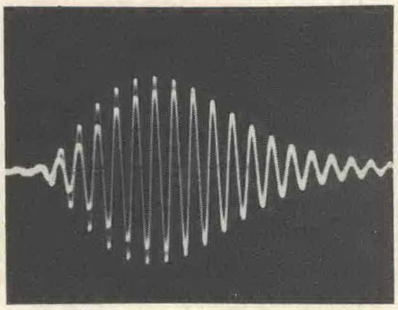

FIG. 4. Oscilloscope display of echoes 2 and 3 from Fig. 2 properly overlapped with respect to "in-phase" condition. The delay time between these two echoes is 2 μsec. The carrier frequency is 20 MHz.

Matec model 2470 unit to provide the double delay strobe to intensify the two rf echoes being monitored on the oscilloscope for velocity changes. The strobes simultaneously open two gates within the attenuation recorder so as to select from the entire echo train the video form of these same two echoes. Following peak detection, the logarithmic difference between the two selected echoes is measured and displayed on a built-in X–Y recorder.

The velocity measuring section of the system depends on the matching of the period of the repetition-rate generator to the round trip time in the sample. The output of this generator is divided down by a factor of 100 or 1000 to what may be considered a more normal repetition rate for ultrasonic pulse-echo equipment. The low frequency trigger is referred to as the Master Sync. For a preliminary setup, this Master Sync is used not only to trigger the rf pulsed oscillator and the attenuation recorder but also the oscilloscope. A conventional display of rf echoes, as shown in Fig. 2, is obtained. The time delays of the attenuation recorder may then be adjusted so that the output strobes intensify those two echoes to be monitored. The video output of the receiver may be displayed also on the dual display oscilloscope. An automatic gain control (AGC) circuit in the attenuation recorder may then be energized. This will maintain the first strobed (and selected) echo at a constant amplitude which is necessary for proper operation of the model 2470. The next step is to switch the oscilloscope x axis to the output of the repetition-rate generator. Ideally, under these conditions, each echo is displayed on a separate sweep on the CRO. If the intensity is turned up, all the echoes will, indeed, be observed (providing a fast enough sweep is used so that sufficient retrace time is provided). As the intensity is slowly backed off, all echoes except the two being strobed will extinguish, and the display shown in Fig. 3 will be observed (only single channel operation should be used at this point). The frequency of the repetition-rate generator can now be critically adjusted for proper superposition, as shown in Fig. 4. Some difficulty may be experienced in obtaining proper scope synchronization because of the very high trigger rates and short recovery times available. It may then be necessary to apply the sinusoidal output of the HP-606B directly to the horizontal amplifier input. A satisfactory display can be obtained in this way. However, a triggered operation of the scope is preferable for two reasons: first, a linear sweep is obtained; second, a dual display operation of the scope is possible. In the dual display mode the rf echo output of the receiver may be applied to both vertical inputs and the scope attenuators adjusted so that both the monitored echoes have approximately the same amplitude. Such a display assists in adjusting the repetition-rate generator for exact phase overlap.

This modified method has several advantages over the pulse superposition method. The pulsed rf oscillator is driven at a relatively low PRF which insures stable operation. The CRO display consists of the rf overlap of *any* pair of returning echoes in the decaying pulse train (rather than the superimposed addition of all echoes in the train). While the pulse superposition method requires an echo train of at least 10 reasonable returning echoes for an accurate and unambiguous measurement, the pulse-echo-overlap method requires only two good echoes. The difference in CRO display allows accurate measurements of time delay in high loss materials. Another advantageous feature of the pulse-echo-overlap method is that the method allows an observation of the rf display directly rather than a video (rectified) display. Therefore, in practice, measurements are easier to make; the proper "in-phase" condition can be applied visually. In addition, the technique is no longer critically dependent on the shape of the pulse envelope.

The division factor of the triggering oscillator could be, in principle, 10^4 or even 10^5 which would allow measurements of velocity in extremely thin samples subject only to the limitations imposed by the loaded Q of the transducer. It is concluded that the modified ultrasonic pulse-echo-overlap method (after Papadakis) allows one to make accurate measurements of the acoustic velocity for extremely small samples and offers the only technique presently available to isolate and study the phase shift due to the transducer–sample bond. The method discussed here provides for simultaneous measurement of acoustic attenuation and velocity of elastic waves.

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