INTRODUCTION

Beam stability is a key factor in meeting the specifications for intensity and brightness desired to be achieved by NSLS-II. The multi-beam stored electron beam condition for vertical and horizontal resolution, as well as long term stability must be less than 200 nm. The NSLS-II BPMs are installed in thermally stabilized racks which are regulated to +/- 0.1 degree C of operating room temperature, which is essential to meet the stability requirements [2,3]. This paper will detail the implementation of various test procedures designed and performed on each BPM receiver (Fig. 1) pre and post-installation.

PHASE 1 TEST

Communication interface and Firmware verification - This test is performed based on the IP address, MOXA port assignment, Mode, Firmware version, and PLL status - as shown in Fig. 4. Each BPM is remotely configured for Single-Phase, Booster, and Storage Ring applications. They are assigned a unique IP address and is mapped to a geographical location at NSLS-II. Upon power-up, the BPM is examined to determine proper configuration mode. The IP address and MOXA port are manually configured. The firmware version, PLL status, and port assignment is obtained by executing Phase 1 test script. Each BPM is automatically configured to one of three operational modes, as all three operational modes are derived from the storage ring operation frequency.

PHASE 2 TEST

ADC Raw Data set, ADC Raw Data in Time & Frequency Domain, TBT Position, PA Position, and 175MHz/Phase Noise (Fig. 5) plot - These tests are MATLAB based and are performed on each receiver both as a lab test, as well as a site test after installation, and compiled into a data set in the Time and Frequency Domain response of each ADC channel output, as well as 175MHz PA position data, and TBT position data. The test setup is fairly similar (shown in Fig. 5) and essentially a representation of operational configuration. The site test is performed when all BPMs are installed in the rack and cabled with production hardware.

PHASE 3 TEST

Cable Orientation Verification (COV) - Static Gain Calibration (SGC), and In-Operational On-Line System Test (IOTS) - There is a need for MATLAB routines developed to perform these tests, and in part of site scale system integration. In addition the on-board Digital Step Attenuators are used for the SGC and IDT improvements. The COV test is performed to certify all cable connections between the PTC and receiver, and is pilot tone based. Note the attenuation is used to calculate the offsets due to channel-channel AFE amplifier gain differences. The IDT routine quantifies a channel as a function of position vs. signal power over the range of the Digital Step Attenuator in the Pilot Tone Analyzer (0-31db, in 1db increments, and uses the PT as CW source. The hardware setup is identical for both SGC and IDT, as shown in Fig. 11.

FIGURE 1: NSLS-II RF BPM Production Unit

FIGURE 2: Pilot Tone Combiner Module (PTCM)

PRE/POST-INSTALLATION TESTING

Testing is conducted in a controlled laboratory environment using a custom test setup including PMT based continuum source, data acquisition, and post processing. MATLAB and Python based scripts have been developed to execute routines to test key functionalities and features of the BPM receiver. Performance test procedures are first comprised in a testing Pilot Tone Board (PTB) using a dedicated receiver chassis populated with a Digital Pilot Tone Board (DPTB). System testing is accomplished using custom MATLAB based software to capture data for all three phases of functional tests, and utilizes the on board Pilot Tone Synthesizer as a CW source. The data is then organized, plotted, and archived on a per unit basis. Test results are stored in PRE-HBDM, an area server image using MASTLAB publishing framework. System integration tests are performed when BPM receivers are installed, and are run using EPICS to test network communications as well as IO functionality and is presented using Control System Studio (CSS) as the user interface. High level applications are developed to run via Control System Studio (CSS) via a dedicated BPM IO Server, with the added benefit of remote access to all of the BPM receivers installed in the accelerator [1]. These tools are used pre and post installation for lab based as well as integration tests and commissioning. Engineering panels for CSS have been developed to easily control parameters of each BPM in real-time. (Fig. 3) shows one of the CSS Engineering panel.

FIGURE 3: CSS Engineering Panel for BPM Control

There are 3 phases of testing performed on each BPM receiver prior to installation. Each phase test has several scripts performing various tests, as shown in Table 1.

FIGURE 4: Phase 1 Test Data (Communication/Firmware Verification)

TABLE 1: Stages of Testing and Results

FIGURE 5: Phase 2 Test setup

All test scripts are ran local to racks via portable laptop computer. EPICS based applications via CSS engineering panels can also be used in a cross check during the phase of site testing, and in part of the integration testing equipment. The Phase 2 test plan for the VCO/PLL output is also produced a Rhoda & Schroot SPF Signal Source Analysis. Fig. 6-10 show the plots of data for phase 2 test.

FIGURE 6: Phase 2 Data - Channel A

FIGURE 7: Phase 2 Data - Channel B

FIGURE 8: Phase 2 Data - Channel C

FIGURE 9: Phase 2 Data - Channel D

FIGURE 10: Phase 2 Data - TBT Post

FIGURE 12: Phase 3 Data - Post dBm vs. TBT

FIGURE 13: Position Vs. Attenuation after applying Static Gain Calibration

Static Gain Calibration (SGC) - To address differences in the channel-channel AFE amplifier gain, which would result in significant offsets to the calculated position values, a MATLAB based test and calibration process was developed. The pilot tone drive through a calibrated 1:4 splitter is supplied at the tunnel PTC. The power is then measured at the receiver. The MATLAB routine selects one of the four channels as the unity. The difference remaining between unity and unity channel is calculated. This process is repeated in 3db increments from 0db to 31db, which is the standard digitally controlled attenuators. A 21-3 element matrix is generated with weighting coefficients for each channel across the gain range and shown in Table 2 below.

Anomoly Dependence Test (ODT) - Intensity dependence test is pilot tone based and is performed on each BPM site wise as a measure to test performance specifications of 200 nm stability in its linear range. It is the same hardware setup for the SGC test, and implements a custom MATLAB script. The on board Pilot Tone Synthesizer is used as a CW source and the Digital Step Attenuator is varied from 0db to 31db in 1db increments, and shows a low intensity dependence and rms noise with power range of 40 db.

FIGURE 11: Phase 3 Intensity Dependence Data

TABLE 2: Static Gain Coefficient Matrix

Summary

Beam position Monitor system test and integration procedures including custom software routines and data output, contributed to a methodology that provided effective and successful diagnostics for system level testing both pre and post installation. In particular, Storage ring commissioning. This streamlined efforts to meet system requirements as well as schedule for operations timeline. An exhaustive set of test procedures proved to produce a very high yield of working production units, as well as improving system integrity site wise. This also provided a means to characterize and calibrate performance of each BPM unit prior to site wise installation. This data was also dependent on as baseline measure for integration testing, as to ensure that design specifications were met.

