Real-time Measurement and Evaluation System of Electromagnetic Field Emission with Short-time Frequency Conversion Based on Virtual Instrument Technology

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***Abstract*—In view of the problem of high cost in measuring electromagnetic field emission signals with short-time frequency conversion using the test method stipulated in EMC standard, in this paper, a real-time electromagnetic field emission measurement and evaluation system based on virtual instrument technology is designed. The system mainly includes four parts: measurement sensor, data acquisition and analysis, signal transmission and conversion, display and evaluation. Experiments show that the designed test system can accurately capture the maximum electromagnetic field emission amplitude of short-time frequency conversion signals at each frequency points, and it also has the advantage of obtaining the test and evaluation results in real time.**

***Keywords*—short-time frequency conversion; electromagnetic emission; test and evaluation; virtual instrument technology;**

I. INTRODUCTION

With the innovation of science and technology, electromagnetic launch system will be widely used[1]. Electromagnetic launch system is a kind of energy conversion system which can transform electromagnetic energy into instantaneous kinetic energy required by launching object. It will produce high-intensity short-time frequency conversion electromagnetic field emission when it works. Accurate measurement of short-time frequency conversion electromagnetic field emission generated by high-power electromagnetic launch system is a prerequisite to evaluate its effect on sensitive equipment, personnel and ordnance.

It is high cost to obtain the frequency spectrum of short-time frequency conversion interference signal using the standard testing method[2]. For this reason, some scholars put forward the method of using oscilloscopes to store time-domain waveforms for post-analysis of software, but they can not do it in real-time. And only the analysis method of the low-frequency magnetic field signal is carried out, but the research on the measurement method of the high-frequency electric field emission signal is lacking[3,4]. In this paper, based on virtual instrument technology, a real-time measurement and evaluation system of electromagnetic field emission signal with short-time frequency conversion is developed. It can not only meet the requirement of "capture the maximum electromagnetic emission signal amplitude at each frequency point of electromagnetic launch system", but also obtain the test and evaluation results in real time.

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II. DESIGN IDEA AND BASIC COMPOSITION

The real-time measurement and evaluation system of electromagnetic field emission with short-time frequency conversion mainly monitors the electromagnetic field emission signal generated in the working process of electromagnetic launch system, and carries out real-time raw data acquisition, computation and spectrum analysis, data factor correction, storage, transmission and display, and the real-time comparison with the standard limit value to show the evaluation results. The basic block diagram of the test and evaluation system is shown in Fig.1. Among them, measurement antenna, oscilloscope module, spectrum analyzer module and so on are mature commercial products. Aiming at the characteristics of short-time frequency conversion signal, this paper adopts virtual instrument technology to design and integrate test and evaluation system, and develops test and evaluation software based on Labview software.

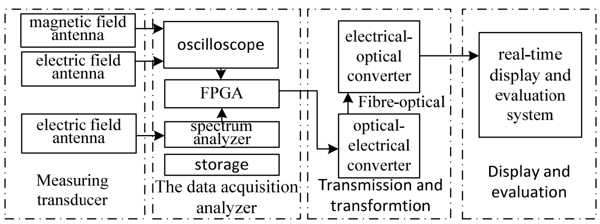


Fig. 1. Block diagram of test system

III. SYSTEM HARDWARE DESIGN

A. Hardware composition

The data acquisition analyzer is constructed with NI PXI modular RF instrument, and the real-time signal processing program is customized by programming method to realize the real-time calculation of FFT power spectrum under ultra-high sampling rate. The system key hardware functions and performance indicators are shown in TABLE Ⅰ.

TABLE I. FUNCTIONAL AND PERFORMANCE INDICATORS

Module	Function and performance indicators	
PXIe-8880	purpose	Master computer
	performance	2.3G Intel smart eight core, 8GB memory, 2 Gigabit Ethernet LAN
NI 8261	purpose	High-speed data storage
	performance	2.9TB memory, 2GB reading and writing speed per second.
PXIe-5668R	purpose	Down-side Frequency and digitization of RF signal
	performance	Vector signal spectrum analyzer, 20Hz to 26.5GHz/200MHz bandwidth,when 1GHz center frequency, the average noise background is -165 dBm/Hz
PXIe-5170R	purpose	Middle and low frequency signal acquisition
	performance	4 synchronous sampling channels, 250MHz bandwidth and 250MS/s sampling rate

B. Multi-channel parallel signal acquisition

For steady-state signal, the traditional multi-channel signal acquisition system generally adopts matrix switch mode, and uses an oscilloscope or spectrum analyzer module to realize multi-channel signal acquisition by matrix switch time-sharing switch, in which way, the cost can be greatly saved and the development difficulty of test software can be reduced. However, for the short-time frequency conversion signal, because the amplitude and frequency are changing contantly, it is impossible to acquire multi-channel signals in real time and parallel by matrix switch, which results in the loss of part time signals and the acquisition of the maximum spectrum envelope of short-time frequency conversion signals. The hardware structure of multi-channel parallel acquisition is used in this system as shown in Fig.2. In this way, magnetic field, low-frequency electric field (10kHz~30MHz), high-frequency electric field (30MHz~200MHz) enter two ports of oscilloscope module and spectrum analyzer module respectively and the controller controls the signal's A/D conversion, spectrum calculation, data processing, storage can be achieved at the same time.

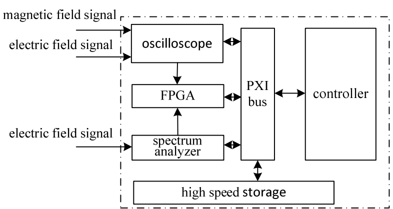


Fig. 2. Hardware architecture of multi-channel parallel acquisition

The 5170R oscilloscope module has four synchronous triggers and 14 bit channels for synchronous sampling, 100MHz analog bandwidth, 250MS/s sampling rate. After calculation, it is ensured that the background noise is low, the processing accuracy is high and the background noise is basically consistent. The high-frequency electric field signal is recorded by 200MHz bandwidth spectrum analyzer module, and the digital down-conversion and FPGA techniques are used to carry out fast analysis and evaluation to achieve real-time analysis and evaluation.

C. Environmental adaptability design

The data acquisition subsystem works in the field environment, and the environmental conditions are harsh. Therefore, the design and reinforcement of the three defenses are carried out. According to the environmental historical temperature and humidity conditions, the high performance temperature controller of the system is customized, and the temperature of the data acquisition subsystem is controlled within a certain adjustable range to ensure that the system can meet the harsh environmental conditions of -55 ℃ and 50 ℃.

IV. DATA PROCESSING METHOD

A. FFT transformation

Assuming that a short-time frequency conversion signal contains multiple spectral components, its functional expression can be expressed as:

$$y(t)=\sum_{f=0}^{\infty}A(f)\cdot\cos(2\pi ft+\phi) \quad (1)$$

The FFT changes of the short-time frequency conversion signal are as follows:

$$\mathrm{F}_1(f)=\mathrm{FFT}[y_1(t)]=\{A(0),...,A(f_{\max})\} \quad (2)$$

B. Frequency-domain windowed filtering

After the original time-domain waveform is obtained by FFT, the frequency-domain filter is selected by using the hamming window. Only the spectrum components in the effective bandwidth [fx-f_{RBW}, f_X-f_{RBW}] are extracted, and the formula (3) is approximated as follows:

$$\mathrm{F}_{2\mathrm{B}}(f)=F_1(f)P_x(f) \quad (3)$$

Assume that the original time-domain signal is N equispaced sample $y(t_j)$, j=1,…,N, The spectrum of its FFT transformation can be expressed as:

$$\mathrm{F}_1(f_k)=\sum_{j=1}^{N}y(t_j)\cdot\exp[-\mathrm{i}\cdot 2\pi\frac{(j-1)(k-1)}{N}] \quad (4)$$

Assuming the frequency range of hamming window interception $K_1\le k\le K_2$, the filtered iFFT output in time-domain is as follows:

$$y_3(t_j) = \frac{1}{N}\sum_{k=1}^{N}\mathrm{F}_2(f_k)\cdot\exp[\mathrm{i}\cdot 2\pi\frac{(j-1)(k-1)}{N}] \qquad (5)$$
$$= \frac{2}{N}\sum_{k=K_1}^{K_2}\mathrm{real}\{\mathrm{F}_2(f_k)\cdot\exp[\mathrm{i}\cdot 2\pi\frac{(j-1)(k-1)}{N}]\}$$

C. Detection output

$$y_{4\mathrm{A}}(t) = \frac{N}{2(K_2-K_1+1)}\cdot\frac{\mathrm{abs}\{y_{3\mathrm{A}}(t)\}}{\sqrt{2}} \qquad (6)$$

D. Windowed frame overlap technique

Because the electromagnetic transmission system produces very short-time pulse signal in the process of operation, in the process of FFT transformation, if the pulse signal is intercepted by two adjacent FFT frames, the spectral information of the pulse signal will be partially lost and the test result will be lower than the real result. To solve this problem, frame overlap technique is used in FFT transform, duplicate data between two computational frames with 60 steps (which can be adjusted in real time by parameters), calculate FFT by 40% time window at a time, in order to improve the time resolution of the whole system and reduce the direct FFT on the signal because of the frequency leakage caused by the truncation effect.

V. TEST VERIFICATION

A. steady state signal

In order to verify the accuracy of the test and evaluation system, the standard signal source is used to output the given amplitude signal at different frequencies, the test and evaluation system is tested and verified. The test validation results are compared as shown in Fig.3. The maximum error is only 1.53dB, and it appears at the frequency point of measurement boundary, which proves the accuracy of the system.

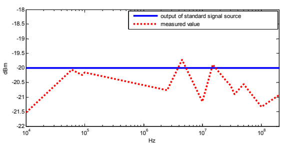
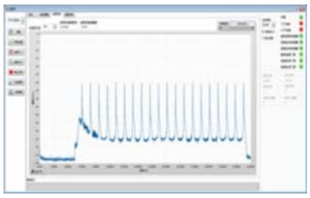


Fig.3. Steady-state signal test verification results

B. Verification of short-time Frequency conversion signal Test

In order to verify the ability of the test and evaluation system to capture the short-time frequency conversion signal, the signal source is used to program the output of the frequency conversion jump signal in the laboratory, and result of the test and evaluation system is compared with that of traditional peak holding mode of the spectrum analyzer. The accuracy and test efficiency of short-time frequency conversion signal are compared. The test results show that the developed test system can synchronize with the signal source and get the peak value of each frequency point in one test. In the traditional peak holding mode of the spectrum analyzer, because of the frequency sweep mode, the maximum peak value of each point can be obtained through numerous signal source outputs. And the maximum error of the system is only about 1dB. The test results are shown in Fig.4 and Fig.5 :



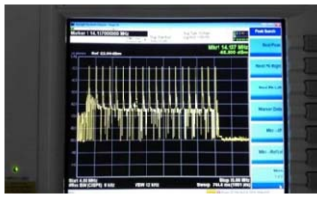


Fig. 4. System test results Fig. 5. Test results of spectrum analyzer

VI. CONCLUSION

In this paper, a real-time measurement and evaluation system for electromagnetic emission with short-time frequency conversion is developed and compared with the test system specified in the EMC standard. The error of the test results is small. The designed measurement system can accurately measure the maximum amplitude of the equipment to be tested at each frequencies, and neither need multiple measurement receivers nor run the equipment to be tested many times. The test results can be compared with the corresponding standard limits in real time, which has the advantages of accurate measurement, low cost, short time consuming and real-time display.

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