IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

BEAM POSITION MEASUREMENT SYSTEM AT THE ARGONNE RAPID CYCLING SYNCHROTRON*

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Introduction

The position measurement system for the Rapid Cycling Synchrotron (RCS) was originally designed with a four plate, combined function, capacitive pickup pi electrode situated in each of the six short straight sections. During subsequent operation, it was discovered that these electrodes were limiting the aperture and, therefore, were being activated by the circulating proton beam. In addition, the activation made it difficult to maintain the active electronic components in the RCS tunnel. The new position measurement system has been designed to eliminate these problems. The electrode's horizontal and vertical dimensions have been increased and the plates reorientated for simpler, separate function signal processing. A passive impedance matching network has replaced the active cathode follower, eliminating maintenance requirements in the accelerator tunnel. The Radio Frequency (RF) beam signals are transmitted directly to the Main Control Room (MCR) for processing.

Original System Description

The original RCS position system is described in detail elsewhere,[1] therefore, only a short description will be presented here. The pickup electrode was constructed of stainless steel in a configuration shown in Fig. 1, and provided both horizontal and vertical position information. The electrode aperture was 10.2 cm horizontally and 6.3 cm vertically, the same dimensions as the good field region of the synchrotron magnets. Because of the expected radiation levels in the RCS tunnel, no solid-state electronics were used; instead, initial signals from each plate were conditioned using a pentode as a cathode follower. The solid-state processing electronics were located outside the radiation shield in the RCS building. The six horizontal and vertical slow beam position signals were then transmitted to the MCR. However, only one set of fast position signal processing electronics was provided.

Initially, this system was adequate for the operation of the RCS. However, as accelerated beam intensities and the repetition rate increased,[2,3] it became evident that the electrodes were limiting the aperture and were being struck by the proton beam. These beam losses were saturating some of the beam position electronics, making their signals useless. With increasing beam intensity, fewer and fewer electrode signals were usable. Together with the higher intensity, indications appeared of severe beam instabilities and their investigation required a complete set of reliable fast beam position signals. In addition, the relatively high radiation levels in the synchrotron tunnel made it difficult to maintain the cathode followers and thus maintain calibration. Also, system performance could not be monitored because of high radiation levels in the RCS building during normal operation.

All of the above factors prompted an immediate re-evaluation and redesign of the existing system.

*Work supported by the U. S. Department of Energy.

New System Description

Electrodes

During the design stage of the new electrodes, the decision was made to make the horizontal and vertical position electrodes separate to simplify signal processing. The horizontal and vertical apertures were increased to 11.6 cm and 7.0 cm respectively, but due to straight section space limitations, the total electrode length had to remain constant and each plane's pickup electrode was limited to a length of 2.5 cm. Concern over the sensitivity of such a short electrode was eliminated when a single prototype horizontal electrode was quickly built, installed, and tested. Laboratory tests prior to installation indicated that the smaller electrode structure was a significant improvement over the older style electrode; the lowest electrode resonance was above 100 MHz compared to the average 42 MHz for the other electrodes. Actual tests in the accelerator indicated that signal levels were more than adequate, even with the use of less efficient cables for signal transmission to the MCR (Fig. 2), and beam position resolution of ± 1 mm could be achieved. In addition, after a lengthy period of operation with high beam intensities at 30 Hz, the area around the new electrode showed significantly less radiation background than the areas around the other electrodes. With these promising results, a full scale production began.

The electrodes are constructed of 63 mil aluminum. Each electrode is constructed individually with a shield having a 63 mil lip around the upstream and downstream aperture to shield the pickup electrodes from any scattered beam and to minimize coupling between pickup plates. The pickup plates are positioned by using ceramic spacers. The completed horizontal and vertical electrodes are soldered together and mounted on the vacuum flange assembly. The four electrode signals are brought out through a vacuum tight octal pin connector. Figure 3 shows one of the six complete electrode assemblies ready for installation.

Signal Processing

Relatively high radiation levels in the RCS tunnel precluded the use of any type of active devices, particularly solid state, for processing the signal at the

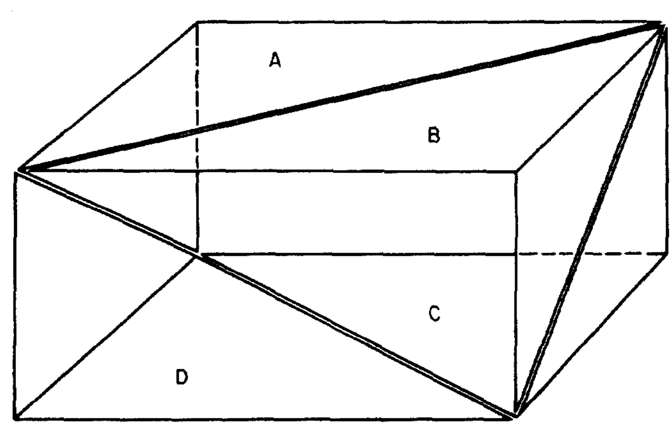

Fig. 1 Original Combined Function Electrode Configuration

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electrodes, and the high levels of electromagnetic and RF interference in the RCS did not allow for transmitting the unprocessed signals for any appreciable distance. A solution was found by using broadband matching transformers to match the electrodes to the low loss, low impedance (50 Ω) RG-213/U coaxial cables which are used to transmit the signals the 90 m between the RCS tunnel and the MCR. Each plate signal is processed individually by its own matching transformer and transmitted on its own cable. The cables from all the electrodes are of equal length to eliminate any timing mismatch, not only from the individual plates but also from one electrode to another. This method was costly in terms of cable, requiring over 2000 m but provides the benefit of allowing the comparison of all the fast position signals in real time.

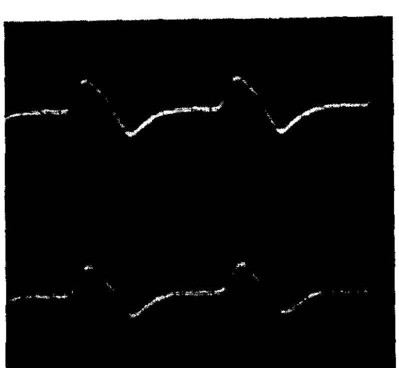
The processing electronics were designed to provide enough versatility in the available output signals so that almost any requirement of machine physicists could be easily provided. The electronics for each plane of each electrode is completely contained in one standard NIM module, and the modules are totally interchangeable (Fig. 4). Multiple test points and adjustments are provided on the front panel for fast system testing and calibration.

Figure 5 shows a block diagram of the processing electronics. Initially, the two signals from the individual plates are processed independently. The input signal is amplified, integrated to restore the beam bunch shape information, and the baseline is restored. At this point, buffered outputs are provided for monitoring the individual plate signals, as well as to provide a signal to the betatron tune measurement electronics.[4] The individual plate signals are then processed by high speed sum and difference operational amplifiers to yield the fast A+B and A-B signals. These are also provided as buffered outputs and will be used to provide beam intensity and phase information, as well as being the main signals for studies of beam motion and instabilities. The outputs of the sum and difference amplifiers are further processed by low-pass filters to yield the slow sum and difference signals and finally by an analog divider which provides the intensity normalized slow position signal, A-B/A+B. The outputs of all the position electronics are calibrated for $\Delta V = 1.0$ V/cm.

Signal Presentation

All of the position signals are presently available to the operator as analog signals. All 12 slow position signals are also monitored by the RCS computer, and the beam position from any one electrode can be displayed on a dedicated digital readout at an operator selectable time. No additional computer processing has been available because of the limited memory space

Right Plate



Left Plate

Fig. 2 Unprocessed Signal From New Electrode
100 ns/cm 0.2 V/cm

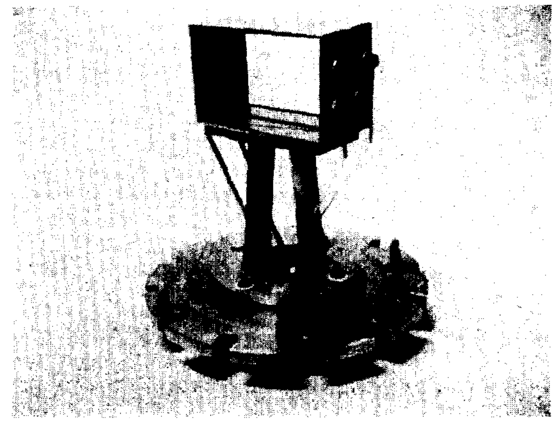


Fig. 3 Electrode Assembly Ready For Installation

of the computer. The RCS computer system is being upgraded from a Nova 210 to an Eclipse AP-130, and the increased computing capability will greatly enhance the quality and quantity of the signal presentation. Initial plans call for simultaneous display of all 12 beam positions on the computer terminal CRT and eventually, the on-line calculation of the closed orbit. Future plans call for high speed sampling circuits for the fast sum and difference signals and the generation of software to analyze turn-to-turn beam motion.

Conclusion

The new beam position measurement system has created several important benefits to the constant effort of increasing the operating performance of the RCS. The elimination of the aperture limit has decreased the activation inside the tunnel and has simplified the servicing of other RCS systems. The elimination of any active devices from the tunnel has simplified the position system maintenance. The improved electrode characteristics and signal processing have provided an increased number of reliable signals for the study of beam motion.

References

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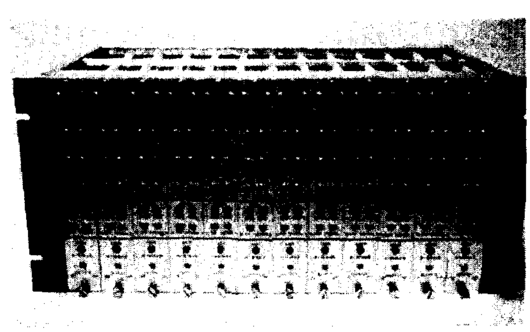

Fig. 4 Processing Electronics

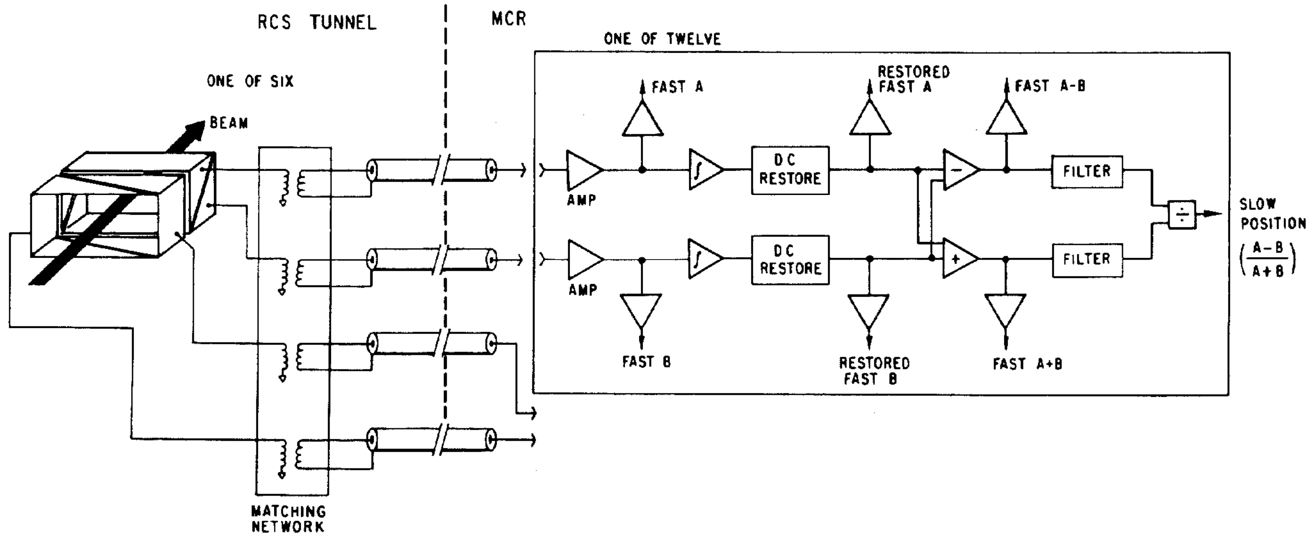

Fig. 5 Position Block Diagram

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