BRITISH ACOUSTICAL SOCIETY
Meeting on Tuesday 6th June, '72
Gloucester Hotel, Weymouth.

Underwater Acoustic Test Facilities
and Measurements.

72·46

SOME PROBLEMS AND TECHNIQUES USED IN THE ULTRASONIC SIMULATION OF RADAR

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SUMMARY

This paper sets out a brief description of the simulation of radar by ultrasonic radiation. It then describes some of the problems encountered in carying out this task and the ways in which solutions have been found.

THE SIMULATION OF RADAR BY ULTRASONICS

In the evaluation of a radar system one important piece of information required is often the most difficult to obtain, namely the reflection characteristic of the target which it is hoped that the radar in question will detect. The way in which this varies with aspect angle, will determine the probability of detection for any given radar system, for known directions of approach. The use of ultrasonic radiation in water enables measurements to be carried out on scale model targets at any scale factor from 1 : 1 to 200 : 1. The table below shows the ultrasonic and scaled radar frequencies corresponding to scaling factor, and related to X band.

ULTRASONIC FREQUENCIES	50 kHz	500 kHz	1 MHz	2 MHz	4 MHz	10 MHz
WAVELENGTH	3 cm	3 mm	1.5 mm	.75 mm	.38 mm	.15 mm
SCALING FACTOR REL. TO X BAND	1.0	1/10	1/20	1/40	1/80	1/200
CORRESPONDING FREQUENCY FOR SCALED RADAR	10 GHz	100 GHz	200 GHz	400 GHz	800 GHz	2000 GHz

Since 1966 work has been carried out at EMIE Feltham in close association with R.A.E. Farnborough on the measurement of radar reflection characteristics of targets using the two facilities at Feltham housed in a 60,000 gal. water tank. The first facility consists of a fully automated narrow beam close range system (Ref 1) capable of accurately setting a target and ultrasonic probe in both position and angle and then scanning the target with a narrow beam of ultrasonic energy, producing a pen recorder trace of the reflection characteristics of the target.

The second facility consists of a manipulator, capable of setting a target in elevation and azimuth, and a fixed ultrasonic probe fully illuminating the target at long range. The output data from this consists mainly of tables of radar echoing area for the individual sources on the target at various aspect angles.

The majority of the acoustic problems have been concerned with the formation of specific radiation patterns which are required for the various ultrasonic probes and, it is these problems, all loosely covered by the general classification of beam shaping, with which the rest of this paper is concerned.

SIDE LOBE SUPPRESSION

For use on the short range narrow beam facility is is necessary to produce ultrasonic probes having radiation patterns equivalent to those produced by microwave slot arrays. Such arrays typically, have a tilt polar pattern of beamwidth ten degrees or less, with a fan beamwidth in the region of 100°. In order to produce beams of this nature, standard elements consisting of thin strips of PZT ceramic are used. For 1/20th scale of X band these are between 10 and 25 mm long, 0.5 mm wide and thickness resonant at 1 MHz. Standard elements of nominally uniform polarisation produce the correct pattern in the main lobe but have been found experimentally to have side lobe levels in the range 10-15 dB, which are not representative of a real aerial system as side lobes are normally suppressed to some 30-40 dB below the main lobe. To simulate this type of aerial, the same method of amplitude taper across an array as as used in the full scale case could have been applied. However the physical size of the elements need to be some 0.5 mm square with attendant difficulties in the manufacture of such an array. Two methods are being used to obtain the required suppression. Removing part of the silver electrode from one side of the transducer element an effective amplitude taper is achieved and the side lobes partially suppressed. Further modification of the side lobe level is obtained by shaping the waterproof wax coating which normally covers the element.. The combination of the two techniques makes it possible to produce elements with side lobe levels 50 dB below the main lobe.

FORWARD THROWN CONICAL BEAMS

In some applications the narrow beam produced by the microwave arrays is required to lie along the surface of a cone, having a semi angle of the order of 50-70 deg. to the array. This is achieved in the case of the microwave system by having a phase shift between each source but in the ultrasonic case this is not possible in view of the difficulties outlined above.

A solution is possible however by putting the transducer element in a slot between two glass plates. The top edge of this slot then acts as a secondary source and if the element is at an angle to the surface, this secondary source has a gradual phase shift along its length and the beam is then consequently thrown forward in the required manner.

THE FLAT TOPPED BEAM

In the fully illuminated target case, the objective is the measurement of discrete reflectors which make up a complex target. In order to do this the target is illuminated with a very short pulse of ultrasonic radiation and the return signals are displayed on a c.r.t. A-scan; range discrimination being used to distinguish between the various reflectors. A fairly uniform response across the width of the target is necessary rather than the (sin x)/x beam shape of a uniform disc transducer, otherwise reflectors of interest towards the extremities of the target appear insignificant when compared with similar reflectors at the centre. It is also important to have a sharp cut-off outside the target to avoid unwanted reflections from the target support.

It is well known in diffraction theory that the amplitude distribution across an aperture and the amplitude distribution of the radiated pattern in the far-field (defined as a^2/λ, where the aperture is 2a wide) are fourier transforms of each other. In the case of a piston source, the amplitude is uniform across the aperture and zero outside it, and the far-field radiated pattern consists of the well known Airy pattern. In the case under consideration a far-field pattern equivalent to the piston source distribution a source with an Airy distribution the far-field would consist of almost constant amplitude over a certain width and be zero outside this width. In theory the Airy pattern extends to plus and minus infinity but in practice only a small ripple results from truncating it. For the work in hand it was anticipated that an aperture of approximately twice the width of the main lobe which would include the main lobe the first side lobe and a proportion of the second side lobe would be adequate. An aperture of the correct size placed in the far-field of a piston source would represent a suitable source apart from considerable phase distortion across the aperture and, it is therefore necessary to introduce a compensating lens. Although it is relatively simple to calculate the position and diameter of this lens, the simple theory gives no indication of the form of the lens and an experimental approach to this problem was adopted. It was found by trial and error that a solid length of polystyrene terminating in a concave surface gave the optimum results.

ACKNOWLEDGEMENTS

The author wishes to thank E.M.I. Electronics Ltd. for permission to publish this paper and to acknowledge the work carried out on these subjects by his colleagues in the Ultrasonics and Assessment Group, Systems & Weapons Division.

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