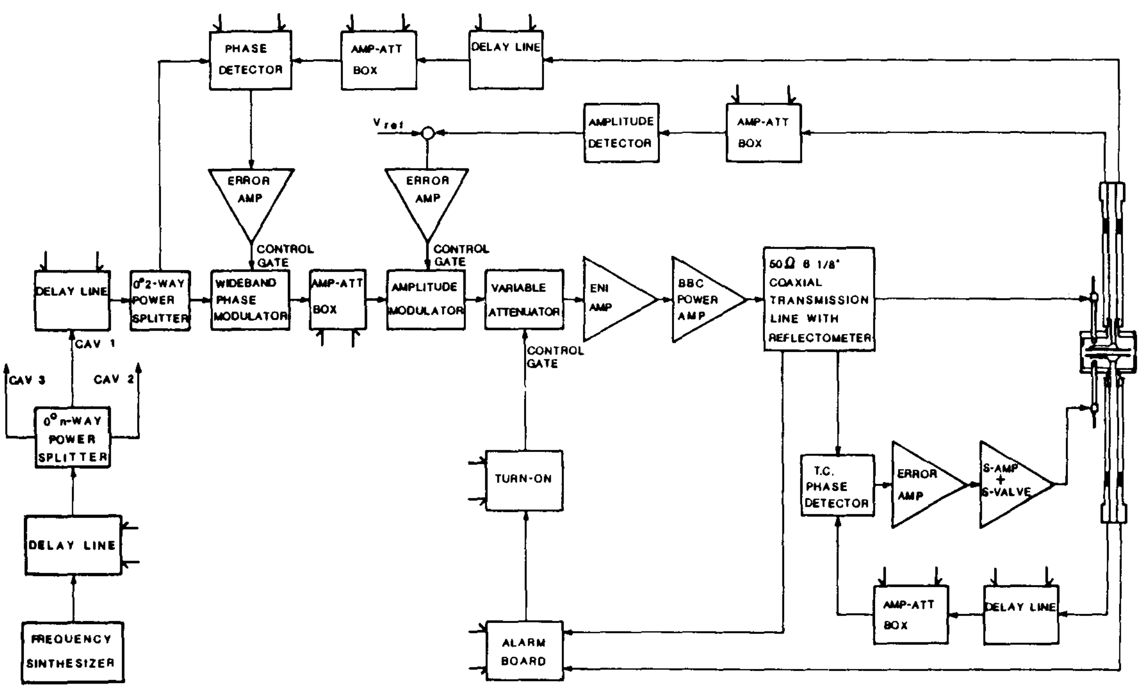

Fig. 1 - Block diagram of one chain of the RF Control Electronics.

(for cavity 2 and 3) being identical and connected to the 0° n-way power splitter. Almost all blocks are computer interfaced for preliminary setting and monitoring.

All the analog circuits, which are used for the control of the accelerating voltage (amplitude and phase), the cavity fine tuning and the RF system protection, are almost identical to those which where successfully tested, the main difference being the computer interface for remote setting and monitoring.

Each chain has been installed into a cabinet, the subsystems being assembled in individual 19" units. To improve flexibility and simplify maintenance procedures, each unit is internally organized on a common board and a mimic diagram is engraved on the front panel. A picture of three cabinets is presented in Fig. 2, while, as an example, the internal organization of the phase regulation subsystem is shown in Fig. 3.

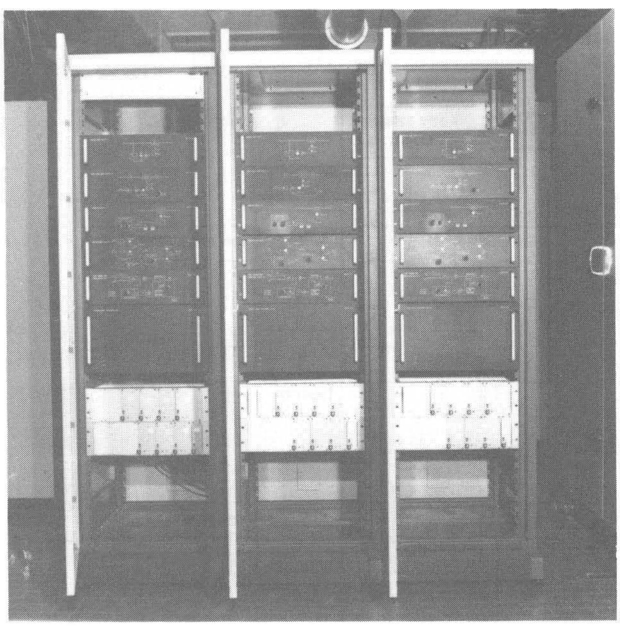

Fig. 2 - A front picture of three cabinets.

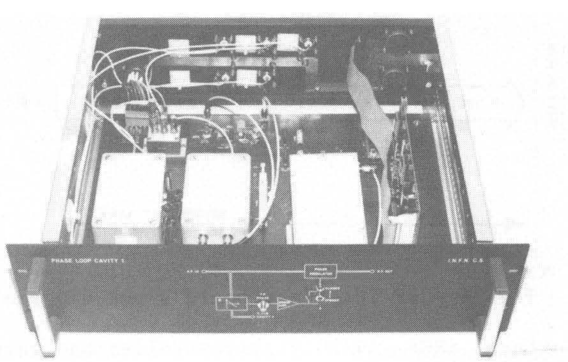

Fig. 3 - Internal organization of the phase regulation subsystem.

Two main problems, due to the wide RF frequency range (15-48 MHz)[4], have been met and solved, developing two special components.

- The pick-ups used to take samples of the dee voltage are strongly influenced by the signal frequency and amplitude. In particular the coupling between the inductive loops and the H field changes with the frequency, giving an input signal to the amplitude and phase detectors which is frequency dependent and modify the expected loop gain. Since an analog compensation inside a so wide frequency range, while elegant, was impractical, a computer controlled stepping attenuator/amplifier (AAB) has been developed in order to keep the loop gains independent from the amplitude and the frequency of the sampled signals.
- Because a proper phase relation, independent from the operating frequency, is required between the input signals of the phase detectors, a Variable Length Delay Line, able to perform a wide range of phase shifting, has been developed too.

AABs and Delay Lines have been both designed as general purpose and computer controlled devices, in cooperation with a private company (SIRA).

DESCRIPTION OF THE NEW COMPONENTS AND CIRCUITS

Attenuator/amplifier box

This device has been designed to remote control the amplitude of the RF power in a range of ≃ 30 dB with one dB step. Its block diagram is presented in Fig. 4.

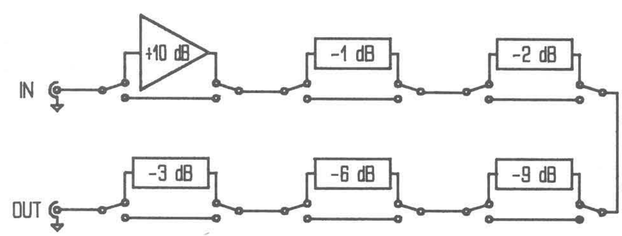

Fig. 4 - Attenuator/amplifier box block diagram.

It is composed of five Minicircuits AT series fixed attenuators and one Avantek UTO-561 amplifier (10 dB gain). Six RF relays shunt the attenuators and the amplifier in order to insert or bypass the desired component. A stripline transformer at the input of each relay has been inserted to ensure a VSWR below 1.5 all over the frequency range, in spite of the impedance mismatching introduced by the RF relays. The device is enclosed in a compact aluminum box together with a logic board for the gain (attenuation) selection. This solution ensures good shielding together with a high flexibility in its use.

Another version of the AAB, with a second 10 dB amplifier instead of the 9 dB attenuator has been developed too.

Continuously variable delay line

This device is a modular six bits computer controlled stepping line (1 ns step for 63 ns maximum delay) together with a continuously variable length line used for fine adjustment in between two adjacent steps. The delay line block diagram is conceptually similar to that of the AAB. The device has been assembled using six pieces of RG 58 coaxial cables of different length shunted by six RF relays. An impedance transformer is placed at each relay input to obtain a VSWR < 1.5. The variable length delay line is a little trombone line with a motorized sliding short. The device is assembled in a single rack unit, together with its control electronics. A picture of the delay line is shown in Fig. 5.

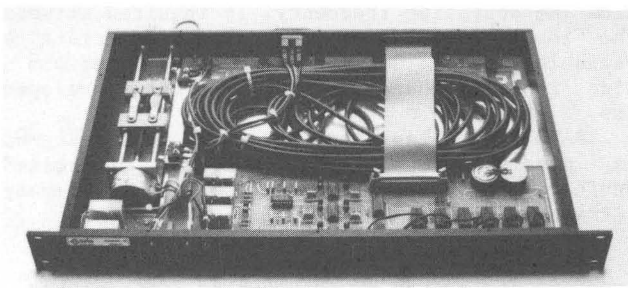

Fig. 5 - Delay line.

A control logic board has been designed and realized, in order to set via computer the ten delay lines of the RF control electronics, using only one iRCB 44/10 board[7].

Sliding short movement

The Sliding Short positioning is involved in the preliminary settings, when the cavities are tuned to the operating frequency[5].

This procedure is intended to be standardized putting the codified sliding short positions (corresponding to the required working frequency) in a data base file, following the same philosophy adopted for the BBC power amplifier settings.

A precise absolute encoder (ELESTA), mounted on the motor transmission shaft, is used as a digital position sensing system with a 10°/bit resolution, which corresponds to a sliding short displacement of ≃ 0.1 mm. The conversion from swing degrees to the absolute position of the sliding short, with respect to the cyclotron median plane, is made via software.

COMPUTER CONTROL

The RF computer control[2] essentially satisfies the need of performing operations such as system settings and main parameter monitoring from a remote console. The actual RF computer control architecture has been developed starting from this basic idea, according to the general architecture of the M.S.C. Computer Control[8].

Particularly, a multicomputer based station has been dedicated:

- to perform data acquisition from sensors;
- to convert measurements to engineering units for data base updating and monitoring;
- to coordinate the activities of the whole RF system.

Furthermore the RF computer control has to be a part of the cyclotron computer control. So that the RF control station has been designed as a Multibus I[6] based card-cage (310) which acts as a master of a low level field bus (Bitbus[6]) according to the general architecture. The master station is connected to the control local area network, in order to exchange data with the other stations and the main console.

Bitbus is a hierarchical system with a master and a number of slaves. The slaves, iRCB 44/10 and iRCB 44/20, are connected to the control electronics via an expecially designed interface, in order to increase the control capability of a single microcontrolled unit[3].

This interface board sets standard procedures for the electronics subsystem controls and the software logic structure of the microcontrollers is the same, independently from the device to be controlled. The RF-Interface block diagram is shown in Fig. 6.

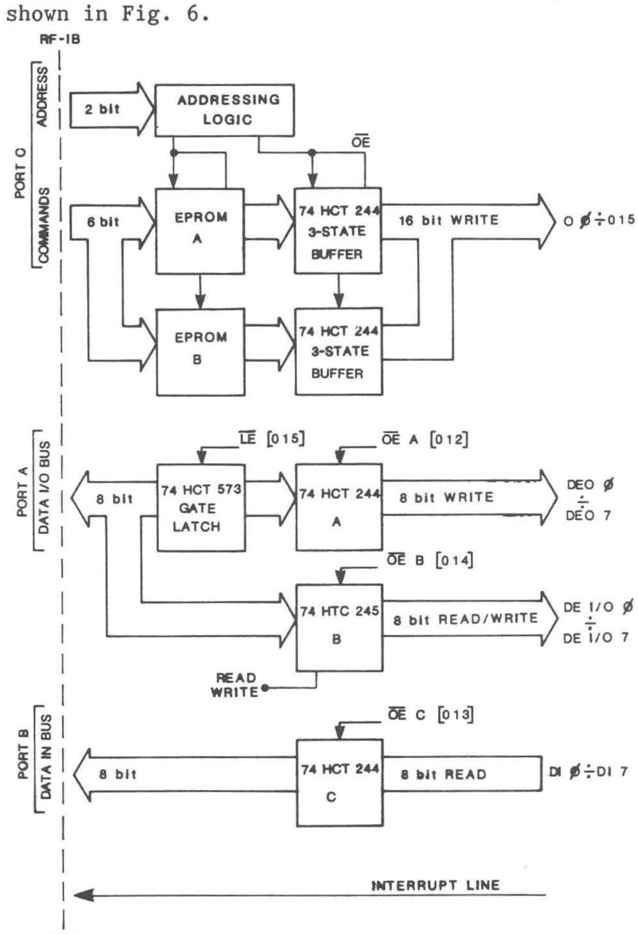

Fig. 6 - RF Interface board block diagram.

Each iRCB 44/10 microcontroller can support up to four interface boards.

The status of each element of the RF control electronics can be acquired through the B port. From the microcontroller point of view, each operation is seen as writing (or reading) a binary value on a port, simplifying the software structure[7]. The control program is reduced to properly choose the value to be set on the microcontroller ports.

CONCLUSIONS

Five cabinets contain the control electronics. In particular three of them contain the control circuits dedicated to each cavities, another one contains the common control devices, while all the microcontrollers are assembled in the computer cabinet. The arrangement of the cabinets is schematically shown in Fig. 7.

Computer	Control El. x 3	Common
iRCB 44/10 iRCB 44/20 GP IB	Phase Loop	Frequency Synthesizer
RF IB Server	Amplitude Loop	ZPV Vector Analyzer
Analog Inputs	Turn On Logic	RF Mux
4 Channels Oscilloscope	Protections	Delay lines 1 + 10
	Trimming Cap. & Coupler	Interlock
	Sliding Short	Delay Lines Selection
		Power Amps Settings
KNIEL Power Supplies	KNIEL Power Supplies	KNIEL Power Supplies

Fig. 7 – Control Electronics Cabinet Arrangements.

All the main subsystems have already been successfully tested and the whole RF system, together with the control electronics, computer assisted, is expected to be completed by the end of this year.

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