SUPPRESSION OF SIDE LOBES FOR ACOUSTICAL FIELD EXCITED BY DIFFERENT SHAPE RADIATORS

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Paper is devoted to consideration of the method of side lobs suppression for acoustical field that excited by different shape sound radiators. The method consists in application of additional elements in sound transducer that correct the acoustical field space distribution. The optimized configuration of sound round-shape radiator allows to suppress the first order side lobs level at more than three dB . The calculation show that the reduced level of suppressed side lobs is kept in the wide frequency band.

Keywords: Acoustical field, side lobs, acoustooptics, acoustical microscopy, high-resolution objectives, high frequency acoustics, electroacoustical transducers

1. INTRODUCTION

The problem of side lobs suppression for acoustical field remains very actual for many applications. Thus, for example, in Acoustooptical Tuneable Filters (AOTF) the level of first order side lobs of sound field much influences to the spectral characteristics of AOTF. The acoustical beam, formed by disc-shape transducer, has big side-lobes, which lead to parasitic signals excitation, that disturbs the summary response. In Acoustical objectives for acoustical microscopy the suppression of first order side lobes allows to enhance the space resolution and dynamic range of the system. In present paper the method of first order side lobs suppression is considered for acoustical field excited by round shape and rectangular radiators.

It is easy to calculate that diffraction at the disc shape radiator gives the level of first order side lobs about 1.74% (we use the relation between the disc radius and the wavelength equal to 80.48) in compared with the maximum intensity in zero order. At work [1] is shown that by putting the diaphragm to the center of optical hole it is possible to about two times suppress the first order side lobes and to increase the resolution of optical system. In present work on the basis of suggestion [2] for further suppression of side lobes the disc plus two rings-shape appodization is used and optimized. It is shown numerically the possibility for about 2.5 times suppression of first order side lobes.

2. THEORY

Angular spectrum of radiators we find as two-dimensional Fourier transform form corresponding field distribution in the plane of radiator's aperture.

$$U(P) = C\iint\limits_{A} \exp[-ik(p\xi + q\eta)]d\xi d\eta\,, \tag{1}$$

were U - the oscillation amplitude in the point P, with coordinates p and q, and A - the radiation aperture, k is a wave number, C is constant field amplitude level at the radiator's plane.

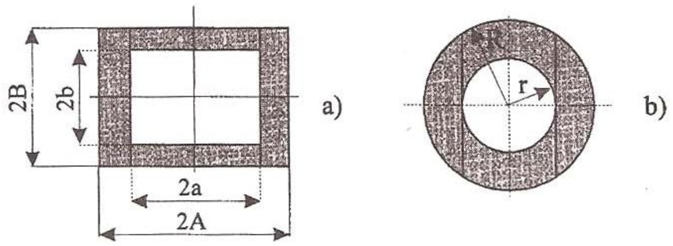

Fig.1. a) - Rectangular frame radiator elements designation;
b) - Ring-shape radiator elements designation.

2.1. Solid rectangular radiator

For rectangular radiator with measures *2a* and *2b* the formula (1) can be rewritten as

$$U(P) = C\int\limits_{-a}^{a}\int\limits_{-b}^{b} \exp[-ik(p\xi + q\eta)]d\xi d\eta\,, \tag{2}$$

2.2. Rectangular frame

Let us consider the radiator having a shape of rectangular frame with external sizes *2A* and *2B* and internal sizes *2a* and *2b*. For calculation let us divide that figure at for parts with beginning of coordinates at the center of figure (Fig.1,a). Then designate for shortening $\exp[-ik(p\xi + q\eta)] = \mathrm{e}[\xi,\eta]$ we can write a sum:

$$U(P) = C\{\int_{-A}^{-a}\int_{-B}^{B} e[\xi,\eta]d\xi d\eta + \int_{-a}^{a}\int_{-B}^{-b} e[\xi,\eta]d\xi d\eta + \int_{-a}^{a}\int_{b}^{B} e[\xi,\eta]d\xi d\eta + \int_{a}^{A}\int_{-B}^{B} e[\xi,\eta]d\xi d\eta\} \quad (3)$$

2.3. Disc-shape radiator

For disc-shape radiator angular spectrum calculation in rectangular system of coordinates let us express one of coordinate a, via the radius R of the disc and another coordinate b from the circle equation: $a^2 + b^2 = R^2$.

$$a = \sqrt{R^2 - b^2} \quad (4)$$

Then we can get the equation for disc shape radiator angular spectrum:

$$U(P) = C\int_{-R}^{R}\int_{-\sqrt{\eta^2-R^2}}^{\sqrt{\eta^2-R^2}} \exp[-ik(p\xi + q\eta)]d\xi d\eta \quad (5)$$

2.4. Ring-shape radiator

As in the case on rectangular frame we divide the ring with external radius R and internal one r, onto four parts like it can be seen from picture b) on Fig.1. For calculation of angular spectrum of ring-shape radiator* we can get the following sum:

$$U(P) = C\{\int_{-R}^{-r}\int_{-\sqrt{R^2-\eta^2}}^{\sqrt{R^2-\eta^2}} e[\xi,\eta]d\xi d\eta + \int_{-r}^{r}\int_{-\sqrt{R^2-\eta^2}}^{-\sqrt{r^2-\eta^2}} e[\xi,\eta]d\xi d\eta + \int_{-r}^{r}\int_{\sqrt{r^2-\eta^2}}^{\sqrt{R^2-\eta^2}} e[\xi,\eta]d\xi d\eta + \int_{r}^{R}\int_{-\sqrt{R^2-\eta^2}}^{\sqrt{R^2-\eta^2}} e[\xi,\eta]d\xi d\eta\} \quad (6)$$

By using formula (5) together with equation (6) it is possible to calculate the angular spectrum of radiator which consists on the disc and desirable number of rings.

The intensity of calculated sound field is found as a square of amplitude modulus. We can note, that angular spectrums for disc-shape and ring-shape radiators can be calculated by using the Bessel functions in cylindrical system of coordinates as it was done in [3]. At present paper we use the Fourier method just to keep the uniform approach for calculation of both rectangular and round-shape form radiators. Besides this approach allows calculating for any desirable shape of radiator.

3. CALCULATIONS

On Fig. 2, two graphics of angular spectrums (the sound field intensity versus to spatial angle) of solid square-shape and three inserted to each other frames radiators are given for the direction in perpendicular to one side of the square. The sides of neighboring internal and external frames are related as 2/3.

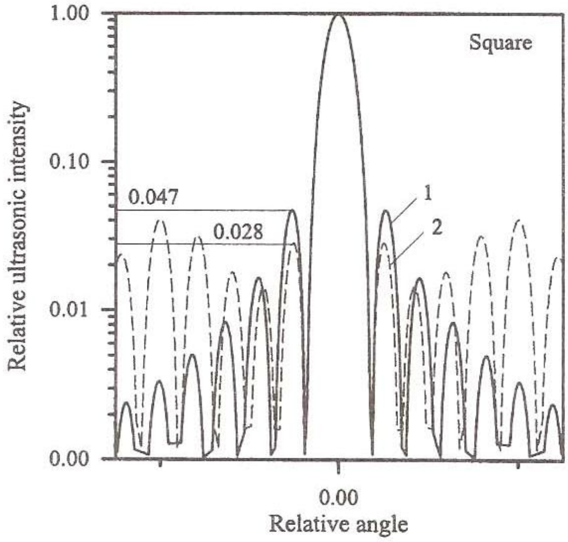

Fig. 2. Angular spectrum of square-shape radiators.
1 - solid square radiator; 2 - three square frames - shape radiator.

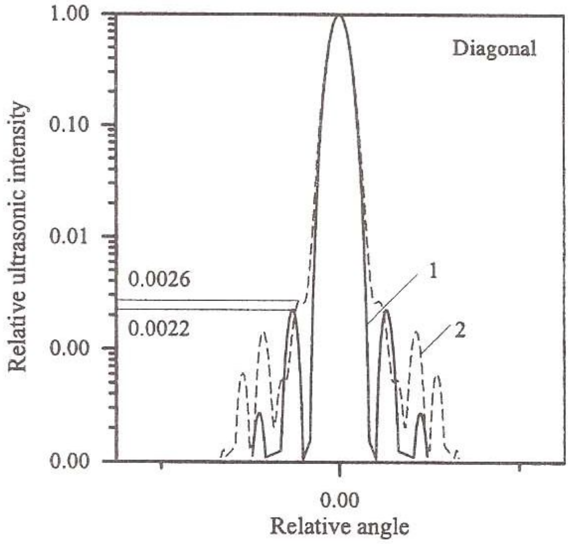

Fig. 3. Angular spectrums of rectangular radiators in diagonal direction:
1) - rectangular solid; 2) - rectangular frames.

The clearance between neighboring frames as small as this distance can be neglected. It is seen from the picture that the application of three frames-shape radiator gives about 1.7 times suppression of the first order side lobe level in comparison to solid rectangular radiator. But this level (0.028 of maximum intensity in the zero order) is still big enough and leads to undesirable effects when applying, for example in acoustooptical devices as electroacoustical transducer.

On Fig. 3., the results of angular spectrums for the same radiators but calculated in the diagonal direction, are given. It is known from the theory of diffraction that in diagonal direction of rectangular radiator the level of first order side lobes is small and corresponds to about 0.0022 on maximum in zero order. As it seen from the picture, the application of frames in this case not gives the positive effect and even leads to widening of angle aperture.

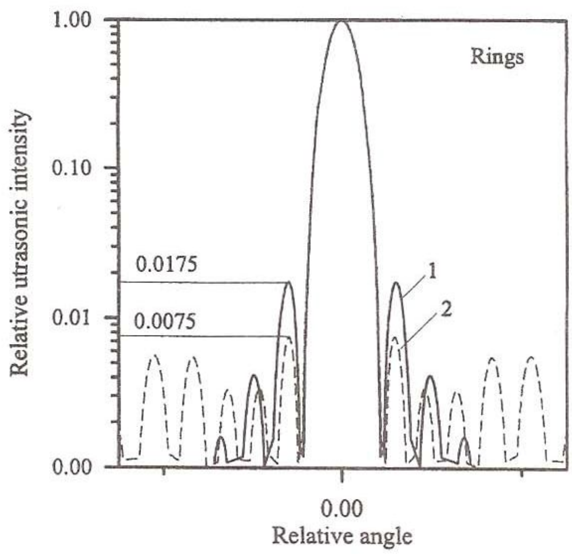

Fig. 4 . Angular spectrum of round-shape radiators.
1- solid disc radiator; 2 - three rings-shape radiator.

On Fig. 4., two graphics - for solid disc and three rings-shape radiators - are shown. In this case dividing of radiator's disc to three rings, the radiuses of which are related as 2/3, gives the first order side lobe suppression in about 2.5 times.

The calculations show that this relation of first order side lobe levels is almost independent on the wavelength and remains unchangeable in wide band of operating frequency. Which means that this method can be use, for example, in acoustical microscopy for dynamic range enlargement and spatial resolution enhancement.

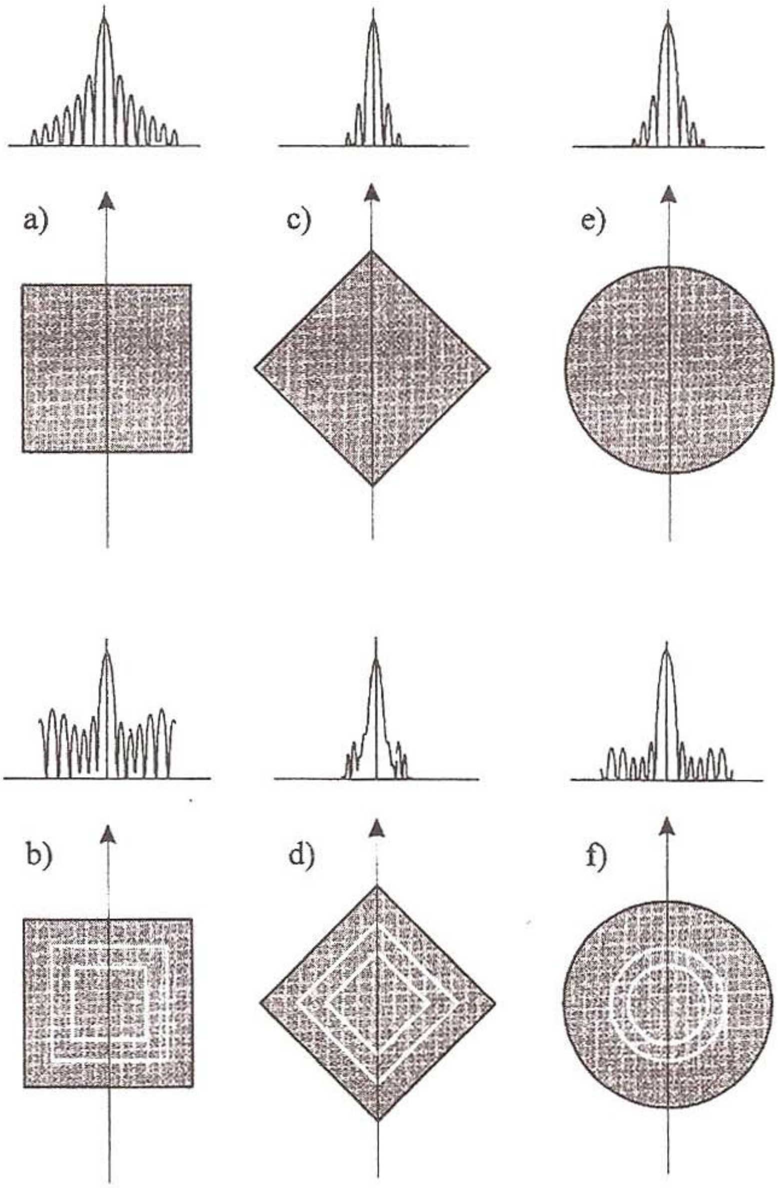

Fig. 5. Different shape radiators and corresponding angular spectrums in the direction marked by arrow. a), c) - solid square radiator; b), d) - three rectangular frames shape radiator. a), b) - directivity diagram calculated for the direction in perpendicular to one side of the square; c), d) - directivity diagram calculated for diagonal direction.

On Fig. 5., the geometry of before mentioned radiators and their angular spectrums in considered directions is presented. It is seen from the comparison of these pictures that for rectangular radiators in the direction along of one side, the first order side lobes can be suppressed in about 1.7 times by using the division of radiator to separated frames with side relation 2/3. In the diagonal direction, where side lobe levels are minimal, the radiator division to frames doesn't lead to any enhancement. The best advantage from the application of the method of separation of solid radiator to several coaxial radiators gives the round shape case. The use of rings with radius relations as 2/3 gives about 2.5 times the first order side lobes suppression.

6. CONCLUSION

In present work the method of wave radiator division for several coaxial parts is considered for investigation of its influence to the directivity diagram of radiator. There are discussed three groups of radiator angular spectrums - rectangular radiator (solid and framed) in the direction along of one side and along the diagonal, and round shape radiator (solid and rings). It is shown that the best suppression of first order side lobes can be obtained for round shape radiator when dividing it for three separate rings with internal-to external radius relation equal to 2/3. Suggested method can be used, for example in acoustical microscopy and in acoustooptic devices for dynamic range enlargement and spatial resolution enhancement.

REFERENCES

1. M.Born, E.Wolf, *Principles of Optics*, Pergamon Press, Oxford-London-Edinburg-NewYork-Paris-Frankfurt, 1968.
2. V.Petrov, S.Lapin, V.Chirkov. *Head for acoustical microscope*. Patent RF # 34794 for useful model. Priority 4 Sept. 2003.
3. V.Petrov, S.Lapin, V.Chirkov. *High resolution Objectives for Acoustical Microscopy*. Proc. of 5-th Congress on Ultrasonics WCU 2003, September 7-10, Paris, France, p.45, 2003.