Test of BPM Cables vs Temperature and Humidity

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Abstract

Measuring the absolute position of the beam in the intensifier and storage ring of a high energy photon source (HEPS) requires measuring the offset between the electrical and mechanical centers of the beam position monitor (BPM). In the HEPS project, a four-electrode BPM is used, and the signals from each of the four electrodes of the BPM probe are led out by a cable. During the operation of the intensifier and storage ring, the influence of ambient temperature and humidity on the BPM cable and the difference between the four channels will directly lead to changes in the BPM measurement results. In this paper, vector network analyzer (VNA) is used to test the data of signal amplitude change of two BPM cables within ten hours when temperature and humidity change. The conclusion is that the influence of temperature on the signal is about 0.01 dB/℃, the influence of humidity on the signal is about 0.05 dB/10%, and the relative change between channels is about 5%.

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BPM system

A complete beam position measurement system is typically comprised of two main components: BPM probes and BPM signal processing electronics, often connected by coaxial cables, with the basic structural framework illustrated in Figure 1. The BPM probes are designed to detect electromagnetic field signals produced as the beam passes, thereby acquiring information on the beam's position. Each BPM probe consists of a cavity with two or four symmetrically arranged electrodes, depicted in the left section of Figure 1. The signals captured by the BPM probes are transmitted via coaxial cables to the BPM signal processing electronics, where they first undergo processing by the Analog Front End (AFE) circuitry to handle the analog signals. Subsequently, these signals are converted into digital signals by the Digital Front End (DFE), and after algorithmic processing, the final beam position information is obtained.

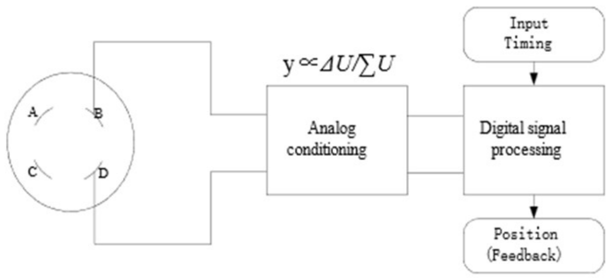

Figure 1: Basic structure of BPM system

BPM probes

BPM probes consist of a cavity that mirrors the shape of the vacuum pipe and four symmetrically arranged electrodes. These electrodes capture electromagnetic field signals generated by the beam, which are then converted into electrical signals and transmitted through the output port to the connecting cable. BPM probes are typically situated near the quadrupole magnets of the accelerator. There are various types of BPMs, with button and stripline types being the most commonly utilized.

Table 1: Comparison between button-type BPM and stripline BPM

	button-type BPM	stripline BPM
Coupling mode	Capacitance	Capacitance, inductance
Signal strength	Lesser	Larger, depending on azimuth
Signal quality	Because of the limited size and capacitance, the signal may be distorted	Less distortion
Mechanical structure	Easy	Complexity
Installation position	Small size, can be installed in many places	Generally located in the linear accelerator, requires a large installation space
Directional coupling	No	Yes

Signal processing electronics

Signal processing electronics are utilized to adjust and process signals originating from BPM probes, providing beam position information in digital form for acquisition by the accelerator control system. The output signals from BPM probes require conditioning through appropriate radio frequency circuits and a digital processing unit, after which beam position information is calculated. The most commonly used processing methods are: the logarithmic ratio method, amplitude to phase conversion (AM/PM) method, and the difference and ratio method.

Table 2: Comparison of transmission equations of three position algorithms

Property	Log-Radio	AM/PM	The division of the difference by the sum
Carrier frequency	~2.7GHz	~500MHz	>200MHz
bandwidth	<100MHz	<10MHz	>100MHz
Dynamic range	large	large	small
Complexity	medium	high	low
Cost	medium	high	low

Aim

This study aims to investigate how variations in humidity and temperature affect the amplitude of signals transmitted through BPM cables, with a particular focus on testing the relative drift among multiple cables, as common drift across all cables does not impact position measurement.

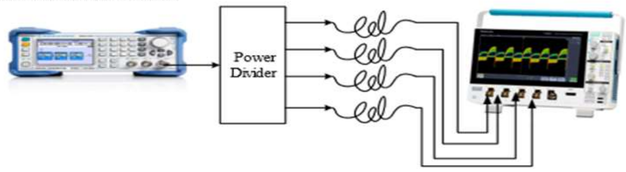

Figure 2: Experimental platform structure diagram.

Method

To meet the performance requirements of HEPS, environmental conditions similar to those of the HEPS storage ring BPM installation and operation environment were simulated in the laboratory. A temperature control box with a volume of 400L was used in this study. The structure of the experimental platform is shown in Figure 2, and the RF signal generator is on the left. In the middle is a four-channel power divider. On the right is a four-channel vector network Analyzer (VNA). In addition, a temperature and humidity recorder is placed inside and outside the temperature control box. Two kinds of cables were tested in the experiment, namely PWB480 (30m) and LMR240 (30m).

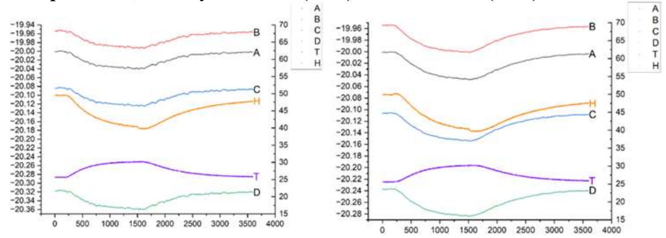

Figure 5: (a) PWB480 test results (b) LMR240 test results.

Conclusion

The beam tuning work for the High Energy Photon Source is being vigorously carried out, and as an integral component of particle accelerators, the precise detection by the beam position measurement system is crucial for achieving the beam trajectory stability required by HEPS. This study primarily investigates how environmental temperature and humidity variations affect the amplitude of signals transmitted through BPM cables. The experimental findings indicate that an increase in temperature impacts the signal amplitude by approximately -0.01 dB/° C, a decrease in humidity affects the signal by about -0.05 dB/10%, and the relative change among the channels is around 5%.