DAMPING OF TRANSVERSE OSCILLATIONS IN THE ISR

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(presented in summary by M. J. de Jonge)

1. Abstract

A feedback system to remove horizontal injection errors in the ISR as proposed in 1) is described. The system treats the 20 bunches injected from the CPS individually.

As the damping process extends over many revolutions (typically 100) the power needed to drive the kicker magnet is modest (30 kW).

A different feedback system against resistive wall type instabilities of the stacked beam is mentioned.

2. General principle
(see Fig. 1)

The radial pick-up signals from the 20 successive bunches are switched rapidly between 20 filters; each filter forming a memory of the instantaneous amplitude and phase of the 9th azimuthal mode of coherent oscillation of a single bunch.

A pulsed transmission line deflection structure kicks the kth bunch when the error signals contained in the kth memory have a phase interval such that the kick will reduce the error.

The time taken by a bunch to pass the kicker (Damping Magnet) is typically 15 nsecs and the duration of a deflecting pulse is typically 30 nsecs.

The cross-section of the kicker is such that in the main the newly injected beam from the CPS is acted upon by the deflecting electric and magnetic fields, whereas the stack is kept shielded, see Fig. 2. There is, however, a slight penetration of the deflecting fields into the shield. Computer calculations show that in the case that all PS pulses are injected with the same error, the damping process will blow-up the stack by an amount corresponding to a few percent of this error.

3. Hardware

The electronics for driving the damping magnet is shown in block form in Fig. 1, and described briefly in the following.

The input is taken from a pick-up electrode and amplified by the normal head amplifier. As the information we wish to extract is represented by varying pulse height, we improve the signal to noise ratio by removing the lower portion of the pulse in a diode clamp. To reduce the transients on the filters at injection we use a differential amplifier combining the signals from both plates of the P.U. electrode. Compensation for unbalanced outputs caused by changing beam orbits is effected by varying the gain of one differential channel over a narrow range. The signals are then passed to a parallel group of linear diode gates. These gates are opened in turn to allow the signal associated with a particular bunch to pass into the correct filter. Switching of the gates is done by a circular shift register, started by a pulse from the machine timing system, and stepped round by a clock synchronised to the bunches.

Each filter unit in turn thus receives the height varying pulse derived from one particular bunch as it passes the P.U. electrode. In the filter unit it is amplified, phase shifted to ensure that the resulting feedback is negative, and shaped and stored in an L.C. filter. This filter extracts the 9th mode betatron oscillation (an approximate sine wave) which is converted into a train of TTL pulses by passing through a limiter, a zero crossing detector and pulse shaper.

The outputs from all twenty filters are then combined into a single pulse chain by a multiplexing unit. This unit builds up the chain by switching round in synchronism with the input diode gates. Both the gates and the multiplexer can be thought of as two single-throw twenty position switches, stepping round together at the bunch frequency. The multiplexer output is shaped and amplified by transistors up to the 40 volt peak level, then it goes to the driver stage, a six tube distributed amplifier A ferrite core transformer couples this amplifier to the final stage, a ten tube distributed amplifier. To simplify the output coupling the final amplifier is operated with HT+ on ground, and as a safety measure it is enclosed in a special double box. Both amplifiers use capacitor storage voltage multiplying power supplies as the continuous current drain is small.

The rise time of the amplifier chain is about 5 nsec and the output about 2.5 kV peak on 75 Ω. The driver amplifier uses six 4 CX 350 tubes and complete with power supply it occupies 13 cm height in the rack. The power amplifier has ten 4 CX 600 tubes and with power supply needs 62 cm rack height.

4. Preliminary trials

The following two pictures show the filtered radial pick up signal after injection of four bunches into the ISR without and with damping.

Fig.1 General principle

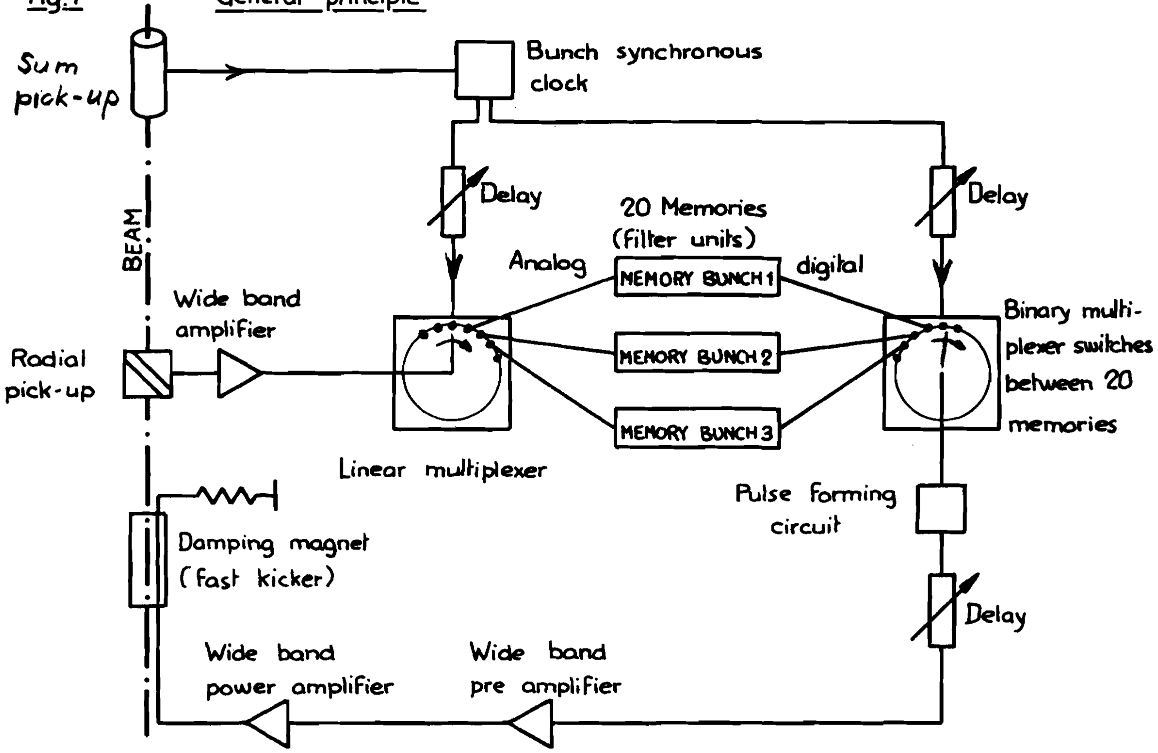
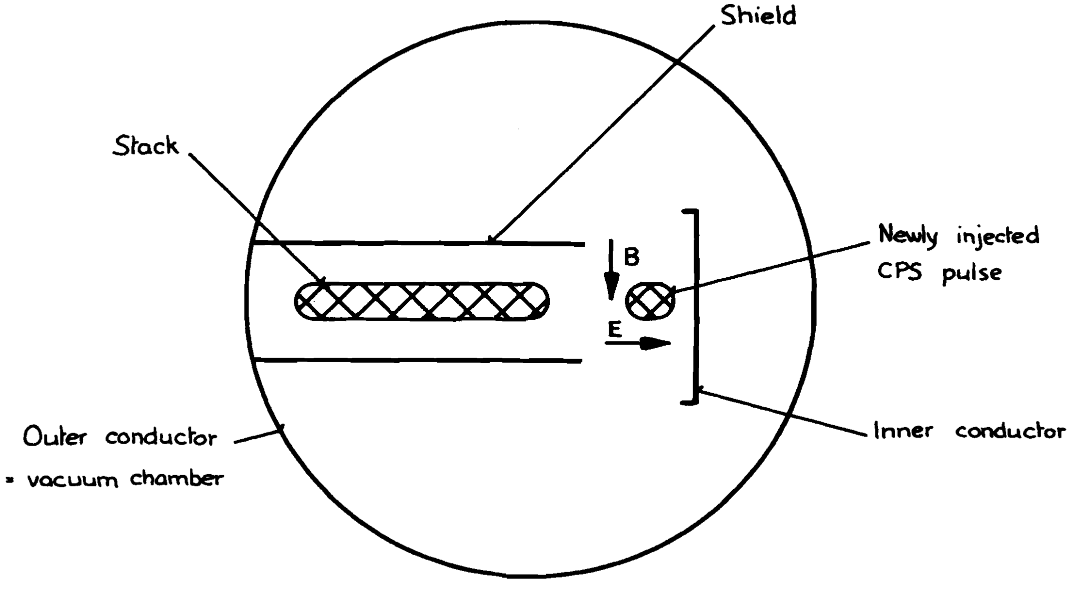
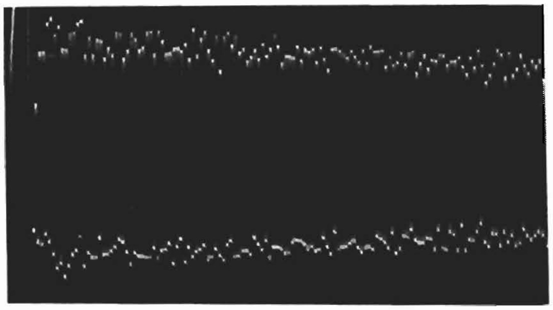
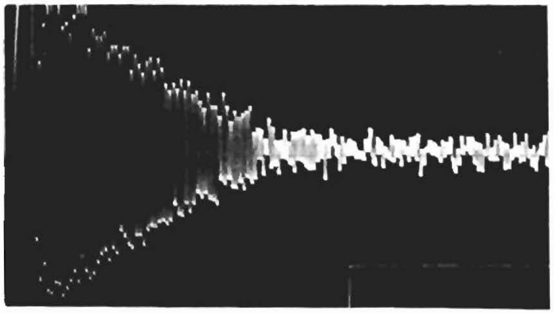


Fig. 2 Damping magnet cross section (75 Ω transmission line)



The injection error was of the order of 5 mm peak to peak. The damping magnet was operated for about 500 μs and the peak power through the kicker was about 50 kW.





5. Feedback damping of coherent instabilities of the ISR stack

Resistive wall instabilities at high currents have been partly suppressed by the use of feedback.

Vertical and horizontal pick-up signals are amplified and applied approximately 1 revolution later to a set of clearing electrodes, in the vertical case, and to the Q-measurement kicker, in the horizontal case, to damp the instabilities.

So far 15 - 145 kHz filters have remained inserted to limit the process to the 9th mode of betatron oscillations.

For machine conditions with vertical instabilities, an improvement of the stacking rate as well as of the maximum current has been observed.

The long term blow up of the stack due to the noise in the system remains to be investigated, as well as the usefulness of damping higher order modes of betatron oscillation.

6. Acknowledgements

The zero crossing detector was developed by P. Brown and S. Hansen. The diode clamp is the work of J. Pett. J. Borer suggested the diode circuit for the linear gates.

7. References

1. E. Keil, W. Schnell and P. Strolin: "Feedback damping of horizontal beam transfer errors", CERN 69-27, 1969.