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POSITION MEASUREMENTS FOR THE ISOTOPE PRODUCTION FACILITY AND THE SWITCHYARD KICKER UPGRADE PROJECTS*

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Abstract

The Los Alamos Neutron Science Center (LANSCE) is installing two beam lines to both improve operational tuning and provide new capabilities within the facility. The Isotope Production Facility (IPF) will provide isotopes for medical purposes by using the H^+ beam spur at 100 MeV and the Switchyard Kicker Upgrade (SYK) will allow the LANSCE 800-MeV H^- beam to be rapidly switched between various beam lines within the facility. The beam position measurements for both of these beam lines uses a standard micro-stripline beam position monitor (BPM) with both a 50-mm and 75-mm radius. The cable plant is unique in that it unambiguously provides a method of verifying the operation of the complete position measurement. The processing electronics module uses a log ratio technique with error corrections such that it has a dynamic range of –12 dBm to –85 dBm with errors less than 0.15 dB within this range. This paper will describe the primary components of these measurement systems and provide initial data of their operation.

IPF AND SYK BEAM LINES

The LANSCE facility is constructing an IPF to provide radioisotopes for diagnosis and treatment of diseases [1]. This spur beam line starts at the 100-MeV transition region of the accelerator and transports H^+ beam to a target area where samples may be irradiated, safely handled, and packaged for shipment to U. S. medical facilities. The new beam line contains eight BPMs used to diagnose the beam's position throughout the transport and verify the beam's placement on the target/sample region during either a 10-kHz raster or static operation.

At the end of the 800-MeV LANSCE accelerator, a switchyard directs the beam to either line D or to line X [2]. Line D contains such facilities as the proton storage ring and line X contain such experiments as the proton radiography and ultra cold neutrons. Prior to the installation of the upgraded switchyard kicker beam line, a lengthy process was required to reconfigure the switchyard beam line in order to transport the beam to either lines D or X. With the completion of the SYK, LANSCE can now simultaneous provide H^- beams to both beam lines by rapidly switching between them using fast kickers located in the new SYK. Three additional BPMs, located in the new SYK, provide beam position information to the facility operators.

Table 1 summarizes key operational requirements of the position measurements for IPF and SYK (a more complete table is in reference [3]). While for IPF and SYK, the beam species are of opposite signs, many measurement parameters are either the same or very similar, e.g. bunching frequency of 201.25 MHz and data acquisition rate of <10 Hz. However, note the IPF H^+ beam does not have any chopped structure in it, resulting in lower IPF bandwidths requirements for measuring rastered beams. Also note the dynamic range of the both types of signals is larger than the macropulse beam current range would indicate. This range difference is due to the amount of additional range required to cover off-centered beam conditions at either the highest or lowest beam currents. The SYK chopping structure for the various experimental beam lines can be quite complex. If allowed, these chopped-beam structures could further broaden the SYK BPM dynamic range requirements. However, it was decided that monitoring the position of these chopped beams was unnecessary as long as there was a non-chopped tuning beam available.

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Table 1: Overall position measurement requirements.

Parameter	IPF	SYK
Macropulse Length (ms)	0.05 to 1	0.15 to 1.2
Chopped Beam Rate (MHz)	N/A	2.8 & 5.6
Chopped Beam DF (%)	N/A	22 to 56
Pulse Beam Current (mA)	16.5 to 0.1	13 to 0.1
Base Bandwidth (kHz)	15	~2500
Position Precision/Accuracy (% of pipe radius)	0.3/~3	0.25/~2
Beam Pipe Radius (mm)	50.4, 76.2	50.4
Position Measurement Dynamic Range (dB)	63	70

BPM BEAMLINE COMPONENTS

A previous paper details the BPM's mechanical construction and mapping of the IPF BPM's, this paper will only briefly discuss the SYK BPM's characteristics [3]. Figure 1 and 2 show a SYK BPM and its associated beam line components in picture and schematic form. The SYK BPMs were characterized to have a 0.54 dB per mm sensitivity and typical offsets < +/- 1mm. This is within 20% of the theoretical 0.66 dB per mm. Since the SYK and IPF BPMs have feed-throughs at both the downstream and upstream end of each of the four electrodes, a unique method of measurement operation is performed to monitor the BPM's condition during beam operation. As shown in Figures 2, there is a completely

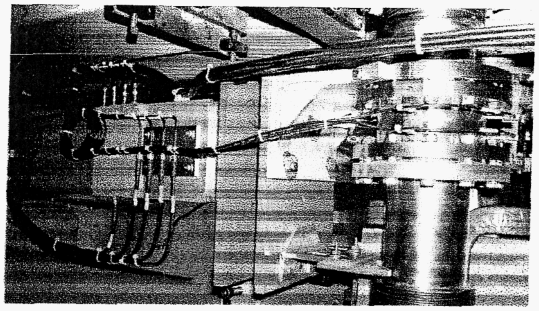

Figure 1. SYK BPM LXPM01 (oriented vertically) is shown with its associated 5 RF coaxial cables from the rack and a strain relief, divider and 20-dB attenuators.

unambiguous signal path to and from the processor module through each BPM electrode. The 20-dB attenuators in each electrode signal path provide both additional RF divider leg isolation and 50-Ω termination for the BPM electrode downstream ports. The typical round trip attenuation is 36 dB +/- 1 dB and with an injection signal power of –25 dBm, the resulting verification power measurements are performed at –61 dBm. Since the components in this loop are linear, a single mid-dynamic-range power measurement for each cable/electrode loop path is sufficient to determine the health of the any of the serial components within the loop. If a cable is inadvertently crimped or a BPM electrode is injured to the point of losing its 50-ohm characteristics, the total loop attenuation will change. With the help of a software process, this attenuation measurement is performed on an hourly basis in-between beam pulses so that facility operators always have a quantitative method of detecting BPM and cable health.

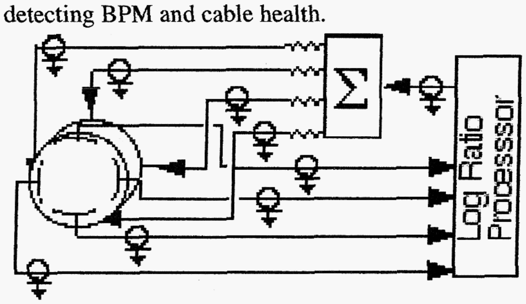

Figure 2. The verification test hardware, shown in this simple bock diagram, contains an additional cable, 4-wayd RF divider, and set of 4 20-dB RF attenuators.

LOG-RATIO ELECTRONIC PROCESSOR

The log-ratio electronics processor used in this VXI-crate-based processor module has a digital motherboard with on-board digital signal processor daughter cards, wide-bandwidth analog-front-end (AFE) circuitry that uses a logarithmic amplifier in each of the four channels, and an on-board 201.25-MHz oscillator on a calibrator daughter card. Figure 3 shows a simplified block diagram of the AFE and calibrator daughter cards. The previous calibrator circuitry was reduced in size and cost while maintaining low SWR and reducing the attenuator switching speed by using a GaAs solid-state digital attenuator.

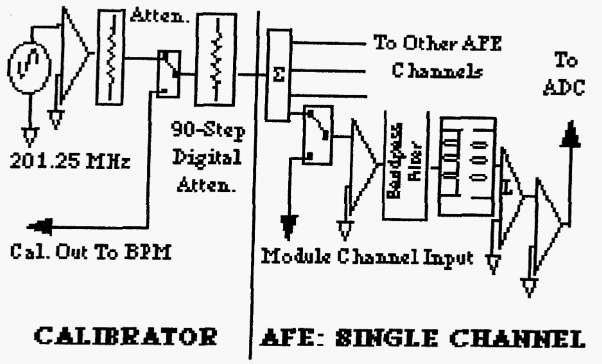

Figure 3. Simplified functional block diagram of the AFE and calibrator daughter cards.

Figure 4 shows the result of the calibration circuit changes. The constant and deterministic calibrator errors are subtracted from each of the AFE channels during a software calibration procedure. The error bars, typically <0.1 dB, on these data represent the random errors and total uncertainty of the calibrator.

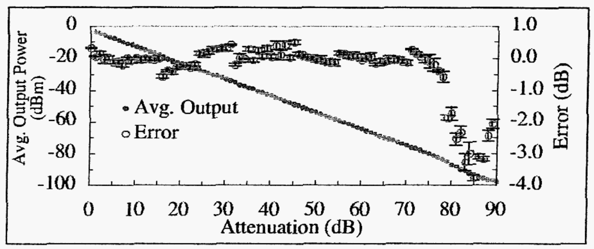

Figure 4. This graph displays a particular calibrator signal power and its deterministic systematic error. The +/-1 rms error bars denote the random uncertainty due to the calibration during calibration of the processor.

The present AFE circuitry can measure very low signal power with a wide bandwidth. To accomplish this goal, a Temex 201.25-MHz bandpass filter was placed between the input transformer to the AD8307 log amplifiers and a GALI-52 Mini-Circuits preamplifer. Since there is lower harmonic 201-MHz-signal power than expected, this bandpass filter was placed to reduce the broadband digital signal noise finding its way into the log-amp input. These 8.4-MHz bandwidth filters also have short rise and fall times, typically 170- and 260-ns respectively, providing sufficient bandwidth to measure various chopped-beam conditions in the SYK beam line.

Figure 5 shows the result of two subtracted module channels, thereby providing a log-ratio process, prior to a 90-dB software calibration using the calibrator and AFE shown in Figure 3. The data labeled "Pre-Cal Error" is the deterministic error from a theoretical logarithmic function. These errors are primarily due to the log-amp's logarithmic non-conformity and are subtracted out during the calibration routine. The Pre-Cal errors are shown for a centered beam condition and an off-centered beam condition. The data are plotted as a function of input signal power in dBm where a 1 mA current will occur at approximately –55 dBm. Also plotted in Figure 5 are the random error data, the ultimate limitation to the calibration process. Note that the processor module axis is calibrated to within a <0.15 dB from approximately –12 to –85 dBm. In terms of positional error and beam current applied to the 50-mm IPF and SYK BPMs, this is equivalent to a 0.25 mm rms error over the 20 plus to 0.1 mA beam current range.

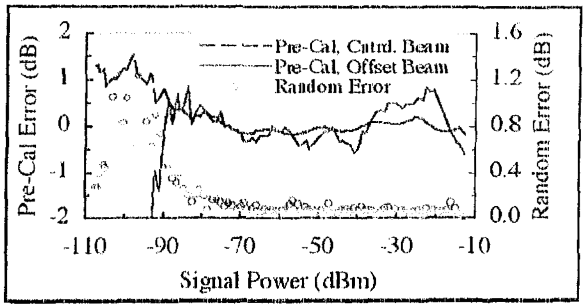

Figure 5. This graph shows the deterministic errors prior to the software calibration and random errors after the calibration. For the IPF and SYK BPMs, the measurement precision defined by the random errors is <0.3 mm throughout the operation beam current range.

POSITION MEASUREMENT SOFTWARE

The calibration procedure is controlled by a PC-based input-output-computer (IOC). The procedure uses the same calibrator daughter-card signal-source shown in Figure 3 that the verification measurement uses but in this case, digital-controlled step attenuators are used to step through a 90-dB dynamic range. This procedure was first described in a previous paper [5].

A LabVIEW virtual instrument (VI) process continuously runs on the PCIOC that performs the calibration and verification procedures, repeating on an approximate hourly basis. Upon receiving a timing signal through each VXI processor module, the VI instructs the module hardware to acquire the digital information from the four channels' analog-to-digital converters (ADC) via the digital signal processor (DSP) daughter cards on the motherboard [5]. These data are then calibrated by addressing a specific memory location in a 4096 location RAM look-up table (RAMLUT) that contains the correct calibrated data (both in counts) on the motherboards. These RAMLUTs remove the "Pre-Cal Errors" for each of the four-processor channels. After the calibration has been completed on all four processor channels, opposite-electrode calibrated-signal powers are then digitally-subtracted to produce a calibrated log-ratio signal. Since both IPF and SYK are pulsed beam facilities, a separate timing signal between beam pulses initiates the calibration and verification sub-VI. This calibration process loads a RAMLUT while another previously loaded RAMLUT is used to provide previous calibration information. As the RAMLUTs are filled, the VI switches between RAM tables, therefore, always providing the measurement with a timely calibration. After that calibration RAMLUTs have been loaded and applied to incoming data, another sub-VI switches the appropriate GaAs RF switches in the AFE and Calibrator daughter cards so that the verification procedure checks the health of the cables and BPM electrodes as described earlier.

Finally, the VI serves the data via a portable channel access sub-VI written to interface with the accelerator control system, EPICS (Experimental & Physics Industrial Control System). The VI also allows the facility operators to initiate an "on-demand" calibration and verification, however, for this check to be an accurate, the beam is not allowed through the BPM.

SUMMARY

This paper described a beam position measurement system presently installed in the LANSCE IPF and SYK beam lines. The measurement system uses 50- and 75-mm radius micro-stripline BPMs, an unambiguous verification process that monitors the measurement system's beam-line-hardware health, and a calibration process that removes deterministic and thermal errors on a continuous basis without operator intervention. It has a dynamic range of > 73 dB as defined by errors that are less than or equal to 0.15 dB (or <0.3 mm). Even with this wide dynamic range, the measurement systems bandwidth has been measured to be > 2.5 MHz.

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