International Conference on Antenna Theory and Techniques, 6-9 October, 2009, Lviv, Ukraine pp. 125-127

A DOUBLE-REFLECTOR ANTENNA OF MILLIMETER RANGE WITH WIDE-ANGLE SCANNING

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Abstract

It is described the results of numerical simulation and experimental investigation of a double-reflector antenna. The antenna is made according to a certain scheme and it consists of a parabolic reflector (transreflector) horn feed, flat convergent mirror (twistreflector) and a dielectric radome. The transreflector is a thin parabolic radome which has a system of thin wires applied on it. It reflects the waves of linear polarization. The twistreflector turns the plane of polarization around 90.

Keywords: Double-reflector antenna, transreflector, twistreflector, scanning, physical optics method, millimeter range.

1. PREAMBULE

Two reflector antennas with a planar subdish and a parabolic reflector are used to provide wide-angle scanning [1]. The reflector is a system of parallel wires which is deposited on a layer of dielectric, it is radio transparent for waves in which electric-field vector is perpendicular to the reflector wires. Such a reflector is called transreflector. Scanning is provided by swinging of the planar subdish (twistreflector), which also provides the plane polarization 90-degree turn of a wave reflected from it.

It is known that such an antenna allows to realize scanning in wide angle range almost without distortions. However, there are not enough detailed analysis of this antenna, the description of main lows and designing recommendations.

In the paper are described the results of numerical modeling and experimental investigation of the antenna. It is taken into consideration the dielectric layer, which the system of thin wires is deposited on, and also the additional protective radome. Numerical modeling have been done in a wide range of changing geometrics of antennas elements. The results of numerical modeling are compared with the results of the experimental investigation of an antenna sample which works in short-wave part of the millimeter range.

2. CONTENT

2.1. THE METHOD OF NUMERICAL ANALYSIS

In order to determine the field of the antenna, it have been used the method of physical optics together with Kirchhoff method.

- The field of a feed pyramidal horn, excited by dominant mode, is determined by Kirchhoff method. At the same time it have been considered the nonlinear phase distribution on the horn aperture depending on its depth.
- According to the field of the feed horn it have been found the distribution of the conduction current density on the transreflector surface and then its co- and cross-polarization field on the twistreflector surface.
- The surface current density distribution on the twistreflector was found by the physical optics method over the field on its surface and then it was determined co- and cross-polarization twistreflector field in an established space point.
- The presence of two dielectric layers was considered by multiplication of the twistreflector field by the coefficient of transmission through these two layers.
- It was calculated the far-field radiation pattern (RP) at the electric and magnetic plane, RP parameters and the gain of the antenna by the transreflector field.
- The mathematical model and the program realizing it allow to analyse the field distribution in any space zone at the sphere surface of desired radius, picture plane, along focal line,it also allow to focus the antenna to the assigned distance.

2.2. THE MAIN MODELLING RESUSLTS

The numerical simulation was done for the antennas which has the aperture diameter of the transrfletor is 10 λ_o at the frequency 10 GHz and 80 λ_o at the frequency 94 GHz (λ_o is the wave length in the air). The analysis of gained results allows to draw the next conclusions:

1. At a given transreflector diameter D_1 , there is an optimal twistreflector diameter D_2 equal to the diameter of transreflector D_1. The main lobe width and side lobe level decrease with increasing D_2, but dimensions of the antenna rise.

2. With increasing twistreflector plane angle of deviation from transreflector aperture plane, the main lobe width of the radiation pattern increases, side lobes rise a little, the atenna gain reduces. In Figure 1 for illustration, it is shown E-plane RP of the antenna with aperture reflectors diameters $D_1 = D_2 = 10\,\lambda_o$ for two scan angles θ_m=0º (full line) and 50º (dotted line).

The irradiation level of the transreflector edge with respect to the center is 0,3. In the Figure it is given the main lobe width value $2\theta_{0,5}$ and the maximum side lobes level Fbm .

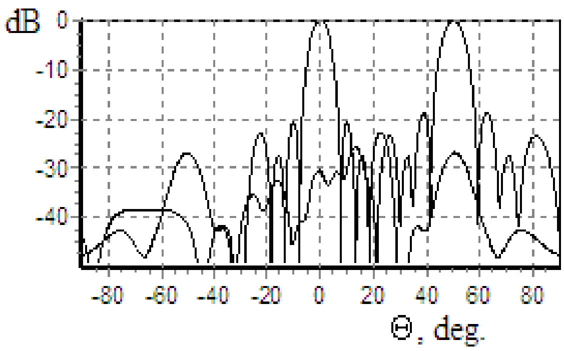

Fig. 1. Antenna RP for two scan angles.

When θ_m=0º: $2\theta_{0,5}$=6°; Fbm =-20,6 dB

When θ_m=50º: $2\theta_{0,5}$=6°; Fbm = -18.8 dB

3. The impact of two radomes appears at some reduction of far-out side lobes and the antenna gain. These effects depend on the radome wave width and they are minimal when the wave width is half-wavelength in the dielectic and when scan angle is 0º.

When the layers width is 0.25 wavelength in the dielectric the radome influence is minimal. This case is illustrated in Fig.2 where the radiation pattern of the same antenna is given with taking into consideration the radomes (line 1) and without (line2).The width of the radomes is $\Delta_1 = \Delta_2$ =0,25 wavelength in the dielectric λ, the width of air space between the rodomes is Δ_o=0,25 wavelength in air λ_o. In Figure 3 it is shown the dependence of reduction of the antenna ($D_1 = D_2 = 10\lambda$) gain because of reflections from radomes versus scan angle θ_m.The relative dielectric constant is ε=4 and dissipation factor is 0,0045. The width of dielectric layer is half-wavelength.

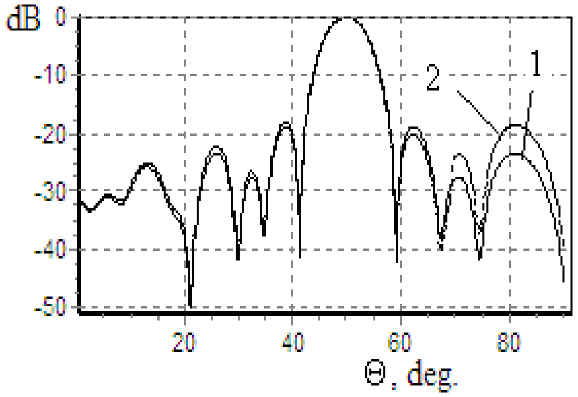

Fig. 2. Impact of the radomes to antenna RP when: $\Delta_1 = \Delta_2$ =0,25λ, Δ_o =0,25 λ_o .

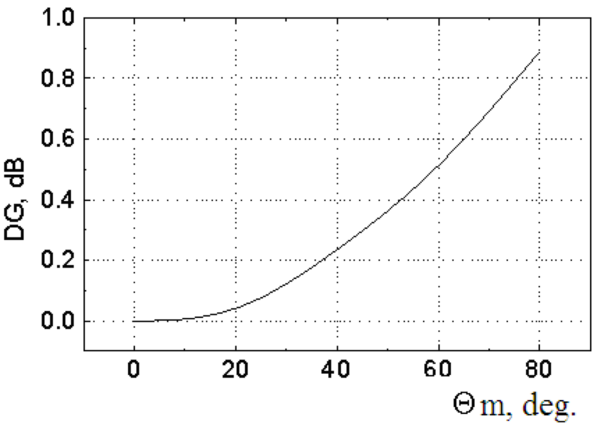

Fig. 3. Antenna gain reduction versus scan angle when: $\Delta_1 = \Delta_2$ =0,5λ, Δ_o =0,5 λ_o .

The maximum antenna gain reduction is observed when the radomes layers width is 0,25 λ. Figure 4 illustrates this case.

It have been investigated the impact of an accidental error of manufacturing transreflector shape on the antenna parameters. It have been approximately taken into account the impact of transreflector manufacturing error on phase distribution of the field in the transreflector aperture plane. It have been used the geometrical optics method. Transreflector and twistreflector reflect a wave on the way from the feed to the twistreflector aperture. If manufacturing shape error appears, ray length at this way changes on the value $DR = 2(DR_1 + DR_2)$, where DR_1 and DR_2 are the manufacturing shape errors of trans- and twistreflector, respectively. The phase during two ray reflections changes on the value $DF = 2\pi \cdot DR / \lambda_o$. During numerical modeling an accidental value DF have been set in the range $0 \ldots DF\max$ for M realizations. For every phase distribution realization have been calculated an radiation pattern and then it have been gained the average radiation pattern and its parameters: beam axis, main lobe width, the maximum side lobe (Fbm) and average side lobe level (Fs). The phase error value

DF max have been recalculated to the reflectors shape deviation value from rated shape with the assumption $DR = DR_1 = DR_2$.

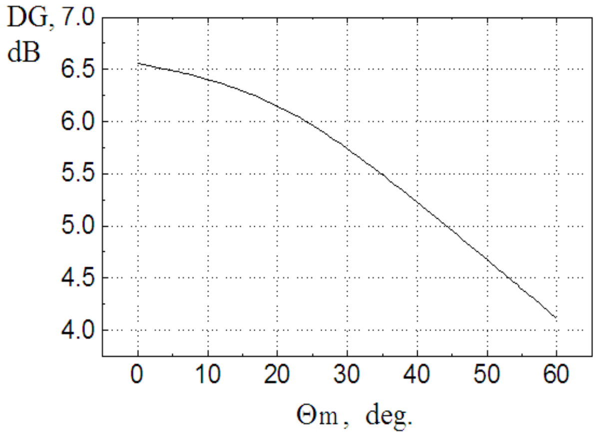

Fig. 4. Antenna gain reduction dependence from scan angle when: $\Delta_1 = \Delta_2$ =0,25λ, Δ_o =0,25 λo

In Figure 5 It is shown the dependence Fbm and Fs for the antenna with transreflector aperture 80 λ_o at the frequency 94GHz from the manufacturing reflectors shape error $DR = DR_1 = DR_2$.

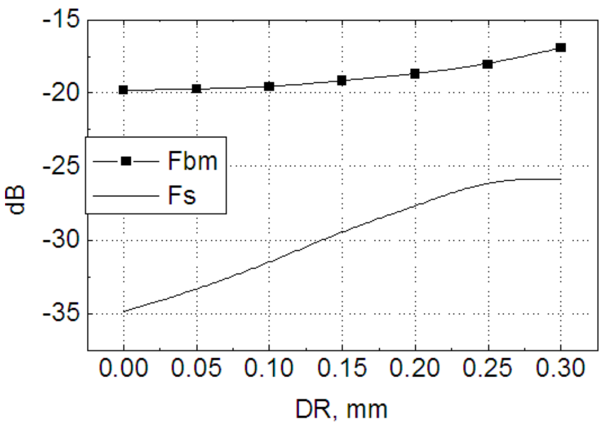

Fig. 5. Dependence sidelobes level Fbm and Fs from the manufacturing reflectors shape error

Averaging have been done using 20 radiation patterns.

Numerical modeling results have been compered with measurements results. The experimental model have been made at the working frequency 94 GHz, transreflector aperture diameter is 80 λ_o . In Figure 6 it is shown theoretical radiation pattern (line 1), calculated for accident manufacturing shape error is $DR_1 = DR_2$ mm and measured radiation pattern (line 2).

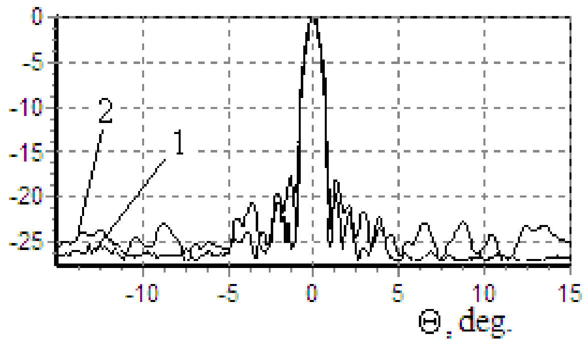

Fig. 6. Theoretica (line1) and measured (llin2) radiation patterns

3. Conclusion

It is described numerical analysis results of the characteristics and parameters of the two reflector antenna with a plane twistreflector providing wide angle scanning. The theoretical and experimental results have been given by physical optics and with usage a antenna model, made at the working frequency 94 GHz, respectively. It have been taken into account the two dielectric layers impact: the base for laying of the transreflector wires system and the protecting radome. It was investigated the dependence of antenna gain from scan angle (the turn of twistreflector). It have been shown that the level of side lobes, situated out of the angle sector equal 10 main lobe width, doesn't rank over -25 dB, if irradiation level of the transreflector edge is 0.3 compare with its center and manufacturing transreflector shape error is less than 0.1 wavelength. In this case the maximum side lobe is nearly -17… -18 dB.

When the width of dielectric layers is 0.5 wavelength, the antenna gain reduction is minimal and it doesn't exceed 1 dB in scan sector -80º…80º.

References

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