A SIMPLE FOUR-BEAM SCANNABLE REFLECTARRAY ANTENNA

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EXTENDED ABSTRACT

A Cassegrain type reflectarray antenna is presented which, by using dual polarization features and rotating its planar reflector, scans into four directions. To this extent, the reflectarray with a feed on its center axis is designed in such a way that it has a beam slightly tilted with respect to broadside in one polarization, and another beam with a greater tilting angle in the respective other polarization. If the reflector now is rotated by 90° (while the feed is kept fixed), the reflector is illuminated with the same polarization with respect to space, but the resulting beam is determined by the reflecting elements rotated by 90°. Consequently, the second characteristic with increases tilting angel occurs. Rotation by another 90° brings back the original orientation, but with the beam to the opposite direction. The same happens for another rotation by 90°, this time with the beam with greater tilting angle at the opposite side. Consequently, each 90° of rotation results in different (symmetric) beams.
A prototype antenna of 100 mm diameter was fabricated and tested at 58 GHz, adjusted for beams at ±3° and ±9° with beamwidths of 3.5° and 3.7° in E- and H-plane, respectively. Sidelobe level is better than -15 dB. With an improved version of the subreflector, a gain of 32 dB could be achieved at 58 GHz.

A SIMPLE FOUR-BEAM SCANNING REFLECTARRAY ANTENNA

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Abstract

A Cassegrain type reflectarray antenna is presented which, by using dual polarization features and rotating its planar reflector, scans into four directions. A prototype antenna of 100 mm diameter was fabricated and tested at 58 GHz, adjusted for beams at ±3° and ±9° with beamwidths of 3.5° and 3.7° in E- and H-plane, respectively.

Introduction

Planar reflectarrays [1-3] have proven as an alternative for standard reflector or lens antennas, especially in the mm-wave frequency range. In addition, folded versions of such antennas [4, 5] have been developed, too, providing very compact antenna arrangements. For some applications, beam scanning is required to switch between different users in a communication network or different directions of a radar sensor. One solution to this task is a multibeam antenna where different beams, each associated to a separate feed, can be switched to the front-end [6]. Alternatively, a (planar) reflector may be tilted for beam scanning, as presented in [7]. It would, however, be much more convenient if a simple rotation could be used for scanning, as it will be demonstrated in this contribution.

Design of the scanning antenna

For the reflectarray described in this contribution, the reflection phase angle for a plane wave incident on a periodic structure of printed patches or dipoles on a dielectric substrate with backside metallization is adjusted by the geometry of the patches. The phase angle mainly depends on patch length (Fig. 1). The same structure, however, can be used for the orthogonal polarization with different adjustment of phases, thus different beams, beam shapes, or beam directions can be adjusted with the same or a different feed position. Some results for such antennas have been presented in [4]. Now, a planar reflectarray with a feed on its center axis is designed in such a way, that it has a beam slightly tilted with respect to broadside in one polarization, and another beam with a greater tilting

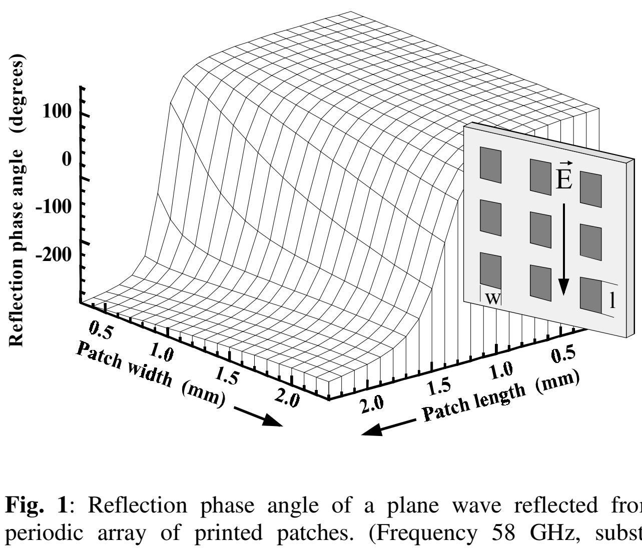

Fig. 1: Reflection phase angle of a plane wave reflected from a periodic array of printed patches. (Frequency 58 GHz, substrate thickness 0.254 mm, dielectric constant 2.22, patch spacing 2.4 mm, normal incidence of the wave).

angle in the respective other polarization. If the reflector now is rotated by 90° around its center, while the feed is kept fixed, the reflector is illuminated with the same polarization with respect to space, but the resulting beam is determined by the reflecting elements rotated by 90°. Consequently, the second characteristic with increases tilting angel occurs. Rotation by another 90° brings back the original orientation, but with the beam to the opposite direction. The same happens for another rotation by 90°, this time with the beam with greater tilting angle at the opposite side. Consequently, each 90° of rotation results in different (symmetric) beams.

To achieve a more compact setup and to place the feed behind the antenna arrangement, a Cassegrain antenna arrangement as shown in Fig. 2 was selected. A second substrate of half-wavelength thickness was used to fix the subreflector, thus there is at least no aperture blocking by any supporting struts. To make the principle of this antenna clearer, two typical rays for two positions of the reflector are indicated, each ray for one polarization. A rotation by 180° for each position brings the rays to the opposite side.

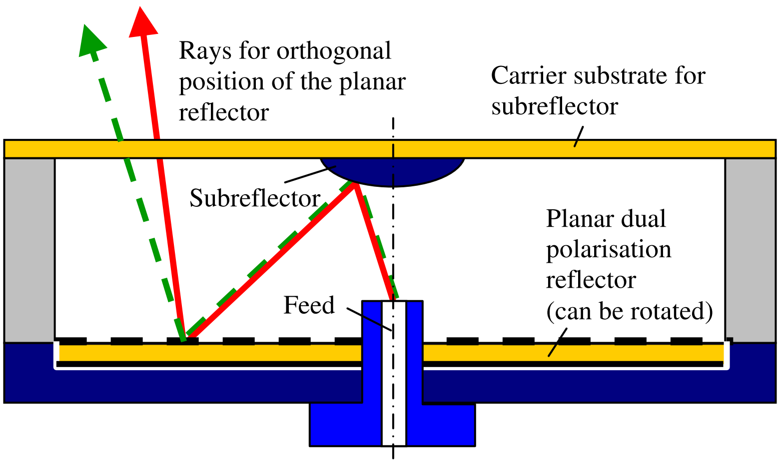

Fig. 2: Principle cross section of the scanning antenna and two typical rays.

Results

A test antenna with a diameter of 100 mm, a distance of 34 mm between the two substrates (Fig. 2) was designed for a frequency of 58 GHz. The reflector substrate and the top substrate are Duroid substrates with 0.254 mm and 1.59 mm thickness, respectively, and a dielectric constant of 2.2. The beams were designed to be at ±3° and ±9° in the H-plane. A photograph of the planar reflector and the feed of the antenna is shown in Fig. 3. According to the two tilted beams, an asymmetric pattern of the reflector elements can be recognized. The antenna was built and tested. Fig. 4 shows the antenna radiation diagrams in the scanned H-plane. Four beams with a beamwidth of about 3.7° are shown. Amplitude was normalized to the respective maximum value of each lobe. Due to the aperture blocking by the subreflector, an increased sidelobe level of about -15 dB results. Bandwidth is at least 4 GHz with slightly increased sidelobe level at

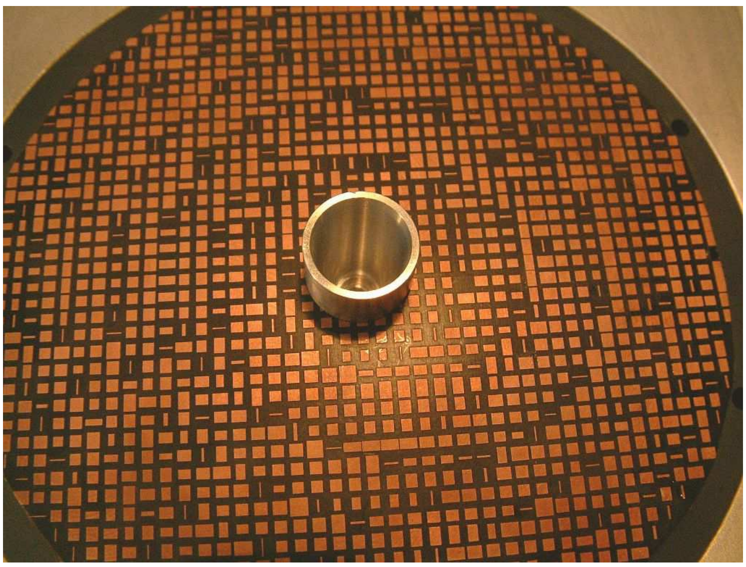

Fig. 3: Photograph of planar reflector and feed of the antenna.

the upper frequency limit. Fig. 5 finally shows the E-plane radiation diagrams of the four beams, each measured in the respective maximum of the beam. A beamwidth of about 3.5° can me stated in this plane, and sidelobe level is similar to the other plane.

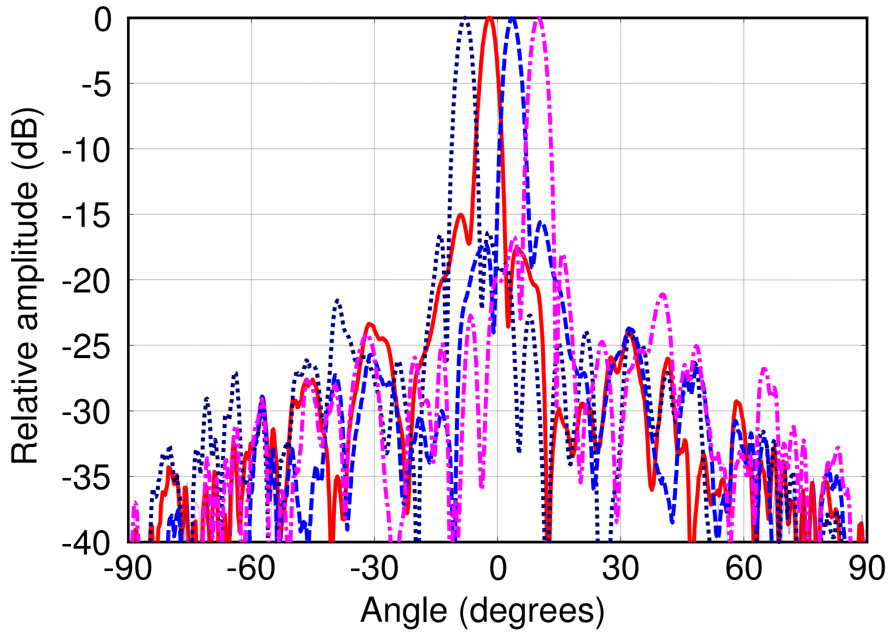

Fig. 4: H-plane radiation diagrams of the antenna for the four different positions.

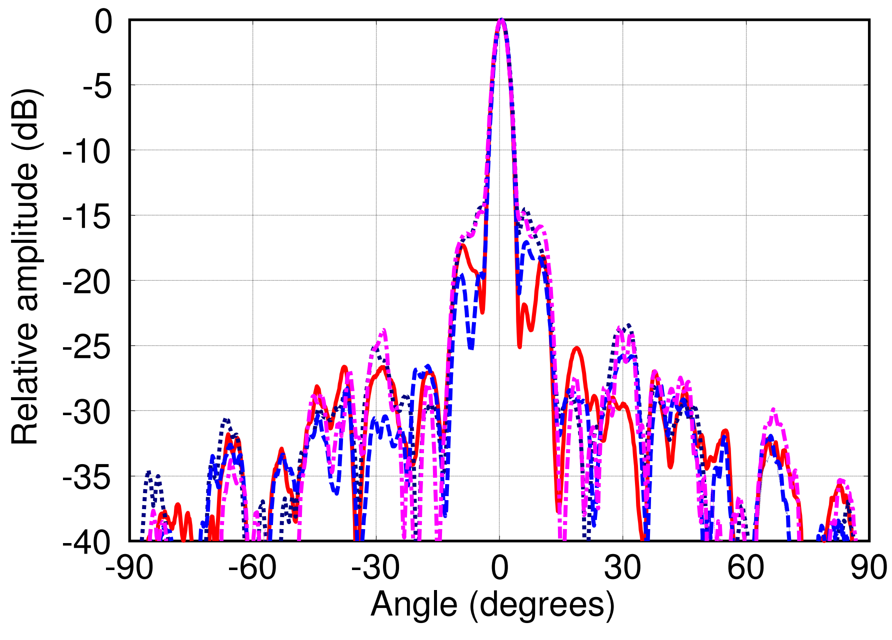

Fig. 5: E-plane radiation diagrams of the antenna for the four different positions (measured in the respective maximum).

To reduce the effect of power loss due to aperture blocking, the hyperbolic subreflector was replaced by a cone of similar dimensions. While the radiations diagrams hardly changed, gain could be increased in this way from 30 dB to 32 dB.

Conclusion

Making advantage of the double polarization properties, a scanning reflectarray antenna was designed. Scanning is performed by rotating the planar reflectarray, thus the different reflector properties for the two polarizations become effective alternatively with 90° rotational angles. A test antenna was built at 58 GHz, proving the feasibility of the proposed approach. Symmetric beam positions can be adjusted freely at arbitrary angles. With the selection of a broadside beam for one polarization, a three beam scanning antenna results where the central beam is active twice with each rotation.

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