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Design of IIR Filters for Ultrasonic Target Detection

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Abstract: **Ultrasonic target detection is generally used on steel and other metals and alloys. Materials with less resolution such as concrete and wood can be inspected under ultrasonic. Important areas of application for ultrasonic are industrial automation, aerospace, automotive and other transportation sectors. Flaw detection is the most commonly used method in Non-destructive testing. Being it is a most safe method, it is used in various areas like industries services and production process. Particularly ultrasonic is used in applications where detection becomes messy because of microstructure scattering noise. The paper gives an overview of the implementation of ultrasonic flaw detection using filters. Split spectrum processing is used as an effective method for obtaining frequency diverse information.**

***Keywords*: IIR filter, SSP.**

I.INTRODUCTION

Ultrasonic target detection is usually tested on steel and other metals and alloys. It can also be performed on concrete and wood. Ultrasonic is having applications in industries along with aerospace, automotive and other transportation areas, as it is used as measure of non-destructive testing. Ultrasonic detection is a precious tool in non-destructive testing in industries. But the only challenging problem associated with ultrasonic detection is scattering microstructure noise. Ultrasonic is the application of ultrasound. Flaws in materials can be efficiently detected without damaging its internal structure. Thickness of objects can also be inspected. Most commonly used frequencies are 2 mHz to 10 mHz. For manufacturing process, inspection of material can be automatic or manually. Along with the metals we can inspect plastic as well as concrete. Lower frequency materials can be inspect satisfactorily. Such as wood, concrete and cement as they are having frequency in between 50-500khz.

Previously before few decades, radiography was used for the inspection of welded joints, but nowadays ultrasonic is the best alternative for non-destructive testing. The benefits of using ultrasonic as an alternative to existing methods are, it actually reduces ionization radiation with the cost. Safety is also increases to great extent. In welded joints, depth of flaws can also be detected by using ultrasound. Ultrasonic target detection can be carried out in two ways, either manually or one can use computerized systems. An ultrasonic test of a joint will be performed then we can get the information about the existence of flaws, flaw size, and their location. All welded material is not having identical properties for ultrasonic inspection because materials with large size are having more grain noise.[1]

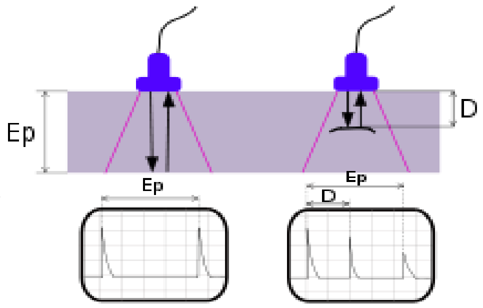

Fig.1. Principle of flaw detection with ultrasound.

Split spectrum processing of ultrasonic signals combined with filtering is very effective to improve the flaw to clutter ratio. In this paper, real time ultrasonic data processing is achieved by use of frequency-diverse detection architecture. Clutter echoes can be suppressed and defects can be made more visible by using frequency-diverse ultrasonic detection. So in this manner, we implementing a frequency-diverse ultrasonic detection method and split spectrum processing (SSP) based on fast Fourier transform.

II. FILTER DESIGNING TECHNIQUES

In ultrasonic techniques, information on flaws specification possibilities has required more effective techniques development than classical methods. These methods should be more sensitive for defect detection, and for serving this purpose these methods use signal processing algorithm in order to increase signal to noise ratio. In this paper, signal processing algorithms like wavelet transform, spectral mesh processing, quasi parametric algorithm and split spectrum processing (SSP), and are listed in brief and among all these techniques we are going to use Split spectrum processing..

A. *Wavelet Transform:* This algorithm is useful to enhance flaw visibility.Generally speech coding is most known area of wavelet transform. In case of microstructure this algorithm can be useful for applications like pitch detection, multiresolution analysis and estimation of multiscale processes. The principle behind detection of signals is based on mathematics and physics along with engineering. Wavelet decomposition can give frequency conversion in terms of a signal into a time-scale plane. Each scale in the time-scale plane corresponds to a frequency domain in the time-frequency plane.

B. *Spectral Mesh Processing:* This algorithm has been developed to solve a diversity of problems including mesh compression, correspondence, parameterization, segmentation, sequencing, smoothing, symmetry detection, watermarking, surface reconstruction, and remeshing.

C. *Quasi Parametric Algorithm:* This algorithm is useful for synthetic aperture radar (SAR) target feature extraction and imaging targets with angle diversion. QUALE first determine the model parameters such as amplitude sequence, constant phase, scatterer location in range and cross range. Data missing can be detected by 2-D range finder.

D. *Split spectrum processing:* This is algorithm used for an ultrasonic signal-processing. SSP is introduced in 1979. It uses frequency diversity to improve the signal to noise ratio. So that flaw detection can be achieved more easily.

III.OVERVIEW OF THE SYSTEM-SPLIT SPECTRUM PROCESSING

Split spectrum processing is effective method in ultrasonic target detection which is used for of obtaining frequency- diverse information.[2][3] Frequency diversity improves the signal-to-nose ratio. In ultrasonics, sometimes scattering of signal may cause problems. When the wavelength of the signal is same as magnitude of particles then the returning echo obtained is weak. A similar example is the light in a headlamp, which is scattered by small droplets in fog. In this example the droplets are having same size as that of wavelength of light. So there is problem with scattering. This scattering can be increased by increasing the intensity of light.[4]

In the industrial ultrasonics, the scattering of signal takes place because of metallurgical grain structure of the material being tested. Due to this scattering there is introduction of grain noise. This noise then can be reduced by increasing the wavelength of signal.

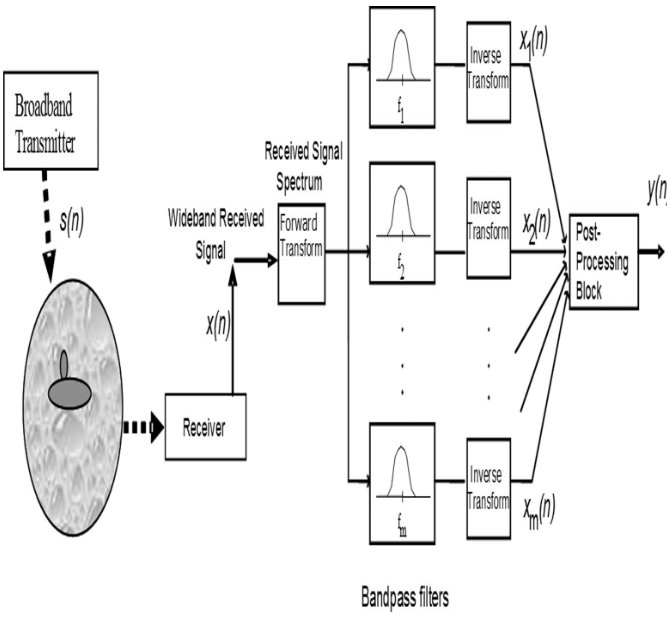

Fig.2 Flow diagram of SSP.

Referring fig. 2, procedure of SSP can be given in several steps. Data acquisition is the very first step. Pulse generator is used for data acquisition which produces the electrical impulses to drive the ultrasonic transducer. Then comes the receiver which is used to receive the ultrasonic echoes. On the received signal data, digitization is achieved and further transform operations (such as FFT or discrete cosine transform (DCT) wil be carried out. and several bandpass filters to split the spectrum into different subbands. The output signals from the subbands are then given into a post-processor for target detection [5][6].

IV.ZERO-PHASE IIR FILTERS DESIGN

IIR filters are effectively used for signal decomposition. The only problem associated with these filters is addition of random phase delays because of nonlinear delay variation of filter. Now, due to the random phase delay the exact location of targets cannot be determined. This problem can be overcome by the use of zero-phase filter.

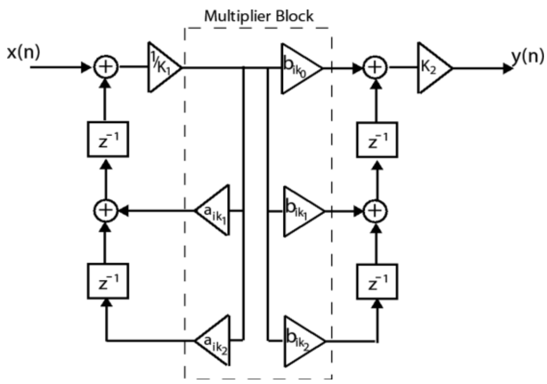

Fig.3 Second order IIR filter structure.

IIR filters are having feedback path, due to this they become very sensitive to integer operation and quantization. Any overflow and rounding errors can make its operation unstable. So, in this paper we are using IIR filters which are more resilient to errors. Therefore, higher order filters are divided in terms of 2^{nd}-order filters and implemented in cascade form as shown in fig.3.

Fig. 4 shows the zero-phase IIR filtering operation steps.The design of ZP-IIR filter can be achieved in the following mannar as:

Step1: The discrete backscattered ultrasonic signal is time-reversed;

Step 2: Then filter it with an IIR bandpass filter, H(z);

Step 3:output of the IIR bandpass filter is then time-reversed;

Step4: then filter it again by the same IIR bandpass filter. Ultimately, it can be shown that the last output is not phase distorted [7].

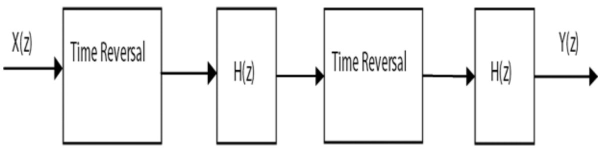

Fig. 4 Zero-phase IIR filter implementation.

V.SSP IMPLEMENTATION USING ZP-IIR FILTERS

We have to implement our zero-phase IIR filters in the ultrasonic detection system. Eight bandpass filters are used for SSP implementation. Time reversal logic is also used here.

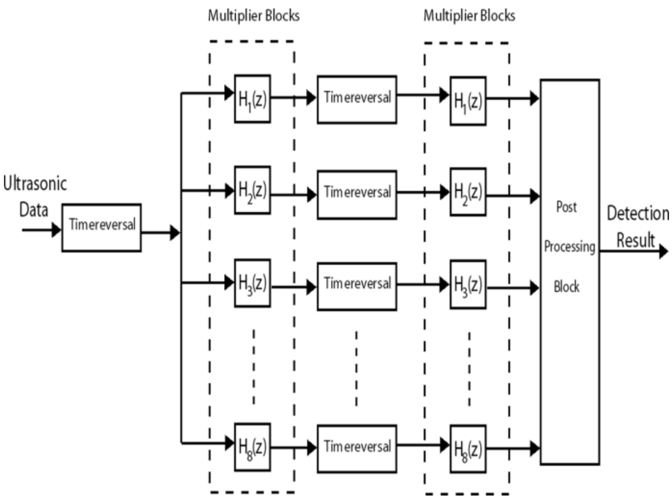

Fig.5 SSP using ZP-IIR filters.

Multiplier blocks are used for constant coefficient multiplications for 16 filters. Total latency of the system is 2N clock cycles for n-point input data. Here N clock cycles are performed in first IIR filtering and after time reversal another N cycles are performing in second IIR filtering. Finally all the data is collectively passed to post processing block and detection results are displayed.

VI.CONCLUSION

In this paper, split spectrum processing is analyzed after that design of ZP-IIR filers is carried out. Split spectrum processing is then performed by the filters. SSP is used for signal-to-noise decorrelation. This paper is having future scope as implementing these filters in FPGA based architecture. All the architecture will follow the principal of system-on-chip (SoC) development.

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