Analysis of DC offset Influence on Transient Signal

Y Wang, J Lin and G H Zhou

Key Lab of Geo-Exploration and Instrumentation (Jilin Univ.), Ministry of Education, Chang Chun, 130061, China

E-mail: wyan99@jlu.edu.cn

Abstract. Based on the characteristic of transient signal and the principle of floating-point data acquisition circuit, the influences of DC offset on transient signal are analyzed. And the conclusion can be obtained that the singularity and saturation distortions in transient signals can be produced by DC offset through the detailed principle analysis, the limits calculation of DC offset, and waveform simulation while the DC offset is present in floating-point amplifier circuit of floating-point data acquisition circuit. At the same time, the distributions of distortions in those conditions that the single and several theoretic transient signals and also in actual measured transient signal are compared and discussed. Finally, the corresponding solutions are given according to the main factors which produce the waveform distortion. In a word, this research can provide useful references for the adjustment of floating-point receiver and the analysis of waveform distortion.

1. Introduction

The transient electromagnetic method (TEM) is one important geophysical exploration method. The transient signal received is a wide-bandwidth time-domain signal whose frequency is from 0Hz to N KHz (N integer). And its amplitude varies very large which can be as small as N μV or even less, and also can be as large as N V or even bigger. The features of signal attenuation at different period are different which has fast attenuation and big amplitude at early period and slow and low at mid and late periods. This kind of feature can be used to determine qualitatively the characteristics of the geological bodies by analyzing, comparing and computing all the measured points. Therefore, any interference in the receiver may result in the distortion of the signal, and lower the data quality and the precision of the interpretation. However the DC offset in any chip, the asymmetry of the bipolar supply power and output power are unavoidably present, and then what influence on the transient signal will be brought by DC offset since 0Hz should be received in the circuit?

2. Key principle of the receiver

In order to acquire the transient signal without distortion in a large time-domain, high enough sampling rate and large dynamic range should be guaranteed. Because 24bit A/D has lower sampling rate and high price in its early days, the floating-point data acquisition are usually used to realize high precision and sampling rate of receiver in almost the seismic and electromagnetic methods.

Receiver consists of network matching circuit, pre-subsection amplifier, low-pass filter, floating-point data acquisition and main control unit PC104.

Floating-point data acquisition comprises instantaneous floating-point (IFP) and A/D converter. Here, IFP realizes different inputs with different gains, and this floating gain is called “exponent”, the A/D output “mantissa”, so the point measured can be expressed by “exponent” and “mantissa”. In this
system, if the conversion digits are \( N \), and the range of floating-point gains are \( K^0, K^1, \ldots, K^L \), and then the resolution will be as equation (2.1):

\[
\frac{1}{K^2 (2^N - 1)}
\] (2.1)

Given \( K=2 \), and then the dynamic range is as equation (2.2):

\[
DR = 20 \log_{10} 2^{L+N} = 6.02(L + N)(dB)
\] (2.2)

Figure 1 gives the floating-point data acquisition diagram. Here the “exponent” is produced by high-speed 8bit AD7821 and coding circuit, and the detailed positive values of input signal and their corresponding gains can be obtained in table 1. Here, the resolution of AD7821 decides the varied step of signal. And IFP adopts the combination of PGA202 and PGA203 from BB Company realizing gain from 1 to 100. At the same time, limiter is added in the IFP in order to ensure the output signal will not extend the input limited range \( \pm 2.5V \) of A/D. At last, 16bit AD7805 is used to produce the “mantissa”. And then the \( L \) value can be calculated as 10 by the gains in IFP and preamplifier, so from equation (2.2) the dynamic range is obtained as 156dB.

Figure 1. Floating-point acquisition circuit.

### Table 1. The relation of positive input ranges, gains and the limited values of offset in floating-point circuit.

| \( V_{in}(V) \) | 0,0.0195 | 0.0195,0.03125 | 0.03125,0.0625 | 0.0625,0.125 | 0.125,0.25 |
|-----------------|-----------|----------------|----------------|-------------|------------|
| Gain            | 100       | 80             | 40             | 20          | 10         |
| \( V_{off}(V) \) | 0.025,0.0055 | 0.01175~0) | 0.03125~0) | 0.0625~0) | 0.125~0 |

| \( V_{in}(V) \) | 0.25,0.3125 | 0.3125,0.625 | 0.625,1.25 | 1.25,2.5 |
|-----------------|-------------|--------------|------------|-----------|
| Gain            | 8           | 4            | 2          | 1         |
| \( V_{off}(V) \) | 0.0625~0) | 0.3125~0) | 0.625~0) | 1.25~0 |
removed by bipolar accumulation technique. Therefore, the limited values of DC offset are calculated and shown in table 1.

If the transmitter moment and the effective area of receiver are given, transient electromagnetic induction of uniform earth in any time can be simulated, as the real and bold line shown in figure 2 (time from 0.5ms to 1.5ms, amplitude from 0.0019381V to 0.030211V, and time interval 5μs). If this signal is taken as the input of IFP and this circuit has an offset as 0.01V, and then the signal influenced by DC offset can be gotten as the real and fine line in figure 2, here in order to make the distortion notable, the offset value in distortion points is not removed. Obviously, the wave is distorted, and the distortion appears in two forms, one is singularity point and the other is saturation. The singularity is the same as those brought by ambient sferics noise, and then are those singularities produced by two different reasons can not be distinguished? No, when we do with the signal in normal process and find that the direction of distortions is exactly opposite, shown in figure 2 as the dashed. That is, if you see a signal with down singularity, and this distortion may be caused by offset.

![Figure 2](image1.png)  
*Figure 2. Theoretic transient signals for uniform half-space. Real and fine line stands for the line which is affected by DC offset but the distortion points having the DC offset value; real and bold line stands for the line which is not affected by DC offset; dashed line affected by DC offset having removed offset value.*

![Figure 3](image2.png)  
*Figure 3. Theoretic transient signals for sphere object. Dashed line stands for the line without the DC offset influence, and real line stands for with DC offset influence.*

According to the characteristics of transient signal that fast decay and large skipped amplitude in early period, and slow decay and variation of amplitude in late period, the result that the number of affected points may be different in theory can be obtained, in which one point as the singularity form often exists in early time and several points as saturation form occurs. However this does not stands for the singularity only exists in early period and saturation only exists in moderate and late period, such as it is appear in mid time in figure 2. This is because transient signal reflects the characteristic of underground objects, such as size conductivity and depth etc. and then the amplitude and decay rate are different of measured points over different objects, and then the distortion distribution will be different in different curves. In addition, the experiment parameters in transmitter and receiver and configuration (transmitting current, transmitting moment, receiver area, in-loop or coincide loop etc.) can also affect the distribution of distortion. Simulate again in conductive sphere instead of uniform half-space as shown in figure 3. Singularity and saturation are also existed but the distortion begins from early time, furthermore, the amplitudes where distortion occurs are around the change of “exponent”.
In theory, the forms of distorted curve are what described above, but because of the big geologic, sferics and systematic noise, the form always occur as singularity rather than saturation while the late datum are seriously affected. At the same time, the singularities are always mixed with the noise, and can not be noticed by the observer. Note that, although the curve has been distorted before A/D, this kind of distortion can not be acquired definitely by A/D because of the resolution of A/D. The common distorted curve in field is shown in Figure 4, and this kind of distortion is usually considered the effect by big sferics noise, but now we know DC offset is another factor.

And then where the offset comes from? In the IFP, the maximum value of PGA202 or PGA203 is 0.013V (25°C, G=1) in its specification, and we know this value will vary with the change of gain, temperature, and time. In addition, the supply power for IFP are ±12V by DC-DC, and the common DC-DC has the precision of ±1%, thus the output is easily dissymmetric especially when the load affects. Table 2 gives the actual DC offset values of the measured parameters in IFP part, and from this table we know the supply power has big offset.

| DC offset values(V) | +5V | -5V | +12V | -12V | PGA202 | PGA203 |
|---------------------|-----|-----|------|------|--------|--------|
| 0.029               | 0.065 | 0.082 | 0.107 | 0.012 | 0.004  |

4. Methods to lower the DC offset

According to the above discussion, the lower resolution in “exponent” production circuit causes that the existence of bigger DC offset will bring the distortion in the transient signal. Here, several solutions are listed hereunder based on the above reason.

4.1. Minimum of the DC offset

For the bought chips, the first thing is to find whether the DC offset is beyond the specification. If yes, using the DC offset adjustment method to adjust it. For the chip PGA202/203, you can use the following circuit figure 4 to adjust them. And then, try your best to lower the asymmetry in DC-DC power output especially in the condition the external circuit is loaded. If the circuit has low request for the current, the linear supply chip can be used.

4.2. Improvement of the “exponent” circuit

The proper reduction of the gains in coding can lower the probability of distortion. However, at the same time this method will also reduce the system resolution and dynamic range which is what we do...
not expect. If another AD with high-resolution is used and recode, then this circuit will have lower request for DC offset, and the distortion also can be reduced.

4.3. Improvement of the data acquisition
At present, many companies have recommended their high sampling rate 24bit A/D, such as CS5361 and AD7762. If a suitable AD chip which can be used for transient signal acquisition, then the distortion of signal can be reduced largely, at the same time, many questions may be also solved, such as cost, size, noise, complexity, and reliability etc.

5. Conclusion
In the transient electromagnetic receiver realized by floating-point amplifier technique, the DC offset in this kind of “exponent” production circuit with low resolution can produce the distortion in transient signals easily. And the distortion has two forms that singularity and saturation. When offset is the same, the distribution in different transient signals relates with the measured objects and measurement parameters etc. In the actual distortion, saturation is seldom present, and the singularity always exists. So we should pay attention to the offset, and in order to avoid offset causing this distortion, some improvement in receiver should be done.

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