

THE ZERO GRADIENT SYNCHROTRON CLOSED ORBIT POSITION MONITORING SYSTEM*

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Summary

Four segment induction electrodes are being installed in each of the eight Zero Gradient Synchrotron (ZGS) straight sections. Due to the presence of other equipment, these electrodes can only be 10-in long in the direction of beam travel. The small length-to-width ratio of these electrodes creates special problems.

Five pieces of information are transmitted from each electrode to give detailed data on the beam orbits. Four of these consist of varying dc signals representing the beam envelope on the segments. These signals are remotely processed to simultaneously give radial and vertical position of the beam. The fifth signal is an unfiltered bunch signal which is locally processed to give a fast radial, vertical, or sum signal at the bunch frequency.

Introduction

Orbital data from a number of different points in a synchrotron helps the machine physicist understand many phenomena. The ZGS, with its picture-frame type guide magnets, has limited access to the beam. Only at its eight straight sections can this data be obtained. These straight sections are already crowded with extraction magnets, beam probes, beam damping electrodes, ion collection electrodes, etc. Due to this equipment crowding, the induction electrodes to obtain this position data may be only 10-in long in the beam direction, although they are 36-in wide.

Figure 1 shows the split electrode to consist of four right triangular sections, two above and two below the beam. Individual processing of the four signals allows simultaneous radial and vertical position information to be derived.

Problems of Short Electrodes

Induction electrode theory assumes that the electric flux lines from some fraction¹ (K) of the protons over an electrode does not terminate on the electrode. The shorter the electrode, the greater the value of K. Exotic guard shapes and/or circuits have been tried by some to minimize K. Experience here at the ZGS points to the fact that K only affects the calibration of beam intensity (Q) electrodes and causes no problem on position-sensing electrodes. Its only significant effect on our short electrode has been to reduce the signal size. This is no problem until beam intensities get down to about 3% of normal.

In split position-sensing electrodes, the amount of beam sensed decreases as the electrode is shortened, but the segment-to-segment capacitance remains

constant. This can cause errors in position readout. As the beam is moved radially (X), we have found the voltage (V) on the individual segments to be in error by a linear factor of the form $\pm\beta XV$. To correct this, our electronic analog arithmetic units must have a fixed gain factor which includes the value of β as one of its determinants.

The relative increase in segment-to-segment coupling can also create paths that cause self-resonance or ringing of the electrode at some harmonic frequency of the beam bunch. Also, for primarily economic reasons, the four required connections to the electrode are made through one 5-in diam penetration of the vacuum chamber. The nearness of the connecting leads to each other adds to the crosstalk problems mentioned above. Ground planes placed between the leads and even between the electrode plates can decrease the crosstalk, but only at the expense of decreased signal size and possible disturbance of the induced voltage versus radial position relationship that is desired. The solution chosen was not to use any isolating planes. Instead, it was decided to get the signals out of the electrode with short straight minimum inductance connections and then to resistively load each electrode segment to prevent self-resonance. This resistive loading also helps to rapidly dissipate any low frequency effects such as proton or ion capture.

Mounting and Structure

Figure 2 shows a photo of an electrode mounted to a straight section coverplate. It is attached to an adjusting framework which allows about 1/2 in of movement both radially and vertically. Two rotational degrees of freedom on this framework allow rotation about one axis for leveling and the other axis for perpendicularity to the beam direction. These adjustments allow the electrode to be surveyed in place with reference to the coverplate before it is installed in the straight section. This limits radiation exposure to surveying personnel.

Figure 2 also shows the four right-triangular electrode plates which are made of 0.090-in thick aluminum. A perforated ground screen of aluminum with 1/2-in square holes on 11/16-in centers surrounds the electrode plates. Five-in diam intruding brass cans move the vacuum penetration to within 1 or 2 in of the ground screen for a low inductance connection to the electrode. The two narrow electrode ends are connected to the vacuum feedthroughs by extending the electrode plate itself through the ground screen to the feedthrough. Type G-10 glass-filled phenolic is used throughout for standoffs, mounting, etc.

Electronics

Figure 3 shows a four-section circuit board which plugs into the brass feedthrough cans. The signals representing the beam envelope on each of the four

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electrode sections are processed on this circuit board only 2 in from the feedthrough. One signal path takes the bunch signal to an RF integrated circuit differential amplifier. At one location, the four fast signals are added to form a fast Q signal for synchrotron oscillation damping. In other locations, they are selectively added and subtracted to form a radial or vertical position signal at the bunch frequency. These signals, after additional processing in other circuits, are used in our beam size damping equipment or are used in measurements of machine characteristics. The RF amplifier is an RCA 3040 capacitor coupled into an emitter follower which acts as a 90- Ω line driver.

Another signal path for each electrode segment couples the bunch signal into an RF-to-dc peak detector. This detector is simply a combination beam and fixed dc-biased high frequency transistor. It is connected as a common base amplifier. Its emitter load is a 10^{-4} s time constant RC filter, which removes the bunch structure, leaving only the unipolar low frequency beam envelope. These four low frequency signals are transmitted to the Main Control Room (MCR) through coaxial cables. Electronics in the MCR carry out the following functions:

1. Sums all four signals to form a signal proportional to beam intensity.
2. Selectively adds, subtracts, and applies scaling factors to form a beam sensitive radial position signal.
3. Divides No. 2 above by No. 1 to form a radial position signal that is independent of beam intensity.

Other circuitry forms a vertical position signal and makes it beam insensitive in a similar manner.

In addition to distribution around the MCR as required, the various position signals are fed into an 8-channel multiplexer for simultaneous display on a large 8-in x 10-in oscilloscope. Triggered 8-channel sample-and-hold circuitry takes a simultaneous $100\mu\text{s}$ sample of all eight signals for comparative orbit information at any selected beam energy. These samples may then be displayed on the large scope in the proper spatial relationship.

Conclusion

Five of the eight electrodes of our system have been installed and are operating. The remainder will be installed when operating conditions permit. Radial signals accurate to about 1/2 in from the 36-in wide electrode have been obtained in an intensity range of 2.5×10^{12} to 3×10^{11} protons per pulse. The accuracy limitation seems to be the linearity with respect to beam intensity of the RF-to-dc transducers, but improvements can be made. The semiconductor electronics in the brass feedthrough cans are showing no signs of radiation damage after 6 months of exposure.

Acknowledgments

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Reference

- ¹C. E. Swartz, "Pickup Electrodes," The Review of Scientific Instruments, (Sept. 1953), Vol. 24, No. 9, pp. 851-53.

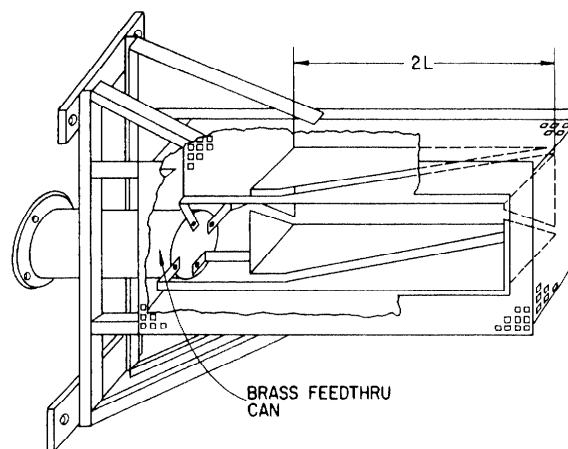


Fig. 1 Cutaway sketch of electrode construction.

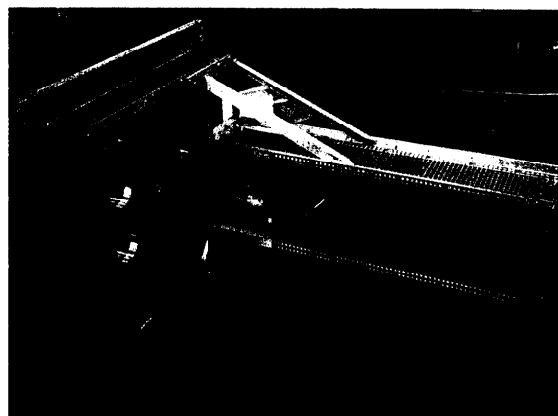


Fig. 2 Electrode mounted on adjustable frame.



Fig. 3 Four-segment pickup circuit board.