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ANTENNA ARRAY WITH SUPER DIRECTIVITY PROPERTIES AND POSSIBLE UWB APPLICATION

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АНТЕННА РЕШІТКА З ВЛАСТИВОСТЯМИ НАДСПРЯМОВАНОСТІ ТА МОЖЛИВИМ НШС ЗАСТОСУВАННЯМ

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Abstract.*The algorithm for full rejection of the side lobes of a pattern antenna array at the given azimuth angle points outside the main lobe area are considered. Ultra wideband (UWB) radars are use not only ultrashort pulses, but also a very low level of radiated power for compressed signals with long enough duration. High range resolution and accuracy of mesuaring the distance to the target is provided by UWB radars. High spatial resolution also provides the ability to isolate the target from background noise [11]. The modern UWB radars aren't free from lot of drawbacks, including high enough side lobes level of radar antenna array diagram. It leads to impossibility of separation reflected signals from the big targets (which have big effective reflecting surface (ERS)) and from the small targets, which has small ERS, and which are situated on the same distance and have azimuth angle's with close value. The solution of this problem can be obtained by means radar antenna pattern formation on the base of antenna array with controlled elements The algorithm for full rejection of the side lobes of a pattern antenna array at the given azimuth angle points outside the main lobe area are considered. The antenna pattern side lobes required suppression level are realized with the simple methods by using the arrays with limited number of tunable weight coefficients of spatial filter (antenna array elements), for example, with only two of such tunable weight coefficients. In this case all weights coefficients* W_i *of the receiving antenna array, except two (first and last:* W_1, W_N*), are fixed (selected under the condition of providing the required average antenna pattern side lobes level -* $W_2;W_3;...;W_{N-1}$*).Those (no tuning) elements of the array are chosen to obtain given average side lobe level suppression with given value of the antenna directivity. Also, different algorithms for calculation fixed weights coefficients for providing the required average antenna pattern side lobes level are presented: on the base mean-square criteria [5,6] and more simple ones on the base of weighting functions sin(x) and* $(sin(x))^2$ *[7,8], which give the possibility of changing depth of modulation of weighting function in wide interval (from equal values maximum and minimum weight coefficients till the biggest possible difference between them) and correspondingly different levels of the average side lobes suppression and losses in antenna's directivity. Numerical examples were considered for demonstration the efficiency of different weighing functions suggested for fix coefficients. The partial diagrams were calculated for this purpose. The specisl interaction of these no tuning elements for realizing the superdirectivity properties is used. The full reception diagram of 10 elements antenna (2 tuned elements and 8 fix elements) provided side lobes suppression in given points with equal and unequal elements weighting functions are investigated. The efficiency of suggested design has been investigated. The structural diagram of the array is presented.*

Keywords*: antenna array, weight coefficients, side lobes level, partial diagram, superdirectivity*

Анотація. *Розглянуто алгоритм повного придушення бічних пелюсток антенної решітки в заданих точках азимутального кута поза області головного пелюстка. Надширокосмугові (НШС) радари не тільки пов'язані з використанням надкоротких імпульсів, але також з використанням дуже низького рівня потужності випрмінювання задля стислих сигналів з достатньо великою протяжностью у часі.НШС радари забезпечують високу розподільну можливість і точність по далині. Висока просторова расподільна можливість також забезпечуе якісні характеристики віділення цілей на фоні завад[11]. Сучасні НШС радари ні вільні від недоліків, зокрема, мають достатньо високий рівень бокових пелюсків діаграми антеної решітки. Це приводить ло неможливості розділення відбитих синалів від веких цілей (які мають велику ефективну поверхню розсіянн (ЕПР))і від малих цілей з малою ЕПР,які знаходяться на однаковій відстані і мають близьки значення азімутальних вуглів..Рішення цієї проблеми може бути знайдено на основі формування діаграми* *спрямованості антени за допомогою антенної решітки з контрольованими елементами. Метою представленого дослідження є формування алгоритму для пригнічення бічних пелюстків діаграми спрямованості антени судового радіолокатора за допомогою антенних решіток з контрольованими елементами. Методика дослідження полягає в розробці методів пригнічення бічних пелюстків діаграми спрямованості антени за допомогою використання антенних решіток з обмеженою кількістю налаштованих вагових коефіцієнтів просторового фільтру (елементів антенної решітки). Як відомо, через досить високий рівень бічних пелюстків діаграми спрямованості антени неможливе відокремлення відбитих сигналів від великих цілей (які мають велику ефективну площу розсіювання (ЕПР)) та від малих цілей, що мають малу ЕПР, що розташовані на одній дальності та мають близькі значення азимутальних кутів. Результатом дослідження є розрахований алгоритм пригнічення бічних пелюстків діаграми спрямованості антени в зазначених точках за допомогою двох налаштованих вагових коефіцієнтів (першого та останнього W_1, W_N), а всі інші вагові коефіцієнти W_i прийомної антенної решітки фіксовані (обтраються за умови забезпечення небохідного середнього рівня бічних пелюстків діаграми спрямованості – $W_2;W_3;...;W_{N-1}$) [6]. Також, представлені різноманітні алгоритми для розрахунку фіксованих вагових коефіцієнтів для забезпечення необхідного середнього рівня бічних пелюстків діаграми спрямованності антени: на основі середньоквадратичних критеріїв [5,6] та простіших, на основі вагових функцій $sin(x)$ і $(sin(x))^2$ [7,8], що дають можливість зміни глибини модуляції вагової функції в широкому интервалі (від рівних значень максимальних і мінімальних вагових коефіцієнтів до максимально можливої різниці між ними) і відповідно різних рівней пригнічення середнього рівня бічних пелюстків та втрат в коефіцієнті спрямованності антени. На основі отриманих результатів розрахунків побудовано діаграми спрямованності, які відображають отримання пригнічення бічних пелюстків в зазначених точках. Також приведено структурну діаграму запропонованого алгоритму. Представлене дослідження можливо застосовувати у модернізації існуючих та побудові нових систем морської радіолокації та звя'зку. Досіджуваний підхід досить простий для розрахунків и не потребує впровадження процедур чисельної оптимізації.*

Ключові слова: *антенна решітка, вагові коефіцієнти, рівень бічних пелюсток, часткова діаграма, надспрямованість*

1 INTRODUCTION

The modern radars are the high-powered technical mean of navigation and take important role in protection from the space-time interference. But they aren't free from lot of drawbacks. The high enough side lobes level of radar antenna array diagram is the one of such drawback. It leads to impossibility of the separation reflected signals from the big targets (which have big effective reflecting surface (ERS)) and from the small targets, which has small ERS, and which are situated on the same distance and have the azimuth angle's with close values. The solution of this problem can be obtained by means radar antenna pattern formation on the base of antenna array with controlled elements. The optimal methods of such diagrams formation are known and connected with the need of all array elements tuning by difficult algorithms [1]. At the same time the reaching of the antenna pattern side lobes required suppression level may be realized with the simple methods by using the arrays with limited number of tunable weight coefficients of the spatial filter (antenna array elements), for example, when there are only two of such tunable weight coefficients. In this case all weights coefficients w_i of the receiving antenna array, except two (first and last: W_1, W_N), are fixed (selected under the condition of providing the required average antenna pattern side lobe's level) $(W_2;W_3;...;W_{N-1})$. Value of the two tunable weights coefficients are selected for providing zero values in two points (θ_1,θ_2) of the reception pattern. This approach can be used not only for narrowband antenna system but also for broadband and ultra wideband (UWB) antenna system. Corresponded broadband characteristics of antenna may be achieved by means proper choose of antenna construction [2]. For example, good broadband characteristics can be gotten using horn elements in antenna array [2] (see also [3]). Theoretically antennas which are constructed on the base of biconical elements may be provided pattern as well as impedance which are practically independent of frequency inside of certain interval [2], [3]. It is known UWB antenna array based on planar dipole elements [4]. In chapter II the main expressions for calculation the tuned weight coefficients and the resulting reception pattern are presented. In chapter III the different algorithms for calculation the fixed weights coefficients for providing the required average antenna pattern side lobes level are presented: on the base mean-square criteria [5,6] and more simple ones on the base of weighting functions $\sin(x)$ and $(\sin(x))^2$ [7,8], which give the possibility of changing deep of modulation of weighting function in wide interval (from equal values maximum and minimum weight coefficients till the biggest possible difference between them) and correspondingly different levels of the average side lobes suppression and losses in the antenna's directivity. Numerical examples were considered for demonstrationthe efficiency of different weighting functions suggested for fix coefficients. The partial diagrams were calculated for this purpose. As the all numerical examples in this work were considered for tenth elements array, so the partial diagrams were calculated for N-2=8 elements array with the equal weight coefficients values and the other weighting functions with the unequal weights coefficients values. In chapter IV the full reception diagram of 10 elements antenna (2 tuned elements and 8 fix elements) which provided side lobes suppression atthe given points with equal and unequal elements weighting functions are investigated. In chapter V the realization of twice number of suppression points of diagram without the increasing number of tuned elements are considered. In chapter VI the possibilities of the decreasing of the main lobe width are investigated. Because the algorithms of reception diagram side lobes suppression in given points by means the tuned weights and decreasing the average level of side lobes in other points by means the weighting correction of fix element leads to increasing the width of main lobe of antenna diagram [9]. The algorithm was suggested for providing decreasing the main lobe width on the base of forming two partial diagrams and using the special interaction between them. The expression for the main lobe width was obtained on the level 0,5G(0), which shows the possibility of the significant narrowing the main lobe. So the Superdirectivity property may be realized [10,11]. Thermal noise and technological errors are limited real possibilities of such narrowing. The expression was obtained for the evaluation of the the real main lobe width value with considerationthe equivalent noise level. The corresponding calculations and the structural diagram of antenna array realizedthe suggested algorithm are presented.

2 MAIN EXPRESSIONS FOR CALCULATION

The expressions, which are describing the reception pattern of linear array antenna $G(\theta)$ for the considered case, may be written in the following form:

$$G(\theta)=\sum_{i=1}^{N}W_i\cdot e^{-j2\pi(d/\lambda)(N-1)i\sin\theta}=G_{N-2}(\theta)-\gamma_1\cdot G_{N-2}(\theta_1)-\gamma_2\cdot G_{N-2}(\theta_2), \tag{1}$$

where $G_{N-2}(\theta)$ – partial diagram,

$$G_{N-2}(\theta)=\sum_{i=2}^{N-1}W_i\cdot e^{-j2\pi(d/\lambda)(N-1)i\sin\theta}; \tag{2}$$

$$W_1=\frac{G_{N-2}(\theta_2)\cdot e^{-j2\pi(d/\lambda)(N-1)\sin\theta_1}-G_{N-2}(\theta_1)\cdot e^{-j2\pi(d/\lambda)(N-1)\sin\theta_2}}{e^{-j2\pi(d/\lambda)(N-1)\sin\theta_2}-e^{-j2\pi(d/\lambda)(N-1)\sin\theta_1}}; \tag{3}$$

$$W_N=\frac{G_{N-2}(\theta_1)-G_{N-2}(\theta_2)}{e^{-j2\pi(d/\lambda)(N-1)\sin\theta_2}-e^{-j2\pi(d/\lambda)(N-1)\sin\theta_1}}; \tag{4}$$

$$\gamma_1(\theta)=\frac{e^{-j2\pi(d/\lambda)(N-1)\sin\theta_2}-e^{-j2\pi(N-1)(d/\lambda)\sin\theta}}{e^{-j2\pi(d/\lambda)(N-1)\sin\theta_2}-e^{-j2\pi(N-1)(d/\lambda)\sin\theta_1}}; \tag{5}$$

$$\gamma_2(\theta)=\frac{e^{-j2\pi(d/\lambda)(N-1)\sin\theta}-e^{-j2\pi(N-1)(d/\lambda)\sin\theta_1}}{e^{-j2\pi(d/\lambda)(N-1)\sin\theta_2}-e^{-j2\pi(N-1)(d/\lambda)\sin\theta_1}}; \tag{6}$$

$\phi - 2\pi d \sin\theta/\lambda$ – signal phase; λ – wave's length; d – distance between antenna's array elements;
θ – angle between the normal to the axis of the array antenna and direction of coming signal.

3 WEIGHTING FUNCTIONS FOR FIX ELEMENTS

(*N*–2)-fixed weight coefficients may be selected under condition of additional suppression average level of reception diagram's side lobes (2) with possible widening of the main lobe of antenna array diagram (1). So, the full number of the coefficients, which creates reception array diagram, equals *N*. The expression for fixed weight coefficients optimized by mean-square criteria has the next form [5,6]:

$$W_f = D^{-1} \cdot 1, \tag{7}$$

where D^{-1} – inverse matrix; 1 – identity column-vector, which consists of all unit numbers.

Matrix *D* is formed as follows:

$$D = \sum_{L_1}^{L_2} Q_l 1 \cdot 1^t Q_l^* , \tag{8}$$

where Q_l – diagonal matrix, which has the next form:

$$Q_l = \begin{bmatrix} e^{j2l2\pi\frac{d}{\lambda}\sin\Delta\theta} & 0 & 0 & ... & 0 \\ 0 & e^{j3l2\pi\frac{d}{\lambda}\sin\Delta\theta} & 0 & ... & 0 \\ ... & ... & ... & ... & ... \\ 0 & 0 & 0 & ... & e^{j(N-1)l2\pi\frac{d}{\lambda}\sin\Delta\theta} \end{bmatrix}; \tag{9}$$

$\Delta\theta_f$ – an interval between suppressing points of the spatial diagram $G_{N-2}(\theta)$; 1^t – transposed matrix; L_1, L_2 – lower and upper bounds for suppressed points situation.

Choosing in Q_l (8) step $\Delta\theta_f$, and also values L_1 and L_2 we can provide different values of average level of side lobes suppression $G_{N-2}(\theta)$, but with varying degrees of its main lobe widening. Such approach was considered in [6] and [7].

If $\Delta\theta_f = \arcsin\left[1/\left(2\left(d/\lambda\right)\left(N-2\right)\right)\right]$, (ratio $d/\lambda = 0.5$ was set everywhere), $L_1 = 0$ and $L_2 = N-2$ from (7), (8) we are getting the case, where all $W_i = 1\left(i = 2 \div N-2\right)$.That is the case of reception diagram $G_{N-2}(\theta)$ with equable correction, which is corresponded the condition of absence of main lobe widening (Figure 1).

If $\Delta\theta_f = \arcsin\left[1/\left(4\left(d/\lambda\right)\left(N-2\right)\right)\right]$, and $L_1 = 3$, $L_2 = 2N-3$, the unequal values of weight coefficients can be obtained, which provides compromise between the average value of side lobes suppression (more than – 30 dB) and relatively small main peak's extension (about 10 %) (Figure 1).

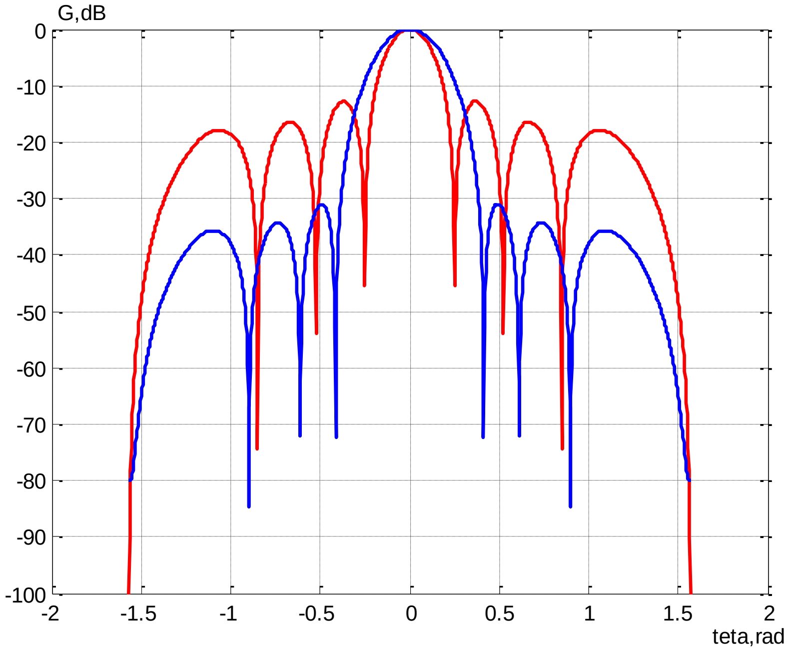

Figure 1 – Partial reception diagram: — with equal weight coefficients values;
— with unequal coefficients values.

This diagrams are showing, that average level of suppression with different W_i is higher, than in the case, when $W_2 = W_3 = ... = W_{N-2}$.

Thelosses in antenna's directivity to fully sinphased common-mode reception diagram (with equal weght coeffissients) [7, 9]:

$$\rho = \frac{|G(0)|^2}{N\sum_{n=1}^{N}|W_n|^2} \tag{10}$$

Let's consider more simple form for different weight functions effect on the reception diagram, which allow transforming the reception diagram properties. The expression for the untunable weight coefficient in this case has the next form [7,8]:

$$W_n^{(1)} = \sin\left[\pi\left(\frac{y}{N+1-2} + \frac{n-2}{N+z-2}\right)\right]; \tag{11}$$

$$W_n^{(2)} = \left[\sin\left[\pi\left(\frac{y}{N+1-2} + \frac{n-2}{N+z-2}\right)\right]\right]^2, \tag{12}$$

where: $n = 2 : N-1; \quad y < [N/2]; \quad z = [2y(N-2)-(N-2+1)]/[N-2+1-2y]$.

We can regulate the main lobe widening by parameter 'y'. The bigger value of the parameter 'y', leads to the less main lobe widening. For example, the reception diagrams calculated with (11) and (12) with different values of 'y' are shown on figure 2.

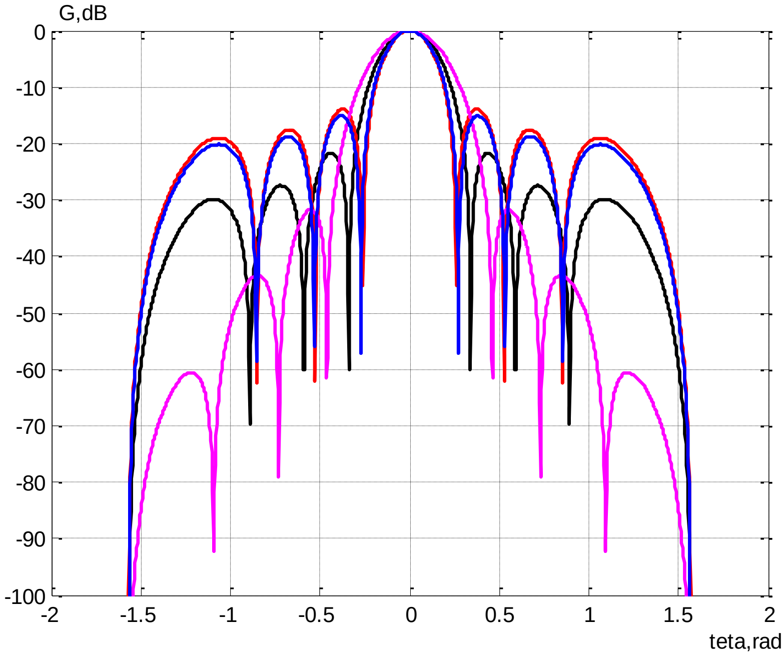

Figure 2 – Partial reception diagram with **y=1**, **y=3** by $W_n^{(1)}$; **y=1**, **y=3** $\left(W_n^{(2)}\right)$

4 FULL DIAGRAM ANALYSIS

The full reception diagrams of 10-elements antenna (2 tuned elements), calculated according (3) and (4), and 8 fix elements with equable correction) with side lobes suppression in the given points are shown on figure 3.

The similar type of expressions, as (3), (4) were obtained erlier for the task of signal - time processing in the case of frequency separation of receiving signals [12] and the time-frequency task separation of signals [13].

As we can see, the suppression of this points is high enough, and the side lobes level between the suppressed points is low enough (about – 80 dB). Losses in antenna's directivity (10) are increase with drawing those points closer to main lobe, and in considered case isn't more than –1.4 dB.

The reception diagrams side lobes suppression in given points, calculated by (11) are shown on figure 4.

So, we can correct the non-regulated part of reception diagram by different weights functions. This approach doesn't require the implementation of numerical optimization procedures as were described in [1]. Choosing of such kind the weighting functions we can get additional average side-lobe suppression, but with the widening main lobe.

The supression with double distance between suppression points is shown on figure 5.

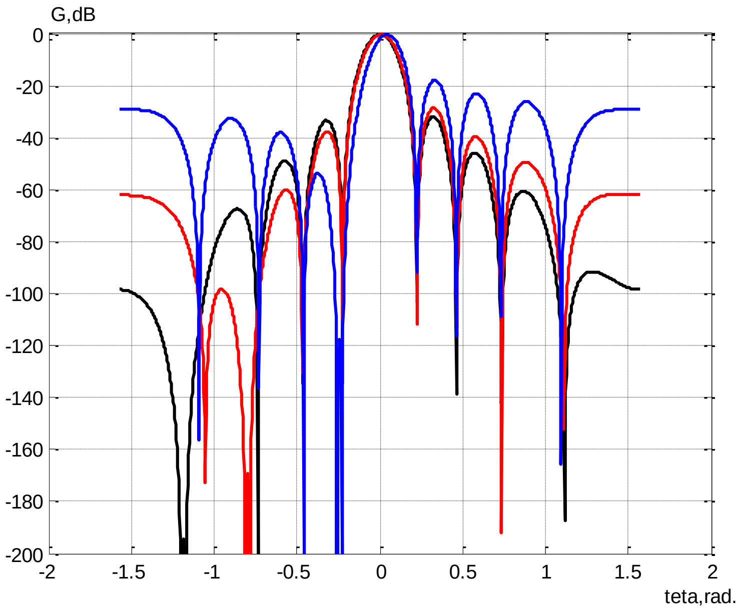

Figure 3 – Reception diagram (partial diagram with equable correction)

$$\theta_1 = -1.2001, \quad \theta_2 = -1.1718, \quad \rho = -0.2238 \text{ dB};$$

$$\theta_1 = -0.8137, \quad \theta_2 = -0.7854, \quad \rho = -0.2784 \text{ dB};$$

$$\theta_1 = -0.2576, \quad \theta_2 = -0.2293, \quad \rho = -1.4107 \text{ dB};$$

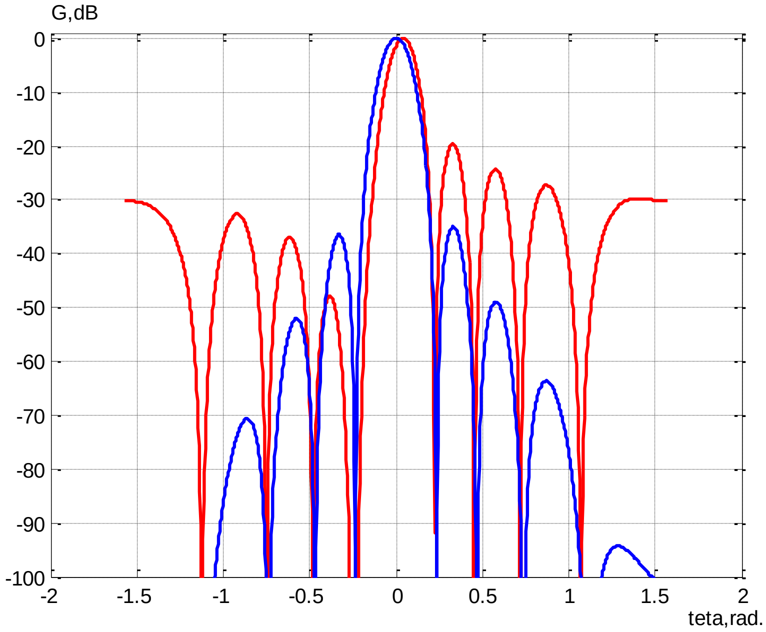

Figure 4 – The reception diagram side lobes suppression in points (y=3, $w_n^{(1)}$):

$$\theta_1 = -1.2001, \quad \theta_2 = -1.1718, \quad \rho = -0.2238 \text{ dB};$$

$$\theta_1 = -0.2576, \quad \theta_2 = -0.2293, \quad \rho = -7.4690 \text{ dB}.$$

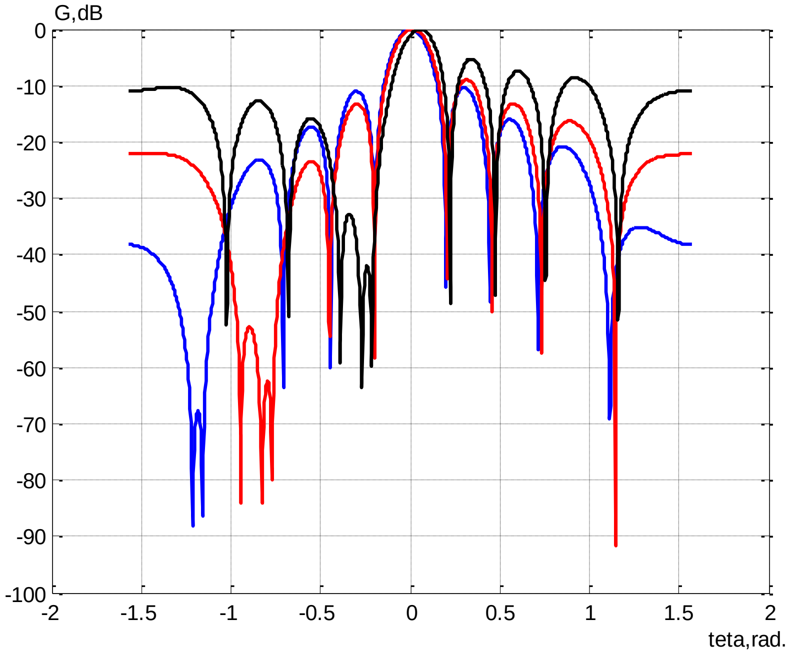

Figure 5 – The reception diagram with double distance between suppression in points:

$\theta_1 = -1.2143, \quad \theta_2 = -1.1577, \quad \rho = -0,2228$ dB;

$\theta_1 = -0.8278, \quad \theta_2 = -0.7712, \quad \rho = -0.2749$ dB;

$\theta_1 = -0.2717, \quad \theta_2 = -0.2152, \quad \rho = -1.3647$ dB.

Increasing distance between suppresssion points give the possibility to increase rejection area nearby of supression points. In [14] were gotten estimates of values of side lobes level between suppression points depending of the distance between them. Using those estimates we may choose the proper distance between supression points.

5 TWICE NUMBER POINTS OF SUPPRESSION

It is interesting to note, than if instead of reception diagram, which described by (1), we use the expression for symmetrical form with real coefficients (14), (15) in following form [7]:

$$G^{(1)}(\theta) = G^{(1)}{}_{N-2}(\theta) - \gamma_1^{(1)} \cdot G_{N-2}^{(1)}(\theta_1) - \gamma_2^{(1)} \cdot G_{N-2}^{(1)}(\theta_2), \tag{13}$$

where

$$G_{N-2}{}^{(1)}(\theta) = G_{N-2}(\theta) \cdot e^{j\pi(N-1)\frac{d}{\lambda}\sin\theta};$$

$$\gamma_1^{(1)}(\theta) = \frac{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_1\right]}{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_2\right] - \cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_1\right]} - \\ - \frac{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta\right]}{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_2\right] - \cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_1\right]} \tag{14}$$

$$\gamma_2^{(1)}(\theta)=\frac{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta\right]}{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_2\right]-\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_1\right]}-$$
$$-\frac{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_1\right]}{\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_2\right]-\cos\left[-j2\pi(N-1)\frac{d}{\lambda}\sin\theta_1\right]} \quad (15)$$

We can get the reception diagram with suppressing in four points with symmetrical positioning relative to main lobe (using only two tuned weights, as in previous cases). As an example, on figure 6 are shown such diagrams.

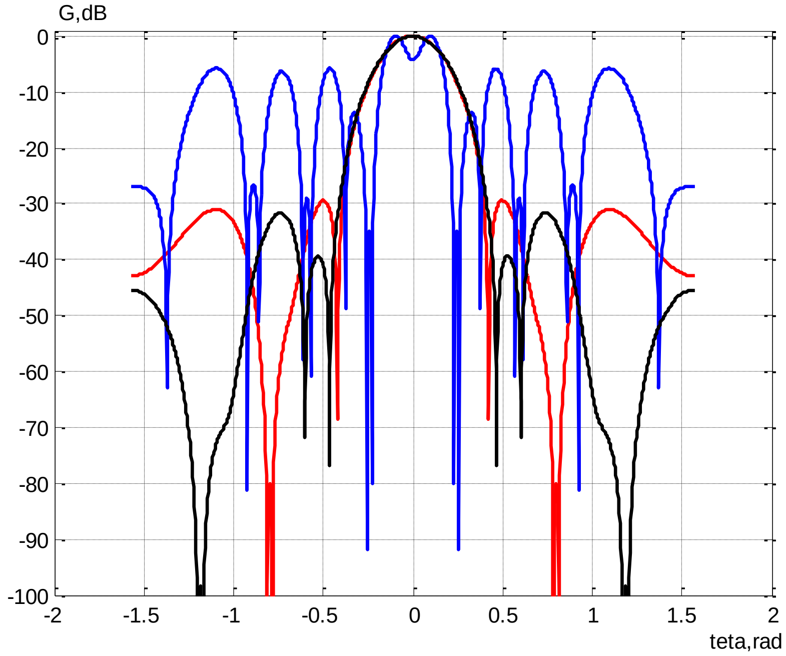

Figure 6 – The reception diagram with real coefficients (simmetrical):
$-\theta_1=-1.2001,\quad \theta_2=-1.1718,\quad \rho=-1.0848$ dB;
$-\theta_1=-0.8137,\quad \theta_2=-0.7854,\quad \rho=-1.5527$ dB;
$-\theta_1=-0.2576,\quad \theta_2=-0.2293,\quad \rho=-2.4359$ dB;

6 DECREASING WIDTH OF ANTENNA DIAGRAM MAIN LOBE AND SUPERDIRECTIVITY

The method of increasing angle selectivity without losses in suppression of given points and in average side-lobe level may be suggested. In considered case at the output of $N-2$ antenna array (no tunable part of reception antenna (1) (see (4))) we have complex signals $X_1, X_2,...X_N$ [5]. By the first $N-2$ signals is created the sum:

$$Z_1=\sum_{i=1}^{N-2}W_{i+1}X_i\,. \quad (16)$$

Beside (16) the second sum is created:

$$Z_2=\sum_{i=3}^{N}W_{i-1}X_i\,, \quad (17)$$

where $X_i=S_i+N_{1i},\quad S_i=|S_1|e^{j(i-1)\phi},\quad \phi=2\pi d\sin(\theta/\lambda),\ N_{1i}$ – thermal noise.

If root-mean-square value of thermal noise is negligible small and $|S_1| = 1$, (15) coincides with (2) and $Z_2 = Z_1 e^{j2\varphi}$.

Then the sum is created [15]:

$$G_R(\phi) = \left| \begin{bmatrix} 1 & e^{-j\psi} \end{bmatrix} \begin{bmatrix} Z_1 \\ Z_2 \end{bmatrix} \right|, \tag{18}$$

$$\psi\wedge = -2arctg \cdot \mu \sin\phi / (1 - \mu \cos\phi), \tag{18'}$$

where μ – coefficient $(0 \le \mu \le 1)$,

$$\sin 2\phi\wedge = \mathrm{Im}\left[\left(Z_1^* Z_2 \right) / \left(|Z_1||Z_2| \right) \right], \qquad \cos 2\phi\wedge = \mathrm{Re}\left[\left(Z_1^* Z_2 \right) / \left(|Z_1||Z_2| \right) \right]$$

From (18), using (18'), after some transformations we can get:

$$G_R(\phi) = \left[G_{N-2}(\phi) \cdot 2 \cdot |\mu - \cos\phi| \right] \Big/ \left[\sqrt{1 - 2\mu\cos\phi + \mu^2} \right] \tag{19}$$

Considering (17) and (18), (19) may be represented in the form:

$$G_R(\theta) = G_{N-2}(\theta) \cdot G_S(\theta), \tag{20}$$

$$G_S((\theta)) = \left[2 \cdot \left| \mu - \cos 2\pi \sin\theta (d/\lambda) \right| \right] \Big/ \left[\sqrt{1 - 2\mu \cos 2\pi \sin\theta (d/\lambda) + \mu^2} \right], \tag{21}$$

where $G_{N-2}(\theta)$ is determined by (2).

As we can see from (19) the angle selectivity of antenna may be essentially increased by means proper choose the value of μ. The width of the main beam of (19) on the level $0.5 G_S(0)$ is:

$$\Delta\theta_0 = 2\arcsin\left[(\arccos\mu) / (2\pi d/\lambda) \right]; \tag{22}$$

$$\Delta\theta_{0.5} = \arccos\left[\mu/2 + \left(\sqrt{2 - \mu^2} \right) \Big/ 2 \right] \Big/ (\pi d/\lambda). \tag{23}$$

From (16) follows, that if $\mu \to 1$, then $\Delta\theta_{0,5} \to 0$. So superselectivity may be provided by means (21).

Consider some peculiarities of antenna array working according to diagram (21). Due to functional transform (18) linearity of processing and principe of superposition are breaking under affecting a few signals from different direction. If two interfering signals have close angels of arrival, may be provided good enough suppression of both signals. If the difference of arrival angels is big and intensity one is bigger enough than another, we get the suppression of the bigger signal. These considerations are stay in force for the case of more, then two signals. Thus for providing functionality of proposed principle of selection for multitarget situation special condition should be provided. Which suppose that signals with approximately equal intensity would have small difference of arrival angels, and for signals with essential different angels of arrival would be provided corresponding difference in their intensities. It may be realise by means antenna with diagram $G_R(\theta)$ (20). So, approximately equal intensities will be took place only in narrow angels interval, determined by main lobe bean width of diagram $G_{N-2}(\theta)$. For the signals which have essential difference of arrival directions, weighting of their intensities would be provided by the same diagram $(G_{N-2}(\theta))$.

Thermal noise and errors of practical realization are limited the maximal value of μ and thus limited the minimal value of main lobe beam width. If η – noise/interference ratio (supposed equivalent noise, which included thermal noise and technology errors), so $\mu \le 1/(1+\eta)$. Using this value in (20) we can get restriction on main lobe beam width.

The partial reception diagrams, calculated by (17) with weight coefficients, calculated by (11) and (12), equal and unequal correction are shown on figure 7, and 7a.

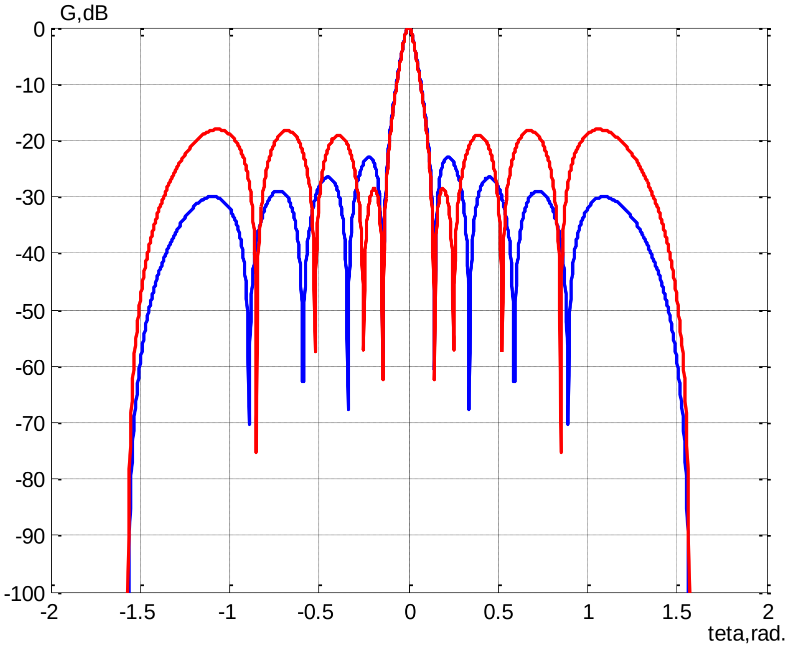

Figure 7 – The reception diagram $W_i(G_{N-2}(\theta))$, $\mu = 0.9$:
— with equal correction; — with unequal correction, $y = 1$

The reception diagrams side lobes suppression in given points, calculated by (17), and for comparison reception diagram 10 element phased array with equal correction, calculated by (2) are shown on figure 8. We can see that not only the side lobs suppression level was reserved, but and the main lobe width is decreased in twice comparatively to simple phased array without amplitude correction.

7 CONCLUSION

In this paper linear antenna array design capable to obtain the given side-lobe suppression with controlled value of the directivity coefficient and with possible realization of the Superdirectivity property is suggested. The approach is simple enough for calculations and does not require the implementation of numerical optimization procedures. It's very useful for practical implementation, when it's necessary to get the given side lobes suppression with the given main lobe properties.

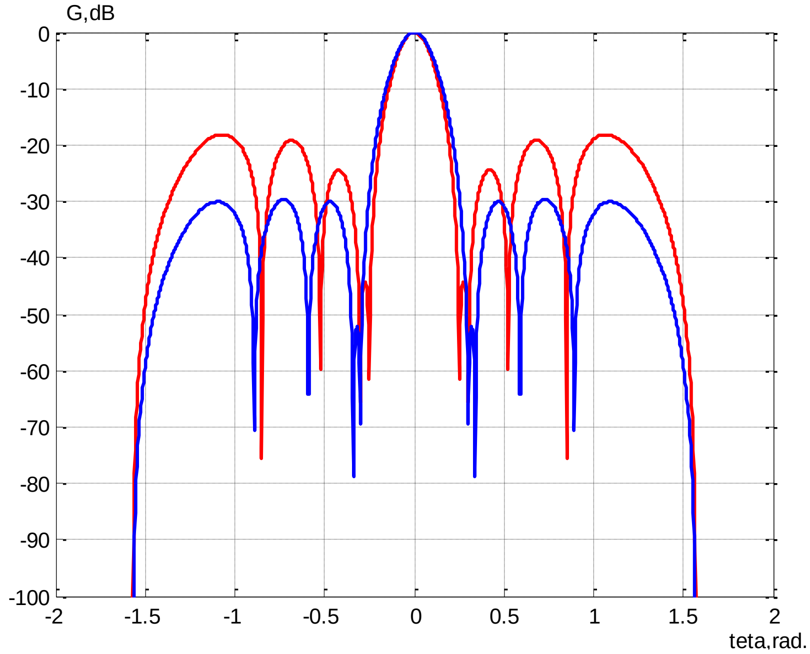

Figure 7a – The reception diagram $W_i\left(G_{N-2}\left(\theta\right)\right)$, $\mu=0.6$:

— with equal correction;

— with unequal correction, y = 1

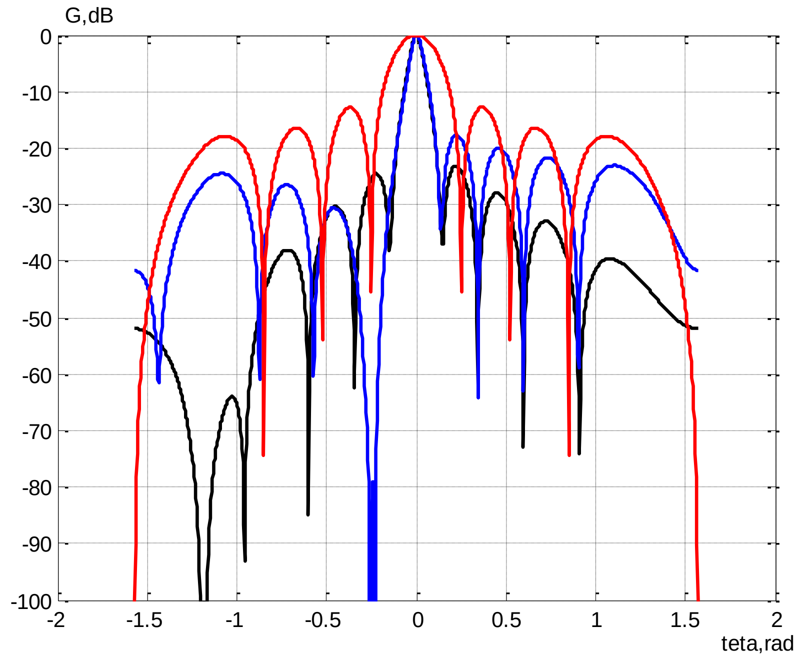

Figure 8. The reception diagram $W_i\left(G_{N-2}\left(\theta\right)\right)$ side lobes suppression in points:

—— $\theta_1=-1.2001$, $\theta_2=-1.1718$, $\rho=-0.2238$ dB; y = 1, $W_n^{(1)}$, $\mu=0.9$;

—— $\theta_1=-0,2576$, $\theta_2=-0.2293$, $\rho=-7.4690$ dB; y = 1, $W_n^{(1)}$, $\mu=0.9$;

—— with equal correction (all W_i=1).

The block diagram of the proposed ten elements radar antenna array algorithm is shown in Figure 9.

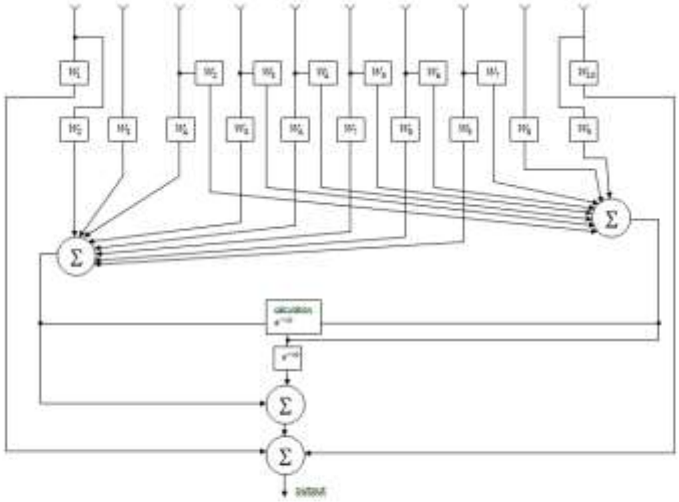

Figure 9 – Block diagram of the proposed algorithm

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