A FOUR-ELEMENT MICROSTRIP PATCH ANTENNA ARRAY WITH COMPACT FEED STRUCTURE

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ABSTRACT

A modified feed structure for a microstrip patch antenna is used to realize a four-element patch array. The two by two array consists of two of the elements fed by a standard inset microstrip feed line, while the other two elements are fed by an inset feed line extended beyond the center of the patches. In this way, again an impedance match for the single elements can be achieved, combined with a 180° phase shift in the excitation of these patches compared to the standard excitation. As a consequence, the feeding network can be concentrated to the space within the patches; resulting in reduced feed line lengths and reduced overall circuit size. Applications are compact feeds for reflector or lens antennas or building blocks for larger microstrip array antennas. An 8 by 8 element array at 10 GHz is demonstrated as an example.

INTRODUCTION

Impedance matching for directly fed microstrip patches can be achieved in different ways; one solution is an inset feed as shown in Fig. 1a (e.g. /1/). Typically, a single patch gives a beamwidth much too wide, combined with a low gain. For applications as planar feed element for reflector or lens antennas, a four element configuration can provide a suitable radiation characteristics. For proper phase adjustment of the single patches, these normally have to be fed from the same side (Fig. 1b), or two of the lines must include half-wavelength delay lines. Anyway, this results in increased feed line length with increased losses and increased overall size of the feed structure. With reflector or lens antennas, this causes increased aperture blocking, and for larger array antennas, a closer feed line spacing with increased coupling may occur.

MODIFIED FOUR ELEMENT ARRAY

To achieve a feeding of array elements with 180° phase difference, the inset of the feed line was increased beyond the center of the patch, as indicated in Fig. 2a. By a proper adjustment of the inset depth, both an impedance match and a 180° phase reversal is possible. To include the influence of the modified patch geometry and the increased coupling of patch and feed line, a full wave design procedure was used, /2/. As a first test structure, a two element antenna (Fig. 2b) was investigated. The theoretical return loss including mutual coupling of this structures is shown in Fig. 3. A bandwidth of about 0.8 GHz (at -10 dB) near 20 GHz (or 4 %) can be stated.
Next, a four element array according to Fig. 4 was designed for 20 GHz, fabricated, and tested. The feed line characteristic impedance at the patches was chosen to 200 Ω, and the wider line connecting the two subarrays to 100 Ω, respectively, resulting in a feed point impedance of 50 Ω for a coaxial connector mounted to the center of the 100 Ω line. As this configuration presents a close assembly of both patches and feed lines, a full wave calculation of the complete planar circuit was done. Fig. 5 gives the computed as well as the experimental return loss of the array; a good agreement can be stated. H- and E-plane radiation diagrams are plotted in Fig. 6, once again with good agreement. Some asymmetry of the E-plane radiation diagram is caused by the close coupling of the 100 Ω microstrip line to two of the patches (Fig. 4), and slight discrepancies between theory and experiment are due to the small finite substrate size /3/.

APPLICATIONS OF THE SUBARRAY

With its compact size, such an array is ideally suited as planar feed structure for reflector or lens antennas which already incorporate planar structures in the plane of the feed, as shown in Fig. 7 (/4/, /5/). Employing it in the folded lens antenna according to /4/, hardly any difference in radiation diagram or in gain could be stated.

Furthermore, this four element array can be used as a building block for larger microstrip array antennas. While the antenna elements as demonstrated here can be realized on a relatively thick substrate with a low dielectric constant, a simplified feed network on a thinner substrate - and possibly with a higher dielectric constant - can be placed on a separate substrate back to back with the antenna substrate using via interconnects between the general feed network and the subarrays. A test antenna of this type has been realized at 10 GHz using 16 of these subarrays (8 by 8 radiating elements). The planar antenna array was fabricated on a 1.52 mm thick substrate with a dielectric constant of 2.5; the feed network uses a Duroid substrate of only 0.254 mm thickness. The interconnects were realized by wires soldered between the transmission lines of antenna and feed lines. In Fig. 8, the overall array and the feed network are plotted one overlapping the other. It should be remarked that the feed line widths would be six times larger if the network had been realized on the same substrate as the antenna elements. The bandwidth of the antenna (10 dB return loss) amounts to about 400 MHz. The radiation characteristics of the resulting antenna is plotted in Fig. 9. While in the H-plane, the diagram matches that of an antenna with constant amplitude taper, some problems occurred in the E-plane due to some phase error in the subarrays (some unsymmetry) and excitation and radiation of surface waves, as the substrate, for this frequency, was slightly too thick /6/. A gain of 23 dB at center frequency was measured compared to 25 dB of an ideal antenna. Part of these losses are due to the relatively long line to feed the antenna in the center.

CONCLUSION

A novel type of microstrip antenna subarray was demonstrated showing a very compact feed network. Its application can be found as feed antennas for reflector or lens antennas or as element in a larger microstrip array, as has been demonstrated with a test antenna at 10 GHz.

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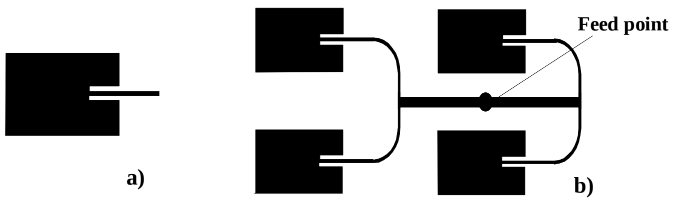

Fig. 1: Single patch antenna with inset feed (a) and array of four patches with typical feed lines (b).

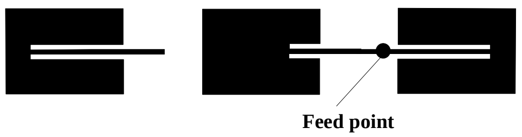

Fig. 2: Single patch antenna with modified inset feed and array of two patches.

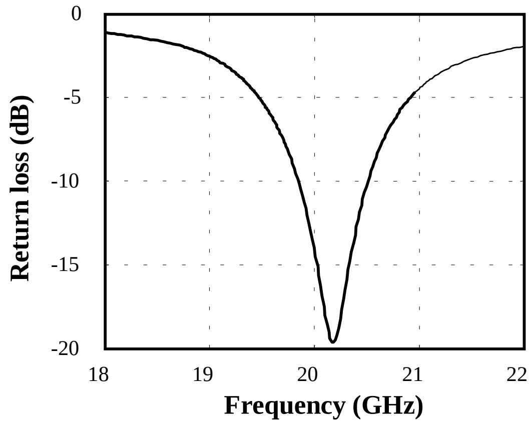

Fig. 3: Return loss of an array of two patches according to Fig 2b. (Substrate height 0.76 mm, ε_r=2.5, feed point impedance 100 Ω).

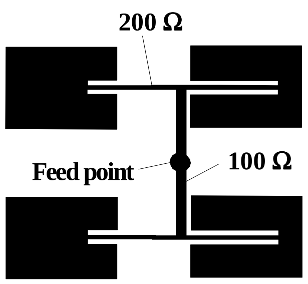

Fig. 4: Array of four patches with novel feed configuration.

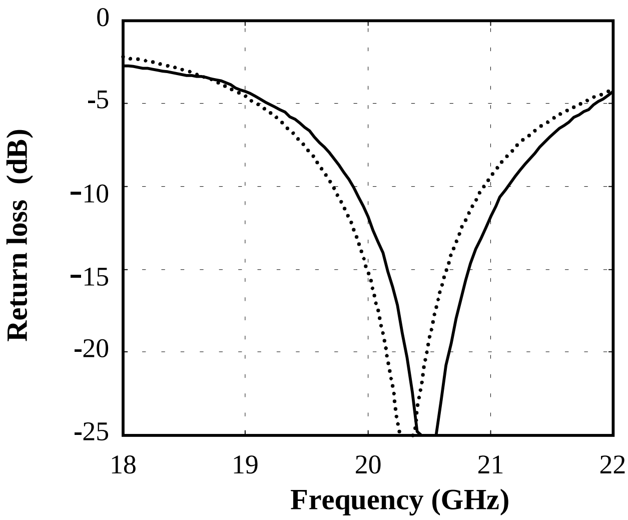

Fig. 5: Theoretical (....) and experimental (——) return loss of the four patch array according to Fig. 4 (Substrate height 0.76 mm, ε_r=2.5).

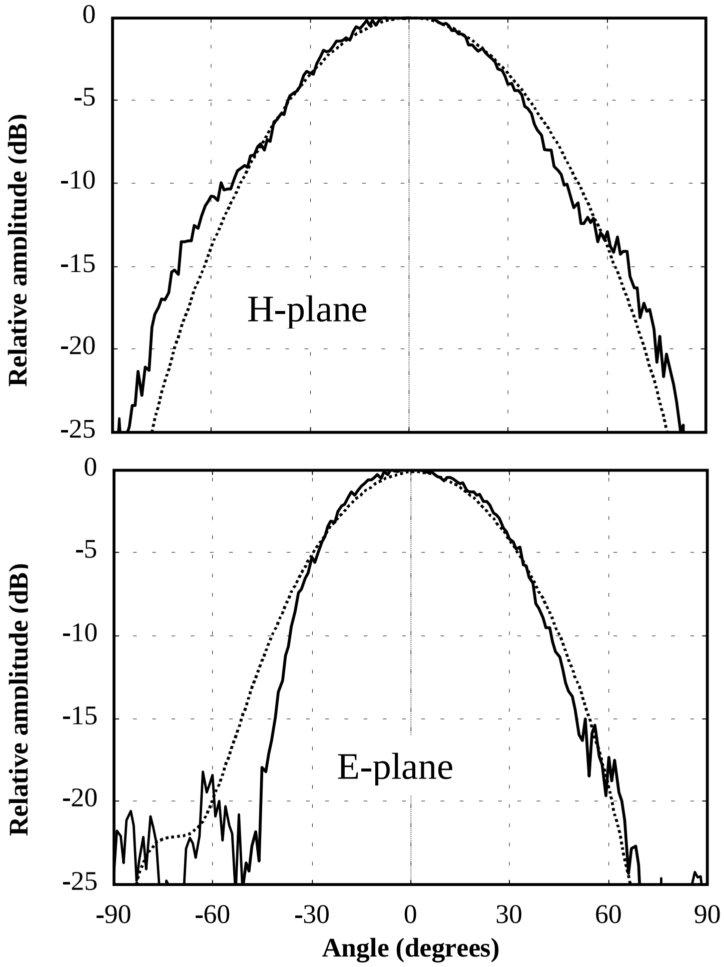

Fig. 6: Theoretical (---) and experimental (——) radiation diagrams of the array according to Fig. 4.

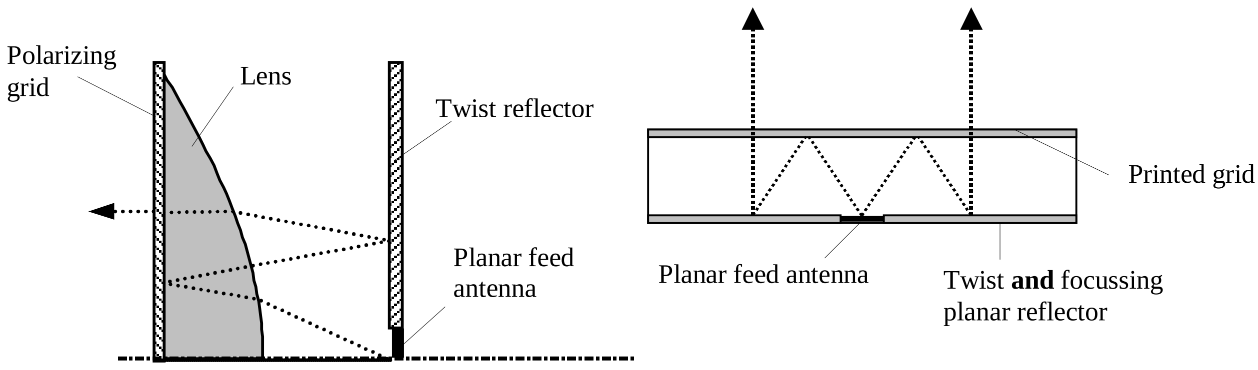

Fig. 7: Principles of folded lens and reflector antennas according to /4/ and /5/.

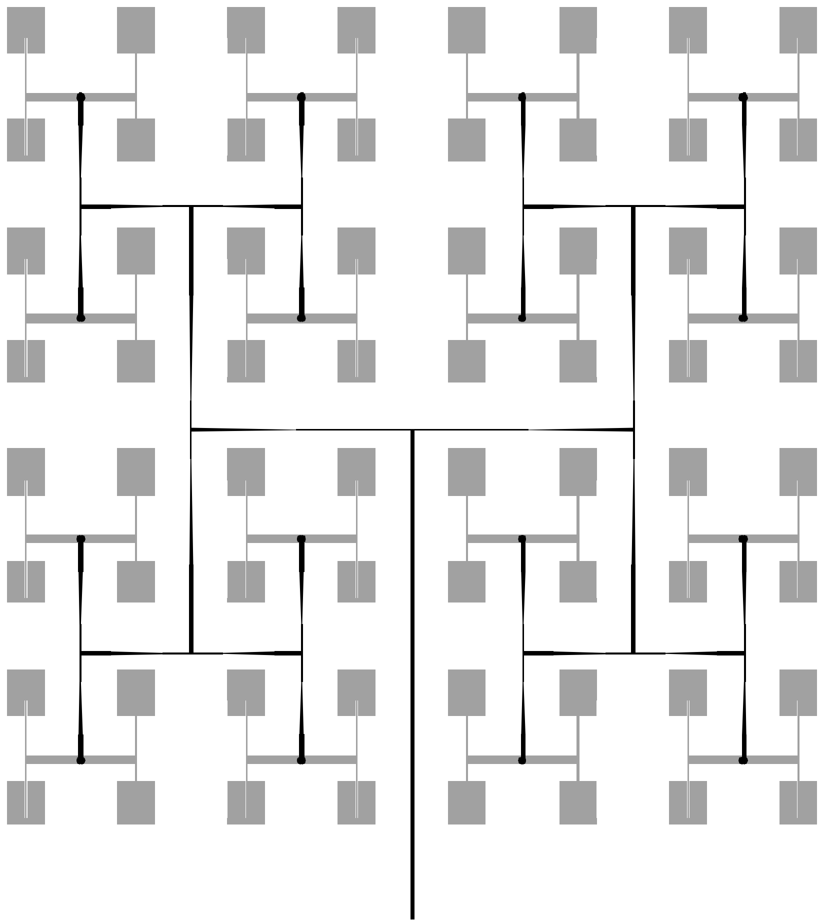

Fig. 8: Layout of microstrip array antenna. (The antenna elements (grey) are realized on a 1.52 mm thick substrate, the feeding network (black) on a 0.254 mm thick one. The feed line widths would be six times larger if the network had been realized on the same substrate as the antenna elements.)

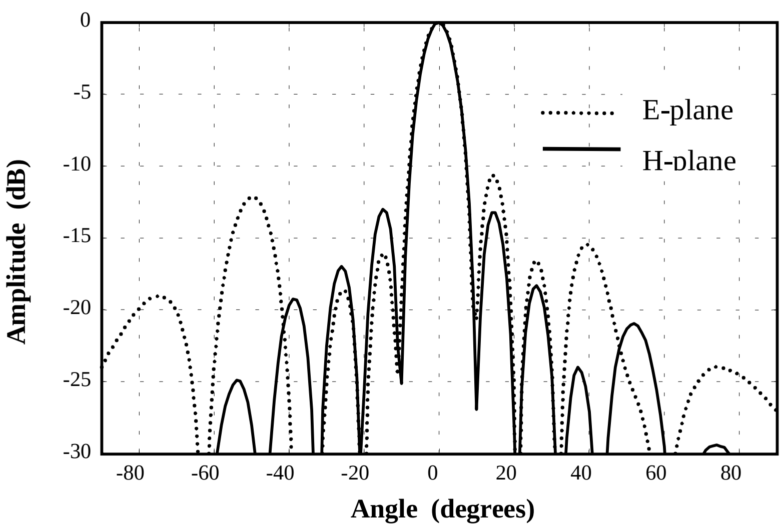

Fig. 9: Experimental radiation diagram of microstrip array antenna (f = 10 GHz).