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DIRECTIVITY PATTERN OF A LINEAR ARRAY TRANSDUCER IN HIGH FREQUENCY RANGE

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Résumé. — Cet article présente des résultats utiles pour l'étude, la construction et le calibrage d'un transducteur linéaire expérimental de haute fréquence qui permet l'émission d'un champ acoustique déterminé au moyen de l'alimentation propre de ses éléments et grâce auquel un changement continu du diagramme directionnel est possible.

En acoustique sous-marine, des dispositifs transducteurs ont été étudiés et construits dans un domaine de basse fréquence (10-40 kHz). Par contre le dispositif décrit ici est employé dans un domaine de fréquence plus élevée (500-1 000 kHz) et peut être ainsi utilisé pour la détection de défauts et pour l'établissement de diagnostics.

Abstract. — This paper presents the results for the design, construction and calibration of an experimental high frequency linear array transducer which permits the generation of a determinate acoustic field by means of proper alimentation of its elements and of which a continuous change of the directional pattern is possible.

In underwater acoustics, array transducers have been studied and constructed for low frequency ranges (10-40 kHz). The array described here, instead works in a much higher range (500-1 000 kHz) and so it can be employed for flaw detection and in the field of diagnostic investigation.

1. Introduction. — This paper presents the results for the design, construction and calibration of an experimental high frequency linear array transducer which permits the generation of a determinate acoustic field by means of proper alimentation of its elements.

In underwater acoustics, array transducers have been studied and constructed for low frequency ranges (10-40 kHz). The array described here, instead works in a much higher range (500-1 000 kHz) and so it can be employed for flaw detection and in the field of diagnostic investigation.

2. Transducer design. — As it is well known a linear array transducer is formed by distinct and functionally independent sources of sound arranged on a line. By means of a suitable distribution of the amplitudes and phases of the electric signals applied to the single source it is possible to control the minor lobe levels and the deflection of the major one.

If d is the distance between the center of the source and λ is the wavelength of the sound, the ratio d/λ must be contained within the limits :

$$0.5 \leq d/\lambda \leq 1$$

in order to obtain satisfactory results.

Both for flaw detection and in the field of diagnostic investigation we must work with wavelengths equal to or minor than one millimetre in order to obtain good resolutions, and so, d , becomes a fraction of one millimetre. The construction of a linear array in high frequency range then involves miniaturizing problems,

which, however, can be resolved fairly easily by the actual technology. But it is important to keep in mind that the acoustic intensity of one elementary source is proportional to the area of its radiating surface, and so the miniaturizing process cannot get below certain limits if we want to reach an adequate acoustic pressure without using an excessive number of elementary sources.

We have studied and constructed a plane array of an odd number, N , of linear sources of equal length, l , and with an equal space d , between them.

The elementary sources of the array have been taken from one piezoelectric ceramic plate bonded to a sandwich formed by a copper tinsel (0.1 mm), a disk made of a decoupling material, balsa wood, and a metal holder (see Fig. 1). Cuts 0.8 mm wide and parallel with the xy plane have been made with a diamond lap ; the copper tinsel has been cut together with the ceramic plate and so the lower electrodes have been realized.

As the electric field is applied along the X axis and since the plate is poled as shown in figure 1 the thickness, s , determines the resonance frequency.

Pieces of balsa wood have been inserted between and around the ceramic elements in order to form a continuous baffle.

Figure 2 shows the final assembling. The transducer is placed in an earthed box of stainless steel ; the baffle, covered with metallic paint, functions as earth electrode. The back of the box is filled with Araldite AV 138.

The number, N , of the elements has been limited to

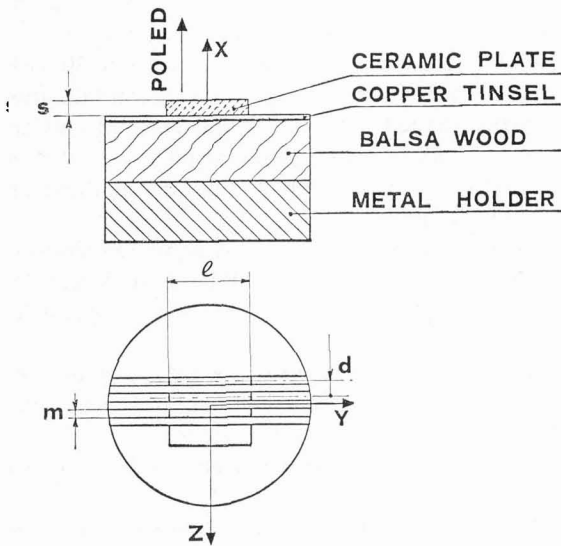


FIG. 1. — Sandwich formed by ceramic plate, copper tinsel, balsa wood, metal holder.

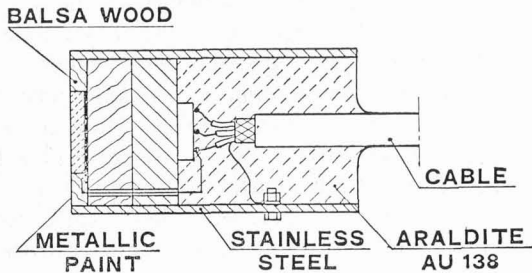


FIG. 2. — Cross section of the transducer.

seven in order to simplify the construction. The distance, d (1.8 mm), between the centers of the adjacent elements makes it possible to achieve a ratio d/λ ranging from 1 to 0.73. The width of the elements, m (1 mm), is always minor than the wavelength of the sound.

3. Experimental results. — Up till now we have studied only the characteristics of the directivity

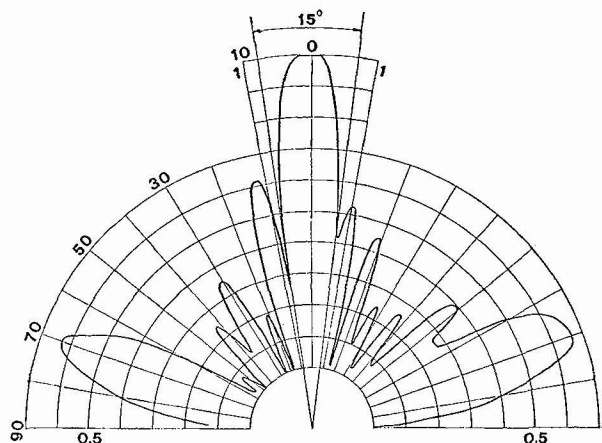


FIG. 3. — Directivity pattern of the transducer at 850 kHz; $d/\lambda = 1.04$, $R = 3.6$ dB.

pattern of the transducer : The beam patterns of the single sources have been measured ; these are all resonant at the same frequency, 850 kHz, and show a very similar distribution of the acoustic pressure. Further a series of measurements of the directivity patterns of the whole transducers have been made for various frequencies (850, 750, 650 kHz). The results are shown in figures 3, 4, 5.

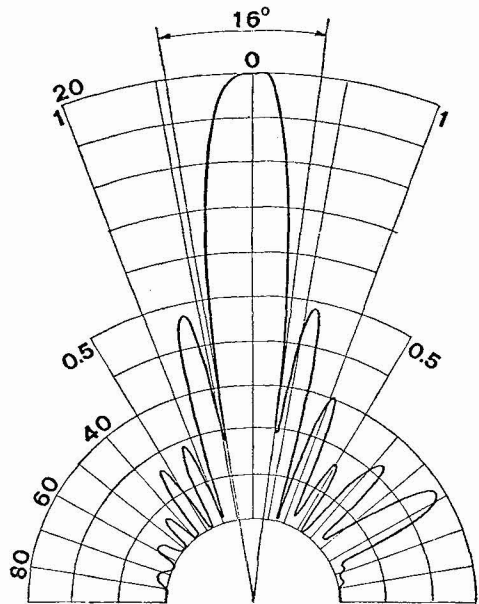


FIG. 4. — Directivity pattern of the transducer at 750 kHz; $d/\lambda = 0.91$, $R = 6.4$ dB.

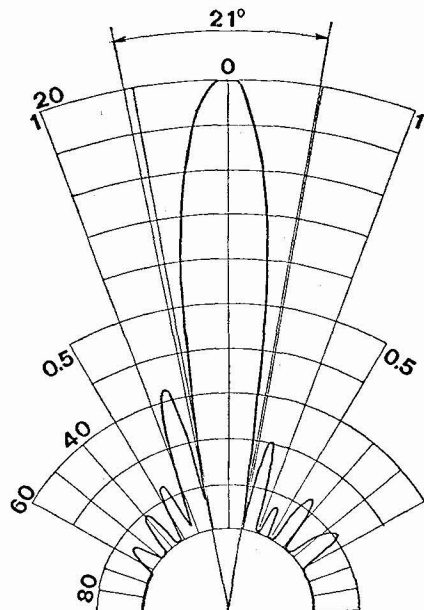


FIG. 5. — Directivity pattern of the transducer at 650 kHz; $d/\lambda = 0.73$, $R = 9.6$ dB.

With a proper distribution (shading) of the acoustic pressures emitted by the single elements it is possible to control the minor lobe levels. For the frequency of

650 kHz the method of optimization developed by Dolph [2] has been used in order to obtain a reduction of 30 dB of the minor lobe. In fact with this method it is possible to achieve the narrowest major lobe when the ratio, R (dB) between its amplitude and those of the minor lobe is fixed. The shading coefficients have been calculated by means of the Tschebyscheff poly-

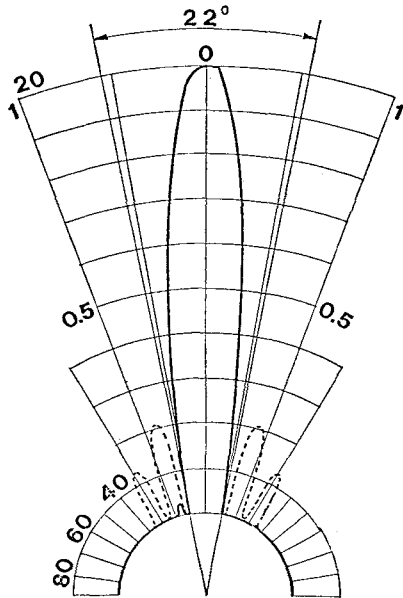


FIG. 6. — Directivity pattern of the transducer at 650 kHz shaded by the Dolph method; $d/\lambda = 0.79$, $R = 30.4$ (full line) and theoretical diagram of the corresponding plate $R = 12.9$ dB (dashed line).

nominals [1]. Comparing the result obtained in this way with the one obtained without shading we can see that the actual ratio, R , passes from 9.6 to 30.4 dB.

In figure 7 are shown both the experimental diagram of the array shaded with the Dolph method and the theoretical diagram of a rectangular plate with dimensions equal to the maximum dimensions of the array at the same frequency.

As it can be seen there is considerable reduction of the minor lobe levels, and so it will be useful to employ an array rather than a simple piezoelectric plate for some special applications.

The transducers have been tested as projectors and the calibration has been carried out in a tank filled with water by means of the pulse method.

The transducer is keyed on a turnable table synchronous with a polar recorder.

The results obtained so far show that the transducer array theory developed in the field of underwater acoustic can be employed with success for the design of an ultrasonic array.

The next step will be an examination of the possibility of deflecting the direction of the major lobe by means of a proper phase distribution. Further it will be possible to achieve continuous and repetitive deflections of the major lobe by means of time controlled varying phase shifters and so to perform a fast scanning of the beam pattern electronically.

With a further developed technology and a better design it will be possible to achieve higher working frequencies.

References

- [1] ALBERS V. M., Underwater Acoustic Handbook, The Pennsylvania University Press (1965).
- [2] DOLPH C. L., A Current Distribution of Broadside Arrays which Optimizes the Relationship between Beamwidth and Side Lobe Level, Proceedings of the Institute of Radio Engineers, June 1946