

# Modelling of Polarization Rotator of the Broadband Scanning Antenna Array

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**Abstract.** In the paper on the basis of the finite-element method an operation of broadband polarizer in an aperture of a scanning antenna array is analyzed in the frequency range 8 to 18 GHz. The effect of broadband four-grid 45° rotator of polarization on the characteristics of the linear array of parallel-plate waveguides (VSWR, gain, radiation pattern) in scan sector  $\pm 45^\circ$  in E-plane is evaluated.

## 1. Introduction

In antenna techniques various microwave polarizers of electromagnetic waves [1] are widely used. Antenna arrays with oblique polarization are applied in modern devices of radio technical monitoring of RF radiation sources. Broadband scanning arrays and multipath antenna arrays with oblique polarization can be realized on the basis of radiators with horizontal or vertical polarization. A turn of a polarization plane in subsequent can be carried out by means of polarization rotators (polarizers) located in an aperture of antenna array.

The multilayer UWB transmission polarizers [2-4] are most studied. They implement a rotation of the polarization of the electromagnetic wave transmitted over a wide frequency range and a large sector of angles of incidence. The designing of polarizers can be executed by means of rigorous methods [2], the CAD programs [5] and an approximate impedance method [6].

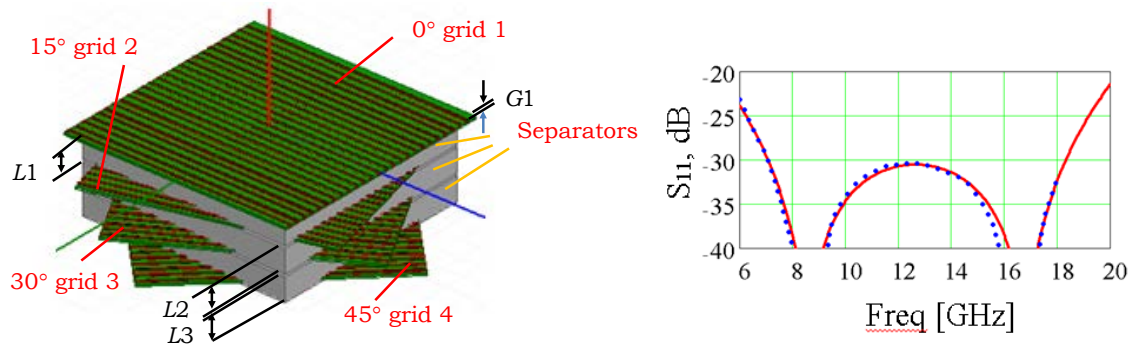
Properties of broadband polarizers on the basis of multistage dense wire grids with the changing slope angle of conductors from a grid to a grid are widely investigated for a case of normal incidence of plane wave on a polarizer.

The aim of this work is to analyze of operation of antenna array with the polarizer in the given sector of scanning of array and to find out an effect of a polarizer on characteristics of antenna array (in the form of the linear waveguide array) in this sector of angles.

## 2. The model of a polarization rotator

Let us analyze the polarizer operation in the given sector of scanning in frequency range 8 to 18 GHz. The model of the 45° polarization rotator has four grids (1 mm grid step) and three separator layers ( $\varepsilon = 1.02$ ). The thicknesses of separator layers ( $L1$ ,  $L2$ , and  $L3$ ) and grids ( $G1$ ,  $G2$ ,  $G3$ , and  $G4$ ) were variable parameters. The left part of figure 1 and table 1 show the design and dimensions of the polarizer as result of the optimization. The model is analyzed by means of the finite-element method (FEM) using HFSS. In a case of normal incidence the characteristics of a polarizer were calculated by an impedance method [6].





**Figure 1.** Model of four-grid polarizer (left) and its return losses (dot line – FEM; solid line – impedance method) (right).

**Table 1.** Final polarizer parameters.

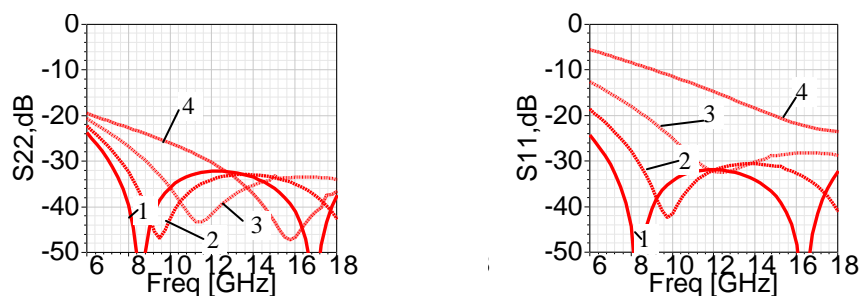
Parameter	$L1$	$L2$	$L3$	$G1$	$G2$	$G3$	$G4$
Dimension (mm)	5.8	5.8	5.8	0.1	0.1	0.1	0.1

The calculated frequency responses of return losses of the polarizer in a case of normal incidence and for an impedance method are shown (the right part of figure 1). It is visible that in frequency range 6 to 20 GHz the return loss entered by the polarizer less than minus 20 dB. To compare in the right part of figure 1 the dot line shows the return losses calculated for the same model of the polarizer by the finite-element method. Coincidence of the compared results received by two different methods confirms reliability of the developed model of the polarizer.

### 3. The analysis of angle characteristics of the polarizer when scanning

The angle characteristics of four-grid polarizer model were calculated with step of 250 MHz. The analysis showed that with increase of angle of incidence of electromagnetic wave in E-plane, the range of its operating frequencies is displaced in more high-frequency domain (the left part of figure 2). The level of the return loss remains low.

In the same sector of angles of incidence, but in H-plane, the shift of characteristic grows with increase of angles of incidence (up to 4.5 GHz for angle of incidence of 45°; the right part of figure 2). The level of the return loss with increase of angles of incidence until 60° in H-plane grows to 6 dB (at frequency of 6 GHz).



**Figure 2.** Return losses of the polarizer in E-plane (left) and H-plane (right) in a case of different angles of incidence: 1 - 0°, 2 - 30°, 3 - 45°, 4 - 60°.

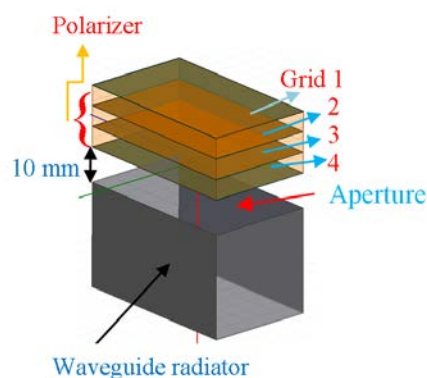
Therefore, the designing of a broadband polarizer to operate in a wide sector of scan angles, can consist of two stages. At the first stage the designing of the polarizer in a case of normal incidence is performed by means of an impedance method. Polarizer has to provide the given characteristics in the

more wide frequency range. The expansion of the range is carried out towards the lower frequencies. It equals to the shift of frequency response of the polarizer for the angle of incidence at on boundary of scanning sector. At the second stage, a design of a polarizer is optimized to operate in antenna array aperture in the given sector of scan angles.

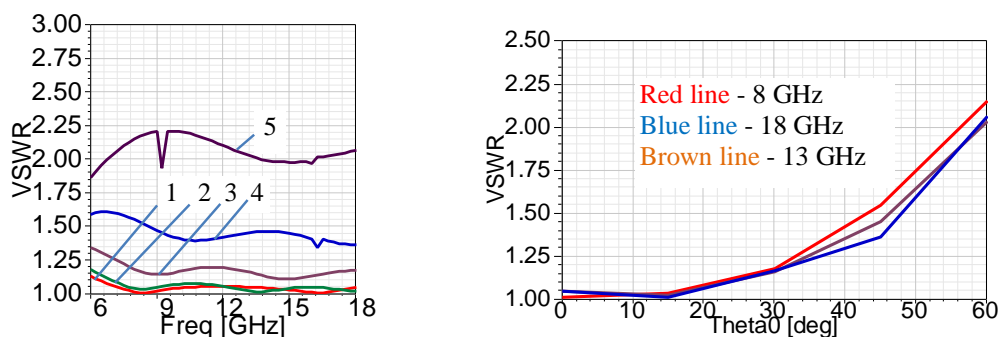
#### 4. The analysis of antenna array characteristics with the polarizer in the aperture

Effect of the polarizer on array characteristics (VSWR, gain, radiation pattern) is calculated by FEM in the given sector of scan angles. The model of the antenna array consists from linear array of 50 parallel-plate waveguides with the sizes of total aperture of  $250 \text{ mm} \times 50 \text{ mm}$ . The waveguide aperture size in E-plane was 5 mm; in H-plane – 50 mm. The four-grid model of the  $45^\circ$  rotator of polarization (described above) is optimized for operation in frequency range 8 to 18 GHz in scanning sector  $\pm 45^\circ$ . Polarizer is placed in front of apertures of waveguides on distance of 10 mm. In figure 3 the antenna array unit cell with the polarizer in an aperture is shown.

Calculations were carried out at frequency of 18 GHz with step of 250 MHz; its precision after 6th steps, when the construction was divided on 4574 tetrahedra, was 0.0007. The VSWR versus frequency for the array with the polarizer in the aperture in a case of different angles of scanning were presented in the left part of figure 4. The VSWR versus angle of on an input of radiators (as a part of antenna array) for scanning in E-plane of waveguide at frequencies 8 GHz, 13 GHz and 18 GHz are given in the right part of figure 4.



**Figure 3.** Antenna array unit cell with the polarizer in the aperture.

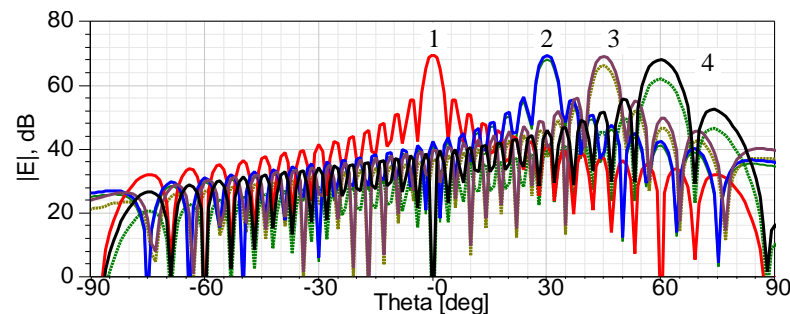


**Figure 4.** VSWR frequency dependences of the array with the polarizer in the aperture in a case of different angles of scanning: 1 -  $0^\circ$ , 2 -  $15^\circ$ , 3 -  $30^\circ$ , 4 -  $45^\circ$ , 5 -  $60^\circ$  (left) and VSWR angular dependences when scanning in E-plane (right).

The calculations show that in E-plane in the sector of scan angles of  $\pm 45^\circ$  the VSWR on an input of antenna array with the polarizer in the aperture remains not higher than 1.56; VSWR increases to 2.12 in the sector of scan angles of  $\pm 60^\circ$ . On boundary of the sector of scanning of  $45^\circ$  lowering of antenna array gain about 1.5 dB and increase of the main-lobe beamwidth (figure 5) are watched.

Patterns for orthogonal components of far field of the antenna arrays with the polarizer are provided in a case of different scan angles of  $0^\circ$ ,  $30^\circ$ ,  $45^\circ$  and  $60^\circ$  in E-plane of waveguides at the upper frequency of operating range (figure 5). It is visible that the difference between magnitudes of two orthogonal components of far field of the antenna array grows with increase of the scan angle. For example, it equals about of 3 dB for scan angle of  $45^\circ$ . Therefore the slope angle of E-vector of far field changes with increase of the scan angle.

Also the patterns for far field ellipticity were calculated in a case of the same scan angles. The polarization remains the almost linear in the sector of scan angles up to  $60^\circ$  with ellipticity not worse than 40 dB.



**Figure 5.** Patterns on orthogonal line polarizations (vertical polarization – solid lines; horizontal polarization – dash lines) at the upper operating frequency in the plane of scanning in a case of different scan angles: 1 -  $0^\circ$ , 2 -  $30^\circ$ , 3 -  $45^\circ$ , 4 -  $60^\circ$ .

## 5. Conclusion

In the paper we have investigated the operation of broadband polarizer in the aperture of antenna array is analyzed. The effect of the polarizer on the characteristics of the linear array of parallel-plate waveguides in scan sector  $\pm 45^\circ$  in E-plane has been evaluated. Expected VSWR of the element of phased array with the polarizer is less than 1.6 in the frequency range 8...18 GHz. The gain decrease of antenna array about 1.5 dB as well as the increase of the main-lobe beamwidth and the difference between magnitudes of orthogonal components of the far field about 3 dB on boundary of scan sector  $45^\circ$  are watched.

## Acknowledgement

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