ISSN 2347 - 3983

Volume 8. No. 7, July 2020

International Journal of Emerging Trends in Engineering Research

Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter49872020.pdf

https://doi.org/10.30534/ijeter/2020/49872020

Method of Focusing Sequences of Space-Time Pulses with Phase-Frequency Control

Rayisa Yuriy[1], Svitlana Liulchak[2], Viktor Nikitchenko[3], Volodymyr Larin[4], Natalia Sachaniuk-Kavets'ka[5], Viktoriia Kostrytsia[6]

1. Department of Biophysics, Informatics and medical equipment, Vinnytsia National Pirogov Medical University, Ukraine rayisakoval1@gmail.com

[2]Department of Innovation and Information Technology in Education, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Ukraine. svitlanal2016@gmail.com

[3]Chief of Section, Research Institute Of Armament And Military Equipment Testing And Certification, Ukraine nazar200914@gmail.com, scopus667@gmail.com

[4]Department of application and operation of automated control systems, Ivan Kozhedub Kharkiv National Air Force University, Ukraine. *L_vv83@ukr.net*

[5]Department of Higher Mathematics, Vinnytsia National Technical University, Ukraine skn1901@gmail.com, sachanyuk@vntu.edu.ua

[6]Department of Communications and Automated Control Systems, National Defense University of Ukraine named after Ivan Chernyakhovsky, Ukraine. vika.kostryca@gmail.com

ABSTRACT

The method of forming sequences of focused spatial – temporal pulses based on a single-disc single-stage frequency distribution over the aperture of a cylindrical phased antenna array is considered. The calculated relationships are presented that allow one to determine the spatial-frequency characteristics of the radiated field with a mutually consistent spatial-phase-frequency control of the emitted signals in the channels of the transmitting cylindrical phased antenna array.

Key words: semiconductor, affection, probability, microprocessor technology, control system, space-time signal, mathematical model.

1. INTRODUCTION

One of the possible ways to create specialized radio equipment to transmit information of great power and stealth is the development of antenna systems using focusing of electromagnetic radiation in the Fraunhofer zone [1-4].

In [5, 6] focusing methods of electromagnetic radiation based on mutually agreed spatial-phase-frequency control of emitted signals in transmitting flat phased antenna arrays and multi-position emitter systems are considered. It is noted that focusing of electromagnetic radiation can be achieved due to additional degrees of freedom in control, which makes it possible to form powerful short spatial-temporal radio pulses in space.

One of the known methods for focusing electromagnetic radiation based on mutually agreed spatial-phase-frequency control of emitted signals is a method that provides for single-stage and multi-stage frequency distribution over the aperture of transmitting flat phased array antennas [12-15], which are known to have a number of disadvantages compared to convex (conformal) phased array antenna.

The purpose of this article is to analyze the focusing possibilities of a phased cylindrical antenna array with spatial-phase-frequency control of electromagnetic radiation using the equal-discrete law of frequency distribution over its aperture.

2. MAIN MATERIAL

The widespread use of convex phased antenna arrays (cylindrical, annular, conical, spherical, elliptical, etc.) is caused by the following main advantages [4-15]:

- the ability to optimize the step of placing their elements;

- the ability to significantly reduce the number of elements in a cylindrical phased antenna array along the generatrix (by increasing the placement step to d $\leq 1,1\ \lambda$, where λ is the wavelength);

- the absence of distortion of the radiation pattern during scanning in the plane of symmetry (for example, in the azimuthal plane for an annular, cylindrical, conical phased antenna array);

- the possibility of a relatively simple implementation of the circular overview in the plane of symmetry.

The main structural features of a cylindrical phased antenna array, which should be taken into account when analyzing the spatial, temporal, and energy characteristics of focused electromagnetic pulses, include the following:

- radiating elements are located on a convex surface, the shape of which must be set in the coordinate system adopted for calculations;

- the axis of the radiating elements are normal to the convex surface and are not parallel to each other.

It is known [8] that the amplitude of the electric field for a single emitter of a cylindrical phased antenna array in the far zone has the form:

$$\dot{E}_n(P) = \dot{F}_n(\varepsilon,\beta)\sqrt{60 P_n G_{\max n}} / R_F, \qquad (1)$$

where $\dot{F}_n(\varepsilon,\beta)$ – normalized radiation pattern along the field of the nth emitter;

P_n, $G_{\max n}$ – power supplied to the emitter and its maximum gain;

R_F – distance to focus point.

Taking into account expression (1), the total value for the electric field strength at the observation point created by the cylindrical phased antenna array is determined by the superposition of the fields Mx × Ny emitters (figure 1):

$$\dot{E}(P,t) = \sum_{m=1}^{M_x}\sum_{n=1}^{N_y} \frac{\dot{F}_{mn}(\alpha_F,\beta_F)}{R_{mn}}\sqrt{60 P_{mn} G_{\max\ mn}} \times \\ \times \exp\left\{ j\left[2\pi f_{0\,mn}\left(t - \frac{R_{mn}}{c}\right) + \varphi_{0\,mn}\right]\right\}, \qquad (2)$$

where m=1,…,M_x и n=1,…,N_y – indexes determining the number of the emitter;

M_x, N_y – the number of radiating elements along the generatrix and guide cylinder, respectively;

$\dot{F}_{mn}(\alpha_F,\beta_F)$ – antenna pattern;

α_F, β_F – azimuth and elevation towards the focus point (figure 1);

P_{mn}, $G_{\max mn}$ – power supplied to the emitter and its maximum gain;

f_{0mn} и φ_{0mn} – initial frequency and phase of the mnth emitter of the antenna array;

R_{mn} – distance from the emitter to the observation point (focus);

c – speed of light;

t – point in time of observation.

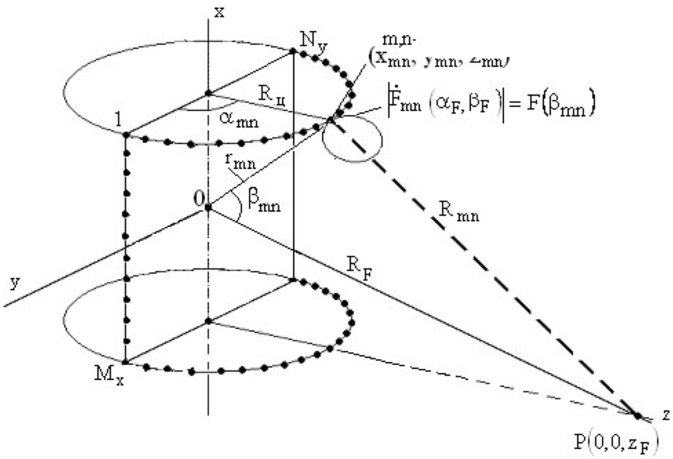

Figure 1: Design of a cylindrical phased array antenna

Assuming that the emitters of the cylindrical phased antenna array are pyramidal horns with a separable amplitude – phase distribution, the expressions for the current distributions in the horizontal and vertical planes will be [8]:

$$\dot{i}_г(x,y) = \cos\left(\frac{\pi x}{L_H}\right)\exp\left[j\left(-k\frac{x^2}{2R_H}\right)\right], \\ \dot{i}_в(x,y) = \exp\left[j\left(-k\frac{y^2}{2R_E}\right)\right], \qquad (3)$$

where x, y – current coordinates of the point in the aperture of the emitter of a cylindrical phased array antenna;

k – wave number;

R_H=R_E – speaker length;
L_H – mouthpiece size.

Suppose that the phase distortions in the aperture are small: less than π / 8 in the E – plane (elevated) $F_E(\Theta)$ and less than π / 4 in the H – plane (azimuthal) $F_H(\Theta)$. In this case, the opening can be considered in-phase, and the amplitude radiation patterns will be described by the following expressions [8]:

$$F_E(\Theta) = \frac{1+\cos\Theta}{2}\frac{\sin\Psi}{\Psi}, \\ F_H(\Theta) = \frac{1+\cos\Theta}{2}\frac{\pi}{4}\left[\frac{\sin(\Psi+\pi/2)}{\Psi+\pi/2} + \frac{\sin(\Psi-\pi/2)}{\Psi-\pi/2}\right], \qquad (4)$$

where $F_E(\Theta)$ – elevation pattern $|\dot{F}_{mn}(\beta_F)|$,

$F_H(\Theta)$ – azimuthal radiation pattern $|\dot{F}_{mn}(\alpha_F)|$,

Θ – elevation angle of the observation point (focus);

$\Psi = \frac{\pi L_{E,H}}{\lambda}\sin\Theta$ – generalized angle.

When determining the elevation angle of the focus point P (xF, yF, zF) for the mn-th emitter, it is necessary to first calculate the coordinates xmn, ymn, zmn of the source location in the given coordinate system (figure 1). In this case, the initial data for the calculation are the radius of the cylinder guide Rc, the number of emitters along the guide Ny, which allows us to determine the lattice pitch dy, the length of the generator and the number of emitters along the generatrix Mx (for reasons of directivity in the elevation plane), which allows you to determine the lattice pitch dx:

$$d_y = \frac{2\pi R_ц}{N_y}, \ \alpha_{mn} = 2\arcsin\left(\frac{2R_ц}{nd_y}\right), \ d_x = \frac{L_{обр}}{M_x}. \quad (5)$$

For the assumptions made, the coordinates of the mn-th emitter will be:

$$x_{mn} = md_x, \ y_{mn} = R_ц \cos\alpha_{mn}, \ z_{mn} = R_ц \sin\alpha_{mn}.$$

Then the distance from the origin to the location of the emitter will be:

$$r_{mn} = \sqrt{x_{mn}^2 + y_{mn}^2 + z_{mn}^2},$$

from emitter to focus point:

$$R_{mn} = \sqrt{(x_F - x_{mn})^2 + (y_F - y_{mn})^2 + (z_F - z_{mn})^2},$$

from origin to focus point:

$$R_ф = \sqrt{x_F^2 + y_F^2 + z_F^2}$$

and elevation angle of the observation point for the mn-th emitter:

$$\beta_{mn} = \arccos\left(\frac{r_{mn}^2 + R_F^2 - R_{mn}^2}{2r_{mn}R_F}\right).$$

Note that the angle β_{mn} is an analog of the angle Θ in expressions (4), i.e. in the accepted notation we get:

$$\left|\dot{F}_{mn}(\alpha_F, \beta_F)\right| = F(\beta_{mn}).$$

For the calculated relations obtained above, expression (2) is transformed to:

$$\begin{aligned} \dot{E}(P,t) = \sum_{m}^{M_x}\sum_{n}^{N_y} \frac{F(\beta_{mn})}{R_{mn}}\sqrt{60 P_{mn} G_{\max mn}} \times \\ \times \exp\left\{ j\left[2\pi f_{0\,mn}\left(t - \frac{R_{mn}}{c}\right) + \varphi_{0\,mn}\right]\right\}. \end{aligned} \quad (6)$$

Let the focus point be on the Oz axis (figure 1) and have the coordinates P (0; 0; zF). For a cylindrical phased antenna array, the distance to point P from each radiating element is equal to:

$$R_{mn} = \sqrt{x_{mn}{}^2 + y_{mn}{}^2 + (z_F - z_{mn})^2}.$$

It follows from expression (6) that, in order to ensure coherent addition of electromagnetic pulses from each element of the phased array, it is necessary that the phase incursions of waves from each element of the phased array to the focusing point be compensated due to the initial definition of the phase distribution over the aperture (or time delays).

The condition of coherent wave addition is satisfied in the case:

$$2\pi f_{0mn}\left(t_F - \frac{R_{mn}}{c}\right) + \varphi_{0mn} = 0,$$

where $t_F = \frac{\sqrt{x_F^2 + y_F^2 + z_F^2}}{c} = \frac{z_F}{c}$;

$$\varphi_{0mn} = -2\pi f_{0mn}\left(\frac{z_F}{c} - \frac{R_{mn}}{c}\right).$$

We expand R_{mn} in a Taylor series at the focal point and restrict ourselves to the first two terms of the expansion:

$$\begin{aligned} R_{mn} &= (z_F - z_{mn})\sqrt{\frac{x_{mn}^2 + y_{mn}^2}{(z_F - z_{mn})^2} + 1} = \\ &= (z_F - z_{mn}) + \frac{x_{mn}^2 + y_{mn}^2}{2(z_F - z_{mn})} \end{aligned}. \quad (7)$$

With this in mind, we have:

$$\begin{aligned} \varphi_{0mn} &= -\frac{2\pi f_{0mn}}{c}\left(z_F - (z_F - z_{mn}) - \frac{x_{mn}^2 + y_{mn}^2}{2(z_F - z_{mn})}\right) = \\ &= \frac{\pi f_{0mn}}{2c(z_F - z_{mn})}\left[2z_F z_{mn} - \left(x_{mn}^2 + y_{mn}^2 + z_{mn}^2\right)\right] \end{aligned}$$

Suppose that for a system of pyramidal horns the amplitude distribution over the aperture is separable:

A (x, y) = A (x) A(y). In this case, the most general function of the amplitude field distribution in the aperture is a dependence of the form:

$$A(x,y)=\left[\mu_x+(1-\mu_x)\cos^{\alpha}\frac{\pi x_{mn}}{L_x}\right]\times$$
$$\times\left[\mu_y+(1-\mu_y)\cos^{\beta}\frac{\pi y_{mn}}{L_y}\right],$$

where $\mu_x, \mu_y \in (0;1);\ \alpha, \beta = 0, 1, 2, \ \ldots$.

Choosing the parameters, one can approximate all sorts of real distributions with sufficient accuracy for practice.

Mutually consistent control of signals in the channels of transmitting antenna arrays leads to the formation of spatial-temporal pulses in the vicinity of the focus point. The use of a linear frequency distribution makes it possible to form a sequence of spatial-temporal pulses in a given angular direction during continuous or long-pulse radiation of signals by elements of a phased array antenna.

The duration of the generated spatial-temporal pulses will depend on the width of the spectrum of the signals exciting the emitters of the phased antenna array and can be several nanoseconds when each channel of the phased antenna array emits a continuous monochromatic or long pulse signal. When changing the linear law of spatial-frequency control over the aperture of a phased antenna array, additional temporal pulse modulation of the emitted signals is necessary to form sequences of spatial-temporal pulses, which significantly complicates the phased antenna array.

Consider the method of forming sequences of focused spatial-temporal pulses based on a single-disc, single-stage V-shaped frequency distribution over the aperture of a phased array antenna. In this case, the law of spatial-frequency control of signals in a phased antenna array has the form [5]:

$$f_{0mn}=\begin{cases} f_0+|m|\Delta F_x, \text{ если } |m|\Delta F_x \geq |n|\Delta F_y, \\ f_0+|n|\Delta F_y, \text{ если } |m|\Delta F_x < |n|\Delta F_y, \end{cases} \quad (8)$$

Where

$$m \in \left[-\frac{M_x-1}{2};\ldots 0;\ldots\frac{M_x-1}{2}\right]$$
$$n \in \left[-\frac{N_y-1}{2};\ldots 0;\ldots\frac{N_y-1}{2}\right].$$

The law of distribution of the initial phases of the emitters of the phased antenna array for the implementation of coherent addition of fields at the selected focus point will be:

$$\varphi_{0mn}=\frac{\pi f_{0mn}}{2c\left(z_F-z_{mn}\right)}\left[2z_F z_{mn}-\left(x_{mn}^2+y_{mn}^2+z_{mn}^2\right)\right]. \quad (9)$$

The calculated relations (5), (7), (8) allow one to determine the spatial-frequency characteristics of the emitted field with the mutually agreed spatial-phase-frequency control of the emitted signals in the channels of the transmitting cylindrical phased antenna array.

3. CONCLUSION

The method of forming sequences of focused spatial-temporal pulses on the basis of a single-disc one-stage frequency distribution over the aperture of a phased cylindrical antenna array is considered. The calculated relationships are presented that allow one to determine the spatial-frequency characteristics of the radiated field with a mutually consistent spatial-phase-frequency control of the emitted signals in the channels of the transmitting cylindrical phased antenna array.

REFERENCES

1 Glan Chance V. **Trandsin mixer damage**, *IEEE, MTT-S Int. Microwave Symp. Digest.*, 1989, P.475-477.

2 Christon A. **GAAS mixer burnout mechanisms at 36-94 GHz**, *Annual Proc.Reliab.Physics*, 1980, P.140-144.

3 Dale M., Neylon S., Condie A., Kearacy M.J. **Planar doped barrier diodes offering improved microwave burnout performance over Si and GaAs Shottky diodes**, *19 Europe Microwave Conf. Proc.*, 1989. – p. 237-243.

4 Whalen J.J. **The RF Pulse Susceptibility of UHF Transistors**, *IEEE Trans., Vol. EMC-17. – N1.*, 1975, P.118-126.

5 Gadetski N. P., Magda I. I., Kravtsov K. A. **Studies of electromagnetic radiation of ultra-short duration pulse interference on UHF electronics devices**, *AMEREM'96 Conference, Book of Abstracts. Albuquerque, USA*, 1996, P. 79.

6 LoVetri J., Wilbers A.T.M., Zwamborn A.P.M. **Microwave interaction with a personal computer: Experiment and modeling**, *Proc. of the 13th Int. Zurich Symposium*, 1999. – P. 203.

7 Revesz A.G. **Chemical and structural aspects of the irradiation behavior of Si02 films on silicon**, *IEEE Trans. Nucl. Sci., V. 24, № 6*, 1977, P. 2102-2107.

8 Grunthaner F.J. **Radiation-induced defects in Si02 as determined with XPS**, *IEEE Trans. Nuclear Physics, V. 29, №6*, 1982, P. 1462-1466.

10 Schwank J.R. **Irradiated silicon gate MOS device bias annealing**, IEEE Trans. Nucl. Phys. V. 30, № 6, 1983, P.1100-1104.

11 Hussein W. N., Kamarudin L. M., Hussain H.N., Hamzah M. R., Jadaa K. J. **Technology elements that influence the implementation success for big DATA analytics and IOT- oriented transportation system,** *IJATCSE. 8(5),* 2019, pp. 2347-2352.
doi: 10.30534/IJATCSE/2019/74852019.

12 Singhal Ankur, Nijhawan Parag, Sinha Amrita, Rai Kamlesh. **Approach for Efficiency Enhancement of Microwave Ovens,** *IJATCSE. 8(2),* 2019, pp. 265-270. doi: 10.30534/IJATCSE/2019/27822019.

13 Nawaz Nishad. **Artificial Intelligence interchange human intervention in the recruitment process in Indian Software Industry,** *IJATCSE. 8(4),* 2019, pp. 1433-1441. doi: 10.30534/IJATCSE/2019/62842019.

14 Karthikeyan R., Parvathy A.K., Priyadharshini S. **Energy Optimization of Residential Energy Management in Micro Grid using Cyber Physical Controller**, *IJATCSE. 9(2),* 2020, pp. 1166-1171.
doi: 10.30534/IJATCSE/2020/41922019.

15 Smyrnova I., Horbenko V., Lutsyshyn A., Kaminskyi V., Sasiuk Z., Selivyorstova T., Ienina I. **The method of determining the Probability of Affection of the Semiconductor Elements under the influence of the Multifrequency Space-Time Signals**, *IJETER. 8(5),* 2020, pp. 1776-1779. doi: 10.30534/ijeter/2020/46852020.