Proceedings of The Institute of Acoustics

DESIGN, CONSTRUCTION AND MATCHING OF A 38 KHz, 4·3° CONICAL BEAM TRANSDUCER.

P.J.Stevens B.Sc. PhD. C.Eng. M.I.E.E.
UNIVERSAL SONAR

Introduction

A variable conical beamwidth transducer was required for fish estimation experiments. The price/beamwidth curve based upon a fixed unit cost per element suggested that a six ring transducer containing 127 elements was a cost effective choice. A typical cost/beamwidth analysis is shown in table 1.

This paper describes briefly the design and construction of this transducer and presents preliminary test results. The initial experimental work using this transducer will involve a 1·1 Km cable between the transducer and the transmit/receive electronics. An outline of a cable matching system which maintains the flexibility of the transducer operations is also described.

Elements

A conventional prestressed sandwich element was used, with an aluminium head mass, 38mm diameter, two PZT4 rings connected back to back, and a steel tail mass. The overall length of the element was 55mm and weighed 250 gm. The admittance/frequency characteristic of a typical element is shown in Fig.1. The elements used in the final transducer had resonant frequencies within ± 250 Hz of 38 KHz.

Case Design

Some of the features of the high frequency scanning transducers described previously (1) and (2) have been adapted to house low frequency elements. The case for this transducer was machined from a solid block of nylon 4" thick and 24" square. The positioning of elements was as shown in table (2) and the intention was to avoid repetitive patterns in the element positions which may give rise to high sidelobe response in certain directions. The wiring of elements and connections to the eightway underwater bulkhead connector, were made in the recess machined in the rear of the block. Each element is stuck onto a pressure release pad capable of withstanding a load of 600 psi and these assemblies are stuck into the machined holes in the case, the two wires from each element passing through clearance holes to the rear recess. The front and rear recesses were then filled with the encapsulating resin. The overall weight of the transducer was 45 Kg in air and 13 Kg in water.

Test Results

The admittance/frequency characteristics for each of the six rings are shown in Fig.2. Ring 1 includes the centre element. The beam patterns obtained at 8m range for selected combinations of rings are shown in Fig.3.

Cable Propagation

Consideration of the effects of propagation in the cable upon the admittance/frequency characteristics is best accomplished diagrammatically using the Smith Chart notation.

Assuming the characteristic impedance of the cable is $Z_o = 75\Omega$ and its unit capacitance $C = 67$ pf, the propagation velocity V is given by

$$V = \sqrt{\frac{1}{LC}} \quad - (1)$$

where L is the unit inductance and may be calculated from $L = Z_o^2 C$ (2)

ie: $L = \cdot 376 \mu H/m$

hence $V = 1\cdot 99 \ 10^8$ M/S

The wavelength λ of the carrier at a frequency f propagating at velocity V is given by

$$\lambda = \frac{V}{f} \quad - (3)$$

which for $f = 38$ KHz

$\lambda = 5\cdot 23 \cdot 10^3$ m

The 1·1 KM of cable will be 0·210 λ long.

Consider the admittance circle for ring 3 as shown in Fig.2. The admittance at resonance and the -3dB points are as follows:-

35 KHz	11 + j 15	mS
38 KHz	20 + j 7·5	mS
41 KHz	11 + j 1·0	mS

Normalising these values by the characteristics admittance of the cable ie: $Y_o = \frac{1}{20} = 13$ms gives

35 KHz   •84 + j 1•5 (A)
38 KHz   1•53 + j •54 (B)
41 KHz   •84 − j •08 (C)

These three points lie roughly on a circle (1) with centre at 0•75 + j 0•48 as shown in Fig. 4A.

The resultant admittance of any point on this circle after propagating in 0.21λ of cable is found by the following constructions. Line OX is drawn through the centre of the Smith Chart and the centre of the admittance circle.

Line OX' is drawn through the centre of the Smith Chart at an angle $\theta = \frac{0\cdot 21}{0\cdot 5} \cdot 360^{\circ}$ in a clockwise direction. A full rotation (ie:360°) represents propagation down 0•5λ length of cable. The original circle is reconstructed along line OX', each point maintaining the same angular position to OX' as it had to OX. The apparent resonant frequency occurs at the point on this circle which has the maximum conductance, ie: point f in Fig.4a. Clearly f is lower than the original resonant frequency at point B.

In order to correct this shift of resonance which can be considered due to the addition of series inductance, resulting from termination of the cable by a resistive component less than Zo and investigating the resultant impedance $<\frac{\lambda}{4}$ from the termination, a series capacitor may be added.

To demonstrate this process, the admittance circle (2) is inverted about the centre of the Smith Chart to form the series impedance representation of the transducer and cable combination. This is circle (3) on Fig. 4B. The addition of series capacitance results approximately in a movement of the circle down the lines of constant resistance to form circle (4). The series capacitance required in this case being 43nf. The resultant resonant frequency is now at point A which when inverted to form circle (5) has a conductance of about $\frac{1}{Zo}$ and a susceptance of $\frac{0\cdot 9}{Zo}$ This susceptance component may be tunned out with a shunt inductor. Clearly this process has not restored the correct resonant frequency (Point B) but further rotation by using a larger series capacitor will achieve the desired result, although the resultant conductance component will have to be modified by use of a transformer.

A slightly different approach is to transform the transducer characteristics prior to the propagation in the cable, to achieve for example a desired load impedance at the generator. The effect on the initial positioning of the admittance circle on the Smith Chart is shown in Fig.4C where the effects of any shunt self inductance of the transformer has been neglected.

To reproduce the characteristics of each transducer ring at the far end of the 1·1 Km of cable, each ring is transformed to the same impedance and connected to a seperate core in the cable. The same connection components may be used on each channel and the original characteristics restored by a further transformer.

A typical equivalent circuit of one channel is shown in Fig.5.

References. (1) High Resolution Sonar Systems. J.W.R.Griffiths, A.R.Pratt and P.J.Stevens. Oceanology International 78. Technical Session J.

(2) High Frequency Deep Water Transducer Arrays. A.R. Pratt P.J. Stevens. I.O.A. Transducer Workshop Proceedings 1976.

BEAMWIDTH (-3dB Points)	No. of Rings	No. of Elements	Case Dimensions cms	Price £50/element.
11.2°	2	19	10 x 25 sq	950
8°	3	37	" x 35	1850
6.2°	4	63	" x 42	3150
5.1°	5	93	" x 50	4650
4.3°	6	127	" x 60	6350
3.7°	7	175	" x 75	8750

TABLE 1. COST / BEAMWIDTH FOR CONICAL BEAM TRANSDUCERS.

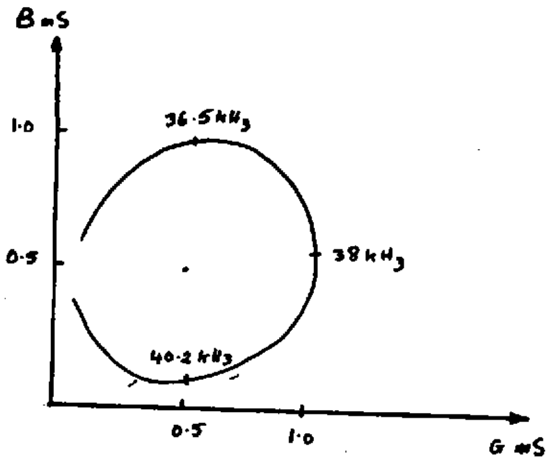
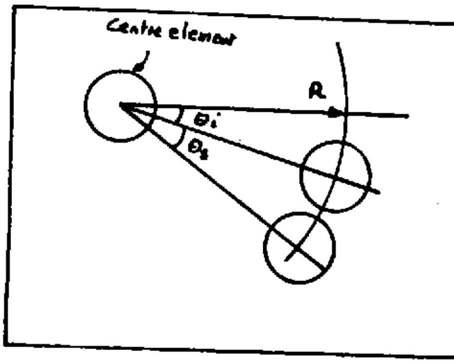


FIGURE 1. Admittance / Frequency Characteristic of a single element.



Ring	R_{mm}	θ_i	θ_s
1	44	0°	60°
2	88	15°	30°
3	132	0°	20°
4	176	10°	15°
5	220	0°	12°
6	264	5°	10°

TABLE 2. POSITIONING OF ELEMENTS

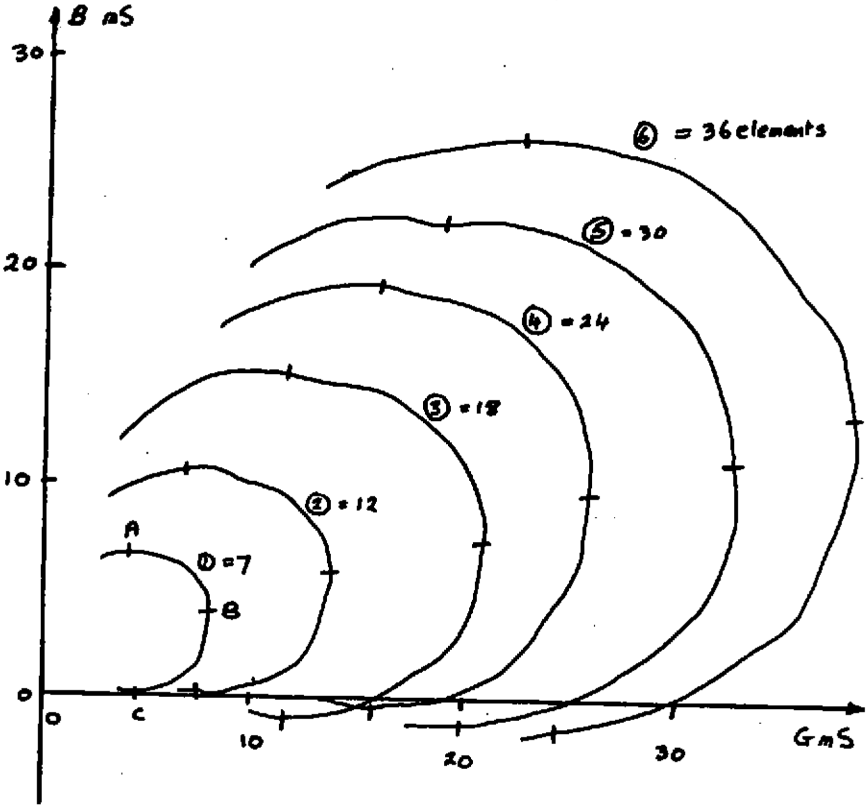


Figure 2. Admittance / Frequency responses for each of the six rings of transducers. A - 35kHz, B = 38 kHz C = 41kHz.

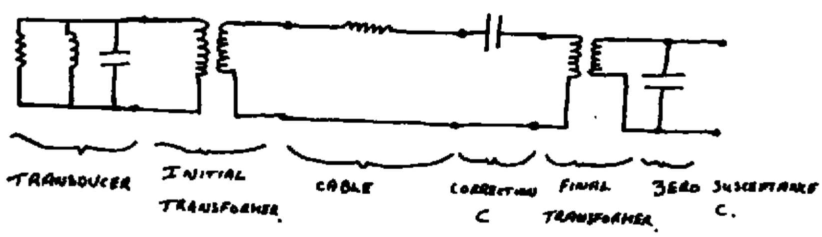


FIGURE 5 Equivalent Circuit of one ring of transducer with cable and matching components.

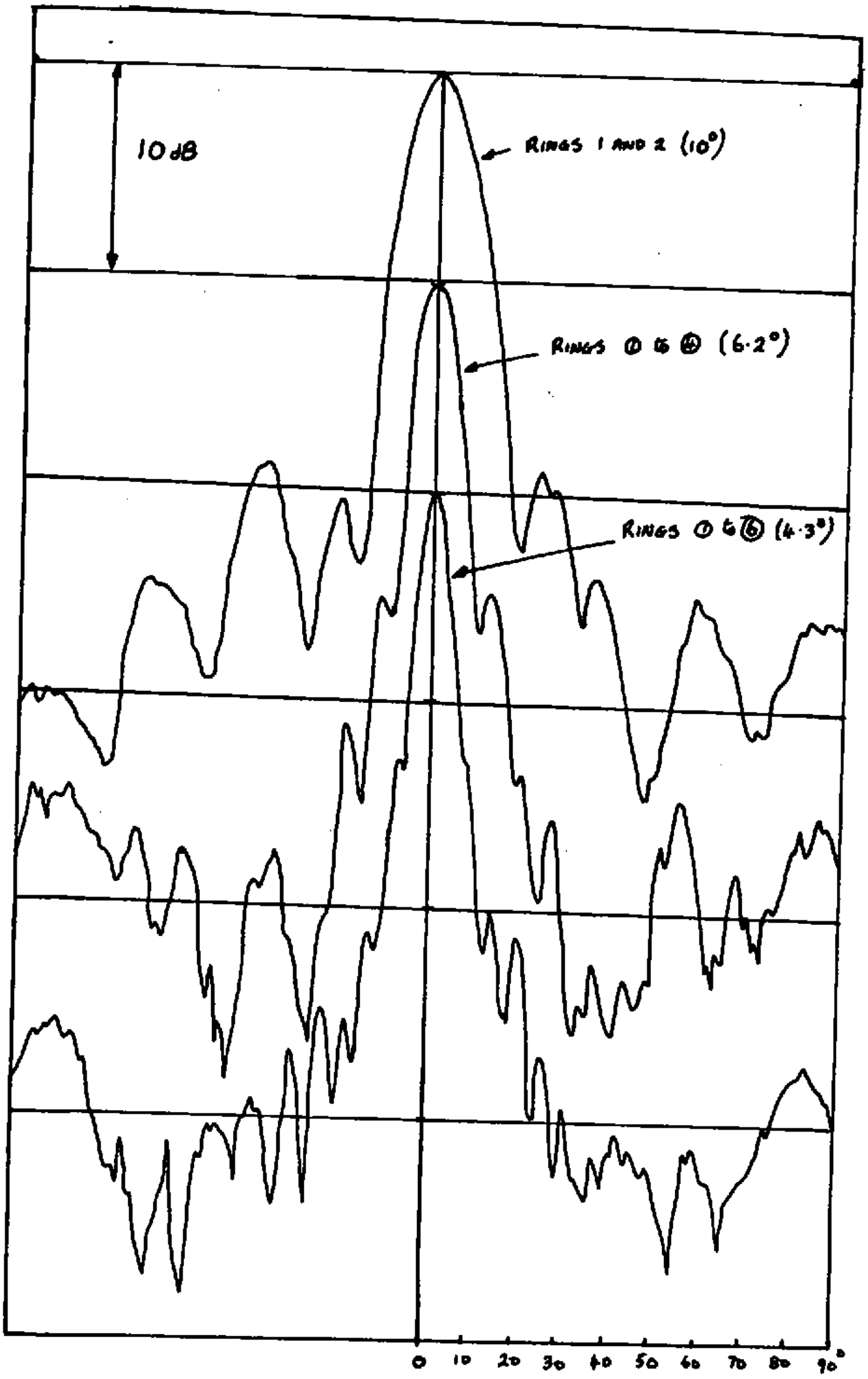


Figure 3. Beam patterns of 19, 63 and 127 elements.

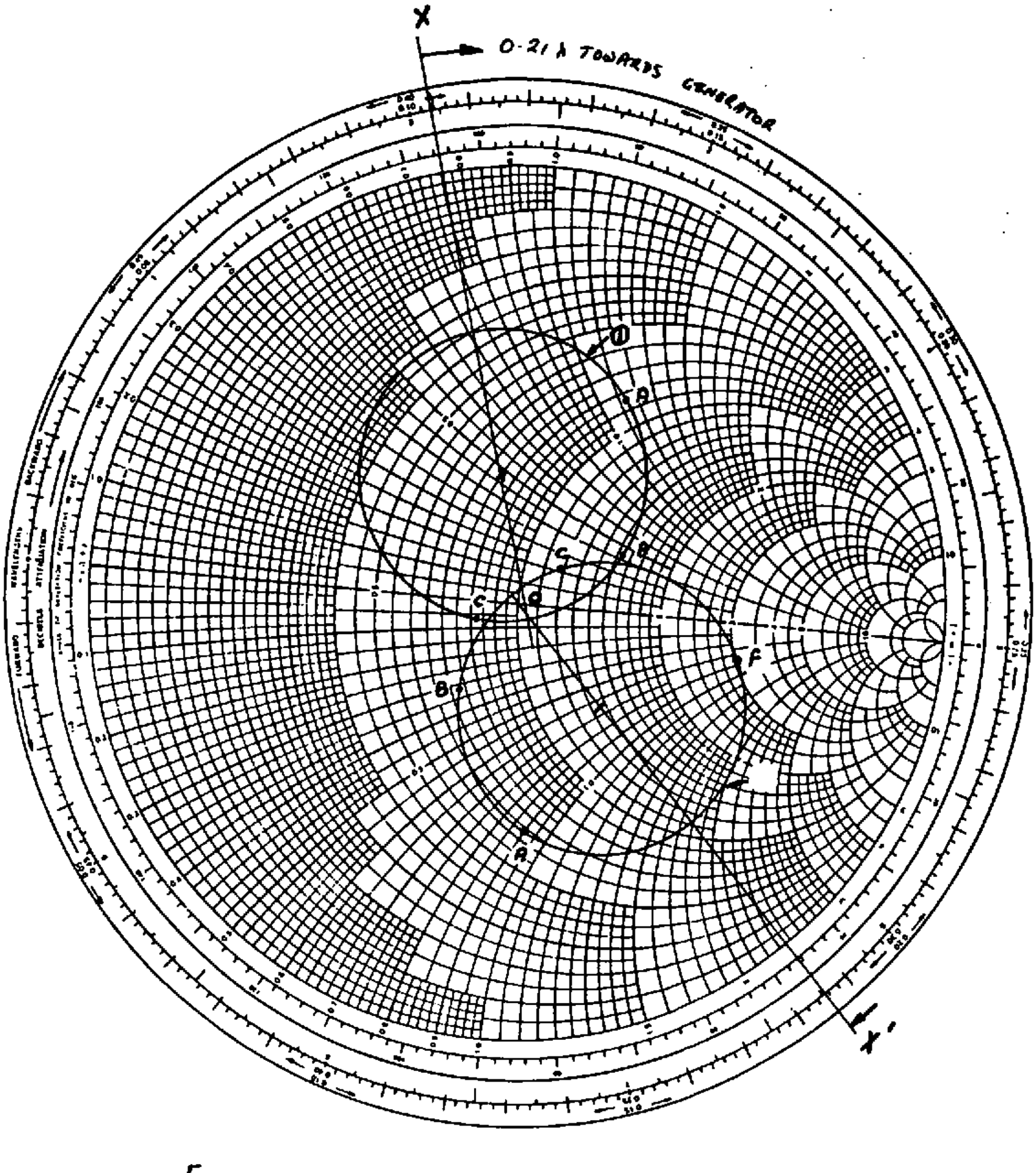
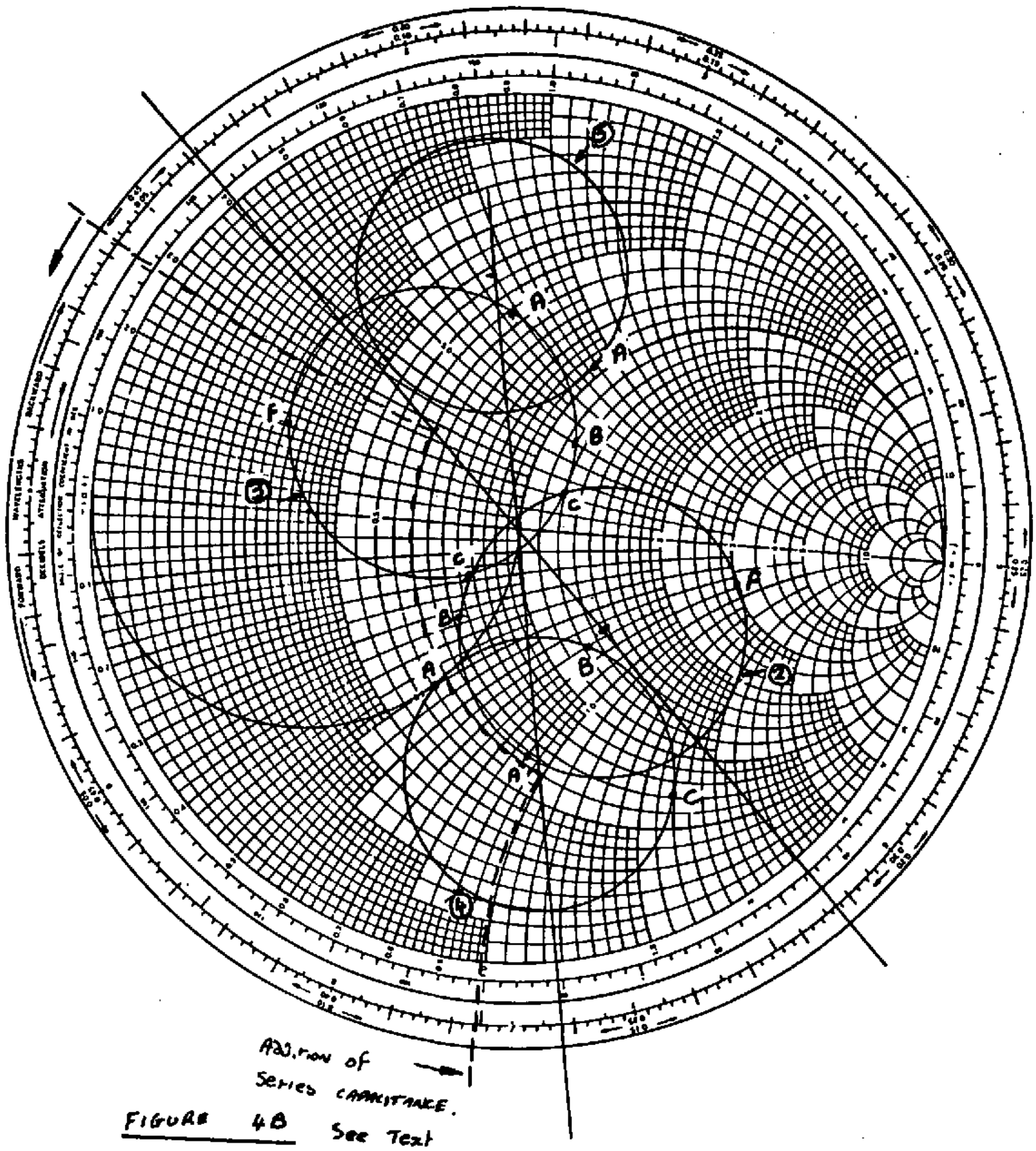


Figure 4A See Text



Addition of
Series capacitance.

FIGURE 4B See Text