MAIN RESULTS ON THE RF AMPLITUDE AND PHASE REGULATION SYSTEMS IN OPERATION AT GANIL

A. Joubert, B. Ducoudret, J. C. Labiche, J. M. Loyant

GANIL - CAEN - FRANCE

ABSTRACT

The general features of the amplitude and phase regulations and their control systems are briefly reviewed. These feedback control systems are fully under the control of the main computer aided by dedicated CAMAC microprocessors for actions such as starting, parameters tuning or phase stability surveying. Numerous results obtained with spectrum analysis method give the actual RF purity and the residual modulation and crossmodulation noise level for all RF signals picked up in the RF resonators. A typical value for the noise immunity is 80 dB below the carrier at 100 Hz deviation. Another set of results gives the actual long term phase drift between resonators (< 0.2 RF degree within 6 hours). The stability of the RF phases is confirmed by on line beam phase measurements.

1. INTRODUCTION

The GANIL RF systems have been described elsewhere [1,2,3]. However it seems useful to briefly recall their main features :

Common required characteristics :

- Frequency range : 6.5 to 14 MHz
  (the working frequency for a
  given particle is the same
  for all the resonators)
- Dee voltage stability : $\sim 10^{-4}$
- Phase stability : $< 0.5°$

Configuration of the GANIL resonators :

	Type	tuning mode	Max Dee voltage peak value (kV)*	
			(a)	(b)
Injector	$\lambda/4$ (1 stem cantilever)	2 capacitive movable panels in lateral position	20	100
Buncher	$\lambda/4$ (1 stem hanged)	2 capacitive movable panels in lateral position	20	100
SSC1 ** and SSC2 **	$\lambda/2$ (2 stems sloping)	1 capacitive movable panels at the near position of the dee	100	250

Notes :

* Values given for the min. (a) and the max. (b) frequency

** 2 identical resonators in opposite position

2. SERVO TUNING SYSTEMS

The quality of the amplitude and phase regulation systems is dependent on the precision of the servo tuning systems.
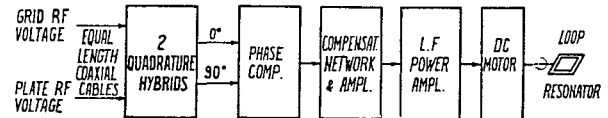

Fig. 1

The same principle has been used for all the 6 GANIL resonators Fig 1. One combines the action of a rotating loop (fast reponse but small correction range : ± 20 RF degrees) and of the capacitive movable panel(s) : (slow action but non limited correction range). Because of small mechanical vibrations observed above 20 Hz, the unity gain bandwidth of these servoloops had to be reduced to 7 Hz in SSC's resonators with an adapted multipoles low-pass filter. So the tuning of the resonators is remained within ± 3°.

3. AMPLITUDE REGULATION SYSTEM

3.1 Description

The amplitude loop structure is shown in Fig. 2. To carefully preserve the same working point and therefore the open-loop gain constant over the whole amplitude range, one has two automatic gain control devices : the first using analog divider and multiplier circuits keeps constant the transfer function of the RF detector the second, by back control of a RF attenuator, keeps constant the RF gain of the amplitude modulator.

The table below summarizes the main characteristics :

Open loop gain at	300 Hz	57 dB
	600 Hz	51 dB
Small signal unity gain bandwidth		12 kHz
Regulation accuracy		$< 10^{-4}$
Absolute thermal drift (including dee voltage probe RF detector and offset voltage drift)		$< 10^{-5}$ V/°C
Reference voltage generator stability		$< 10^{-6}$ per day

The predicted characteristics have been reached for all the resonators. Nevertheless a difficulty about the absolute dee voltage measurement is still not solve : (case of the 2 SSC's resonators) direct low level reading method, X-ray calibration and beam turn separation are in agreement within only 15%.
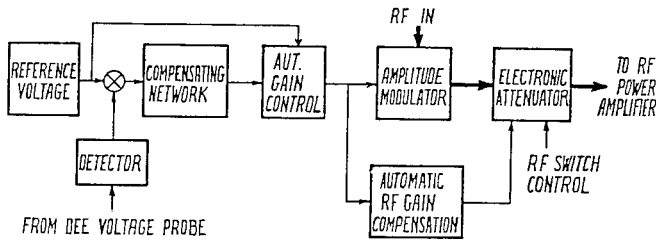
Fig. 2

Watching the accelerated beam, the SSC dee voltage long term stability is good enough but difficult to know precisely, because the measurement method do not include the small mechanical variations regarding the dee to RF probe distance. The following spectrum analyses in Fig. 3 prove the good amplitude noise immunity (residual modulation coefficient less than 10^{-4}).
These spectra have been done the beam being fully accelerated.
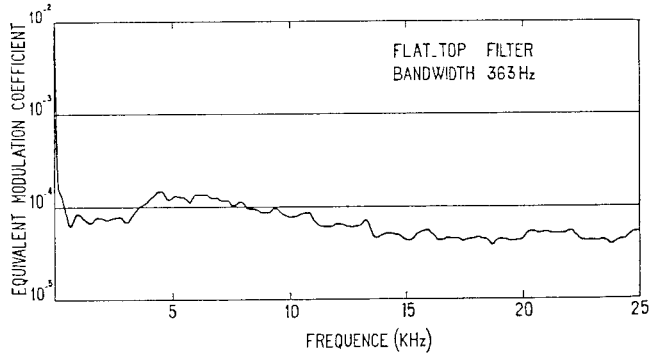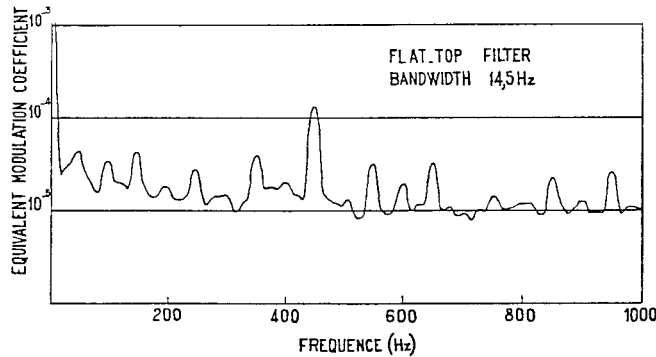
$$SSC\ 2, res\ 1 - \hat{V}_{rf} = 113\,kV,\ F = 8.48\,MHz.$$

Fig. 3

3.2 Computer Control and Operation

The amplitude regulation systems are controlled by 4 dedicated CAMAC microprocessors (injector, buncher, SSC1, SSC2) which are in charge of :

a. the voltage reference control itself coming from the main computer.

b. the starting operation (choice of low level RF voltage for frequency tuning operation, rising the RF dee voltage up to the asked level).

c. The automatic gain control through the attenuator (§ 3.1).

d. the on-off actions.

Before starting, all the transmitter and resonator parameters (i.e. movable panel or variable condensator positions) are verified after having read the working frequency value.

The access to the RF voltage levels and the amplitude regulation status via the main computer is easy by means of special tasks[4].

4. PHASE REGULATION SYSTEM

4.1 Description

Common for all the GANIL resonators this complex system has 2 goals :

a. to clean the RF dee voltage of any parasitic phase noise modulation in the range of 0 to 15 kHz. This role is devoted to the fast phase regulation devices.

b. to make possible precise phase adjustements between RF systems and not only between the two resonators of one SSC, but also between injector, buncher, and the two SSC for beam tuning. Of course this must be possible for any value of the GANIL frequency range and the phase values kept constant as well as possible within ± 0.5 RF degree.

This last part is the most complex of the whole system : it is fully controlled by a dedicated CAMAC microprocessor and uses stepping phase shifters combined with continuous mechanical phase shifters. A HP vector voltmeter is used as a precision on-line phasemeter.
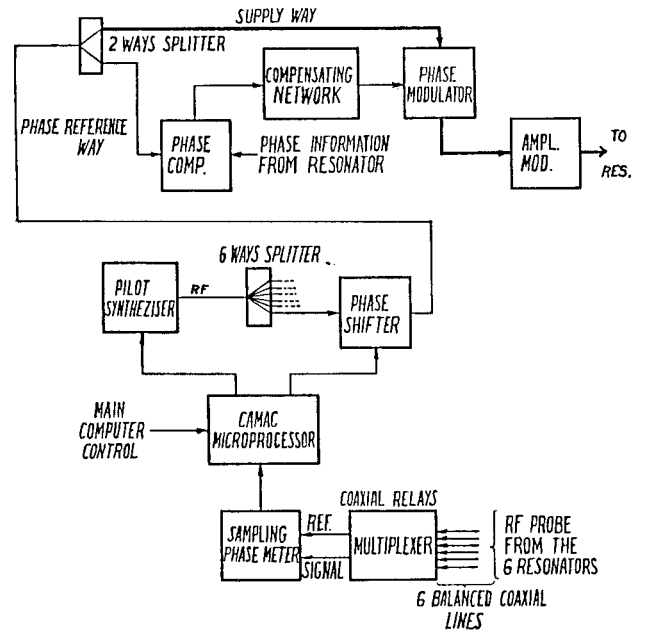

Fig. 4

The Fig. 4 shows the detailed structure. The RF signal provided by the master generator is distributed in 6 ways. Every one is itself divided in two signals : the first is sent to a phase modulator and then to the related RF transmitter, the second is the floating RF phase reference for the fast phase regulation device. "Floating" means that any phase adjustments made before the last divider do not disturb the fast phase loop.

Outside of the CAMAC system, the other important part is the phase-measurement system. The 6 back RF signals given by the RF resonator probes are conducted by phase balanced cables (equal electrical length) connected to the vector-voltmeter through a well balanced multiplexer.

4.2 Operation and Results

Injector resonator gives the phase reference, for all RF systems, except resonator n° 2 of both SSCs (for which the phase reference is taken on the opposite resonator n° 1).

The 5 relative phase values (injector-buncher ; injector-SSC1 reson. 1 ; injector-SSC2 reson. 1 ; SSC1 reson. 1-reson. 2 ; SSC2 reson. 1-reson. 2) are periodically measured by a local surveying program which sends an error message to the main computer when a phase drift greater than 0.2°, relatively to the reference value, is detected. Then the operator has to get informations by reading status word and, if necessary, can ask the correcting action.

The initial setting of the phase values is done by the main computer through the console keyboard. It is also possible to control any phase value in pseudo-analog mode by hooking one pseudo-knob.

Nevertheless this last action requests to perform a complicated process (dedicated phase control micro-processor) and the final answer may come slowly (several ten seconds due, for the main part, to the slow motion of the mechanical phase shifters). That is not very convenient for on line beam tuning. An improvement is in progress to control directly by pseudo-knob the phase reference of the fast phase loop using directly the electronic phase modulator and therefore by-passing the local processor. In this way we hope to have ± 10° phase variation capability. Consequently the operator will find the correct phase value by watching the beam. To know the precise phase value, then he has to restore the local processor.

FLAT TOP FILTER BANDWIDTH 14,5 Hz

FLAT TOP FILTER BANDWIDTH 145 Hz
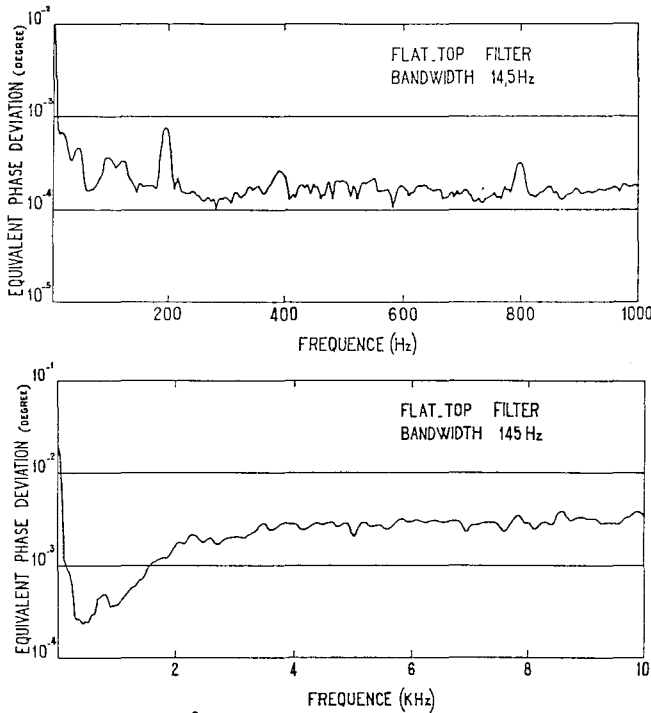
$SSC1$, $res 1$. $\hat{V}_{rf} = 100 kV$, $F = 9.52 MHz$.

Fig. 5

Various spectrum analyses (Fig. 5) and long term recording show that the overall stability of the whole phase control system is better than ± 0.2°.

The phase noise is really very small (better than 0.05°) and the RF spectral purity (given by radio-

frequency spectrum analyses in a bandwidth of 10 kHz around the carrier) is always better than 80 dB for any GANIL resonator : Fig. 6.

FILTER RESOLUTION 10Hz

Pilot syntheziser : 9.52 MHz (phase noise refer.)

FILTER RESOLUTION 10Hz

FILTER RESOLUTION : 10Hz

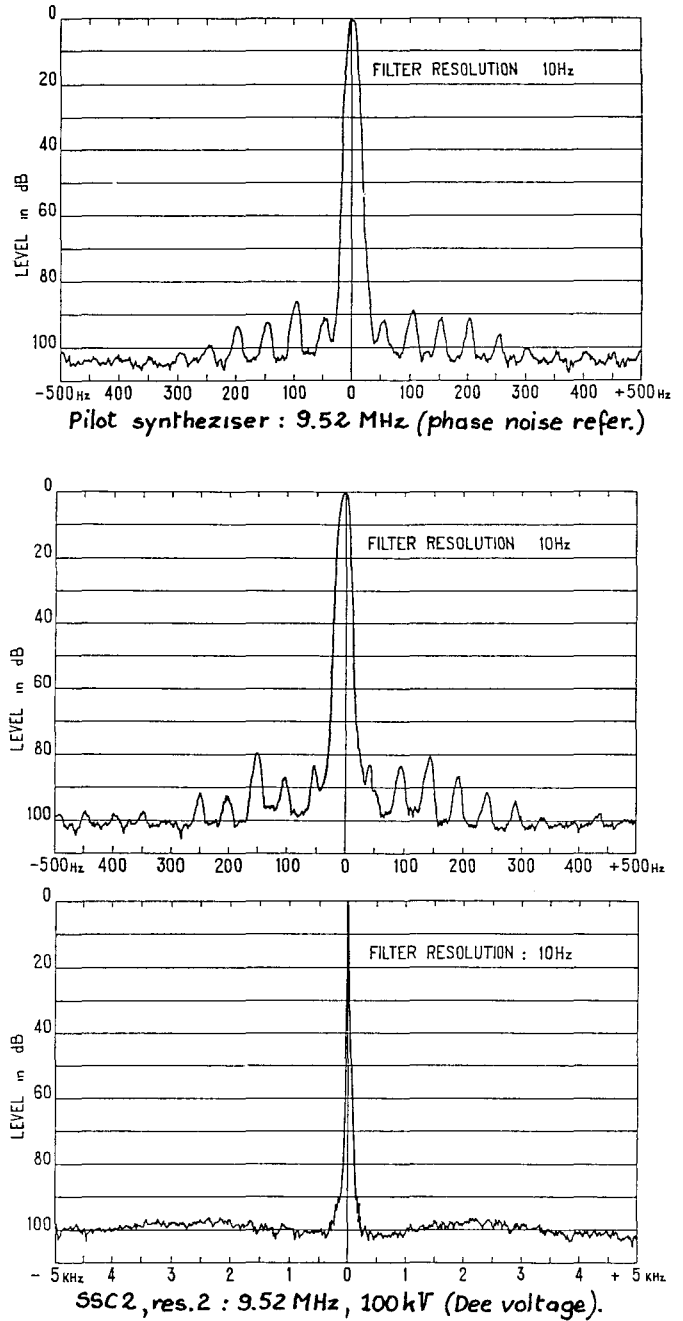$SSC2$, $res.2$: $9.52 MHz$, $100 kV$ (Dee voltage).

Fig. 6

This operating system has now been used for almost 1 year with on line computer control and fortunately it works very well, without serious troubles or failures.

5. MEASUREMENT METHODS

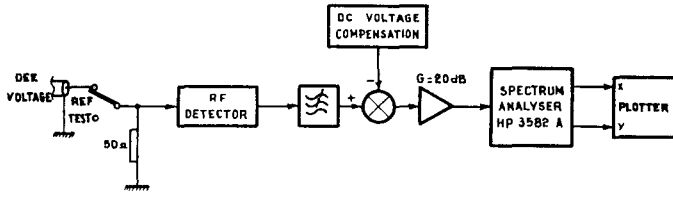Fig. 7, 8 and 9 show the measurement methods in use to record the 3 kinds of spectra.

Fig. 7 : Amplitude noise measurements

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3. C. Bieth, G. Dugay, A. Joubert, C. Pagani, J.M. Baze "GANIL RF Systems" IEEE transaction on Nuclear Sciences Vol NS-26 n° 3, June 1979.

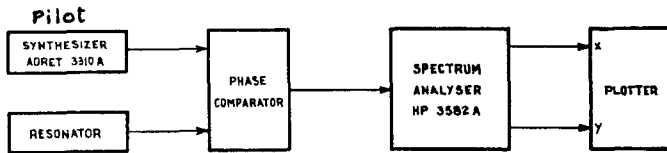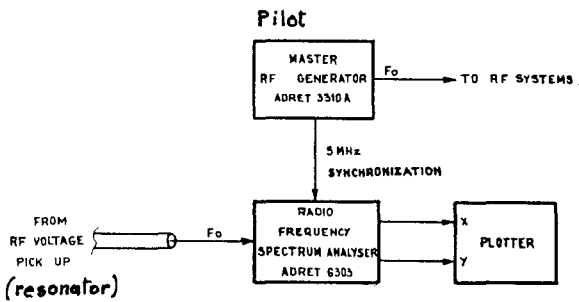4. M. Promé et al. "The Operation of the GANIL Control System" Proceedings of this Conference.

Fig. 8 : Phase noise measurements

Fig. 9 : Overall spectral purity measurement