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ADJUSTMENT AND BEAM FORMING IN CIRCULAR ANTENNA ARRAY WITH CONFORMAL AND PHASE SCANNING

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Abstract

The circular antenna array, composed of M linear antenna sub-arrays, is considered in this work. Every linear antenna sub-array includes N active modules. The signals from active antenna array modules in receive mode are processed in digital form. It is described the of the antenna phase adjustment, which is necessary for this type of antenna. It is also considered the influence of different factors to antenna radiation plot.

Keywords: circular antenna array**,** phase scanning, beamforming, accident error of phase distribution, antenna adjustment.

1. Preamble

The use of circular and cylindrical antenna arrays allow to overcome a number of difficulties during scanning antenna designing and provide a lot of advantage for wireless device on system level. In our days the development of circular antenna arrays (CAA) is the actual task. In spite of this there is not sufficient lighting of questions, connected with beamforming in such an antenna, and other tasks, which it is necessary to solve, when developing antenna system.

In this paper it is considered a circular antenna array, composed of M liner sub-arrays (the sides of CAA). There are N active modules in every liner array. An illustrative drawing of this antenna showed in Fig.1.

During numerical modeling as elementary radiator, it were taken vibrator ,slot antenna, microstrip patch and antennas with given main lobe width. The array is intended for forming of four beams in space with conformal and phase scanning. The signals coming from array modules is processed in digital form. During operating of such an array, necessary step is phase adjustment. In the course of adjustment it is compensated phase error in reception paths and it is summed up the signals for every beam forming subject to weighting coefficients for phase and magnitude. In the paper is described array adjustment algorithm, using the special adjustment antennas, and forming beams in prescribed directions. It is considered the influence of such factors as elementary radiator main-lobe width, phase scanning angle and random phase distribution error to radiation pattern (RP) parameters.

The mathematical model, used for calculating, is based on equivalent liner array (ELA) method.

2. Content

2.1. PHASE ADJUSTMENT IN DIGITAL CIRCULAR ANTENNA ARRAY

The phase adjustment is performed to compensate phase errors at reception paths. The phase distribution, set on elements of digital non-regular antenna array in receive mode, must take into account an inequality and time instability of phase characteristics of every reception paths. Inequality of reception paths phase characteristics is caused by feed lines different lengths and by difference of phase characteristics of reception paths mixers.

In order to calculate the phase characteristics in reception paths of digital antenna array it is realized the adjustment with help of remote antennas. The adjustment is performed in three steps. The phase incursion calculation is realized at reception paths, connected to 256 radiators which is located on 16 sides, using 8 remote adjustment antennas. The adjustment antennas is situated on the circle with diameter 5 m. Every an adjustment antenna adjust three sides: the central side, located opposite the remote antenna, and two adjacent antennas which is adjusted using two neighbouring remote antennas. The algorithm of three sides adjustment is written bellow. The signal, generated by oscillator, with controlled initial phase is radiated by a remote antenna. The sensed signal phase is detected in adjusted reception paths of CAA. The phase shift is calculated as difference between phase of the sensed signal and a signal phase calculated in advance. During the preliminary calculation of the received signal it is taken into account the distance between adjusted radiator and adjustment antenna. By

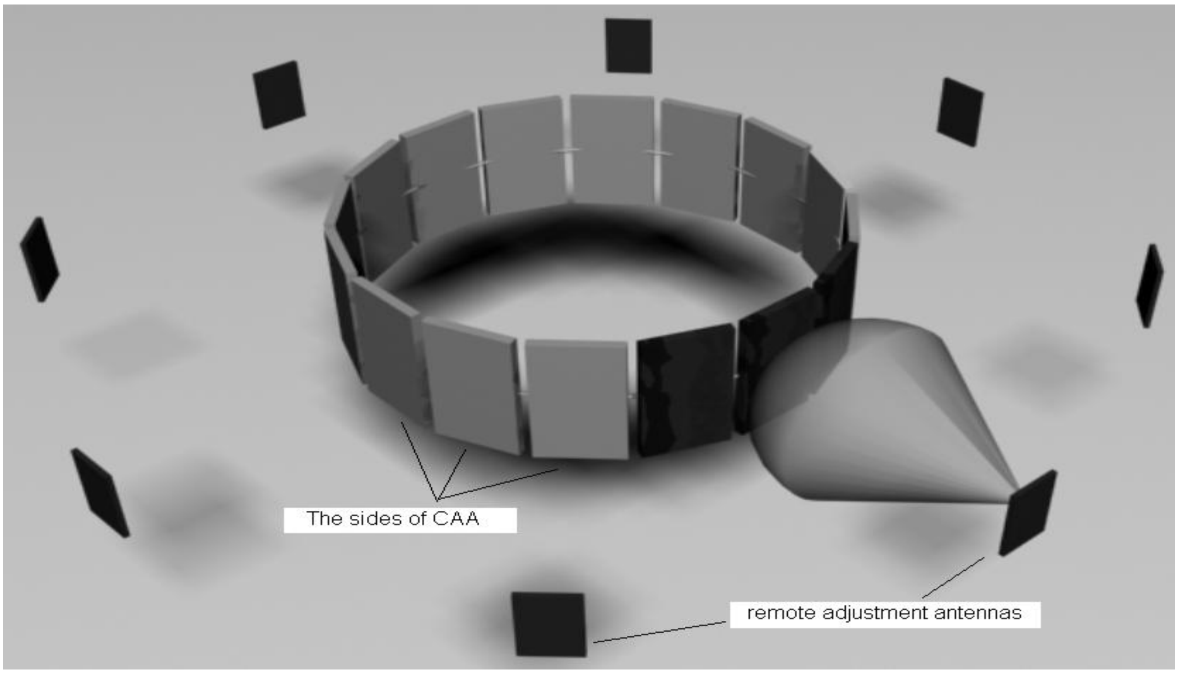

Fig. 1. The illustrative drawing of the circular antenna array with the system of adjustment antennas.

them mutual orientation it is also taken into consideration the phase characteristic of an radiator,

which is added to the value of total phase incursion. In order to adjust the system the radiator phase characteristic can be given for every radiator but it leads to sizeable measurement work or it is possible to use a standard phase characteristic. The second solution can entail random errors of phase distribution, its influence is described bottom in the paper.

2.2. THE RESULTS OF CAA MODELLING

In the capacity of example it is below considered the array having the next parameters: the number of sides is M=16, the active module number on a side is N=16, the length of every side is L=169 mm, the distance between adjacent radiators is Li=18 mm. For forming a beam it is used from 2 to 6 sides as active, but in the paper it is adduced the results for 6 sides. The working frequency is 10 GHz.

2.2.1. The influence of main-lobe width of elementary radiator to CAA radiation pattern.

CAA radiators have different spatial orientation. The CAA sides, situated nearer to the edge of radiating surface, and their radiators is oriented at an angle to the line of ELA. Hereupon two opposite effects appear. If we accept that that CAA radiate in the line of the ICAA normal then first the edge sides radiators emit with smaller gain (it is implied that radiation pattern maximum of a radiator is directed in the line of a side normal). This leads to the reduction of ELA edge radiators excitation level. Secondly, the projection of CAA edge sides to ELA are shorter than the central sides projection. This in turn leads to the growth of radiators location density to ELA edges and increase of edge amplitude distribution. The degree of the first effect impaction depends on main-lobe width of elementary radiator. Modeling have been confirmed that when a radiator main lobe width reduces, the main lobe of CAA is widened and side lobe level is lessened, what is typifying for edge declining amplitude distribution. During CAA modeling it was used uniform radiators amplitude excitation. When the main lobe width of an elementary radiator was large it was observed CAA main-lobe narrowing and side lobes level increasing compare with a line array of the same length, what is typifying for edge growing amplitude distribution. The dependence of side lobe level from elementary radiator main-lobe width presented in Fig. 2.

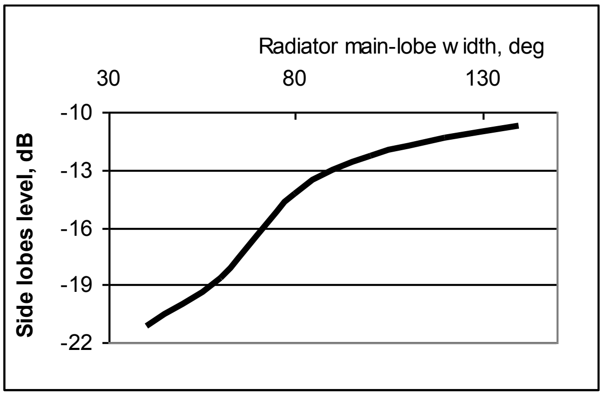

Fig. 2. The dependence side lobes level from the width of elementary radiator main-lobe

2.2.2 The influence phase scanning process to CAA radiation pattern

According to modeling results of radiation pattern for different scan angles it can be included the following:

- During phase scanning process in CAA the main lobe widens faster than in liner array. It can be explained by edge CAA sides cutting on projection to ELA during phase beam turning and by distortion of amplitude distribution which became non-central.
- It is absent the explicit skewness of side lobes level from different sides of main lobe which is typical for liner arrays.
- Side lobes level rises slower in CAA than in a liner array during scan angle increasing. The appearance of the second diffraction maximum in CAA also takes place at greater scan angles. The cause of this is not equidistant radiators layout on ELA surface. The comparison of dependences side lobes level for CAA and a liner array have been given in Fig.3.
- If a number of CAA sides, enabled by forming the beam, reduces, the CAA parameters tends to a liner array parameters.

2.2.3 The influence of phase distribution random error to CAA radiation pattern

There are a lot of factors, which affects the phase distribution on radiating surface in antenna system. Among them can be marked out the next:

- technological parameters spread of radiators during manufacturing;
- unstability of phase characteristics at reception and transmission channels, caused by internal and external factors;
- interference of radiators;
- errors, caused by inaccuracy of accounting radiators phase characteristics during adjustment and calculating of phase weighting coefficients .

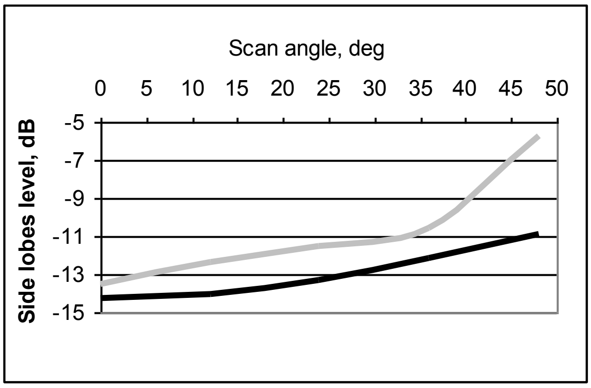

Fig. 3. Side lobes level dependence from scan angle for CAA (black line) and a liner array (gray line)

It have been done statistical analysis of the influence of phase distribution random error to CAA radiation pattern. The random error have been set as maximum phase error in degrees. The average radiation pattern were given by averaging of 50 accidental radiation pattern realizations. In Fig. 4 is given side lobes level dependence form the value of maximum phase error. For the array excitation it was used an edge declining amplitude distribution cos^2 with base level is 0.2.

In addition what have been considered at [1] it was researched the case when the random phase error is distributed unevenly on radiating antenna surface, but the results isn't showed in the paper because of information volume limitation.

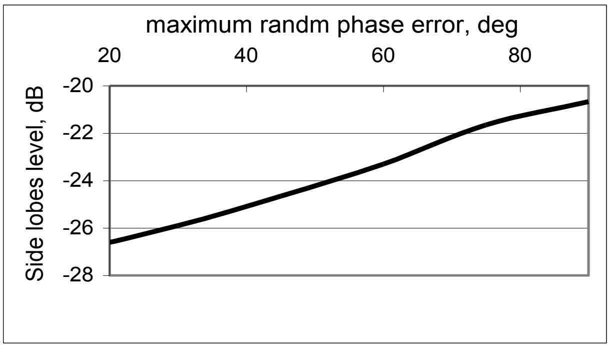

Fig. 4. The dependence of side lobes level from the value of phase distribution maximum random error

3. Conclusion

In this paper is described the influence of such factors as elementary radiator main-lobe width, phase scanning angle and random phase distribution error to CAA radiation pattern (RP) parameters. It have been found out that increasing of main lobe width of an elementary radiator leads to edge growing amplitude distribution and the reduction of the radiator main lobe width leads to edge declining amplitude distribution. During increasing phase scan angle in CAA the side lobes level rises slower and main lobe widens faster compare with the line array having the same length. While the maximum phase random error is rising from 0˚ to 90˚ (CAA have amplitude distribution cos^2 with base level is 0.2) the sides lobe level is rising from -27 dB to -21 dB.

It is briefly considered the question of the digital antenna array adjustment.

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