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RESEARCHONCONDUCTEDEMINOISEDIAGNOSISMETHODBASEDONINFOMAXWTALGORITHM

Research on Conducted EMI Noise Diagnosis Method based on Infomax-WT Algorithm

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Abstract- In this paper, a diagnostic method of conducted EMI noise based on the Infomax-WT algorithm is proposed. Using collected conductive EMI noise samples, several independent noise signals are separated by Infomax. Each noise signal is subjected to wavelet transform to obtain the time-frequency diagram of each noise signal. The noise source is determined according to the frequency characteristic obtained by the time-frequency chart. Finally.

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I. Introduction

At present, the research on conducted electromagnetic interference of electronic equipment mostly focuses on the analysis of the propagation path of conducted electromagnetic interference and the design of EMI filters and other suppression measures. In contrast the research on the diagnosis of interference sources inside electronic equipment is less. In [1], a method of conducted noise diagnosis based on blind source separation was proposed. Literature [2-3] applies the Infomax algorithm to the denoising of EEG signals and proposes an online Infomax algorithm based on the traditional Infomax algorithm, which can effectively eliminate the noise in EEG signals. Literature [4-5] proposed a wavelet transform local feature extraction method to extract the feature of rolling bearing faults, which can effectively diagnose the cause of bearing faults. In this paper, combined with the wavelet transform time-frequency analysis theory, the Infomax-WT algorithm is proposed. The Infomax-WT algorithm is applied to the diagnosis of conducted electromagnetic interference noise, and its feasibility is verified by simulation experiments.

II. Diagnosis Method of Conducted EMI Noise based on Infomax-WT Algorithm

a) Wavelet transform

Compared with the Fourier transform, the wavelet transform is a local transform of space (time) and frequency, to effectively extract information from the signal [6].

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Supposing $\psi(t) \in L^2(R)$, $L^2(R)$ represents the square-integrable real number space. That is, the signal space with limited energy, and its Fourier transform is $\hat{\psi}(\omega)$. When the following allowable conditions are met:

$$\hat{\psi}(0) = \int_R \psi(t)dt = 0 \tag{1}$$

$$C_\psi = \int_R \frac{|\psi(\omega)|^2}{|\omega|} d\omega < \infty \tag{2}$$

Where $\psi(t)$ is the mother wavelet or the basic wavelet. After the mother function $\psi(t)$ is stretched and translated, a wavelet sequence is obtained.

For the continuous case, the wavelet sequence is expressed as:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \psi(\frac{t-b}{a}), a, b \in R; a \neq 0 \tag{3}$$

Where: *a* is the expansion factor, *b* is the translation factor, and $\psi_{a,b}(t)$ is the wavelet basis function of the parameters *a* and *b*.

Assuming that the window width of the wavelet mother function $\psi(t)$ is Δt, and the window center is t0, the corresponding window center and window width of the continuous wavelet basis function $\psi_{a,b}(t)$ can be obtained as:

$$t_{a,b} = a_0 + bt, \Delta t_{a,\tau} = a\Delta t \tag{4}$$

Supposing $\hat{\psi}(\overline{w})$ is the Fourier transform of $\psi(t)$, the frequency-domain window width is Δw, and the center of the window is w0, and then:

$$\overline{\psi}_{a,b}(\overline{w}) = \sqrt{|a|} e^{-jwb} \varphi(aw) \tag{5}$$

So this time, the frequency-domain window center and window width are respectively expressed as:

$$w_{a,b} = \frac{1}{a} w_0, \Delta w_{a,b} = \frac{1}{a} \Delta w \tag{6}$$

It can be seen that the time domain and frequency domain window center, and window width of the continuous wavelet are all functions of the parameter *a*.

$$\Delta t_{a,b} \cdot \Delta w_{a,b} = \Delta t \cdot \Delta w \quad (7)$$

That is, the window area of the continuous wavelet basis function is fixed.

For any function f(t), the continuous wavelet transform on L2(R) can be expressed as:

$$W_f(a,b) =< f,\psi_{a,b} >= |a|^{-1/2} \int_R f(t)\overline{\psi(\frac{t-b}{a})}dt \quad (8)$$

Convert it inversely to:

$$f(t) = \frac{1}{C_\psi}\int_{R^+}\int_R \frac{1}{a^2} W_f(a,b)\psi(\frac{t-b}{a})dadb \quad (9)$$

Where $C_\psi = \int_R \frac{|\overline{\psi}(w)|^2}{|w|}dw < \infty$ is the admissibility condition of $\psi(t)$.

Moreover, in the process of the wavelet transform, the energy should be kept in proportion, namely:

$$\int_R \frac{da}{a^2}\int_R |W_f(a,b)|^2 db = C_\psi \int_R |f(x)|^2 dx \quad (10)$$

According to the definition of the continuous wavelet transform, wavelet transform is an integral transform and has multi-resolution characteristics. It is realized by the expansion factor *a* and the translation factor *b*. According to the changes of parameters *a* and *b*, the local characteristics of the signal can be obtained. If f(t) is a two-dimensional function, then its continuous wavelet transform is expressed as:

$$W_f(a,b_x,b_y) = \frac{1}{a}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f(t_1,t_2)\overline{\psi(\frac{x-b_x}{a},\frac{x-b_y}{a})}dxdy \quad (11)$$

Where *bx* and *by* are translations in two dimensions, and the continuous wavelet inverse transform is expressed as:

$$f(x,y) = \frac{1}{C_\psi}\int_0^{+\infty}\frac{da}{a^3}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} W_f(a,b_x,b_y)\psi(\frac{x-b_x}{a},\frac{y-b_y}{a})db_x db_y \quad (12)$$

The characteristic functions of the time-frequency diagram are as follows:

$$M_{SP}(\theta,\tau) = \iint |S_t(\omega)|^2 e^{j\theta(\tau-t)\omega}dtd\omega = A_s(\theta,\tau)A_h(-\theta,\tau) \quad (13)$$

$$A_s(\theta,\tau) = \int s^*\left(t-\frac{1}{2}\tau\right)s\left(t+\frac{1}{2\tau}\right)e^{j\theta t}dt \quad (14)$$

Equation (14) is the ambiguity function of the signal, and the above method can also be used to define the ambiguity function of the window[8] Simultaneous equations (13) and (14):

$$E_{SP} = \iint P_{SP}(t,\omega)dtdw = M_{SP}(0,0) = A_s(0,0)A_h(0,0) = \int |s(t)|^2 dt \times \int |h(t)|^2 dt \quad (15)$$

Therefore, if the energy of the window is set to 1, then the energy of the time-frequency diagram is the energy of the signal, so the energy of the noise signal can be judged by the time-frequency diagram obtained by the wavelet transform time-frequency analysis of the conducted EMI noise signal [9].

b) Simulation Research of conducted EMI noise diagnosis method based on Infomax-WT algorithm

Matlab is used to simulate the basic performance of Infomax-WT algorithm. Three sinusoidal signals are created to form a mixed-signal x(t), which is used to simulate conducted EMI noise signal, namely:

$$x(t) = \sin(2\pi \bullet 100t) + \sin(2\pi \bullet 200t) + \sin(2\pi \bullet 400t) \quad (16)$$

As shown in Fig. 1, the mixed signal is separated into three noise components by the in fomax algorithm, and the waveform of each noise component is shown in Fig. 2. It can be seen that the three noise components are the three noise source signals constructed. Wavelet transform is applied to the three noise components to obtain the time-frequency diagram of each noise component. As shown in Fig. 3, the frequency of each noise component is 100Hz, 200Hz, and 400Hz respectively, corresponding to the three source signals.

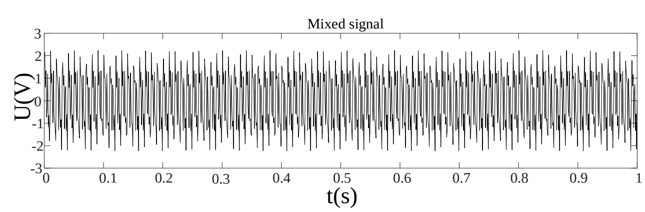


Fig. 1: Time-domain wave of the conducted noise signal

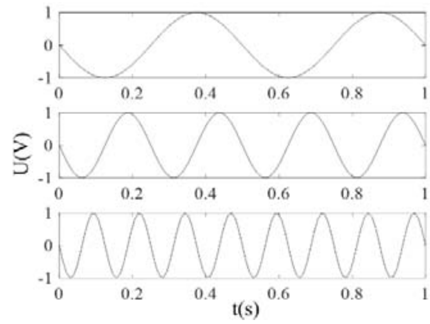
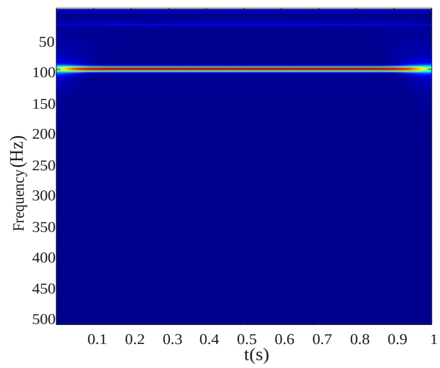
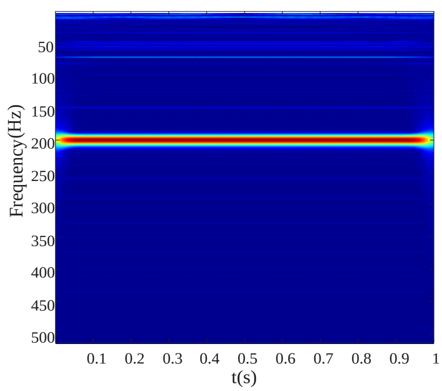


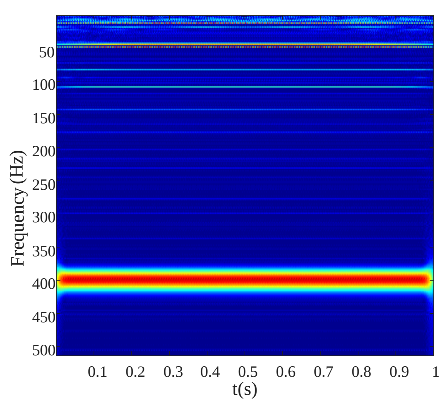
Fig. 2: Waveform of noise components



(a) Noise component 1



(b) Noise component 2



(c) Noise component 3

Fig. 3: Time-frequency diagram of noise components

The results show that the frequency characteristics of each separated noise signal are extracted after separating the mixed conducted EMI noise based on In fomax-WT method, which makes the diagnosis result more accurate.

c) *Verification experiment of conducted EMI noise diagnosis method based on Infomax-WT algorithm*

The principle diagram of the conducted EMI noise diagnosis method verification experiment is shown in Fig. 4. The resistance values of R1, R2, R3, and R4 are all 50Ω, the capacitance values of C1 and C2 are both 0.1μF. The LISN RF output port is composed of capacitors C1, C2 and R1 and R2. R3, R4 and signal generators V1 and V2 constitute an analog noise source.

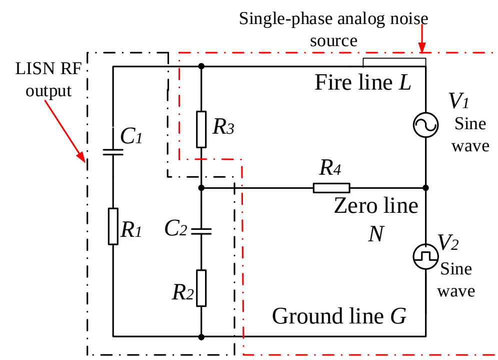


Fig. 4: The principle diagram of the conducted EMI noise diagnosis method verification experiment

V1 generates a sine wave, and V2 generates a square wave with an amplitude of 4V and frequency of 200kHz and 400kHz, respectively. The noise voltage on the live wire L is the mixed conduction noise of *V1* and *V2*, extracted by resistance R1. The waveform of mixed conducted noise measured by the oscilloscope is shown in Fig. 5.

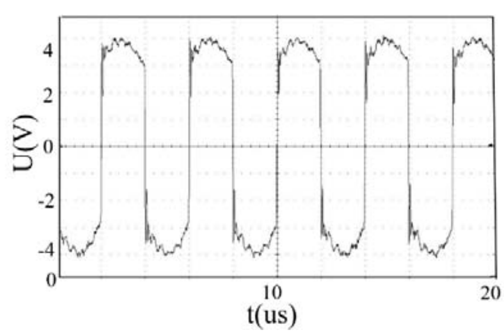


Fig. 5: The waveform of mixed conducted noise

The extracted mixed conducted noise is separated into two noise components by the infomax algorithm, as shown in Fig. 6 (a) and Fig. 6 (b). Compared with the analog conducted noise signal waveform shown in Fig. 5, it can be seen that the waveform characteristics of the two are the same. The frequency characteristics of the separated signal are extracted by wavelet transform, and the time-frequency diagram is obtained. As shown in Fig. 7, the frequency

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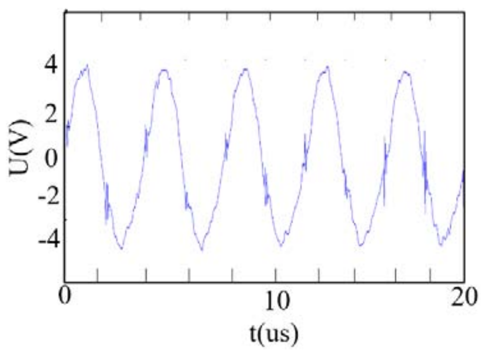
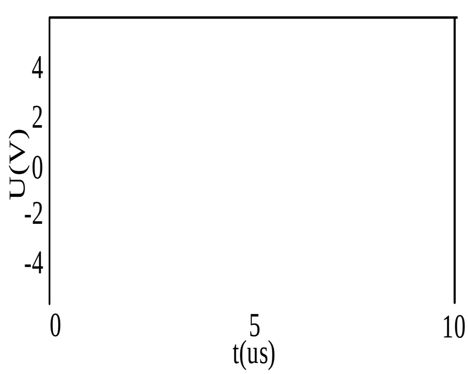
of the separated signal is 200kHz and 400kHz, respectively, which is consistent with the noise signal frequency simulated by the signal generator. Therefore, it can be determined that the conducted EMI noise sources are *V1* and *V2*.

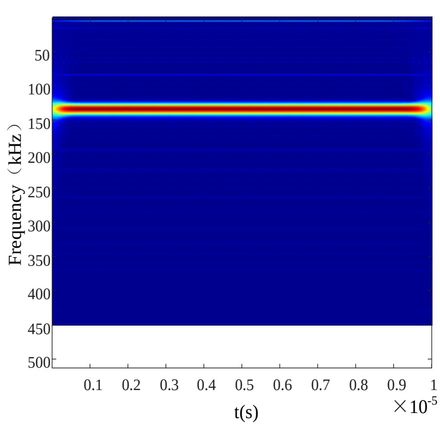


(a) Separated signal 1

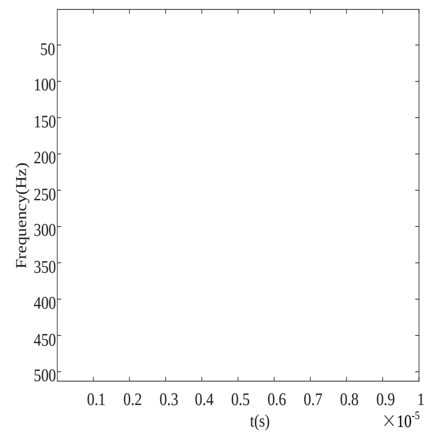


(b) Separated signal 2

Fig. 6: Conducted EMI noise separated by Infomax-WT



(a)



(b)

Fig. 7: Conducted EMI noise diagnosed by Infomax-WT (a) Signal 1 (b) Signal 2

The experimental results show that the conducted EMI noise diagnosis method based on the Infomax-WT algorithm can accurately diagnose and identify the conducted noise sources with different waveforms and frequencies, which verifies the feasibility and effectiveness of this method.

III. Application of Infomax-WT Algorithm in Conducted EMI Noise Diagnosis and Suppression

a) Problem Description

The test results of the conducted EMI noise of a type of anorectal therapy instrument are shown in Fig. 8. According to the medical equipment industry-standard YY 0505-2012 class B standard, the noise exceeds the standard seriously at 1.9 MHz frequency point.

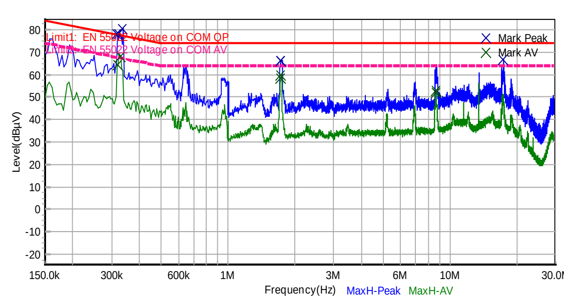
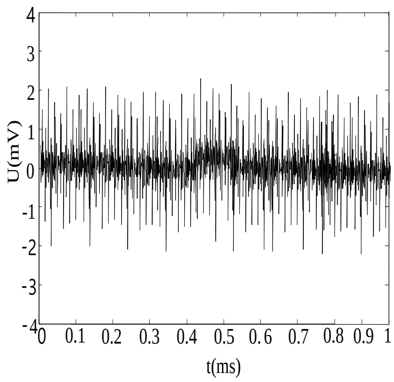


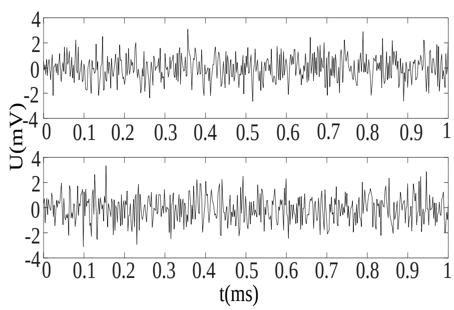
Fig. 8: Conducted EMI noise before rectification

b) Cause analysis and suppression measures

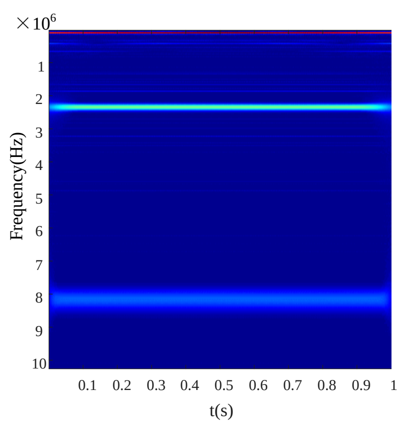
There is a power conversion chip with a high frequency of 2MHZ on the main circuit board. It is preliminarily predicted that the power conversion chip is the main reason for the excessive conducted noise.



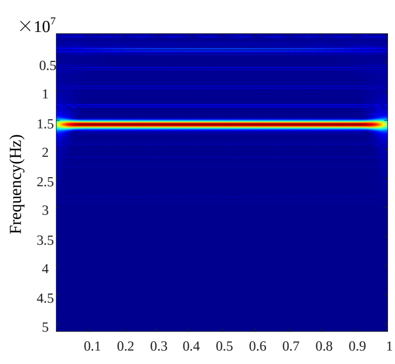
(a) Mixed time-domain signal



(b) Separated signals



(c)Time-frequency diagram of separated signal 1



(d)Time-frequency diagram of separated signal 2

Fig. 9: Diagnosis of conducted noise based on Infomax-WT algorithm

To accurately diagnose the noise source with excessive conducted EMI noise, the Infomax-WT algorithm is used to analyze the conducted EMI of the equipment. The time-domain noise is collected by the conducted EMI noise diagnosis system, and the waveform is shown in Fig. 9 (a). The signal characteristics of the separated signals are separated and extracted by the Infomax-WT algorithm, as shown in Fig. 9 (b), 9 (c), and 9 (d), respectively. It can be known that the main noise component is 2MHz and its frequency doubles. Therefore, it can be determined that the 2MHz power conversion chip is the main reason for the excessive conducted noise of the equipment under test.

According to the above noise diagnosis results, the suppression measures are as follows:

1) A T-type EMI filter is connected in series at the entrance of the power line.
2) Clamp the magnetic ring on the signal line.
3) Improve the wiring, increase the distance between the AC power line and the DC power line, isolate the power line and the signal line, and separate the cables on the primary and secondary sides of the transformer.

c) Suppression result analysis

After the suppression measures are taken, the conducted EMI noise test is shown in Fig. 10. It is found that the noise of the equipment has been suppressed and has a safety margin, which meets the test standard.

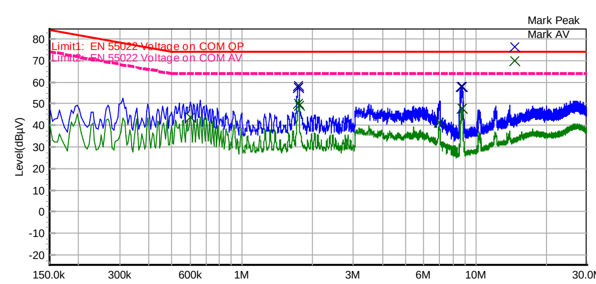


Fig. 10: Conducted EMI noise after rectification

IV. Conclusion

The conducted EMI noise diagnosis method based on the Infomax-WT algorithm effectively compensates for the defect that the infomax algorithm can only separate time-domain mixed conducted EMI noise signals and cannot reflect the frequency characteristics of noise signals. The simulation and experiment in Chapter 2 prove the effectiveness of this method in conducted EMI noise diagnosis.

This method is applied to the rectification of conducted EMI noise of anorectal therapy instrument. The Infomax-WT algorithm is used to diagnose and locate the noise source. The feasibility and engineering practicability of the method is verified.

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