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SHORT PULSE PROPAGATION BETWEEN THICK TRANSDUCERS IN A WATER MEDIUM.

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INTRODUCTION

Kozina and Makarov (1) showed that a transient disturbance in the field of a baffled plane piston radiator consisted of a direct wave which was geometrically bounded by a right prism with the piston surface as base and an edge wave which was radiated from a line source around the periphery of the piston. Both components radiated into the half space in front of the piston and combined in opposite phase in the acoustic field. This combination can be described by an equivalent impulse response (2). The field response to any real source velocity function is derived in the time domain by convolution. For short transient source functions the direct and edge wave components can be resolved separately in time. Weight and Hayman (3), using single cycle 4MHz radiation showed experimentally that the edge wave signal is dominated by radiation from those points on the line source which were closest to and furthest from the field point under study. Layton et al (4) have published similar evidence using Gaussian shaped pulses of 200 ns duration. In this paper experiments are described in which rapid step function transients (rise time $<$ 20 ns) are propagated between two piezoelectric transducers set in a water medium. The use of such short transients extends previous results to higher frequency limits.

ACOUSTIC FIELD STEP RESPONSE

Fig.1 shows two circular transducers aligned coaxially. Rhyne (5) has discussed the impulse response for radiation coupling between two discs of the same diameter. Similar ideas can be applied to two discs of different diameter. If the transmitter (the largest element in fig.1) is excited by a voltage step at time $t=0$, then the receiving transducer will receive the direct wave step at $t_0=z/c$. Diffraction components from the periphery of the transmitter arrive in the interval $t_1<t<t_2$ where $t_1=m_1/c$ and $t_2=m_2/c$. If we assume that the electrical signal at the receiver terminals is proportional to the average pressure on its face and that it has infinite bandwidth, then we would expect the edge wave to exactly cancel the direct wave during $t_1<t<t_2$. The resulting electrical signal consists of a rapid step at t_0, followed by a monotonic decay to zero during $t_1<t<t_2$ (inset, fig.1).

GENERATION AND RECEPTION OF SHORT ULTRASONIC TRANSIENTS

If 20ns transients were to be studied using plate transducers operating below their resonant frequency, then devices as thin as 25×10^{-6}m would be required (resonance frequency 100 MHz, lead zirconate-titanate material). It is technically easier to use very much thicker transducers generating short transient signals at low p.r.f.(6). The impulse response of a piezoelectric element operating in this fashion consists of a series of impulses of alternating sign and diminishing at a rate depending on the backing and load conditions (7), fig.2a. Where two transducer elements are in a transmit receive system the overall impulse response of the two transducers is the convolution of their individual responses, fig.2b. If the dimensions of the two transducers are carefully chosen then the intervals between the reverberations in the overall transducer impulse response can be made large enough to accommodate the duration of the direct wave and edge wave diffraction components in the acoustic field, and these can be observed independently of transducer reverberation. The effective bandwidth available for such observation is very high and depends only on the losses associated with the transduction process at the active faces of the transducer.

THE EXPERIMENTAL SYSTEM

Two cylinders of PXE4 material (Philips Ltd) were used as transducer elements set in a water medium. The transmitter (10mm dia x 10mm long) was excited by an avalanche generator, rise time$<$8ns. The receiver (6.3mm dia x 16mm long) was terminated resistively (75Ω) and mounted on a micro manipulator. Both elements were connected to an oscilloscope, rise time 18ns. The transducers could be set with the distance between their active faces in the range 20mm to 80mm, $\pm$1mm. At each range position they were alligned coaxially as follows: The receiver was placed in a near coaxial position by eye and rotated until minimum rise time was observed in the step signal at its terminals. It was then traversed in two directions perpendicular to the transmitted beam. The positions at which the sharp rising edge of the transient disappeared at the extremes of the motion were noted and the coaxial position was taken as halfway between these two. The adjustment was performed alternately in the two directions until no change of axial position occurred in subsequent movements. Reproductability was $\pm$0.1mm. The waveform at the receiver was recorded at ranges z = 20, 40, 60 and 80mm.

RESULTS

The waveforms obtained at the transmitter and at the receiver terminals for each of the four range positions are shown on fig.3. The times t_1 and t_2 have been calculated from the geometry of fig.1 and marked on fig.3 (t_1 upward arrow, t_2 downward arrow). The internal propagation times in the two elements were calculated at 2.2μs and 3.5μs respectively. The signals at the receiver had the form expected of them; they rose rapidly and began to decay and reach zero at the predicted times t_1 and t_2. After one transmitting element propagation delay a transient of similar shape was observed of opposite polarity and twice the amplitude (marked b on fig.3) corresponding to the arrival of the backface transmitter component. After a total interval equivalent to one internal propagation time in the receiver a third transient was observed (c) which corresponded to the arrival of the transmitter front face signal at the back of the receiver element. The measured height of the initial peak in the receiver response was 94mv, which compares well with the value expected by calculation (87mv).

DISCUSSION AND CONCLUSION

The results presented above are in excellent agreement with expectation based on the transient analysis of both the acoustic field and piezoelectric transduction. The results are most important for two reasons: (a) They show that very fast transients may be generated using thick piezoelectric elements and this provides for signals of very high bandwidth which may be used to study diffraction phenomena; (b) The form of the signals received in a two transducer propagation experiment can be explained on the basis of direct wave/edge theory of near field diffraction.

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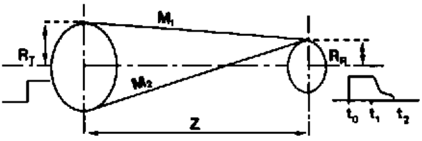

Fig 1 Circular transmitting and recieving transducers. Inset: Step response of acoustic field measured at reciever.

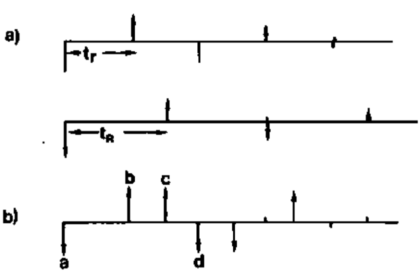

Fig 2 a) Impulse responses of different length transmitter and reciever elements. b) Responses combined by convolution.

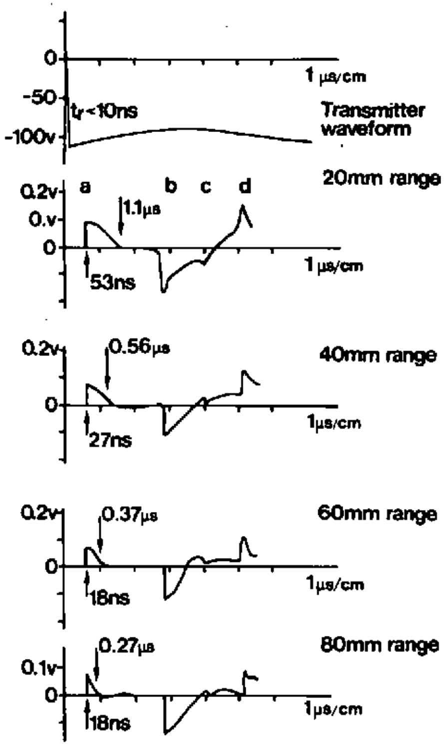

Fig 3 Waveforms obtained at the transmitter and at the reciever for each of the four range positions.