시간-주파수 영역 반사파 계측 시스템에서 다양한 시간-주파수 분포 함수의 영향 연구

곽기석*, 최덕선*, 윤태성**, 박진배*, 고재원***
*연세대학교 전기전자공학과, **창원대학교 전기공학과, ***유한대학 컴퓨터제어과

The Comparative Effect of Time-Frequency Distribution Function in a Time-Frequency Domain Reflectometry System

Kwak, Ki-Seok*, Tok Son Choe*, Tae Sung Yoon**, Jin Bae Park*, Jae Won Kho***
*Dept. of Electrical & Electronic Engineering, Yonsei Univ. **Dept. of Electrical Engineering, Changwon National Univ.
***Dept. of Computer Aided Control Engineering, Yuhan College

Abstract - The time-frequency domain reflectometry(TFDR) is well known to detect and locate a fault in a coaxial cable[3]. Traditional reflectometry methods have been achieved in either the time domain or frequency domain only. However, the time- frequency domain reflectometry utilizes time and frequency information of a reflected signal passed through a cable to detect and locate the fault. The purpose of this paper is to find appropriate time-frequency distribution function suitable for a TFDR system. Choosing the appropriate time-frequency distribution function implies one can detect the fault and estimate the location accurately. We consider and compare adequate time-frequency distribution function on the basis of experimental results.

1. Introduction

One solution for monitoring the electrical wiring system is to use the reflectometry which utilizes some kind of reference signal to propagate on the wire and then check the reflected signal. Until now, this reflectometry method has been broadly classified into two areas; Time Domain Reflectometry(TDR)[1], and Frequency Domain Reflectometry(FDR)[2]. However, these methods have resolution limitations because only one domain, either time or frequency, is considered. TFDR is a new type of reflectometry in which we consider time and frequency domains together in order to obtain high accuracy based on time-frequency domain analysis[3]. Gaussian envelope chirp signal is used as a reference signal and time-frequency based algorithm is used to detect and estimate actual delay of the reflected signal caused by a fault.

There are a lot of ways to obtain and construct time-frequency distribution. The basic objective of time-frequency analysis is to devise a function that will describe the energy density of a signal simultaneously in time and frequency, and that can be used and manipulated in the same manner as any density. The Wigner distribution, as considered in signal analysis, was the first example of a joint time-frequency distribution that was qualitatively different from the spectrogram.

The approach characterizes time-frequency distributions by an auxiliary function, the kernel function. The properties of a distribution are reflected by simple constraints on the kernel, and by examining the kernel one readily can ascertain the properties of the distribution. This allows one to pick and choose those kernels that produce distributions with prescribed, desirable properties. This paper is organized with following sections. In Sec. 2.1, the TFDR system is discussed. In Sec. 2.2, the TFDR measurement algorithm and time-frequency distribution functions are described, and the result for picking up the adequate distribution function is shown in Sec. 2.3. The conclusion of this paper is provided in Sec. 3.

2. TFDR System and Time-Frequency Distribution Function

2.1 TFDR system

The TFDR system consists of the four components: signal generation, signal acquisition, signal distribution, and algorithm execution. The signal generation part makes the input signal which is the linearly modulated chirp signal with Gaussian envelope.

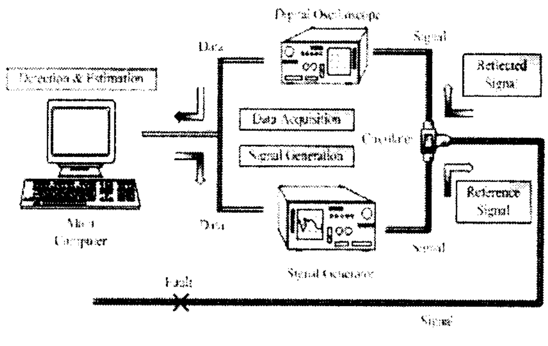


Fig. 1. Experimental setup of the TFDR.

This part is implemented by the AWG PXI(Arbitrary Waveform Generator) instrument module. The signal acquisition part obtains both the input signal from the AWG and the reflected signal from the fault of a cable. It is implemented with the DSO PXI(Digital Storage Oscilloscope) instrument module. The signal distribution part is implemented by the circulator to interlink the AWG, DSO, and the target cable. The algorithm execution part is implemented by the PXI controller. In this part, the TFDR algorithm is accomplished to detect and estimate the fault location on the target cable. The controller also has the function of controlling each PXI instrument module. The TFDR system is shown in Figure 1.

2.2 The TFDR Algorithm and Time-Frequency Distribution Function

The basic concept of the TFDR algorithm is to analyze the input and the reflected signals in the time-frequency domain simultaneously. The input signal designed as the form of the linearly modulated chirp signal with Gaussian envelope which is localized in the time and the frequency axes at the same time is used. The measurement algorithm is organized with the following steps[5].

Data acquisition of the reference signal from AWG and the reflected signal at fault is processed in step 1. Since, the acquired siganl in step 1 has a small DC voltage offset, we should remove the DC component in step 2. The Hilbert transform is taken in step 3. The time-frequency distribution of Hilbert transformed signal is obtained in step 4. The time-frequency distribution function reconstitutes the data against the time axis into the data against the time-frequency axis. We use eq.(1) in case using Wigner-Ville distribution, eq.(2) in case adopting Butterworth distribution, eq.(3) in case using Choi-Williams distribtion, and eq.(4) in case with Margenau-Hill time frequency distribution functions to get time-frequency distribution for the reference and the reflected signals.

$$W_x(t,\nu)=\int_{-\infty}^{+\infty} x(t+\frac{\tau}{2})x^*(t-\frac{\tau}{2})e^{-j2\pi\nu\tau}d\tau \quad (1)$$

$$Bud_x(t,\nu)=\int_{-\infty}^{+\infty}\frac{\sqrt{\sigma}}{2|\tau|}e^{\frac{-|t|\sqrt{\sigma}}{|\tau|}}x(t+\nu+\frac{\tau}{2})\,x^*(t+\nu+\frac{\tau}{2})e^{-j2\pi\nu\tau}d\nu d\tau \quad (2)$$

$$CW_x(t,\nu)=2\int\int_{-\infty}^{+\infty}\frac{\sqrt{\sigma}}{4\sqrt{\pi}|\tau|}e^{\frac{-\nu^2\sigma}{16\tau^2}}x(t+\nu+\frac{\tau}{2})\,x^*(t+\nu+\frac{\tau}{2})e^{-j2\pi\nu\tau}d\nu d\tau \quad (3)$$

$$MH_x(t,\nu)=\int_{-\infty}^{+\infty}\frac{1}{2}(x(t+\tau)x^*(t)+x(t)x^*(t-\tau))\,e^{-j2\pi\nu\tau}d\tau \quad (4)$$

In step 5, we can extract the input signal and obtain time-frequency distribution. Calculation of time delay between the input and the reflected signals is operated in step 6. Finally, the estimation of the fault location can be done in step 7.

2.3 Experimental Results

The experiments are accomplished by using the proposed TFDR system for the 10C-FBT coaxial cable which has a fault at 100m from the starting point of the cable.

The parameters of the input signal used in these experiments are described in Table I.

Four representative time-frequency distribution functions are used as we mentioned earlier for comparison each other. The results of various time-frequency distribution functions are shown in Table II.

TABLE I

THE PARAMETERS OF THE INPUT SIGNAL

Parameters	Value
Center Frequency	15 MHz
Frequency Bandwidth	10 MHz
Frequency Sweep Range	10 - 20 MHz
Time Duration	700 ns
Peak to Peak Voltage	8 V

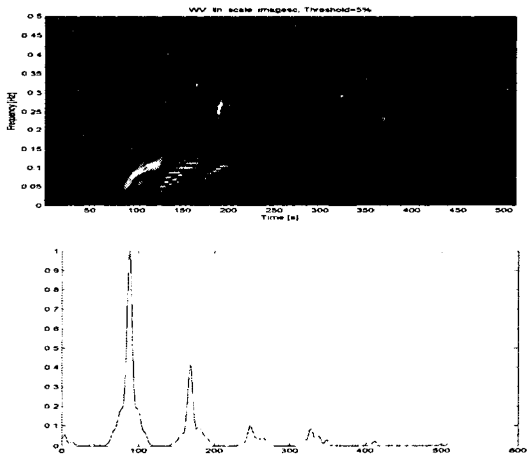
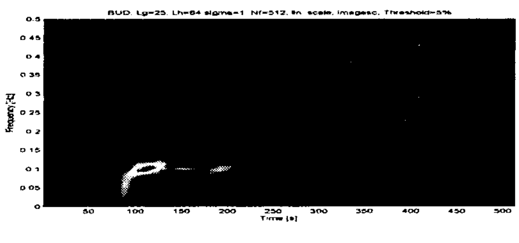


Fig. 2. Wigner-Ville distribution and its time-frequency correlation.



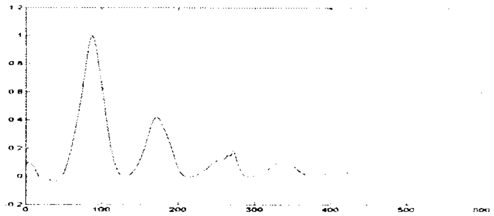


Fig. 3. Butterworth distribution and its time-frequency correlation.

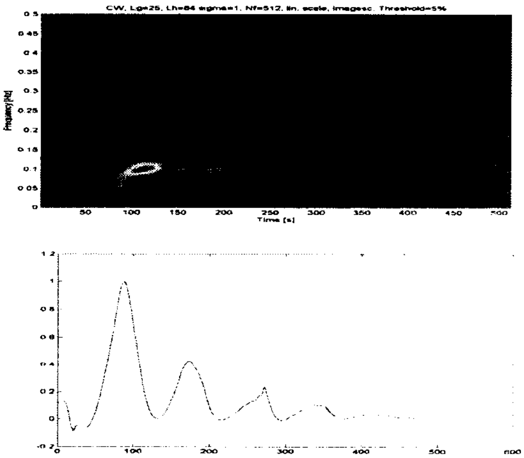


Fig. 4. Choi-William distribution and its time-frequency correlation.

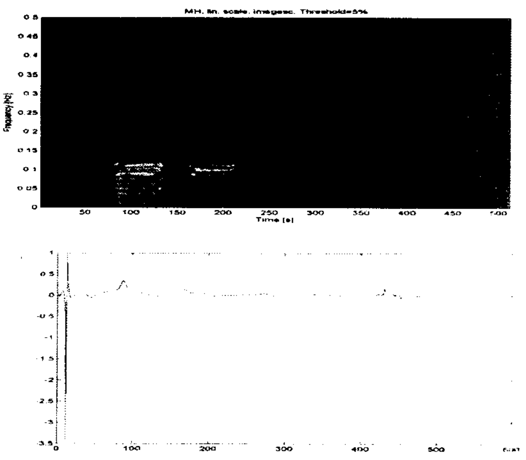


Fig. 5. Margenau-Hill distribution and its time-frequency correlation.

TABLE Ⅱ
EXPERIMENTAL RESULTS

	Wigner-Ville distribution	Butter-worth distribution	Choi-William distribution	Margenau-Hill distribution
Estimation Value(m)	100.5732	107.0397	108.9200	95.0644

3. Conclusion

In this paper, we investigate the suitable time-frequency distribution function for the TFDR system by experimental method. Among the time-frequency distribution functions the Wigner-Ville time-frequency distribution offering reliable time-frequency correlation is the best decision in the proposed TFDR system. The various time-frequency distribution functions except the Wigner-Ville time-frequency distribution are designed by reducing interference effect between the input and the reflected signals. In further study, it can be expected that the more mathematical approach to prove these results is invaluable.

ACKNOWLEDGEMENT

This work was supported by KOSEF R01-2001-000-00316

[참 고 문 헌]

[1] C.P.Nemarich, "Time Domain Reflectometry Liquid Level Sensors", IEEE Instrument and Measurement Magazine, Vol. 4, pp.40-44, Dec.2001.

[2] Vanhamme, H., "High Resolution Frequency Domain Reflectometry", IEEE Transaction on Instrumentation and Measurement, Vol. 39, pp.369-375 Apr 1990.

[3] T.S. Choe, C.Y. Hong, J.B. Park, "Detection and Estimation of a Fault on Coaxial Cable via Time Frequency Domain Reflectometry", Proceedings of the 20th IEEE IMTC, Vol. 1, pp. 190-195, May 2003.

[4] Leon Cohen, "Time Frequency Analysis" Prentice Hall, 1995.

[5] T.S. Choe, C.Y. Hong, J.B. Park, T.S. Yoon, "Implementation of a Time Frequency Domain Reflectometry Systmem with PXI Platform for a Coaxial Cable", Proceedings of the 21th IEEE IMTC, Vol. 2, pp. 964-968, May 2004.