Evaluation of Libera Single Pass H for ESS LINAC*

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Abstract

The Beam Position Monitor system of the ESS linac will include in total more than 140 BPM detectors of different sizes and types. The resolution and accuracy of the position measurement with the nominal 62.5 mA beam current and 2.86 ms pulse width need to be 20 µm and 100 µm respectively, and those of the phase measurement are 0.2 deg and 1 deg respectively. Options for the implementation of the ESS BPM electronics include: 1) a custom or commercial front-end card combined with a commercial digitizer with in-house developed firmware and 2) a fully commercial off the shelf system.

Libera Single Pass H is an instrument intended for phase, position and charge monitoring in hadron and heavy ion LINACs. The instrument was tested at the ESS laboratory, to prove the feasibility of operation with ESS beam conditions. The results present resolution and accuracy evaluation, as well as a stressful long-term tests. This poster presents the achieved results of the Libera Single Pass H for the ESS beam parameters.

ESS button BPMs and signal levels

Most of the **ESS BPM detectors** will be of electrostatic button type. The signal levels expected from the BPMs are calculated using an analytical model, applying the value of the influential parameters listed in Table 1:

Parameter	Value	Unit
RF frequency	352.21 and 704.42	MHz
Bunch repetition rate	352.21	MHz
Pulse repetition rate	14	Hz
Pulse duration	0.1 - 2.86	ms
Pulse current	6.25 – 62.5	mA
BPM diameter	60 and 100	mm
Button diameter	24 and 40	mm
Button capacitance	5.2	pF
Beam max displacement (with reference to the beam pipe)	50	%

Table 1: ESS beam and BPM characteristics

Considering the extreme cases, with the beam in the center of the pipe:
- **First harmonic** at 352.21 MHz ranges from -3.55 to -27.98 dBm
- **Second harmonic** at 704.42 MHz ranges from -1.13 to -25.56 dBm

Setup with a 4-way splitter

The role of the **test-setup** is to simulate the signals coming from the accelerator BPMs. One possibility is to start from a suitable RF source and split the signal with a 4-way splitter. Figure 1 introduces the setup used for the measurements in centred beam conditions (all inputs have roughly the same amplitude).

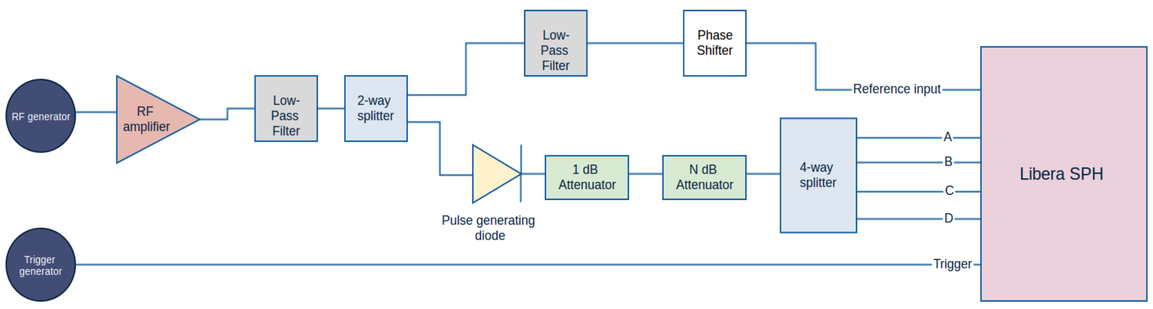

Figure 1: Block diagram of the measurement setup used for measurements with centred beam conditions.

- The phase shifter is used to control the phase difference between inputs and reference
- In the BPM signal path, the pulse-generating diode provides a signal which contains also the second harmonic, a good approximation of the BPM signals.
- Attenuators are used to control the signal level and to reduce the signal reflections caused by the diode impedance mismatching.
- Low-pass filters clean the reference signal from the unwanted harmonic components.

Measurement results

Figure 2 shows the **resolution** of phase and position decreasing the input input signal level, evaluated as the RMS value calculated over 2000 samples in a single acquisition. Figure 3 presents the **accuracy** evaluation, comparing the phase measurements collected with a Vector Network Analyzer (0.2 deg accuracy) and those gathered with the Libera SPH unit.

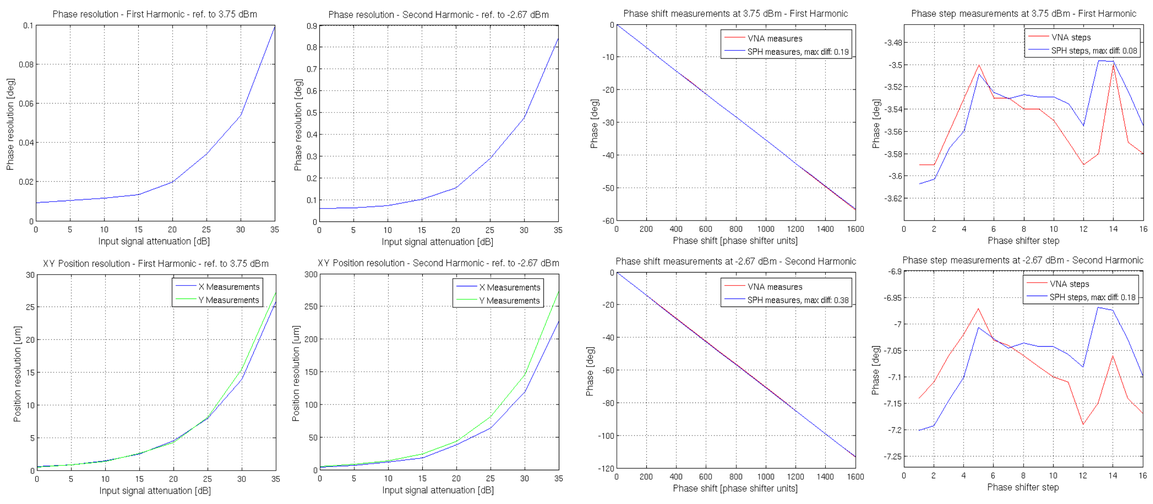

Figure 2: Phase and position resolution measurements.

Figure 3: Phase accuracy measurements.

The phase shift measured at the second harmonic is two times the shift which affects the first harmonic. All the measures with the second harmonic should then be divided by two. Furthermore, the unit used has a standard RF front-end with a bandwidth limited by the analog filters to 575 MHz. This attenuates the level of the input signal at 704 MHz. Substantial improvements are expected using an RF front-end tailored on ESS parameters.

Temperature stability of the measurements was evaluated with a **24h long-term test**. The room temperature variation was 6-7 degrees. Figures 4 and 5 show the results.

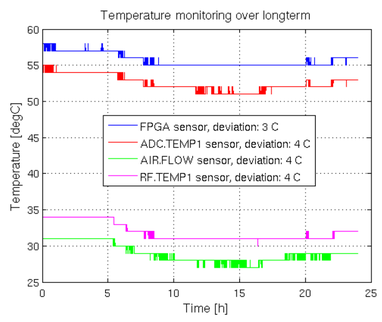

Figure 4: Temperature profile measured with the instrument sensors.

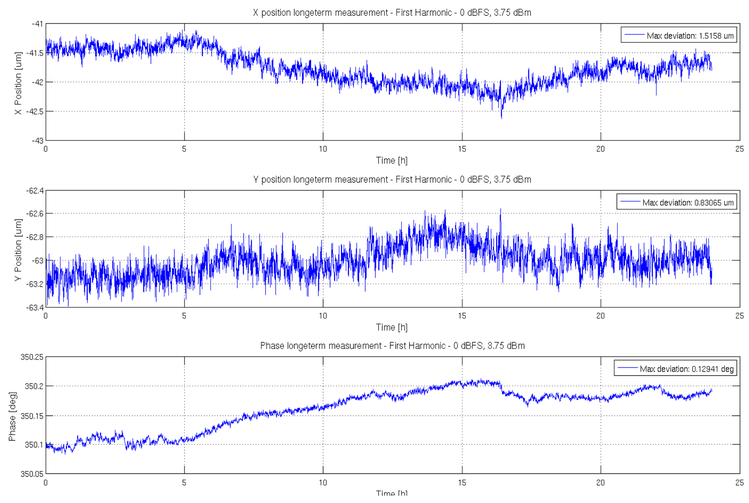

Figure 5: Phase and position measurements during the whole test duration.

Setup with BPM test-bench

A **BPM test-bench** was used in order to evaluate the position accuracy. The device consists of a section of a **60 mm beam pipe with a BPM** in the middle of it. Inside of the pipe, the beam is simulated with current impulses which pass through a wire. A mechanical slide is used to control the wire X position.

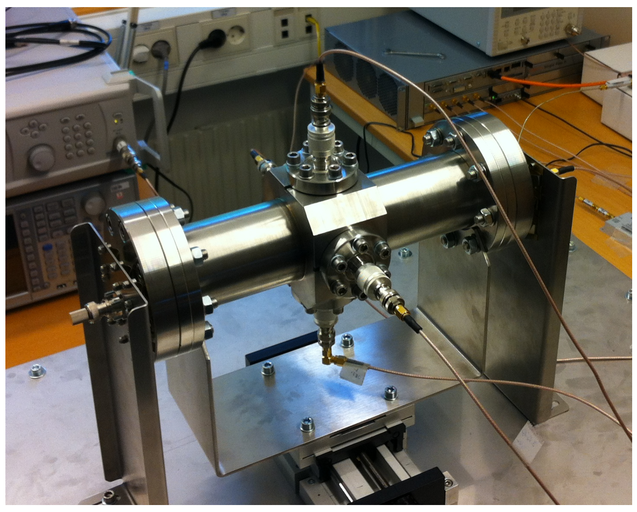

Figure 6: BPM test-bench designed and assembled at ESS.

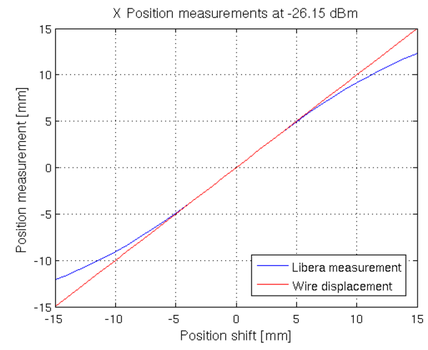

Figure 7: Position measurements in the range of [-15, 15] mm.

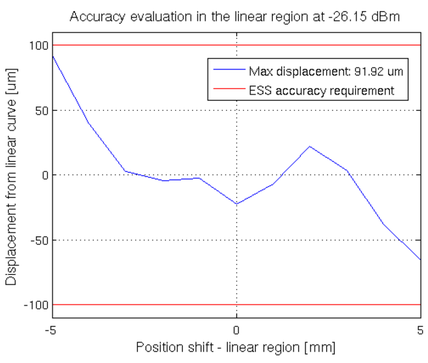

Figure 8: Position accuracy within the linear region, [-5, 5] mm.

Conclusions

This poster presents the measurements performed at the European Spallation Source with Libera Single Pass H instrument. The BPMs analytical models and the accelerator beam parameters provided enough information to identify the BPM signals which are expected at the instrument input. These signal conditions were reproduced in the ESS lab by using different tools and test-setups. Resolution, accuracy and stability of phase and position were evaluated. The achieved results show that Libera SPH meets the ESS requirements. Better performance is expected with an RF front-end tailored to the ESS machine parameters.

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