RF and Beam control system for Celsius

T. LOFNES

The Svedberg Laboratory, Uppsala, Sweden

ABSTRACT

A ferrite loaded RF cavity and beam control electronics has been built at CERN and been in operation for one and a half year at the CELSIUS storage ring in Uppsala. The operating frequency range of the cavity is either 0.4 to 2.0 MHz or 1.0 to 5.0 MHz and the maximum gap voltage is presently 1600 V. In the beam control system the frequency program is calculated from the magnetic field measurement data (with possibilities to add bumps in the program directly from the control system). Also, a phase servo is used to damp out the syncrotron oscillation that are generated either by the frequency steps or by ripple (or noise) in the ring. This is done by controling the AC phase difference between the beam revolution frequency (measured with a pick up) and the gap frequency. No radial servo is used. The present status of the system is presented.

INTRODUCTION

The Rf-system consists of a cavity and amplifier, a voltage control system, a tuning control system and a beam control system.

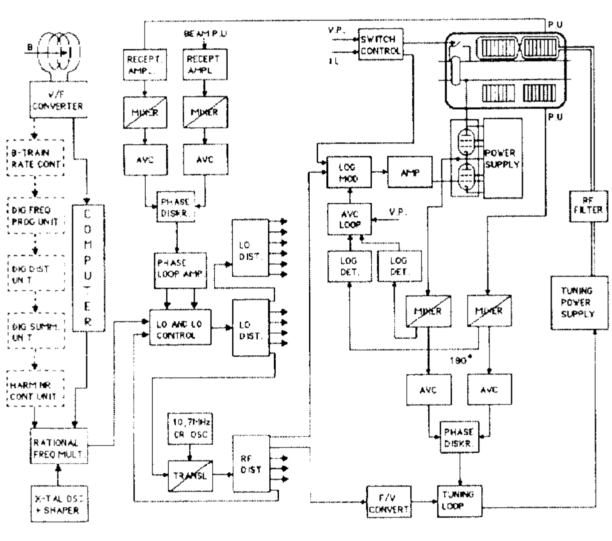

Fig. 1 the RF system functional diagram

The voltage control system controls the voltage on the cavity and makes it follow a voltage program. High bandwith of this system is useful if adiabatic capture is wanted. The tuning control system calculates the tuning current as a funktion of the frequency and controls the tuning by feeding back the phase shift over the cavity.

THE CAVITY AND AMPLIFIER

A λ/4 ferrite loaded cavity (1) with a frequency span of either 0.4 to 2.0 MHz or 1.0 to 5.0 MHz , and a maximum tension of 1600 volts is used . To change from the lower frequency range to the upper a condenser has to changed manually. To tune the cavity , two turns in a figure of eight are employed together with a 5 V 1500 A generator.

The amplifier consists of a Eimac 4CW 10000C power tetrod, with 5.5 kV on the anode, and cathod driven by 10 Eimac 4CX350A tetrods in paralell, with -600 at the cathods.

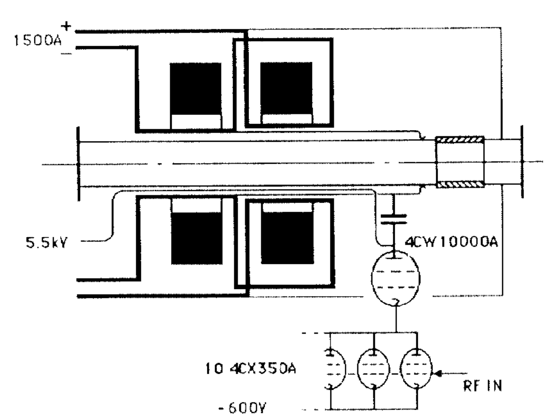

Fig. 2 Celsius cavity schematic diagram

THE BEAM CONTROL SYSTEM

The appropriate frequency is calculated by the computer from the magnetic field measurement. This frequency is changed with steps of 160 Hz.

In order to damp out the syncrotron oscillations that are generated when the frequency changes stepwise (or by ripple or noice generated in the Rf-system or anywhere in the ring) a phase loop is used. In the phase loop, as shown in fig 2, the phase error - the phase difference between the beam and the cavity (measured by pick up's) is controlled. This is done by feeding back the phase error - over a loop filter - to the phase control input of the phase locked loop that furniches the rf-frequency.

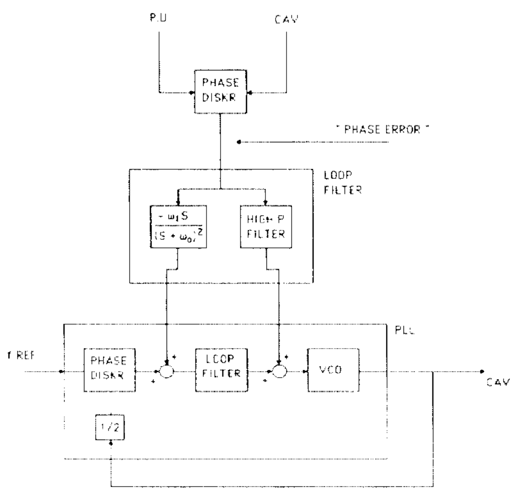

Fig 3 The phase loop

The loop filter is chosen to (in laplace operators);

$$\frac{\omega_1 s}{(s+\omega_0)^2}$$

Noting that the longitudinal beam transfer function for the ring is;

$$\frac{s^2}{s^2+\Omega_s^2}$$

where Ω_s is $2\pi f_s$ and f_s is the syncrotron frequency of the ring. Then the open loop responce of the beam becomes.

$$\frac{s^2}{(s^2+\Omega_s^2)}\frac{\omega_1 s}{(s+\omega_0 s)^2}$$

Which gives a stable system if

$$\omega_0\omega_1 \leq \Omega_s^2$$

This system is though limited by the bandwidth of the PLL. To increase the bandwidth of the phase loop , a direct coupling of the phase error to the VCO of the PLL over a high pass filter is used at the same time.

Since Ωs is a funktion of both the rf amplitude and frequency, the loop filter has to be changed at certan levels of Ωs. This can be done with switches that changes the constants in the loop filter at these levels.

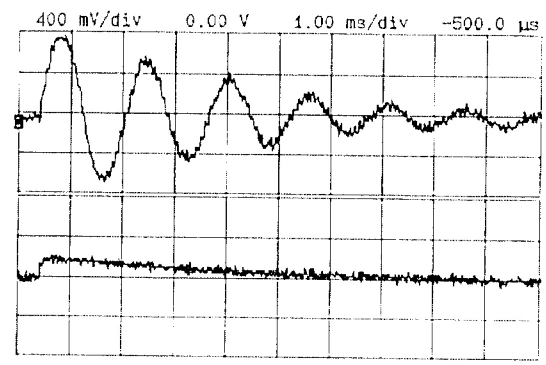

Fig 4 Damping of the phase oscillations (syncrotron oscillations) created by a frequency step . Upper without phase loop lower with phase loop

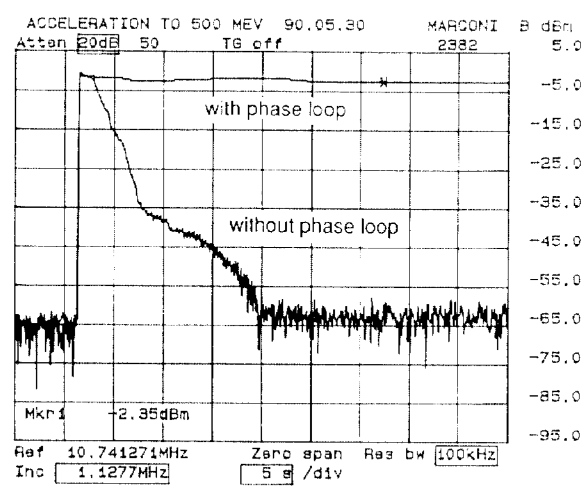

Fig 5 Beam intensity at acceleration (in dB).

Since there is a zero root in the numerator of the loop filter , dc phase errors are ignored by the phase loop. This makes it possible to use any pick up in the ring regardless of the distance to the cavity.

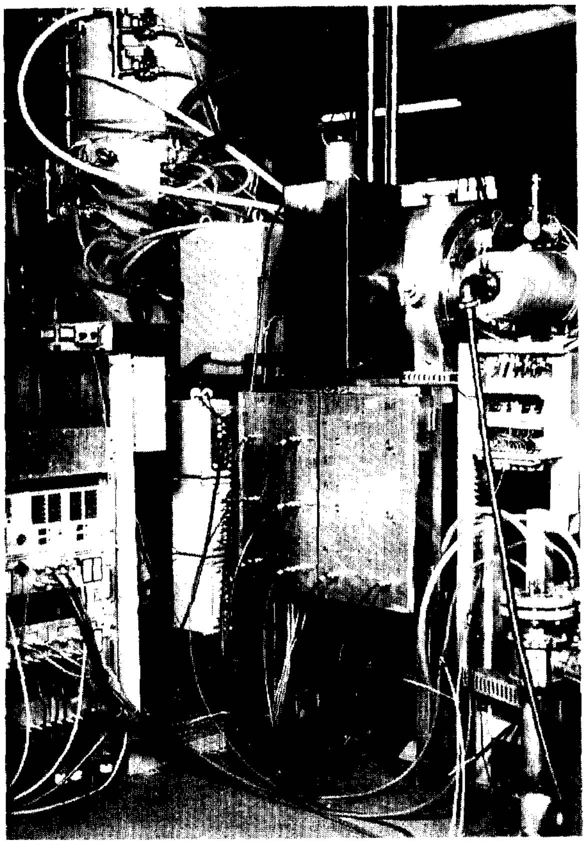

Fig 6 The cavity

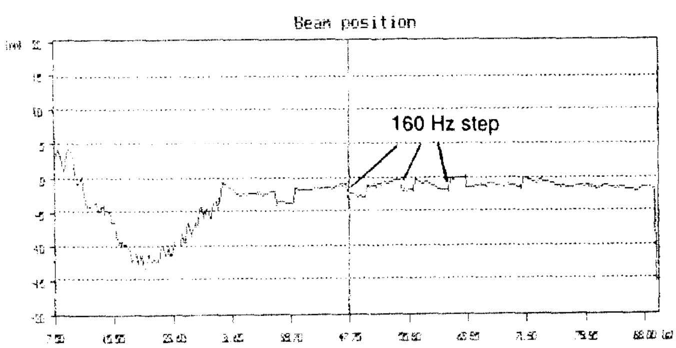

Fig 7 Change in radial position due to 160 Hz frequency step.

CONCLUSION

A small cavity with low voltage do not seem to be any limitation at celsius.
Direct calculation of the frequency without any radial feedback also works although some thoughts of using a radial loop has been discussed , since there are some difficulties of measuring the magnetic field with high accuracy.

A better resolution of the frequency is also desired since a 160 Hz change at higher energy levels gives a 4 mm change in radial position.
The phase loop improves the lifetime of the beam and decreases the loss at acceleration with a considerable amount. The use of switches in the phase loop filter may also inprove the performance.

REFERENCES

(1) A Susini , Low frequency ferrite cavities. EPAC 88