Beam Position Monitoring in the AGS Linac to Booster Transfer Line*

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Abstract

A beam position monitor system has been developed[1] and used in the commissioning of Brookhaven's Linac to Booster transfer line. This line transports a chopped, RF modulated H- beam from the 200 MeV Linac to the AGS Booster. Over a 15dB dynamic range in beam current, the position monitor system provides a real-time, normalized position signal with an analog bandwidth of about 20 MHz. Seven directional coupler style pickups are installed in the line with each pickup sensing both horizontal and vertical position. Analog processing electronics are located in the tunnel and incorporate the amplitude modulation to phase modulation normalization technique[2]. To avoid interference from the 200 MHz linac RF system, processing is performed at 400 MHz. This paper will provide a system overview and report results from the commissioning experience.

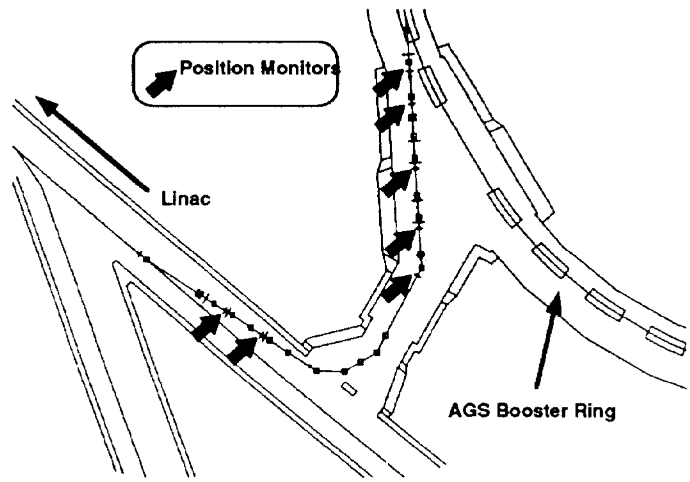

Figure 1. Site Plan.

I. INTRODUCTION

In April of 1991, commissioning of the AGS booster synchrotron commenced with the successful transport of an H- beam from the 200MeV linac to the first sextant of the Booster ring. During this exercise, the beam position monitoring system was used in conjunction with the loss monitor, current transformer, and multi-wire systems. Only the position monitoring system will be described here. This system consists of stripline style pickups with analog processing electronics located in the tunnel. The analog processing modules normalize the position signal by applying the amplitude modulation to phase modulation technique. These signals are then routed to an equipment building for digitization and analog distribution. During commissioning, both digitized and analog signals were available.

II. SYSTEM DESCRIPTION

A. Position monitors

As shown in figure 1, seven position monitors are distributed throughout the transfer line. Each position monitor contains four stripline electrodes to allow position measurement in both the horizontal and vertical planes. To avoid coupling, the horizontal and vertical pairs of electrodes are offset axially from each other. Furthermore, the length of each stripline is chosen such that the first peak in the frequency response occurs at 402.5 MHz, which is a harmonic of the 201.25 MHz bunching frequency. In this way, much of the interference from the linac RF system can be avoided. A cross-section of the monitor is shown in figure 2.

B. Electronics

As illustrated by figure 3, the analog processing modules are located in the tunnel. Each module provides a

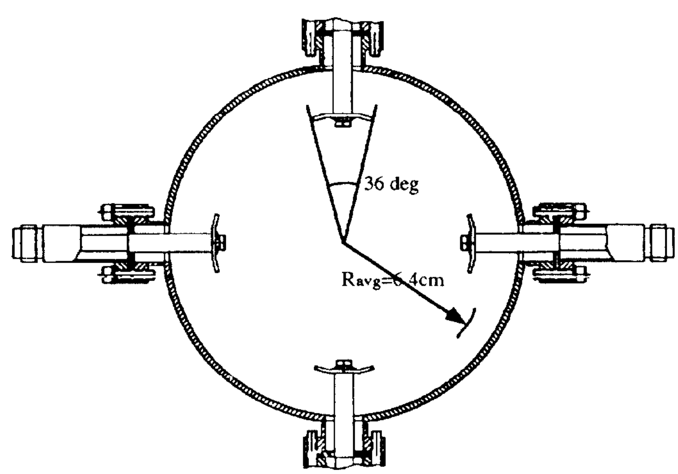

Figure 2. End view of beam position monitor.

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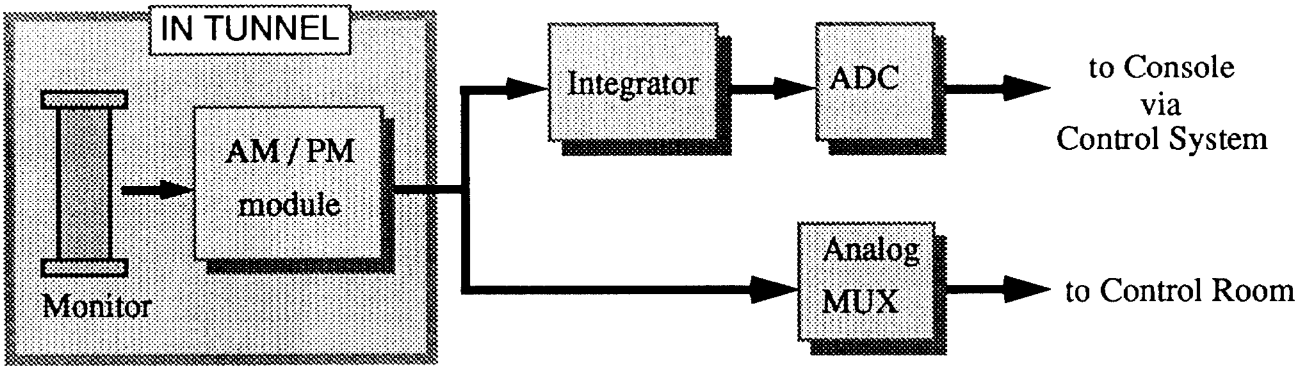

Figure 3. Block diagram of beam position monitoring system.

synchronously detected sum signal and two normalized position signals. For simplicity, all processing is performed without downconversion at the carrier frequency of 402.5 MHz. The normalization is achieved via the amplitude modulation to phase modulation technique.

All signals from the tunnel are transformer isolated and routed on coax to a nearby equipment building. Here the signals are split with one part going to an analog multiplexer and the other to a gated integrator. After integrating over a programmable window time (minimum of about 15μs), the signal is then held until it can be digitized.

III. BENCH TESTS

CW Calibration

Before installation, each module is calibrated on the bench. This calibration is accomplished with an automated testing system that maps the module's transfer function point by point over its full range of beam position and current. The transfer functions for several intensities are then averaged and the result is fitted in three ranges to transcendental functions. An example transfer function is shown in figure 4 with the three fits overlaid. The control system uses these fits to correct for the nonlinearities that arise when measuring large beam displacements.

Transient Response

During normal operation, the beam in the transfer line will be chopped into pulses to allow efficient capture in Booster RF buckets. The chopper, operating at a frequency of about 2.5 MHz, produces pulses that are a few hundred nanoseconds long. Therefore, the transient response of the AM/PM module is of interest. Also, for diagnostic purposes, a measurement of position variation within a pulse could be worthwhile. Tests were arranged to simulate both a short burst of beam current and a rapid change in beam position. Results from the latter are shown in figure 5. For this test, amplitude unbalanced, phase coherent signals were injected into two input ports on the module. The ratio of the two amplitudes at the input ports was then suddenly changed for a duration of 200ns, thus simulating a beam that suddenly moves transversely by one centimeter and then back again.

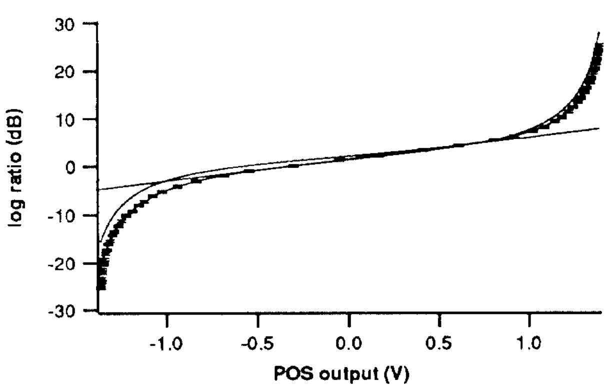

Figure 4. Example of fits to average transfer function.

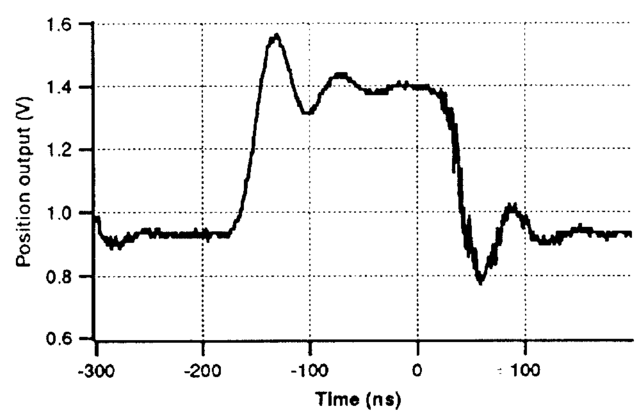

Figure 5. Module's response to simulated beam displacement.

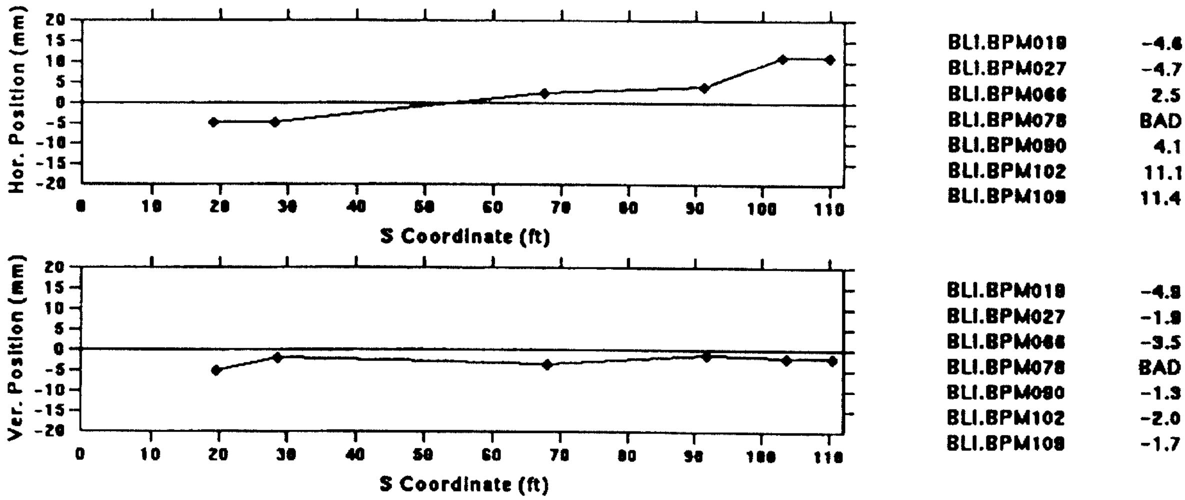

Figure 6. Beam position as displayed on control room console.

IV. COMMISSIONING EXPERIENCE

After the system performed well on the bench, the true test came during use with actual beam. Figure 6 shows a portion of a console display as it appeared during the beamline commissioning in April 1991. Before building the display, the control system utilizes the transfer functions of the monitors, AM/PM modules, and integrators to provide position information as accurately as possible. The information here is also used by an automated steering algorithm that calculates appropriate corrector settings[3]. During the first stage of commissioning, this program corrected the vertical trajectory to ±0.5mm in a single pass. Horizontal correction required two passes, possibly due to an inaccuracy in the last position channel for large displacements. Intensity information was also available and this helped the commissioning team identify valid position measurements.

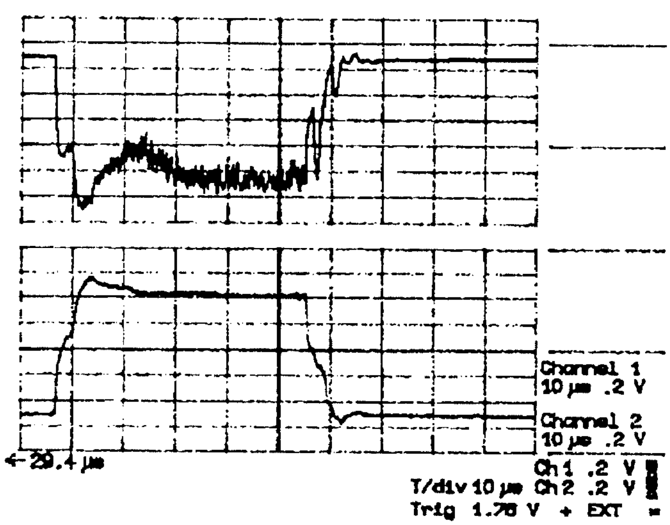

Figure 7. Analog signals: horizontal on top, vertical on bottom. 100mV corresponds to a 1mm displacement.

In addition to the fully calibrated readings displayed on the console, the raw analog signals were also available in the control room via an analog multiplexer. Figure 7 shows a typical digital oscilloscope display of one module's output. The availability of these signals in the control room was crucial at early stages of commissioning because it allowed verification of integrator timing and control system operation.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

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