ULTRASONIC IMAGING USING CORRELATION TECHNIQUES

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ABSTRACT

We report here results of comparative experimental studies between pulse-echo and correlation imaging systems. The latter is optimized by computer simulation in order to reduce the signal to clutter ratio. The experimental results - in A mode - shows that in correlation experiments, the emitted power is about 10^4 times lower than the power needed in the classical pulse-echo technique to extract an echo signal from ambient noise.

INTRODUCTION

In a B-scan imaging device the system generates perodically a short duration high voltage pulse, e(t), which is sent to the transducer and causes pressure impulse to be launched into the medium. Part of the emitted energy is reflected by various discontinuities of the medium. In the linear regime of operation the received signal, s(t), is expressed as:

$$s(t) = \int h(t)\ e(t-\tau)\ d\tau \ = e(t) * h(t) \qquad (1)$$

where h(t) is the combined response of both the propagating medium and of the transducer working alternatively in its transmission and reception mode. If e(t) is short enough ($e(t) \approx \delta(t)$) the received signal, s(t), provides the impulse response of the system.

It can be shown [1] that, for linear systems, the cross correlation,

$$R(\tau) = \int e(t)\ s(t-\tau)\ dt \ , \qquad (2)$$

is also related to the impulse response h(t). Indeed taking into account equation (1) one gets:

$$R(t) = Cee(t) * h(t)$$

$$\text{where } Cee(\tau) = \int e(t)\ e(t-\tau)\ dt \qquad (3)$$

If e(t) is a cyclic pseudorandom binary code [2] Cee can be considered as a Dirac impulse to a good approximation.

Although both pulsed and correlation systems appear equivalent, the correlation technique provides an enhanced signal to noise ratio (SNR)[3]. The increase in SNR partially overcomes the dependence of the attenuation on the frequency and on the depth. This will allow us to explore biological tissues of increased thickness without increasing emitted energy and for a given tissue thickness to significantly increase the signal frequency, leading to an enhanced image resolution. Futhermore, because the correlation technique preserves phase information signal processing of received echoes could be done in order to provide quantitative information about the medium.

EXPERIMENTAL RESULTS

In order to demonstrate the applicability of the correlation technique to ultrasonic imaging we performed computer simulation of an echographic A-mode line. Propagation mechanism such as diffraction, attenuation and diffusion were considered separately first and then all together in order to provide a comparison between the correlation and conventional echo system. Propagating medium absorption was considered weak enough to separate attenuation and diffraction effects. Furthermore we neglect multiple scattering (Born's approximation). Most of the simulation was performed in the frequency domain and the temporal behaviour was obtained by FFT of computed results [4]. The computer simulations of an echo A-type line allowed us to optimize the emitted signal and to design the signal processing apparatus that uses the correlation procedure. Our experimental system uses two paired transducers mounted on the top of a water tank one used as an emitter and the other as a receiver. Their working frequency was 2.25 MHz and their corresponding bandwidth was 1 MHz. The electric signal was a 511 bits pseudorandom code. The duration of each bit was 0.44µs and its amplitude was randomly set to +0.3 or -0.3 volt. The target, a 1.5 mm in diameter silicon tube, was embedded in a synthetic sponge (α = 0.5 dB/cm MHz). The sponge was used because the high reflectivity of its internal structures yeilds a noisy background in ultrasonic images and mimics the speckle echoes of biological tissues.

The figure below shows an A-mode echographic line obtained with the correlation technique. The significant peaks correspond to the front plane of the sponge (1), the front wall (2) and the back (3) of the silicontube.

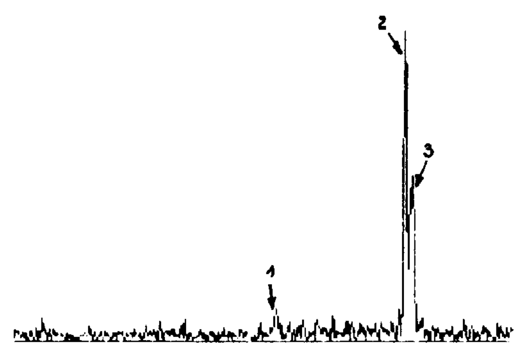

Figure 1. An A-type line obtained with correlation system

Using the same experimental setup, we performed a similar experimentin pulsed mode. A 90 volts (peak to peak) amplitude pulse was necessary to extract unambiguously the echo tube signal from the ambient noise. Thus in correlation experiments the emitted power was 1.7 10^4 times lower than in classical ultrasonic technique.

This study shows the advantages and the feasibility of the correlationtechnique in medical imaging and nondestructive testing where noisy and strongly attenuation media are encountred

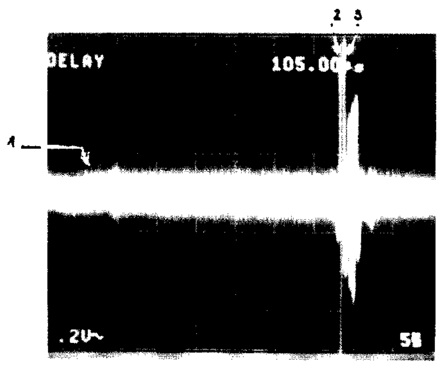

Figure 2. An A-type line obtained with pulsed system

REFERENCES

[1] J. MAX, "Méthodes et techniques de traitement de signal," Masson ed. Paris France (1985)
[2] N.W. PETERSON, "Error correcting codes," J. Wiley and sons, N.Y. USA (1961)
[3] D.NAHAMOO, A.C.KAK, "Ultrasonic echo imaging with pseudorandom and pulsed sources," Ultrasonics, Vol.3, pp.1 (1981)
[4] M..GINDRE, C.LEBEAULT, J.PERRIN, F.RIEUNEAU AND W.URBACH. "Acousticalimaging," Vol 17 tobe published

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