September 1981, Caen, France

# GANIL RF SYSTEMS : FEEDBACK CONTROL SYSTEMS AND ELECTRONICS

B. DUCOUDRET, A. JOUBERT, F. LABUSSIERE.

*GANIL (Grand Accélérateur National d'Ions Lourds) BP 5027 14021 CAEN Cédex Tel(31) 94 81 11*
*Telex : 170533 F.*

Abstract.- The philosophy, technology and results concerning the tuning, the amplitude, the phase regulation and control including beam phase correction for all resonators are described.
A CAMAC microprocessor unit is used to automatically start and survey the RF voltage of each independant RF resonator. All this devices are finally controlled by the main computer.
Experimental results on the injector cyclotron are given.

## 1. Servo tuning system.-

### 1.1. Trimmer

The fine tuning adjustment is obtained by a ± 20° rotating loop working in the short circuit region of the resonator[1]. This loop moved by a fast DC motor is water cooled for RF power losses up to 1 kW in the worst conditions.
As shown on fig.1 the phase error signal is the phase difference between grid and plate RF voltage of the power amplifier final stage through two balanced coaxial cables and two broadband quadrature hybrids.

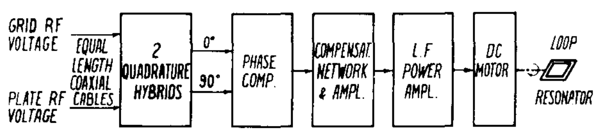


Fig. 1 : Main servo tuning system.

| Working Frequency | MHz | 6 | 14 |
|---|---|---|---|
| Relative frequency deviation for ± 20° loop rotation | - | $\pm 3\,10^{-4}$ | $\pm 5\,10^{-4}$ |
| Corresponding frequency deviation | kHz | ± 2 | ± 7 |
| Frequency resolution | Hz | 2 | |
| | RF degree | 0,1 | |
| Settling time for 40Hz disturbance | ms | 32 | 40 |
| Open loop gain at 1 Hz | - | 50 | |
| Small signal unity gain bandwidth | Hz | 20 | |
| Movable panel : mechanical resolution | m | $10^{-6}$ | |
| Electrical resolution | RF degree | 3,5 | 0,6 |

Table 1

### 1.2. Combined action of movable panel

The movable panel actuator is driven by a stepping motor and a hydraulic piston. Since the trimmer frequency deviation is small, the movable panel action can be triggered if necessary by an extreme angle position of the rotating loop. (Fig.2) Table 1 gives the main characteristics.

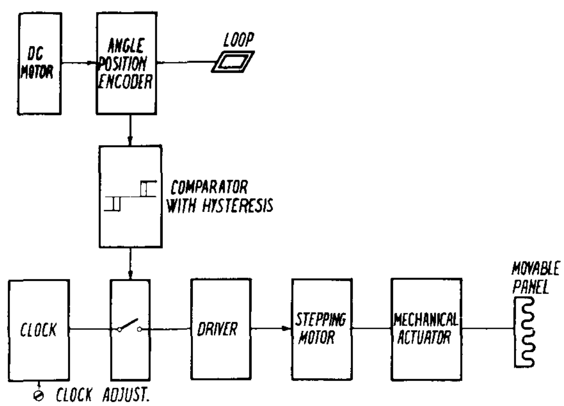


Fig. 2 : Complementary servo loop.

## 2. Amplitude regulation system.-

This is a classical analog device[2] using high quality components[3] in order to have a relative dee voltage stability better than $10^{-4}$. An automatic gain control system keeps the open loop gain constant over more than 20 dB dee voltage variation. Another additionnal servo loop working via a microprocessor keeps the RF amplier gain nearly constant whatever is the RF frequency and the RF power. (Fig.3) See table 2 for main characteristics.

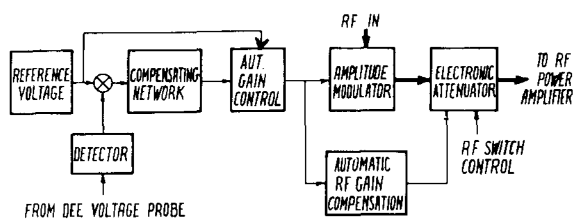


Fig. 3 : Amplitude regulation system.

| | | |
|---|---|---|
| Open loop gain at 300 Hz<br>600 Hz | dB<br>dB | 57<br>51 |
| Small signal unity gain bandwidth | kHz | 12 |
| Amplitude range (after detection) | V | 1 to 9 |
| Spectral purity :<br>(amplitude noise only) :<br>Residual AM for 50Hz and harmonics | dB | < 90 dB below the carrier |
| Regulation accuracy | - | $<\pm 5 10^{-5}$ |
| Absolute thermal drift (including dee voltage probe,diode detector and offset voltage drift) | V/°C | $10^{-5}$ |
| Reference voltage generator stability | V/day | $2,5 10^{-5}$ |

Table 2

Performances have been tested with spectrum analysis technique. Fig.4 gives the amplitude regulation accuracy and the open loop gain. This analysis was done on injector cyclotron dee voltage after detection.

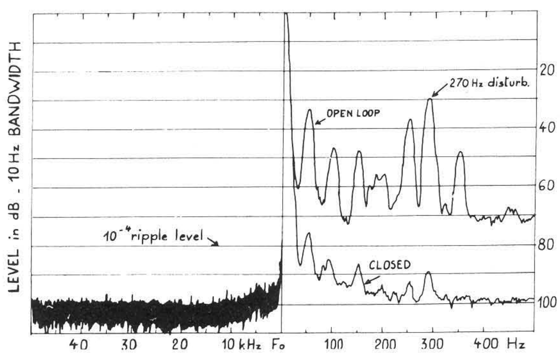


Fig. 4 : Amplitude noise spectrum analysis.

3. Computer control.- Each RF resonator including RF power amplifier and electronics is directly controlled by a local CAMAC microprocessor[4] working with a programmable controller for interlocking problems (Fig.5)This system has been designed to have three working mode possibilities :

a) Without both main computer and local CAMAC microprocessor

A RF specialist is required to start and survey manually the resonator. The programmable controller must be operational in any case to respect several safety and interlocking conditions.

b) Without the main computer

A non RF specialist operator can switch on in local mode the concerned resonator. All the starting steps and surveying are automatic.

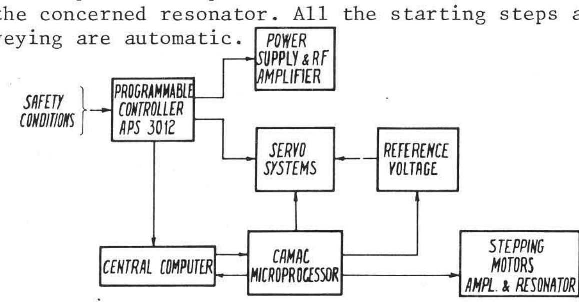


Fig. 5 : Philosophy of the computer control.

c) The whole chain is fully operational

This is the normal mode of operation from the main control room.

4. Phase regulation system

4.1. Fast regulation system (one per resonator) Even with a good amplitude regulation the RF resonator voltage has much phase noise (Fig.6). A fast servosystem[5] has been designed to reduce the phase noise level to less than .05° phase deviation. This device needs a very pure phase reference signal. Our pilot synthesizer has a signal to noise ratio greater than 100dB at 200 Hz of the carrier. The long term phase stability and the absolute value of the RF phase cannot be obtained with this phase lock system only. This last role is devoted to the slow system.

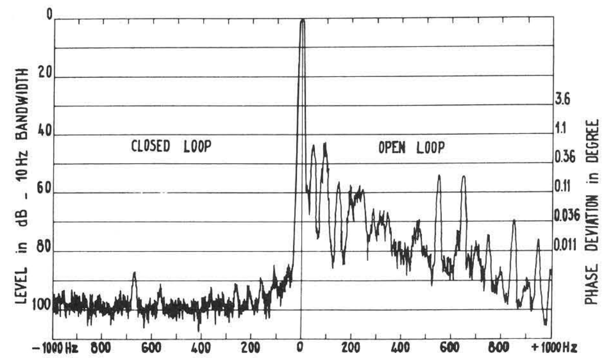


Fig. 6 : phase noise spectrum analysis.(The amplitude regulation is on)

As shows Fig. 7 the fast loop is made with two important components designed at GANIL :

a) the phase comparator is made of an analog multiplier

Saturated mode provides constant transmittance over a range greater than 20 dB RF amplitude variation.

b) the phase modulator using vector addition technique

combined with output regulation level gives an amplitude rejection better than 55 dB.

The main loop characteristics are summarized on table3.

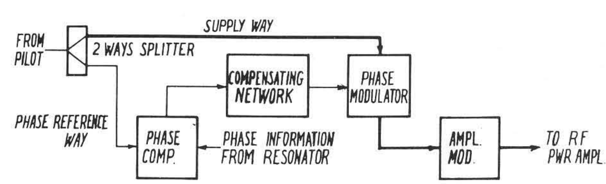


Fig. 7 : Principle of fast phase loop system.

The setting of the phase closed loop in case of frequency change is entirely done with a single CAMAC microprocessor.

The phase reference can be added to the back beam phase signal[6] (by mean of a special input) to lock the RF phase to the beam phase itself. The bandwidth of this complementary servo system is around 1 kHz.(Fig.8)

| | | |
|---|---|---|
| Open loop gain at 300 Hz<br>600 Hz | dB<br>dB | 40<br>34 |
| Small signal unity gain bandwidth | kHz | 12 |
| Spectral purity :<br>(phase noise only)<br>Residual PM for 50 Hz and harmonics | dB | < 80 dB below the carrier |

Table 3

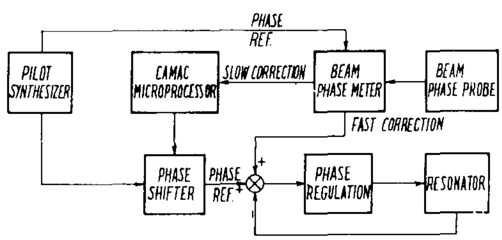


Fig. 8 : Beam correction system.

4.2. Phase adjustment system between cyclotrons - Slow stabilisation.

The principle of operation is shown on Fig. 9. The phase setting system operates with two kinds of phase shifters :

a) stepping phase shifter.
This type of phase shifter is made of stepping delay lines which are CAMAC controlled and programmed. The elementary delay is 0.66 ns and the total delay is 160 ns per unit corresponding to more than 360° phase rotation at 6.4 MHz.

b) continuously variable phase shifter.
This second type made of a length variable line (micro-strip) actuated by a slow AC motor has a maximum delay of 1 ns and provides the phase interpolation within only one step delay of the previous delayline.

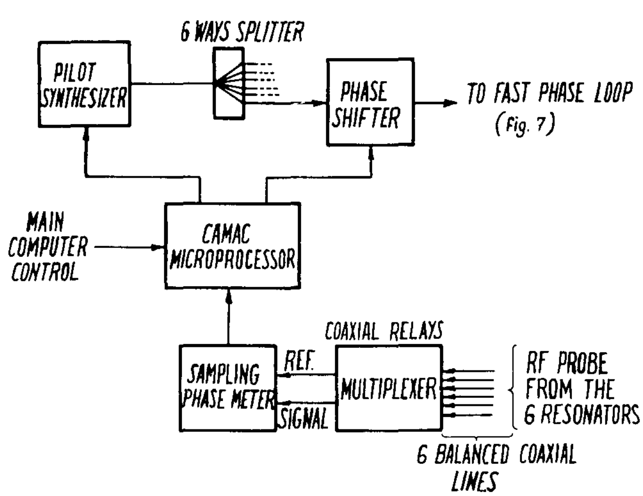


Fig. 9 : General phase adjustment system.

The injector cyclotron dee voltage is the phase reference for all others RF systems. The phase difference is directly read from the concerned resonator by a sampling phase meter (Hewlett Packard Vector - Voltmeter). Its analog phase information is sent to a CAMAC microprocessor. After on-line calculations the chosen phase value is indexed to the corresponding stepping phase shifter through the CAMAC BUS. Then the phase value is periodically corrected as a function of the slow phase drift.
Of course the phase values are adjustable from the main control room.
This system can moreover receive slow corrections coming from the beam phase measuring system.

Références.

1. B. DUCOUDRET, A. JOUBERT ; Etude du système d'accord rapide asservi pour l'injecteur I1 ; GANIL 79N/004/HF/01.
B. DUCOUDRET ; Systèmes d'accord rapides asservis des CSS et de I1 : Optimisation sur base d'essais ; GANIL 79N/149/HF/28.

2. B. DUCOUDRET, A. JOUBERT, G. SCHMIECHEN ; Stabilisation de l'amplitude HF des résonateurs CSS ; GANIL 80R/068/HF/10.

3. A. JOUBERT, M. TRIPON; Diviseurs capacitifs pour l'amplificateur 100 kW et pour les résonateurs ; GANIL 79N/111/HF/21.

4. B. PIQUET, Programme JCAM de démarrage et de gestion des cavités HF. GANIL 81/023/CC/02.

5. A. JOUBERT, J.C. LABICHE, Stabilisation de la phase HF des résonateurs CSS. GANIL 79R/34/HF/09.

6. F. LOYER, Diagnostic de phase centrale à sonde capacitive. GANIL 79R/168/CC22.