SUPER-LOW FREQUENCY ELECTROMAGNETIC NOISE PROCESSING SYSTEM BASED ON ADAPTIVE FILTERING

Shanshan Zhao*, Nan Wang, Li Chen, Jian Hui, Chengye Zhang, Qiming Qin*

Institute of Remote Sensing and Geographic Information System, Peking University, Beijing, 100871, China

ABSTRACT

Super Low Frequency electromagnetic prospecting methods, based on natural source, have seen an increasingly trend in geophysical applications. It is known that natural source electromagnetic signal is weak, and how to extract useful information has drew great attention worldwide. In this paper, we designed a signal processing method, an adaptive filter, to filter out the strong power frequency interference at 50Hz and its harmonics mixed in the output signal from induction magnetic sensors. As the output could change with the input, the adaptive filter system is related to its input signal closely and specifically. Because of its stronger adaptability and better filtering performance, the adaptive filter showed good effectiveness.

Index Terms—Super Low Frequency, electromagnetic, power frequency, adaptive filter

1. INTRODUCTION

As a new remote sensing technique, the passive Super Low Frequency (SLF) detection utilizes the natural alternating electromagnetic field source in a frequency range from 3 Hz to 3000 Hz to explore the subsurface electrical structure, and it has been effectively used in oil and gas exploration, and geothermal energy[1]. However, the electromagnetic signal is so weak that it is easily interfered by various noise inevitably during the process of the data acquisition[2], with which the results would be severely deteriorated. The noise could be sorted as source noise, geologic noise, human noise and random noise[2]. The power frequency noise, a kind of human noise, has the characteristics of morphological rules, high amplitude, and can be clearly observed as the sine wave interference at frequency of 50 Hz and its harmonics in the time series. Thus, useful signal is very difficult to identify or almost completely submerged beneath this kind of interference. In order to acquire the high quality data, the noise components in the signal must be suppressed with effective methods. The adaptive filtering is developed from a series of linear filters like wiener filter and kalman filter[3]. Because of its stronger adaptability and better filtering performance, it has been widely used in communication, system identification, echo cancellation and the adaptive line enhancement, adaptive equalization, speech linear prediction and adaptive antenna array, and many other fields[4-5]. Its coefficient could be adjusted automatically according to the input signal. The results show that the noise could be reduced by 38dB. It is effective in the suppression of power frequency noise.

2. METHODS AND DATA PROCESSING

2.1 The diagram of the system

The Super-Low Frequency Electromagnetic

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the sensor’s output signal, to confine the bandwidth and to convert the analog signal to digital signal. The digital part is a further step to deal with the noise. The adaptive filter is the main role that functions. With regards to the statistical properties of the unknown signal, the adaptive filtering system is a time-varying, nonlinear system, closely related to the characteristics of its input signal. The output would change as along with the input changes.

2.2 The adaptive filter

The adaptive filter is composed of the filter and the adaptive algorithm, as shown in figure 2. The filter structure is designed according to the processing functions; and the adaptive algorithm is used to adjust the filter coefficient. X (n) is the input signal at the time n in the time series. Y (n) is the output signal. D (n) is the reference signal or the desired signal. E (n) is the error signal, the difference between D(n) and Y(n).

*Figure 2. The schematic diagram of adaptive filter*

When adaptive filter is used to filter out the noise, the input signal should be the observed signal with the noise, and the reference signal should be the expected power frequency noise. So in the processing of SLF data, the X(n) represents the signal collected actually with the noise. Since we can simulate the power frequency noise, D(n) equals the expected noise. The iterative formulas as as follows:
\begin{align*}
y(k) &= \sum_{j=0}^{N} w_j(k)x_j(k) = \sum_{j=0}^{N} w_j(k)x_j(k - i) \\
e(k) &= d(k) - y(k) \\
w(k + 1) &= w(k) + 2 \mu e(k)x(k)
\end{align*}

During the actual application, the power frequency noise could be collected for some time prior to the data collecting period. Through the field investigation in the downtown area, the power frequency noise is mainly at the 50Hz, 100Hz and 150 Hz, and the amplitude is 10v, 4.5v, 1v respectively. So we get the reference signal. In the system, the FIR LMS adaptive filter is chosen as the stereotype to filter the SLF signal, as shown in figure 3. The parameters of the filter conclude maximum iterations, learning rate, filter order, and their values are 50, 0.1, 100, 0.5.

Figure 3. The structure of LMS Adaptive filter FIR

3. RESULTS AND CONCLUSION

After the processing of the adaptive filter designed, the useful signal is effectively extracted with the power frequency noise suppressed, as shown in figure 4.
Adaptive filtering systems are designed for catering to the natural electromagnetic environment, and it can also update its structure according to the statistical properties of the external sources, as well as achieving the minimum mean square error filter and anti-interference performance. When applied in the processing of the SLF electromagnetic signal, adaptive filter can filter out the intense noises effectively. Further studies will be focused on the accomplishment on the FPGA, so that it can be applied in the field investigation in real time.

4. REFERENCES


