ИЗВЕСТИЯ ВЫСШИХ УЧЕБНЫХ ЗАВЕДЕНИЙ
Т. 58, № 10/3 ФИЗИКА 2015

УДК 621.391.244

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SPATIAL FOCUS FOR UWB SIGNALS[1]

Method of focus in the time domain and its analogue, a method of radiowave tomosynthesis in the frequency domain by the criterion of level artifacts in the reconstructed radio images of the test object are compared. To verify the advantages of focus in the time domain method numerical model of clocked nonequidistant flat antenna array has been developed at the Department of Radio Physics at Tomsk State University.

Keywords: *radio tomography, an ultra-wideband sensing, synthetic aperture, focusing the radiation antenna array.*

Introduction

One of the promising area of UWB radar is a creation of short-range radar to detect people behind radiotransparent obstacles (under the rubble, behind the walls of the buildings), as well as fast quality monitoring of pavements and embankments. Such investigatios are actively carried out by various research groups in Russia and abroad [1,2].Thus, summarizing the existing publications, it should be noted that the important advantages of the developed radar is their mobility, small-size, the possibility of a unilateral access and ease in use: switch on - get the picture. Currently widely used standard GPR are not applicable, because they don't adequately provide the required characteristics, such as speed and resolution. Therefore it is required to create new systems that are based on multi-element arrays using algorithms receiving radio images of high resolution in real time. The most promising approach from this point of view, is based on hardware and software focusing of UWB radiation [3, 4]. Focusing is performed by sequential summation of the received signals from the alignment of time delays of pulses scattered by point with given coordinates. At the same time the resulting radar image has a resolution better than the spatial extent of the probe pulse.

In the case when radio waves penetrate into such media, we can talk about the restoration of its internal structure on past or scattered field. This structure represents itsef the spatial distribution of the values of the permitivitty. Sharp changes in gradient of this permeability are typical for the borders of the media division or objects immersed in them. A characteristic example is looking for hidden archaeological burial under ground, engineerig communications and personnel mines. Though such kinds of problems are not simple but a number of effective solutions based on the phenomenon of focusing radiation have been developed.[5,6]. Our aim is to test the focus method in time domain and its analogue - a method of radiowave tomosynthesis in the frequency domain by the criterion of level artifacts in the reconstructed radio images of the test object. To verify our assmption the numerical model developed at the Department of Radio Physics at Tomsk State University planar array antenna clocked nonequidistant is considered.

Spatial focus

The UWB radiation is known to have high temporal spatial resolution. Besides, due to the low frequency components in the spectrum of UWB probing signals high penetration through the obstacles is provided, thus it is especially important fact for the detection of hidden objects behind the dielectric barriers.

The basic idea of processing the UWB data goes back to the technology of synthetic aperture and firmware focus radiation. Focusing is performed by sequential summation of the received signals from the alignment of pulses time delays scattered by point with given coordinates. So it is necessary to make the delay in the received signal corresponding to the total transmission time from the transmitter to the object and back. It is required to calculate the delay time for each pulse.

At the same time, all registered signals at various points in the radiation-receiving $\boldsymbol{\rho}_j$ are summed in a phase for each defined focus point $\mathbf{r}$ with the correction of existing delay. In the single-scattering

[1] This work was supported by the Russian Ministry of Education as a part of the project № 3.694.2014/K.

approximation when the signal $S_0(t)$ is radiated, and the received radar signal is generated as a

$$S(\rho_j,t)=k_0^2\iiint_V S_0(t-2\frac{|r_1-\rho_j|}{c})\frac{\Delta\varepsilon(\boldsymbol{\rho}_1,z_1)}{\left(4\pi|r_1-\rho_j|\right)^2}\left(d^3 r_1\right) . \quad (1)$$

With a sufficient amount of the recorded data and short probe pulse, this function approaches "smeared» δ-function, allowing you to identify the results of focus $F(r_1)$ distribution of the dielectric constant $\Delta\varepsilon$:

$$\Delta\varepsilon(\boldsymbol{\rho}_1,z_1)\sim F(r_1).$$

This registered datum represents the approximate solution tomography. In fact the obtained solution is a kind of interference field, which has a maximum at the points of the true position of the scattering points. In another points signals will emerge with a random delay, and there will be observed a low value of the focused field. The more better result, the more independent variables are involved in focusing. Recorded solution is extremely simple, but the implementation requires a lot of hardware resources which are necessary to carry out the summation signal for each point of focus. Using the fast algorithms allows us to speed up this procedure. One of such approaches is the method of radiowave tomosynthesis (RT). This method is a generalization of the Fourier- synthesis for the case of wave fields. However, it has been developed if a monostatic scheme area is happened. In the case of bistatic sounding scheme quality of the radio image using this method may be deteriorated. Below we present the results of numerical simulations allowing us to estimate the performance of each approach.

Numerical simulation

During the simulation array with arrangement of antenna elements shown in Figure 1 was used. The size of the lattice is 55x44 cm. The number of antenna elements is 37, from which 24 are receiving antennas and 13 are transmitting ones. The antenna arrangement was optimized by the criterion of maximum quality of the radio. Moreover, the condition of saving the same distance between the receiving and transmitting antennas at each switching cycle must be fulfilled. This condition is needed to attract the fast signal processing algorithms, in particular the method of radiowave tomosynthesis. Figure 1 shows the location of the transmitting and receiving antennas, where the white dots mark the transmitting antennas and black dots mark the receiving ones. In the process of each transmitting antenna radiation the survey of all nearest receiving antennas was conducted.

For sensing pulse of 0.1 ns was chosen. As an object step size of triangle 15 x 15 cm, the step size D = 5 cm at a distance R = 30, shown in Figure 2 was selected. In figure 3 the results of shape recovery of the object using the method of radiowave tomosynthesis is shown. The three-dimensional tomogram section in the region of 30 cm to the test object is presented. Figure 4 shows the total intensity of the three-dimensional cross-sections of the radio range for the RT method. For convenience, the image intensity in each angle was normalized on the layer intensity in which the object was. Figure 5 and 6 shows similar results for spatial focusing method in the time domain.

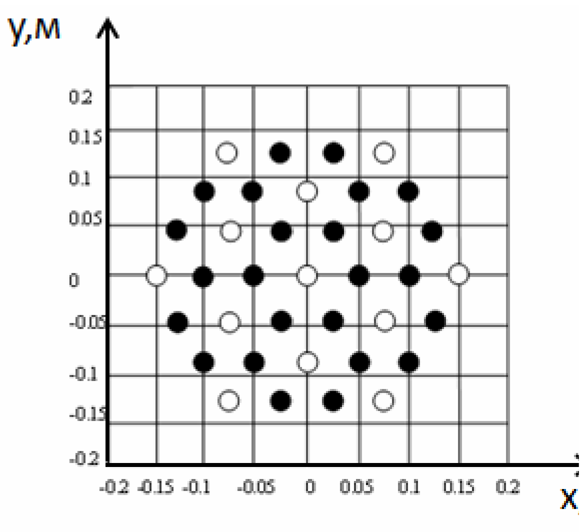

Fig. 1. Location of the antennas

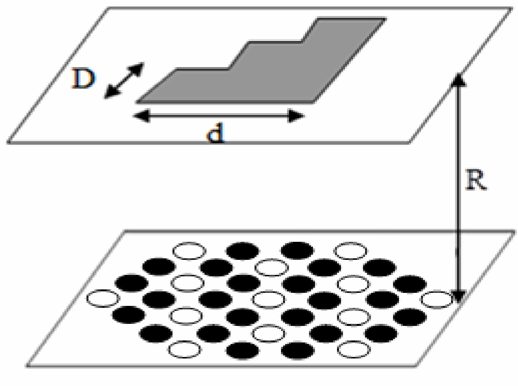

Fig. 2. The geometry of the experiment

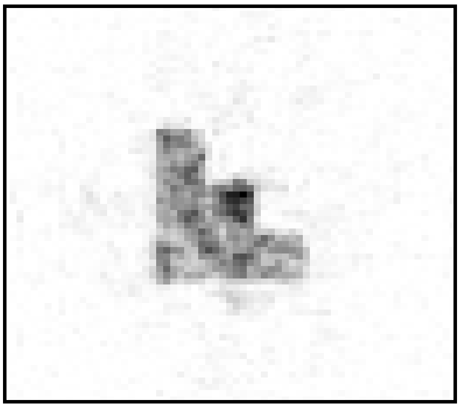

Fig. 3. The reconstructed image of the object at a distance of 30 cm

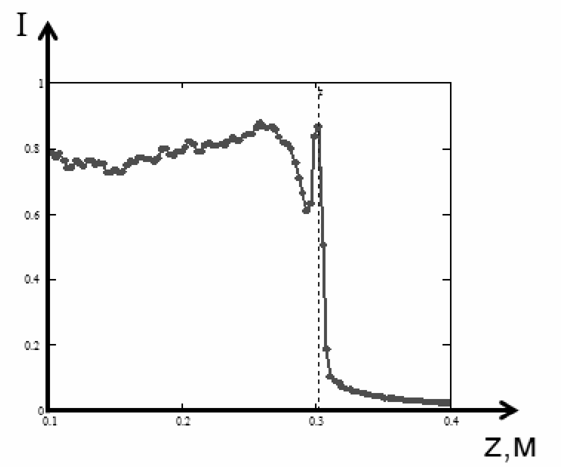

Fig. 4. The total intensity radio image in range

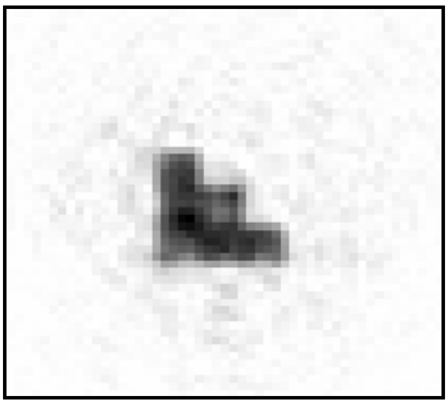

Fig. 5. The reconstructed image of the object at a distance of 30 cm

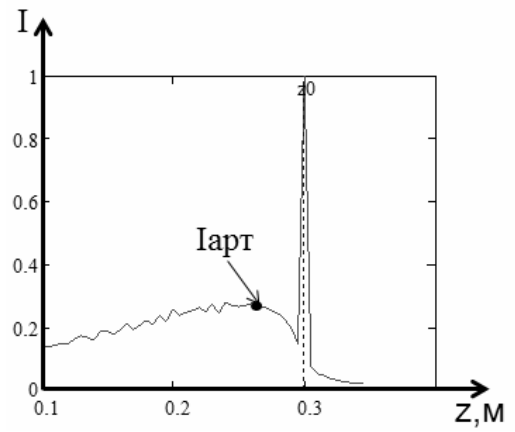

Fig. 6. The total intensity radio image in range

Comparison of Figures 3 and 5 shows that the method gives a more spatial focusing radio image quality than the method of RT. Also, the value of the artifacts in the total intensity of the RT method is much higher than the value of the total intensity of the artifacts of the spatial focus method. One of the reason of the lower quality radio images, obtained by RT, one can consider the using of bistatic sounding scheme. A large number of artifacts indicates to sparsity array that corresponds to a small number of angles. To increase the number of angles a mechanical movement of the grid is required. The simplest solution is a rotation of the antenna array around a central axis. Figure 7 shows the antenna array at three different angles of rotation at 45°.

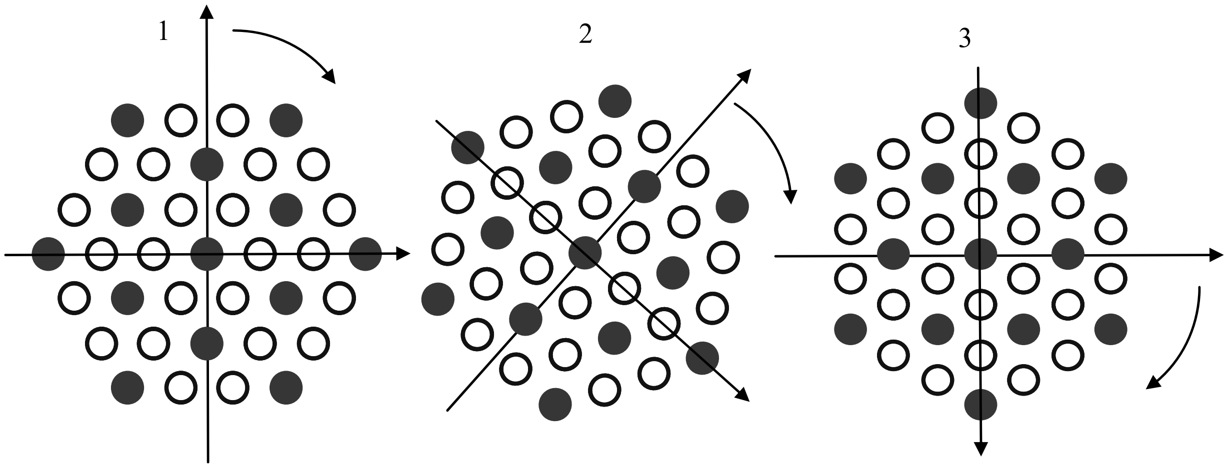

Fig.7. The antenna array at three different angles of rotation of 45°

Simulation of the effect of the number of rotations of the lattice in the angle range from 0° to 90° in the accumulation mode perspectives on the value of the artifacts radio image was conducted. Figure 8 shows the total intensity of the three-dimensional cross-sections radio image with the different number of rotations of the lattice.

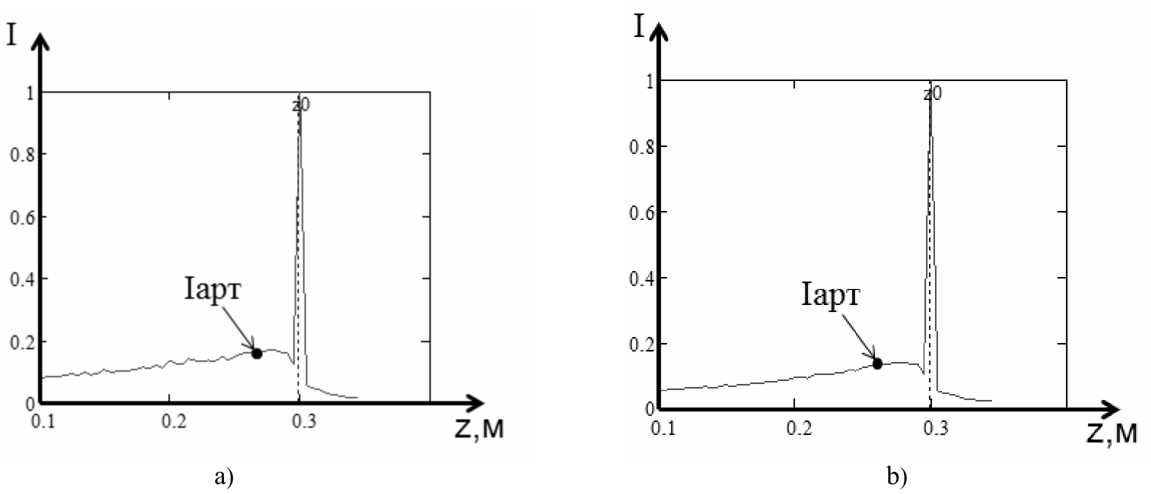

Fig.8. The total intensity radio image a) the number of turns 2, b) the number of turns 3

Figure 9 presents a plot of total intensity level of the artifacts by the number of rotations of the lattice in the range of angles from 0° to 90°. As shown in the figure the increasing a number of turns more than two ones does not significantly reduce the level of artifacts.

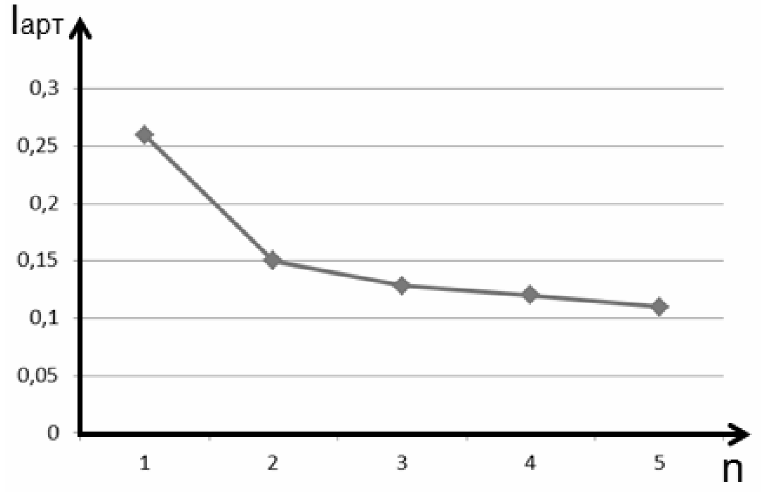

Fig.9. The total intensity level of the artifacts by the number of turns

Conclusion

In this paper the numerical experiments obtaining the radio imaging of the test object using the method of spatial focus and method of radiowave tomosynthesis were carried out. Analysis of the results showed that the method of RT allows to calculate quickly the algorithms of radio images at once on the entire range of distances, but it gives us the higher level of artifacts than the method of spatial focusing. When using the selected antenna array the number of viewing angles due to the rotation of the object around its own axis lattice must be increased. Increasing the angle of rotation due to the lattice reduces the level of 90° artifacts than 1.5 is reduced.

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ПРОСТРАНСТВЕННАЯ ФОКУСИРОВКА СШП СИГНАЛОВ

Сравниваются метод фокусировки во временной области и его аналог, метод радиоволнового томосинтеза в частотной области по критерию уровня артефактов в восстанавливаемом радиоизображении тестового объекта.

Для проверки рассматривается численная модель плоской тактируемой неэквидистантной антенной решетки, разработанной на кафедре радиофизики Томского государственного университета.

Ключевые слова: *радиотомография, сверхширокополосное зондирование, синтезирование апертуры, фокусировка излучения , антенная решетка.*

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