Research Journal of Applied Sciences 11 (11): 1313-1316, 2016
ISSN: 1815-932X

Advanced Phased Array Antenna (PAA)

Nikolai M. Legkiy and Timur R. Sabirov
Moscow State Institute of Radio Engineering, Electronics and Automation (MIREA),
78, Prospect Vernadskogo, 119454 Moscow, Russia

Abstract: The study presents a new design of the Phased Array Antenna (PAA) with improved performance characteristics and provides photographs of the PAA element as well as its measured characteristics.

Key words: Antennas, industrial engineering, PAA, super-high frequency, Russia

INTRODUCTION

Now a days, Phased Array Antennas (PAA) are finding increased practical implementation because of their design features. The phased array antennas allow spatial summarizing capacities of a large number of transmitting modules, controlling Angular Pattern (AP) without mechanical devices and producing fast-response spatial movement of the antenna beam which is of a high importance in the use of the PAA in different applications (Callus, 2008; Gao *et al*., 2014; Inclan *et al*., 2011; Legay and Shafai, 1994).

In designing modern PAAs, tendencies of their functional and structural complicating, decrease in their volume (physical size) and power consumption and increase in importance of information technology in their functioning and design (use of CAD) are observed (Balanis, 1997; Bankov and Kurushin, 2009; Garg *et al*., 2001).

Applying radiating modules based on bulk structures in the PAA allows decreasing mass-dimensional parameters. Antenna arrays with radiating modules constructed with the use of bulk structure technology are complex engineering devices which comprise a large number of radiating elements, power adders, electrodynamic contactless communication with significant electrodynamic interactions of varied manifestations, conditioned by the vector spatial wave processes. A special part of phased array antennas is the antenna of a radiating element. Key parameters of the entire PAA depend mostly on the quality of the design and manufacture of each radiating element.

MATERIALS AND METHODS

Proposed design of the PAA: The classical problem of synthesizing an antenna array consists in a search for the distribution of sources at the input ports of the emitters according to the specified requirements for the pattern function. In the meantime, the problem of antenna synthesizing in its classical formulation does not give an answer to the question of the antenna implementation method which makes it necessary to set practically significant problems of parametric or structural synthesis. The problems of this class allow determining all the parameters of an antenna array (including geometrical ones) that specify the required characteristics of the antenna. Inverse electrodynamical problems such problems can be reduced in most cases to the solving quite difficult nonlinear multiextremal problems through numerical methods with the involvement of high-speed computers.

It should be emphasized that the results of miniaturization have been affected antenna technology as well, since the decrease in mass-dimensional parameters is only possible with a cross-cutting approach to the issue of antenna systems construction. Furthermore, it is known that the best results in designing and developing super-high frequency modules for radio-electronic equipment are obtained while meeting the following requirements: optimality of the basic element (each basic element must have the best transmission line) and structural adequacy.

Classical evaluation of ideal isotropic emitters geometrically arranged in a square array allows estimating the known array factor and when using standard emitters based on single vibrators (slots), the minimum number of transmitting modules required to implement specified characteristics. The number of transmitting modules in the array is $N = n \times n$ and reduction in the number of radiating and as a consequence of transmitting modules, can be achieved by using emitters with the suppression of extraneous major maxima of the array factor. To reduce the number of transmitting modules, we propose to

Corresponding Author: Nikolai M. Legkiy, Moscow State Institute of Radio Engineering, Electronics and Automation (MIREA), 78, Prospect Vernadskogo, 119454 Moscow, Russia

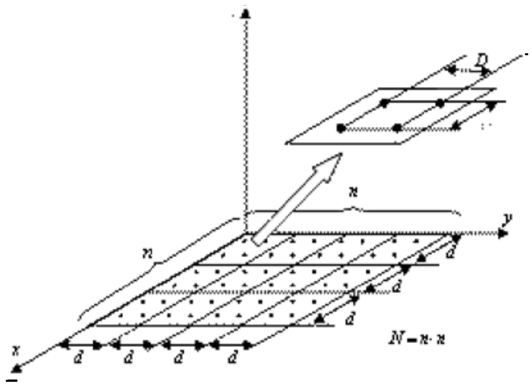

Fig. 1: PAA structure

construct the PAA based on the emitters whose geometry is determined by four isolated elements representing an aperture of a small non-scanning subarray of the PAA. The distance between the elements of the subarray is chosen as D_x and D_y (Fig. 1).

We have carried out the work on optimization of the emitter's arrangement in a single module according to criteria assuring parameters of the synthesized module diagram (mainly these of suppression of extraneous major maxima of array factor) and possibilities of constructive realization, all other parameters remain constant (Sabirov, 2012a, b).

As a result, we have obtained a sample of the PAA emitter whose mathematical model is based on the principle of spatial summation of the amplitudes of four elements of the non-scanning subarray. The distance between D_x and D_y (Fig. 1) in the given subarray were chosen different from the distances between radiating elements of PAA d_x and d_y; they are approximately equal to half of the wavelength ($D_x = 0.45\cdot\lambda$ and $D_y = 0.525\cdot\lambda$). The angular pattern $F(\theta, \varphi)$ of such a non-scanning subarray is defined as:

$$F(\theta, \varphi) = \sum_{p=0}^{N_x} \sum_{q=0}^{N_y} A_{p,q} e^{j(p.\frac{2\pi}{\lambda}\sin(\theta\cos(\varphi)).Dx + q\frac{2\pi}{\lambda}\sin(\theta)\sin(\theta).D_y)} \quad (1)$$

Where:

- N_X, N_Y = Number of subarray elements
- p, q = Numbers of elements along the axes X and Y, respectively
- θ = The angle between the normal to the antenna's axis OZ and the direction to the observation point
- φ = Azimuthal angle
- $A_{p,q}$ = Amplitude of an element in the line p and column q determined by calculation of the element's model through numerical methods of electrodynamics

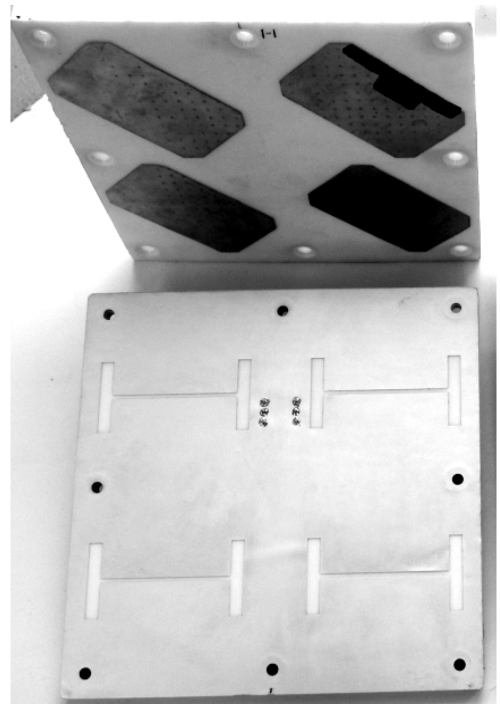

Fig. 2: Old PAA strudture

Implementation of the module with 4 radiating elements ensures a two-fold reduction of the used modules while technical characteristics remain the same which in turn allows reducing the total mass of radiating and receiving modules (Hienonen *et al.*, 1999). Figure 2 shows a picture of the old design of the PAA element while Fig. 3 represents the proposed new design.

RESULTS AND DISCUSSION

Figure 4 and 5 shows the Standing Wave Ratio (SWR) measurement results. It can be seen that in the range of operation frequencies, the frequency response of the construction of the old type (Fig. 4) has significant fluctuations with respect to a calculated value (solid dark line) that along with the distortion of shape of the angular pattern, significantly influences the characteristics of the radiation. The analysis of the measured characteristics of the radiating elements shows that the updated design has no critical sensitivity with regard to the arrangement of the layers in a radiating element as well as with regard to their arrangement relative to each other. Moreover, even 1 mm displacement of the layers does not affect radiation characteristics and it can be seen that the previously observed fluctuations are reduced to a considerable degree.

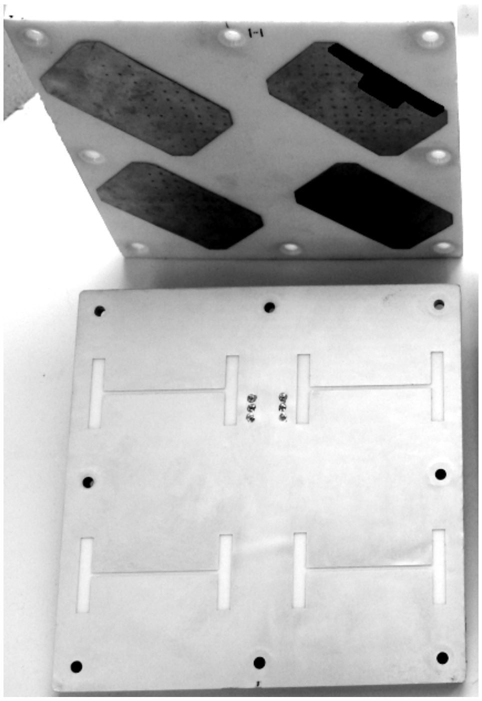

Fig. 3: New PAA structure

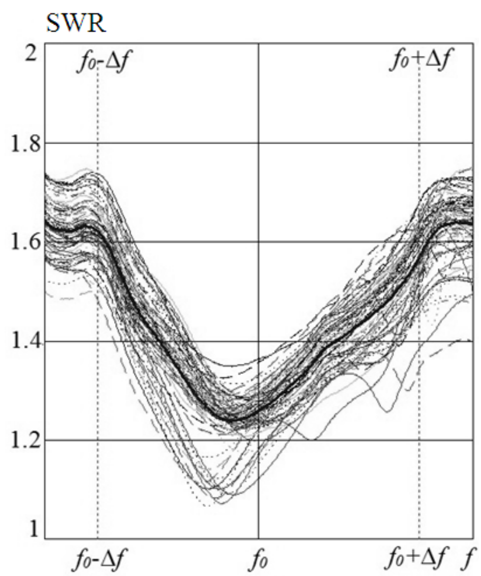

Fig. 4: Old PAA SWR measurement results

Based on the modelling results, a prototype of the portable antenna (Fig. 3) at X-band for satellite communications was proposed. Its only difference from (Inclan *et al.*, 2011) is the shape of a radiating element. The testing validated the proposed technological

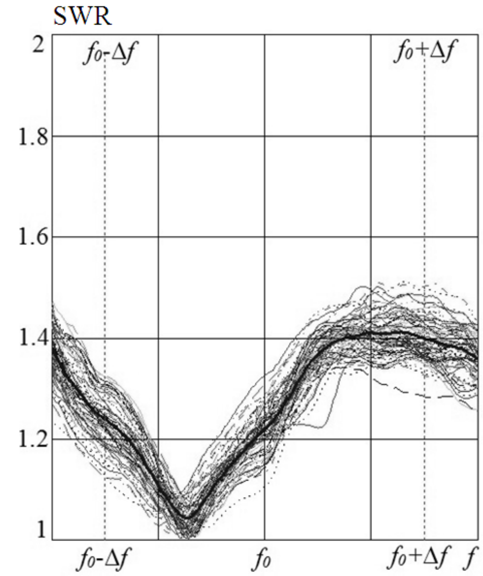

Fig. 5: New PAA SWR measurement results

solutions. The findings have been confirmed (Sabirov, 2012a, b). The present article contains all the data necessary to reproduce the experiment. As can be seen from the characteristics obtained from measuring the SWR on the finished product (Fig. 5), the amplitude of a new PAA in operational frequencies is lesser as compared to calculated values; therefore, the new PAA has better characteristics.

CONCLUSION

The proposed design of the radiating element with a complex dumbbell-shaped radiating slot allows creating a radiating element with required performance characteristics. Moreover, during its manufacturing, satisfactory repeatability of radiating elements can be achieved which makes it possible to reduce the number of radiating elements by two times when building phased array antennas, reducing at the same time variations of their angular pattern.

REFERENCES

Balanis, C.A., 1997. Antenna Theory Analysis and Design. 2nd Edn., John Wiely and Sons Inc., New York, USA., ISBN-13: 978-0471592686, Pages; 960.

Bankov, S.E. and A.A. Kurushin, 2009. Electrodynamics and Microwave Technology for CAD Users. Institute of Radioelectronics, Kharkiv, Ukraine,.

Callus, P.J., 2008. Novel concepts for conformal load-bearing antenna structure. Air Vehicles Division, Defence Science and Technology Organisation, Melbourne, Victoria, Australia.

Gao, S., L. Qi and Z. Fuguo, 2014. Circularly Polarized Antennas. John Wiley & Sons, Chichester, England,.

Garg, R., P. Bhartia, I. Bahl and A. Ittipiboon, 2001. Microstrip Antenna Design Handbook. 1st Edn., Artech House Inc., Boston, London, ISBN: 0-89006-513-6, pp: 845.

Hienonen, S., A. Lehto and A.V. Raisanen, 1999. Simple broadband dual-polarized aperture-coupled microstrip antenna. Proceedings of the 1999 IEEE International Symposium on Antennas and Propagation Society, July 11-16, 1999, IEEE, Espoo, Finland, ISBN:0-7803-5639-x, pp: 1228-1231.

Inclan, A.J.M., G.A. Aguilar, V.L. Herrero, F.J.M. Gonzalez and S.J. Jara *et al*., 2011. Modular planar antenna at X-band for satellite communications. Proceedings of the 2011 30th Symposium on General Assembly and Scientific, August 13-20, 2011, IEEE, Madrid, Spain, ISBN:978-1-4244-5117-3, pp: 1-4.

Legay, H.and L. Shafai, 1994. New stacked microstrip antenna with large bandwidth and high gain. IEE. Proc. Microwaves Antennas Propag., 141: 199-204.

Sabirov, T.R., 2012a. Characteristics of radiation of the transmitting active phased array antenna in the presence of steering error and amplification channels failures. J. Radio, 11: 1-7.

Sabirov, T.R., 2012b. Ultra high frequency airborne active phased array antenna installed on military spacecraft. Topical Issues Des. Space Syst. Complexes, 13: 101-118.