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GRAPH-BASED WAVEFORM DESIGN FOR RANGE SIDELOBE SUPPRESSION

HAGHSHENAS H. AND NAYEBI M. M.

The cross-correlation between transmitted and received signals is known as a common processing method in noise radars, but, it creates a lot of undesirable sidelobes which can mask weak echoes of far targets. A lot of receiver-based algorithms are developed due to masking effect suppression. In this paper, a transmitter-based method of waveform generation based on the graph theory is presented. First stage of this method tries to design a graph consisting of nodes each corresponds to a random subsequence. In Second stage, output sequence is generated by moving from one node to another based on the probability of each edge. First stage is done offline while the second one is performed online. The subsequences are designed in a way that the correlation sidelobe levels generated by two adjacent subsequences are reduced. The waveform randomness is measured and compared with purely random waveforms.

Keywords: Random waveform generator, Graph theory, Random walk.

1. INTRODUCTION

Random signal radar (RSR) is a kind of radar whose transmitted signal is generated by microwave noise source or modulated by the lower frequency white noise. Noise radar applications are very versatile [1], such as range profiles measurement, detection of buried objects, interferometry, collision warning, subsurface profiling, and ISAR and SAR imaging. One of the main problems is the masking effect of strong target echoes on weak ones. Several methods have been developed to counter the masking effect [2] such as adaptive lattice filter [3, 4], stretch processing [5, 6], apodization filtering [7], inverse filtering [8] CLEAN method [9, 10] and etc. Most of methods can be categorized as the receiver side methods. While there are various methods in this category, there are few methods focusing on the waveform design at the transmitter part of noise radars. In our previous works [11-13], it is clarified that masking effect reduction in noise radar is possible by concentrating on waveform design. The developed method is called “Forward-Design” method which can generate a random signal based on consecutive subsequences.

In this paper, we expand this method and combine it with the graph theory due to online generating unlimited-length noise-like waveform based on an offline design. The online generation of waveform from a given graph is handled by means of random walk. In this paper the method of generating and expanding a strongly connected graph is discussed. The way of designing subsequence of each node in a way that the correlation sidelobe levels are reduced is explained. Then the method of random walk is described. Finally, by means of computer simulation, the ability of the proposed method in decreasing masking effect is evaluated. Moreover, the randomness future of the generated waveform is taken into consideration.

2. CORRELATION PROCESS

Commonly, receiver unit of a noise radar performs correlation processing between reference signal and the received one [14], represented by x_k and y_k, respectively. In this paper phase-modulated (PM) signal is taken into consideration. The amplitude of signal, without loss of generality, is assumed to be one and its phase is the design object.

$$x_k = e^{j\theta_k} . \qquad (1)$$

Since the maximum correlation shift is far less than the integration time, the correlation process can be done on N-point adjacent subintervals of the reference signal and corresponding $2N$-point subintervals of the received signal. This process is made in M parallel pulse compressors (PC), where M is the number of adjacent subsequences of the reference signal. Each PC unit outputs $N+1$ samples which correspond to radar range cells. The r^{th} output sample of m^{th} PC is shown by $p(r,m)$, where $r=0,1,...,N$ and $m=0,1,...,M-1$. Outputs of PC groups are then processed by Doppler processing which can be implemented by applying M-point FFT [9]. Using an appropriate CFAR detection algorithm, existing targets can be extracted from range-Doppler matrix $Q=\left[q(r,m)\right]$.

$$p(r,m) = \sum_{k=mN}^{(m+1)N-1} x_k y^*_{k+r} \qquad (2)$$

$$q(r,m) = \sum_{k=0}^{M-1} p(r,k) e^{-jkm\frac{2\pi}{M}} \qquad (3)$$

We suppose that the received signal is a delayed version of the transmitted one (d samples), the stretch of the signal envelope due to target movement during the integration time of one subinterval and also its Doppler effect are negligible.

$$p(r,m) = \sum_{k=mN}^{(m+1)N-1} x_k x^*_{k+r-d} \qquad (4)$$

Range mainlobe is occurred when r and d are equal; in other cases, range sidelobes are produced. We divide sidelobes of Point Spread Function (PSF) into two groups based on the sign of $r-d$, represented by C_p and D_p ($p=1,2,...,N$). We show both C_p and D_p together with S_p ($p=1,2,...,2N$). S_0 (C_0 or D_0) represents the mainlobe level of PSF.

$$C_p^{(m)} = \sum_{k=mN}^{(m+1)N-1} x_k x^*_{k+p} \qquad (5)$$

$$D_p^{(m)} = \sum_{k=(m+1)N}^{(m+2)N-1} x_k x_{k-p}^* \tag{6}$$

$$S_p = \begin{cases} C_p, & p = 1,2,\ldots,N \\ D_{p-N}, & p = N+1, N+2,\ldots,2N \end{cases} \tag{7}$$

The Integrated Sidelobe Ratio (ISLR) is used as the measure of range sidelobe effect evaluation. ISLR is defined as the ratio of total sidelobes energy to the mainlobe energy of the PSF.

$$J = \frac{1}{2N}\sum_{p=1}^{2N}\left|S_p\right|^2 \tag{8}$$

$$ISLR = 2NJ \Big/ \left|S_0\right|^2 \tag{9}$$

It can be considered that the expectation value of ISLR equals to 2 in the case of purely random signals [11].

3. SUBSEQUENCES DESIGN

The methods presented in literature and discussed in section 1, try to decrease masking effect by applying an appropriate signal processing method on the received signal. In [11], it is shown that an alternative solution is usage of a well designed random waveform which leads to a better ISLR in comparison with pure random waveform. Moreover it is illustrated that obtaining a waveform with lower ISLR that can keep its randomness characteristics is possible by imposing some appropriate constraints on the waveform generator.

Considering (5)-(9), it is obvious that ISLR of each PC subinterval only depend on N-point reference signal of current and next subsequences. This property is the base of the proposed method in [11], called "Forward-Design" method. The main idea behind the Forward-Design method is to calculate each N-point subsequence of reference signal as a function of previous one with supposing ISLR minimization as the cost function. To begin the method, the first subsequence is selected randomly. The second subsequence is derived by minimizing the cost function of the first one. Applying the same procedure to the second subsequence leads to the generation of the third one and this process can be continued until the arbitrary length is reached. According to this method, a random sequence can be generated by attaching these subsequences.

The procedure of Forward-Design method can be modeled as a directed path graph [15]. The directed graph, generated by this method, has only one path. Actually, this directed graph is a weakly connected graph. It means that replacing all of its directed edges with undirected edges produces a connected (undirected) graph [16]. To generate a larger path in this method, it is necessary to add new nodes to the graph. Therefore, in order to generate unlimited length waveforms, design of new subsequences is required to be performed online. This characteristic imposes heavy computational expense on the transmitter. An alternative method to generate random waveform based on predesigned subsequences is developed in this paper. To develop a method for generating random waveform offline, we need to produce a strongly connected graph which contains at least one path from one node of the graph to every other node [16]. To generate and expand a strongly connected graph, we need to introduce a way to insert a node into an existing strongly connected graph. To fulfill this purpose, we should find a method of generating a subsequence which is placed between two existing subsequences and satisfy minimum ISLR condition. By reformulating the Forward-Design algorithm in reverse order (Backward-Design) and combining with forward order (Forward-Design), each N-point subsequence of the reference signal can be calculated as a function of the next and previous subsequences by minimizing ISLR as the cost function. This method is called "In-Between-Design" method. By applying this method, we can produce a subsequence which is laid between two known subsequences and has a reduced ISLR in correlation with its previous and next subsequences.

The cost function of In-Between-Design method is assumed to be the summation of the cost functions of Forward-Design (J_0) and Backward-Design methods (J_1).

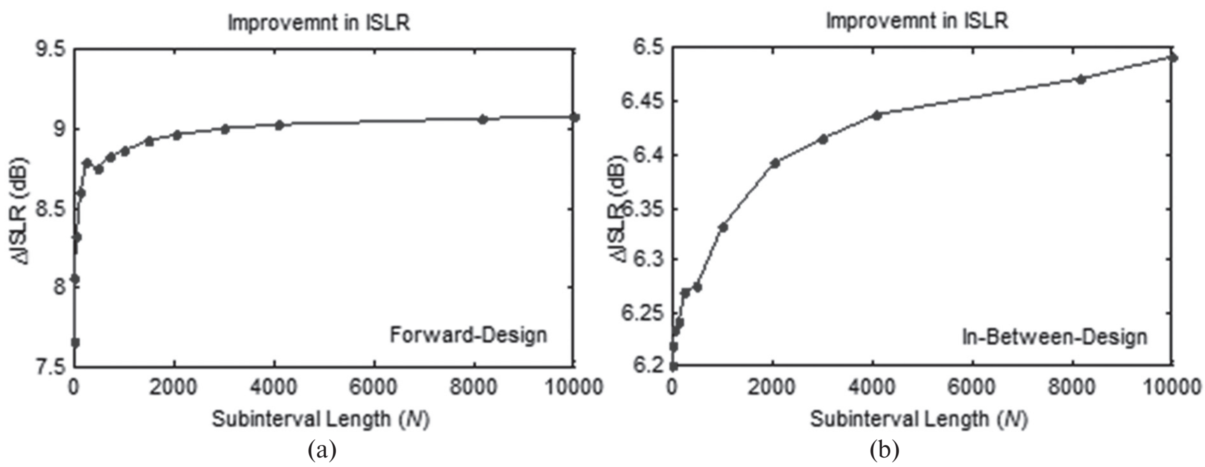

Fig. 1. Improvement of ISLR in dB versus subinterval length for (a) Forward-Design method and (b) In-Between-Design method

$$J_T = J_0 + J_1 . \tag{10}$$

Minimization of the above cost function is performed by means of numerical solutions such as Gradient Descent (GD) algorithm. To fulfill this purpose partial derivatives should be taken with respect to unknown variables, θ_k ($N \le k < 2N$).

$$\xi_0(\theta_k) = \sum_{p=k-N+1}^{N} C_p^{(0)*} e^{j\theta_{k-p}} + \sum_{p=1}^{N} D_p^{(0)} e^{j\theta_{k-p}} + \\ + \sum_{p=1}^{2N-k-1} D_p^{(0)*} e^{j\theta_{k+p}} \tag{11}$$

$$\xi_1(\theta_k) = \sum_{p=1}^{k-N} C_p^{(1)*} e^{j\theta_{k-p}} + \sum_{p=1}^{N} C_p^{(1)} e^{j\theta_{k+p}} + \\ + \sum_{p=2N-k}^{2N} D_p^{(1)*} e^{j\theta_{k+p}} \tag{12}$$

$$\frac{\partial J_T}{\partial \theta_k} = \frac{1}{N} \operatorname{Im}\left\{ \left(\xi_0(\theta_k) + \xi_1(\theta_k) \right) e^{-j\theta_k} \right\} \tag{13}$$

To evaluate the ability of the Forward-Design and In-Between-Design methods to generate a random subsequence with a lower ISLR, a lot of different simulations have been done and the achieved results prove the ability of the method to decrease the average power of sidelobes. For some different values of N (16, 32, 64, 128, 256, 512, 1024, 2048, 3000, 4096, 8192 and 10000), improvement of ISLR expectation value of the proposed waveform is compared with that of pure noise waveform ($\Delta ISLR(N)$). For each value of N , more than 100000 Monte Carlo replications, including 100 different waveforms with the length of 1000 subintervals, have been performed. Improvement of ISLR expectation value of the proposed waveforms generated by utilizing Forward-Design method and In-Between-Design one are shown in Fig. 1(a) and (b), respectively. As this figure shows, we achieved about 8dB and 6dB improvement in decreasing ISLR for Forward-Design and In-Between-Design methods respectively. Although the improvement achieved by In-Between-Design is less than Forward-Design method, this method can be applied to develop the random waveform generating based on the graph.

4. GRAPH GENERATION AND EXPANSION

According to previous section, one of the methods of offline generation of a waveform is using strongly connected graph (SCG). In this part, we introduce a way of producing a primitive SCG and expanding it. The method commences with a primitive SCG that could be a simple cycle graph [17] with L nodes. It is obvious that L must be at least 3.

Generating the cycle graph starts from choosing an arbitrary N-point subsequence which corresponds to the first node of the graph. Employing the Forward-Design method a directed path graph of length $L-1$ can be formed. Eventually, to obtain a cycle graph, L^{th} node is inserted between the last and the first nodes of the directed path graph. For expansion of the existing graph we need a tool which keeps the graph strongly connected. The procedure that can fulfill this requirement is In-Between-Design method. To insert a new node to the existing graph, two nodes are selected as initial and terminal nodes, respectively. Utilizing the In-Between-Design method, a new node will be added between the initial node and the terminal one. It is obvious that two edges, one from the initial node to the new one and another from the new node to the terminal one, are added to the graph. Q times repeating of the expansion procedure, a graph with $V = L + Q$ nodes and $E = L + 2Q$ edges is obtained. In Fig. 2 a random SCG is drawn. It can be easily proved that the achieved random graph shown by $RSCG(L,Q)$ remains strongly connected.

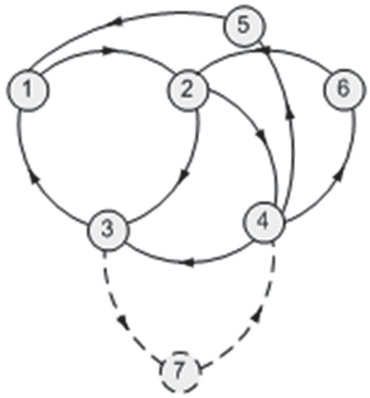

Fig. 2. A random strongly connected graph

Since we want to form a sequence by a random walk on the graph which meets each node with the same possibility (uniform stationary distribution); the regularity of the generated graph is preferable. To make the above graph regular there are two ways. Firstly, initial and terminal nodes in each expansion stage can be selected in a way that keeps the nodes degree the same as much as possible. Secondly, a suitable weight set of edges can be determined to make stationary distribution more uniform.

In q^{th} stage of expansion procedure ($1 \le q \le Q$), the existing directed graph contains $L + q - 1$ nodes and $L + 2q - 2$ edges. In this stage, the initial and terminal nodes are chosen from existing nodes according to the following probabilities:

$$p_i = \frac{1}{\sum_{k=1}^{L+q-1} \left(\frac{D_i}{D_k} \right)^{\alpha}}, \; i = 1,2,3,\ldots, L+q-1 \tag{14}$$

where parameter α is a non-negative number, i is node index and D_i denotes the outdegree and the indegree of i^{th} node for choosing initial node and terminal one, respectively. The number of incoming edges to a node and outgoing edges from a node are called indegree and outdegree, respectively. Using large value for α increases the possibility of being selected for low degree nodes.

Evaluation of the graph regularity is performed by measuring the standard deviation of node degrees (σ_d). The expectation value of σ_d versus α is depicted in Fig. 3 for four different size of graphs. For each size of graph, 1000 simulations have been performed. We can see that this method results in a non-zero standard deviation of node degrees, because nodes selected early in the process will get more neighbors than nodes selected later on. As this figure shows, the generated graph becomes asymptotically regular for sufficiently large α and small ratio of L to Q. On the other hand, small value of α offers more choices to the expansion algorithm for selecting the initial and terminal nodes, and consequently increases the graph randomness. By making a trade-off between the regularity and randomness, a suitable value for α could be something like 5.

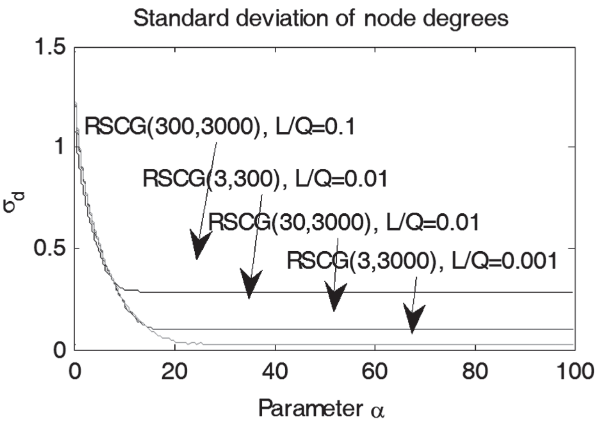

Fig. 3. Expectation value of the standard deviation of node degree versus parameter α, for four different graph sizes

However increasing the parameter α may make the stationary distribution closer to uniform distribution; it can limit the variety of the generated graphs. An alternative solution to make stationary distribution more uniform is determining a suitable weight set of edges. To optimize the uniformity of the stationary distribution of graph $G(V,E)$, the following 5-step iterative algorithm is suggested.

(1) Set the weight of all the edges equal to 1.

$$w_{uv} = \begin{cases} 1 & if\ uv \in E \\ 0 & otherwise \end{cases} \quad 1 \le u, v \le V \tag{15}$$

(2) Calculate the transition probability matrix $\mathbf{P} = [P_{uv}]$ as follows:

$$P_{uv} = \frac{w_{uv}}{\sum_{i=1}^{V} w_{ui}}, \ 1 \le u, v \le V \tag{16}$$

(3) Calculate the stationary distribution (row) vector $\mathbf{\Pi} = [\pi_i] : \mathbf{\Pi} \times \mathbf{P} = \mathbf{\Pi}$.

(4) Update the weight of all the edges:

$$w_{uv} = \begin{cases} (1-\xi) w_{uv}, & \pi_v > \dfrac{1}{V} \\ w_{uv}, & \pi_v = \dfrac{1}{V} \\ (1+\xi) w_{uv}, & \pi_v < \dfrac{1}{V} \end{cases} \tag{17}$$

(5) Go to 2

The optimization procedure is terminated when no noticeable change in the stationary distribution is observed. The uniformity degree of the stationary distribution is measured by means of normalized root mean square deviation (NRMSD) of π_i from the ideal value of $1/V$.

$$NRMSD = \frac{\sqrt{\frac{1}{V}\sum_{i=1}^{V}\left(\pi_i - \frac{1}{V}\right)^2}}{\frac{1}{V}} = \sqrt{V\|\mathbf{\Pi}\|^2 - 1} \tag{18}$$

where notation $\|\mathbf{\Pi}\|$ denotes the norm of vector $\mathbf{\Pi}$.

Table 1

Expectation value of NRMSD, in three conditions

Graph size	Expectation value of NRMSD		
	EW, $\alpha = 0$	EW, $\alpha = 5$	OW, $\alpha = 5$
RSCG(10,100)	1.08	0.46	0.23
RSCG(3,100)	1.14	0.51	0.2
RSCG(10,500)	1.14	0.51	0.22
RSCG(3,300)	1.17	0.52	0.21
RSCG(3,3000)	1.2	0.49	0.21

In Table 1, the expectation values of NRMSD in three conditions: equal weights (EW) with $\alpha = 0$, equal weights with $\alpha = 5$ and optimized weights (OW) with $\alpha = 5$ are tabulated. For each size of graph, 1000 simulations have been performed. By comparing the results, the effect of the parameter α and the ability of the described algorithm in making the stationary distribution more uniform are evident.

5. GENERATING RANDOM WAVEFORMS BY THE USE OF RANDOM WALK

Given a graph G and a starting node, we select a neighbor of it at random according to the transition matrix P, and move to this neighbor; then we select a neighbor of the new node at random, move to it and so on and so forth. The (random) sequence of nodes selected in this way is a random walk on the graph. A random walk is a memoryless Markov chain on graph G. Markov property implies that knowledge of previous states is irrelevant in predicting the probability of subsequent states. Therefore, the next state depends entirely on the current state.

Since each node corresponds to an N-point signal, attaching these signals according to the random walk can generate a random waveform. Although designing the finite random graph and the random subsequences of its nodes is done offline, the random walk is performed online with infinite (or arbitrary) length.

As the number of nodes of the generated graph is limited, same subsequences are possible to be repeated in the generated waveform which can be a potential threat to the LPI property. An effective solution is to vary the subsequence of each node during the random walk progression. It is desired that each time this procedure happens, the resultant node subsequence becomes more uncorrelated to the previous subsequence of that specific node and also we face minimum degradation in ISLR improvement, albeit as far as possible. In [18], we have developed a modulation-based method to update the subsequences on each random walk state. Our suggested method makes a random linear change in phase and frequency of the subsequences in each step of the random walk. This method is equivalent to modulating the output sequence of random walk procedure with a random step frequency modulation (RSFM). By making change in phase and frequency of signal x, signal z is defined as follows:

$$z_k = x_k e^{j\left(2\pi \frac{k}{N} F_m + \phi_m\right)}, \quad m = \left\lceil \frac{k}{N} \right\rceil \tag{19}$$

where ϕ_m and F_m are phase shift and frequency shift of m^{th} subsequence, respectively. These parameters are selected according to a recursive equation

$$\begin{cases} F_m = F_{m-1} + \Delta_m \\ \phi_m = \phi_{m-1} - 2\pi\Delta_m \end{cases} \tag{20}$$

We suppose that in each step of the random walk, the frequency step (Δ_m) is selected randomly according to a normal distribution such as $N\left(\delta, \delta/\sqrt{3}\right)$, where δ is the distribution parameter.

$$\Delta_m \sim N\left(\delta, \delta/\sqrt{3}\right). \tag{21}$$

Appling RSFM with relatively small δ may lead to a few degradation in ISLR improvement of In-Between-Design method. where ϕ_m and F_m are phase shift and frequency shift of m^{th} subsequence respectively. Although using larger value for δ in RSFM results in further degradation in ISLR, it can increase the randomness of the output sequence. By making a trade-off between the performance and randomness, an appropriate value for δ should be selected.

5. RANDOMNESS

The quality of randomness can be measured in a variety of ways. To ensure that using the proposed waveforms retains the LPI characteristic, a well-known measure of randomness called spectrum flatness measure (SFM) are considered in this article. This criterion measures whiteness of the frequency spectrum of the test sequence. It is defined as the ratio of the geometric mean to the arithmetic mean of the power spectrum [19]. SFM is usually used for evaluating the amount of randomness that exists in a signal. A high SFM corresponds to a random signal in the sense that no significant information can be obtained by looking at longer blocks of signal samples [20]. Since the above measure is not zero mean in the case of random signals [21], a test of whiteness, which is a modified version of SFM, is used. This test is developed by Drouiche [22] and is implemented as follows:

$$W = \ln\left(\frac{1}{2\pi}\int_{-\pi}^{\pi} |X(\omega)|^2 d\omega\right) - \frac{1}{2\pi}\int_{-\pi}^{\pi} \ln\left(|X(\omega)|^2\right) d\omega - \gamma \tag{22}$$

where γ represents Euler-Mascheroni constant and $|X(\omega)|$ is the spectrum of a given sequence S with the length of L_S. It can be shown that $W \approx 0$ for a white noise and $W \to \infty$ if the sequence is maximally correlated. In practice, it will be assessed as the whiteness hypothesis if $W < \eta$ [23].

$$\eta = \sqrt{\frac{2\upsilon}{L_S}} \operatorname{erf}^{-1}(1 - 2\alpha), \tag{23}$$

where η is a threshold obtained for a test size α, $\upsilon = \pi^2/6 - 1$, and $\operatorname{erf}^{-1}(x)$ is the inverse of the standard error function.

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt. \tag{24}$$

In this paper, we set $\alpha = 10^{-3}$ which results in $\eta = 2.48/\sqrt{L_S}$. In addition, calculation of the frequency spectrum in (22) is accompanied by Gaussian window. The SFM criterion for the proposed PM waveforms (with RSFM) with different lengths of sequence (L_S) and subinterval (N) is simulated and its average is tabulated in Table 2 in the case of graph size $RSCG(10,300)$. For each value of N and L_S, 1000 different waveforms are considered. As the table illustrates, SFM values are very close to zero, which confirms the randomness characteristics of the proposed waveforms. Furthermore, the probability of accepting whiteness hypothesis, listed in Table 3, demonstrates that the proposed waveforms are more likely to be random rather than periodic or predictable. To clarify this statement, the Average SFM of the proposed PM waveforms with the length of $N = 64$ is plotted as a function of the sequence length in Fig. 4 and is compared with purely random waveforms and periodic ones with the period of $N = 64$. To apply RSFM on the random walk process, value of δ in all simulations is assumed to be 0.1.

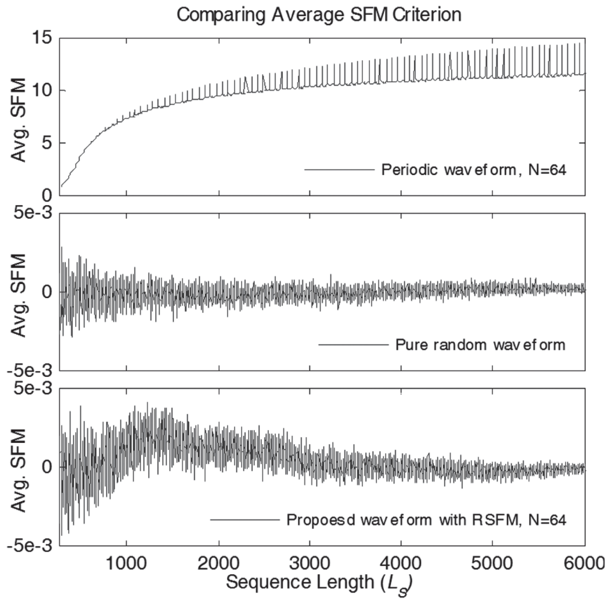

Fig. 4. The Average SFM versus the sequence length (L_S)

The obtained results reveal that the SFM values of the proposed waveforms and random ones are very close together and as the sequence length approaches higher values, the SFM values of the proposed waveforms tend to zero, similar to random sequences. Opposite to the SFM values of the proposed waveforms and random waveforms, the SFM values of periodic waveforms are extremely large and increase with the length of sequence.

Table 2

The average SFM versus N and LS for graph size RSCG(10,300) with α=5 and optimized weights and RSFM with δ=0.1

L_S	N=64	N=512	N=2048
10N	-1.08E-3	4.31E-4	1.26E-4
100N	2.92E-4	4.39E-4	1.13E-4
300N	7.74E-5	1.61E-4	8.56E-5
500N	5.35E-5	9.8E-5	6.34E-5
1000N	3.25E-6	5.44E-5	7.55E-6
3000N	3.21E-6	6.33E-6	8.08E-7
5000N	3.14E-6	1.15E-6	6.91E-7

Table 3

The probability of whiteness hypothesis versus N and L_S for graph size RSCG(10,300) with α=5 and optimized weights and RSFM with δ=0.1

L_S	N=64	N=512	N=2048
10N	-1.08E-3	4.31E-4	1.26E-4
100N	2.92E-4	4.39E-4	1.13E-4
300N	7.74E-5	1.61E-4	8.56E-5
500N	5.35E-5	9.8E-5	6.34E-5
1000N	3.25E-6	5.44E-5	7.55E-6
3000N	3.21E-6	6.33E-6	8.08E-7
5000N	3.14E-6	1.15E-6	6.91E-7

6. CONCLUSION

We proposed a new method for designing waveforms in noise radars based on the graph theory in order to generate waveform with a lower correlation sidelobe online. According to the developed algorithm, a strongly connected graph with a finite (but arbitrary) number of nodes can be produced by minimizing the cost function over subsequences of adjacent nodes. In this method, output waveform is produced by applying a random walk process on the designed graph. Although designing the random graph and the random subsequences of its nodes is done offline, the random walk on the graph is executed online with infinite length which leads to arbitrary length of random waveform. This method has much less online computational complexity in comparison with Forward Design method.

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Mohammad M. Nayebi, for photograph and biography, see this issue, p. 16.

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Метод уменьшения боковых лепестков, основанный на графах / А. Хагшенас, М. Найеби // Прикладная радиоэлектроника: науч.-техн. журнал. – 2013. – Том 12. – № 1. – С. 25–31.

Известно, что кросс-корреляция между переданным и опорным сигналами является общепринятым способом обработки сигналов в шумовых радарах. Однако такая обработка приводит к появлению большого числа нежелательных боковых лепестков, которые могут маскировать слабые отклики от удаленных целей. Разработано много алгоритмов приема для уменьшения эффекта маскирования. В данной работе представлен алгоритм генерации сигнала, основанный на теории графов и работающий на стороне передатчика. На первой стадии этого метода составляется граф, состоящий из точек, соответствующих случайным субпоследовательностям. На второй стадии генерируется выходная последовательность путем перехода от одной точки к другой согласно вероятности каждой грани. Первая стадия выполняется на этапе подготовки, вторая осуществляется в режиме реального времени. Субпоследовательности составлены в таком виде, что боковые лепестки корреляционной функции, производимые соседними субпоследовательностями, компенсируют друг друга. Степень случайности сигнала измерена и сравнена с чисто случайным сигналом.

Ключевые слова: генератор случайных сигналов, теория графов, случайный переход.

Табл. 2. Ил. 4. Библиогр.: 23 назв.

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Метод зменшення бічних пелюсток, заснований на графах / А. Хагшенас, М. Найєбі // Прикладна радіоелектроніка: наук.-техн. журнал. – 2013. – Том 12. – № 1. – С. 25–31.

Відомо, що крос-кореляція між переданим і опорним сигналами є загальноприйнятим способом обробки сигналів у шумових радарах. Однак така обробка призводить до появи великого числа небажаних бічних пелюсток, які можуть маскувати слабкі відгуки від віддалених цілей. Розроблено багато алгоритмів прийому сигналів, покликаних зменшити ефект маскування. У даній роботі представлений алгоритм генерації сигналу, заснований на теорії графів, що працює на стороні передавача. На першій стадії роботи цього методу складається граф з точок, які відповідають випадковим субпослідовностям. На другій стадії генерується вихідна послідовність шляхом переходу від однієї точки до іншої згідно з ймовірністю кожної грані. Перша стадія виконується на етапі підготовки, друга здійснюється в режимі реального часу. Субпослідовності складені в такому вигляді, що бічні пелюстки кореляційної функції, вироблені сусідніми субпослідовностями, компенсують одина одну. Ступінь випадковості сигналу виміряна і порівняна з чисто випадковим сигналом.

Ключові слова: генератор випадкових сигналів, теорія графів, випадкових переход.

Табл. 2. Іл. 4. Бібліогр.: 23 найм.