PRINTED QUASI-OPTICAL MM-WAVE ANTENNAS

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INTRODUCTION

For communication and sensor applications, antennas with low profile, low loss and low production cost are required. While planar antennas are optimal with respect to antenna depth and cost, they suffer from high losses, especially for narrow beamwidth [1], [2]. Arrays of horn antennas with a waveguide feed network [3] or waveguide slotted arrays [4], [5] are lower in loss, but partly complicated in their design, and they do not readily lend themselves to low cost fabrication. Recently, some work has been reported on the fabrication of waveguide networks and antennas using plastic injection molding and electroplating [6]. As an alternative solution for printed low-cost antennas, this contribution describes quasi-optically fed printed antennas, i.e. printed reflector type antennas consisting of arrays of printed patches or dipoles acting as fixed reflection phase shifters.

The basis for the design of such antennas is a periodic array of dipoles printed on a dielectric substrate with backside metallization. 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 [7]. The phase angle varies over nearly 360°, thus such elements can be used as phase shifters. As it was realized during this work, these phase angles calculated from a periodic structure can be used for the design of antennas with dipoles on a periodic grid, but different dimensions [8], [9].

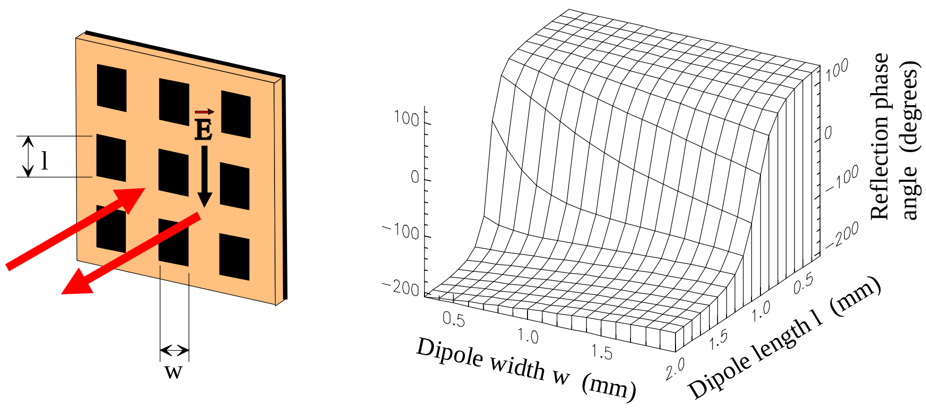

Fig. 1: Periodic array of dipoles and reflection phase angle as a function of dipole geometry
(substrate thickness 0.254 mm, dielectric constant 2.22, dipole distances 2.2 mm × 2.2 mm, f = 76.5 GHz)

PRINTED OFFSET-FED REFLECTOR ANTENNA

Based on earlier work [8], an offset-fed printed reflector antenna was designed, fabricated and tested (Fig. 2). For each dipole, its length was chosen to give a plane front of the reflected wave. In parallel, a spectral domain calculation [10], [11] was done for the complete antenna in order to check the simple design approach and to enable an optimization of the antenna. Theoretical and experimental radiation diagrams for H- and E-plane are plotted in Fig. 3. Up to 15°, the agreement is excellent; for larger angles, effects like the finite substrate size not included in the calculations or direct feed radiation lead to some deviations.

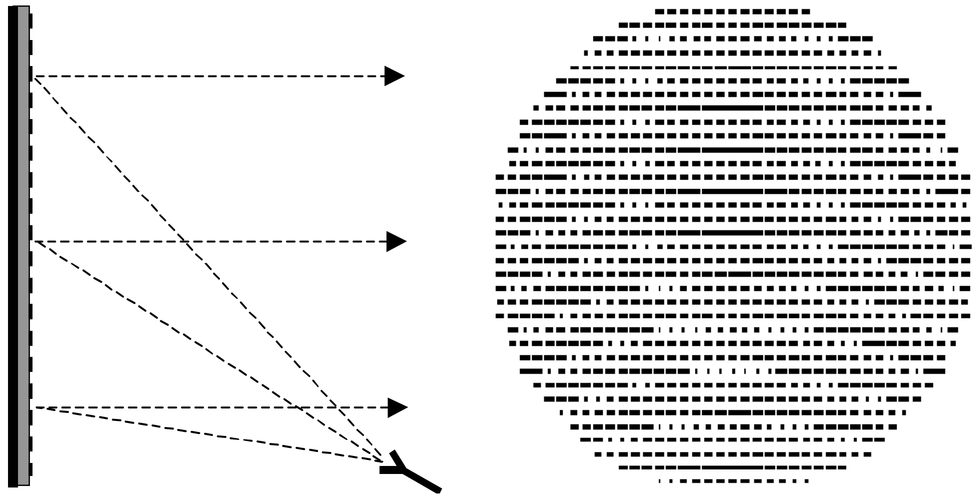

Fig. 2: General principle and layout of the offset-fed printed reflector antenna.

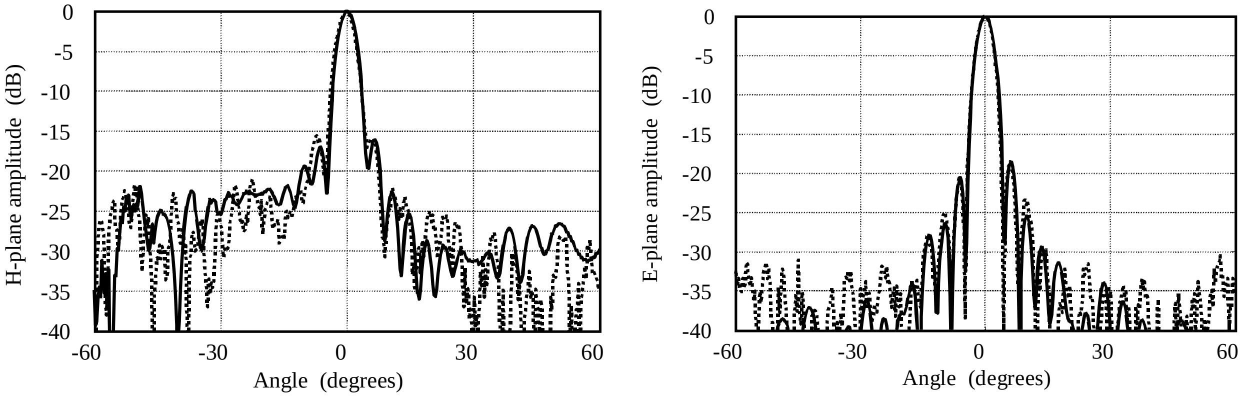

Fig. 3: H- and E-plane radiation diagram for the offset-fed printed reflector antenna (substrate thickness 0.76 mm, dielectric constant 2.5, frequency 24 GHz).

DUAL FUNCTION PRINTED REFLECTOR ANTENNAS

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. As an extreme test for this, a dual frequency antenna for 24 and 60 GHz was designed. To maintain, on the one hand, the full reflection angle range for 24 GHz which requires a maximum dipole length of $\lambda/2$ (including the effect of the dielectric), and on the other hand, to avoid grating lobes at 60 GHz, a substrate with a dielectric constant of 6 had to be chosen. The overall reflector with a diameter of 150 mm included about 5000 dipoles. Part of the reflector dipole structure is shown on the left side of Fig. 4, the azimuth radiation diagram at the two frequencies on the right side .

FOLDED REFLECTOR ANTENNAS

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 [12]. The principal function of this antenna is indicated in Fig. 5. 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. If the polarizing grid or slot array is replaced by the circular polarizer as described in [13], even circular polarization can be achieved with this type of antenna. A photograph of the twisting and focussing array of a 60 GHz antenna is shown in Fig. 5 on the right side. In Fig. 6, radiation diagrams of two different antennas are plotted for 28.5 and 58.4 GHz, typical frequencies for point-to-point communication applications. The 28.5 GHz antenna has a rectangular shape of 260 mm × 280 mm, a height of 55 mm, and beamwidths of 2.4° and 2.3°, while the V-band antenna has a round aperture with a diameter of 100 mm and a height of 25 mm. As this antenna area was not completely illuminated, 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. In addition, in [14] a 77 GHz antenna is reported for automotive applications. Tilting the reflector plate, even some beam scanning is possible.

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. As examples, an offset-fed and a dual frequency printed reflector antenna as well as folded reflector antennas for different applications have been 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.

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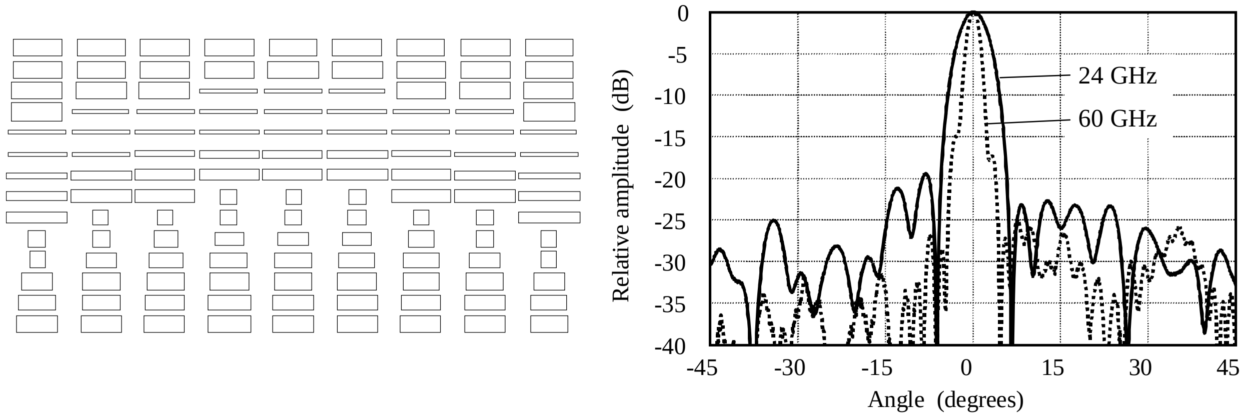

Fig. 8: Small section of the reflector layout and radiation diagrams of dual frequency printed reflector antenna. (Substrate thickness 0.635 mm, dielectric constant 6).

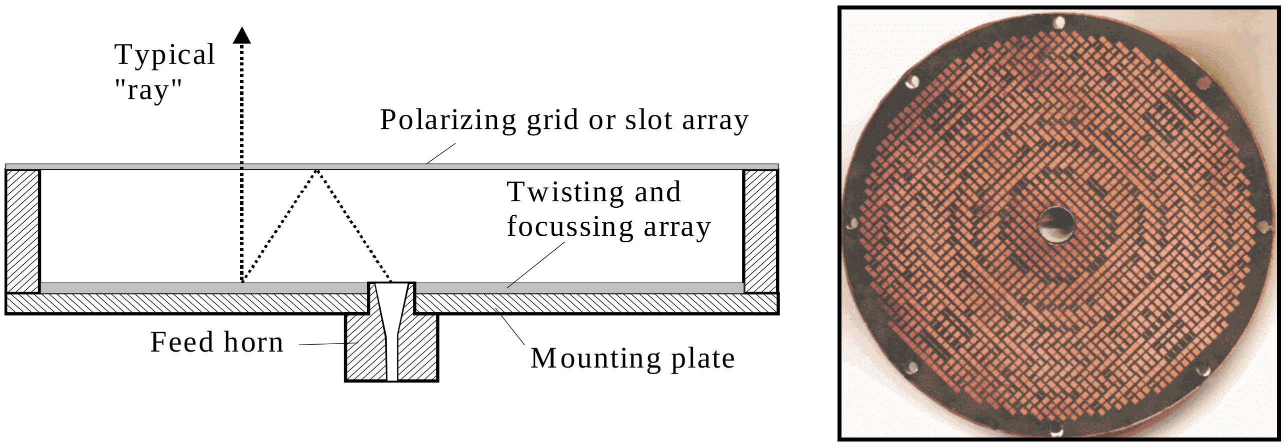

Fig. 5: Basic principle of the folded reflector antenna and photograph of the focussing and twisting reflector for a 60 GHz antenna.

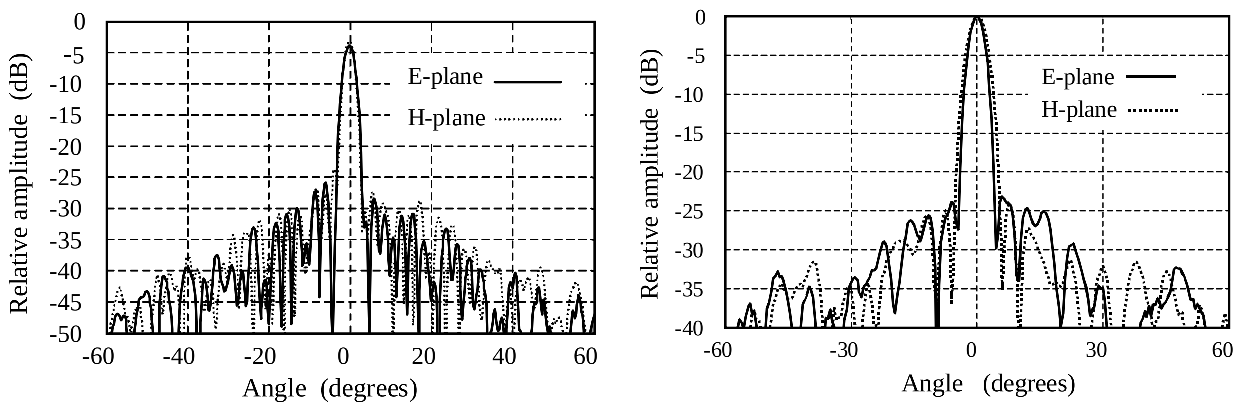

Fig. 11: Radiation diagrams of a 28.5 GHz (left side) and a 58.4 GHz (right side) folded reflector antenna. (Reflector substrates: 28.5 GHz: h = 0.5 mm, ε_r = 2.33; 58.4 GHz: h = 0.254 mm, ε_r = 2.22).