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ARRAYS OF DISCRETE SOUND SOURCES AND / OR CONTINUOUS LINE-RADIATORS

Arrays of Discrete Sound Sources and Continuous Radiators

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Advantageous properties of linear arrays as directional radiating systems are well known and enough work and investigation has already been done in this field. / 1 - 6 / This contribution will therefore incline rather towards the economical aspects in considering the basic properties of linear arrays and continuous radiators.

1. Basic properties of linear arrays and continuous radiators.

The directivity function of a linear array consisting of point sound sources the number of which is n and distance between any two adjacent beeing a constant d can be written as equation :

$$R_d(\alpha) = \frac{\sin\left(\pi n \frac{d}{\lambda} \sin\alpha\right)}{n \sin\left(\pi \frac{d}{\lambda} \sin\alpha\right)} \qquad (1)$$

The angle α is measured from the axis of symetry of the array. In the equation (1) we can introduce the total lenght ℓ instead of d and then, as a limit case, for n going to infinity and d to zero , if ℓ is constant, the equation (1) can be rewritten as equation :

$$R_c(\alpha) = \frac{\sin\left(\pi \frac{\ell}{\lambda} \sin\alpha\right)}{\pi \frac{\ell}{\lambda} \sin\alpha} \qquad (2)$$

Let us now investigate the differences between the first and second equations. Both the first and the second equations are periodic functions of the angle α and the functions are furthermore depended on the ratio of the total lenght of the system and the wave lenght ℓ/λ . However, the esential difference is that the second function can have only once the value <u>one</u> when $\alpha =$ Ø , while the equation (1) obtains the value of <u>one</u> for a number of different angles α in general. The directivity function according to the equation (1) has one main lobe if the wave lenght is longer or maximally equal to the product of the distance <u>d</u> and the number of radiators <u>n</u> . If the wave lenght is just equal to the distance <u>d</u> another two main side-lobes reach the value of <u>one</u> just for the angles $\pm 45^{\circ}$. If the frequency increasis then more and more energy is radiated by the side lobes and the directivity does not increase. Basically, the utilisable frequency range of the array is limited by the ℓ/λ ratio value when these side lobes ocure.

Between each two main lobes that can reach the value of <u>one</u> a total number of <u>n - 2</u> secondary maxima will ocure - secondary lobes - the maximum value of which, however, can not reach the maximum value of main lobes. The lewel of the secondary lobes depends on the position of the particular secondary lobe concerned and on the number of the radiators in the array.

For the most important first secondary lobe, that is just next to the main lobe the lewel difference between the main and secondary lobe maxima goes from <u>10,5 dB</u> for a three element array to only <u>13,2 dB</u> for the continuous line radiator. / 9 / It is evident that by increasing the number of separate sources in the array the suppression of the secondary lobes just adjacent to the main lobe does not icrease appreciably. The levels of the following secondary lobes of course decrease with the position and with increasing <u>n</u> . With line radiators all lobes lie within two lines running paralel - in the direcitivity patterns - to the zero angle axis in the distance $\lambda/\pi\ell$. / 9 / This holds well if $\ell/\lambda > 1$. In this range the advantage of continuous radiators against the systems consisting of not a very high number of discrete radiators is obvious. However a different situation ocures in the region where $l/\lambda < 1$. On the Fig. 1. we can see the course of the directivity coeficient S of the array of point radiators as it depends on the ratio l/λ and the number of elements in the array. From this graph it can be seen that in the region of approximately from 0,5 to 1,5 of l/λ the directivity coeficient of the three element array is on average nearly 1,4 - times higher than that of continuous radiator of the same lenght. Looking at this graph we can say that while for high frequencies the use of continuous line radiators is advantageous, for low frequency region - on the contrary - systems with low number of radiators can be expected to be more advantageous.

The same conclusion can be made with all probability according to the next graph - Fig. 2. On this graph is shown the dependance of the main lobe width on the number of the point sources in the array and on the ratio l/λ . It is evident e.g.that two loudspeaker system can have better directivity than more-element systems; this conclusion holds practically up to approximately 0,65 l/λ. /9/ As to the continuous line radiator,it would have to be almost twice as long as the two-element radiator for the same directivity again approximately up to 0,65 l/λ. However, in the high frequency range, where the corresponding wave lenghts are very short, the systems consisting of high number of elements or espacially continuous radiators give better directivity patterns with good suppression of spurious lobes.

2. Examples of design, based on previous considerations.

On the basis of the simple considerations of basic properties of linear arrays as have been mentioned briefly in the part 1. some ways of certain improoving directional loudspeaker systems can be sugested,if considering both the performance and economy. As the first example of a design where there was searching for both performance and economy a simple columnar system can be shown with non-constant distances between the loudspeakers, using at the same time the shortening of the efective lenght of the coulumn with the frequency by the simplest way - that is by the paralel condensers connected to the external loudspeakers. On the Fig. 3. there is an example of the sven speaker array connection with the two steps of electrical shortening of the efective lenght of the array. The second diagram on the Fig. 3. shows the wireing possibility where only two condensers are necessary. On Fig. 4. there is the frequency response of such columnar system of the ower-all lenght of 1,3 m where seven loudspeakers TESLA ARE 467 have been used. On Fig. 5. there are shown the courses of the electrical input impedance of this column, as in the first characteristics - with and without the compensating condensers. On the Fig. 6. there are the corresponding directivity patterns. The rated impedance of the individual loudspeakers was 4 Ohm and the capacities has been 12 and 4 μF. The rated vertical directivity patterns width was to be approximately $\pm 25^{o}$ and the average directivity coeficient in the region of 250 Hz to 4 kHz was 10.

On the Fig. 7. there is shown a simplest solution of a continuous radiator for the high frequency range. It is an ordinary horn tweeter with the mouth of the horn slot shaped. The directivity patterns of such horn can be furthermore modified using insertable lenses. On the Fig. 7. there is a simple focusing lens that can be used with the loudspeaker. On the Fig. 8 there is the frequency response of the loudspeaker TESLA ART 581 shown on the Fig. 7. The frequency response is given both for the loudspeaker without the lens and with the lens. On the Fig. 9. there are the corresponding directivity patterns.

On the last Fig. 10. there is outlined an example of a more complex three-way system of higher quality,that has been determined for performing arts (a"polyekran"in this case). For the lowest octave two woofers has been used, for middle frequency range the seven speaker compensated array and for the upper part of the audio range the horn speaker with the lens.

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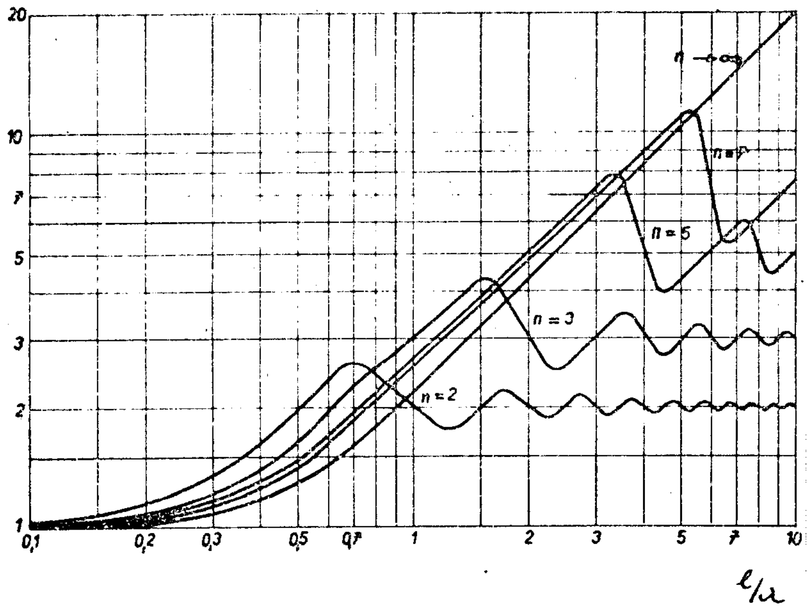


Fig. 1. Directivity coeficient of point-radiators array

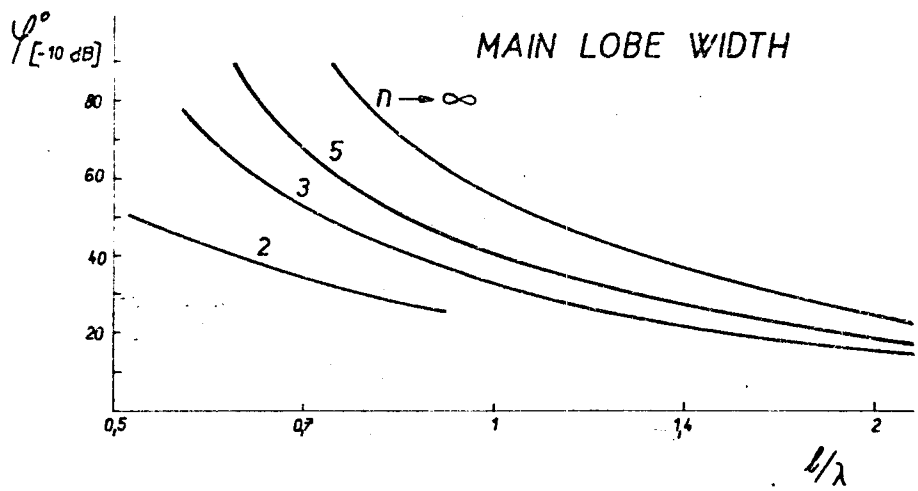


Fig. 2. Main lobe width of point-radiators arrays

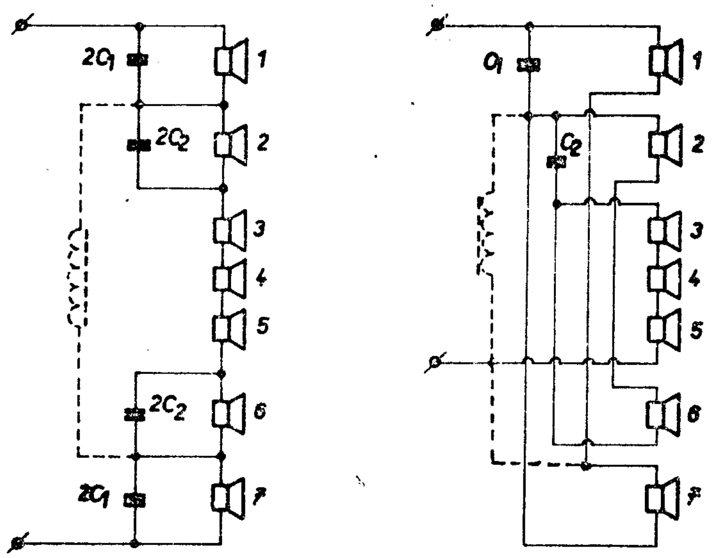


Fig. 3. Seven speaker compensated system connection

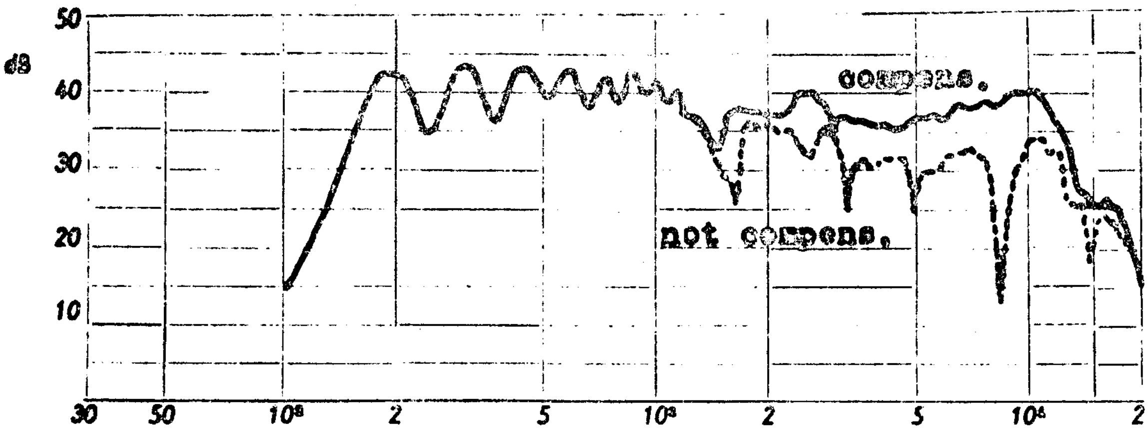


Fig. 4. Frequency response of the seven speaker system

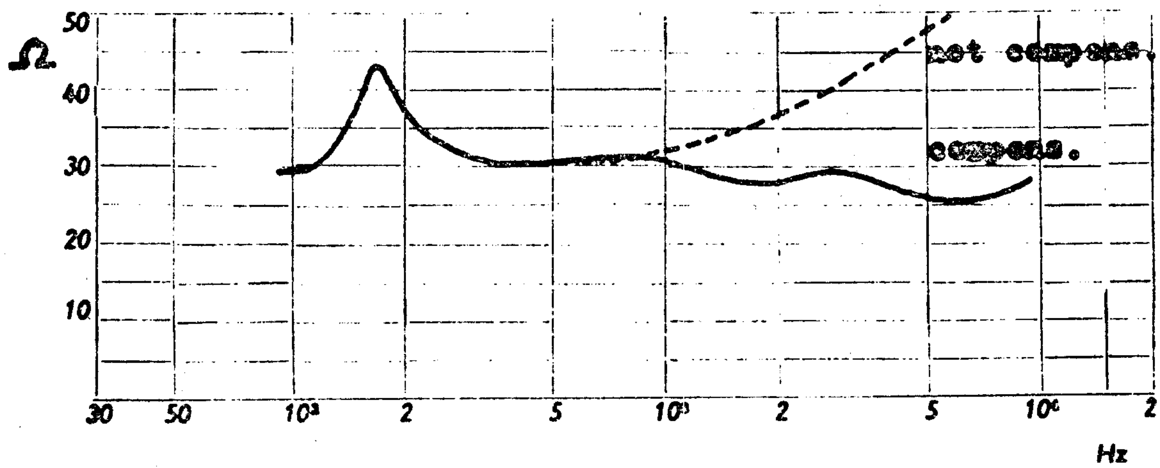


Fig. 5. Input impedance of the seven speaker system

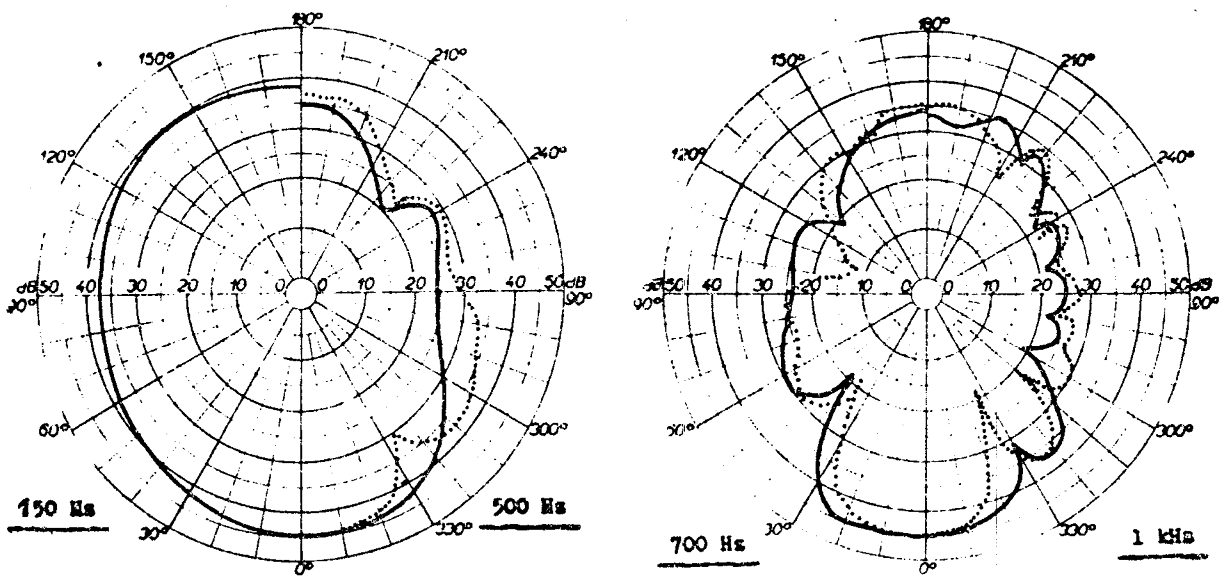


Fig. 6. Directivity patterns of the seven speaker column

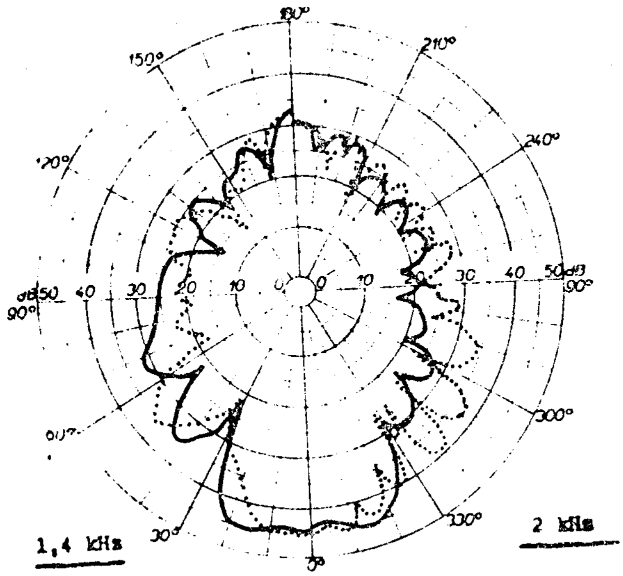


Fig. 6a.

Directivity pattern of the seven speaker compensated column.

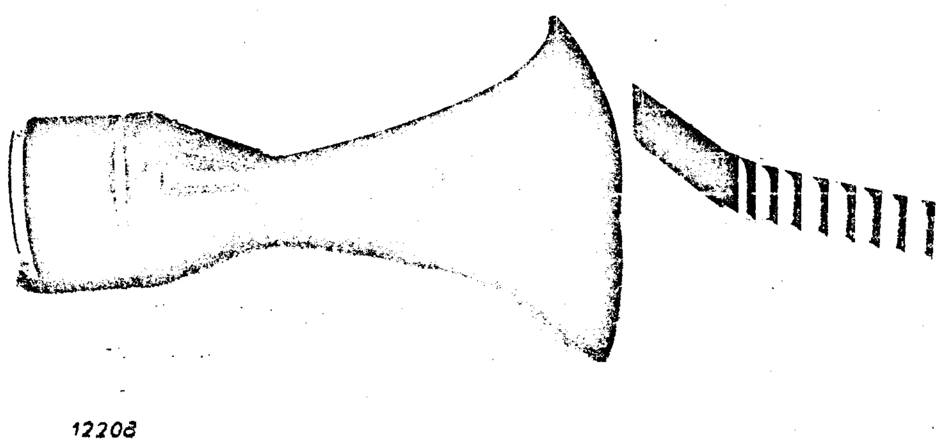


Fig. 7. Loudspeaker TESLA ART 581 and the focusing lens

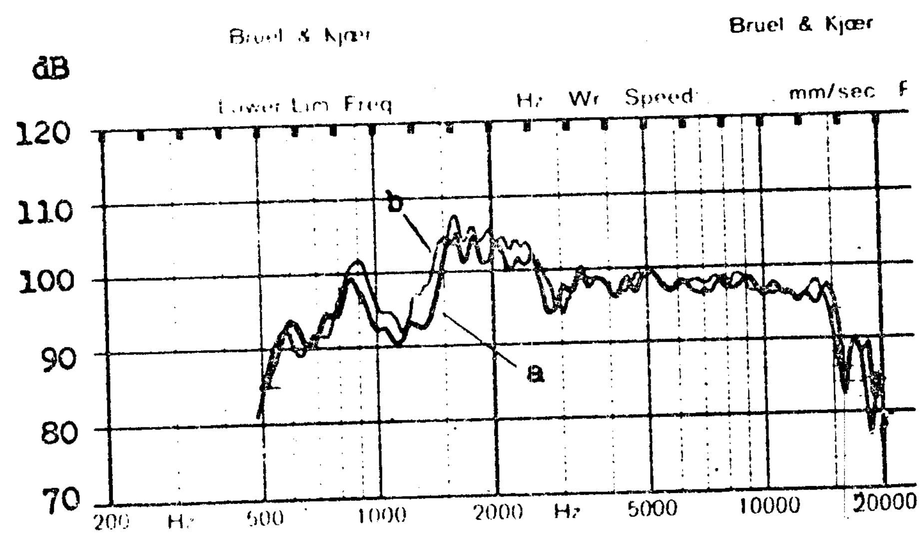
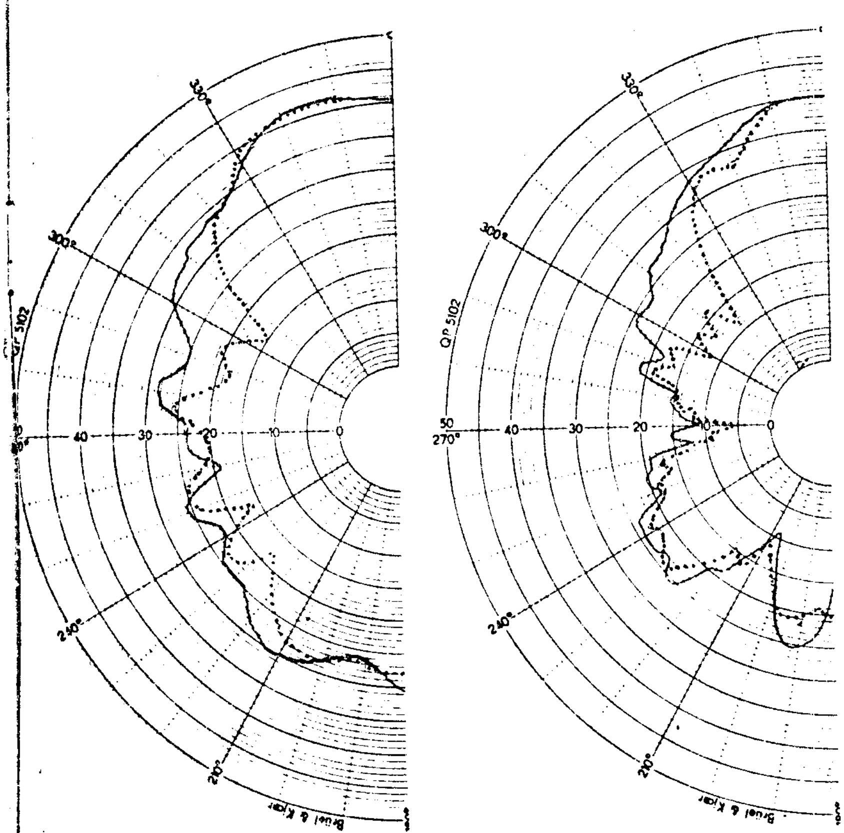


Fig. 8. Frequency response of ART 581 without and with the lens.



4 kHz 8 kHz 12,5 kHz

Fig. 9. Directivity patterns of ART 581 without and with the focusing lens.

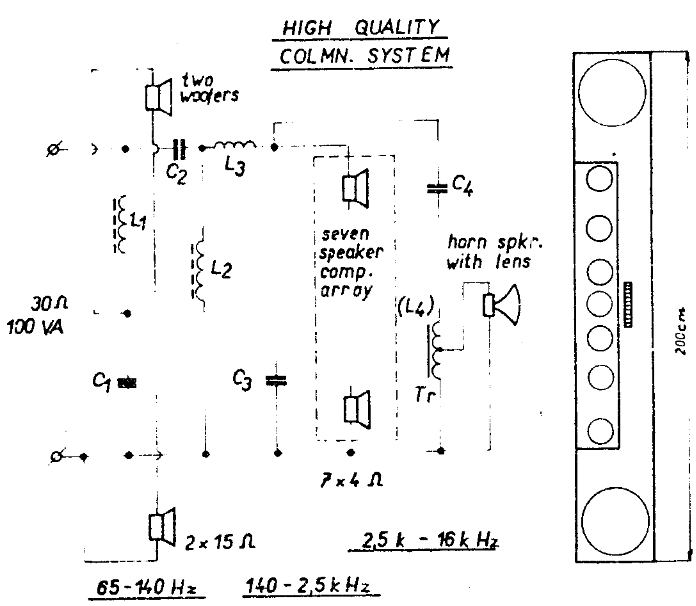


Fig. 10. Three-way columnar system for high quality of reproduction.