may be determined directly. A low level continuous wave from the other harmonic generator can be superimposed on the reflected pulses. Then the frequency can be varied until the reflected pulses can be varied until the reflected pulses move up and down in unison when the phase (delay) of the low level continuous wave is varied. This will mean that the path is an integral number of wavelengths at the frequency being employed. A measurement of this frequency will give an accurate measure of the velocity of wave propagation.

2) Method 2 -- Phase Comparison -- A second method is a special phase comparison technique for relatively high attenuating materials where only two or three echoes of the ultrasonic signal can be observed. The block diagram is shown as Figure 20.

For this method, two similar pulses are propagated in the material through an appropriate delay so that the driving signals will not interfere with the reflected signals. Initially, both signals are applied simultaneously, then the phase of amplitude of one is adjusted slightly for complete cancellation of the first echo reflected from the back of the test specimen. Gate 2 is opened later than gate 1 so that the first reflection from the second gate lines up with the second echo from the first gate. The frequency is then adjusted until phase cancellation takes place between these two reflections and each of the subsequent pairs. At this frequency, the path length will be an odd number of half wavelengths and an accurate velocity determination can be obtained when the frequency is known.

3) Method 3 -- Modified Phase Cancellation -- The third method is a modification of the first technique discussed. It appears that it would be easier to implement than the first technique for materials which do not attenuate the ultrasonic signal excessively. The block diagram is shown as Figure 21.

The transducer is placed on the test specimen and driven by a wave train which is approximately three times the length of the test specimen in that material. This causes the last one third of any given wave train to be adjusted until phase cancellation or addition takes place for each of these successive reflections where the signals overlap. The time between reflections which can be obtained from the oscilloscope display and knowledge of frequency being used permit an accurate determination of the transit time of the ultrasonic pulse.

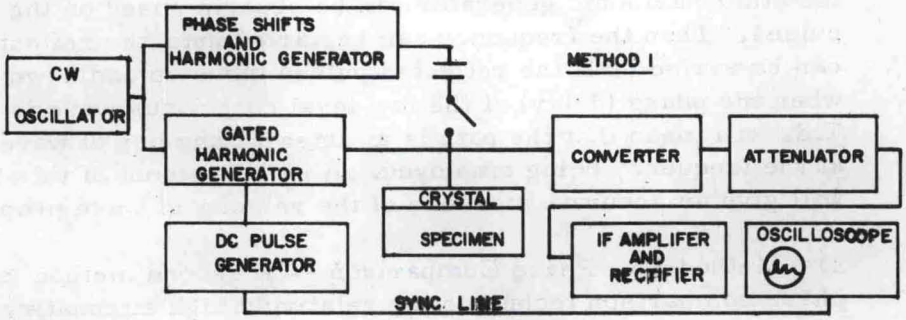

Figure 19 BLOCK DIAGRAM FOR PULSE-ECHO PHASE COMPARISON MODE

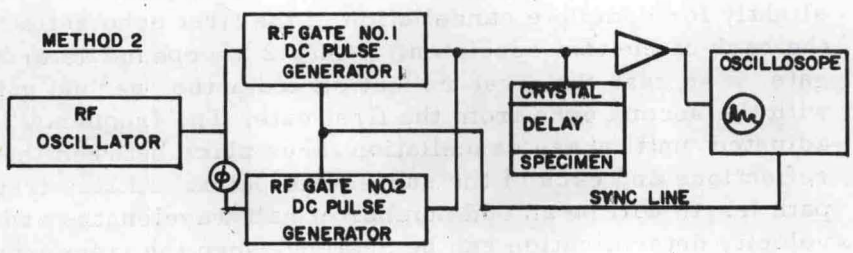

Figure 20 BLOCK DIAGRAM FOR PULSE-ECHO PHASE COMPARISON MODE

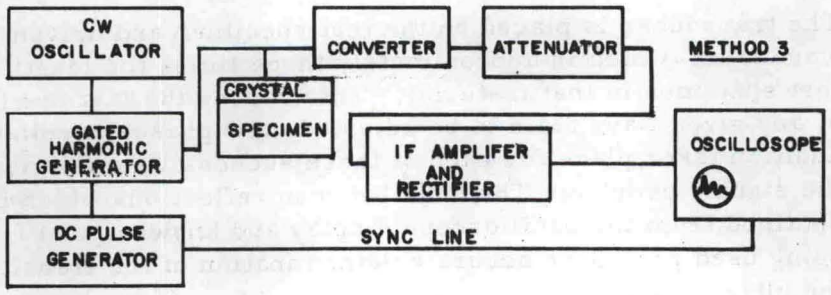

Figure 21 BLOCK DIAGRAM FOR MODIFIED PHASE CANCELLATION MODE