DEVELOPMENTS FOR IFMIF/EVEDA LIPAc BEAM POSITION MONITORS: THE SENSORS AT THE MEBT AND THE WIRE TEST BENCH*

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Abstract

Within the framework of the IFMIF Engineering Validation and Engineering Design Activities (EVEDA), the Linear IFMIF Prototype Accelerator (LIPAC) will be a 9 MeV, 125 mA CW deuteron accelerator which aims to validate the technology that will be used in the future IFMIF accelerator [1]. In the Medium Energy Beam Transport line (MEBT) connecting the RFQ and the SRF linac, electromagnetic Beam Position Monitors (MBPMs) will measure the transverse position and phase in order to control the beam steering. The response of the MBPMs must be optimized for a beam energy of 5 MeV, and a peak beam current of 125 mA. Due to the lack of space in the MEBT, the MBPMs will be located inside the magnets without perturbing the magnetic field. In this contribution, the electromagnetic and mechanical design of the MBPM will be presented. On the other hand, in order to validate and characterize all the LIPAc BPMs once they are manufactured, a wire test bench has been constructed and verified at CIEMAT. The design and validation results of the test bench will be discussed here.

WIRE TEST BENCH

The stringent requirements from beam dynamics for the LIPAc BPMs force a complete characterization of the response of the BPMs before installation in the machine. Hence the use of a wire test bench is almost mandatory to minimize the mechanical and electronic errors of each BPM. A wire test bench has been designed and manufactured at CIEMAT similar to the ones constructed for similar tests at other facilities [2, 3]. The setup has been designed in order to be well adapted to all the different type of BPMs used along the LIPAc, from the MEBT to the end of the HEBT. The setup is able of simulating a bunched beam although the present configuration is optimized for a single frequency operation.

Description

A thin conducting wire of 0.25 mm is used as internal conductor of the coaxial structure created with the BPM and the tube extension (Fig. 1). The wire is stretched between two coaxial connectors at each side of the support and one of them terminated in 50 Ω to minimize reflections in the setup. The other connector interfaces the test bench with the input RF signal.

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In order to carry out linearity and sensitivity tests, the wire support can be moved in two perpendicular axes by using a two micromovers structure. The performance of the Newport ILS100CC micromovers is summed up in Tab. 1. The aperture of the BPMs range from the 48 mm diameter of the MBPMs to the 150 mm diameter of the last BPM in the HEBT. As can be seen in Fig. 1, the solution implemented to adapt them has been to use an interface plate for each BPM between the mechanical support of the BPMs and the BPMs themselves. The precise alignment of the BPMs with the test bench structure is certified by the use of pins between the mechanical support and the interface plate.

Table 1: Main Specifications of the two Microvers Structures

Travel	±50 mm
Accuracy	2.5 μm
Bi-directional repeteability	0.7 μm
XY ortogonality +/-	50 μm

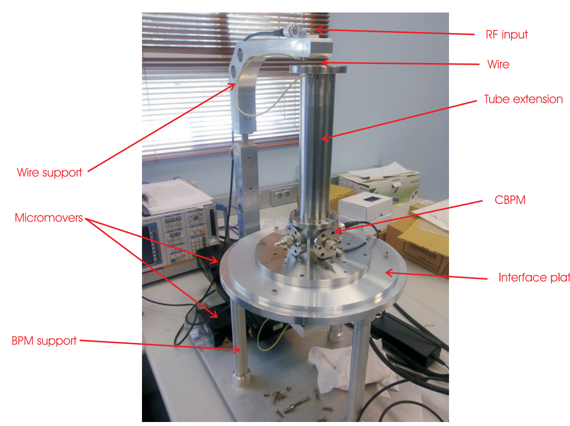

Figure 1: The CIEMAT BPM test bench.

The test bench has a transmission of -58 dB at 175 MHz and -44 dB at 350 MHz. This is due to the bad matching between the 50 Ω signal input and the impedance of the coaxial line. To overcome this issue, a matching network will be developed. In the meantime, an RF amplifier has been implemented to maximimize the output signal power at the required frequency.

Each measurement is automatized by a home-made Labview GUI. The application controls the wire movement, captures the result of e.g. the network analyzer, plots the data in a 3D surface plot and analyze them. The main parameters like the sensitivity and linearity can be calculated in the GUI. The interface with the network analyzer is done by GPIB, and the one with the micromovers controller by RS232.

In addition, in order to test the offset between the electrical and mechanical center, a special piece was developed to obtain the absolute position of the mechanical center of the interface plate–and the BPM–with respect to the micromovers. The piece is made of a narrow hole with a similar size of the thin wire which is positioned precisely in the mechanical center with the pins of the interface plate. An accuracy $< 100\ \mu$m is obtained with this technique.

Validation

In order to check the correct simulation of the beam, a prototype of the Cryogenic BPM (CBPM) [4] was installed in the test bench by developing a special BPM chamber similar to the one to be used in the solenoid package, and using the final CBPM buttons.

A network analyzer type R&S ZVB4 was used to simulate the beam frequency components and obtain the transmission response of each electrode. As this is a two channel device, each measurement had to be repeated four times - one per sensor- increasing the time cost of the procedure. The scheme of the experiment is detailed in Fig. 2.

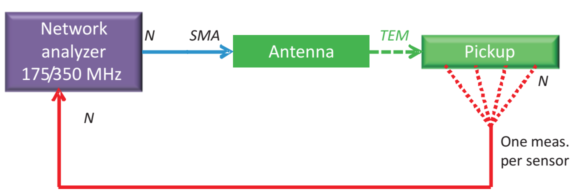

Figure 2: Scheme of the BPM wire tests using a network analyzer.

A mapping of the difference over sum signal was carried out in order to calculate the sensitivity constant and cross-check the result with the theoretical and simulated sensitivity (Fig. 3). The measured sensitivity is around 12.8 mm in both axes. This sensitivity is a bit smaller than the one estimated before at CERN [5], 12.6 mm. Three main reasons can cause this discrepancy: 1) differences in the capacitance of the simulated and real sensors, 2) geometry of the BPM chamber, and 3) the low resolution of the measurement.

MEBT BPMS

Introduction

In order to keep the beamline as compact as possible, the beam dynamics simulations require the MEBT BPMs (MBPM) to be inserted into the middle of the quadrupoles [6]. With these restrictions, capacitive BPMs are better suited than striplines. The design is based on the BPMs to be installed at SPIRAL2 [7], although it has to be adapted to the MEBT beam parameters (Tab. 2).

For a proper design of the monitors a first rough estimation can be done by implementing simple analytical models. However, powerful 3D electromagnetic software should be used for a more careful optimization of the geometry, the monitors response and the coupling to the beam. Some of the examples of the design optimization with these tools will be presented hereafter.

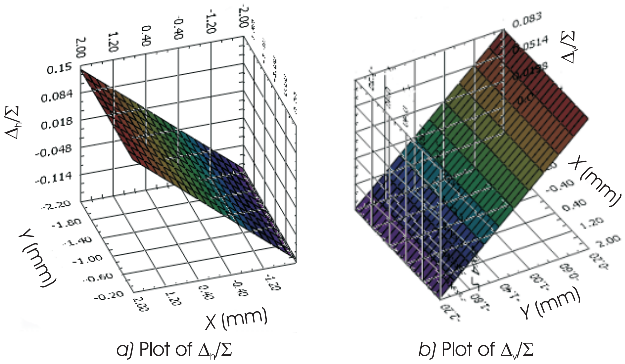

Figure 3: 3D plots of the response of the CBPM at 350 MHz: a) Horizontal delta over sum, b) Vertical delta over sum.

Table 2: Range (approx.) of the Beam Properties for the MBPMs

Beam parameter	Value
Energy E (MeV)	5
$\beta = v/c$	0.0727
Peak current I_b (mA)	10-125
Average current $\langle I_0 \rangle$ (mA)	0.1-125
Pulse length T_p (ms)	0.1-CW
Duty factor (%)	0.1-CW
Bunch length σ_z (ns)	0.18
Transverse size $\sigma_{x,y}$ (mm)	1-3

Length Optimization

The electromagnetic design of the electrodes have been done by using and 3D code, CST Design Studio [8]. The subtended angle of the electrodes was fixed to 60°. Using a 3D code the electrode length was optimized to maximize the pickup response at the fundamental and first harmonic: 175 MHz and 350 MHz. As expected by the theoretical formulations, there is a length which maximizes the response of the pickup at each frequency. They correspond to 70 mm at 175 MHz, and 30 mm at 350 MHz. As seen in Fig. 4, if the pickup is to be operated at both frequencies, a length of around 40 mm should be selected. The crosscheck between the agreement of the theoretical and simulated optimum lengths is out of the scope of these proceedings.

Capacitance Optimization

Another important parameter to optimize the response of the BPM is the analysis of the capacitance. The value of the

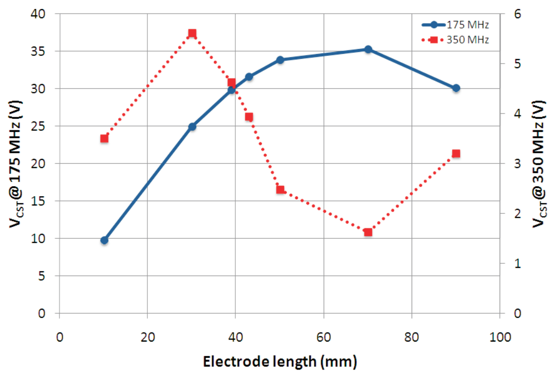

Figure 4: Response of one electrode as function of the length.

capacitance is related with the beam facing geometry but also with the dimensions between the electrode and the external body. The capacitance value can be simulated using TDR with a 3D code. Results of applying this technique to one electrode is shown in Fig. 5. From the response to a step stimulus the capacitance C_{el} can be calculated with the following expression:

$$C_{el} = \frac{t_2 - t_1}{R_0 \ln 2}, \tag{1}$$

where t_1 is the time when the response crosses zero, t_2 the time when the response is 50% the maximum value, and R_0 the load resistance, which in this case is 50 Ω.

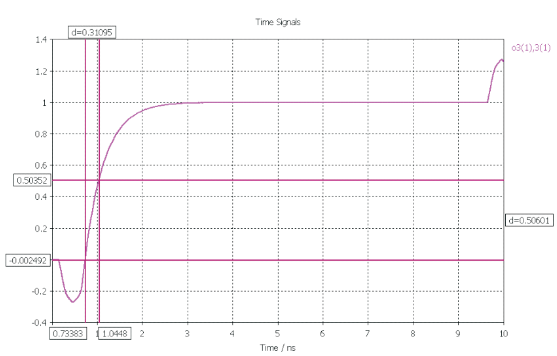

Figure 5: Time domain reflection response of one sensor to a step stimulus.

Figure 6 shows how the capacitance increases linearly in the center region between 40 mm and 90 mm. At the extreme regions the contribution to the capacitance is bigger from other parts of the electrode geometry and the dependence changes. For the previously selected length of 40 mm the capacitance of each electrode is around 9 pF. As both the area and the length are very similar to the CBPM, the output signal will be very similar. The same conditioning electronics can be foreseen, reducing the operation range and the cost. However, the detailed design of the coaxial feedthrough and the assembly with the electrode are not fully completed at the moment. Once this is fixed the final capacitance must be recalculated as it can make slightly vary the final result.

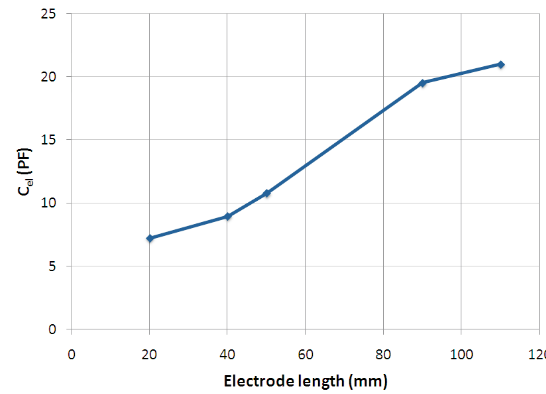

Figure 6: Capacitance of one electrode as function of the length.

CONCLUSIONS

The CIEMAT wire test bench has been designed, constructed and validated with the prototype BPM of the LIPAc SRF linac to be capable of successfully simulating a bunched beam. The setup is totally automatized in order to speed up the measurements. In addition, several improvements are already being done to improve the performance, like increasing the RF input and matching the test bench with the input network.

In the MEBT, the mechanical design of the BPMs to be installed inside quadrupole magnets is being finished and a prototype will be manufactured in the oncoming months. The combination of theoretical formulae and 3D simulation codes has been shown as a very powerful tool for the optimization and validation of the design.

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