DESIGN AND FABRICATION OF THE STRIPLINE BPM AT ESS-BILBAO

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Abstract

A stripline-type BPM has been designed and built at the ESS-Bilbao premises. The design is based on traveling wave electrodes principles to detect the transverse position of the beam enclosed within the vacuum chamber. In the design of stripline setup, it has been considered to keep the comparison conditions with previously used pick-ups as similar as possible. The length of strip electrodes is 200 mm and the coverage angle is 0.952 rad. The structure is rotationally π/2 symmetric and the alignment of electrodes are π/4, 3π/4, 5π/4 and 7π/4. The design is optimized for a frequency of 352 MHz, however it can function on a wide range of frequencies out coming from the measurement results. Striplines in general have well defined behavior even for low beta and low intensity beams as well as functionality at low and high frequencies. A report on the design and characteristics measurement of stripline is presented which includes the frequency range, the effect of insulation of electrodes, the electrode response as well as their sensitivity to beam power and position.

INTRODUCTION

The ESS-Bilbao (ESSB) project comprises a light-ion linear accelerator feeding a low-energy neutron source. Beam Position Monitors (BPMs) are some of the diagnostic systems under current development. A first stage in such an endeavor was the full development of a Button Pick-up BPM prototype [1] which attained full performance specification. The main drawback of button pick-ups concerns their weak sensing response at low energy and low beta beams such are the ones already under consideration within ESS-Bilbao. To overcome such difficulty, in collaboration with the Department of Electricity and Electronics of the University of the Basque Country (UPV/EHU), we have designed, built and tested a stripline monitor consisting of four electrodes as schematically shown in Fig.1. The implementation of this BPM system includes the pick-ups and stripline BPMs, the test stand for simulating beam conditions, the analog and digital electronic units and the control system [1]. The control system integrates the BPM system into the Experimental Physics and Industrial Controls System (EPICS) [2] network of the accelerator.

GENERAL DESIGN AND CONSIDERATIONS

The electromagnetic structure of the stripline BPM was separated into two smaller structures for the ease of the electromagnetic simulation [3]. One structure includes the tube and electrode strips and the second structure comprises the transitions and feedthroughs. The criteria of maximum sensitivity at the ESSB RF frequency of 352 MHz and the 50 Ω impedance for the elements are taken as constraints to the design. The rigid N-type feedthrough with long signal pin is chosen as also the signal feed out from stripline to the electronics via coaxial cables. The transition from the strip electrode to the feedthrough was simulated and optimized in order to minimize the signal reflection in both ways. The optimum length of electrode, for which the sensitivity of the signal to the beam displacement is maximum, occurs at a signal walk equal to one quarter of wavelength of the exit beam. The stripline tube inner diameter is 57 mm and the length of strip electrodes is 200 mm, while the azimuthal coverage angle is 0.952 rad. Increasing the coverage angle could result in signal integrity deterioration due to coupling between adjacent strip electrodes. The assembly angles of strip electrodes are π/4, 3π/4, 5π/4 and 7π/4. This corresponds to a π/4 rotation of the stripline block around the beam axis in order to be fitted easily on the test stand.

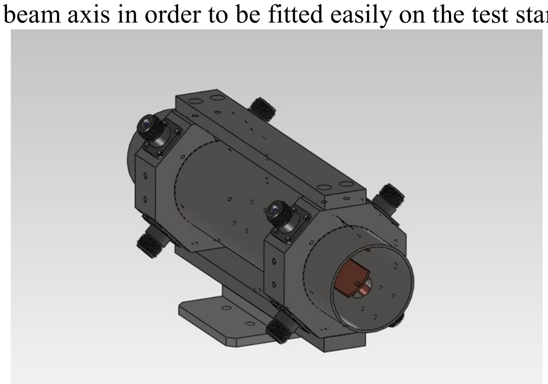

Figure 1: 3D schematic of the stripline BPM.

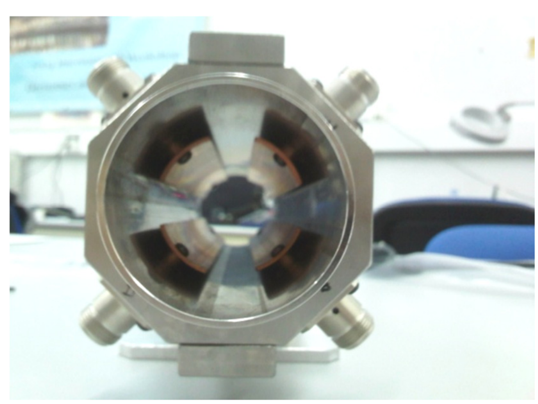

Figure 2: Stripline BPM fabricated electrodes configuration.

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STRIPLINE MEASURED CHARACTERISTICS

To perform the measurements of the BPM system, a test stand has been developed at ESSB and UPV/EHU to allow assembling a stripline BPM block.

BPM Test Stand

For the laboratory tests, a copper rode with a diameter of 9 mm was inserted inside the stripline block and located initially at the transverse center of the stripline block. In the absence of real beam, this rode carries the RF signal and mimics the bunched beam at the specific frequency. The relative position of the internal rode simulating the beam can be changed with respect to the outer tube within a range of ~20 mm for both X and Y planes with positioning steps less than 10 µm.

Characteristics Impedance

The copper rode ends with a 50 Ω load. The upstream ports of the stripline are terminated with a 50 Ω load when not in use; while the downstream ports have short circuit terminations. Fig. 3 shows the Smith chart of one strip electrode. Since the four electrodes are almost identical, data shown in one graph also represents the other three electrodes. The red dot corresponds the location of working frequency of 352 MHz. It shows the characteristic impedance of around 50 Ω up to 1.5 GHz.

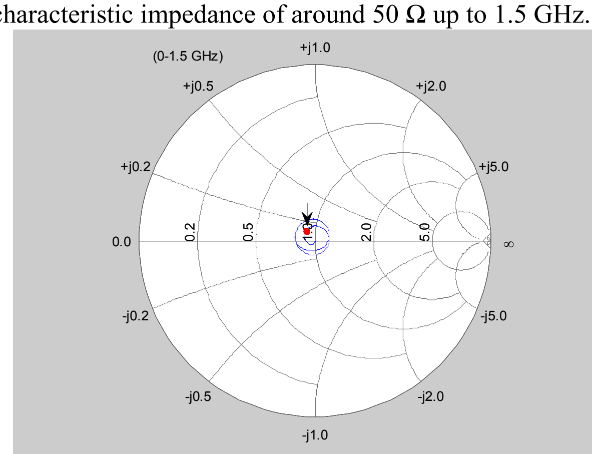

Figure 3: Smith chart for one stripline electrode.

Electrodes Insulation

In general terms, highly insulated electrodes should translate into lower coupling and thereby higher accuracy of the beam position monitoring. In contrast, high coupling values between electrodes increases the non-linearity of the sensitivity curves, which complicates the extraction of accurate information on the beam position from the electrode signals. The Fig. 4 shows that the insulation between two adjacent electrodes is 21 dB and for the opposite electrodes is 34 dB at 352 MHz. This can be translated onto the values for the coupling between adjacent and opposite electrodes at the corresponding frequency. This corresponds to a 0.9% voltage coupling between adjacent electrodes at 352 MHz [3].

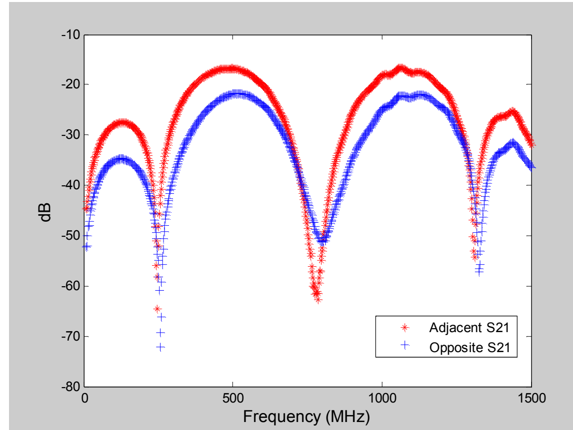

Figure 4: Measured insulation between electrodes of the stripline.

Frequency Response

The response of the electrode strips to a 0 dBm centered beam at different frequencies up to 3 GHz was measured and it is shown in Fig. 5. The plot is expected to show peaks at values corresponding to odd harmonics of RF frequency (1st, 3rd, …) and minimum responses at even harmonics of the RF frequency (2nd, 4th,…). The measurement results also agree with a peak response (-14 dBm) at 352 MHz and a minimum response (-38 dBm) at the second RF harmonic.

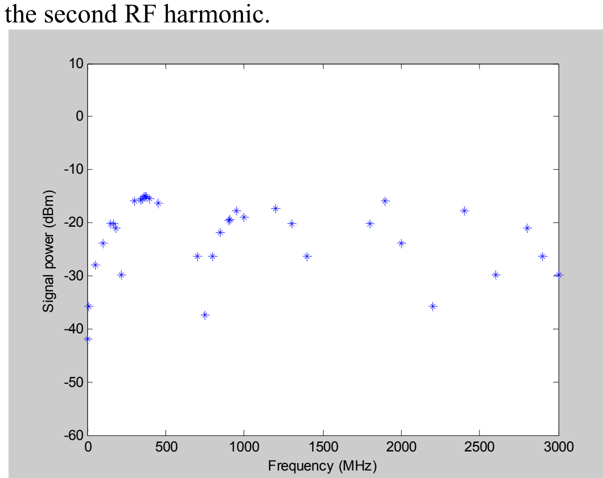

Figure 5: Stripline response to beam frequency variation.

STRIPLINE RESPONSE TO BEAM CURRENT VARIATIONS

In order to test the linearity of the stripline response to beam current variations, RF signals ranging from -40 dBm to 15 dBm were inserted into the central rode of the stripline which represents the beam on the test stand. The Fig. 6 shows the measured power from each electrode of the stripline together with its linearity to beam current variations. It is also worth mentioning that the stripline electrode signal magnitude is strongly dependent upon its distance to the beam center as well as to the beam frequency. In real numbers, such a magnitude for measurements carried out at our test stand has yielded a value of -15 dBm for a 0 dBm, 352 MHz beam.

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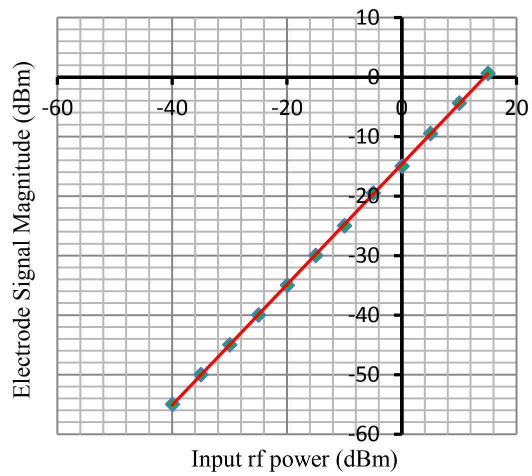

Figure 6: Measured input and electrode signal variation.

LINEARITY OF X/Y POSITIONING

The Fig. 7 shows the measured linearity of the position reading in horizontal and vertical planes at the bunch frequency of 352 MHz. The displacement data was acquired only within one plane, while the beam position was kept unchanged within the other plane at the same time. This measurement scheme was repeated for horizontal and vertical planes and relevant data pertaining the instantaneous reading of beam position were taken. The Fig. 7 shows the linear sensitivity curves near the transverse center for X/Y planes. However the non linearity shows up as the distance from the center of the stripline is increased. The fitted values correspond to the slopes of the straight lines and yield 0.977 and 0.997 for horizontal and vertical planes respectively.

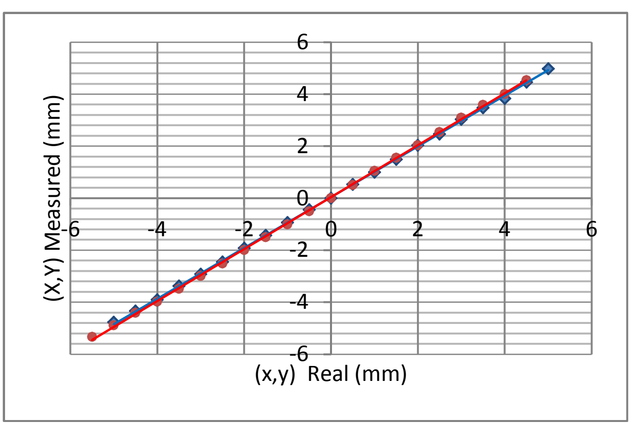

Figure 7: Linearity in X and Y planes at 352 MHz.

STABILITY MEASUREMENTS

In order to perform long term stability measurements of the position measurement at horizontal/vertical planes and phase, the whole system is left operating overnight within a relatively quiet location, using the electronics system developed for the BPMs [4]. The room temperature of the measurement laboratory was also recorded during the measurement time; although the ambient temperature was not controlled. The gathered data are then analyzed using procedures developed in Matlab® from where the long term stability for horizontal/vertical planes and phase are extracted. No meaningful correlation between temperature variation and the position stability of readings was found. The measurement was repeated for the two reference frequencies of 352 MHz and 175 MHz. At 352 MHz, the input beam power to the rode inside the stripline was -23 dBm, which corresponds to -35 dBm in the Logarithmic Amplifiers (log amp) of the Analog Front-End (AFE) unit, based on the data from Stripline characteristics measurement.

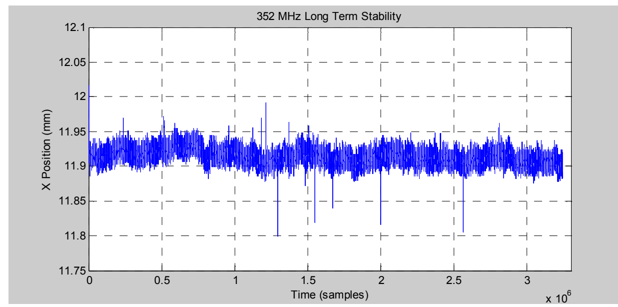

Figure 8: Long term stability measurement of horizontal position at 352 MHz.

For a total time of 11 hours running the system which corresponds to 3.3 M samples, the rms values for stability in horizontal and vertical planes was found to be 9.9 µm and 9.4 µm respectively (Fig. 8). With the same number of samples, the rms for phase stability was 0.38^{o}. For the short term stabilities of the position and phase of the whole system, 10 k continuous samples of each parameter were also acquired. The rms values for stability in horizontal and vertical planes was found to be 6.4 µm and 5.7 µm respectively. The rms of phase stability was less than 0.1^{o} at 352 MHz. The input power to the stripline block was -12 dBm which corresponds to -24 dBm signal level to Log-Amp of AFE unit.

ONCOMING PLANS

In order to characterize the behaviour of stripline type and button pick-up type of BPM system, both types of responses to different beam conditions are being measured and the results will be reported in a separate publication.

REFERENCES

[1] D. Belver, et al. "Overview of the BPM system of the ESS-Bilbao", MOPD21, Proc. of IPAC'11, Germany, May 2011.
[2] P. Echevarria, et al. "Multipurpose controller based on a FPGA with EPICS integration", PAC 2011, NY, US, March 2011.
[3] S. Varnasseri, et al. "Stripline BPM design and fabrication" ESS-Bilbao internal report, January 2012.
[4] D. Belver et al., "Design and measurements of the Stripline BPM system of the ESS-Bilbao", MOPPR041, Proc. IPAC'12, New Orleans, US, May 2012, pp. 870-872.

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