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A HIGH POWER TRANSDUCER ARRAY

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INTRODUCTION

A new high power flexible transmitting system has been developed at the University of Technology, Loughborough (refs. 1,2). Basically this system comprises a large array, the separate staves of which are fed from individual high power linear amplifiers which in turn are driven from a flexible computerised multi-signal generator source - see figure 1. The transducer array is an important component of this transmitter in that it has to be capable of handling the high power levels involved and has to operate over as wide a range of frequencies as possible. It is the transducer array which controls the frequency range of operation of the transmitter since the remainder of the system can operate over a very wide range of frequencies.

ARRAY DESIGN

The desired centre frequency was to be about 40 kHz, and this together with the power levels involved, made piston elements the obvious choice for the array. The individual elements are based on the sandwich construction technique, and were mounted at a spacing of one wavelength at the centre frequency in a large nylatron slab. The element spacing and the desire to mount the elements as close together as possible, dictated the head diameter of 37mm, i.e. 0.91 lambda. The choice of the number of elements and the spacing was necessarily a compromise between cost and performance. To avoid grating lobes ideally the spacing should have been 0.5 wavelength but for a restricted number of channels this would give rather a wide beam. It was decided that 16 channels would be built and a spacing of 1 wavelength was chosen to give a beamwidth of about 3.5 degrees. The diffraction secondaries which appear at the endfire position are attenuated somewhat by the beam pattern of the individual elements but these lobes can be significant when the array is steered electronically.

Figure 2 shows the theoretical beam pattern for a 16 element point array with one wavelength spacing and figure 3 the beampattern of a single circular element diameter 0.91 lambda. Using the product theorem (ref. 3) of arrays we obtain in figure 4 the theoretical beam pattern for the 16 element array using these circular elements spaced at one wavelength centres.

The number of elements in each vertical stave was dictated to a large extend by the need to handle the required power of 1 kilowatt for each stave without cavitation but, of course, the narrow vertical beamwidth is also a practical advantage. Predicting the onset of cavitation is always a difficult matter since it depends on so many factors, but with the face area of an individual element of about 10.75 sq.cm. and to cope with the long pulses we would not expect to be capable of sustaining more than about 50/60 watts per element at an operating depth of 10 metres without cavitation (ref. 3).

The array was constructed in two halves in order to facilitate handling, particularly when the array is being deployed or recovered. Each half of the array, which can be used separately if required, contains 128 elements arranged as 16 staves, each of 8 elements, with the elements in each stave grouped into two sets of 4 to reduce the number of cables required. The total array then comprises 256 elements, i.e. 16 staves each of 16 elements. Figure 5 shows a photograph of the array being deployed at Foremark Reservoir where the testing was carried out.

When the two halves are joined it is not possible to keep the spacing at the joint of one wavelength. However a virtue can be made from this necessity. We showed earlier the beam pattern for 16 elements (figure 2). However a 16 elements array of 1 lambda spacing can be considered as the convolution of two arrays, one of 8 elements at 1 lambda spacing and one of two elements at 8 lambda spacing. The product theorem then allows us to obtain the overall beam pattern as the product of the individual patterns. Figure 6 is the beam pattern for the 8 element and figure 7 the beam pattern for the 2 element array. The product of these two patterns results in the pattern in figure 2. However if we have a gap of 1.5 lambda at the centre of the 16 element array due to constructing it in two halves, then we have to convolve the 8 element array with a 2 element array at a spacing of 8.5 lambda. This latter array has a beam pattern with a zero in the endfire position (figure 8). Thus when we multiply this by the 8 element pattern we get the result shown in figure 9. Finally this has to be multiplied by the individual element pattern giving the overall theoretical vertical beam pattern shown in figure 10. Although this pattern still has a significant lobe near endfire it is better than the original pattern when the array is unsteered and since the array will not be steered electronically in the vertical direction this then is not a problem. The main advantage is that we have avoided the endfire lobe which would have pointed straight up at the surface.

DESIGN OF ELEMENTS

The elements themselves were designed using a combination of standard techniques and iteration from data derived from known designs. A prototype was built and experiments were performed aimed at lowering the "Q". Eventually an element was built with a Q factor in water of about 4.5

During production the elements were monitored by regular plotting on an admittance bridge, so building up a "history" of the elements from bare ceramic to finished element. The elements were back mounted onto pieces of rigid sintactic urethene foam which were in turn glued into individual precision sockets bored in the two blocks of filled nylon. The front face of the array was moulded with a thin layer of Urethane.

Wiring of the elements into substaves, and connection of them to the bulkhead connector, was carried out in a cavity machined at the rear of the block. Thermistors were also incorporated to monitor internal thermal conditions.

Figure 11 shows the general outline of a basic element, and how they are mounted; Figure 12 the layout within the block.

RESULTS

The horizontal beam pattern of the array measured using a hydrophone suspended about 9 metres in front of the array is shown in Figure 13. Using the flexibility of the transmitter the array was focussed on to the hydrophone in order to simulate far field measurements.

Again using the flexibility of the transmitter to generate a long pulse in which the frequency of transmission is stepped over a suitable range, the frequency response of the array can be measured very simply. Figure 14 shows a photograph of the received waveform together with the derived frequency plot. Figure 15 shows the waveform received by the hydrophone under about 2/3 full power conditions. The waveform distortion at this power level, due to the acoustic non-linear effects, is quite obvious. This corresponds to a source level of about 240 dB, ref. 1μ pascal at 1 metre.

ACKNOWLEDGEMENTS

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[2] A.D. Goodson et al, 'A high power flexible sonar transmitter', IERE Conf., Edinburgh, March 1987.

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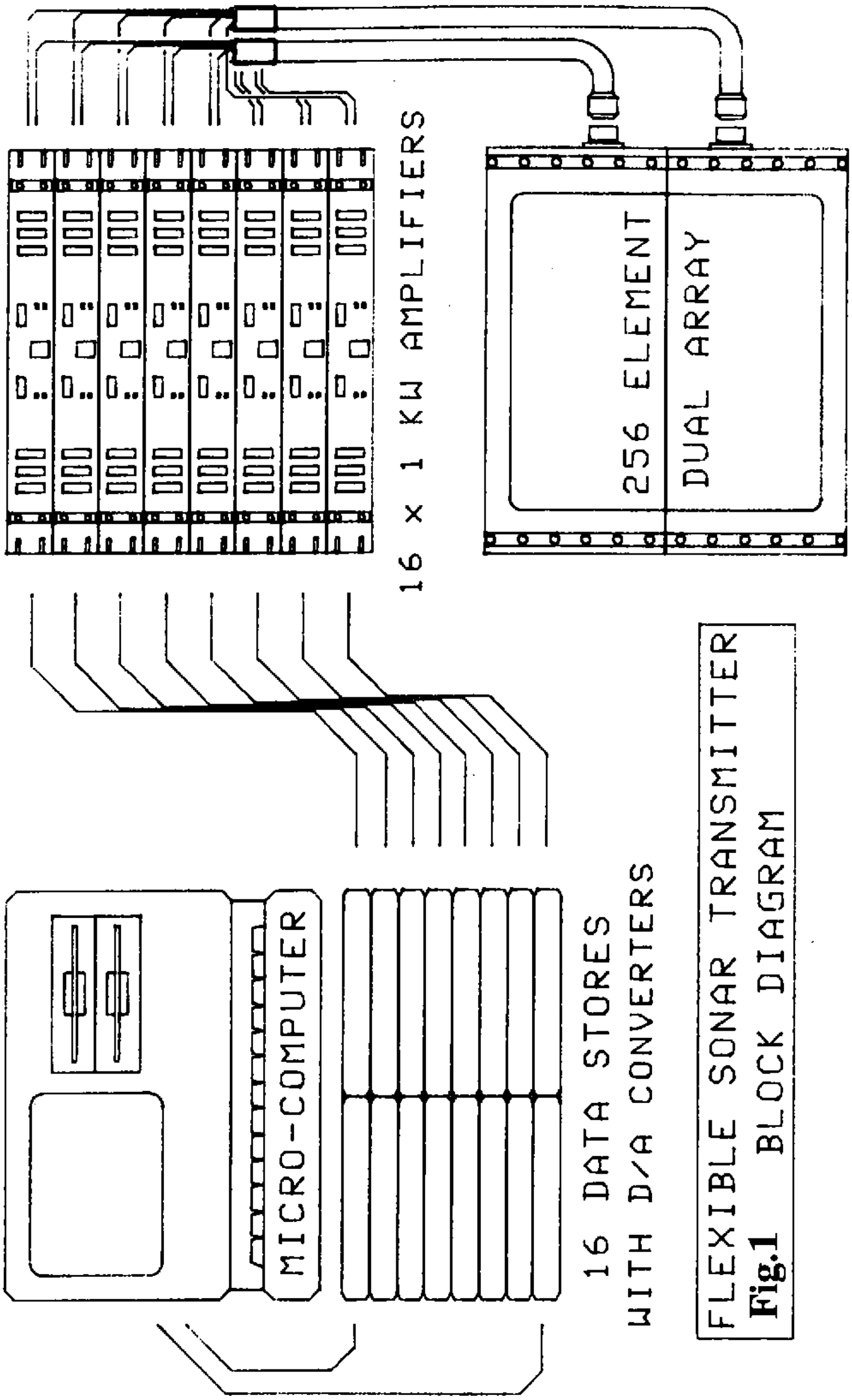


Fig.1 FLEXIBLE SONAR TRANSMITTER BLOCK DIAGRAM

A HIGH POWER TRANSDUCER ARRAY

Fig.2

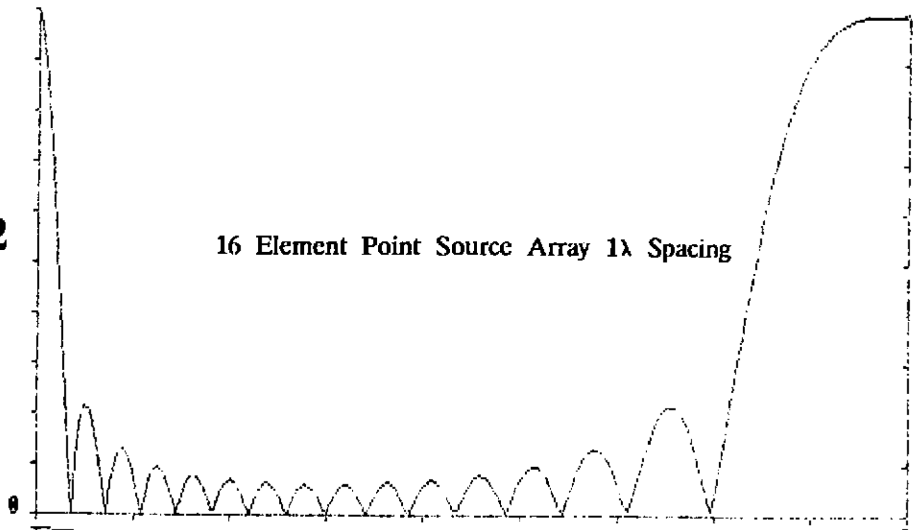


Fig.3

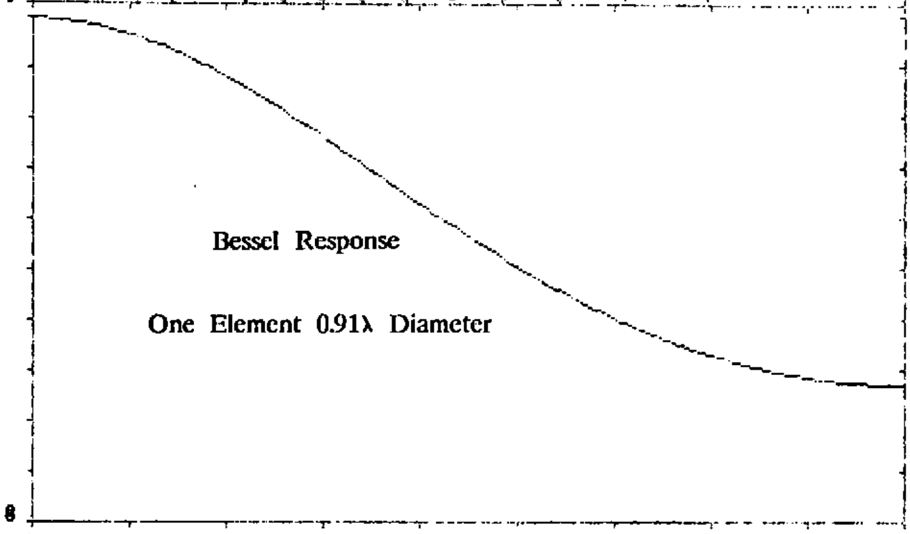
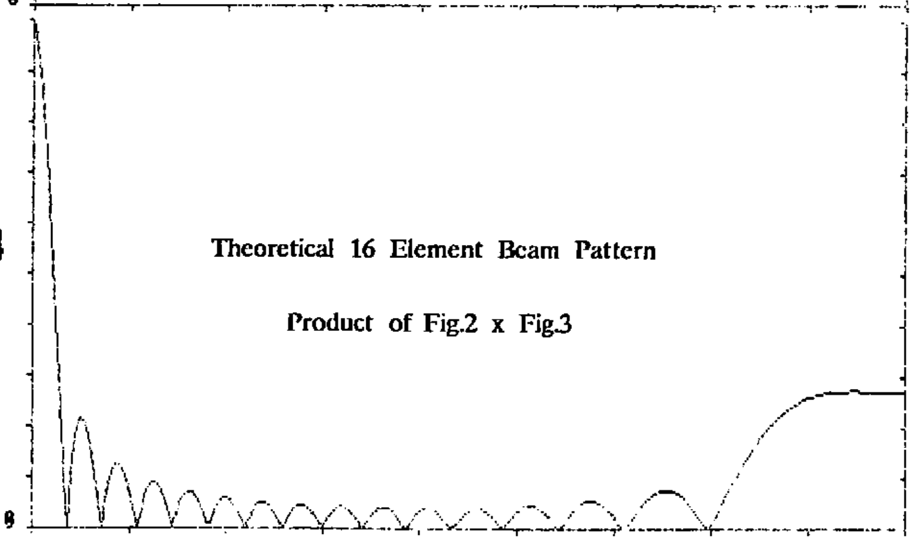


Fig.4



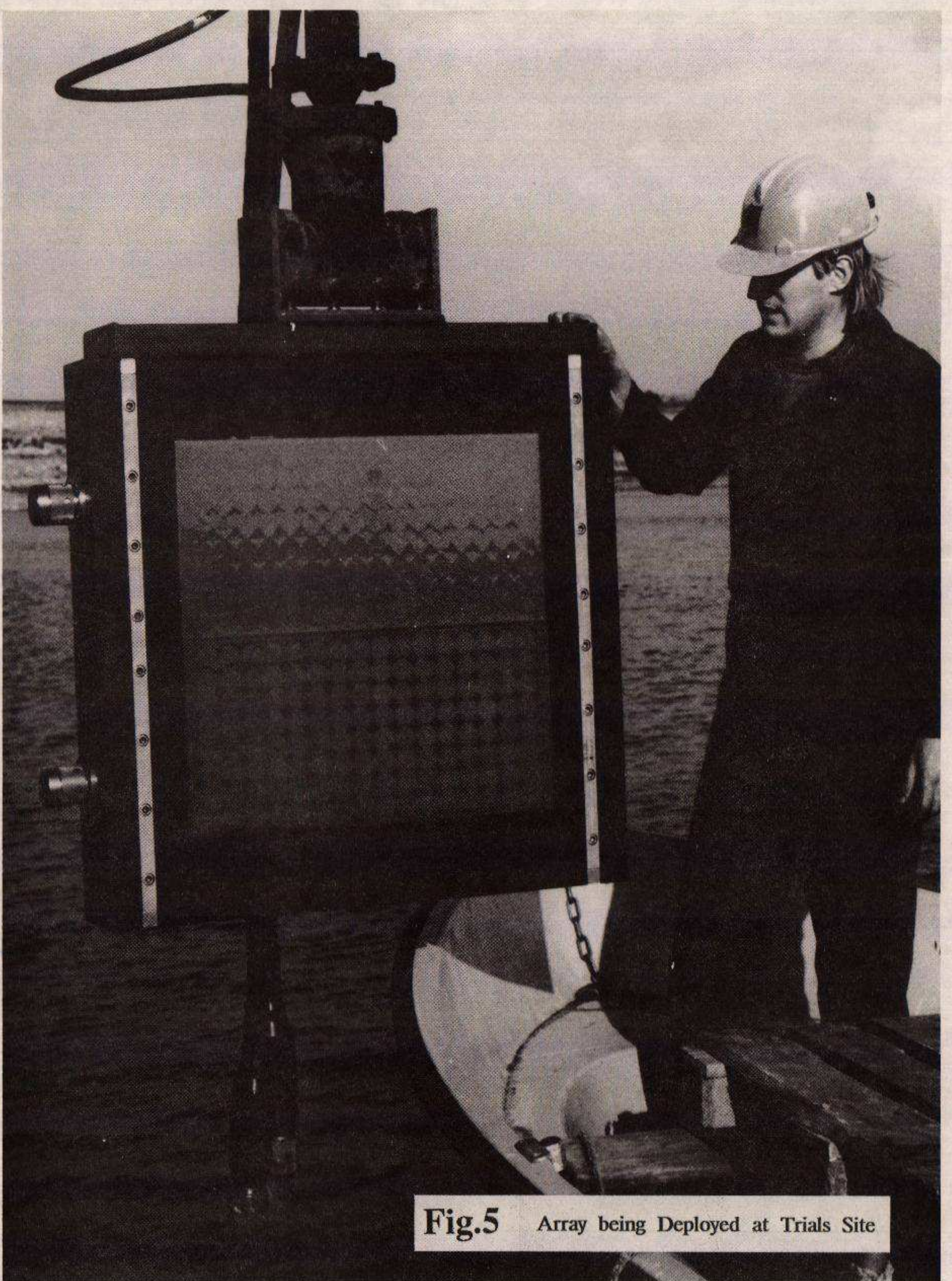


Fig.5 Array being Deployed at Trials Site

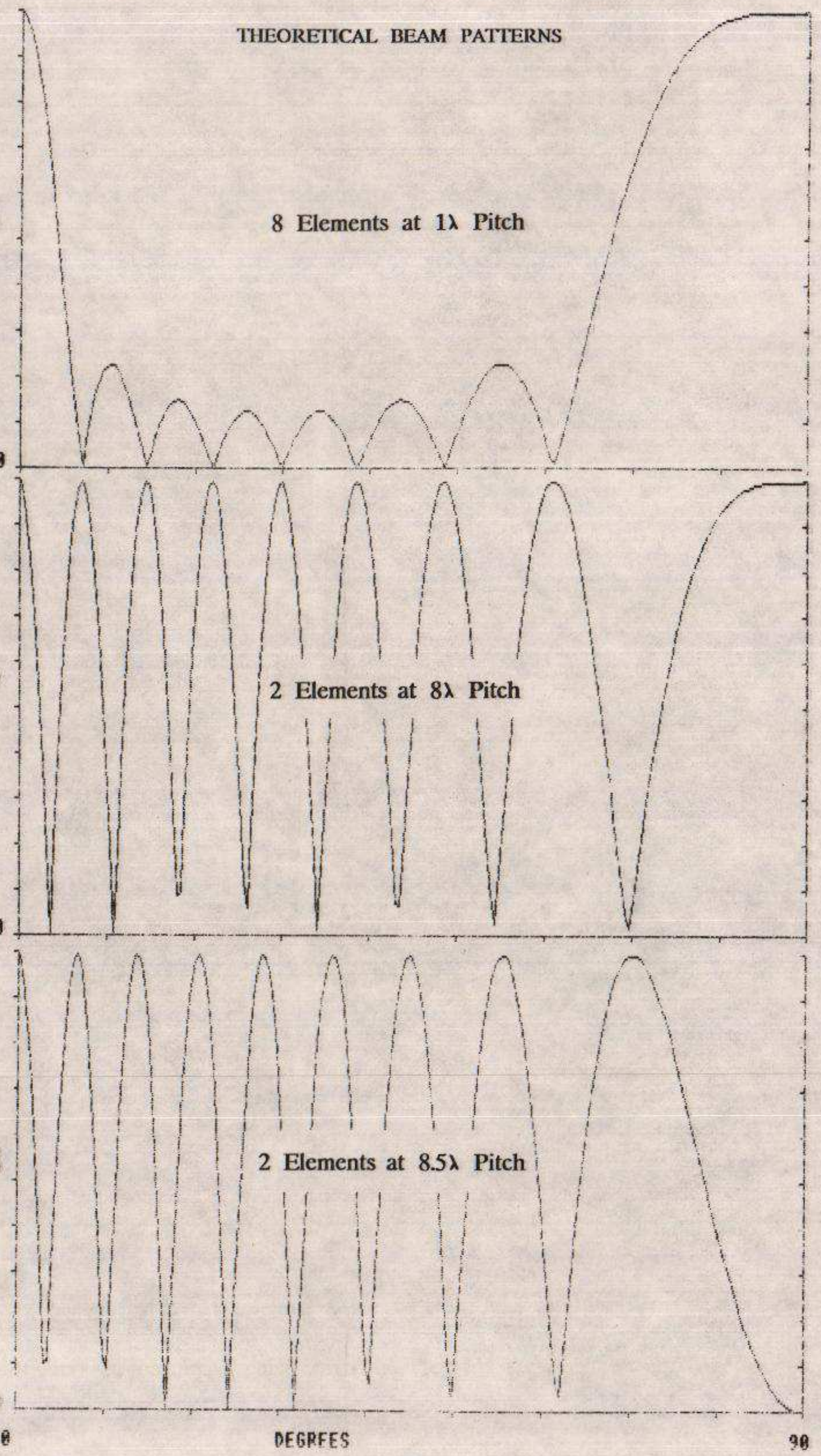


Fig.6

Fig.7

Fig.8

Fig.9

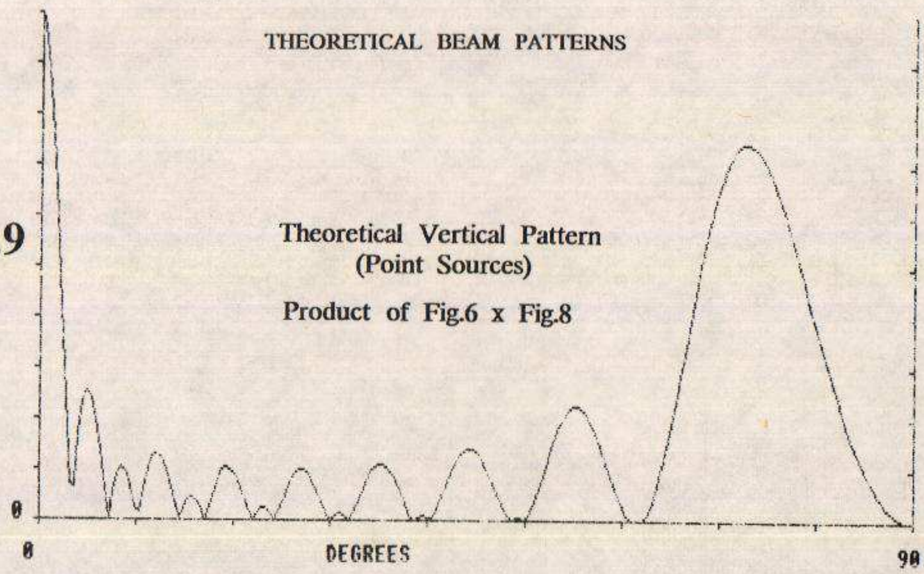
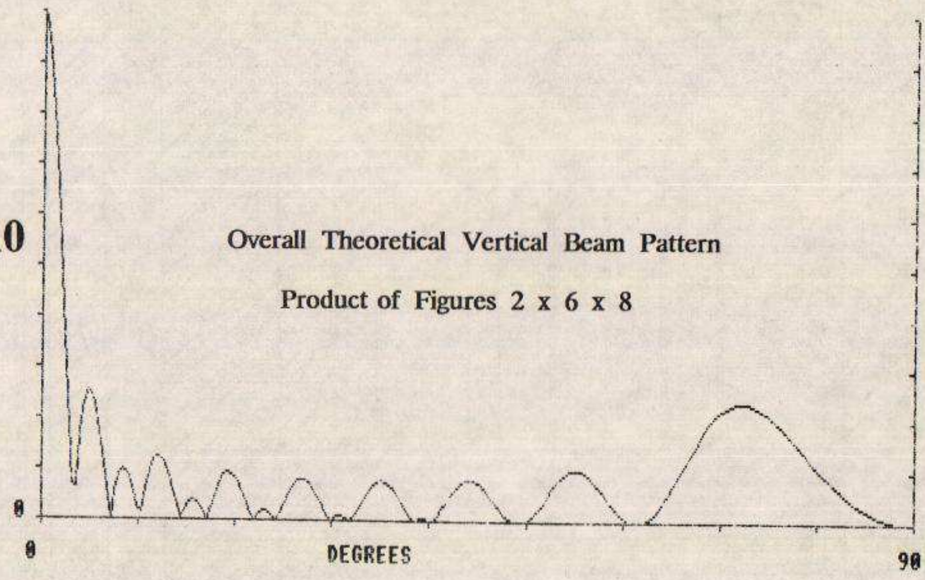

THEORETICAL BEAM PATTERNS
Theoretical Vertical Pattern
(Point Sources)
Product of Fig.6 x Fig.8
0
0
DEGREES
90

Fig.10


Overall Theoretical Vertical Beam Pattern
Product of Figures 2 x 6 x 8
0
0
DEGREES
90

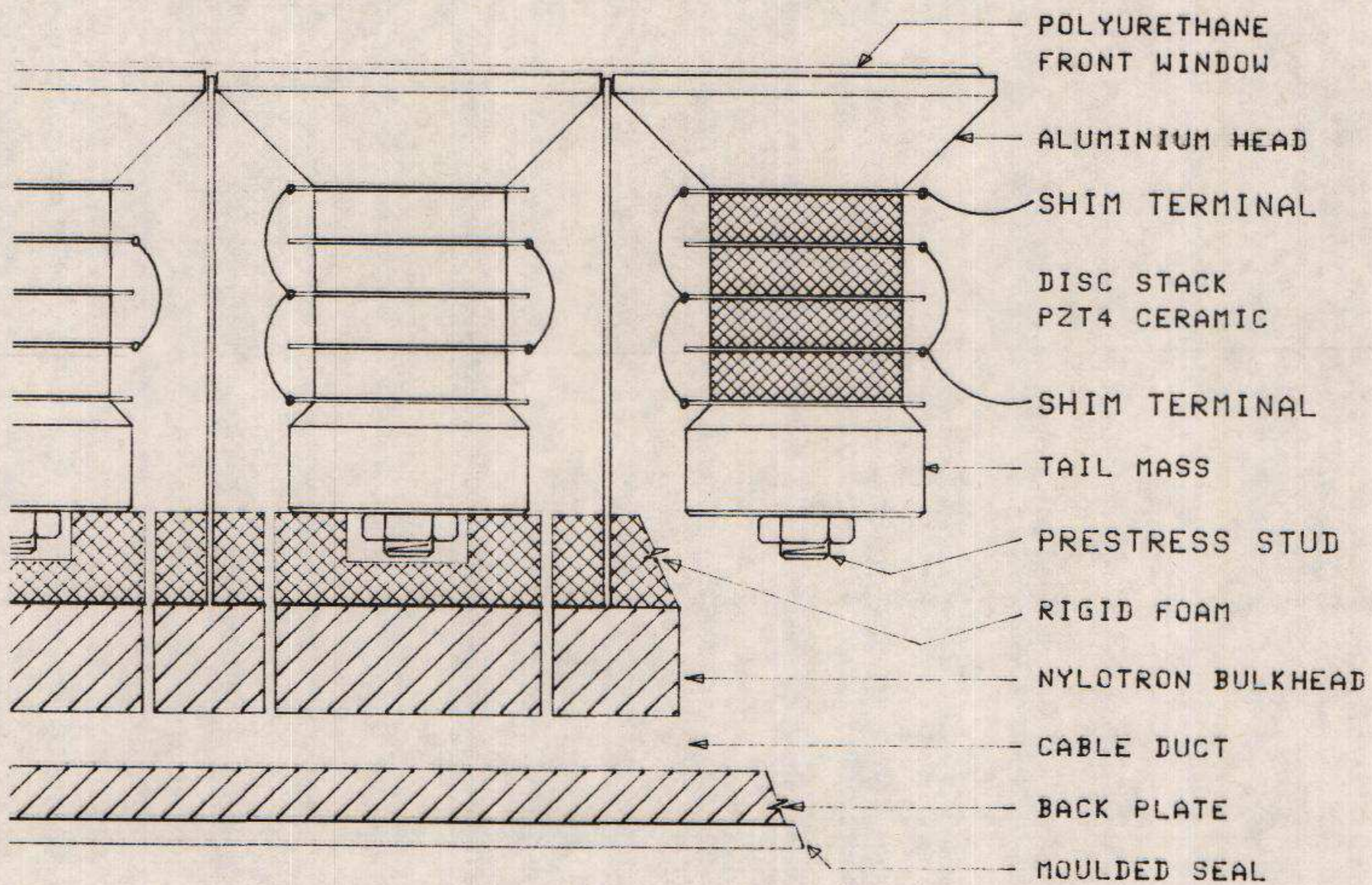


Fig.11 Details of Sandwich Elements and Mounting

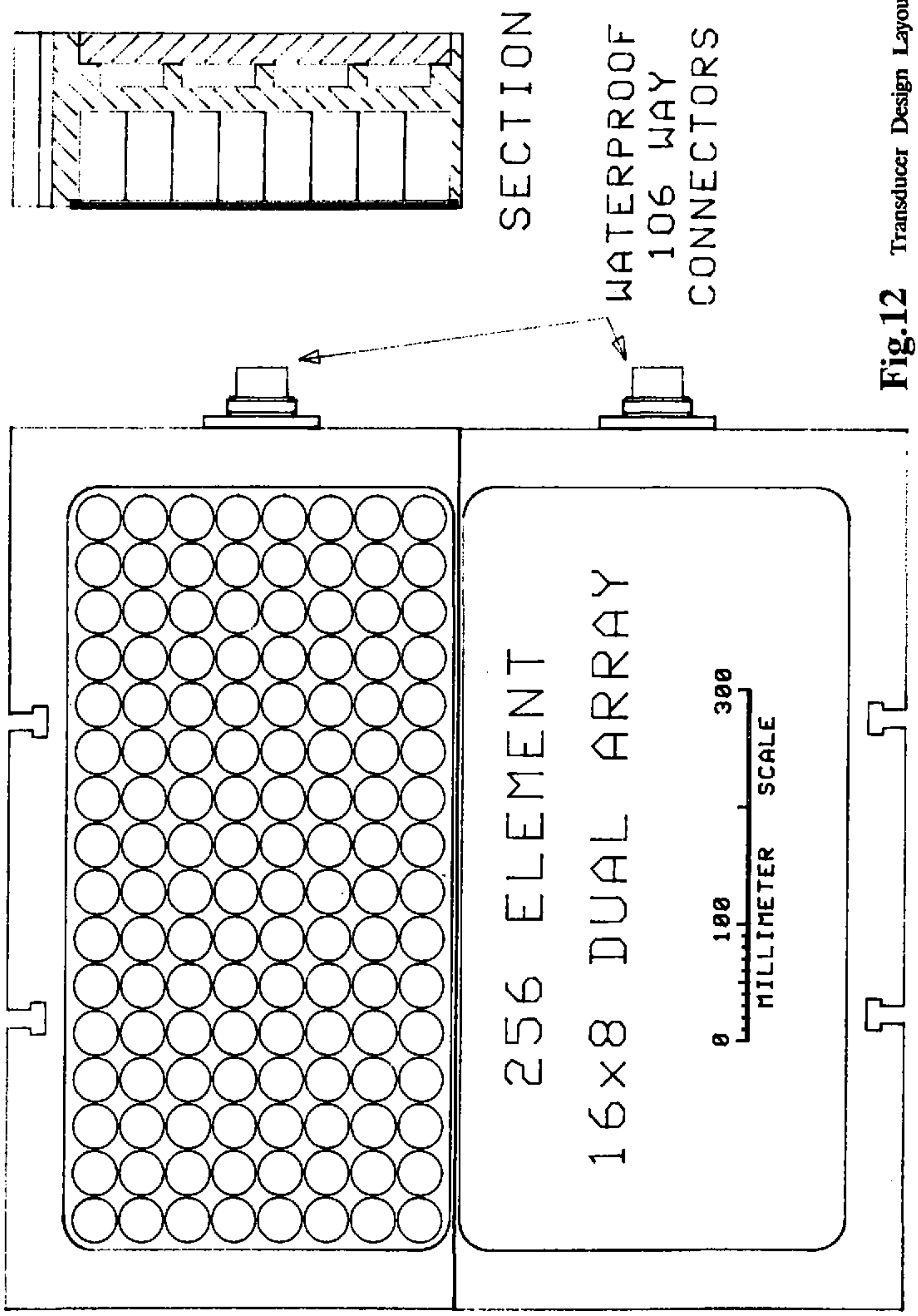


Fig.12 Transducer Design Layout

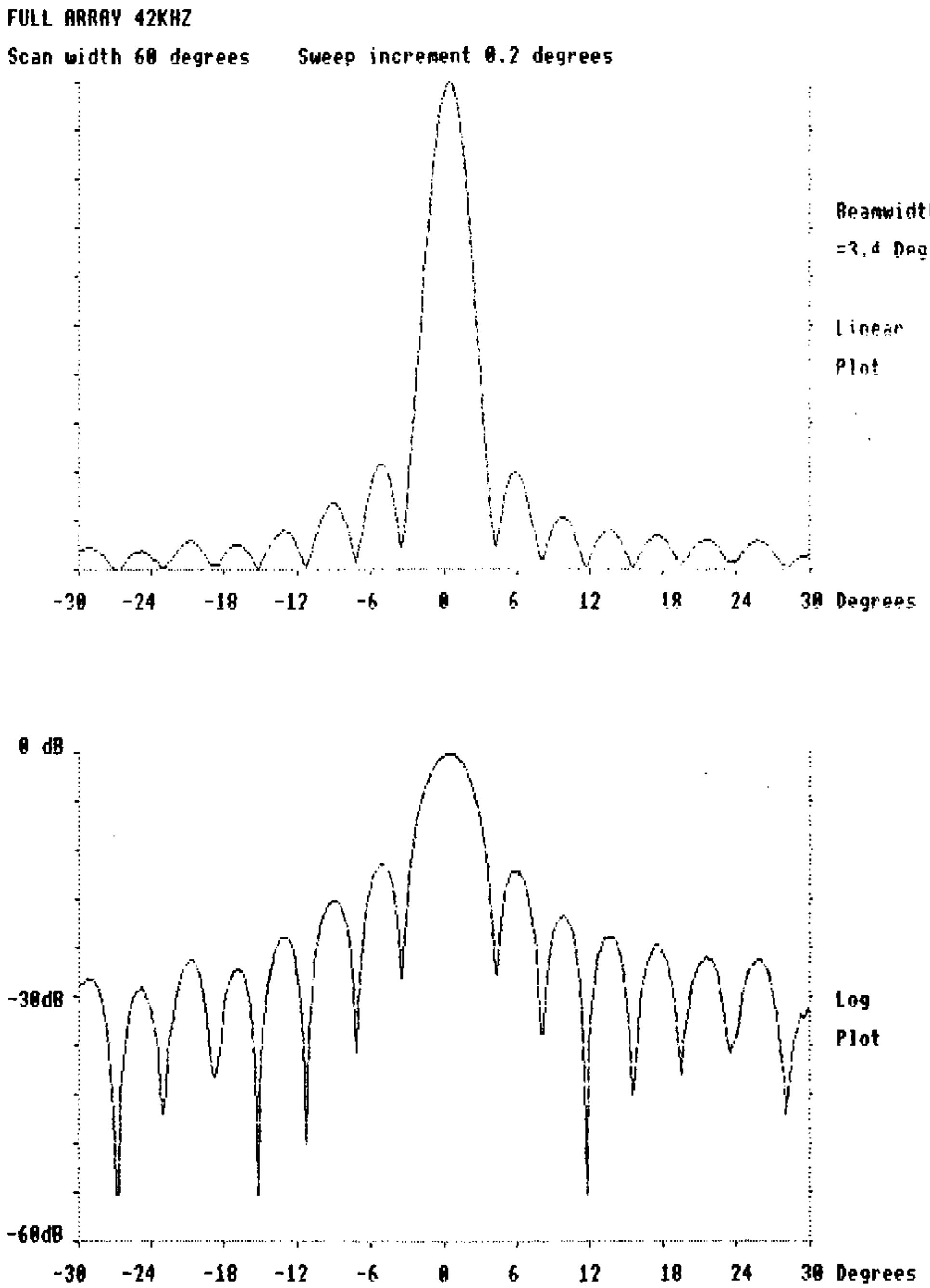


Fig.13 Measured Beam Pattern

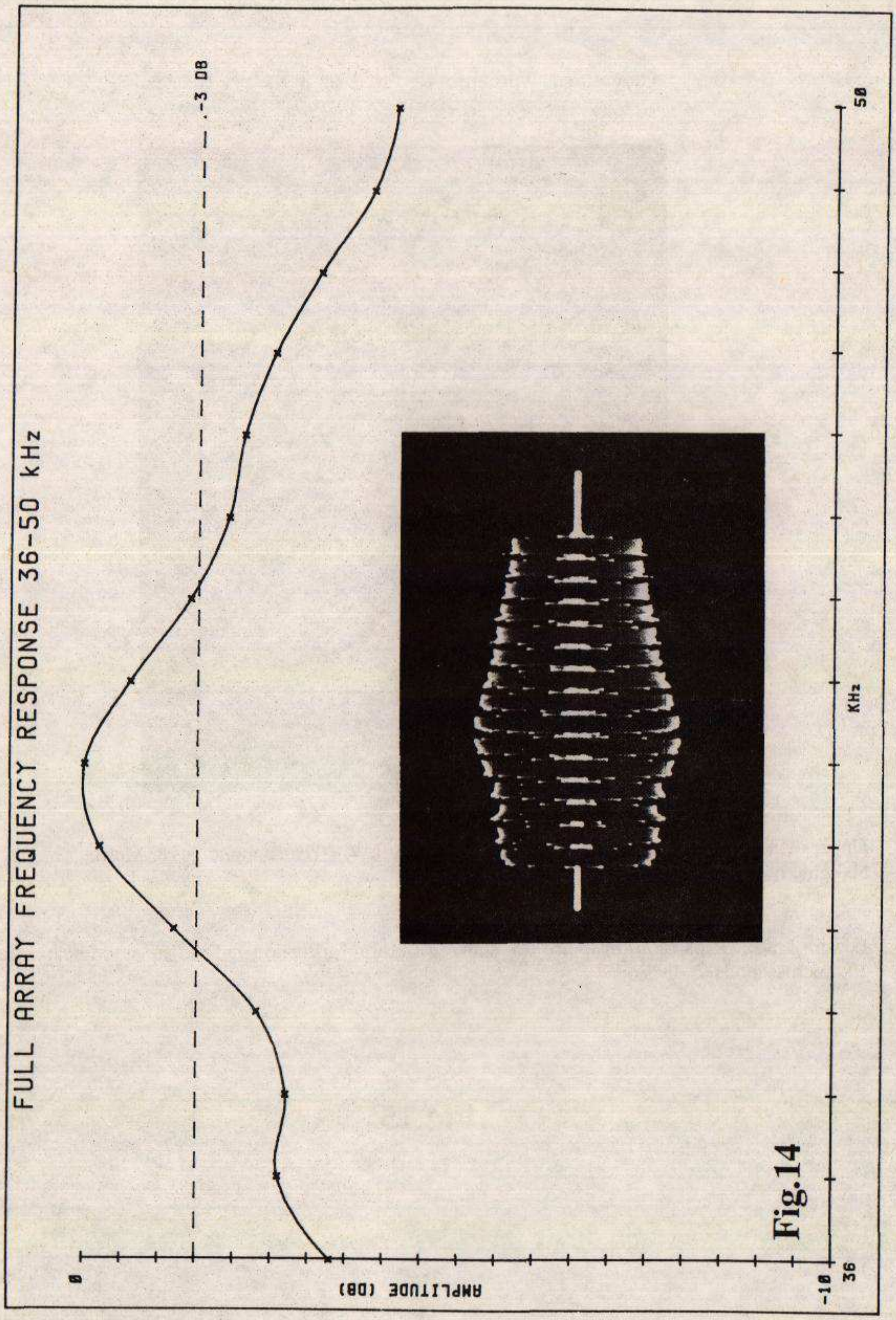
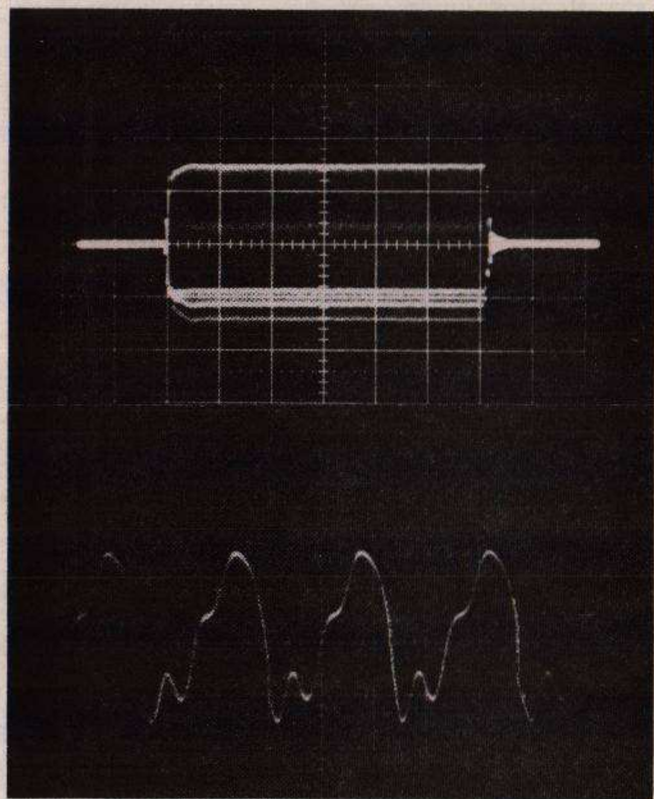

FULL ARRAY FREQUENCY RESPONSE 36-50 kHz
-3 DB
AMPLITUDE (DB)
Ø
-1Ø
KHz
36
5Ø

Fig.14

Transmitted Waveform Received at 8 Metres Range



Upper Trace: 3 millisec Pulse of 43 Khz at 10.5 kW. Hydrophone at 8 Metres.
500 microseconds / division

Lower Trace: Expansion of pulse to show waveform distortion. Due to non-linear effects.
10 microseconds / division

Fig.15