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THE ISR BEAM POSITION MONITORING SYSTEM

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Introduction

This paper describes the beam position monitoring system (BPMS) built for the Intersecting Storage Rings (ISR) of CERN, as used during the present running-in period. This beam observation is based on the direct viewing of beam signals which permit the study of beam dynamics from beam intensity, position and longitudinal structure. The beam position is calculated from the video signals, presently recorded on photographs.

The video (wide band) part of the BPMS consists of the beam monitors (P.U.), head-amplifiers, end of cable amplifier, cable, selection-switch system and finally a dual beam scope. It provides the facility of observing the beam induced signal on vertical or radial pair of electrodes on each of the 53 P.U. in both rings. The bandwidth of the system is 30 kHz - 50 MHz in the main control room and 2 kHz - 110 MHz in auxiliary buildings. Description of present performance of the video signal observation system will be given as the conclusion of this paper.

ISR Electrostatic Beam Monitors (P.U.)

Classical electrostatic monitors have been chosen for the ISR because of their intrinsic linear position transfer function, good bandwidth and sensitivity performances well matched to the requirement of a large aperture (50 x 160 mm).

The design adopted for the ISR has the following notable characteristics :

The beam monitor is bakable up to a temperature of 300°C. Stainless steel metal sheet electrodes and rectangular cross-section were chosen to ease mechanical construction and assembly. Each pair of electrodes for horizontal or vertical measurement, forms one complete pipe. Therefore, the sum of the induced signals is proportional to the beam intensity only and can be used for signal normalisation.

The arrangement of vertical and horizontal electrodes adopted is a balanced structure which cancels the interaction between vertical and horizontal signals without separation by a grounded guard ring. In this way more of the monitor length can be used for the P.U. electrodes. Grounded guard rings are placed at both ends of the electrode assembly and have guard plates protruding within the bellows of the vacuum chamber. This construction meets the linearity requirement of the P.U.'s transfer characteristic.

The peak voltage induced when the beam is in the centre is

$$\hat{e} = 0.955 \cdot 10^{-13} \cdot \frac{N}{B_f} \text{ volt}$$

where : N = number of protons per pulse
B_f = average to peak bunch form factor

The sensitivity of the beam monitor is defined as the difference of the voltage variation on a pair of electrodes for a given displacement of the beam.

The measured sensitivity of the ISR monitor on its radial output is :

$$S_r = 0.0104\, \hat{e}\, \frac{\text{volt}}{\text{mm}}$$

$\hat{e}$ at beam centered.

The vertical sensitivity is about twice because the vertical aperture is half the radial one.

For calibration purposes it is necessary to adjust the electrode capacity to ground. For BPMS accuracy, the electrode capacity must be very stable and balanced with 0.5 x 10^{-3}. Therefore, the electrodes have been placed within a rigid case called a "plug-in", which has high mechanical precision. Its purpose is to define the ground potential for the electrodes and to hold them in their correct position. The used coaxial construction avoids undesirable resonances or common mode spurious signals. The electrodes are supported by specially designed insulators. They are built of aluminium oxide discs and brazed on stainless steel flanges. They are used at the same time as trimming capacitors.

The electrical connection betwwen the electrodes and the electronics is made through 100 Ω coaxial lines. For this purpose special ultra high vacuum coaxial feed-throughs have been developed.

The intrinsic resonance of the P.U. electrodes lies between 250 and 300 MHz. It is damped by the input impedance of the electronic circuitry (about 100 Ω at these frequencies). This resonance lies outside the usable bandwidth of the BPMS. Another resonance may be induced by the beam on the guard ring plates. In storage rings such resonances are inimicable to beam stability. This problem is solved by making guard plates of eight different lengths 5 mm apart, and by damping the resonances with metal film resistors.

Figure 1 shows a pick-up station (one bellow and one guard ring have been removed on one side) on its support.

Head amplifier

The amplifier has a high input impedance in order to reach a lower cut-off frequency of 2 kHz (or 100 Hz if needed) from a capacitive voltage source (95 pF) and an output impedance matched to the coaxial cables (75Ω). Its input capacity is calibrated at the value of 18 pF with wire trimmers. It is important because this input capacity appears in parallel with the electrode capacity. At higher frequencies, >100 MHz, the input resistance (real part) becomes ∿100 Ω and serves to damp the electrode resonances. It is a classical cathodyne amplifier with a UHF triode. Tubes are used because of the high level of radiation to be present in the ISR. All other components have also been chosen for radiation resistance : ceramic capacitors and metallic oxide film resistors. An electrode discharging resistor of 2.2 M is used to eliminate slow charged particles.

The gain of the amplifier and video part of the system is checked by the introduction of a test current to the electrode terminal. The value of the current is defined by a series capacitor of about 1.1 pF (fixed ceramic cap. + trimmer). The gain of the amplifier is stabilised by a large cathode resistance : 1.5 k. This is necessary for the dynamic range of the input signal (max. 20 V peak) and to attenuate the tube aging effect on the amplifier gain. In this way the gain drift is smaller than 1 x 10^{-3} per month. The gain of the head amplifier is about 1/40. It is possible to increase it to 1/2 for small signals, when precision is not necessary. In order to minimize the drift of the tube, its heating is stabilised as well as its biasing anode current.

End-of-cable amplifier

This amplifier amplifies the signals by 20 dB; adjusts the total gain from the electrodes up to its output; compensates the overall frequency response of the system; distributes the signals through two fully independent outputs; makes the transition between 75 Ω and 50 Ω cable system; controls the biasing point of the head amplifiers, and finally warns if the system, up to that point, is not working properly.

It contains two video amplifiers having their inputs in parallel and being independent with 80 dB isolation between them. If the signal is too large and saturates the output stage of the video amplifiers (max. 1.6 Vpp) a relay can be switched on, which attenuates the gain by 20 dB. The overall video gain from the electrodes to the 50 Ω load is 1/4 in the normal gain position and 1/40 in the attenuated gain position.

The overall gain to the output of the end-of-cable amplifier is calibrated with 1×10^{-3} precision at 10 MHz. The video chain bandwidth is 2 kHz (100 Hz) to 100 MHz. Its frequency characteristic is flat within 0.1 dB (1%) from 10 kHz-30 MHz (including the coaxial cable losses). This precision is needed to ensure the precision of the position readings (about 1% signal per mm).

The high precision of the gain requires precision components, selected transistors and very careful construction. Figure 2 shows a photo of the video chain.

Selection Switch System

The signals from the end of cable amplifiers are transmitted to the main control room via remote controlled coaxial switches and equal length low loss coaxial cables. The basic switching element of these switches is a reed contact mounted in a copper tube to form a coaxial line with 50 Ohms impedance. The reed contacts are closed by an external magnetic field generated by a coil fitted on a horseshoe shaped piece of soft iron. The switches have 32 inputs and 2 independent outputs. By mounting the reed contacts in a star-shaped way in a printed board, low crosstalk (-100 dB at 100 Mc/s), low reflection coefficient (8 % at 100 Mc/s) and equal signal path length are achieved. On the printed board holding the reed contacts a second printed board is mounted on to which the horseshoe shaped irons are soldered. A fair amount of power is needed to close the reed contacts, therefore, all switches are equipped with a decoder translating the 1 out of 32 code in a 5 bit binary code requiring little drive power.

Signals are selected for display on the wide band oscilloscope in the main control room by means of push buttons mounted in a synomptic diagram of the ISR. By actuating a push button a 5 bit binary number is generated by an encoder and stored in a 5 bit flip-flop store. The outputs of this store are connected to the inputs of the decoder mounted on the coaxial switch.

By using two switches in parallel, two signal pairs (corresponding to the two independent switch outputs) can be selected simultaneously for display.

Conclusion

The overall performance of the BPMS during the running of the ISR was good. A good high frequency response with low noise level and small amount of parasitic signals was observed, as can be seen from Figure 4. Closed orbits were measured by recording the beam induced signals on photographs and calculating the position from the peak values of pairs of radial or vertical signals. Figure 5 shows the closed orbit in Ring I as measured during the first runs. The present accuracy of the system is ± 1.5 mm (radially).

At a later stage closed orbit measurements will be made and displayed automatically with signal processors coupled to the ISR control computer. With this computerised system the accuracy of beam position measurements will be better than 0.3 mm.

References

The ISR Beam Position Monitoring System, J. Borer and R. Scholl. CERN-ISR-RF/69-55.

The Wide Band Beam Position Measurement System, M.J. de Jonge. CERN-ISR-RF/69-74.

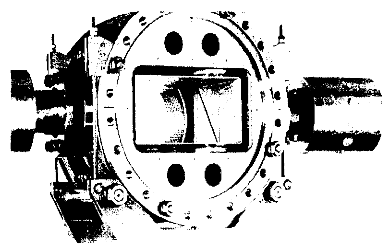

Figure 1

Beam Monitor composed of casing, plug-in, two feed-throughs and ampl. casings.

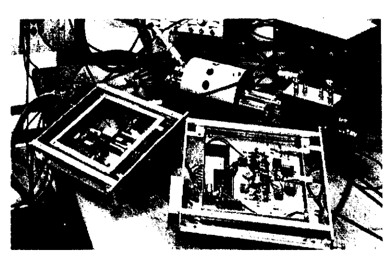

Figure 2

One head amplifier and two end-of-cable ampl. on test set-up.

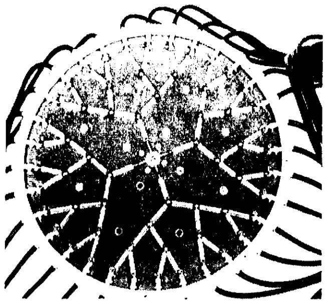

Fig. 3 : Printed board of the switch with the reed relays.

Fig. 4 : typical bunch signal response : BW : 110 MHz 100 mV, 20 ns/div.

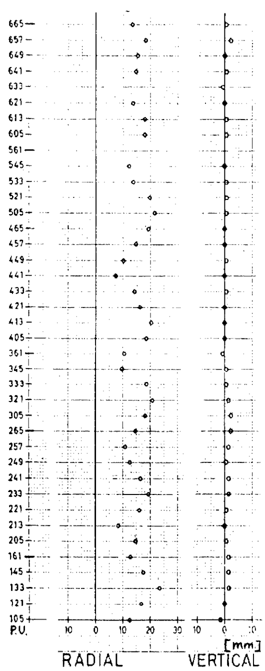

Fig. 5 :Closed orbit measurement.

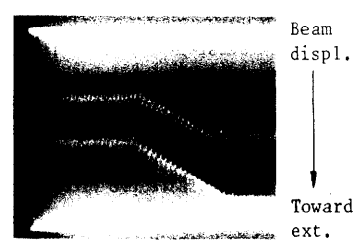

Fig. 6 :Orbit displacement by RF.