BENCHMARKING OF MULTIPARTICLE PHASE SCAN AND ACCEPTANCE SCAN TECHNIQUES FOR THE SNS DTL*

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Abstract

It is important to bring the cavity rf field amplitude and phase to the design for a high intensity linac such as the Spallation Neutron Source (SNS) linac. A few techniques are available such as the acceptance scan and multiparticle phase scan for tuning the Drift Tube Linac (DTL). During the SNS linac commissioning, tuning of cavities was conducted using the acceptance scan and phase scan technique based on multiparticle simulations. The two techniques are benchmarked.

INTRODUCTION

The Spallation Neutron Source (SNS) accelerator system is designed to accelerate intense proton beams to energy of 1-GeV, delivering more than 1.4 MW of beam power to the neutron production target [1]. The design peak current in the linac is 38mA and the macropulse average current is 26mA due to chopping.

Being a high intensity linac, it is crucial to minimize the machine activation induced by beam loss. Finding the right rf set-point can minimize longitudinal halo formation. Because bunch length is relatively long for the DTL, multiparticle tracking is important to accurately simulate the behavior of beam through each tank.

A few techniques for setting rf set-points were studied in depth in the past [2]. In this paper, we describe and compare the results of two techniques used for tuning the DTL, namely, phase scan using BPMs and acceptance scan using Energy Degrader and Faraday Cup (ED/FC). Experimental data were compared with the multi-particle simulations using the PARMILA code [3]. For general SNS linac commissioning results, please refer to [4].

MULTIPARTICLE PHASE SCAN

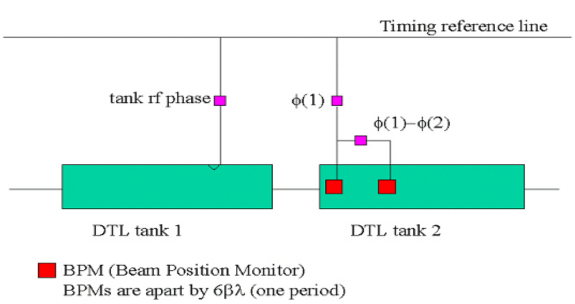

Figure 1: Schematic plot of phase scan with two down-stream BPMs.

The schematic plot of the Phase Scan is in Fig. 1. The two down-stream BPMs of, say, DTL tank 1 are inside DTL tank 2. They are $6\beta\lambda$ apart (a complete period). Phase advance plays an important role in this technique and is a function of tank rf amplitude and the offset from the design rf phase.

Phase Scans were performed using two down-stream BPMs during the SNS linac beam commissioning. The cavity field amplitude, cavity field phase and beam energy are varied to best match the measured values. The simulation is based on multiparticle tracking because bunch is relatively long for DTL tanks 1, 2 and 3.

Phase scan was performed for the DTL tank 1 and the data are shown in Fig. 2. Lines with circles represent the measurement data showing the difference of two BPM phase data $\phi(1)-\phi(2)$. Solid lines are Parmila simulations. The agreement between the measurement and simulation is excellent. The rf set-point obtained from this phase scan is $(A, \phi)=(0.179, -125.5°)$. Here, A is the Low Level RF amplitude and ϕ the LLRF phase. The incoming beam has an energy deviation of –0.0265 MeV from 2.5MeV, that is –1.060 %.

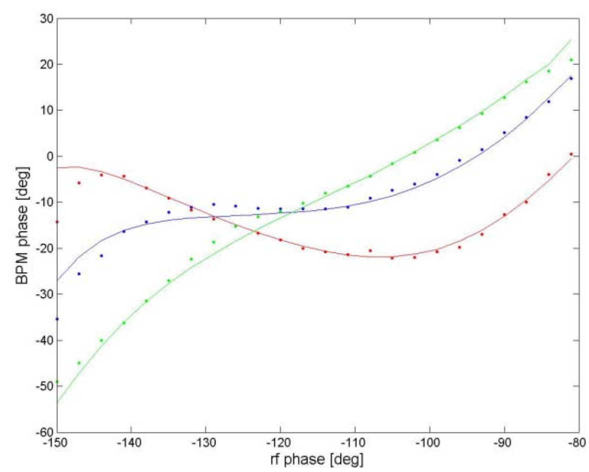

Figure 2: Plots of DTL tank 1 phase scan. Plotted are experimental data (solid lines with circles) and simulation results (solid lines) for three different rf amplitudes.

Phase scan was also performed for the DTL tank 2. The obtained rf set-point is $(A, \phi)=(0.483, 166.5°)$. The incoming beam has an energy deviation of –0.0236 MeV from 7.523MeV, that is –0.314 %. The plotted data in Fig. 3 are also the phase difference of two BPMs phase data. Now the agreement between the measurement and simulation becomes better.

* SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.
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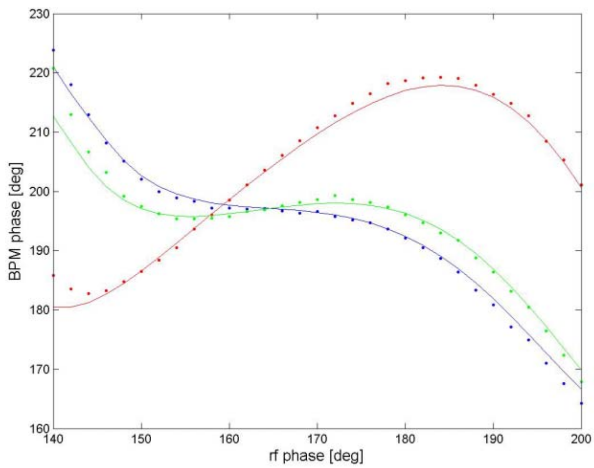

Figure 3: Plots of DTL tank 2 phase scan. Plotted are experimental data (solid lines with circles) and simulation results (solid lines) for three different rf amplitudes.

Phase scan was performed for the DTL tank 3, showing that the rf set-point is (A, ϕ)=(0.490, 105.0°). The incoming beam has an energy deviation of 0.0579 MeV from 22.885MeV, that is 0.254 %. In Fig. 4, the phase difference of two BPMs is plotted.

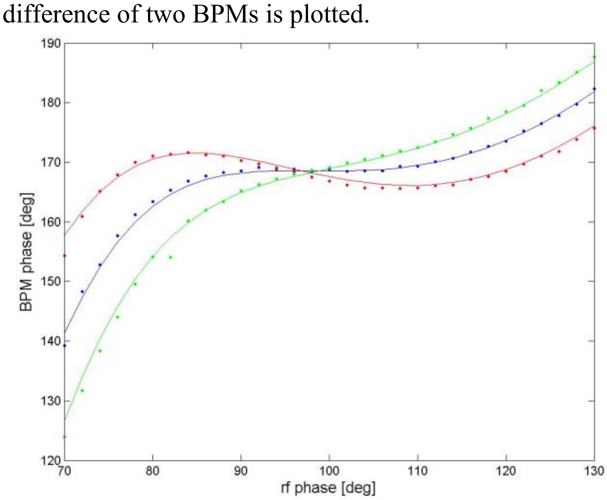

Figure 4: Plots of DTL tank 3 phase scan. Plotted are experimental data (solid lines with circles) and simulation results (solid lines) for three different rf amplitudes.

BENCHMARKING WITH ACCEPTANCE SCAN

Another widely used method for rf set-point is the acceptance scan with the Energy Degrader and Faraday Cup (ED/FC). This is also called phase scan. The absorber removes low energy tail of beam bunch and the surviving beam is collected using the Faraday Cup. A schematic plot of this scheme is shown in Fig. 5.

This technique was widely used in the early commissioning of the SNS DTL. One of the virtues is its simplicity and ease of use. For more reliable and accurate rf set-point, Phase Scan is preferred.

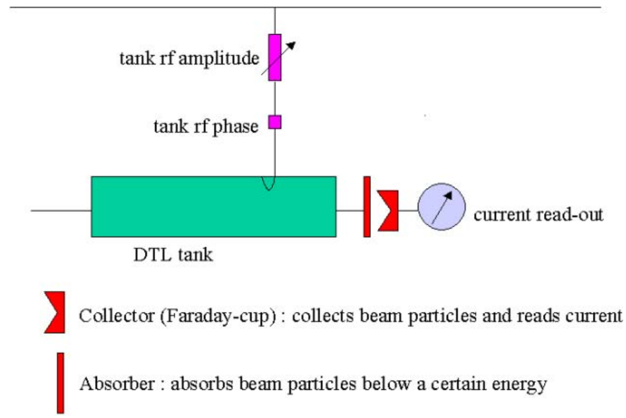

Figure 5: Schematic drawing of acceptance scan with the absorber and collector.

For benchmarking two techniques, acceptance scan was performed for DTL tank 1 to 3 under the identical machine conditions. Figure 6 shows the result of DTL tank 1 acceptance scan, which resulted in an rf set-point of (A, ϕ)=(0.176, -124.6°). Figure 7 shows the result of DTL tank 2 acceptance scan, which resulted in an rf set-point of (A, ϕ)=(0.484, 168.0°). Figure 8 shows the result of DTL tank 3 acceptance scan, which resulted in an rf set-point of (A, ϕ)=(0.494, 104.7°).

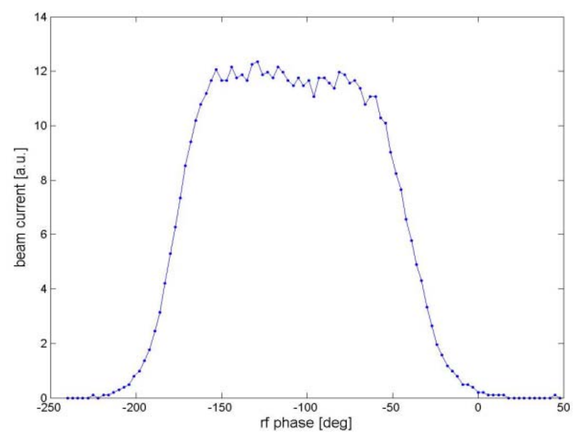

Figure 6: Plot of DTL tank 1 acceptance scan.

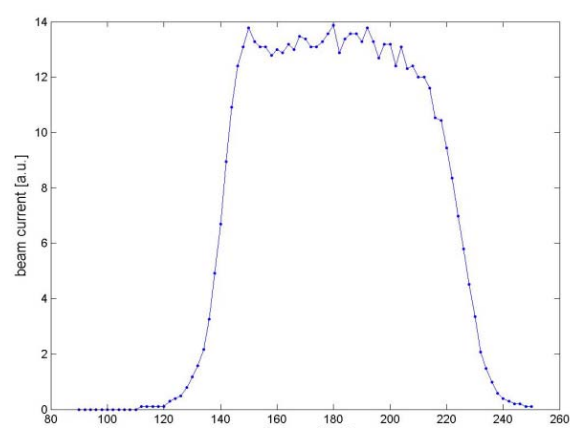

Figure 7: Plot of DTL tank 2 acceptance scan.

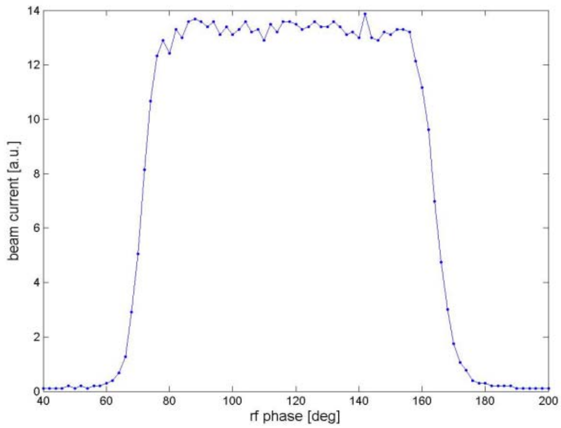

Figure 8: Plot of DTL tank 3 acceptance scan.

Table I summarizes the benchmarking results of the Phase Scan and the Acceptance Scan for the DTL tank 1 to 3. The rf amplitude of the tank predicted by both techniques differ at most by 1.7% and the rf phase by 1.5°. This is an excellent agreement demonstrating the consistency in the analysis of both techniques. DTL tank 1 is deemed to be the most sensitive tank of all. Further analysis is under way for other DTL tanks.

Table 1: rf set-point from PS and AS

	Phase Scan	**Acceptance Scan**
DTL 1	(0.179, -125.5°)	(0.176, -124.9°)
DTL 2	(0.483, 166.5°)	(0.484, 168.0°)
DTL 3	(0.490, 105.0°)	(0.494, 104.7°)

CONCLUSION

Preliminary comparison was made between the Phase Scan and the Acceptance Scan. Both techniques resort to multiparticle tracking with space charge force for the analysis of the measurement data. Tuning results show an excellent agreement for DTL tank 1. At low beam energy for the SNS linac, the longitudinal bunch size is relatively long and multiparticle tracking can guarantee the accuracy of phase scan or acceptance scan simulation. More studies will be conducted during the next commissioning runs. For more accurate rf set-point, the Phase Scan technique is preferred.

REFERENCES

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