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INFLUENCE OF SAMPLING RATE AND PASSBAND ON THE PERFORMENCE OF STRIPLINE BPM

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Abstract

It is obviously that the property of strip-line BPM is influenced by data acquisition system, but how the procedure of data acquisition and processing takes effect is still room for enquiring into it. This paper will present some data simulation and experiment results to discuss the function between resolution and passband, sampling rate or other influence factor. We hope that this paper would give some advice for building up data acquisition system of SBPM.

INTRODUCTION

Thanks to its compact design and high precision, SBPM is widely used for bunch position measurement just as what was in SXFEL [1]. As part of the modularization and generalization of the system, the digital BPM parameter settings used in SBPM measurements are the same as that in other part of beam diagnostics system. As a result, the analog signal measured by SBPM passes through a filter with a passband of 495 MHz-505 MHz, and then is undersampled by a sampling rate of 119 MHz and converted into a digital signal for subsequent processing.

The final measurement accuracy meets the need for beam position measurement of beam diagnostics system in SXFEL. However, With the improvement of machine performance requirements, the optimization of SBPM performance has gradually become more realistic and urgent. Under the premise that it is difficult to greatly optimize the performance of probes, it is a good choice to optimize the filter passband and sampling rate in electronics front-end design.

NUMERICAL SIMULATION

The corresponding signal and spectrum of strip-line BPM are showed below in Figure 1. We assume that the photon in the beam bunch Gaussian distribution, so as the signal waveform [2].

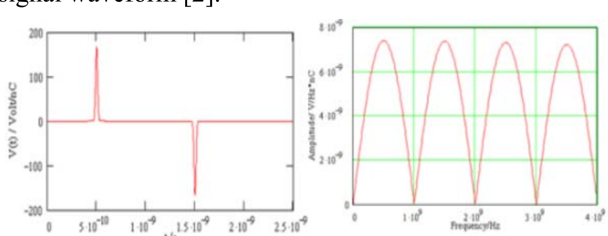

Figure 1: SBPM output signal(left) and the spectrum under the ideal conditions [3].

According to the spectrum, when center of the passband is nearing 500 MHz, the resolution would be optimal. That is the reason why passband is 490 MHz-510 MHz. But when put SBPM in a data measurement system, the conclusion may be different.

In SXFEL, the analog signal of SBPM will be transferred into digital signal before data processing [4]. Considering the influence of ADC, the spectrum of SBPM is shown in Figure 2.

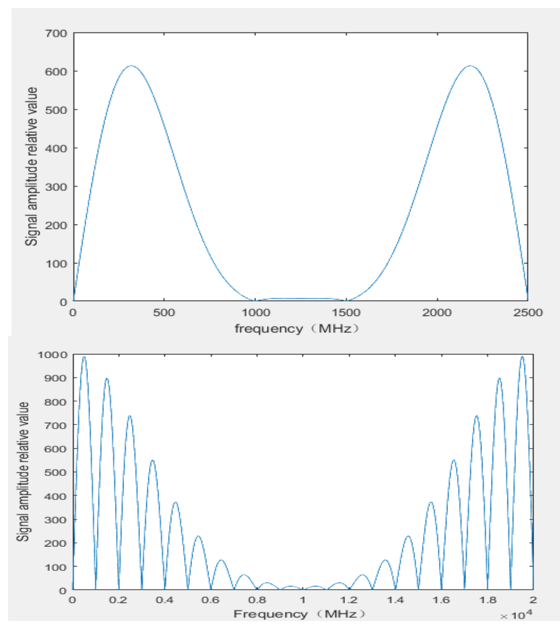

Figure 2: SBPM output spectrum influenced by ADC. Sampling rate are 2.5 GHz (top) or 10 GHz (bottom).

The result of numerical simulation reflects in one aspect how the sampling rate affects SBPM performance. 500 MHz is no longer the peak of the signal frequency after analog to digital conversion. Instead, a lower frequency takes its place. This phenomenon becomes more pronounced as the sampling rate of the ADC decreases. Considering undersampling, the spectral characteristics changes brought by ADC will be more complicated and need to be calculated according to the specific scheme [5].

The above is discussing the effect of the sampling rate on the peak of signal in frequency domain. On the other hand, the bandwidth of passband would also effect the resolution of SBPM. However, how it matters is more complicated. It depends on the noise composition. When the signal noise from SBPM probe is the main part of the

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noise of the measurement system, it is obviously that a narrow band around the peak is optimal. However, if the noise is mainly derived from electronic noise, the electronic front-end design needs to be taken into consideration.

In this situation, if there is no more than filter and ADC in the electronics front-end, the power of the noise changes little. It means that the wider the bandwidth, the larger the signal to noise ratio. However, as the bandwidth changes, the signal waveform may be following form in the Figure 3.

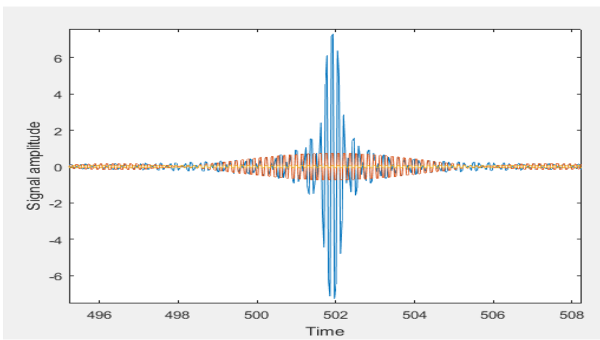

Figure 3: Simulation results of signal waveform while bandwidth changing.

It can be seen that as the bandwidth is gradually reduced, the peak value of the signal is continuously reduced, and the time of the signal is gradually lengthened. For an integrated DBPM system, this means that an amplifier may need to be introduced (Figure 4). On the other hand, too narrow a signal may also result in too little measurable data, resulting in reduced resolution. The impact of this factor needs to be analyzed in combination with specific situations [6].

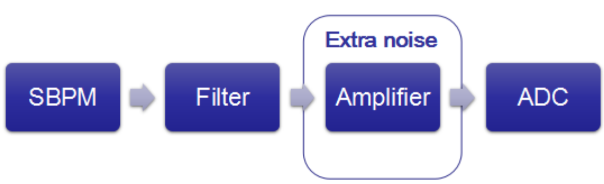

Figure 4: Simple block diagram.

EXPERIMENTAL COMPARISON

Signal Peak Shift

The signal used in the experiment came from the SBPM in SXFEL. According to the specific experimental parameter settings, the signal was filtered by filter and finally collected by a 2.5 GHz sampling rate oscilloscope. Figure 5 shows a set of signals that were directly measured without filter.

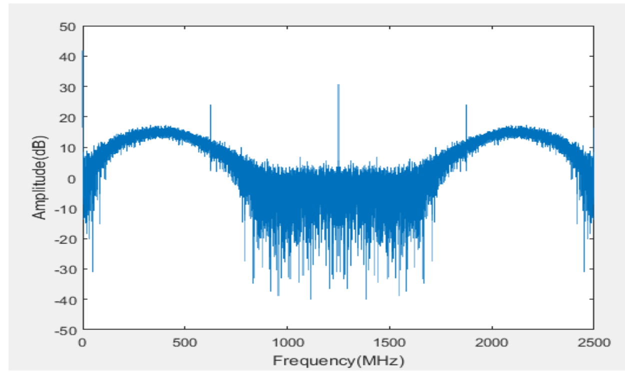

Figure 5: Spectrum when sampling rate is 2.5 GHz (Self-contained 2.5 GHz filter in the oscilloscope).

This situation is more closer to the simulations in the Figure 2 rather than that under ideal condition, which indicated that The ADC does cause the movement of the signal peak.

In order to more comprehensively compare simulation data with experimental data, multiple sets of filtering schemes are provided. Since the passive filters are selected as the experimental device, the passband of the filter is not selectable to some extent. So we can only experiment with existing conditions. The filters used in the experiments are shown in the table below.

Table 1: Filter Passband Schemes used in Experiments

Num.	Passband start frequency (MHz)	Passband end frequency (MHz)	Vpp (V)
1	0	94	0.7
2	0	400	2.0
3	0	560	3.2
4	0	700	3.1
5	450	550	1.2
6	250	560	1.6
7	250	650	1.8

Using the simulation data at the 2.5 GHz sampling rate in Figure 2, we were able to obtain the relative values of the signal power fanned by SBPM under different passbands. Comparing this with the actual experimental measured data, it is possible to define whether there is a change of the signal distribution in the frequency domain compared with that under ideal condition. The resulting contrast image is shown in Figure 6. The abscissa indicates the signal power level under the filtering scheme in the simulation, and the ordinate indicates the SINAD of signals measured.

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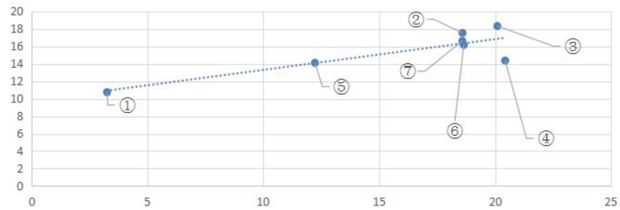

Figure 6: Comparison of simulation data and experimental results.

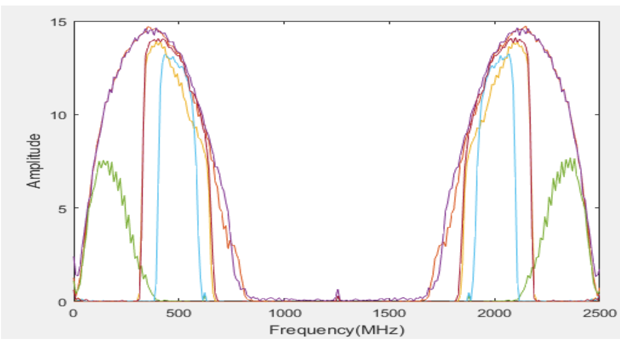

Figure 7: Spectrum of experimental data. In order to reduce the number of data points on the abscissa to simplify the graph, the data on the ordinate is transformed, which made it without unit.

Except for the fourth set of data, the other data matched the simulation results well. As can be seen from Figure 7, the noise on the stopbands of the fourth set is significantly larger than the other groups. And from the results, the experimental data is more different from the data under ideal conditions. So it can be qualitatively said that the preliminary experimental results support the simulation data.

Influence of Bandwidth

As shown in Figure 5, the noise introduced by the SBPM is not the main part in the experiment. Therefore, in the actual selection, a wider passband may be a better choice until the resulting electronic noise affects the system measurement accuracy.

However, the range of the ADC is limited, which brings the amplifier into the DBPM, introducing a new influencing factors. Due to the limitations of experimental conditions, the amplifier was not used in the experiment. Instead, the effects of the amplifier were gotten by data simulation. In Table 1, the peak-to-peak values of the signals in different passbands were listed, and 2V was selected as a suitable range of ADC. Assuming the noise of the amplifier is 6.5nV/rtHz and the noise is all electronics noise, the simulation result could be gotten based on the experimental data, which is shown in Figure 8.

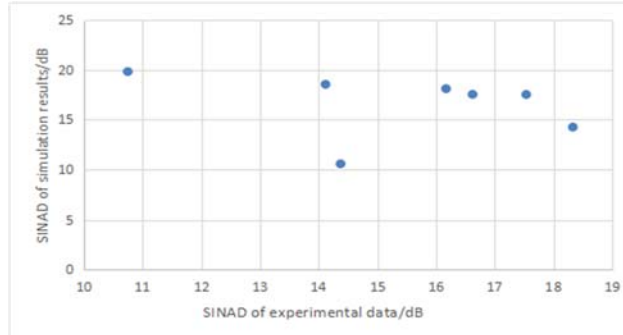

Figure 8: Comparison of experimental data and simulation results of SINAD.

Unlike previous conclusions, narrower bandwidth is better under the influence of electronic factors. This is because of the effects of the ADC. However, when the bandwidth is too small, the noise of the SBPM will be too large, as shown in Figure 9. Therefore, the optimal value of bandwidth needs to consider the influence of multiple factors.

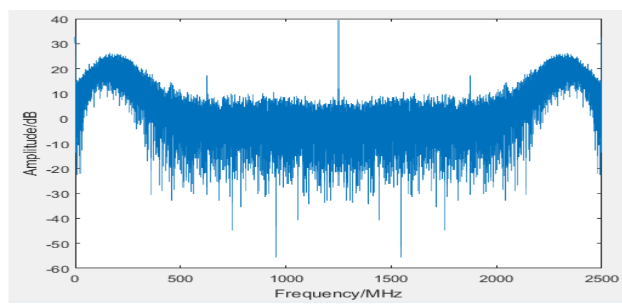

Figure 9: Spectrum of the first set of experiment.

FURTHER RESEARCH

The further research will focus on the experimental part. We would build an integrated measurement platform with FPGA as the core, in order to maximize the experimental verification. Active filtering schemes will also be considered in order to measure the effects of passbands on the measured signals.

CONCLUSION

In this paper, we have simulated and measured the accuracy of the SBPM measurement system around the influence of sampling rate and passband selection. The research mainly focuses on the movement of the signal peak and the influence of the bandwidth on the accuracy of the measurement system, and some experimental results are obtained.

The long-term goal of this research is to establish a simulation and evaluation system, so that designer could filter out the optimal parameter setting in different situations.

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