Study on Influence of Noise on Nuclear Pulse Trapezoidal Shaping

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Abstract. Because real nuclear pulses contain some noises, they are not ideal exponential pulses. These noises have influence on trapezoidal shaping and energy resolution. In this paper, influence of noise on nuclear pulse trapezoidal shaping is studied. The relationship between influence of shaping error and width of trapezoidal shaping is analyzed. The research shows that trapezoidal shaping can suppress noise strongly. Both increasing whole width and decreasing top-line width of trapezoidal pulses can suppress noise further. Trapezoidal shaping can improve energy resolution, so it is very useful and can be widely used in spectrometer.

1. Introduction
Charge sensitive preamplifier outputs exponential nuclear pulses. Because the peaks of these exponential pulses are sharp, when these pulses are digitized, the maximum values of the pulses are not easy to acquire accurately. Exponential pulses are often shaped to other waveform. After pulse shaping, the top of the shaped pulses will be flatter, and the peak value can be acquired more accurately. Exponential pulses are often shaped to other waveform. Trapezoidal shaping has some merits, such as pile-up rejection, high integration, anti-inference, ballistic deficit compensation, so it is used in spectrometer more and more in recent years\cite{1}. Trapezoidal shaping is one of the most important ways of nuclear pulse digital shaping. Through trapezoidal shaping, exponential nuclear pulses will be shaped to trapezoid shaped pulses and the energy spectrum can be measure accurately. However, the real nuclear pulses output from detector of energy spectrometer are not ideal exponential shaped ones, they contain noises. What is the influence of noises on trapezoidal shaping, and how to reduce the influence? These questions are analyzed as follows.

2. Influence of noises on nuclear pulse trapezoidal shaping

2.1. Noises in nuclear pulse
Because of power source noise, electromagnetic interference, electronic component precision, etc., nuclear pulse signals contain noises more or less. A measured nuclear pulse that contains noises is shown as Figure 1. These noises are usually high-frequency interference. If power source and amplifier are designed poorly, the noises may be more serious.
2.2. Trapezoidal shaping of exponential pulses with no noises

Preamplifier of spectrometer is mainly composed of RC circuit. The nuclear pulses are generated through RC circuit charging and discharging. The waveform of the nuclear pulses is exponential. If the radiation dose rate is high, the pulses will pile up. The pile-up nuclear pulses are shown in Figure 2. In this figure, the latter pulses will overlap the former ones.

2.3. Trapezoidal shaping of exponential pulses with noises

According to the former analysis, ideal exponential pulses can be shaped to ideal trapezoidal ones. If the exponential pulses contain noises, how do the shaped pulses change? Exponential pulses that contain noises are shown in Figure 4. The pulses can be thought of as a signal that is composed of ideal exponential pulses and white Gaussian noises.
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Figure 4. Exponential pulses that contain white Gaussian noises.
When these pulses which contain white Gaussian noises are shaped, they can be shaped to the pulses that are shown in Figure 5.

Figure 5. Pulses shaped from exponential pulses that contain white Gaussian noises.
As can be seen from Figure 5, the noises of trapezoidal pulses in Figure 5 are much lower than that in Figure 4. The result shows that trapezoidal shaping can suppress noises in the signal. As can be seen from the above analysis, trapezoidal shaping can improve the resolution of the spectrometer greatly.

Trapezoidal shaping is implemented through convolution of two vectors. The essence of the convolution is weighted average. Through this weighted average, the noises will be suppressed greatly.

2.4. Influence of shaping width
According to Figure 5, the width of the trapezoidal shaping is 100 points. That is to say, the trapezoidal pulses are convoluted through convolution of 100 points.
If the width is decreased to 25 points, the shaped trapezoidal pulses are shown as Figure 6.

Figure 6. Trapezoidal shaping of 25 points width.
According to Figure 6, the noises in the trapezoidal pulses are higher than that in Figure 5. If the shaping width is narrower, weighted average with fewer points of the exponential pulses will cause higher noises, and the amplitude acquisition will be more inaccurate. The wider the trapezoidal shaping width is, the lower the noise will be in shaped pulses. So a conclusion can be drawn that increasing the width of trapezoidal shaping can suppress the noises further.
However, increasing the width of trapezoidal shaping will consume more resource of the electronic system. Moreover, this operation will lead to more pulses pile-up when radiation dose rate is high. So
the shaping width can not be too wide. It depends on the requirements of pulses count rate and energy resolution.

If the whole width of the trapezoidal pulse dose not change, but the top-line width is different, the noises of shaped pulses will not be equal either. The trapezoidal shaping with different top-line width is shown in Figure 5 and Figure 7 contrastively. The top-line width of trapezoidal pulse in Figure 5 is narrower than that in Figure 7, and the noises of shaped pulse in Figure 5 are much lower than that in Figure 7.

![Figure 7. Trapezoidal shaping with wider top-line.](image)

From the above analysis, another conclusion can be drawn. To same whole width of trapezoidal shaping, the narrower the top-line is, the lower noises will be in shaped pulses.

If the shaped trapezoidal pulses in Figure 7 are smoothed through a few pulse points, the noises will descend too. The smoothing will lead to decreasing of top-line width and increasing of bottom-line width. The essence is same as actions of increasing whole width and decreasing top-line width of trapezoidal shaping. So noises are suppressed.

According to the above contrastive measurements, both wider whole width and narrower top-line of trapezoidal shaping are of advantage to decreasing noises in shaped pulses.

3. Conclusions

According to the above analysis and contrastive experiments, the following conclusions can be drawn. Firstly, noises can be suppressed through trapezoidal shaping, and trapezoidal shaping can improve energy resolution of spectrometer. Secondly, the wider the trapezoidal shaping width is, the more the noises are suppressed. Thirdly, the narrower the top-line is, the lower the noises will be. Finally, increasing trapezoidal shaping width will consume more electronic resource and lead to more pulses pile-up when radiation dose rate is high, so the width of trapezoidal shaping depends on the requirements of pulses count rate and energy resolution. In general, trapezoidal shaping can improve energy resolution, so it is very useful in spectrometer.

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