EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN - PS DIVISION

CERN/PS 98-026 (RF)

THE NEW LOW FREQUENCY ACCELERATING SYSTEMS FOR THE CERN PS BOOSTER

A. Krusche, M. Paoluzzi

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A set of four, ferrite-loaded, low-frequency RF cavities equipped with local RF feedback has been built and installed in the CERN PS Booster rings. Together with the modified existing RF systems they now serve for acceleration as well as RF gymnastics of protons and heavy ions up to the highest beam intensities. The systems specifications with a frequency range of about 0.6 to 1.8 MHz and a nominal RF peak voltage of 8 kV satisfy specifically the requirements of acceleration on harmonic 1 of the future proton beam for the LHC. The system design has been guided by the request for safety margins for high beam intensity operation and ease of maintenance and repair. Some design aspects are presented as well as the performance achieved.

6th European Particle Accelerator Conference (EPAC98), June 22 - 26, 1998, Stockholm, Sweden

Geneva, Switzerland
20 July 1998

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1 INTRODUCTION

The request for higher beam brightness from the injector chain for CERN's future Large Hadron Collider has motivated, among other upgrades, the construction of new RF equipment in the PS Booster (PSB). The addition of cavities accelerating on RF harmonic h=1 and supplemented with a h=2 system, contributes to reduce harmful space charge effects and avoids the coupled bunch instabilities observed with the former acceleration scheme on h=5 [1]. These advantages are exploited equally well for all other proton beams handled in the PS accelerator chain [2]. With the abandoning of RF harmonics h=5 it became possible to modify the existing equipment for h=2 operation at little cost. The PSB is now equipped with three RF systems covering the frequency bands 0.6-1.8 MHz (C02), 1.2-3.9 MHz (C04), 6-17 MHz.(C16), and able to perform acceleration, bunch flattening, bunch splitting and longitudinal emittance blow-up on protons and heavy ions. Systems properties are summarised in Table 1.

2 DESIGN CONSIDERATIONS (C02- SYSTEM)

A nominal peak RF voltage of 8 KV with ample margin is required, since high-intensity beams beyond 10^{13} particles per pulse and per Booster ring are to be handled. Vertical installation space is scarce due to the particular PSB construction with four superimposed rings restricting the vertical size of any equipment. For this reason the idea to squeeze four cavities in one PSB straight section was abandoned, and a second section had to be sacrificed to allow usage of large size ferrite rings.

2.1 Cavity design

A classic and conservative NiZn ferrite-based design was chosen, replicating essentially the one-gap design with virtual ground symmetry in the gap mid plane of the other two PSB RF system cavities (Fig 1)[5]. Air cooling of the ferrite through 1 mm spacing between rings gives the best ferrite filling factor, keeps the mechanical construction simple and is very cost effective compared with water cooling. The choice of Philips ferrite material grade 4A11 was made after tests on several small size ring samples, with the absence of resonant absorption phenomena in the required working area as main criterion. Booster operation implies synchronisation of the four rings with the PS cycle on a magnetic flat top at sometimes constant or very slowly changing RF frequency. It is known, that under such conditions ferrite can jump into the so-called High Loss Mode (HLM) at critical excitation and disturb the servo control of the RF voltage amplitude [3]. The onset of HLM appears to arrive earlier at higher DC saturation of the ferrite, i.e. at a higher frequency in our tuned cavities. The ferrite volume and cross section was chosen to stay safely below HLM onset at nominal RF voltage. The selected ferrite grade exhibits a smooth and fairly stable transition into HLM and experience has shown that safe operation well beyond nominal voltage is possible. A temperature check of the individual rings in the operational cavities replaced laborious ferrite reception testing.

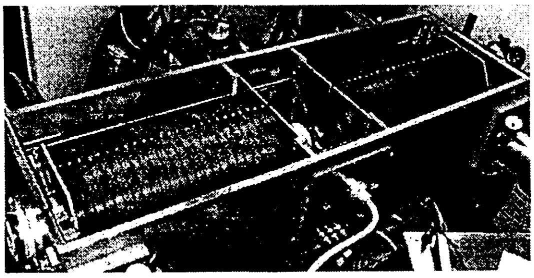

Figure 1: Ferrite loaded cavity C02

2.2 RF amplifier chain

A conservatively-rated wide-band power amplifier was developed using the Tetrode RS1084CJ, driven by a 200W transistor amplifier. Feedback of the gap RF signal provides reduction of the cavity impedance to the beam by 20 dB. Higher values are possible when needed. A particularity of the design consists in the use of a tuned low Q resonant grid circuit [4], synchronised with the DC tuning current of the cavities. Advantages are higher gain, smaller drive power and the possibility to program phase response for increased feedback loop stability. The movable amplifiers are placed near to the cavities and can be easily replaced in case of a repair (Fig. 1,3).

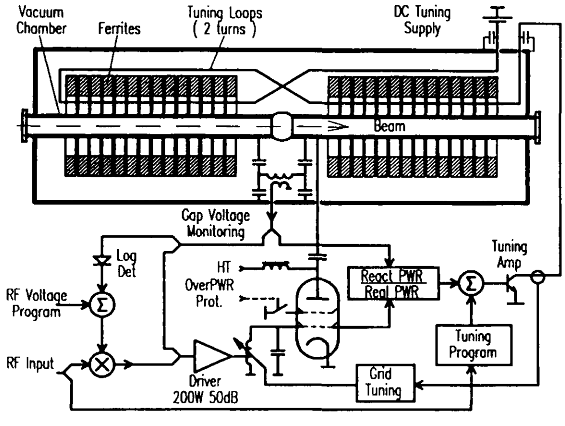

Figure 2: C02 system layout

2.3 *System Electronics layout*

Servo control of RF voltage amplitude is provided by logarithmic detector and modulator electronics. The cavity tuning is made by a novel IGBT linear current amplifier, which is controlled by a reactive power detection module. The frequency to tuning current relationship is pre-programmed in a memory; fine tuning is handled in the analogue feedback loop. An RF overpower detector acts rapidly on the final tube screen grid to prevent system trips. All system electronics was developed to cover the whole frequency range of 0.5-16 MHz and is used in all three PSB RF systems (Fig. 2).

3 The C04 RF System

The existing cavities and amplifiers have been modified to work in a lower frequency band 1.2-3.9MHz by straightforward measures and retaining most of the hardware. System and control electronics are the same as in the C02 system. The lower frequency pushes the ferrite (Philips 4L2) more to the limit, and the nominal RF voltage is reached without much margin. Operation at constant frequency just beyond nominal voltage at strong DC bias may be hampered by appearance of HLM, which with this ferrite grade appears to be unstable.

4 The C16 RF System

This system served before 1998 as second harmonic for the then still operational h=5 RF. Since then, the system is used for longitudinal emittance blow-up only. The main parameters are shown in Table 1.

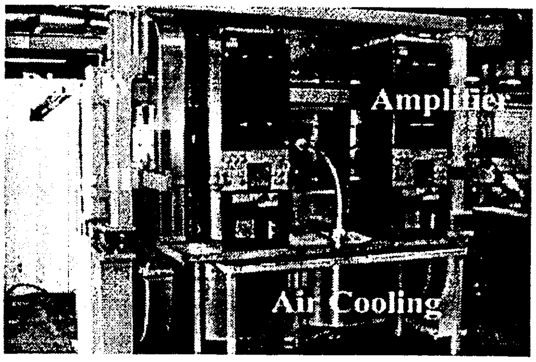

Figure 3: C02 test mount for PSB rings II and IV

Table 1: Main parameters of PSB RF systems

Parameter \ System	C02	C04	C16
Frequency Range [MHz]	0.6 - 1.8	1.2 - 3.9	6.0 - 17.0
Quality Factor	6 - 28	90 - 190	60 - 80
Cav. Shunt Resist.[KOhm]	2.5	9	7
Nominal Gap Vrf [kVp]	8.0	8.0	6.0
Max. Gap Vrf [kVp]	10.0	9.0	8.0
Power Loss [kW]	13.0	3.0	2.5
Peak Power [kW]	50.0	20.0	10.0
CW Power [kW]	20.0	10.0	5.0
RF Feedback Gain [dB]	20	20 - 26	13 - 26
Ferrite Type (Philips)	4A11	4L2	4M2
Permeability at Remanence	~600	~200	~100
Tuning Bias [A* turn]	0 - 500	0 - 1800	0 - 3500
Power density [mW/cm^3]	64	31	58
Magn. RF Flux Dens.[mT]	4-12	3.2-9.4	1-3.2
Ferrite Ring Size [cm]	48x24x3	35x20x3	35x20x3
Total Ferrite Length [cm]	1500	1500	660

5 CONCLUSION

The PSB RF systems have been upgraded by the addition of new, HLM free low frequency ferrite loaded cavities. The specifications needed to assure all so far known beam acceleration and RF gymnastic requirements, including the beam for the future LHC injection, have been met with comfortable margins. The choice of conservative technology has so far been rewarded by a nearly trouble free operation.

6 Acknowledgements

We thank TRIUMF/Canada for providing power converters and ferrite rings within the LHC collaboration contract.

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