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J. Heyman
National Aeronautics and Space Administration

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A NON-PHASE SENSITIVE TRANSDUCER FOR ULTRASONICS

J. Heyman
NASA-Langley Research Center
Hampton, Virginia 23665

I would like to describe some of our programs at NASA, Langley Research Center, Hampton, VA, on the development and use of a new type of phase insensitive transducer we call an Acoustoelectric Converter, or an AEC. In the very short time I have here, I shall indicate why the AEC is significant and show some ultrasonic transmission results obtained from modified isometric attenuation scans of conventional NDE resolution test plates containing simple flaws.

In general ultrasonic NDE, an acoustic wave incident on a transducer is composed of many phase fronts and frequency components which are all added in a complicated way with conventional phase sensitive transducers. For example, consider the simplest use of just two phase fronts at the same frequency entering a piezoelectric transducer from the left, as shown in Fig. 1. To the right of the transducer, the electrical signal thus produced is shown.

If the two incident waves are slightly out of phase, the resulting electrical signal is reduced as shown in Fig. 2. This occurs because a conventional transducer is phase sensitive and averages the piezoelectric voltages.

If the acoustic waves are composed of two different frequencies entering the piezoelectric transducer, then severe phase modulation occurs as shown in Fig. 3. In other words, the use of piezoelectric transducers suffers, if you will, from too much information in some instances; i.e., their output is modulated due to the phase of the acoustic wave front.

Figure 1. This figure shows two incident ultrasonic waves entering from the left and impinging on a conventional piezoelectric transducer in the center of the figure. To the right is shown the resulting electrical signal obtained from the transducer for waves of the same frequency and phase.

Figure 2. Same as Fig. 1, but with a phase shift between the two incident waves. Note the decreased amplitude of the electrical output as compared to Fig. 1.

Figure 3. Same as Fig. 1, but with a frequency shift between the two incident waves. In this case note the severe modulated electrical output.
If one were able to develop a transducer truly insensitive to phase, then, regardless of the phase and the frequency of the incident waves, the resulting signal would merely be the incident power. This is shown for two incident waves of any phase or frequency in Fig. 4. Note that the output for this case is not modulated and that it is a D.C. signal consistent with the concept that the AEC is a power "monitor."

Figure 4. This figure shows the effect of a real power detector instead of a piezoelectric transducer for all cases of phase and frequency. The AEC mentioned in this article approximates a power detector. Note that the output is constant for all phase and frequency and that the signal is effectively D.C.

The characteristics of the AEC are desirable and may provide a significant improvement in NDE as well as ultrasonic imaging quality. The basis for these statements is provided by several figures obtained with the AEC and a conventional transducer. These are presented below without going into the specifics of the AEC which will be forthcoming in another paper. These data are obtained by scanning a conventional flat aluminum test plate with some milled flat bottom grooves and some rather small flat bottom holes. A photograph of the plate is shown in Fig. 5. The smaller holes are of the order of 500 microns; the larger are of the order of a millimeter in diameter. The plate is scanned in a transmission experiment, which is not necessarily the highest resolution technique for conventional detection but does demonstrate the difference between the two transducers.

In Fig. 6, one finds a very complicated signal obtained with a conventional piezoelectric detector. Looking back at Fig. 5 again, one can see that the large grooves are visible but the holes are obscured by the phase information.

Replacing the receiving transducer in this transmission experiment with the new AEC transducer and repeating the scan at the same frequency, one obtains the response shown in Fig. 7, from the plate of Fig. 5. In Fig. 7, using the AEC, one clearly sees the rather small holes. There is no obvious presence of phase modulation which would produce a background signal. Furthermore, one can see in the large grooves that plate resonances are being excited, which is not so obvious from the conventional transducer data of Fig. 6.
In conclusion, we think we have a new transducer which has very definite application to high resolution NDE. It's by no means optimized; we have by no means looked at all the parameters, but we are enthusiastic as to the future potential for the device.

Thank you.

Figure 7. Same identical test as shown in Fig. 6, but with the receiving transducer replaced with an AEC. The small holes are clearly visible and plate resonances in the large grooves are easily discernable.

DISCUSSION

DR. JERRY TIEMANN (General Electric): Would you please state the physical principle or the construction of that transducer?

DR. JOSEPH HEYMAN: Certainly. The transducer is a device which converts the incident acoustic wave into an electrical current through the coupling of the phonons to the free electrons in the detector. It's basically an acoustoelectric-type of detection scheme. When the acoustic wave is incident on the detector, the momentum transferred by the acoustic wave to the electrons results in an electric current which will be independent of the phase of the incident acoustic wave. Therefore, the conversion process of the AEC makes it non-phase sensitive.

PROF. VERNON NEWHOUSE (Purdue University): Was it you who gave the paper at the American Institute of Ultrasonics in Medicine conference of a few weeks ago?

DR. HEYMAN: No. No, I did not.

PROF. NEWHOUSE: Not you or one of your collaborators?

DR. HEYMAN: Dr. Miller and his group at Washington University have been applying the AEC in the medical area for tissue characterization.

PROF. NEWHOUSE: Yes.

DR. HEYMAN: I might add that some very striking figures will be presented by Dr. Miller at the IEEE Ultrasonics Symposium in October, 1976.

DR. STEPHEN HART (Naval Research Labs): What sort of frequency range are you getting at the present time?

DR. HEYMAN: The AEC has been used up to about 10 MHz although there is no practical NDE limit on the higher frequency; at the lower frequency limits, one has less conversion so that there is a poorer signal to noise ratio. With the AEC, one cannot convert the acoustic wave to an electrical signal at the lower frequency without losing some signal strength.
ADAPTIVE DECONVOLUTION TO IMPROVE RESOLUTION*
E. S. Furgason & V. L. Newhouse
School of Electrical Engineering
Purdue University
West Lafayette, Indiana

ABSTRACT

Deconvolution applied to ultrasonic flaw detection offers the possibility of greatly improved resolution through the elimination of the transducer response. Seydel has previously demonstrated that at least a modest increase in resolution is possible provided the signal-to-noise ratio of the signal being deconvolved is large enough. The random signal flaw detection system can be shown to be ideally suited to deconvolution since it provides enormous signal-to-noise ratio enhancement. Furthermore, the bandwidth compression inherent in this system allows A-D conversion of the output at a rate several orders of magnitude lower than the transmitted ultrasonic frequency.

The computer program created to implement the deconvolution procedure also utilizes elementary pattern recognition techniques to deal with the remaining signal noise and ensure a good signal-to-noise ratio for the deconvolution output. The operation of this program was discussed and some preliminary results were presented which showed that at least a ten-fold increase in resolution is possible. At present this processing technique is restricted to a special class of targets, those composed of a series of plane surfaces.

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