Eletronic test bench for the validation of MYRRHA BPM acquisition systems

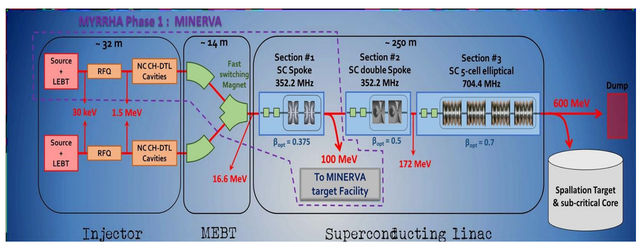
TUP37

M. BEN ABDILLAH†, F. Fournier (University Paris-Saclay, CNRS/IN2P3, IJClab, France)

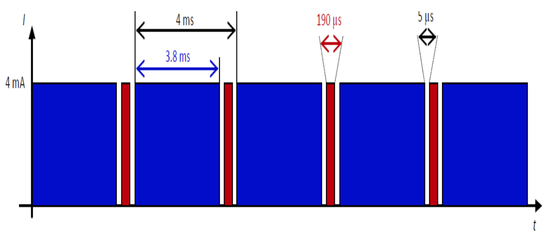
ABSTRACT

MYRRHA (Multi-Purpose Hybrid Research Reactor for High-Tech Applications) aims to demonstrate the feasibility of high-level nuclear waste transmutation at industrial scale. Beam Position monitors are key elements in many accelerators. For instance, once BPMs are installed along a linear accelerator or a storage ring, they remain inaccessible for any validation of updated or rejuvenated electronics. This paper addresses this issue with the realization of an electronic test bench simulating the outputs signals of BPM electrodes for a given beam energy, phase and position. The bench is realized for MYRRHA BPMs and it offers simulated beams with a position precision down to 50µm and phase precision down to 0.5° on a wide range.

MYRRHA PROJECT



TIME STRUCTURE



Parameter	Range	Precision
Energy E	1.5MeV-600MeV	
Current I	0.1mA-4mA	
Duty cycle	2.10^{-4} to 0.125	
F_{acc}	176.1MHz	
Beam pipe diameter	38mm, 56mm, 80mm	
Measured Position on both axes	±5 mm	100µm
Measured Phase	360degrees	1degree
Measured Ellipticity	±5mm	Max(3.2mm²;20%)

In nominal operation, beam position and transverse shape are measured with BPMs. All BPMs will be aligned along MYRRHA sections. Their associated electronics will be installed in a dedicated room located several meters away from their locations.
Once the LINAC is in operation, access to BPMs is mostly denied. In case of BPM operation far from optimal or showing serious dysfunctions, it would be difficult to locate the source of the dysfunctions.
It would be of a great help to have a BPM "Simulator": an electronic card repeating religiously BPM operation.

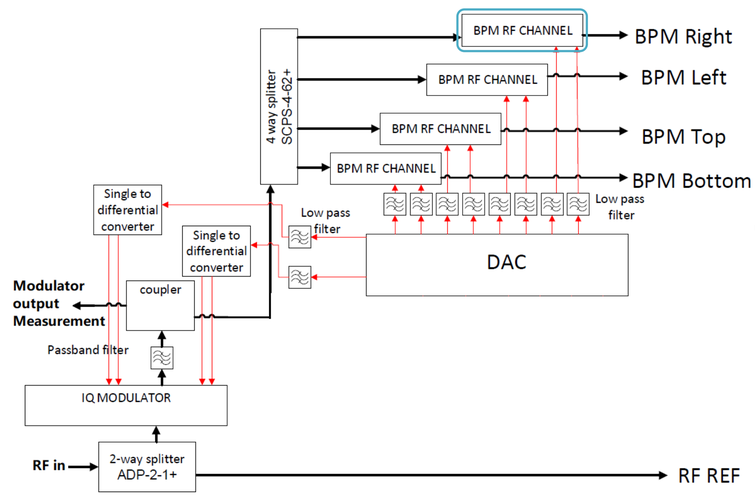
BPM SIMULATOR CONSTRAINTS

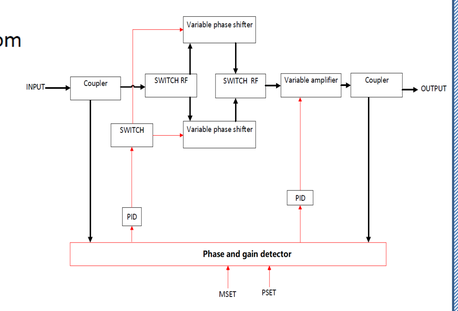
BPM is equipped with 4 probes formed by a sealed 50Ohm feedthroughs attached to an electrode. The beam induces electrical signal on each electrode.
MYRRHA BPM acquisition system processes the said signals by measuring the 1st and 2nd tone levels and using them to provide the beam position and phase shift regarding the frequency reference signal.
Based on different MYRRHA BPM prototypes [1; 2], Table 2 summarizes the tone levels ranges expected at the outputs of different BPMs along MYRRHA

Section	Facc ; 4mA current	2*Facc; 4mA current	Facc ; 4mA current	2*Facc; 100µA current
RFQ exit	[**-7dBm**; -23dBm]		[-39dBm; -55dBm]	
MEBT start	[-15dBm; -29dBm]	[-14dBm; -28dBm]	[-47dBm; -61dBm]	[-46dBm; -60dBm]
MEBT end	[-22dBm; -35dBm]	[-19dBm; -33dBm]	[-54dBm; **-67dBm**]	[-51dBm; -65dBm]
HEBT start	[-19dBm; -26dBm]	[-18dBm; -26dBm]	[-51dBm; -58dBm]	[-50dBm; -58dBm]

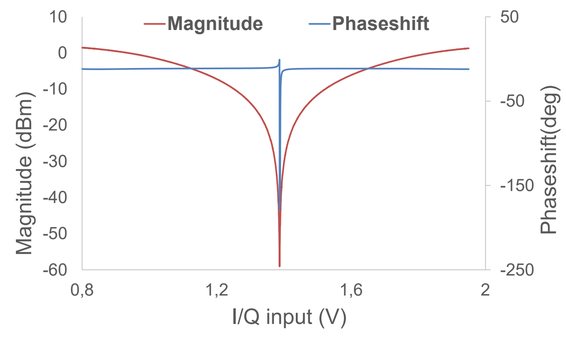
The simulator should cope with the following constraints:
- Deliver four synchronized output signals level in the range [-67dBm to -7dBm] at facc and 2facc:
- At Facc: it could be monitored either with variable attenuators that should be regulated or with IQ modulator where regulation is not needed.
- At 2Facc: in addition to the solutions mentioned above, a frequency multiplier should be integrated (either aside or in the choice of the IQ modulator)
- Deliver output signals phase in the range [-180°;180°] at facc and 2facc: at both frequencies, either variable phase shifters are used and they should be regulated.

BPM SIMULATOR DESIGN





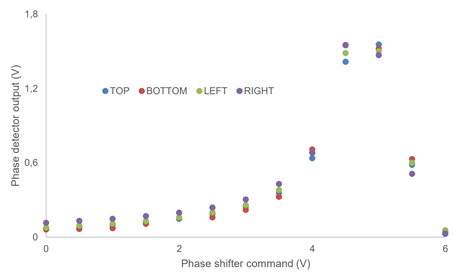
BPM SIMULATOR TESTS: DAC+ IQ MODULATOR

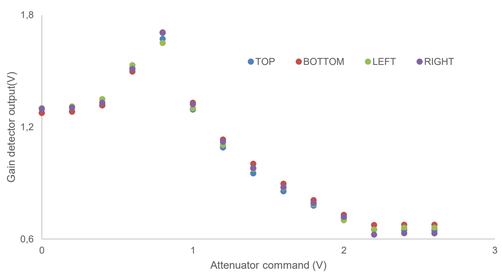


I/Q inputs are set equal and sweep over the range 0.8V to 2V, the modulator output phase shift is expected unchanged.
The magnitude range covers from 1dBm to -60dBm. the phase shift precision is over 1° for output magnitudes lower than -25dBm.

BPM SIMULATOR TESTS: BPM RF CHANNELS

BPM RF channel attenuation and phase shift are monitored with signals respectively called MSET and PSET. Open loop characterizations were performed for the 4 channels. The results, showed excellent agreement between the channels.





The capture ranges of each channel for magnitude and phase shift (referenced to modulator output) are also measured. The capture ranges are not ideally superposed between all channels, therefore, common ranges for magnitude and phase shift is set for the graphical user interface that would ease the use of the simulator.
The said common ranges for all channels in magnitude and phase are respectively [-2.5dB; 15dB] and [-85°; 25°]. The range width in magnitude is 17.5dB and in phase shift is 110°.
The capture range in magnitude could be increased to 23dB with a lower phase shift range (60° instead of 110°).The capture range in phase shift could be increased to 135° with a lower magnitude range (7 dB instead of 17.5dB).

CONCLUSION

The BPM simulator is able to deliver four output signals at facc at level in the range [-67dBm to -7dBm] with precision lower than 0.01dB. The phase shift control is problematic for levels lower than -45dBm.

A new version is under fabrication; it includes testing of ToF feature as well.

BPM simulator is easily matched to test custom or over the shelf acquisition systems not only for BPMs but any system using up to four synchronized signals with magnitude and phase shift controllable over a large range.

REFERENCES

[1] M. Ben Abdillah, P. Blache, F. Fournier, and H. Kraft, "Development of a Low-beta BPM for MYRTE Project", in *Proc. IBIC'19*, https://doi.org/10.18429/JACoW-IBIC2019-WEPP002

[2] M. Ben Abdillah, F. Fournier, "Beam Position Monitor for MYRRHA 17-100MeV section", in *Proc. IBIC'21*, https://doi.org/10.18429/JACoW-IBIC2021-MOPP07

Contact sidi-mohammed.ben-abdillah@ijclab.in2p3.fr

IJCLab - Laboratoire de Physique des 2 Infinis **Irène Joliot-Curie**
Bâtiment 100 - 15 rue Georges Clémenceau - 91405 Orsay cedex - France
UMR 9012, CNRS, Université Paris-Saclay, Université Paris Cité

www.ijclab.in2p3.fr