Frequency Calibration Settings of FFT Spectrogram

Yunqi Gao¹*, Shuai Liu¹, Dehui Qi², Guang Yang³ and Yaning Cui²

¹College of information engineering, North China University of science and technology, Tangshan, China
²College of metallurgy and energy, North China University of science and technology, Tangshan, China
³Metal Material Engineering, College of metallurgy and energy, North China University of science and technology, Tangshan, China

*Corresponding author e-mail: 2972289460@qq.com

Abstract. This article mainly elaborated in the field of digital signal processing in, discrete signal do N point FFT transform, the frequency spectrum diagram shaft calibration set problem, researchers usually tend to be equal to frequency axis, but this may lead to frequency before and after the inconsistent problem, this article from the Angle of the sampling frequency and the odd-even N aspects carries on the analysis, get when the N is an even number shall be on the basis of the original minus $f_s/2$, when N is odd, should be on the basis of the original minus the $((N-1) \times f_s)/2N$ through such method can properly set spectrum frequency scale.

1. Introduction

FFT is an important part of digital information processing technology [1-3]. The reason why FFT is proposed is that the development of large scale integrated circuits [4] enables the Fourier transform to operate on the computer. After FFT transformation [3, 5], it can be transformed from time domain to frequency domain. Therefore, the correct acquisition of spectrum map is the first step in spectral analysis [6], and it is also an extremely important step in FFT transformation. Because some negligence may lead to some errors in the actual operation of the spectrum. When discrete signals are converted to N-point FFT, there may be a difference in the frequency spectrum before and after the transformation. Actual operators usually divide the entire frequency axis [7] into N-points to set the scale, but only when N is odd and only positive frequency is considered, it can be done in many cases. It is necessary to reset the frequency scale. This paper will analyze the setting and conditions of the frequency scale from a specific example.

2. Setting of FFT Frequency Scale

2.1. Problem elicited

When we select any signal for FFT transformation, we often encounter changes in the frequency of the signal before and after transformation, such as choosing the cosine function, which is the most common function for FFT transformation, assuming the cosine function, $f = 30\text{Hz}$, sampling frequency $f_s = 100\text{Hz}$, Signal length $N = 128$. 

---

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
After FFT transformation, the amplitude-frequency characteristic curve is shown in Fig. 1:

![Amplitude-Frequency Characteristic Curve](image)

**Figure 1.** Amplitude-Frequency Characteristic Curve of Equal Frequency

The problem with Fig 1 is why I set it up, but after FFT transformation, it is, after consulting, it was found that the setting of frequency scale was wrong.

### 2.2. Reasons and Solutions

The reason for this is that when $N$ is even and $N$ is odd, the setting method of frequency scale [8] is slightly different, as shown in Fig 2. In this paper, we first discuss the case that $N$ is even, and then discuss the case that $N$ is odd.

#### (1) Frequency scale setting method when $N$ is even

The signal length is $N$, Sampling frequency [9] is $f_s$. From Nyquist sampling theorem after transformation, it can be seen that the frequency of the signal after transformation is between $-f_s/2$ and $f_s/2$, The frequency interval between the lines is

![Schematic diagram of frequency scale setting method](image)
\[ \Delta f = \frac{f_s}{N} = \frac{1}{NT_s} \]  \hspace{1cm} (1)

In style: \( T_s \) is Sampling period [9]. Frequency scale starts at 0, and the maximum frequency is \( f_s/2 \). The frequency scale can be set as shown in Fig 2.

\[ \text{freq} = (0 : N-1) \times \frac{f_s}{N} \] \hspace{1cm} (2)

Because the frequency scale given is \( 0, \Delta f, ..., f_s/2, ..., -\Delta f \), But in fact, there is no frequency component greater than \( f_s/2 \). Because the component larger than \( f_s/2 \) frequency is actually the component of negative frequency. In order to be able to give all the components from negative frequency to positive frequency, the frequency scale should be \( \text{freq} = (0 : N-1) \times \frac{f_s}{N} - \frac{f_s}{2} \) The frequency scale given here is: \( -f_s/2, -f_s/2 + \Delta f, ..., 0, \Delta f, ..., f_s/2 - \Delta f \), It does not include \( f_s/2 \).

If only positive frequencies are calculated, they can be expressed in the following two forms:

\[ \text{freq} = (0 : N-1) \times \frac{f_s}{N} \]

\[ \text{freq} = (0 : N) \times \frac{f_s}{N} \]

If only positive frequencies are calculated, they can be expressed in the following two forms:

\[ \text{freq} = (0 : N-1) \times \frac{f_s}{N} \]

\[ \text{freq} = (0 : N) \times \frac{f_s}{N} \]

If linspace [10] is used to set the frequency scale, The variable F is assigned to set the positive and negative frequencies after dividing it into N parts equally between \( x_i \) and \( x_j \):

\[ \text{freq} = \text{linspace}(0, f_s, N+1) - f_s / 2 \]

\[ \text{freq} = \text{Freq}(1, N) \]

If only positive frequency is set:

\[ \text{freq} = \text{linspace}(0, f_s / 2, N/2 + 1) \]

When N is odd, Reference to 1-2 (b) is similar to the idea and the even number mentioned above, and will not be repeated here. Give only conclusions. Positive and negative frequencies:

\[ \text{freq} = \frac{(0 : N-1) \times f_s}{N} - \frac{(N-1) \times f_s}{2N} \]

Only positive frequency:
If linspace [10] is used to set the frequency scale:

\[ freq = \frac{0 : (N - 1) / 2}{f_s / N} \]

If only the positive frequency part is set:

\[ freq = \frac{F}{Freq(1 : N)} \]

\[ freq = \frac{0, f_s / 2 - f_s / N / 2, (N + 1) / 2}{\text{linspace}(0, f_s / 2, f_s / N / 2)} \]

F = linspace (0, 64, 64) and freq= (0: N/2)*fs/N are used in the above implementation method.

Run the code and get the following Fig 3:

Figure 3. Amplitude-Frequency Characteristic Curve Corrected by Frequency Scale

The amplitude-frequency characteristic curve in Fig. 3 is consistent with the original signal frequency.

3. Conclusion

In the process of spectrum analysis and FFT transformation, it is necessary to have a general understanding of the initial signal's sampling period, sampling frequency, the parity of N and the frequency band needed in practical engineering. The selection of parity of signal length N may have an impact on the setting of frequency axis calibration, which directly results in frequency errors before and after transformation. Understanding the basic information such as period and sampling frequency can deal with various problems in the actual operation process and analyze its rationality.

References

[1] John G. Proakis, Dimitris G. Manolakis. Digital Signal Processing [M]. Translated by Fang Yanmei and Liu Yongqing. Beijing: Electronic Industry Press, 2006: 282-295
[2] John G. Proakis, Dimitris G. Manolakis. Digital Signal Processing [M]. Translated by Fang Yanmei and Liu Yongqing. Beijing: Electronic Industry Press, 2006: 282-295
[3] Gao Xiquan, Ding Yumei. Digital Signal Processing (Third Edition) [M]. Xi'an: Xi'an University of Electronic Science and Technology Press, 2008: 95-105
[4] Dawn, Huang Ru. Large Scale Integrated Circuit Devices and Integrated Technology in Post-Moore Era [J]. Chinese Science: Information Science, 2018, 48 (08): 963-977.

[5] Towards an order-N DFT method [J]. Theoretical Chemistry Accounts: Theory, Computation and Modeling (Theoretica Chimica Acta), 1998, 99 (6): 391-403.

[6] Zeng Shangliang, Shenhua, Yu Zhenli. Signal FFT spectrum analysis and display based on MATLAB system [J]. Science and Technology Bulletin, 2000, 16 (4).

[7] Yu Fei, Wu Wenquan. Error analysis based on FFT frequency measurement [J]. Electronic measurement technology, 2004 (6): 3-3.

[8] Bo Yongbo, Chen Yi. A method of FFT frequency correction based on DSP [J]. Journal of Inner Mongolia Agricultural University (Natural Science Edition), 2011, 32 (4): 274-277.

[9] Hao Jianmin. Development of Sampling Theorem: Research on Sampling Theorem and Nyquist Criterion. Part I [J]. Missile and Space Launch Technology, 1997 (3): 41-49.

[10] K Zhang Zhiyong. Proficient in MATLAB6.5 [M]. Beijing: Beijing University of Aeronautics and Astronautics Press, 2003