INCREASING THE RESOLUTION of SPACE FILTERS

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The method of increasing the resolution of space filters with the multiplicative signals processing of receiving elements is considered. The synthesis algorithm of characteristics of space resolution of considered systems, based on their approximation with Chebyshev's polynomials, is developed. In the paper the processor structure of multiplicative processing of receiving elements signals of space filters is represented. The numerical example of synthesis of 8-element multiplicative array according to its linear prototipe is fulfilled.

INTRODUKCTION

The space filters are intended for obtaining the objects portraits in the different scientific fields: hydroacoustics, radiolocation, optics etc.

The modern space filters must possess the high space resolution with the purpose of detalization of investigated objects portraits and their classification. The usage of untraditional (more complex) methods of signals processing receiving elements permits to improve the characteristics of space resolution.

1. THE STRUCTURE SYNTHESIS of MULTIPLICATIVE SPACE FILTERS

The resolution of space filters is determined with resolution of their antennas, which can be realized in some cases as arrays [1,2].

The increase of array resolution with traditional linear processing of signals of receiving elements is possible only at the expense of increasing the physical dimension of array. The way of increasing the array resolution without increase of their physical dimensions, based on the usage of multiplicative processing of their elements signals, is known [3]. However the application of such method is difficul1t in a view of complexity of synthesizing the structure of processing channel according to the previous stated requirements to the function of space resolution of array. In the given paper the method of structural synthesis of multiplicative array, based on the describing of their output signals with a superposition of Chebyshev's polynomials and approximation in the same base of required function of space resolution.

In a general case the output signal of array has the following form[3,4]:

$$u(\theta) = \int_0^T x^T(t) A x(t) dt, \tag{1}$$

where

$$x_i = X_{\max} \cdot \cos\left(\omega t + \frac{2\pi i d}{\lambda} \cdot \sin\theta\right), \quad i = \overline{1,N} \tag{2}$$

N - number of receiving elements of multiplicative array,

$X_{\max}$ and ω - accordingly amplitude and angular frequency of output signals of receiving elements,

λ - wavelength of a received signal,

d – the distance between receiving elements, A – the coefficients matrix, defined with structure of processor of space filter,

T - time of an average, $T >> 2\pi/\omega$.

Let's consider the processor of space-time signals processing of array with variable transmission coefficients V_i on the each channel - fig. 1

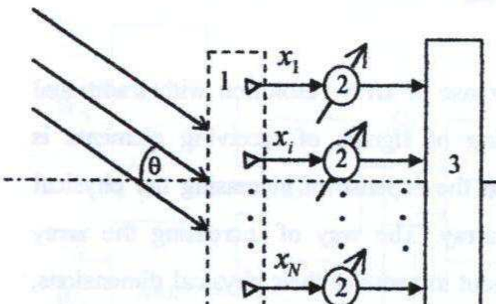

Fig. 1. The structure scheme of space filter with variable transmission coefficients of receiving channels.

In a figure: 1 - unit of receiving elements of array, 2 - units of transmission coefficients V_i, 3 - processor of multiplicative processing, 4 - integrator.

For selected structure of space-time signals processing the matrix A in (1) looks like; $A = \vec{V}\vec{V}^T$. Substituting (2) in (1) and fulfilled integration, we obtaine:

$$u(\theta) = X^2_{\max}\sum_{m=0}^{N-1} \vec{V}^T E_{m+1}\vec{V}\cos 2\varphi_m = x_0^2 \sum_{m=0}^{N-1} b_m \cos 2\varphi_m, \quad (3)$$

$$m = \overline{0, N-1},$$

where E_k - matrix with 1 on k - lateral diagonal,

$\varphi_m = \dfrac{\pi m d}{\lambda}\sin\theta$ - relative phase shift,

$b_m = V^T E_{m+1} V$ - the weight coefficients at Chebyshev's polinomials.

Let's enter an intermediate variable: $y = \cos\pi\sin\theta$, and select the interelement distance $d = \lambda/2$. In this case the expression (3) will be transformed to the following form [4]:

$$u(\theta) = X_0^2 \sum_{m=0}^{N-1} b_m T_{2m}\left[y(\theta)\right], \quad (4)$$

where T_{2m} - Chebyshev 's polynomials of 2m order.

The expression (4) determines the describing of output signal $u(\theta)$ of multiplicative array with a superposition of Chebyshev's polynomials, that allows at the given transmission coefficients V_i to fulfill its analysis. For the solution of the problem of array synthesis the stated function of space resolution is approximated with piece of row of Chebyshev's polynomials, having the kind (4) with the given degree of approximation, and then the coefficients of amplitude distribution are determined [4]. For their obtaining it is necessary to solve the system of non-linear equations:

$$\left.\begin{matrix} \vec{V}^T E_{m+1}\vec{V} = b_m \\ m = \overline{0, N-1} \end{matrix}\right\} \quad (5)$$

where the unknown coefficients are V_i. The solution of the system of non-linear algebraic equations of kind (5) represents itself the independent and enough difficult problem. For enough broads class of array the condition of symmetry of the characteristics of space resolution and, accordingly, of amplitude distribution of transfer coefficients concerning the phase center of array is satisfied:

$$V_1 = V_N; V_2 = V_{N-1}; \ldots V_k = V_{N-k-1} \ldots$$

The condition of symmetry allows to create the recurrent scheme of the solution of a system (5) in the following form:

$$
\left.
\begin{aligned}
&V_1=\sqrt{b_{N-1}};\\
&V_2=b_{N-2}\cdot(2V_1)^{-1};\\
&V_3=(b_{N-3}-V_2^2)\cdot(2V_1)^{-1};\\
&V_4=(b_{N-4}-2V_2V_3)\cdot(2V_1)^{-1};\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
&-for\ \ even\ \ k:\\
&V_k=\left(b_{N-k}-2\sum_{i=1}^{\frac{k-2}{2}}V_{k-i}V_{i+1}\right)(2V_1)^{-1};\\
&-for\ \ odd\ \ k:\\
&V_k=\left(b_{N-k}-2\sum_{i=1}^{\frac{k-3}{2}}V_{k-i}V_{i+1}+V_{\frac{k+1}{2}}{}^2\right)(2V_1)^{-1};\\
&k=\overline{1,N/2}
\end{aligned}
\right\}, \quad (6)
$$

The further standardization of the solution of problem of space filters synthesis can be reached if the technique of synthesis of multiplicative array with according to the linear prototype will be used. At selected interelement distance $d=\lambda/2$ the elements

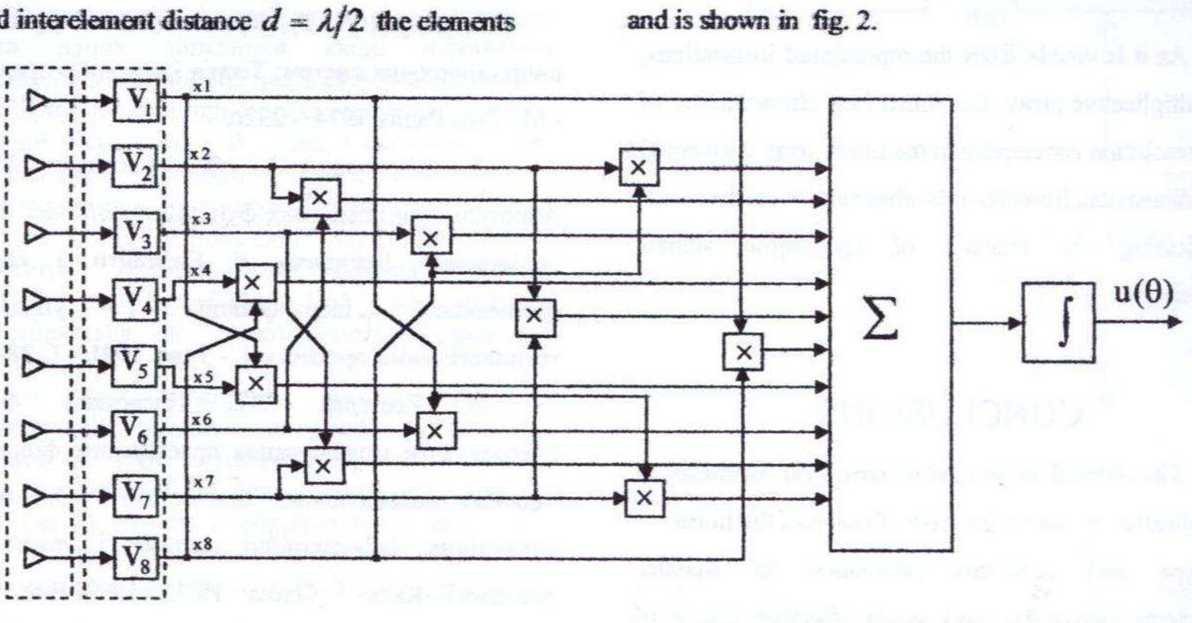

Fig.2. The scheme of the multiplicative processor of space-time signals processing of array.

number of the linear prototype accordingly is equal 2N+1, and the physical dimension of array is twice more, that determines the advantage of multiplicative signal processing.

2. NUMERICAL EXPERIMENT

For a numerical example we consider the synthesis of multiplicative 8-element array according to the linear prototype. As its prototype it is necessary to use 17-element linear array as the order of its polynomial coincides to the order of synthesized array. Let's consider the most complex case of multiplicative array synthesis according to the linear prototype, when the space resolution characteristic of linear array has the narrowest main lobe. For this case the amplitude distribution of the prototype is equal $b_m=1$. Using the recurrent equation (6), we obtain:

$$V_8=V_1=1$$
$$V_7=V_2=1/2=0{,}5$$
$$V_6=V_3=3/8=0{,}375$$
$$V_5=V_4=5/16=0{,}3125$$

The processor structure of multiplicative space-time signals processing is determined with equation (5) and is shown in fig. 2.

For comparison in fig. 3 the function of space resolution of synthesized 8-element multiplicative array according to its linear prototype and 8-element linear array are submitted.

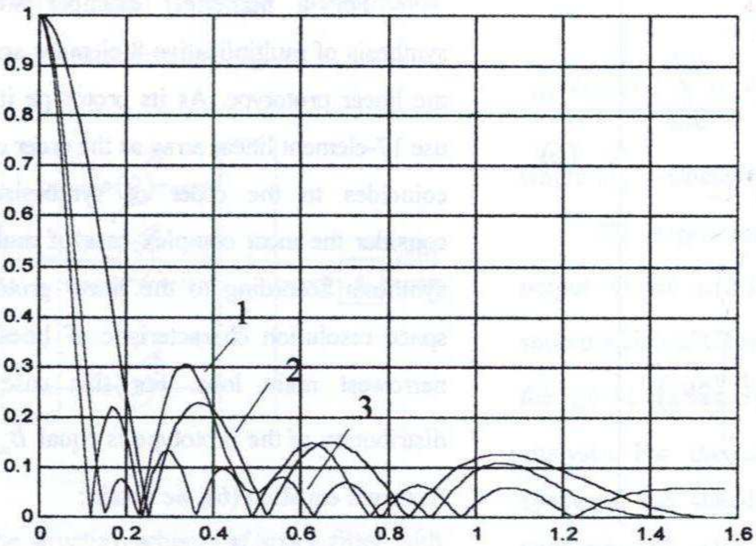

Fig. 3. The functions of space resolution:

1 - 8-element multiplicative array;

2 - 8-element linear array;

3 - 17-element linear array.

As it is visible from the represented illustrations, the multiplicative array, has much best characteristic of space resolution concerning to the linear array with equal linear dimension, however this advantage is reached with complicating the channel of space-time signals processing.

CONCLUSIONS

The offered technique of structural synthesis of multiplicative arrays on the base of usage of the linear prototype and recurrent calculation of transfer coefficients can to be used as an effective means of improvements of space resolution characteristics of space filters at solving the broad class of problems of radiolocation, hydroacoustics, optics, acoustics etc.

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