

AUTOMATIC TESTING SYSTEM FOR EMC TESTING WITH WAVELET ANALYSIS APPLICATION BASED ON LABVIEW

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Abstract. According to the problem that the speed of electromagnetic compatibility(EMC) manual system is slow, a automatic testing system is designed for power supply line conducted emission based on general-purpose interface bus(GPIB) and LabVIEW, which actualizes a series of functions, such as signal generating, monitoring, analyzing and showing. It introduces the constituting of system, testing principle, software structure, and solves the hard problems and key techniques such as hardware's controlling, algorithm's fast convergence, compatibility of software. Because the testing signal include the ambient noise, the wavelet analysis is applied to filter the noise and gain the real conducted electromagnetic interference. Comparing with the other traditional apparatuses and the manual testing, the system improves the test efficiency and has good extensibility.

Keywords: Electromagnetic Interference, LabVIEW, Automatic Testing System, Wavelet Analysis.

Introduction

With the development in new technology of weapon, the number and type of highly sophisticated electronics equipments and system fitted in the congested shipboard, aircraft, guided missile environment, so electromagnetic environment (EME) is extremely complicated. Some equipments were effected by electromagnetism energy in our practice. Therefore, this is an exigent and necessary mission of solving electromagnetic compatibility (EMC) problem. The technology of EMC is not only a new and integrative subject domain, but also a application of engineering scientific technology. As T.shinuzuka depicted in [1], the study of EMC technology and solving EMC problem base on a lot of test research and measure in practice. We need to evaluate EMC of equip and find electromagnetic interference (EMI) problems by test. The problem is presented detailed by B. Sreedevi and N. S. Harischandra Rao in [2].

With the electrical equipment and systems on the modern ship increasing quickly, communication between the equipment is frequent. At present, most EMC testing is manual and the efficiency is poor, so it becomes an urgent task that testing the EMC system fast and reliably. Gong Fengxun and Ma Yanqiu introduced a universal estimating and measurement method of EMI[3]. By researching the EMC testing methods and EMC technique, the paper designs a automatic testing system which can test, save, analyse and process data. Because the testing signal include the ambient noise, the wavelet analysis is applied to filter the noise and gain the real conducted electromagnetic interference. Because of virtual instrument introduction, the

system has short development cycle and high operation efficiency. There is an automated test system for EMC already in existence which is called TILE (Totally Integrated Laboratory Environment System). The paper designed the system which can also undergo "digital signal processing" with wavelet analysis application. At the same time, it has strong extensibility and repeatability which can reduce repeated investment. The research results have important meanings on advancement of testing methods, quality of EMC testing and improvement of EMC techniques. The system has great value to popularize and application, also achieve innovation achievements on hardware drivers based on LabVIEW. Through reading and writing equipment drivers, it can make the equipment collect, analyse and save the signal. At last, the system will give a detailed report and a frequency graph.

Wavelet Analysis

There are much localization in the nonstationary signal analysis with Fourier Transform due to its resolution which Charles K Chui studied. The problem of the detection of a transient signal of unknown amplitude and arrival time, which is buried in noise, is not restricted to electromagnetic signal, but is general to many practical situations. The wavelet analysis is a powerful tool for nonstationary signal analysis because of the better resolution in frequency and time domain. Since the nonstationary signal has complex frequency component, the wavelet transform can set different resolution for noise filtering. Hao Zhang, T.R. Blackburn, B.T. Phung and D. Sen used wavelet transform technique for On-line Partial Discharge Measurements[4]. Yue Zhao, Niu Wencheng presented the application of wavelet analysis in ultrasonic sensor system characteristic signal pretreatment[5].

A.Wavelet Transform. For the function $\phi(x) \in L^2(R)$, the subspace V_j is generated by $\phi_{j,k}, k \in Z$, just as follow

$$V_j = \overline{\text{span}\{\phi_{j,k}, k \in Z\}}, j \in Z \quad (1)$$

In order to construct the model of wavelet analysis, some definitions is given:

Definition1: the space series $\{V_j\}_{j \in Z}$ in the space $L^2(R)$ meets the follow conditions:

(1) uniform monotone: $\cdots V_{-1} \subset V_0 \subset V_1 \cdots$

(2) gradual completely: $\bigcap_{j \in Z} V_j = \{0\}$,

$\text{clos}_{L^2(R)}\{\bigcup_{j \in Z} V_j\} = L^2(R)$

(3) expansion in rule:

$$f(x) \in V_j \Leftrightarrow f(2x) \in V_{j+1}, j \in Z$$

(4) Riesz base exists: there is $\phi \in V_0$, which makes that $\{\phi(x-k)\}_{k \in Z}$ is the Riesz base between limit A and limit B, the base is as follow:

$$\phi_{j,k}(x) = 2^{j/2} \phi(2^j x - k) \quad (2)$$

where $\forall j \in Z, \{\phi_{j,k}, k \in Z\}$, ϕ is scale function.

Then we call Multiple Resolution Analysis(MRA) in the space $L^2(R)$.

If ϕ generate one MRA, because $\phi \in V_0 \subset V_1$, and $\{\phi_{j,k}, k \in Z\}$ is a Riesz base in V_1 , then we get the relationship between scale functions ϕ in $\{p_k\}$

$$\phi(x) = \sum_{k=-\infty}^{\infty} p_k \phi(2x-k) \quad (3)$$

Given that the wavelet meets the permission, the wavelet in V_1 can be generated as follow:

$$\psi(x) = \sum_{k=-\infty}^{\infty} q_k \phi(2x-k) \quad (4)$$

Function family $\{\psi_{0,k}\}$ generates a close subspace W_0 as follow

$$\psi_0 = \overline{\text{span}\{\psi_{0,k}, k \in Z\}} \quad (5)$$

Therefore, $W_0 \subset V_1$ from (2) and (5). When constructiong wavelet, guarantee that V_1 is the direct sum of W_0 and V_0 , that is

$$V_1 = V_0 + W_0 \quad (6)$$

Definition 2:

$$W_j = \overline{\text{span}\{\psi_{j,k}, k \in Z\}} \quad (7)$$

from (2) and (7)

$$W_{j+1} = V_j + W_j, j \in Z \quad (8)$$

Because $\{V_j\}$ is a MRA of $L^2(R)$, therefore

$$L^2(R) = V_L \oplus W_L \oplus W_{L+1} \oplus \dots \quad (9)$$

There is only solution for arbitrary $f \in L^2(R)$

$$f(x) = f_L(x) + g_L(x) + g_{L+1}(x) + \dots \quad (10)$$

Where $f_j(x) \in V_j$, $g_j(x) \in W_j$. $f_L(x)$ is the approximation in low frequency of $f(x)$, $g_j(x) (j \geq L)$ is the detail component in different resolution.

In the actual system, because the resolution of testing equipment is limited, we hold that the information $f(x(K-1)) \in V_0$, from (10)

$$\begin{aligned} f(x(K-1)) &= f_L(x(K-1)) + g_L(x(K-1)) \\ &\quad + \dots + g_2(x(K-1)) + g_1(x(K-1)) \\ &= \sum_{k \in Z} d_{L,k} \phi_{L,k}(x) + \sum_{j \geq L} \sum_{k \in Z} \phi_{L,k} \psi_{j,k}(x) \end{aligned} \quad (11)$$

when using the orthogonal wavelet

$$d_{L,k} = \langle f, \phi_{L,k} \rangle, c_{j,k} = \langle f, \psi_{j,k} \rangle \quad (12)$$

Equation (11) is the MRA wavelet model of the signal $f \in L^2(R)$, just as follow

$$f(x) = \sum_{j,k} w_{j,k} g_{j,k}(x) \quad (13)$$

Wavelet transform is as follows:

$$WT_x(a, \tau) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} x(t) \Psi^*\left(\frac{t-\tau}{a}\right) dt \quad a > 0 \quad (14)$$

Where $\Psi(t)$ is basic wavelet function, a is scale.

When changing a , the lower the frequency is, the lower the time resolution is, so as the opposite. The Morlet wavelet has fast computation speed and can process data online, so we choose the Morlet wavelet:

$$\psi(t) = e^{-t^2/2} e^{i\omega_0 t} \quad (15)$$

$$\hat{\psi}(\omega) = \sqrt{2\pi} e^{-(\omega-\omega_0)^2/2} \quad (16)$$

Disperse the wavelet function:

$$\psi_{j,k}(t) = 2^{j/2} \psi(2^j t - k) \quad (17)$$

$$W_f(j, k) = (f(t), \psi_{j,k}(t)) \quad (18)$$

B. Conformation of Wavelet Threshold Function. As we know, the power of noise is distributed in the whole wavelet domain[6]. Whereas, the power of useful signal concentrates in the big wavelet coefficient. After wavelet decomposed, the wavelet coefficient of useful signal is much bigger than the noise. So we can construct a threshold function to set the filtering threshold adaptively. Then the useful signal can be resumed.

The threshold function is as follows:

$$w_0(x) = \text{sgn}(x) \left(|x| - \frac{b\lambda}{e^{\frac{|x|-\lambda}{\lambda}}} \right), |x| \geq \lambda$$

$$w(x) = 0, |x| < \lambda$$

$$\lambda = \sqrt{2 \log(N) \sigma} \quad (19)$$

When $x > 0$

$$\frac{w(x)}{x} = 1 - \frac{b\lambda}{x e^{\frac{x-\lambda}{\lambda}}} \quad (20)$$

when $x < 0$

$$\frac{w(x)}{x} = 1 + \frac{b\lambda}{x e^{\frac{-x-\lambda}{\lambda}}} \quad (21)$$

Because the nonstationary signal includes break points, the Fourier Transform can't confirm the break time and the variety, which affects the whole spectrum graph of the signal. However, the wavelet change the resolve automaticly, so it can distinguish the break points from noise. A simulation in the MATLAB can prove it as figure 1.

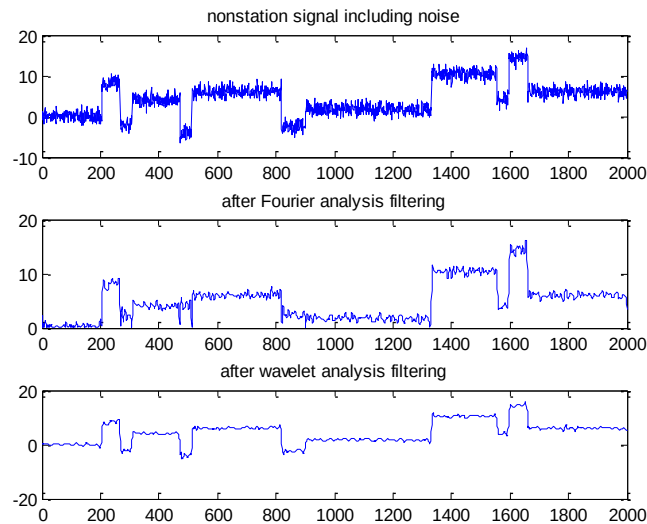


Fig. 1 Compared effect of filtering the noncalm signal between Fourier analysis and wavelet analysis.

From the third graph, the signal processed by wavelet threshold function reserves the edge of useful signal. To the opposite, the Fourier analysis can't distinguish the edge of high frequency in useful signal from noise, just as the second graph.

Testing Principle and System Hardware Structure

Testing conducted emission is to make sure if there is radiofrequency current which affect other equipment's work through power supply line. The current can be conducted to the shell by filter capacitor, and interfere low frequency receiving equipment in the system. Besides, the system can test the noise in the power supply line. The power is connected with line impedance stabilization network (LISN), and the current probe conducts the current value to the measurement receiver. Then the data will be transmitted to the computer and analysed in the LabVIEW.

A. Before Testing, Calibrate the Testing Equipment

(1) Impose 1 kHz, 3 kHz and 10 kHz calibrating signal to current probe, and the level of signal is 6dB lower than the limit value in GJB151A.

(2) Use oscilloscope and load resistance to inspect current value, and make sure if the current waveform is sine wave.

(3) Make the measurement receiver to scan in every frequency as scanning the common data, then check whether the error current level between the value of data recorder and injection current level is in the range of $\pm 3\text{dB}$.

(4) If it is larger or less than 3dB , find the reason and correct it before testing.

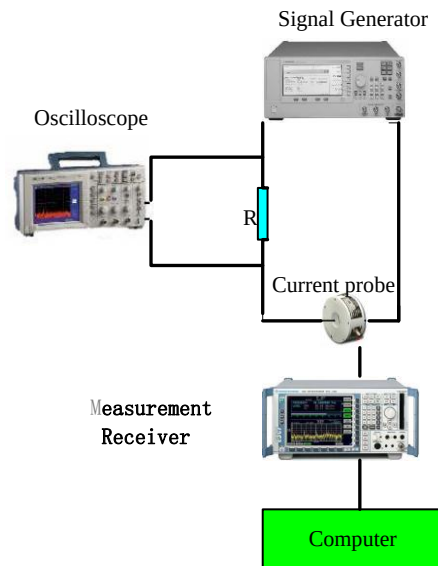


Fig.1 Testing system calibration configuration.

B. After Calibration, Testing the Equipment (EUT)

- (1) Electrify the EUT and preheat it to make it work stably.
- (2) Select one power supply line and fix current probe on it
- (3) Make the measurement receiver scan in the proper frequency according to GJB152A, which regulates the least testing time and bandwidth
- (4) Test the other power supply lines in the method.

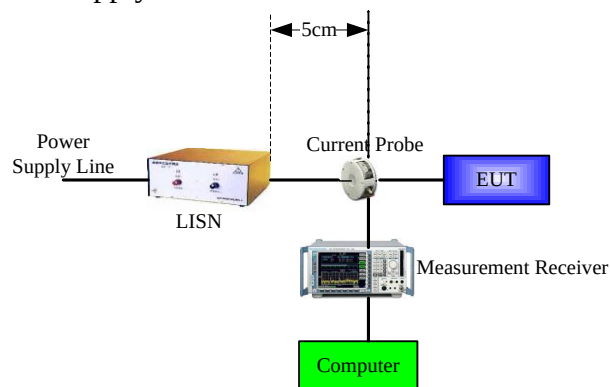


Fig. 2 Testing configuration.

C. Data Provided

- (1) Draw the graph between amplitude and frequency automatically with X-Y axis
- (2) Display proper limit value on the curve graph.

(3) Every curve should be 1% of the frequency resolution of the measurement receiver. GPIB defines the address for every measuring instrument to be convenient for calling. The computer keeps touch with every instrument through GPIB, and analyse the data. The hardware configuration of the testing system is as figure 3.

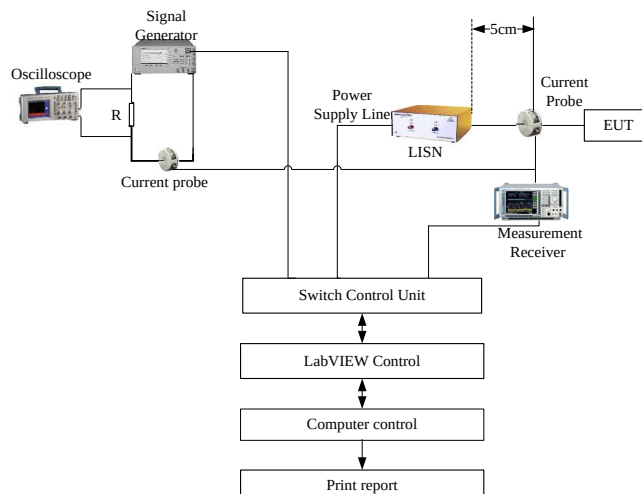


Fig. 3 Testing system configuration

Software Structure of System

The virtual instrument system is constituted by hardware instrument and LabVIEW platform based on GPIB. Compared with other development tools, LabVIEW has special advantage, such as graphical programming, easily for understanding, variety of function library and analyzing subroutine. Besides, it provides plenty of drivers for GPIB instrument.

Automatic testing program for testing is the core of the complete testing software which is an independent executable file (EXE). The EXE file can call the drivers of the instrument automatically to control the instrument. At the same time, it provides checking for dynamic link library (DLL) to make sure the DLL is right. When user want to change the instrument, program will control the instrument depend on the drivers. If system needs new instrument, only one thing needs to do which is developing new instrument drivers.

A. Set up Software Frame. Setting up the whole software frame is important step for the testing system. The software design for the automatic testing system for power supply line is modularity design and hierarchical design. Designing the application use the Top-Down design method. At first, analyse the whole requirements and performance parameter of the testing system. Then divide the system into small function modules such as signal generating, data reading and data analyzing. The program structure not only increases maintainability of the program, but also makes the flow chart clear. It also avoids plenty of repeated programming, and save much time. There are many function modules in the LabVIEW function library. The software structure is as figure 4.

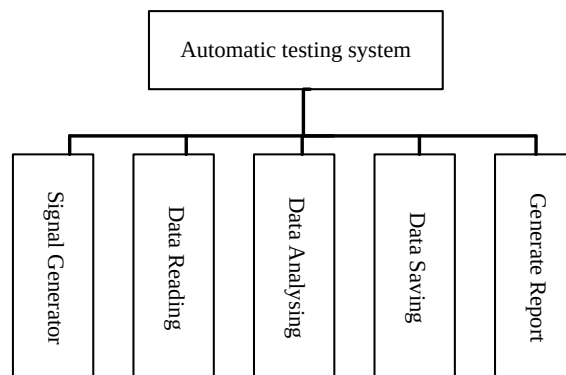


Fig. 4 Testing system software structure

The LabVIEW platform controls the hardware to generate signal, collect data and analyse the data with variety of functions and driver programs. Data disposal department is mainly to analyse signal, and there is rich signal analyzing functions in the software platform.

B. System Program Flow. The system conducts communication to control instrument through GPIB, and applies probe and correction coefficient of measurement receiver. Then increase the frequency and monitor output power and induced current, and generate testing curve and testing report. The program flow is as figure 5.

C. Set Up Virtual System. Set the instrument address initial frequency, last frequency and saving address for report before the experiment. The standard limit value curve and scanning result of the receiver should be shown real-time on the screen which can show if the testing result is higher than standard.

Build virtual platform of the whole testing system according to flow chart. Then simulate every instrument.

Based on every virtual instrument integrate each module and create a virtual interface. Because the testing engineering is flexible and large, and the function of software increase quickly, developing a convenient operation interface is essential for software perfect and user. Different testing module have different interface, and every interface includes login interface, testing selecting interface, parameter input interface, data show interface and so on. The login interface is as figure 6.

The LabVIEW program will call the MATLAB file in the MATLAB scrip node to process the signal. The wavelet analysis program is included in the MATLAB file.

Testing software program gives the testing report like frequency curve and printer prints the testing report and curve. The method not only reduces testing personnel's work, but also meets the user's requirement which is acquiring the report in short time. This working mode avoids inputting data with hand and reduces the testing error, so effectively improves the testing quality. The LabVIEW will pick up the wavelet program files of MATLAB to process the signal. The testing program of LabVIEW is as figure 7.

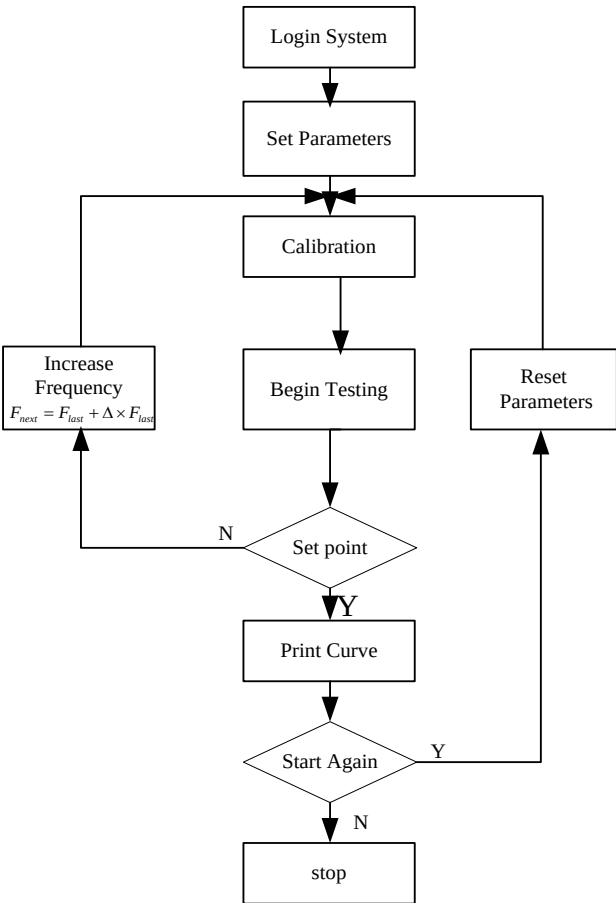


Fig. 5 Software program flow.

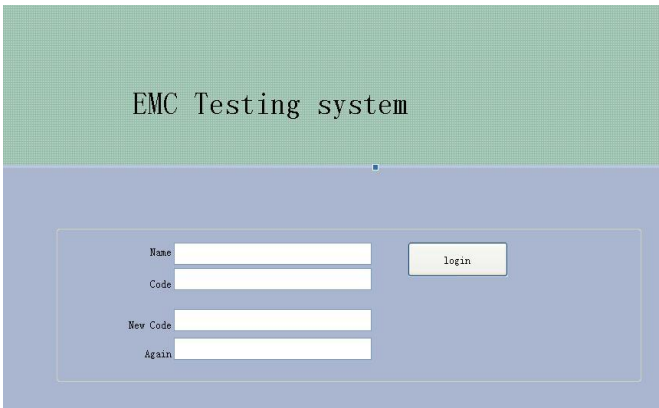


Fig. 6 Login interface.

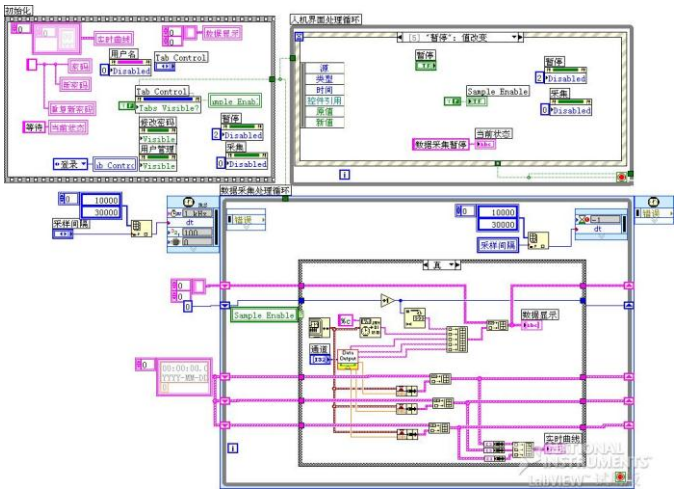


Fig. 7 Testing program of LabVIEW.

D. Result and Analysis. Click testing button, the system start to testing automatically. The beeline in the figure is limit value of power supply line which GJB151A regulates. The curve is the practical testing value. According to the figure, power supply line conducted emission meets the regulation and there is some margin. The printed result likes figure 8.

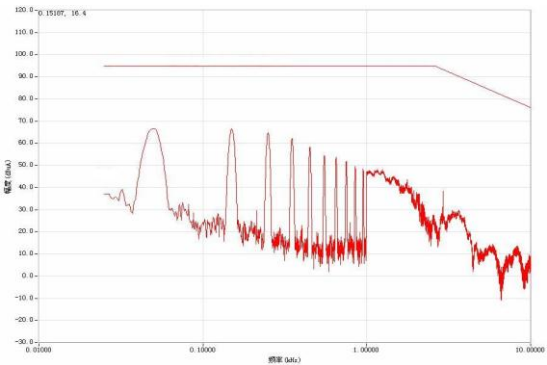


Fig. 8 Testing result and curve

Conclusions

The paper develops a automatic EMC testing system for electromagnetic interference based on LabVIEW platform, which meets the standard of MIL. The system comes from EMC automatic techniques developing, and changes the bad present situation that the efficiency of manual operating is low. It solves the problem that accuracy is poor. The system combines hardware with software, and the computer controls several instrument automatically and coordinated, and the testing results can be real-time showed. The application of wavelet in the digital signal process improves the accuracy of the conducted testing. The conducted interference testing has

high efficiency and precision. The system running has proofed that automatic testing system for conducted emission improves the efficiency of testing work, and reduces the work intensity.

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