PRINTED MM-WAVE FOLDED REFLECTOR ANTENNAS WITH HIGH GAIN, LOW LOSS, AND LOW PROFILE

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Introduction

Antennas with low profile, low loss and low production cost are of increasing importance for communication and sensor applications. While planar antennas are optimal with respect to antenna depth and cost, they suffer from high losses, especially for narrow beamwidth. Arrays of horn antennas with a waveguide feed network or waveguide slotted arrays are lower in loss, but partly complicated in their design, and they do not readily lend themselves to low cost fabrication. As an alternative solution for printed low-cost antennas, this contribution describes quasi-optically fed printed and folded reflector antennas, i.e. printed reflector type antennas consisting of arrays of printed patches or dipoles acting as fixed reflection phase shifters and a printed polarization diplexer, e.g. a printed grid or slot array.

The basis for the design of the planar reflector is a periodic array of dipoles printed on a dielectric substrate with backside metallisation. With a plane wave incident from broadside, the complete power is reflected, the phase angle, however, depends on dipole length and, to a minor degree only, on dipole width (Fig. 1). The reflection behavior of this arrangement is calculated using a spectral domain code [1]. The phase angle varies over nearly 360°, thus such elements can be used as phase shifters. These phase angles calculated from a periodic structure even can be used for the design of planar reflector antennas with dipoles on a periodic grid, but different dimensions [2], [3].

Making use of an independent choice of lengths and widths of the printed dipoles, different properties for the two polarizations, i.e. dual function or dual frequency antennas can be realized, and the focussing array can be modified to include a polarization twisting of the electromagnetic field, leading, together with a printed polarizing grid or a slot array to folded reflector [4].

Basic principle and design of the folded reflector antennas

The principal function of a printed and folded reflector antenna is indicated in Fig. 2. The radiation of the feed is reflected by a printed grid or slot array at the front of the antenna. Then the wave is incident on the printed reflector. The dipole axes are tilted by 45° with respect to the incident electric field. The dimensions of the dipoles are designed in such a way that, on the one hand, a phase difference of 180° occurs between the two components of the reflected wave – giving the twisting performance. On the other hand, an overall phase shift is adjusted according to the focussing (phase shifting) requirements. The outgoing plane wave then can pass the grid or slot array. The original design of this antenna once again is done on the basis of *periodic* structures. For varying dipole dimensions, the reflection phase angles are calculated for both principal polarizations. The optimum combination of phases then is selected from this set of data according to both twisting and focussing requirements.

Results

A number of antennas of this type have been designed, fabricated, and tested. Fig. 3 displays the layout of Ka-band antenna with square aperture (dimensions 254 by 274 mm, distance between reflector and polarizer 55 mm) and the photograph of the printed reflector of a V-band

antenna with circular aperture (diameter 100 mm, distance between reflector and polarizer 25 mm). These two antennas were designed at typical frequencies for point-to-point communication applications (28.5 and 60 GHz). The reflectarray and the polarizing grid of the Ka-band antenna are printed on 0.5 mm and 3.2 mm thick Duroid substrates. As feed element, a circular waveguide horn is used, but a printed structure may be used equally. The radiation diagram of this antenna at 28.5 GHz in both planes is given in Fig. 4 (left side), showing beamwidths of 2.4° and 2.7°, and sidelobe levels in the 20 to 25 dB range. This antenna was intended to be used for a bandwidth of 2 GHz (7 %), the E-plane radiation diagrams are shown for frequencies of 27.5 and 29.5 GHz in Fig. 4, right side. They still provide a very good performance at the band edges.

In Fig. 5 (left side), E- and H-plane radiation diagrams are plotted for the V-band antenna at a frequency of 58.4 GHz. As the antenna area was not completely illuminated (amplitude taper of 15 dB at the edges), beamwidth was 3.6° only. The gain of this antenna was measured to 33 dB, very close to the theoretical value calculated from the beamwidth. Radiation diagrams at different frequencies are given in Fig. 5 (right side), showing a good performance. It can be assumed that this antenna does work below 58.4 GHz as well; this however, was not yet tested.

In addition, in [5] a 77 GHz antenna is reported for automotive applications. By tilting the reflector plate, some beam scanning is possible. If the polarizing grid or slot array is replaced by the circular polarizer as described in [6], even circular polarization can be achieved with this type of antenna.

First results for a full wave calculation of the antennas

For non-folded printed reflector antennas, some effort was made to provide a full wave computation of their radiation diagrams [7], [8]. This technique now was applied, as a first test, to the new type of folded reflector antenna. To this end, the polarizing grid was not included – resulting in an equivalent non-folded antenna with a focal length twice the distance between reflector and grid. Furthermore, two calculations were done for the two polarizations, and the results were superimposed. Fig. 6 shows a comparison of theory (identical diagram for both polarizations) and measured E-plane radiation. Close to the main beam, a good agreement can be seen. For larger angles, etching tolerances, on the one hand, and other influences not included in the theory, like finite substrate size, missing influence of the grid etc., on the other hand, lead to larger deviations.

Conclusion

The application of printed quasi-periodic structures to the design of printed folded reflector antennas has been demonstrated. To this end, use is made of the dual polarization properties of the printed structures. Results of two antennas were presented. The folded reflector antennas show very good radiation characteristics, low losses and a comparably low height. Consisting of two printed substrates only, they can be a promising alternative to conventional printed or slotted waveguide array antennas.

References

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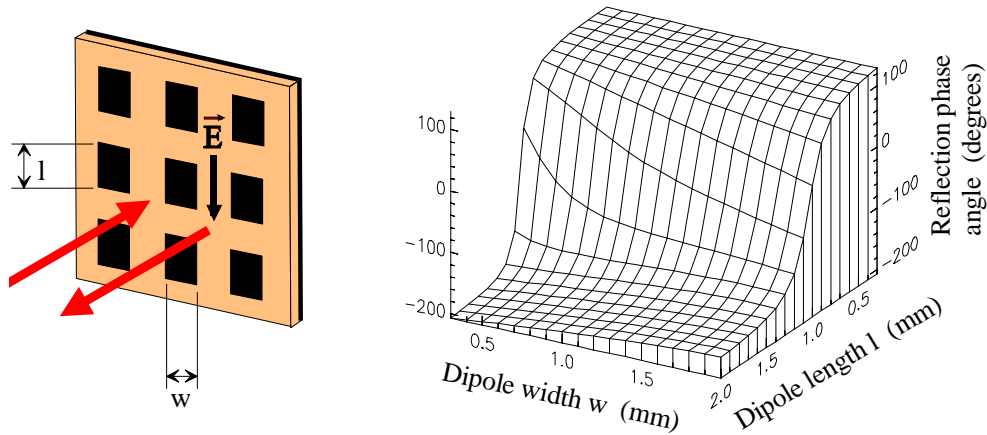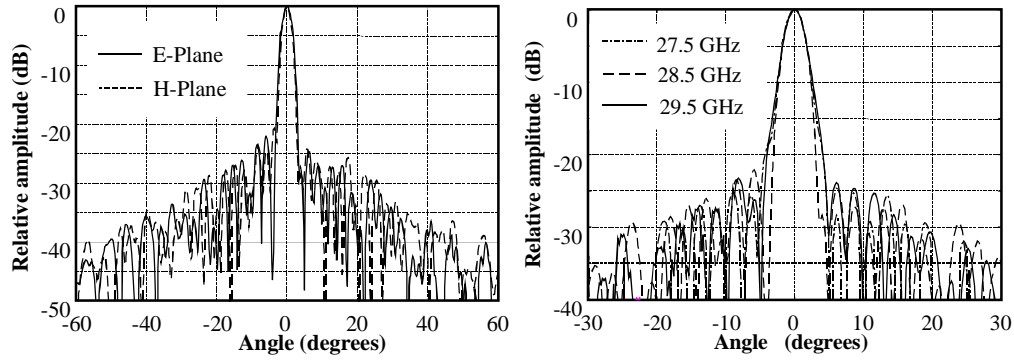
Fig. 1: Periodic array of dipoles and reflection phase angle as a function of dipole geometry (Substrate thickness 0.254 mm, dielectric constant 2.22, dipole distances 2.2 mm × 2.2 mm, f = 76.5 GHz).
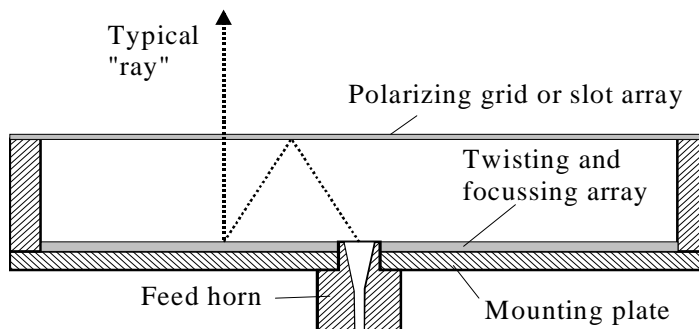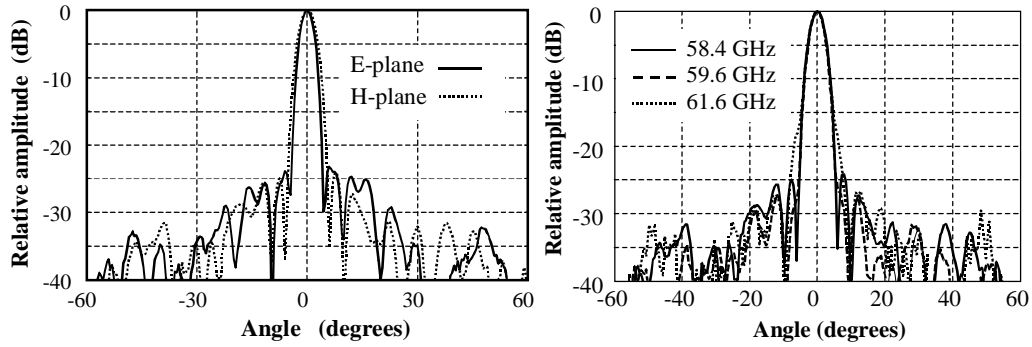

**Fig. 2:** Basic principle of the folded reflector antenna.
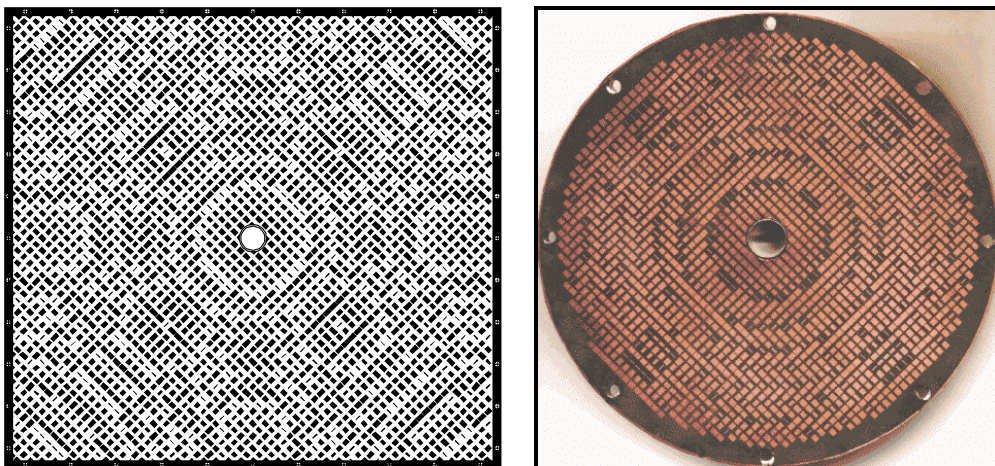
Fig. 3: Layout of a Ka-band and photo of a V-band reflectarray for folded reflector antennas.

Fig. 4: Radiation diagrams of the Ka-band folded reflector antenna.
(Left side: E- and H-plane at 28.5 GHz. Right side: E-plane at 27.5, 28.5, and 29.5 GHz).

Fig. 5: Radiation diagrams of the V-band folded reflector antenna.
(Left side: E- and H-plane at 58.4 GHz. Right side: H-plane at 58.4, 59.6, and 61.6 GHz.
Reflectarray and grid: Duroid material of 0.254 mm and 1.58 mm thickness, respectively).
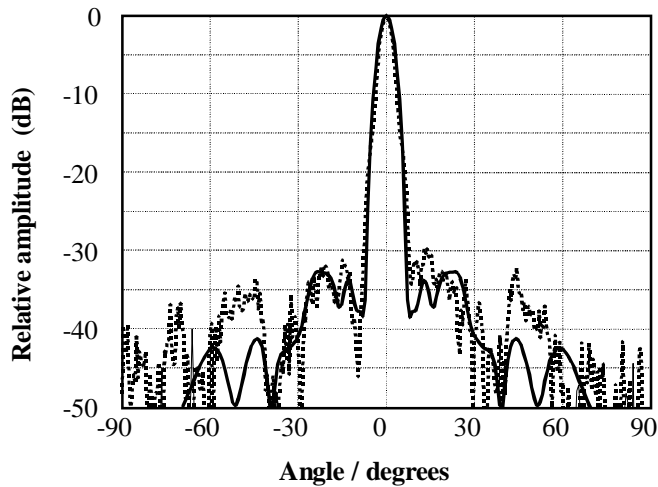
Fig. 5: Radiation diagrams of the V-band folded reflector antenna at 61.2 GHz.
(Solid line: theory, dotted line: measurement E-plane).