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PREPARATION OF PS INSTRUMENTATION FOR THE LHC TEST

J. Belleman, J.L. Gonzalez, S. Johnston, E. Schulte

Abstract

To cope with the LHC test acceleration scheme, using the harmonic numbers $h = 8$ or $h = 16$ and a bunch duration of more than 200 ns at injection, new hardware was developed and some of the existing hardware had to be modified for both the PS accelerator and the PSB-PS transfer line acquisition systems. The changes had to operate in PPM since dedicated MDs were inserted between normal machine operations.

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Preparation of PS Instrumentation for the LHC test

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1. Closed Orbit Acquisition

The synchronisation of the closed orbit acquisition system, which processes the signals coming from 40 pick-ups, was originally based on the harmonic number $h = 20$ for *normal* hadron acceleration. A beam-synchronous RF signal was extracted using two pick-ups, followed by a tracking filter automatically tuned to the 20th harmonic of the revolution frequency using B-train information. The AC coupled nature of the pick-up electronics and the measurement method, which was based on a gated integration of the bunch signal, required the use of base line restitution (BLR).

With the advent of leptons, the system was upgraded to also handle $h = 8$. Since the revolution frequency of leptons in the PS does not change appreciably during acceleration, a filter, tuned to a fixed frequency corresponding to $h = 80$, was used to construct two reference RF signals : $h = 8$, for BLR, and $h = 20$, to take advantage of the existing gate control hardware.

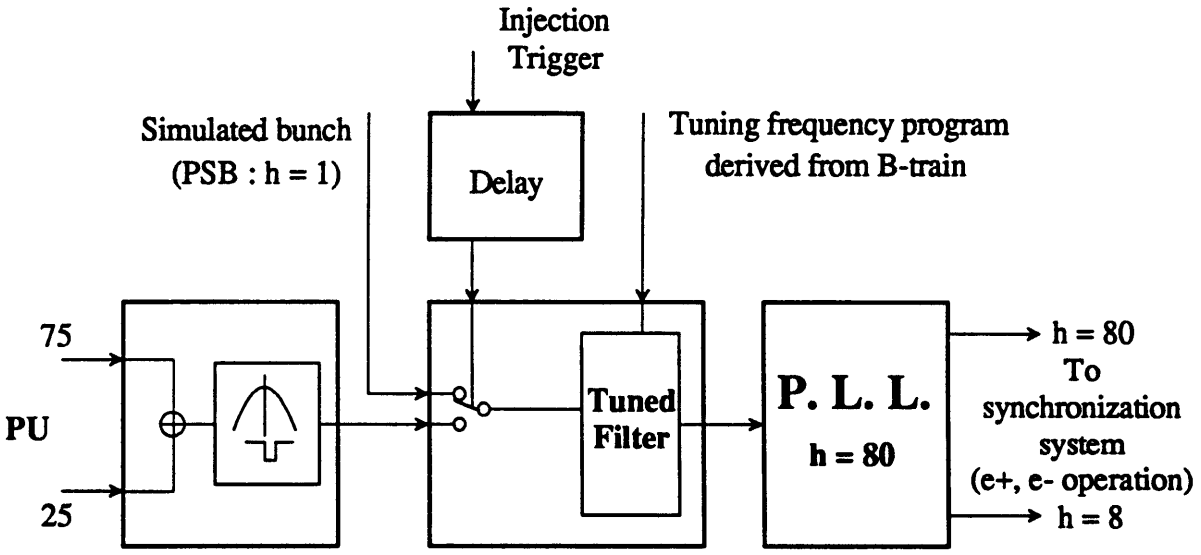

Fig. 1 : Reference frequency for the LHC test beam acquisition is generated using a tuned filter driving a phase-locked loop (PLL).

For the LHC test, hadrons were to be accelerated on $h = 8$, requiring the synchronisation system to follow the changing revolution frequency. This implied the development of a new tracking filter, and to profit from existing lepton hardware, it was implemented as a tuned filter on $h = 8$ driving a phase-locked loop (PLL) on $h = 80$ (fig. 1). The filter is excited either by a

simulated bunch, derived from the Booster ejection frequency prior to injection into the PS, or by a peak discriminator which delivers pulses of constant amplitude and width, coincident with the centre of the bunches as observed by two pick-ups. This discriminator also prevents the subsequent bunch splitting at $h = 16$ from confusing the filter.

The acquisition gates of the system are derived from a reference RF signal on $h = 20$, corresponding to a 125 ns period at injection : much shorter than the new bunch length. Consequently, all the Gate Generators had to be modified to increase the gate length. The BLR timing had to be changed accordingly, thus requiring modification of the lepton hardware.

Many minor modifications were also needed to harmoniously fit the new hardware into the existing system. The total manpower required to construct the modules, modify the installed hardware and test the complete system was more than 4 man-months.

Results from the LHC test have shown that any normal bunch can be acquired on $h = 8$, during the whole cycle (fig. 2). However, at present, it is not possible to acquire position data on the split bunches separately because the gate length covers about two periods of $h = 16$.

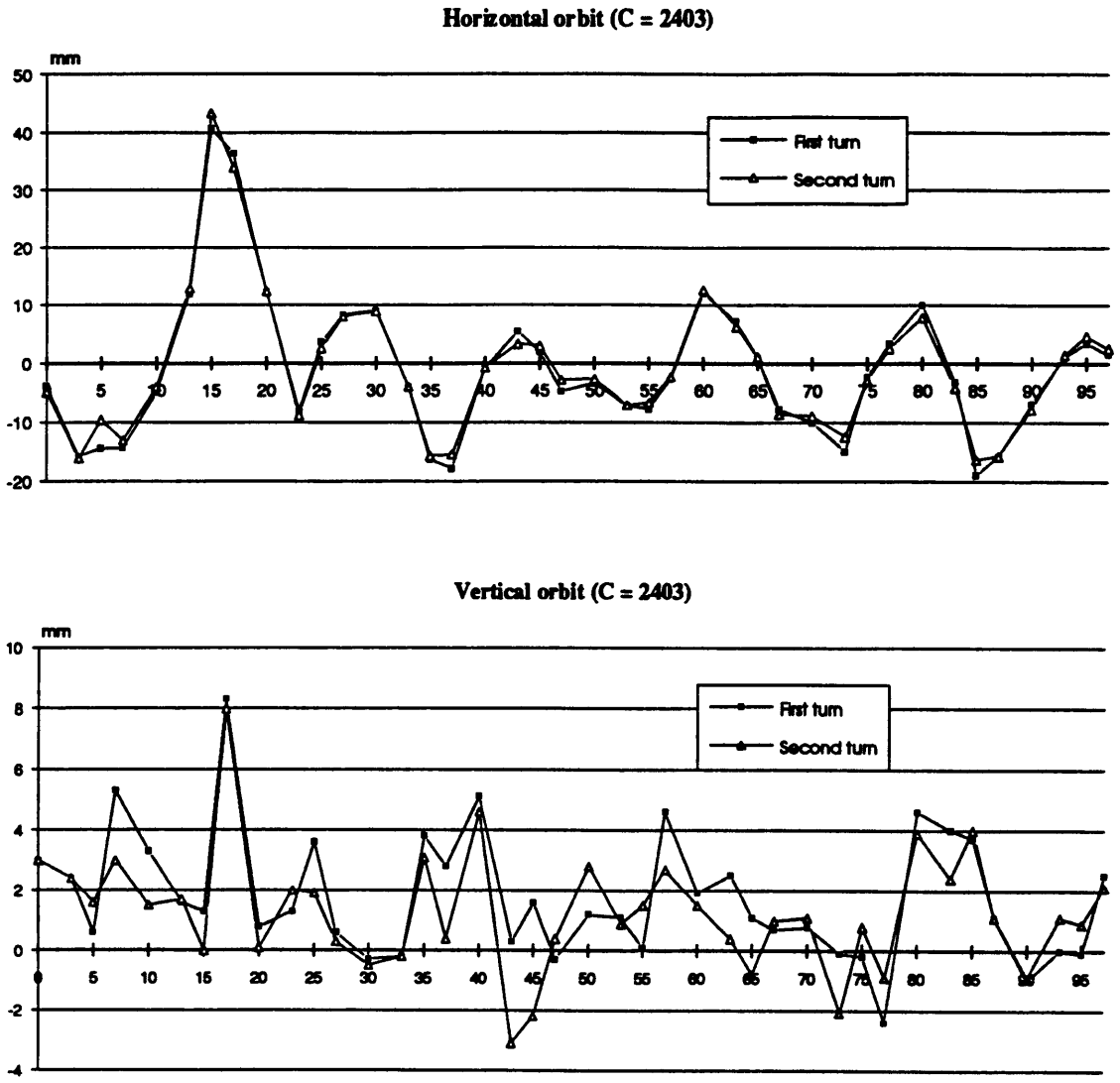

Fig. 2 : Horizontal and vertical orbit acquisitions showing the bump, at C = 2403, prior to extraction of the accelerated beam in the PS.

2. PSB-PS Transfer Line Acquisition

The acquisition system in the PSB-PS transfer line needs three specific Gate Generator modules to acquire the position and intensity signals coming from 14 pick-ups. The gate duration, which is usually 120 ns on harmonic mode $h = 5$, had to be increased to 250 ns for the LHC test on $h = 1$. This required a hardware modification which took about two weeks.

3. Q-Measurement by FFT

As part of the on-going controls conversion project, the PS FFT Q-measurement has been developed for LynxOS [1]. The system was still under development at the time of the LHC test, and it was therefore necessary that it worked as a stand-alone unit in the PS and, more importantly, in the PSB machine also.

In the case of the PS, both the new FFT-based and the old swept-filter Q-measurement systems had to operate side-by-side, using a low-frequency PU to avoid having to use the synchronous detector which was part of the old Q-measurement. Hardware for low-pass filtering, signal amplification and splitting to the two systems was developed specially. A timing unit was also realised to give a trigger to the kicker and VASP-16 Digital Signal Processor, as well as information indicating the plane measured (fig 3).

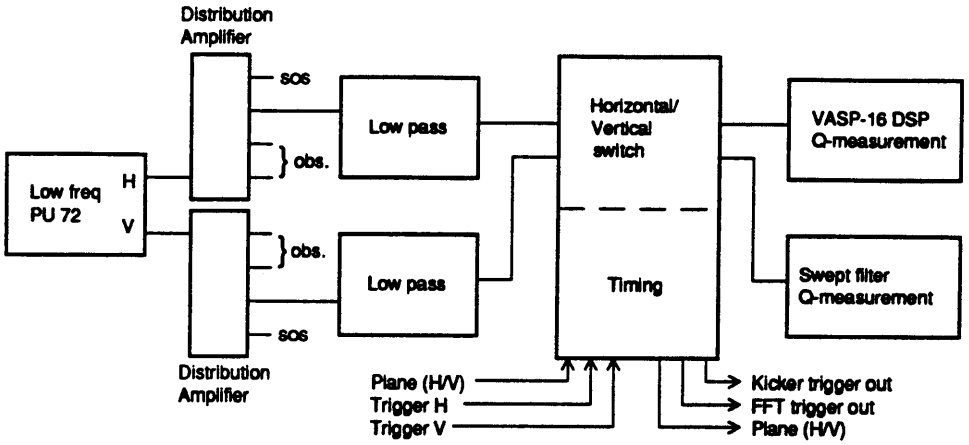

Fig. 3 : Hardware requirement to enable the swept-filter and FFT Q-measurement systems to be used simultaneously.

A PC-based graphics program was written to display the results of the Q-measurement. This program used a TCP/IP socket connection to the DSC in which the Q-measurement was housed (fig 4). A simple menu driven control program, running on the DSC but viewed from the PC screen, allowed measurement requests to be made.

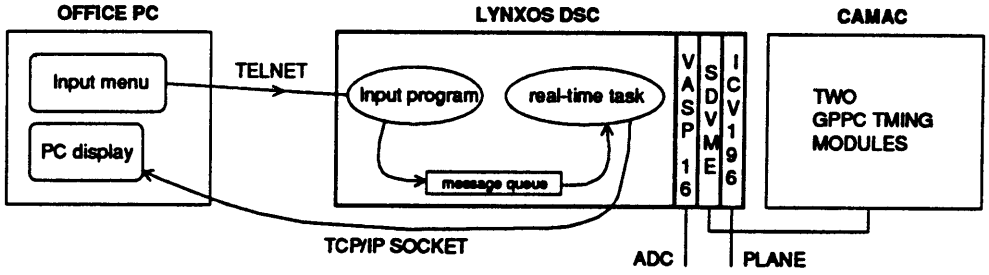

Fig. 4 : Because no application program already existed, a PC-based display was developed. A simple menu driven program running on the DSC interfaced with the real-time software in place of the equipment module.

Initially it was necessary to operate the existing swept-filter system in order to produce trigger pulses to the VASP-16 and kicker system. This was eventually replaced by direct programming of the trigger timing via two GPPC modules housed in CAMAC.

Fig 5 shows a series of Q-measurements by FFT analysis in both planes. Each Q-measurement is spaced 20 ms apart, and ranges from C201 to C2401. The measurements in the vertical plane were performed a few cycles after the measurements in the horizontal plane.

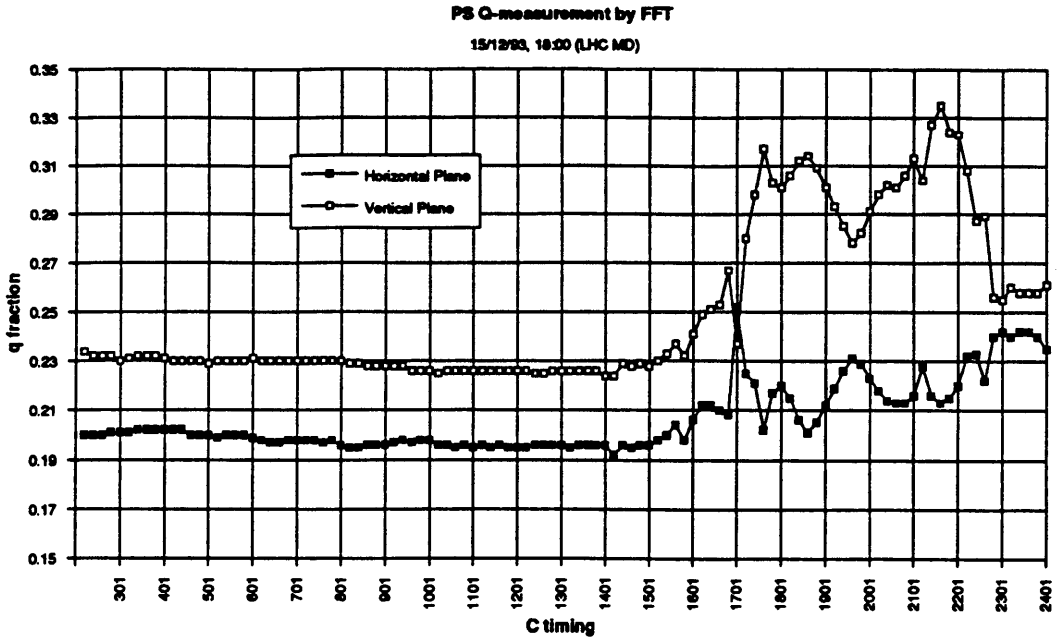

Fig. 5 : Q-measurement analysis during acceleration of the LHC test beam.

The development of a make-shift display program for the PC and the network communications required 10 weeks of work, while hardware production cost 2 to 3 weeks. However, the experience gained from the software development has been useful for providing advice to the developers of the MCR application program. The code used to program the GPPC modules is actually included in the final version of the real-time program, and the LHC test provided a valuable opportunity to test the system before the shutdown.

The FFT Q-measurement is, at the time of writing, going through final tests between BD and CO groups. In the near future, the application program will be developed by OP group, allowing the system to become operational.

4. Transverse Feedback

The hardware development which was necessary to make the transverse feedback system accept harmonic numbers ranging from $h = 8$ to $h = 20$ was substantial and started well before the LHC test run [2]. Installation and test of new electronics was realised during short PS shutdown periods.

Alternatively, the beam revolution frequency contents of the pick-up signal could be rejected using several types of digital notch filters which are now available with pre-programmed coefficients. Up to 16 filters could be switched-in dynamically depending on the PS user line. PPM switching of filter type and digital loop delay values was however momentarily achieved using a dedicated PLS decoder.

The digital signal processing circuits are driven by a reference clock related to the beam accelerating frequency, so as to accurately determine the centre frequency of the notches during acceleration. If sampling and accelerating frequency were different, transverse feedback performance would be highly affected. To avoid poor revolution frequency rejection, care must be taken with narrow notch bandwidths (fig 6) during fast acceleration cycles, as the clock signal comes from the central building on a long coaxial cable.

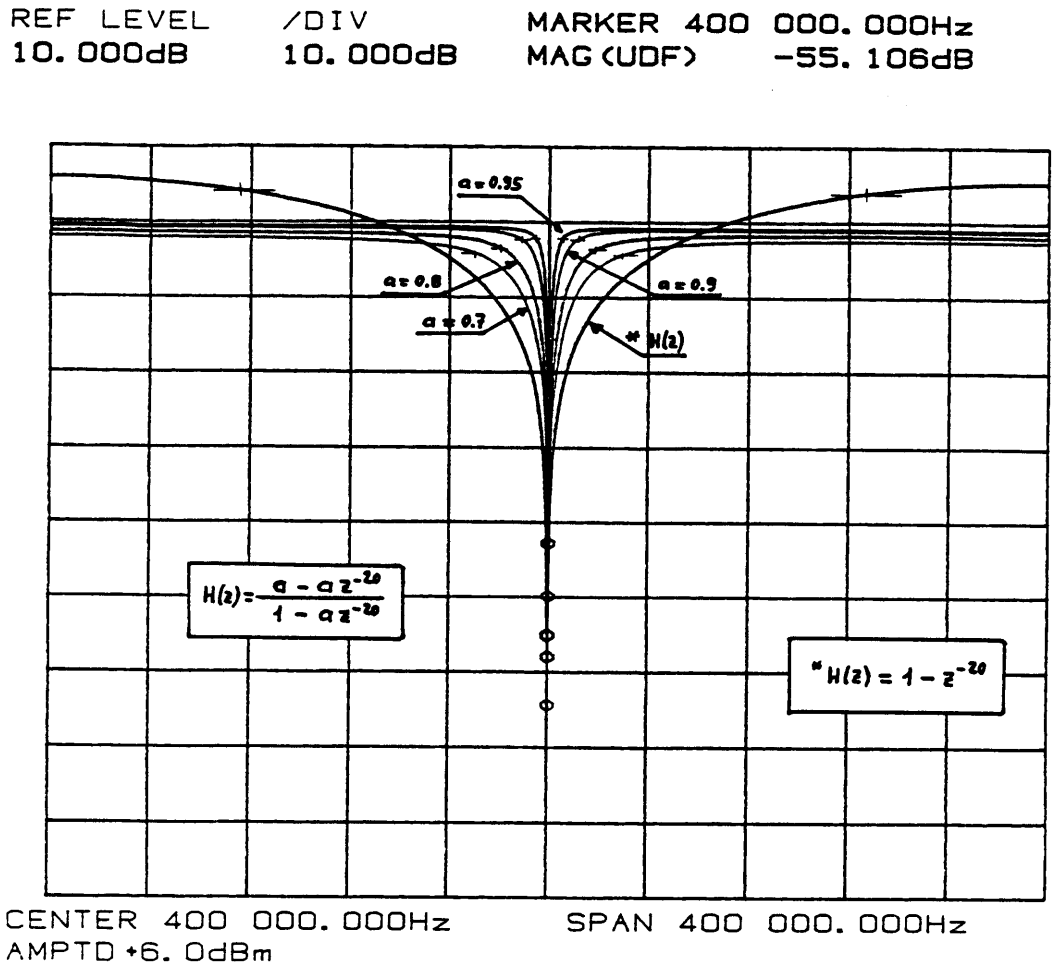

Fig. 6 : Notch filters performance when sampling frequency is constant (8 MHz for $h = 20$ or 3.2 MHz for $h = 8$).

5. Acknowledgements

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6. References

[1] S. Johnston, *"Real-time program for the PS FFT Q-measurement"*, CERN/PS/BD/Note 94-2, January 1994.

[2] J. L. Gonzalez, *"Correction des instabilités transversales des faisceaux de protons de haute densité, dans l'accélérateur PS"*, CERN/PS 93-17 (BD), April 1993.