THE LEDA BEAM-POSITION MEASUREMENT SYSTEM*

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Abstract

This paper describes the beam-position measurement system being developed for the Low Energy Demonstration Accelerator (LEDA) and the Accelerator Production of Tritium (APT) projects at Los Alamos National Laboratory. The system consists of a beam-position monitor (BPM) probe, cabling, down-converter module, position/intensity module, on-line error-correction system, and the necessary control system interfaces. The modules are built on the VXI-interface standard and are capable of duplex data transfer with the control system. Some of the key, system parameters are: position-measurement bandwidth of at least 180 kHz, the ability to measure beam intensity, a beam-position measurement accuracy of less than 1.25 percent of the bore radius, a beam-current dynamic range of 46 dB, a total system dynamic range in excess of 75 dB, and built-in on-line digital-system-error correction.

1 INTRODUCTION

A key part of the APT project is to demonstrate the technical feasibility of the front end of the accelerator. This proof-of-concept machine, called the Low Energy Demonstration Accelerator (LEDA), will operate in both pulsed and cw modes using a 100-mA proton injector, a 6.7-MeV RFQ, a high-energy-beam-transport (HEBT), and a beamstop. This paper describes the beam-position measurement system being designed for the LEDA experiment keeping in mind that the measurement system implemented for LEDA will likely need to be scaled to accommodate a much larger APT facility [1].

Some of the important technical requirements of the LEDA beam-measurement system are shown in Table 1.

Table 1: LEDA Beam-Position Requirements.

Item	Value	Units
Beam Frequency	350.0	MHz
Beam current range	0.5-100	mA
Beam Dynamic range	46	dB
Max. signal dynamic range	75	dB
Req'd # of 20.5 mm diameter probes (1")	1	each
Req'd # of 47.5 mm diameter probes (2")	3	each
Req'd # of 175.3 mm diameter probes (6.9")	1	each
Sensitivity, 20.5 mm probe (at center)	3.38	dB/mm
Sensitivity, of 47.5 mm probe (at center)	1.63	dB/mm
Sensitivity, 175.3 mm diameter probe (at center)	4.22	dB/mm
Measurement Accuracy, each probe (≤ 50% of radius)	≤ 1.25%	of radius
Measurement Accuracy, 20.5 mm probe (≤ 50% of radius)	≤ ±0.13	mm
Measurement Accuracy, 47.5 mm probe (≤ 50% of radius)	≤ ±0.30	mm
Measurement Accuracy, 175.3 mm probe (≤ 50% of radius)	≤ ±1.1	mm
Measurement Resolution (≤ 50% of radius)	≤ 0.2%	of radius
Processing Intermediate Frequency (IF)	2.00	MHz
Position-Measurement bandwidth	≥ 180	kHz

The beam-position-monitor (BPM) probes have inside diameters ranging from 20.5 to 175.3 mm and are the four-lobe type. Image currents from the beam induce voltages on the four lobes proportional to beam position with respect to the lobes and beam intensity.

An additional requirement of the system is to employ real-time error correction to compensate for cable mismatches, probe variations, and processing-electronics offset and gain non-linearities.

There are several common implementations of beam-position-measurement systems: amplitude-to-phase, difference-over-sum, and log ratio [2]. The chosen system uses log ratio. One advantage of the log-ratio transfer function is its improved sensitivity and linearity over that of the other methods. Its main drawback is logarithmic ripple errors in the log amplifiers because they don't strictly follow a true log-transfer function.

Each beam-position measurement system consists of a probe (three probe diameters will be used in LEDA), cabling, a down-converter module, and a position/intensity module. The Error-Correction Reference Chassis provides reference/calibration signals

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to the various systems. A block diagram of one beam-measurement system is shown in Fig. 1.

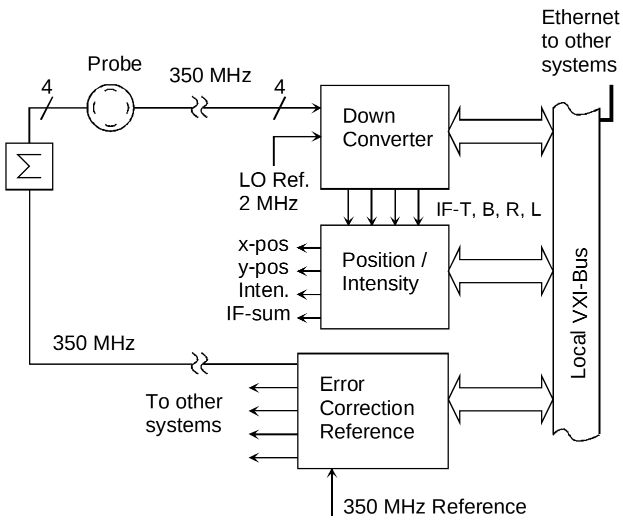

Fig. 1 Block diagram of one beam-position/intensity system.

Signals from each beam-line probe are fed to a down-converter module in which they are converted to an intermediate frequency (IF). These IF signals, labeled IF-T, B, R, and L in the figure, are then sent to the position/intensity module for beam-position and intensity processing. A 2-MHz local-oscillator reference signal is provided to each down-converter module to be used in deriving the 348 MHz. Digital data and control signals are fed to the modules via the VXI-bus. The error-correction reference chassis can accommodate up to six BPM systems. It provides 350-MHz error-correction signals to each system one at a time. An internal multiplexer in the chassis is used to select and switch the signals.

2 DOWN-CONVERTER MODULE

The down-converter module is used to convert the 350-MHz rf signals down to the intermediate frequency (IF) of 2 MHz. It has four rf inputs, one LO reference input (2 MHz), and four IF outputs. Some of its requirements are listed in Table 2.

Table 2: Down-Converter Requirements.

Item	Value	Units
RF input frequency	350	MHz
IF output frequency	2.00	MHz
# of rf inputs	4	each
Input Impedance	50	Ω
Input VSWR	≤ 1.2:1	
# of IF outputs	4	each
LO reference frequency	2.00	MHz
Max. rf input power	0	dBm
Max. IF output power (P_{1dB})	15	dBm
Channel Insertion Gain	15	dB
Max. noise figure	16	dB
Dynamic range	≥ 75	dB
Channel-to-channel amplitude tracking error	≤ 0.5	dB
Channel-to-channel phase tracking error	≤ 3	deg.

3 POSITION / INTENSITY MODULE

The position/intensity module processes the IF signals according to the log-ratio transfer function. This processing technique is explained in detail in several papers including reference [3]. The module uses AD606 logarithmic-amplifiers with usable dynamic range exceeding 80 dB at the 2-MHz IF. Some of the position/intensity module's requirements are listed in Table 3.

Table 3: Position/Intensity Module Requirements.

Item	Value	Units
Number of IF inputs	4	each
Input Impedance	50	Ω
Number of measurement axes	2	each
Range, x-, y-axis (into 1 MΩ)	± 10	V
Range, intensity (into 1 MΩ)	0-10	V
Max. input power	15	dBm
Digitizer Resolution	12	bits

Additionally, this module incorporates digital error-correction circuitry to compensate for non-linearities in the system such as from the cabling, probe effects, and the processing electronics. This module is described in detail in reference [4].

4 ERROR-CORRECTION SUBSYSTEM

The design of the entire beam-position measurement system is built around the central requirement of using real-time error correction. The log-ratio technique provides a good foundation for such a system and was one of the main reasons for its selection. The error-correction process is implemented in the following fashion. The slot-zero controller in the VXI chassis selects the BPM system to correct. It does this by selecting the desired Position/Intensity module. It then addresses the Error-Correction Reference Chassis and outputs a known power level to the pre-selected measurement system. When the cable attenuation, the splitter losses, and the probe parameters are already known and accounted for, the actual power at the input of the down-converter module can be calculated based on the known output power level from the Error-

Correction Reference Chassis. The selected channels on the Position/Intensity module are then read by the control system and compared with the expected value based on known system parameters. The error is then subtracted from the ideal to obtain a corrected value. This error-correction process begins at the largest input-power level and proceeds in 1-dB steps to the lowest expected level. In doing so, an 12-bit array is constructed of expected values and actual values. A linear interpolation routine fills in the corrected table values between the 1-dB sampled steps. Once the tables are computed, the slot-zero controller uploads the correct lookup table values to RAM lookup tables in the selected Position/Intensity module. The process is the same for each of the measurement systems.

After these lookup tables are computed and uploaded to the respective modules, then in real-time, 12-bit sampled data from the log amps in each module is corrected before the algebraic difference is taken. It should be noted that the generation of reference signals, recording these data, and computing the LUT values does not occur in real time.

5 CONCLUSIONS

The beam-position measurement system has been fully specified and work begun on each of the subsystems or modules.

REFERENCES

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