A.S. Batoroev

SLOT-TYPE DIFFRACTION SCREENS FOR MINIMIZATION OF WAVE FIELDS

The Department of Physical Problems of the Buryat Research Center, Siberian Division of Russian Academy of Sciences.
Russia, 670047, Ulan-Ude, Sakhyanova Str., No 8
Tel: (3012) 43-32-54; Fax: (3012) 43 32 38;
E-mail: borto@ofpsrv.bsc.buryatia.ru

The paper presents the problem, in Fresnel formulation, defining optimal parameters of slot-type screens which provide local attenuation of interfering wave fields. Graphical and analytical method of solving a sought equation of the purpose function has been suggested. The values of generalized parameters for the diffraction screen (the dimensions of apertures and opaque strips in the screen) have been obtained by means of this method. The calculation of field distribution near its minimum value confirming efficiency of such screens are given.

One of the urgent problems in wave information transmission is suppression of interfering fields having a disturbing influence on the work of various systems. Presented screens [1–5] won recognition while solving this problem. The advantage of such screens consists in the fact that they do not sufficiently influence the antenna system characteristics and do not require any constructive changes.

The given paper regards the class of rectangular screen having a longer extension in one direction and unbroken slot-type cuts in this direction along the whole length. Thanks to this peculiarity such screens provide a wide suppression area in this direction if slot sizes are well chosen.

The ideal of using slot-type screens was first put forward in work [1] , then is was developed in works [2–4]. The investigations are generally concerned with the selection of optimal parameters and engineering capacity of the created constructions.

However, in the case with arbitary number of slots in the screen, is difficult because of a great number of sought parameters in the equation of the purpose function. Therefore, in the above – mentioned works, the achieved degree of interfering field suppression is either not very high (~15 dB) [3,4] , that shows imperfection of optimization method, or it obtained in a simplest case [2] (the incidence of the flat wave, when the screen has one slot and symmetry relative to its middle), that witnesses its limited application.

The problem of the given paper was to work out rather an effective method of choosing optimal parameters of slot-type screens for local suppression of the interfering wave and to investigate the space structure of suppression areas created near the points of maximum attenuation. k–slot-type screen symmetrical relatively the middle of the central screen (Fig.1) is chosen as a generalized screen, and the function of Φ having the value of diffraction attenuation factor is selected as the the purpose function.

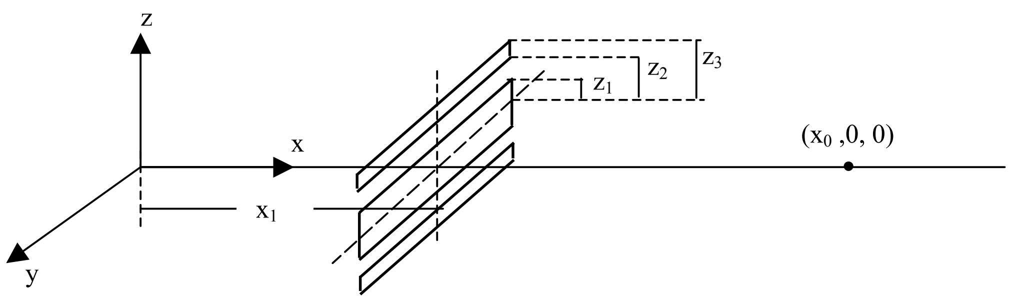


Fig.1

The equation of the purpose function includes the condition of absolute field minimization of Φ=0 in the point (x_0 , 0, 0). Using vector notation, the equation of the purpose function has the form of:

$$\Phi = \sum_{j=1}^{2k+1} (-1)^{j-1} \cdot \vec{a}_j = 0\,, \qquad (1)$$

where $\left|\vec{a}_j\right| = \sqrt{\left[1 - C(\upsilon_j) - S(\upsilon_j)\right]^2 + \left[C(\upsilon_j) - S(\upsilon_j)\right]^2}$, $\varphi(\upsilon_j) = \mathrm{arctg}\dfrac{C(\upsilon_j) - S(\upsilon_j)}{1 - C(\upsilon_j) - S(\upsilon_j)}$ –

the modulus and the phase of $\vec{a}_j$ vector functions, $\upsilon_j = \sqrt{2}\, z_j / b$ is Fresnel parameter and $C(\upsilon_j)$ и $S(\upsilon_j)$ are known Fresnel integrals, b is the radius of the first Fresnel zone.

In order to determine all values of υ_j , corresponding to z_j heights of the screen edges from equation (1), a graphical and analytical method has been worked out. It is based on the use of the optimizer consisting of the vector function hodograph of $\vec{a}_j$, having been calculated and built on the plane, and a mechanism of flat and parallel displacement of rules which summarises vectors and defines those vectors satisfying equation (1). The suggested method is rather simple and provides high accuracy and the velocity of defining parameters of screens. Fig 3 shows data on the dimensions of one-, two-, three-slot-type suppression screens. The data are presented in the form of series of curves: each series corresponds to a certain number of slots, and each curve determines the change of the corresponding edge height in the generalized parameters of υ_j.

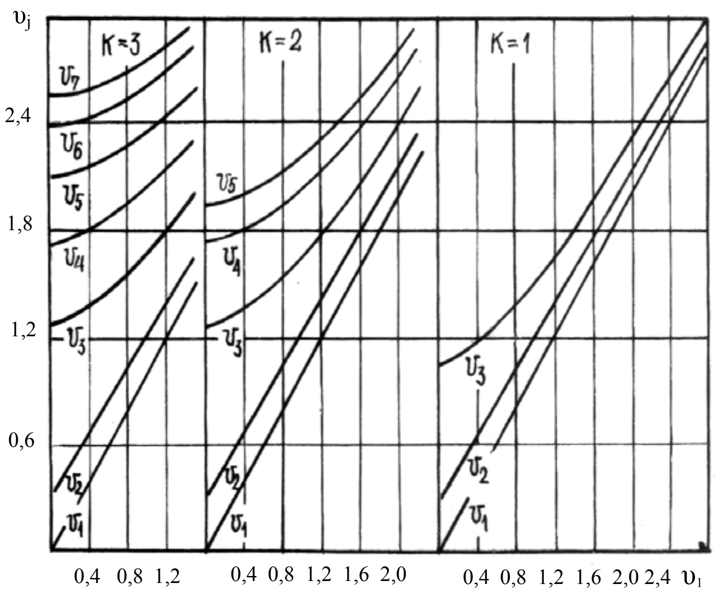


Fig. 2

The graphs given in fig. 2 show that for small values of υ all the curves (expect the first two of υ_1 и υ_2) has an expressed nonlinear nature, however, with the increase of the value of υ they gradually become asymptotic straight lines. It is apparently explained by the fact that two factors such as phase correlation of ray from the edges and the correspondence between their intensities influence the condition of optimal parameter determination for small values of υ. For large values of υ the ray intensifies from the edges become equal and heights of screen edges depend on only phase correlations what causes quasi-linear direction of curves. The graphs presented can be used to determine the distribution of strips and apertures in case when the height of the lower edge υ_1 or the whole height υ_{2k+1} all the screening systems in the indicated limits are given arbitrary. For large parameter values of υ, the widths of the strips and apertures can be approximately considered constant (only the parameter of υ_1 , i.e. the height of the lower edge being changed).

Among numerical methods of solving – equation (1) one the most sutable for our case is Newton iteration method for some reasons: a) the function are continuous and easy to calculate together with their derivatives, b) fast convergence to the solution, c) it is easy to obtain initial approximation using a graphical and analytical method.

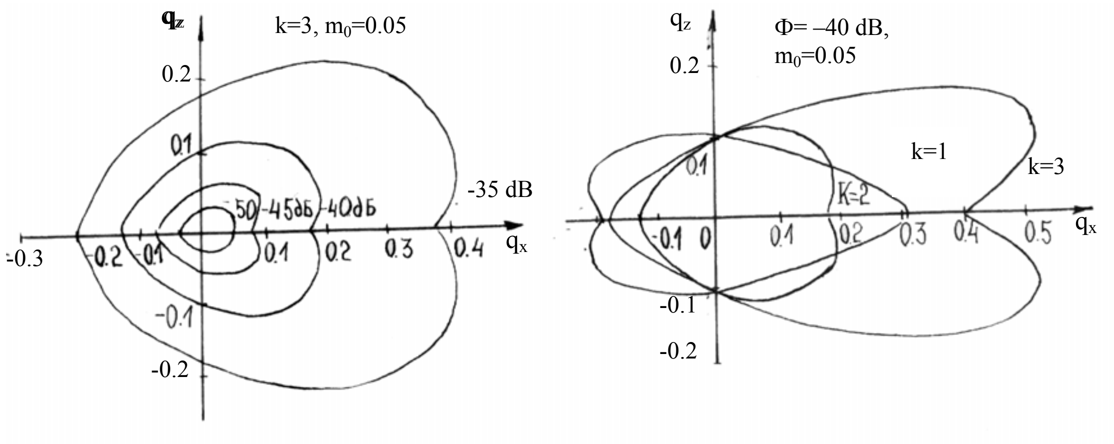
Of practical interest is also a picture of space distribution for the diffraction field near the possible absolute field minimum. Space field distribution is important to appreciate available values when choosing location and dimensions of the screening systems, forming diffraction field as well as to compare and find more efficient variants in some concrete situations.

Lines of constant suppression level in the meridian section give a more dramatic information about space distribution of diffraction field of slot-type screens. It is convenient to build these lines relative to the point local field minimum (x_0 , 0, 0) in the form of value $\Phi(q_x , q_z)$ depending on dimensionless coordinates:

$$q_x = \frac{x - x_0}{x_0} \; ; \qquad q_z = \frac{z}{b(x_0)} = \frac{z}{\sqrt{\lambda m_0 (1 - m_0) x_0}} \; ,$$

which define the location of the investigated point relative to the local minimum point (focal point). There Здесь $x_1 / x_0 = m_0$ is the parameter defining the location of the screen concerning the focal point.

Fig.3 illustrates some calculation results giving a general picture of diffraction field space distribution nearly focal points.



a) b)

Fig. 3

The lines of constant suppression level for screen with any member of slots are asymmetrical concerning the local field minimum (relative to the local point of q_x=0 , q_z=0) along q_x-axis.The observed asymmetry gradually vanishes with the increase of the suppression level. It is well seen in case of two-slot-type (k=2) screen (fig. 3a) , where the line of the constant level can be considered symmetrically relative to q_z–axis even at the level of –50 dB. Special attention is paid to the line shapes of the constant suppression which are from one side saddle-convex (sharpened), the saddle-shaped part facing the screen in case of two– slot–type screens and three–slot–type ones (Fig.3 b).The asymmetry of equal suppression is provided in a wider space area to the right of the focal point (remote from the screen) than to the left of it.

The comparison of space dimensions of the screening area versus k – number of slot in the screen. Fig. 3b illustrates such a comparison on the level of –40 dB it the screens are located in the point having the relative coordinate m_0=0,05. Three–slot–type screen is seen to create a wider suppression area in the right part from the focal point. However, one–slot–type screen is more preferable in the left part (i.e. in the part nearby the screening system). The picture of suppression is repeated on other levels. Therefore, it should be taken into account when choosing the type of the screen in practice. The screen dimensions also play a certain role and should be considered when providing required dimensions of the suppression area (the dimensions of one–slot–type screens are much smaller than others in the given case).

Fig. 4. shows space pictures of field attenuation obtained by means of both the graphical and analytical method and Newton iteration method in comparison. As the comparison showed a more precise definition of parameter data obtained by Newton iteration method has been expressed in the third sign. That confirms rather a high accuracy at the graphical and analytical method itself. Such specification results in an insignificant change of the suppression area structure nearby the focal point of (x_0 , 0, 0).

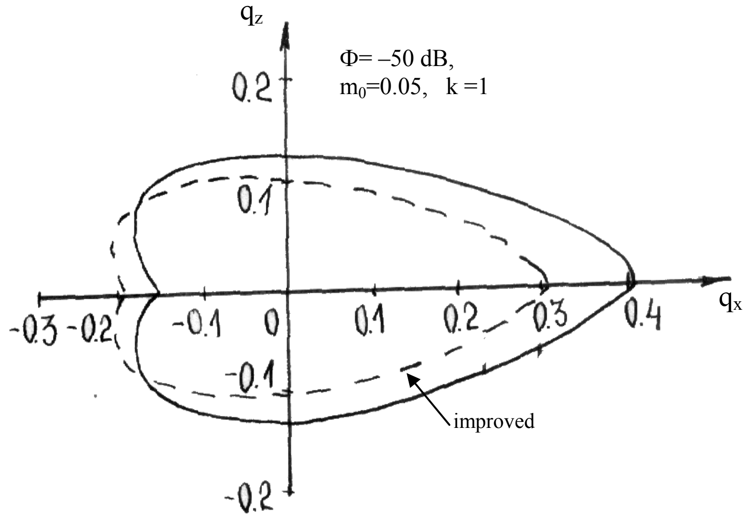


Fig. 4

However, despite the apparent insignificance of specification, the significance of such improvement increases, when the wavelength is shortened, and becomes decisive for the comparative analysis of suppression area space characteristics created by various types of screens near local minima.

REFERENCES

1. Becker J.E, Design Study for AMRAD Anti-clutter Fence // Wheller labs., Inc., Smith town, N.Y., Rept.,1233, 1964, July 22.
2. Melnicov Yu.M. Slot-type Protective Antenna Device // Proceeding of RIR, Moscow, 1975, No. 1, p. 86-92. (In Russian).
3. Becker J.E. Millett R.E. IEEE Double-slot Radar Fence for Increased Clutter Suppression // IEEE Trans. Antennas and Propag., 1968,AP-16, №1. p. 103-108.
4. Preikschat F.K. Screening Fences for Ground Reflection Reduction // Microwave Journal, 1964, V.7, №8б p.103-108.
5. Lokshin V.L., Melnikov Yu.M, Frolov O.P. Yampolski V.C. The Methods of Increasing Noise Protection in Radiolines // Electrosvyaz, 1975, No. 1, p. 6-11. (In Russian).