A TWO-DIMENSIONAL ULTRASONIC SCANNING SYSTEM

W. Rockwell
Nova Scotia Technical College
Halifax, Nova Scotia

B. Grogono
Halifax Infirmary
Halifax, Nova Scotia

ABSTRACT

A two-dimensional scanning system has been developed for use with an ultrasonic pulse echo diagnostic unit. The output is a cross-sectional display on a memory CRT. The main application of this apparatus is in the study of the structure of the soft tissue and bones of the limbs. It is anticipated that the system may be used to study the healing of fractures and to outline soft tissue structures not adequately represented by radiographs.

The object to be studied is placed in a tank filled with water. A transducer is mounted on a circular ring and located such that the transducer face is below the surface of the water and perpendicular to the object to be studied. The ultrasonic pulse path is a diameter of this mounting ring. As the transducer is rotated on this ring, the direction of the CRT trace rotates correspondingly to produce a one-to-one mapping on the face of the CRT of the area seen by the transducer.

The CRT beam is controlled by an electronic transducer position sensing circuit. This circuit maintains the proper trace direction, relative to the transducer, while maintaining a constant trace length and beam velocity. The CRT beam is unblanked whenever an echo is received, producing light spots on the CRT at all the interfaces of the sample under study. With a 360-degree rotation of the transducer, a cross-section of the sample is displayed on the face of the storage CRT.

The two-dimensional ultrasonic scanning system is basically a modified Hewlett-Packard 7214 diagnostic unit. This unit can operate at frequencies from 1 to 10 MHz. The ultrasonic transmitter delivers a single high-frequency pulse to the transmitting-receiving crystal. At the instant that the pulse is transmitted, the receiver is turned on and the beam begins to sweep across the CRT readout. The velocity of the CRT beam corresponds to the velocity of sound in water. Thus, the CRT beam moves across the face of the CRT to correspond with the ultrasonic pulse travelling through the medium under study.

Normally, the CRT beam is blanked; therefore, it is invisible as it moves across the face of the CRT. When the ultrasonic pulse passes into a medium with a change of acoustic impedance, an echo is returned to the crystal transducer. Upon reception of this echo, the diagnostic unit unblanks the CRT beam through an intensity modulation system. This produces a light spot on the storage CRT at the position corresponding to the interface where the echo originated. The distance on the CRT from the transmitted pulse to the echo pulse gives the distance to the acoustic interface in the medium under study.

The modification designed for this diagnostic unit consists of a change in the sweep circuits of the CRT readout unit.

In the system used here, the transducer is mounted on a carriage which travels on a circular track, 24 inches in diameter and mounted on top of a tank of water. Figures 1 and 2 are a top and side view, respectively, of the transducer mounting system. The ultrasonic path is always a diameter of a circle located in a horizontal plane of this tank. This carriage is coupled to a potentiometer so that a signal voltage corresponding to the transducer position is obtained from this mechanism.

A block diagram of the sweep system is shown in Figure 3. The inputs to this sweep circuit are the horizontal ramp, A, generated in the ultrasonic transmitting unit and the carriage position voltage X.

The transducer position sensing device outputs a voltage corresponding to a transducer position of from 0 to 360 degrees. This signal is amplified and fed into a quadrant detection unit which outputs two signals. One signal is an analogue signal of from 0 to 9 volts, corresponding to a transducer position, θ, of from 0 to 90 degrees for each of the four quadrants. The second signal is a digital signal which indicates the appropriate quadrant.

The angle of the transducer θ is fed into a cosine and sine module which outputs a signal corresponding to $\cos\theta$ and $\sin\theta$, respectively.

The sweep signal ramp, A, controls the sweep speed. The slope of this ramp corresponds to the velocity of sound in water. This signal ramp A is amplified to a level B and then fed to two multipliers where it is multiplied by the functions, $\cos\theta$ and $\sin\theta$, respectively. Thus, from the two multipliers, we have the signals $B\cos\theta$ and $B\sin\theta$, respectively. The two signals, $B\cos\theta$ and $B\sin\theta$ are amplified and inverted to produce the functions $\pm A\cos\theta$ and $\pm A\sin\theta$. These four functions along with the quadrant information from the quadrant detection circuit are fed into a deflection circuit switching unit which selects the signals which must be applied to the vertical and horizontal amplifiers of the CRT. In each quadrant, the vertical and horizontal signals are of the form shown in Table 1. Thus, the sweep velocity is:

$$\frac{d}{dt}\sqrt{A^2(\cos^2\theta + \sin^2\theta)} = \frac{d}{dt}A$$

The sweep velocity is the slope of the input ramp A and is constant for all θ.

The operation of this system is accomplished by placing the sample under study in the tank, as shown in Figure 1. The transducer is rotated 360 degrees on its carriage. At the same time, the CRT beam rotates and produces light spots on the CRT at the interfaces in the medium under study. The sample, shown in Figure 1, consists of a plastic tube. The CRT readout for this sample consists of two concentric circles representing the inner and outer boundaries of the tube.

CONCLUSIONS

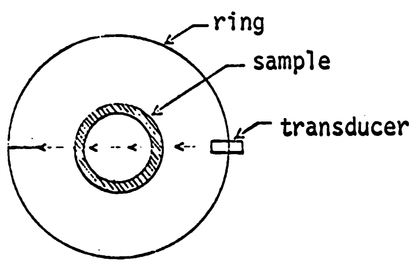
This system is completely electronic, except for the transducer rotating mechanism. In the system, as shown here, the transducer is rotated by hand. If a very fast system is required, the transducer carriage may be replaced by a ring of transducers pulsed sequentially. Each ultrasonic pulse requires 1 ms to traverse the tank and return. For a resolution of 1 degree, 360 transducers could be used with a 360 degree trace accomplished in less than 500 ms. This allows adequate time between transmissions to prevent the transmitted pulse from interfering with the received pulse.

Table 1

Quadrant	Horizontal Signal	Vertical Signal
1	A cos θ	- A sin θ
2	- A sin θ	- A cos θ
3	- A cos θ	A sin θ
4	A sin θ	A cos θ

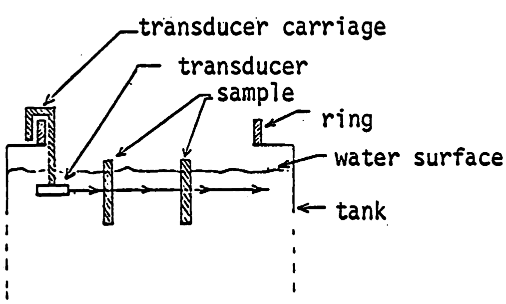
Input to the x - y Amplifiers for Each Quadrant

Figure 1



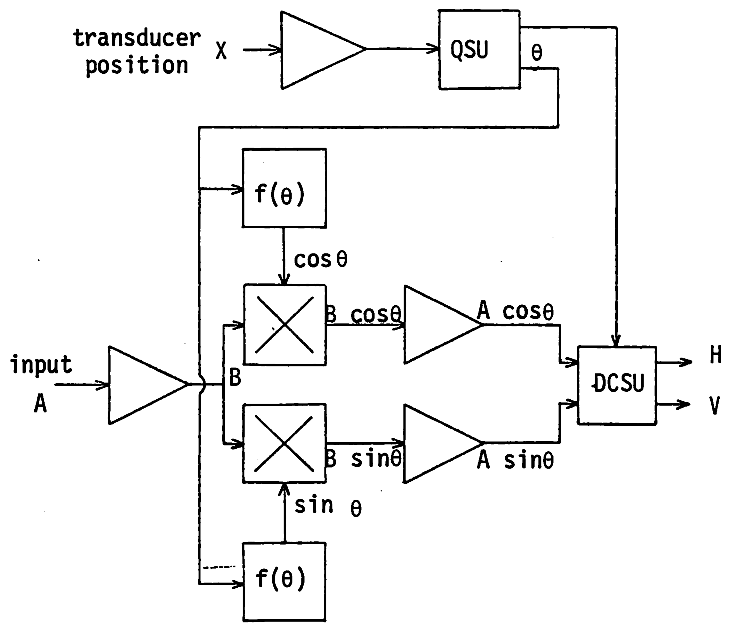
Top View of Transducer Mounting System

Figure 2



Side View of Transducer Mounting System

Figure 3



QSU --- Quadrant Sensing Unit

DCSU --- Deflection Circuit Switching Unit

H --- Horizontal Amplifier

V --- Vertical Amplifier

Block Diagram of Sweep Circuit