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Research on EMI Noise Measurement Technology Based on Wavelet Analysis

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Abstract In this paper, an electromagnetic interference (EMI) noise measurement technique based on wavelet analysis is proposed to measure the electromagnetic radiation generated by the device. The technique uses the time-frequency localization characteristic of the wavelet transform, based on the threshold function. The filtering method divides the test signal by frequency filtering so that it can measure the electromagnetic interference of the equipment in the open field or with noise interference. Simulation and experimental results show that the technology can eliminate or attenuate noise better in the frequency range of 30 Hz ~ 1000 MHz.

Key words: Electromagnetic interference (EMI) measurement; wavelet analysis; frequency filtering; threshold function

0 Introduction

In today's society, with the continuous development of electronic information technology, electronic equipment is more and more widely used, and which contains many electronic components will produce electrostatic discharge, surge and other electromagnetic interference, seriously affecting people's work life, so quickly and accurately The electromagnetic radiation produced by the measuring device is an urgent problem to be solved. When the electromagnetic interference measurement of the equipment, due to the surrounding equipment or mobile communications, ionospheric radiation interference, the measured signal contains a lot of noise, so the current equipment for electromagnetic interference measurement in the dark room and other closed space or in the open space [1-5].

In this paper, an electromagnetic interference (EMI) noise measurement technique based on wavelet analysis is proposed to measure the electromagnetic radiation generated by the device. The technique uses the time-frequency localization characteristic of the wavelet transform, based on the threshold function filtering method. The frequency of the test signal is processed so that electromagnetic interference measurements can be made on the equipment in open spaces or with noise.

1 Wavelet analysis

Fourier transform can only analyze the signal in the frequency domain, and its resolution is fixed, so the analysis of non-stationary signal has limitations. Wavelet transform makes up for the shortcoming of Fourier transform, which can analyze the signal in the time domain and analyze the signal in the frequency domain, and also has good locality. Wavelet transform uses the different resolution to decompose the signal at different levels, thus extracting the transient phenomenon of the signal.

1.1 Wavelet transform

The wavelet transform is shown in equation (1).

$$\mathrm{WT}_x(a,\tau) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} x(t)\Psi^*\left(\frac{t-\tau}{a}\right)\mathrm{d}t, \quad a>0 \tag{1}$$

Ψ (t) is the wavelet function, and a is the scale of action, which makes the resolution increase with increasing frequency.

Because of Morlet wavelet processing signal real-time, so this article uses its wavelet transform, such as (2), (3).

$$\psi(t) = e^{-t^2/2} e^{i\omega_0 t} \tag{2}$$

$$\hat{\psi}(\omega) = \sqrt{2\pi} e^{-(\omega-\omega_0)^2/2} \tag{3}$$

Discrete wavelet functions are obtained by discrete wavelet transform, such as (4) and (5).

$$\psi_{j,k}(t) = 2^{j/2}\psi(2^j t - k) \tag{4}$$

$$W_f(j,k) = (f(t), \psi_{j,k}(t)) \tag{5}$$

1.2 Construction of threshold function

Since the energy of the useful signal is concentrated in the larger wavelet coefficients, the energy of

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the noise is distributed in the entire wavelet domain. After the wavelet decomposition, the energy amplitude of the signal is greater than the noise energy amplitude [6], so the principle of the threshold function. When the resolution is low, all the wavelet coefficients are preserved. When the resolution is high, the wavelet coefficients above the threshold are preserved by setting the threshold, and the reconstruction signal is reconstructed. The filtering method in wavelet transform can be divided into soft threshold denoising and hard threshold denoising [7]. Combined with the advantages of soft threshold de-noising signal continuity and the advantages of hard threshold noise reduction error [8], the two complement each other, construct a threshold function,

$$\left.\begin{aligned} &w_0(x) = \operatorname{sgn}(x)\left(|x| - \frac{b\lambda}{e^{((|x|-\lambda)/\lambda)}}\right), \quad |x| \geq \lambda \\ &w(x) = 0, \quad |x < \lambda| \\ &\lambda = \sqrt{2\log(N)}\sigma \end{aligned}\right\} \quad (6)$$

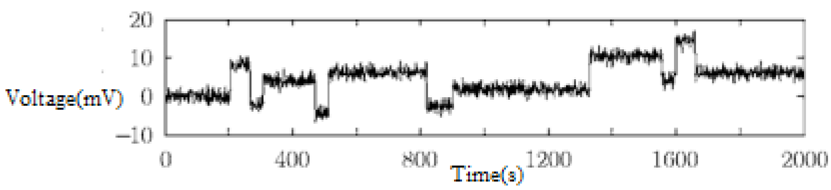
$$\frac{w(x)}{x} = 1 - \frac{b\lambda}{xe^{((x-\lambda)/\lambda)}} \quad (7)$$

When x> 0, the equation (6) becomes

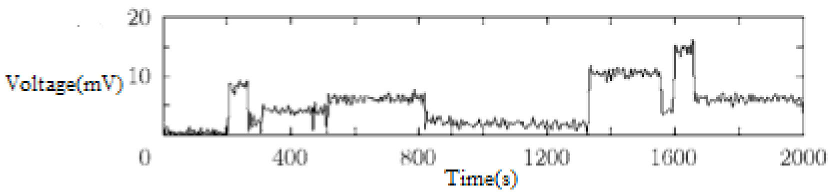
$$\frac{w(x)}{x} = 1 + \frac{b\lambda}{xe^{((-x-\lambda)/\lambda)}} \quad (8)$$

When x <0, equation (7) becomes

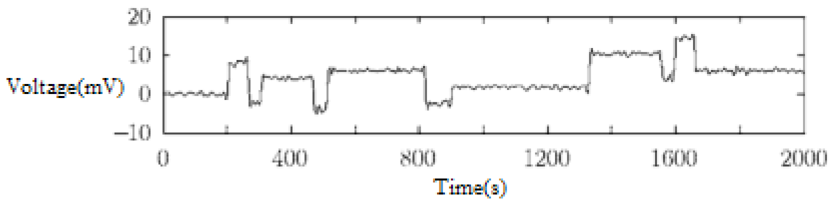
The traditional fourier transform cannot give a certain period of time the signal changes that cannot identify the signal mutation or transient phenomenon, the signal once the change will affect the entire spectrum. The wavelet transform can analyze the signal in time domain and frequency domain, and can reflect the local variation characteristics of the signal, especially for the analysis of the non-stationary signal. In MATLAB, respectively, the signal Fourier transform and wavelet transform, the comparison chart shown in Figure 1.



(A) Contains noise non-stationary signals



(B) De-noising based on Fourier analysis



(C) Noise reduction based on wavelet analysis

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Fig.1 Comparison of Fourier analysis and wavelet analysis filtering effect of nonstationary signals

Fig.1 Fourier analysis of non-stationary signal analysis and wavelet filtering effect comparison chart

It can be seen from Fig. 1 (a) that the useful signal is mainly concentrated in the low-frequency part and the noise is mainly concentrated in the high-frequency part. Since the Fourier transform cannot distinguish the high-frequency part and the noise of the useful signal, it can be seen from Fig. 1 (b) that the Fourier transform does not achieve better denoising effect. And the de-noising method based on wavelet analysis in Fig. 1 (c) achieves good effect and preserves the mutation information of the signal.

2 EMI measurement system

The schematic diagram of the system, as shown in Figure 2. Where s_1 [n] is the signal received by antenna 1, including the useful electromagnetic signal d [n] and ambient electromagnetic interference a_1 [n], a_2 [n] is the ambient electromagnetic signal received by antenna 2, e [n] is output signal, which in turn adjusts the filter coefficients as the input signal of the adaptive filter [9], and finally outputs the useful electromagnetic signal, and is referred to as d [n] because of the error.

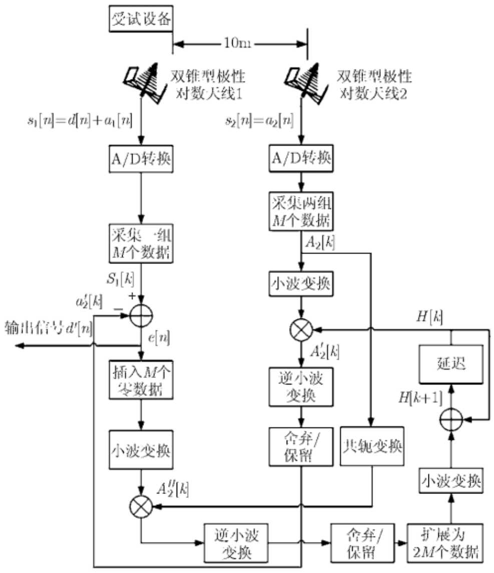
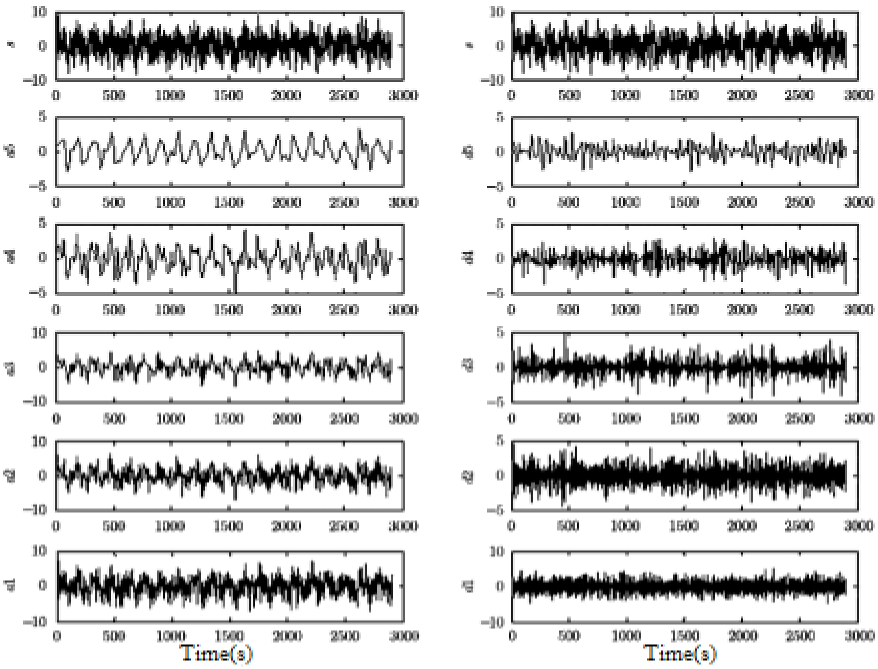


Figure 2 Block diagram of electromagnetic interference test based on wavelet transform

Fig.2 EMI block diagram of the test based on wavelet transform

2.1 Signal decomposition



(A) The low-frequency portion of the original signal (B) The high-frequency portion of the original signal

Through the wavelet transform on the analog / digital conversion of the signal decomposition, as shown in Figure 3.

Figure 3 High and low-frequency decomposition of the measured signal

Fig.3 The high-frequency measurement signal decomposition

It can be seen from the figure, the high-frequency part of the signal d1 layer, the amplified signal shown in Figure 3 (a) below. The d4 layer contains the intermediate frequency part of the signal, and a3 and a4 appear discontinuities in the middle due to the common expression of the intermediate frequency signal.

d4 layer of information is d3 layer to eliminate, it needs a1 ~ a3 layer of information to estimate the IF signal. From the a5 layer can be seen that the low-frequency part of the signal.

If the highest frequency is 1, the frequency band of each layer of the signal is

$a1$: 0−0.5, $d1$: 0.5−1;

$a2$: 0−0.25, $d2$: 0.25−0.5;

$a3$: 0−0.125, $d3$: 0.125−0.25;

$a4$: 0−0.0625, $d4$: 0.0625−0.125;

$a5$: 0−0.03125, $d5$: 0.03125−0.025;

Therefore, through the wavelet decomposition of the signal can be analyzed and processed.

2.2 Threshold filtering

In this paper, we use the threshold function proposed in Section 1.2 to filter the signal. The wavelet transform transforms the signal to identify the abrupt information in the nonstationary signal, and the electromagnetic interference in the surrounding environment is poorly correlated on the fine scale layer. Therefore, in order to enhance the energy of the signal at the abrupt point and suppress the interference energy, the adjacent fine Wavelet coefficients are multiplied, and the results are normalized to obtain the spatial shielding filter, and the new wavelet transform is obtained by multiplying it with the thinnest wavelet transform.

The two input signals are taken as the input of the threshold filter and the signal s [n] is translated (Phs) i = s (i + h) mod n, and the translated signal wavelet coefficients are compared with the corresponding threshold , Values below the threshold will be filtered. Since the Morlet wavelet used in this paper has translation invariance, the translation denoising does not change the original signal. The n-th cyclic translation of the signal wavelet denoising is as follows (9), (10), for the reverse translation, the Ave table is averaged.

$$T(s,(P_h)_{h\in H_n}) = \mathrm{Ave}_{h\in H_n} P_{-h}(\overline{T}(P_h s)) \quad (9)$$

$$H_n = \{h \mid 0 \le h \le n\} \quad (10)$$

2.3 Signal reconstruction

The reconstruction of the signal is the inverse of its decomposition, which can be obtained by iteration [10].

3 Simulation and experimental verification

3.1 Comparison of simulation results

In this paper, the switching power supply as an example of the proposed method to verify the method. Figure 4 for the system designed in this paper on the measured interference with the environment of the switching power supply mixed electromagnetic signal, the filter after the actual switching power supply electromagnetic signal. Figure 5 for the wavelet before and after the comparison chart, that is, the dotted line indicates the filtered electromagnetic radiation signal, the solid line represents the mixed signal received by the antenna 1. By comparing Figs. 4 and 5, it can be found that the interference between FM, GSM, 100 kHz ~ 200 MHz and 400 ~ 500 MHz is completely filtered, and the signal-to-noise ratio is increased by 20 ~ 30 dB. In addition, the signal-to-noise ratio of the fixed signal is increased by 40 dB, 210 to 230 MHz, and the signal-to-noise ratio in the band 575 to 590 MHz and 680 to 760 MHz is increased by 10 dB. Not only has the frequency of the surrounding areas of electromagnetic interference noise attenuation, while also preserving the measured equipment, the radiation signaled spectrum itself.

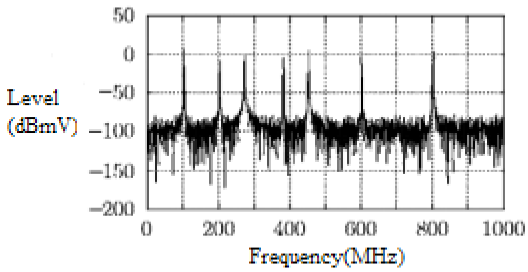


Figure 4 Switching power supply actual electromagnetic interference signal spectrum

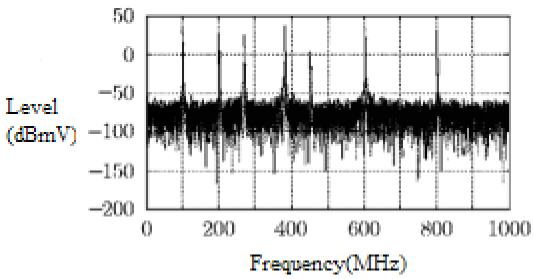


Figure 5 With the ambient noise mixed signal spectrum

3.2 Comparison of experimental measurements

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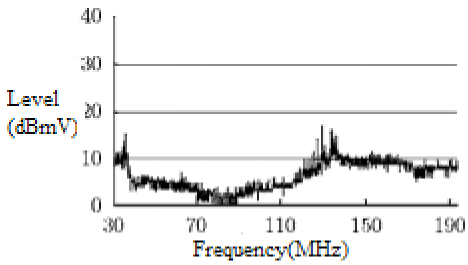
In order to verify the application of the system designed in this paper, the actual electromagnetic interference measurement of some kind of equipment will be used, and Fig. 6 and Fig. 7 are the comparison chart.



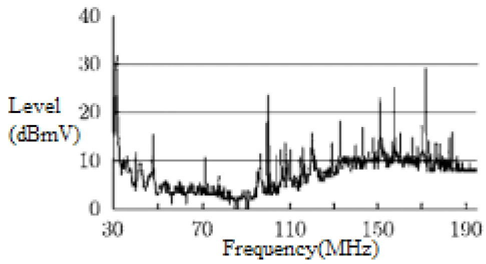


Figure 6 Measurement results before treatment Figure 7 Measurement results after treatment

It can be seen from the comparison of two graphs that the threshold filter EMI noise measurement method based on wavelet analysis can effectively remove the environmental interference signal and keep the electromagnetic signal of the tested equipment. Among them, 30 ~ 100 MHz electronic instrument interference signal and 100 ~ 180 MHz broadcast interference signal are successfully filtered.

4 Conclusion

Aiming at the problem that the electromagnetic radiation generated by the equipment is difficult to be measured at present, this paper proposes a threshold filtering EMI noise measurement technique based on wavelet analysis, which can quickly and effectively filter out the environmental interference signal in a wide range, And is particularly suitable for non-stationary signal filtering. Simulation and experimental results show that the system designed in this paper can eliminate or attenuate the noise in the frequency range of 30 Hz ~ 1000 MHz, and has certain engineering application value.

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