A 38 GHz MICROSTRIP ARRAY
WITH AN E-PLANE WAVEGUIDE FEEDING NETWORK

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***Abstract* – A major restriction of high gain microstrip antenna arrays is found in their high losses, mainly due to the feeding network. In this contribution, design and results of a 38 GHz microstrip array antenna with a low-loss E-plane waveguide feed network are presented. Interconnects between planar structures and waveguide network are done by slot coupling. The waveguide network for this antenna was machined from aluminum, but in a later phase, it might be fabricated using plastic injection molding and electroplating to realize low-loss, low-cost planar antennas.**

I. 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]. Slotted arrays [2] or arrays of horn antennas with a waveguide feed network [3] are lower in loss, but partly complicated in their design or restricted with respect to bandwidth, 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 [4]. As the feed network is the major source of losses for microstrip arrays, some attempt has already been made to replace this by a waveguide feed network [5].

This contribution reports on progress of these efforts, especially towards narrower beamwidth, lower side lobe levels, and a less critical assembly. Frequency was chosen to 38 GHz, a band of increasing interest for point-to-point or point-to-multipoint communication.

II. DESIGN OF THE ANTENNA

The basic principle of the array antenna is shown in Fig. 1. The planar array consists of eight 2×2 subarrays fed by a small microstrip feed network on a substrate with 0.26 mm thickness and a dielectric constant of 2.5. This planar feed network then is coupled to an E-plane waveguide network (WR22) via slots in the ground plane of the planar substrate [6]. The slot coupling provides, at the same time, a 180° phase shift allowing the microstrip network being quite short. Planar elements and waveguide structure were designed using both commercial CAD routines [7] and a FDTD computation technique [8], [9].

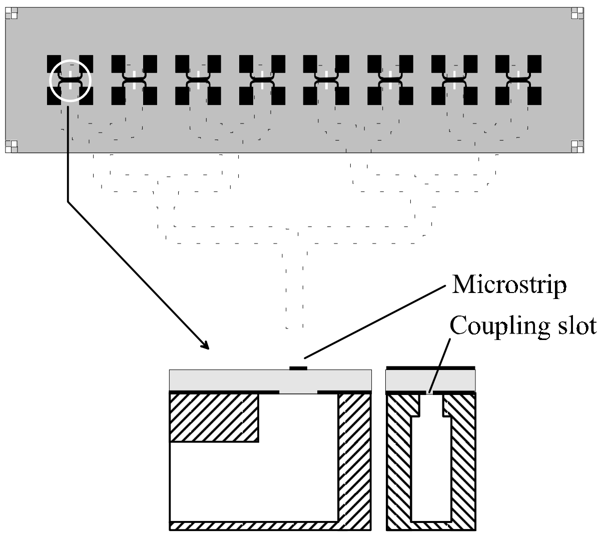

Fig. 1: Basic structure and principle of the waveguide fed microstrip array antenna.

An E-plane circuit was chosen for the waveguide network; this requires less lateral space. Furthermore, splitting the waveguide block in the symmetry plane, less problems occur putting the two parts of this block together. To reduce the sidelobe level, an amplitude taper was included using unsymmetrical T-junctions. Originally, a Dolph-Chebishev distribution was selected; the far-off sidelobes then were further reduced by the subarray characteristics.

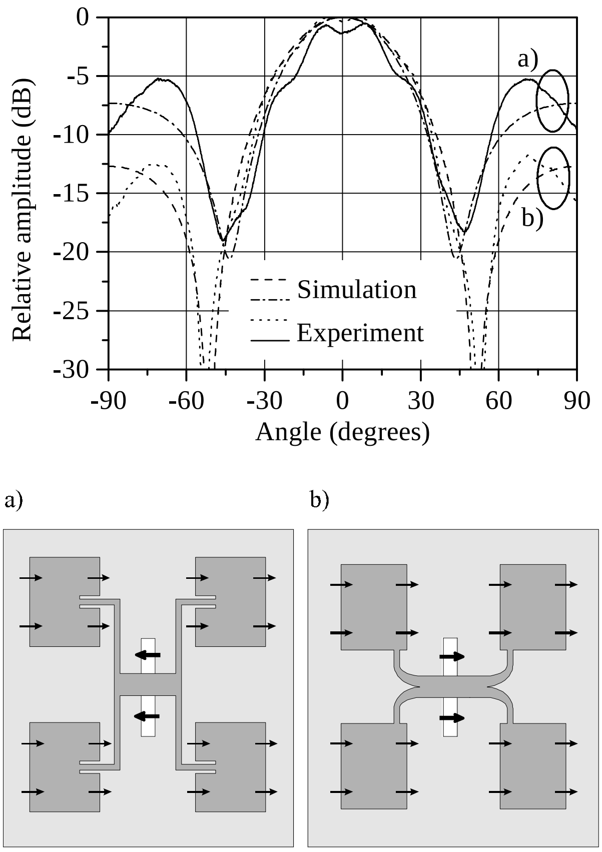

Fig. 2: 2 × 2 subarray radiation diagrams of the original approach with out-of phase radiation of patches and slot (structure as in [5], bottom left) and a modified side-coupled patch arrangement with in-phase radiation of patches and slot (bottom right).

In [5], problems occurred due to residual radiation from the slot coupling; this could not be suppressed here, too. Some effort, however, has been made to reduce its influence by adjusting an in-phase radiation of the slots. With respect to the radiation diagram of the 2 × 2 subarrays, the sidelobe level could be reduced compared to the original approach by selecting a side feeding of the patches, reducing the feed line length and providing a nearly in-phase radiation of patches and slot (Fig. 2). Further optimization was done later on by adjusting the subarray spacings, as will be described in section III.

III. RESULTS OF THE COMPLETE ANTENNA

The complete antenna as indicated in Fig. 1 was built up and tested. Figs. 3 and 4 show the opened waveguide feeding network and the complete antenna assembly, respectively.

The overall return loss of the antenna array (Fig. 5) was better than 10 dB over a bandwidth of 2.3 GHz (6 %).

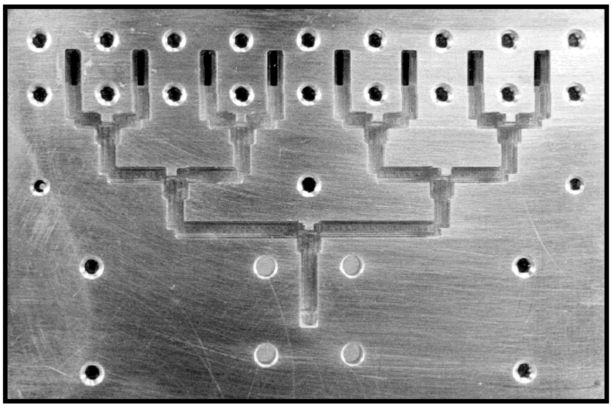

Fig. 3: Photograph of opened waveguide feeding network with coupling slots.

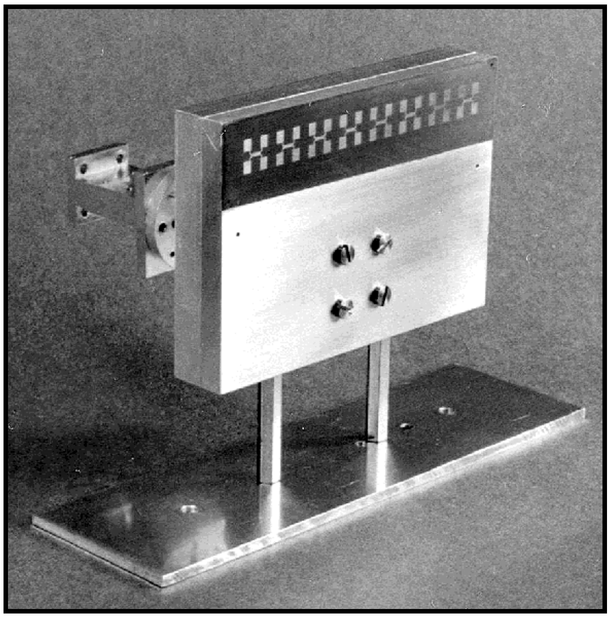

Fig. 4: Photograph of complete antenna assembly.

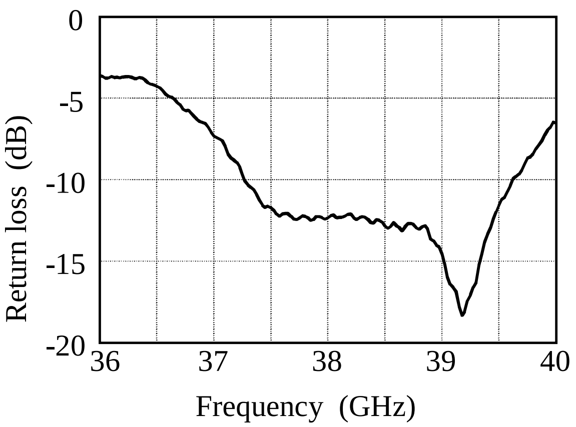

Fig. 5: Measured return loss of the complete array.

Simulated and experimental E- and H-plane radiation diagrams are plotted in Fig. 6. Simulation was done representing the radiating patch edges by magnetic currents. In the E-plane, a 3 dB beamwidth of 5.1° results; the H-plane beam, due to the small antenna dimensions in that plane, is only 35° wide. E-plane sidelobe level is nearly –20 dB (as designed), but once again, extra lobes appear around ±45°. These result from grating lobes of the slot radiation. As the zeros of the "element" pattern of the 2 × 2 subarrays were slightly shifted to larger angles, these lobes are not suppressed as expected, as was confirmed including the slot radiation into the simulation. The top of Fig. 7 shows a superposition of the radiation diagrams of a subarray and the complete antenna, clearly indicating the influence of the subarray nulls. On the bottom of the figure, simulated diagrams are plotted of a subarray, the original complete array and an array with slightly reduced distances of the subarrays (the subarrays themselves are unchanged). As can be seen, it is possible to reduce the extra lobe by about 5dB.

Consequently, a second antenna with reduced distances of the subarrays was built up as well. Fig. 8 shows the experimental radiation diagram. Obviously the level of the sidelobes produced by the grating lobes of the slot radiation is decreased by 4dB. However, it seems that the subarray nulls have shifted slightly and that their depth is decreased. As the distance between the subarrays has been reduced, this effect is likely due to increased coupling between the patch elements.

A further step to optimize the antenna would be a complete analysis of the structure which takes into consideration the coupling between the patch elements.

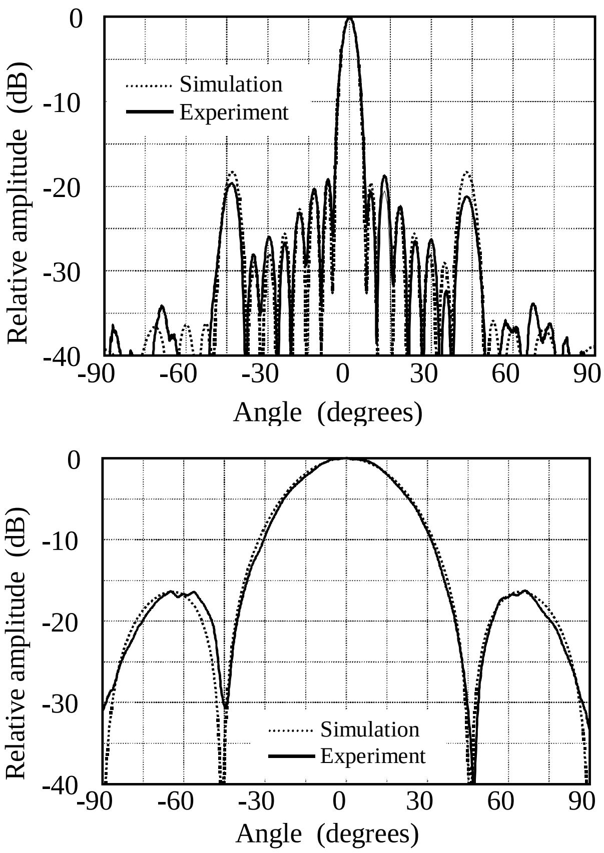

Fig. 6: Simulated and experimental radiation diagrams of the complete antenna. Top: E-plane, bottom: H-plane.

IV. CONCLUSION

A 16 × 2 element microstrip array antenna has been presented. 4 elements each (2 × 2) are combined with a small microstrip feed network, and each subarray is fed by an E-plane waveguide network. A beamwidth of approx. 5° in the E-plane and a side lobe level of about -20 dB could be achieved. This array gives the basis for a 16 × 16 element array with low feed line losses. In a final version, the waveguide network might be fabricated using plastic injection molding reducing fabrication cost.

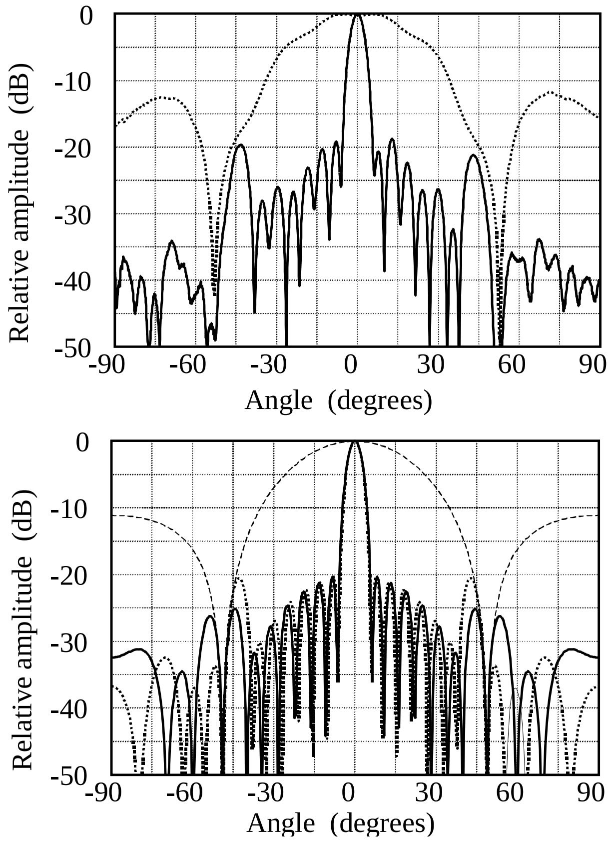

Fig. 7: Top: Experimental radiation diagrams of 2 × 2 subarray and complete antenna. Bottom: Simulated radiation diagrams of 2 × 2 subarray (dashed line) and complete antenna with both original (dotted line) and reduced distances of subarrays (solid line).

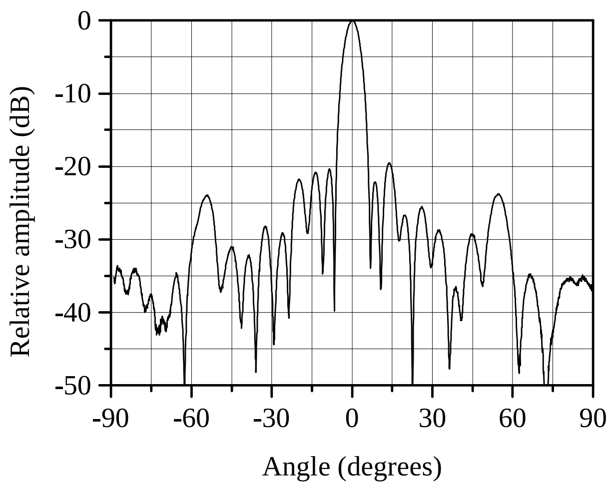

Fig. 8: Experimental radiation diagram of the complete antenna with slightly reduced distances of the subarrays.

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