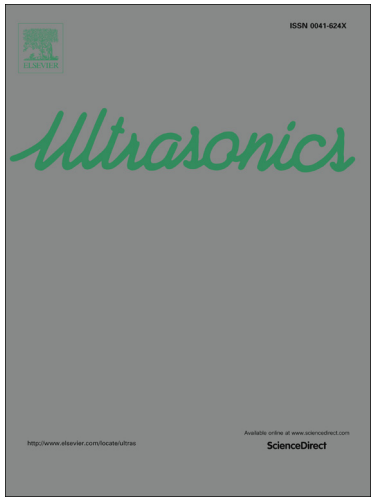

Application of P4 Polyphase Codes Pulse Compression Method to Air-coupled Ultrasonic Testing Systems

Honggang Li, Zhenggan Zhou

PII: S0041-624X(17)30207-X
DOI: http://dx.doi.org/10.1016/j.ultras.2017.03.001
Reference: ULTRAS 5495

To appear in: *Ultrasonics*

Received Date: 28 August 2016
Revised Date: 16 December 2016
Accepted Date: 2 March 2017

Please cite this article as: H. Li, Z. Zhou, Application of P4 Polyphase Codes Pulse Compression Method to Air-coupled Ultrasonic Testing Systems, *Ultrasonics* (2017), doi: http://dx.doi.org/10.1016/j.ultras.2017.03.001

Application of P4 Polyphase Codes Pulse Compression Method to Air-coupled Ultrasonic Testing Systems

Honggang Li [a], Zhenggan Zhou [a, b,*]

[a] School of Mechanical Engineering and Automation, Beihang University, 37 Xueyuan Rd., Haidian District, Beijing 100191,

[b] China 2 Collaborative Innovation Center for Advanced Aero-Engine (CICAAE), Beijing 100191, China

ABSTRACT: Air-coupled ultrasonic testing systems are usually restricted by low signal-to-noise ratios (SNR). The use of pulse compression techniques based on P4 Polyphase codes can improve the ultrasound SNR. This type of codes can generate higher Peak Side Lobe (PSL) ratio and lower noise of compressed signal. This paper proposes the use of P4 Polyphase sequences to code ultrasound with a NDT system based on air-coupled piezoelectric transducer. Furthermore, the principle of selecting parameters of P4 Polyphase sequence for obtaining optimal pulse compression effect is also studied. Successful results are presented in molded composite material. A hybrid signal processing method for improvement in SNR up to 12.11 dB and in time domain resolution about 35% are achieved when compared with conventional pulse compression technique.

Keywords: Polyphase codes; Air-coupled ultrasonic testing; Pulse compression; Wavelet threshold denoising; Ultrasonic transducer

1. Introduction

[1] Air-coupled Ultrasonic Testing (ACUT) technique is a non-contact ultrasonic testing technique. It has a good industrial application prospect because it avoids using couplant compared with the conventional ultrasonic testing techniques [1]. ACUT allows testing and evaluating materials when couplants like water or gels are not suitable, e.g. when testing polymers and composites, couplants may damage these materials. In all cases, it is the fact that no couplant is needed that makes the technique attractive.

But, there are some factors limiting the use of ACUT in industrial application. The main limiting factors are the attenuation of the ultrasound in air, the insertion losses at transducer-air interface, and the insertion losses at air-sample interface [2,3]. The first limiting factor is caused by propagation characteristics of ultrasound in air. The second and last limiting factors are caused by the large difference in acoustic impedance between solid and air. According to the investigation [4, 5], the combined effect of these factors will lead to acoustic energy loss up to 100dB. Therefore, it is difficult to detect the air-coupled ultrasonic signal without using suitable methods to improve signal-to-noise ratio (SNR) of ACUT system and recover the wanted signal.

Normally, there are some ways to overcome these problems: using a better matching layers in the transducer to improve the ultrasound conversion efficiency [6,7,8]; using a low noise preamplifier to amplify the received signal; using an appropriate excitation method to make the transducer generating output signal with higher energy; and using suitable signal processing technology to improve the SNR of ACUT system [9,17,18,19]. However, suitable matching layer materials are expensive and they typically work only over a narrow bandwidth. Increasing the voltage of signal may improve SNR of ultrasonic signal, but the transducer may be damaged when blindly using hardware device. So, using appropriate method to drive transducer and effective signal processing method to improve the SNR of ACTU system are considered feasible approaches. Techniques based on coded waveforms and pulse compression processing techniques can be used to make the transducer generate higher output signal energy and improve the SNR of ACUT systems [10,30,31]. The pulse compression techniques, which are based on cross-correlation with a reference signal, were originally applied in the radar field. The advantage of this technique is increase the average transmitted power while still maintaining the range resolution [11]. Recently, this technique has been adopted in many fields of ultrasound, especially in sonar or medical ultrasound [12-16], to solve SNR problems. Literature shows that the use of

*Corresponding author: Honggang_Li128@buaa.edu.cn