FOCUSING SYSTEMS BASED ON MICROSTRIP REFLECTARRAYS

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1.Introduction

Microstrip reflective antenna arrays (RAA) are considered. Reflective type antenna arrays have a series of remarkable properties on comparison with other types of antennas. Having practically all possibilities, which are peculiar to antenna arrays of so called transfer type, RAA differ by the greater simplicity and reduced cost. To their number first of all it is possible to refer the antenna arrays (including scanning ones) constructed with use of optical principles and various types of diffraction gratings. RAA can be excited by a field of incident plane wave or by generator connected with the array port through Y-circulator. The radiators of a reflective array can be loaded by uncoupled loads possessing generally a complex character of an impedance, or by multiport network of a complicated structure - so-called beamforming networks. The possible RAA application area is discussed and it’s shown the RAA are the very attractive type of array for focusing systems designing at microwaves.

The optical feed circuit application for radiators excitation is an antenna array cost reducing way. Usually these antenna arrays are supplied with such circuits for a radiator feed, which are applied for reflector and lens antennas excitation. Such antenna arrays have little bit lower values of efficiency on a comparison with the prototypes, namely, reflector antennas. These antennas allow realizing electronic scanning and they can be made conformal.

The microstrip technology is the most perspective one of their manufacturing. In this case RAA not only have minimum mass and dimensions, but also can be carried out, as a conformal arrays. It’s also possible to make the multiport network as a microstrip printed circuit and place it on the second layer in immediate proximity from the elements of the array. Array elements control system can be manufactured as the another printed circuit board arranged at the next layer. There may be other layer(s) with some auxiliary elements and circuits. Such RAA packaging are irreplaceable as onboard antenna systems.

In this report the focusing system constructions and mathematical model are considered. These systems allow realizing a focusing of antenna feed field by a microstrip reflectarray. The mathematical model is obtained by integral equation method. Besides microstrip reflectarray properties are investigated by waveguide simulation experimental method. Seven variants of focusing reflector are investigated in this report. The reflector antenna with a flat focusing system experimental model is designed. This antenna measured and calculated patterns are given.

2.Theory

2.1.The microstrip reflectarray construction

The microstrip reflectarrays can be used as a component of onboard radio engineering systems. Besides they can be used for stationary telecommunication systems, satellite television etc. Similar principal function of flat reflector is to ensure feed spherical or cylindrical wave transformation to a plane wave. To achieve this effect it is necessary to realize a feed electromagnetic wave phase correction. The phase correction is achieved by creation of an additional phase delay in radiators of antenna array. The phase delay magnitude should be increased from the marginal elements to central radiators. The usually required phase delay magnitude is determined by account, which based on the geometric optics method [1].

If the microstrip elements will be used as antenna array radiators, then it will allow solving the cheap flat reflector creation problem by the most convenient way. This way is based on a choice of radiator geometry and it's constructive sizes.

2.2.Mathematical model

Microstrip RAA being used as a focusing systems have a large number of re-radiating elements. So RAA mathematical model is founded on the concept of periodical structures. In this report the application of periodic microstrip antenna array for a construction flat reflector is considered. The geometry of the array unit cell is shown in Fig.1. The method based on an integral equation system solution was selected as an analysis method.

The numerical analysis results are scattering fields and reflection factor of the reflectarray. This model allows realizing a choice of reflectarray radiator parameters, basing on computing experiment results. The numerical analysis bases on the following initial parameters: radiator topology, substrate permittivity and permeability, and also sizes of an array unit cell.

3.Numerical results

First of all we research a possibility of a necessary phase delay realization with a reflection from a reflectarray of the non-loaded radiators. To solve the formulated problem, we shall change topology and sizes of the strip elements and to define a copolarization reflection factor phase. The principal problem of these numerical experiments is searching such variants, which ensure a necessary phase delay. Therefore calculations were carried out in a case, when the array-exciting plane wave incidents along normal direction. However, the flat reflector design requires, that the incidence wave angle variation should be taken into account. An each reflectarray radiator and its feed mutual location determine this angle. We research an application as a flat focusing reflector of several reflectarray types. One from other themes these arrays differ, what radiator types is used. First of all we research reflectarray, which radiators have the simple shape microstrip elements.

The microstrip vibrators have the simplest shape. We have carried out calculations and have measured such arrays reflection factors. The phase delays versus vibrators relative length relationships were defined after these researches. The calculation [1] and experimental results have allowed making a conclusion, that printed strip dipole arrays are suitable for a flat focusing reflector construction. The reflection factor phase variation velocity is greatest, when vibrator has resonant length. Besides in this case phase varies in significant limits. However, high phase characteristic steepness can reduce to the unstable numerical solution. Besides this circumstance complicates designing such reflector because of the high requirements to its performance accuracy. Eventually, in this case reflector bandwidth will be narrowest

The similar calculations in a case, when the microstrip radiators have the square shape are given in [2]. The phase delay variation range in this case also is rather great. Now we can achieve, that the relationship between phase delay and square element relative size was close to linear. Such relationship can be received only in that case, when the reflectarray dielectric substrate becomes rather thick. This case corresponds to the reduced Q-factor value of reflectarray microstrip resonator. The reflector design problem requires reaching the compromise between a steepness value and possible reflection factor phase variation range. This compromise is achieved by a choice of a substrate thickness, because in this case we can control the phase characteristic steepness.

We investigated a shape phase characteristic control possibility by additional reflectarray microstrip element complication. This complication is directed on introduction auxiliary frequency-dependent elements. The auxiliary elements change reflectarray resonance and frequency properties. Let such auxiliary element will be a tail. First of all we shall connect a tail to a microstrip vibrator. However, the numerical experiments have shown, that the vibrator supplied by one or several tails does not allow receiving required parameters.

The phase performance shape comes nearer to a desirable form in that case, when the tail is connected to the microstrip element, which has the rectangular or square shape [3]. The reflectarray phase characteristics are given in Fig.2. The reflectarray parameters are: $d_x = 11{,}7$ mm; $d_y = 16$ mm - steps of array; $a = 9{,}9$ mm; $b = 7{,}2$ mm - microstrip patch sizes. The ε of the substrate used is 2,2 , and its thickness is 1,6 mm. The microstrip line segment is a tail. This segment width is equal 0,9 mm. The tail connection place is the middle of that microstrip patch edge, which has the greater size. The free tail edge is left breaked. The relationship between the phase shift of the field re-radiated from an infinite reflectarray and the length of the connected tail is investigated. The solid line in Fig.1 presents this. It is shown, that in this case we manage to ensure reflection factor phase regulation over a wide range and to save a phase characteristic linearity. Besides the phase growth rate appears quite acceptable. Eventually such radiators practically do not change a crosspolarization level. Thus, they can be recommended for such focusing reflector construction, which will work on linear polarization.

It is known [4] that the flat reflector can be made as a printed ring reflectarray. We have executed the numerical analysis of such arrays phase characteristics. The relationship between the phase shift of the field re-radiated from an array and the excited plane wave incident angle was investigated. The numerical analysis has shown, that the reflection factor phase varies enough slowly and smoothly. Really, we shall consider a reflectarray, which is described in [4]. Let excited field has frequency 8,5 GHz. If the incident angle varies from 0 up to 45 degrees, then the phase shift variation will make less than 20 degrees.

The calculation results for a square shape microstrip loops reflectarray are given in [5]. The relationship between the phase shift of the field re-radiated from an infinite reflectarray and the microstrip loop radius was investigated. It is shown that in this case we can control reflection factor phase over a wide phase shifts range. The compromise between a phase characteristic steepness value and possible variation range of reflection factor phase is achieved by a choice of the reflectarray steps values. Besides the microstrip re-radiators shape allows to expand such reflectarrays application region. Really, the microstrip loop is a circular polarization re-radiator. Therefore, in this case a field phase correction is achieved as good as at linear or circular polarization.

4.Measurements

First of all we have selected the design of reflectarray which has the best relationship between a phase shift and parameters of a reflectarray radiator. This variant was applied for a flat reflector creation. The parabolic antenna is the prototype of such flat reflectarray. The way of feed wavefront correction is key feature of such antenna. This feature distinguishes our antenna from a parabolic antenna. The correction of wavefront in a parabolic antenna is carried out, due to the special profile of a reflector. The correction of wavefront in our reflectarray is carried out, due to a special choice of a radiator construction. The radiator of an array provides necessary phase shift value of a scattering wave. A flat reflector operating at 9.4 GHz has been designed and fabricated using the screen printing technique. It has 25-cm diameter and 0.46 F/D ratio. The substrate has 6-mm thickness and 2.05 permittivity. A backfire antenna was used as the feed. This antenna contains active vibrator and wire reflector. These two vibrators are excited by rectangular waveguide. The whole system is shown in Fig. 3.

The antenna was measured in the 3.2-cm wavelength. Fig. 4 shows E-plane radiation pattern of the antenna. The pattern has been shown by solid line. It is obtained by scattering field's superposition of single radiators. We have used the "element by element" technique. Also we have took to account relationship between current distribution into radiator and incident angle of its exciting plane wave.

5.Conclusion

The possible microstrip reflective array application area is extremely wide**:** radar, telemetry, communication systems, systems of the targets identification, ecological monitoring systems etc. However, per last years there is the very large interest of the developers to completely new direction, which is capable to join and even to integrate the listed above variants of RAA applications. That is so-called smart skins. Such structures have to integrate different functions of many devices and to solve a lot number of problems. In this report we have considered one of smart skin components designing at microwaves. It is the focusing systems based on microstrip reflectarrays. Computer simulation is made using mathematical model based on periodical structures theory and integral equation system solution. Some numerical results presented prove the possibility of RAA application as smart covers microwave modules. These researches can be used to develop antennas with optimum parameters.

References

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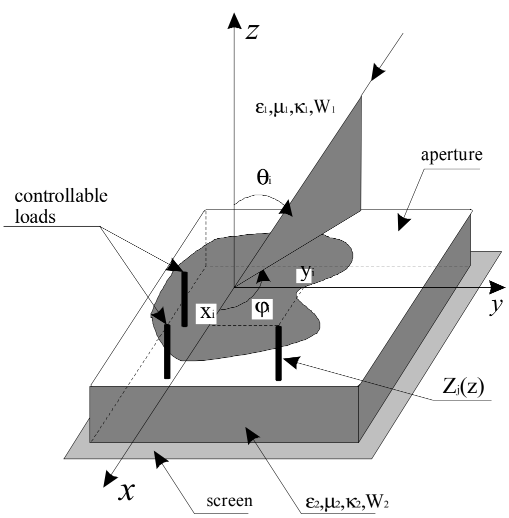

Fig.1

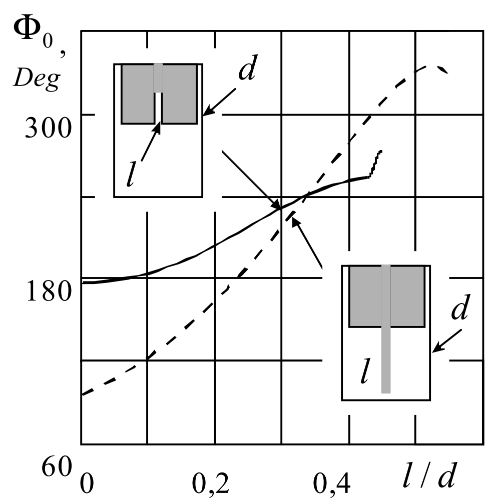

Fig. 2

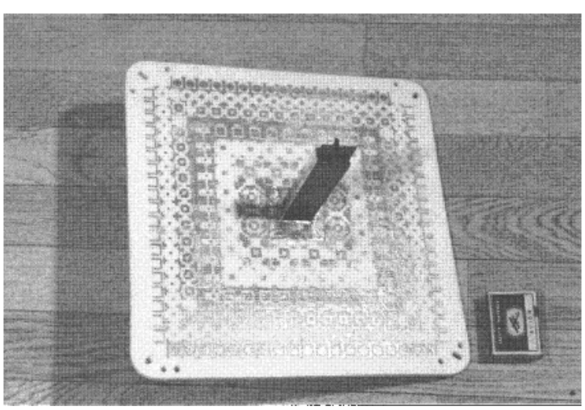

Fig.3

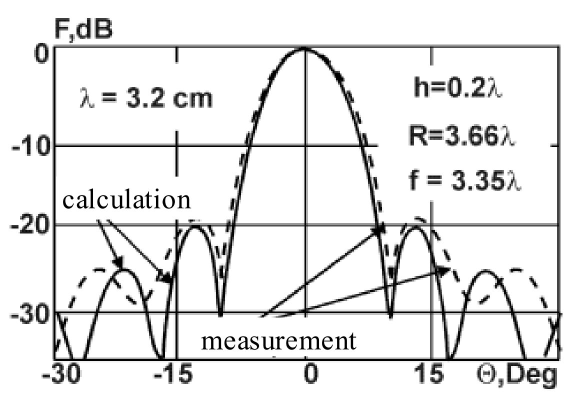

Fig. 4