A 24 GHZ MICROSTRIP ANTENNA ARRAY INCORPORATING A RIDGE WAVEGUIDE FEED 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 24 GHz microstrip array antenna with a quasi-planar, low-loss ridge 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

Today, many systems for communication and sensor applications require low profile, low-cost antennas. In the mm-wave frequency range, narrow beamwidth, high gain antennas can in principle be realized within a small antenna aperture size. This, however, provides increasing difficulties with increasing gain of the planar antenna. Antenna arrays with a *printed* feed network typically suffer from high losses of the feed network [1]. Some improvements in feed losses are possible employing a series type feeding network, this however, is done at the expense of antenna bandwidth. Waveguide slotted arrays [2] or other waveguide based antennas [3] exhibit lower loss, but are more complicated and expensive in fabrication.

To overcome these problems, a novel combination of microstrip antenna elements and waveguide feed circuitry is proposed and demonstrated in this paper. A corporate ridge waveguide circuit is designed for the major part of the feed network, while four element subarrays of microstrip patches are used as radiating elements. The feed network in principle is a very simple, single layer H-plane network which may finally be fabricated using plastic injection molding and electroplating [4], [5]. Ridge waveguide was chosen due its smaller width, as will be explained in Sect. III. The planar subarrays are coupled to the waveguide network by slot coupling [6].

The assembly of the complete antenna thus can be reduced to fix the printed substrate on top of the waveguide block with silver epoxy. This requires a homogeneously glued contact along the waveguide edges; this principally is possible, but for the test antenna described here, the required assembly technology was not available. Therefore a modified arrangement was chosen for the realization of the waveguide network based on two separate parts screwed together (Fig. 1, 2).

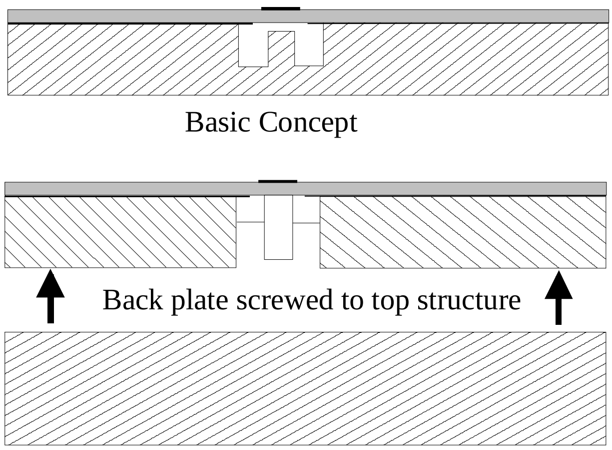


Fig. 1: Basic concept and experimental realization of microstrip antenna with waveguide feed network.

II. MICROSTRIP SUBARRAY AND SLOT COUPLING TO RIDGE WAVEGUIDE

For the design of this antenna, four microstrip elements are combined with a small microstrip network. An impedance matching of each patch is done using an inset feed contact. Two elements each are connected in parallel; two of these structures then are arranged in opposite and combined by another microstrip line (Fig. 2). This planar sub-network is fed via slot coupling [5] from ridge waveguide (Fig. 3). This automatically includes the necessary 180° phase shift for in-phase excitation of all four patches.

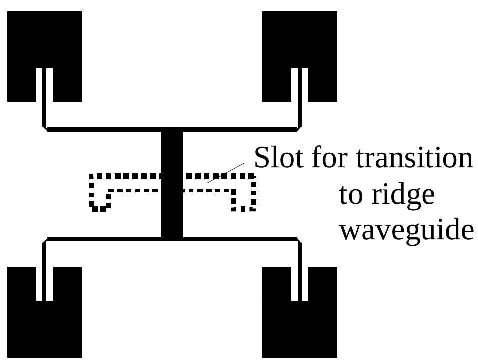


Fig. 2: Principle layout of two by two microstrip subarray.

The single elements and the microstrip subarrays, in a first step, were designed using a commercial CAD package [7], already including some mutual coupling. In a second step, the subarray was computed and reoptimized, together with the slot coupling, using a FDTD code [8], [9]. The overall width of the ridge waveguide and the width of the ridge are 5.2 and 1.2 mm, respectively, waveguide height and ridge height 2.5 and 1.8 mm. Thus each waveguide is considerable narrower than a standard waveguide, allowing not only to feed each planar subarray, but also to realize the complete waveguide network in a single layer. Consequently, the coupling slot had to be bent to give a good return loss at the desired center frequency.

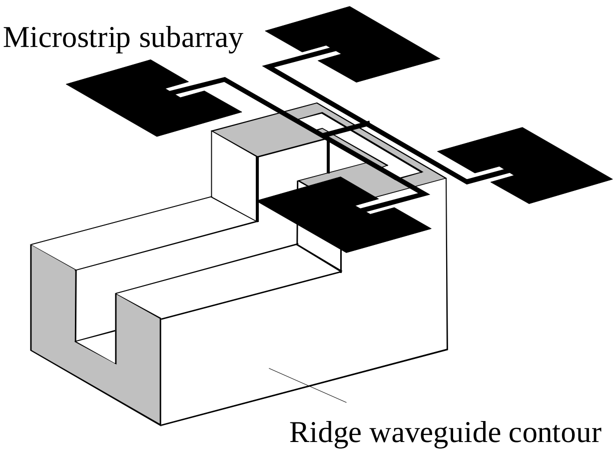


Fig. 2: Basic arrangement and structure of planar subarray and slot coupled ridge waveguide.

The computed return loss of a two by two element subarray including slot coupling is plotted in Fig. 3. The antenna bandwidth (-10 dB return loss) amounts to about 1.4 GHz.

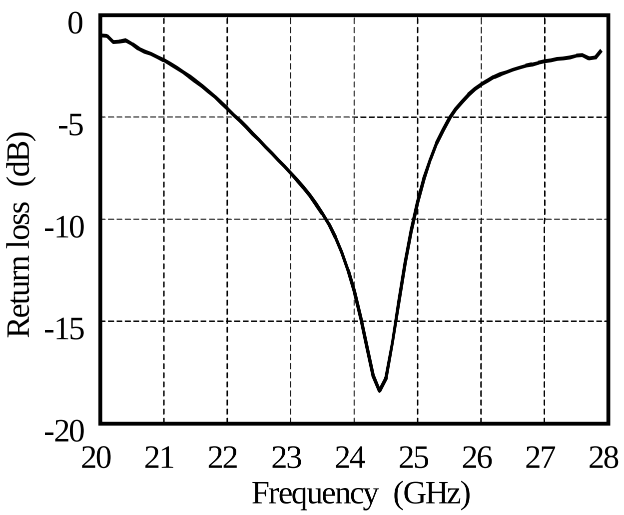


Fig. 3: Computed return loss of 4 element subarray including slot coupling.

As the slot coupling is an open structure, it contributes to the radiation of the antenna. Using FTDT, the field distribution in the structure easily could be checked (Fig. 4). The slot radiates in the same polarization as the patches, but with an approximately 90° phase shift with respect to the patch radiation. While the main beam is unaffected by the slot radiation, there is some influence on the side lobe performance in the E-plane. In a further development step, the slot radiation could either be reduced or optimized for the same phase angle as the patch radiation.

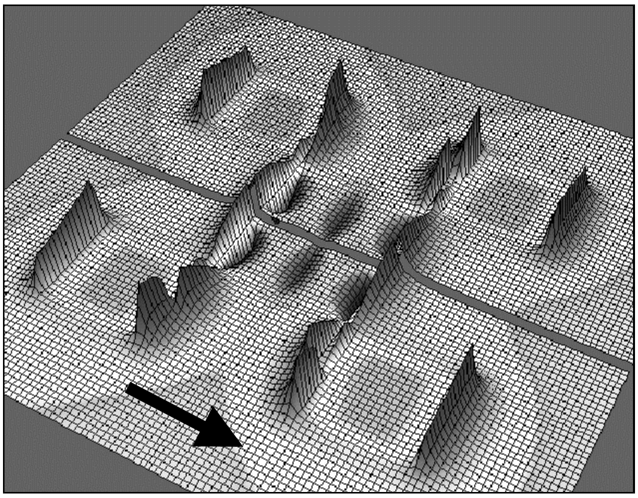


Fig. 4: Electric field distribution on top of the planar subarray (field component indicated by arrow).

III. WAVEGUIDE FEED NETWORK

The feed network is realized on the back side of the antenna with ridge metal waveguide (Fig. 5, 6).

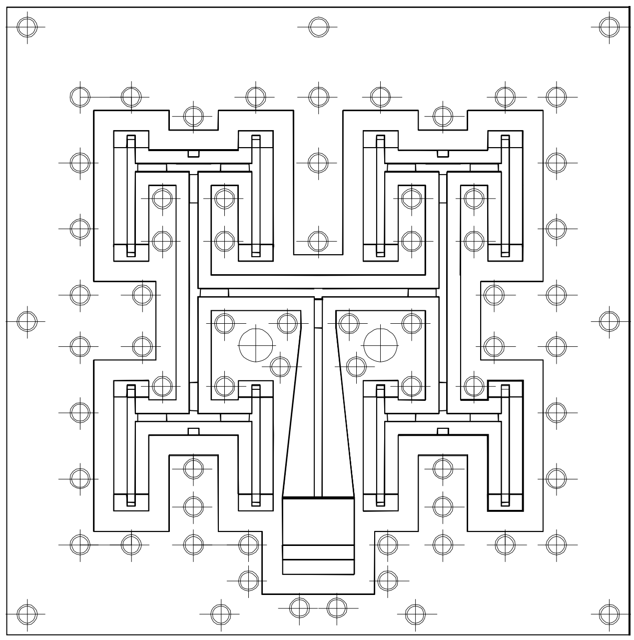


Fig. 5: Ridge waveguide feed network.

Ridge waveguide was chosen to provide enough space for a corporate feeding network, maintaining maximum bandwidth and less stringent tolerance requirements. A tapered transition to standard waveguide and a matched E-plane bend were included to feed the complete antenna. The included waveguide discontinuities were computed using mode matching techniques as well as FDTD. To match the T-junctions, a quarter-wave transformer element was added to the ridges, partly together with some kind of septum opposite to the 90° junction arm. For this antenna, all junctions provide a symmetric power split, resulting in a constant amplitude taper of the antenna. A tapered amplitude distribution, however, would have been possible equally at some higher design effort.

The waveguide network for this antenna was machined from an aluminum plate. Breaks through the plate provide the interconnects to the planar structure. The planar substrate was glued to the backside of this plate. Through the waveguide breaks, the quality of the critical electric contacts around the breaks could be checked. Finally, another aluminum plate was screwed on the backside to close the waveguide structure.

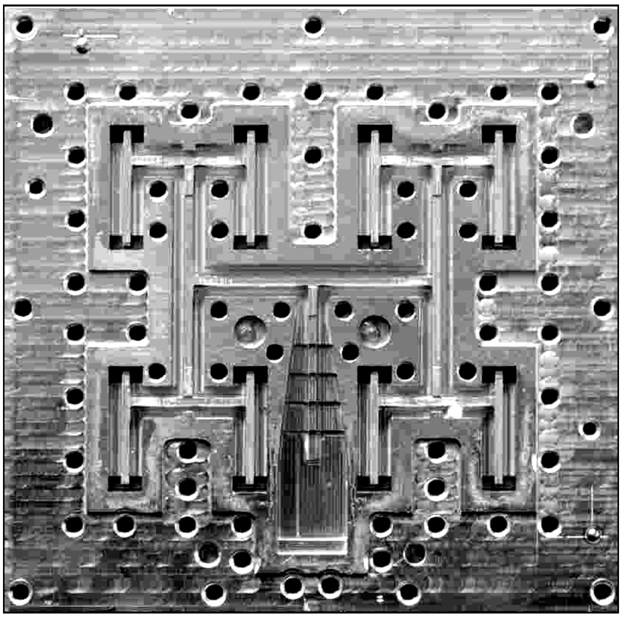


Fig. 6: Photograph of waveguide feed network.

IV. RESULTS

To test this antenna concept, a 8 by 8 element microstrip array was designed, fabricated, and tested. Element spacing was 9.25 mm or 0.74 λ_0. As mentioned before, in this work the waveguide network was machined from aluminum; in future applications, it might as well be fabricated using plastic injection molding and electroplating [8]. A photograph of the complete planar array is shown in Fig. 7. The experimental return loss of the antenna is plotted in Fig. 8. Although quite a number of screws were used to put together the waveguide block and the cover plate, some contact problems occurred in the region of the taper to standard waveguide, as in this area, no screws could be placed between the taper and the adjacent waveguides. This results in some additional reflection and, probably, some losses.

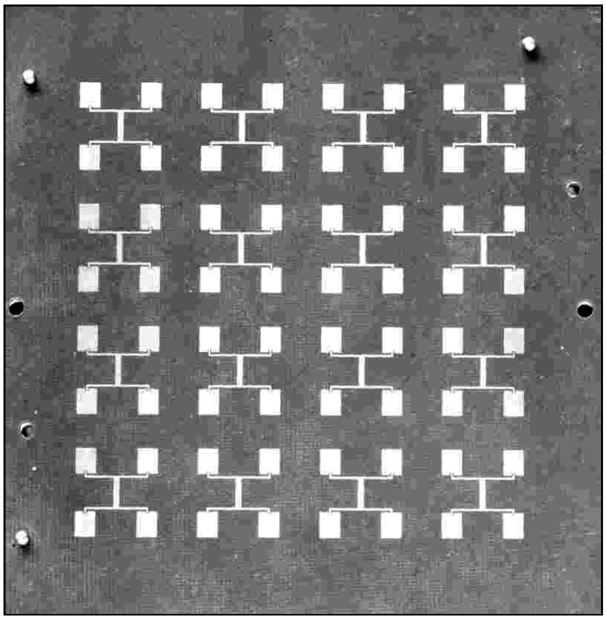


Fig. 7: Photograph of substrate side of antenna.

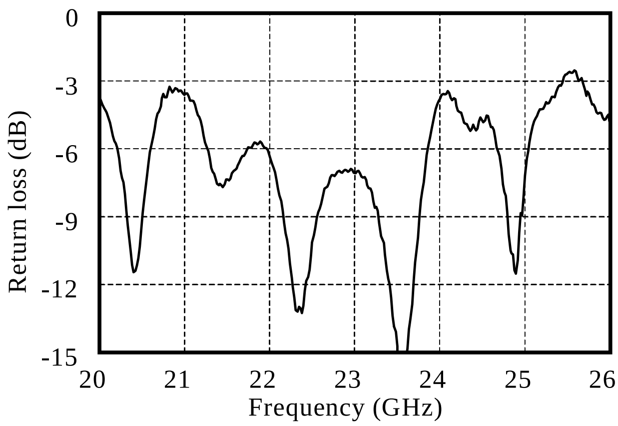
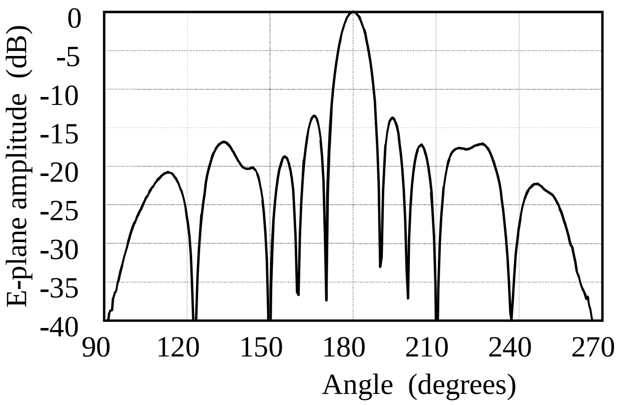


Fig. 8: Return loss of complete antenna.

Radiation diagrams for E- and H-plane are plotted in Fig. 9. Beamwidths of the antenna are 8.5°. As could be expected for a constant amplitude distribution as realized in this example, the side lobe level amounts to -13.4 dB. Except for some slight discrepancies in the E-plane around 50°, the radiation characteristic agrees excellent with theoretical expectations. The discrepancies are due to the radiation from the coupling slots. As the distance between the coupling slots is 1.48 λ_0, grating lobes of the slot radiation exist, effecting mainly the side lobe performance in the E-plane (nearly constant element pattern of a slot in this plane), while the effects to the H-plane diagram are minimal.



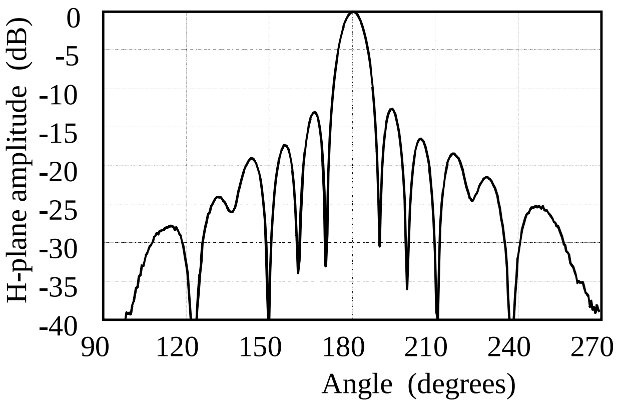


Fig. 9: E-plane and H-plane radiation diagrams of 24 GHz antenna.

V. CONCLUSION

Design and results of a 24 GHz test antenna have successfully been demonstrated. The combination of planar radiating elements (two by two subarrays) and of a ridge waveguide corporate feed network gives the basis for larger low-loss planar array antennas. If finally the feed network is fabricated using plastic injection molding and electroplating, also mass fabrication at low cost is feasible.

VI. REFERENCES

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