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DIFFRACTION CORRECTION CALCULATIONS FOR ULTRASONIC PROPAGATION FROM A DISC TO A DISC.

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Introduction.

When measurements of ultrasonic absorption are being made by the pulse method in the near field, it has been observed that the received signal amplitude does not decay exponentially with increasing path length in the sample, as might be expected. Rather the rate of decay appears to oscillate about a mean decay rate greater than would be attributable to the absorption mechanism alone, and the rate of oscillations is seen to decrease with increasing path length. It is now accepted that this additional loss is due to the diffraction that occurs in the transmission from, and the reception by transducers of finite dimensions.

The problem that the experimentalist faces is that of knowing how much of the measured attenuation to attribute to diffraction losses, and how much to attribute to the absorption of the sample. This problem has been dealt with by a number of authors(1), and for experimental situations involving co-axial transmitting and receiving transducers of equal sizes in a medium of low attenuation, there are a number of possible solutions available, from the tabulated amplitude and phase corrections by Khimunin(2)(3), to the easily calculable expansion of the analytical solution by Rhyne(4). More complicated experimental situations have been dealt with, for example Gitis and Khimunin (5) and Yamada and Fujii(6) have both calculated transfer functions for cases where the transmitting and receiving transducers are of different sizes, and Papadakis(7) has considered the effects of non-piston sources, although only analytic amplitude profiles were considered.

A numerical Solution.

The present study was undertaken because of a need for diffraction corrections suitable for application to an experimental situation involving the measurement of a wide range of ultrasonic absorptions, using transducers that were known to be non piston-like in both transmission and reception. The model used to calculate these corrections, and which has been described in detail elsewhere(8), considered the transmitter as an array of Huygens - Fresnel sources and the receiver as an array of elemental receivers. The received signal is calculated by considering the effect of each transmitting element on each receiving element, and the contribution of each receiving element to the final received signal. The model has been implemented on a digital computer in a form that rendered it more versatile than was immediately required by the experiments mentioned above.

To match the conditions in the experiments the transducers were allowed any radially symmetric amplitude and amplitude sensitivity distribution, and the medium could have any required absorption. In addition to these required features, the model was implemented such that:-

i) the transducers could have any radially symmetric phase and phase sensitivity distribution,

ii) the transducers could be of different radii, and

iii) the receiving transducer could be displaced off the axis of the transmitting transducer.

These additional features suggested an experiment that could be performed to validate the amplitude distribution measurements made over the surface of the transmitting transducer used in the original absorption measurements. In this experiment, field measurements were made with the transducer transmitting into water, and these were compared with the theoretical predictions of the model for a non piston-like transmitter and for a receiver of finite dimensions.

Experiment.

The transmitting transducer, which consisted of a 15mm diameter, 500mm long synthetic quartz buffer rod with a piezoelectric element bonded to its further end, was mounted against a polythene window let into the end of a water filled ultrasonic test tank. A 1mm diameter miniature hydrophone of high sensitivity was positioned in the test tank in front of the transmitter. With the transmitter being driven by short bursts of 1MHz. tone, measurements were made of the received amplitude and phase for up to 30 positions across the transmitted beam, at each of 23 separations, from 1.5mm to 18mm. Amplitude measurements were made by attenuating the received signal back to some preselected level, and phase measurements were made using a multiple time interval averaging technique with electronics developed by Aindow(9).

Results of some of these measurements, each with the appropriate theoretical curve generated by the computer model, are shown in Fig.1(a) and(b), for amplitudes and phases respectively. It should be noted that the amplitudes generated by the model are on an arbitrary scale, and that the predicted phases are only corrections and thus do not include contributions due to the separation between the transmitter and the receiving plane.

Discussion.

From the above it is obvious that no absolute correlation of either amplitude or phase is to be expected between experimental and theoretical values. Referring to Fig.1, for readings at radii greater than about 4mm, reasonable agreement can be seen between the shapes of the theoretical and experimental curves. Within the 4mm radius region, amplitude agreement at transducer separations beneath 10mm is poor, but at larger separations similarities in the structure can be seen as a minimum surrounding a central maximum, with the experimental minimum being at a slightly larger radius than the theoretical. In the same manner, the phase curves show similarities in structure in the central region although to a lesser extent, but again the features in the experimental curves occur at larger radii than in the theoretical.

It is clear that the central region will be the most sensitive to changes in the amplitude distribution across the transmitter, so that this region will exhibit the largest differences between experiment and theory in the event of errors

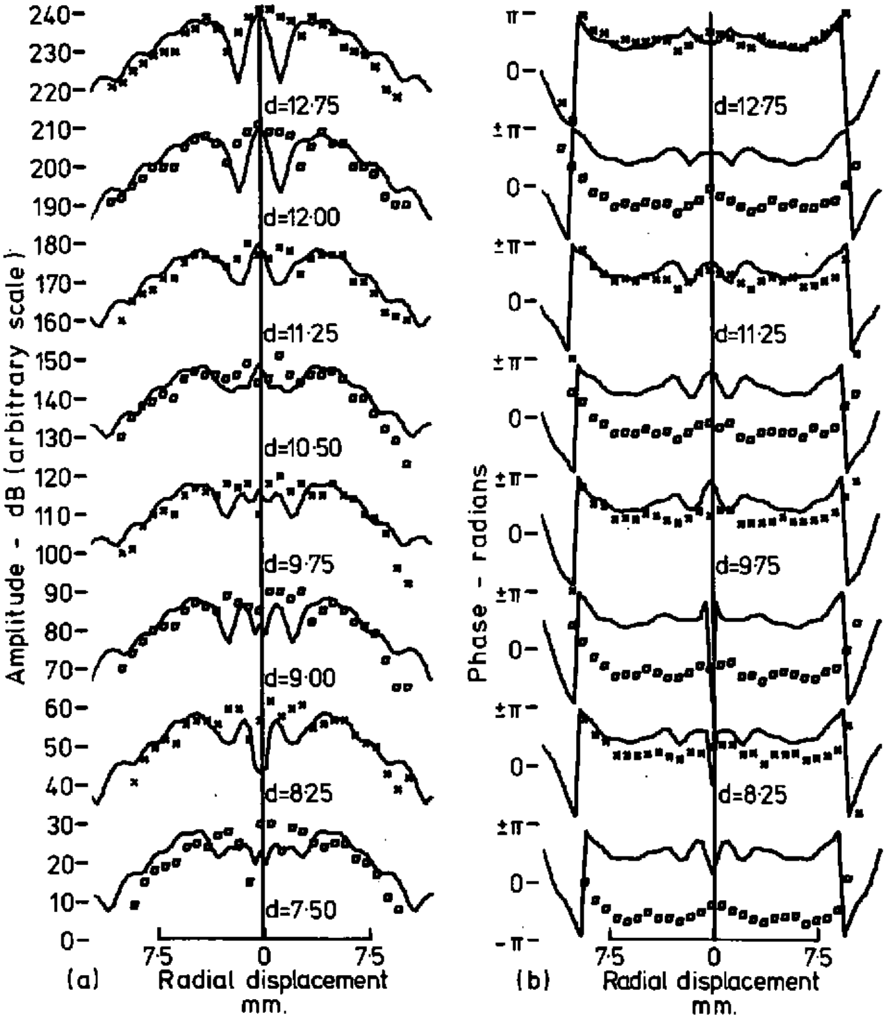

Fig.1. Field measurements of a 15mm diameter non-piston source measured with a 1mm diameter miniature hydrophone. (a) - amplitude, (b) - phase, solid line - theoretical predictions of model,□X- experimental points. 'd' - distance from transmitter to plane of the hydrophone, in mm.

being made in the original transmitter amplitude distribution measurements. When these measurements were made they implied a radial symmetry, and so such a symmetry was assumed for the model. It would appear, however, from the experimental points measured close to the transmitter that small irregularities in the symmetry of the amplitude distribution could have important consequencies for field measurements made close to the source.

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