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COPLANAR FED MICROMACHINED PLANAR ANTENNAS FOR POWER COMBINING APPLICATIONS AT D-BAND FREQUENCIES

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Abstract

Several transitions from coplanar waveguide on thin dielectric membrane to micromachined planar antennas have been investigated. The physical dimensions of the multi-layer planar antenna structures as well as the shape of the micromachined horns have been optimized for operation at 150 GHz. The calculated return losses are low and the direction of maximum radiated power is orthogonal to the plane of the CPW-feedline what indicates a good applicability for power combining array arrangements.

Introduction

Micromachined coplanar waveguides on thin dielectric membranes proved very satisfactory transmission properties for D-band frequencies because of the absence of substrate modes, low losses, and low dispersion [1]. Transmission lines with very good characteristics have already been fabricated. Micromachined shielded coplanar waveguides provide the advantage that neither via-holes as for microstrip applications nor air bridges as for conventional coplanar lines are needed. Unlike other approaches [1], low-resistive silicon substrates have been used which act as a shielding cavity without necessarily having to be coated with gold to ensure a sufficiently good RF short between the two ground planes. This fact implies the additional advantage of low production costs. The planar gold conductors of our structures are entirely based on dielectric membranes of thickness 4μm [2]. In order to radiate power into free space, broadband low loss transitions from coplanar waveguide to planar antenna elements are needed. Several approaches have been made for other frequency bands [3], [4]. Presented here are two different types of antennas which provide good impedance match and radiation characteristics adapted for power combining applications at D-band frequencies. For this purpose, a certain number of exactly identical antenna elements has to be arranged in a quasi-optical power combining structure. That means that the mounting and power feeding components of each single element have to permit that the elements are collocated close to each other. Furthermore, the design must imply reproducibility in fabrication, i.e. the possibility for integrated fabrication by means of micromachining techniques. Both of these properties are provided by the CPW-configurations described in this paper. Beyond the aim of good impedance match and high gain it is important that the main lobe of the radiation pattern is perpendicular to the CPW-plane, and that sidelobes are suppressed as much as possible. These requirements have been optimized for operation at D-band frequencies. The numerical analysis of the investigated structures has been carried out by the field simulator HFSS and the optimization was done by means of empipe3d, both software tools by Agilent Technologies.

Slot-Coupled CPW-Fed Patch Antenna

The first one of the two investigated antenna types is a rectangular patch antenna fed by a coplanar waveguide on membrane as described for a lower frequency band in [3]. In this case, the coupling between the CPW feedline and the patch is performed by a rectangular coupling slot in the ground plane which is connected to the CPW either inductively or capacitively. Both couplings have been investigated but only the inductively coupled type has been optimized for D-band operation. The structure is composed of two stacked layers, one of which is carrying the CPW feedline and the coupling slot, and the other one is carrying the radiating patch. CPW and patch are both lying on dielectric membranes as described above. A schematic of the structure is shown in Fig. 1.

The parameters which have been varied during the optimization procedure were the length of the coupling slot, the dimensions of the radiating patch, and the distance between the patch and the CPW-plane. The calculated return loss $|S_{11}|$ and the radiation pattern at 150 GHz for an optimized structure are shown in Fig. 2 and Fig. 3.

A return loss of -35 dB and an antenna gain of more than 9 dB at 150 GHz have been obtained. However, this type of antenna shows good performance only within a very narrow frequency band. Furthermore, the structure proved high sensitivity with respect to small variations in physical dimensions. Especially the length of the coupling slot that directly influences the center frequency is very critical as far as fabrication tolerances are concerned.

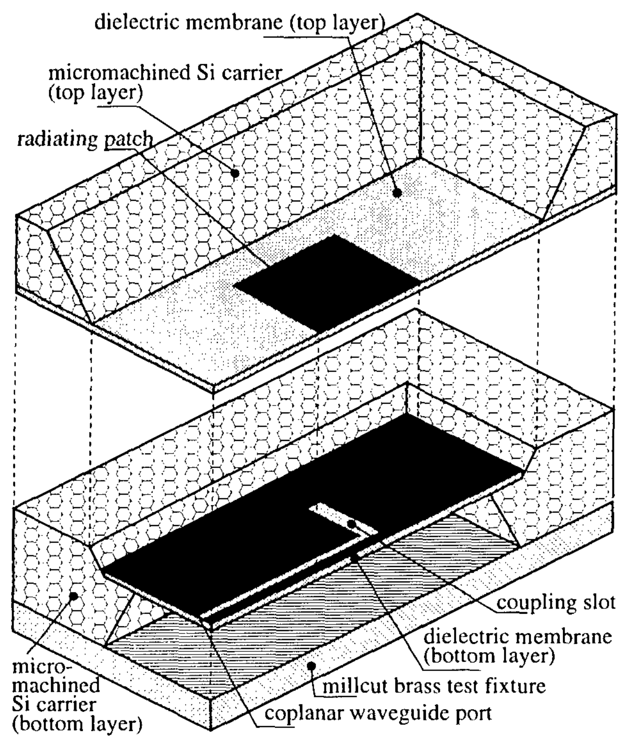

Figure 1: Schematic of the slot-coupled CPW-fed patch antenna (cut in half).

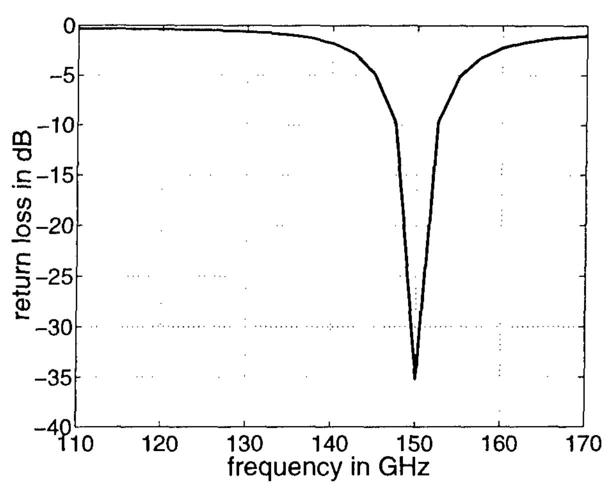

Figure 2: Simulated return loss of the slot-coupled CPW-fed patch antenna.

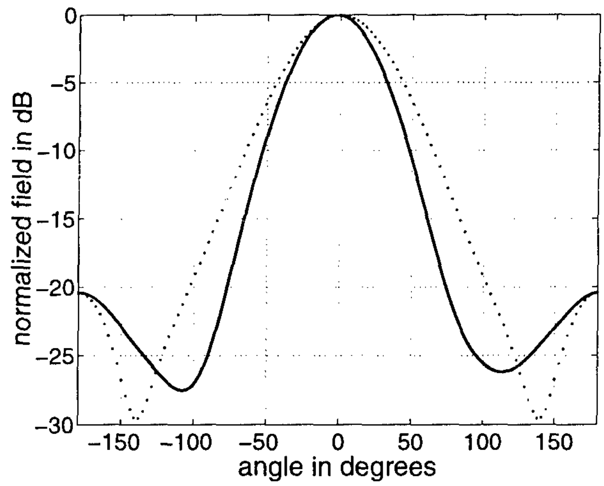

Figure 3: Simulated radiation pattern of the slot-coupled CPW-fed patch antenna: E-plane (solid line) and H-plane (dotted line).

CPW-Fed Microstrip Probe Micromachined Horn Antenna

For the purpose of an enhanced bandwidth another type of planar integrated antenna was investigated. This concept is very promising because it is based on a transition from CPW on membrane to conventional rectangular waveguide which has previously been published and successfully fabricated [5], [6]. This transition consists of a Klopfenstein taper [7] which transforms the coplanar waveguide into a microstrip line followed by a microstrip probe. The latter converts the electromagnetic field of the microstrip line into the TE_{10}-mode of a rectangular waveguide which on one side is shorted at a distance of approximately a quarter of a wavelength from the probe. The transition from the microstrip line to the rectangular waveguide is performed by a triangularly shaped microstrip patch placed in the E-plane of the rectangular waveguide. The membrane as well as the carrier substrate are located in this plane of the rectangular waveguide. Undesired higher order modes are suppressed by means of sufficiently small micromachined shielding cavities surrounding the CPW as well as the microstrip line. On the opposite side of the waveguide short, the rectangular waveguide is terminated by a small micromachined horn in the probe-plane. Fig. 4 shows a schematic of the structure.

The dimensions of the CPW-to-rectangular waveguide-transition have to be slightly modified for satisfactory antenna performance according to the requirements described in the introduction. Optimization parameters were both width and length of the microstrip patch as well as the position of point D in Fig. 4, optimization goals were the center

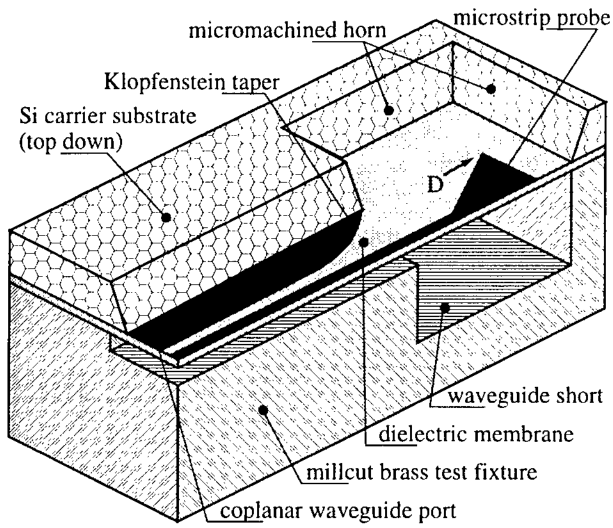

Figure 4: Schematic of the CPW-fed microstrip probe micromachined horn antenna (cut in half).

frequency and the broadband characteristics of the transition. Furthermore, the distance of the waveguide short from the probe has been optimized to improve impedance match. Fig. 5 and Fig. 6 show the calculated return loss $|S_{11}|$ and the radiation pattern at 150 GHz of the presented antenna. Return losses of less than -20 dB and a gain of more than 6 dB were achieved over a frequency range from 140 GHz to 160 GHz.

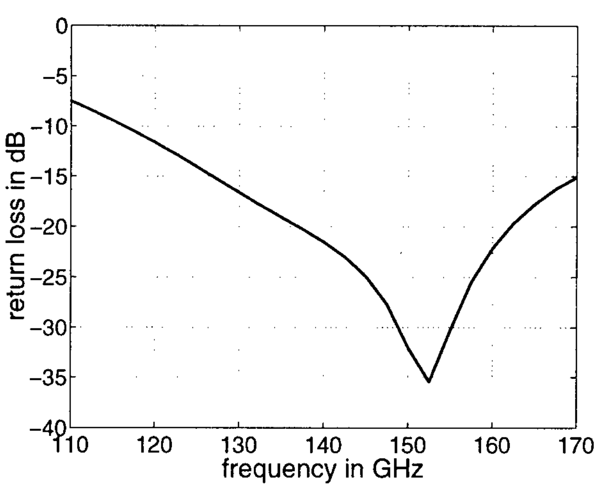

Figure 5: Simulated return loss of the microstrip probe micromachined horn antenna.

Experimental Results

The presented structures have not been fabricated yet, but very similar structures which have not been optimized show satisfactory characteristics what promises good operation for the optimized structures, too. Fig. 7 and Fig. 8 show the simulated and measured return

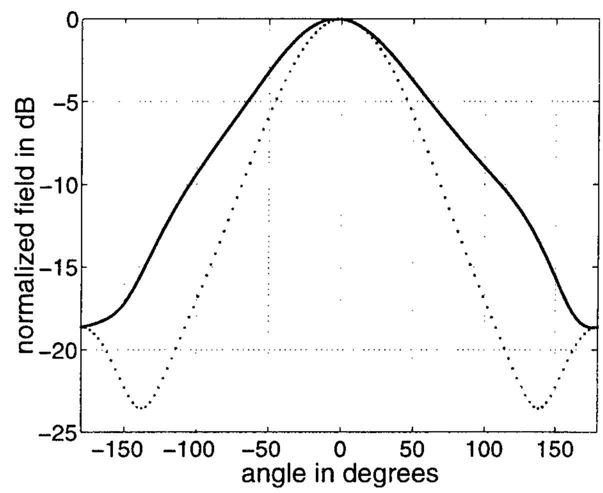

Figure 6: Simulated radiation pattern of the microstrip probe micromachined horn antenna: E-Plane (solid line) and H-Plane (dotted line)

loss $|S_{11}|$ and the radiation pattern for a microstrip probe micromachined horn antenna with a center frequency around 125 GHz.

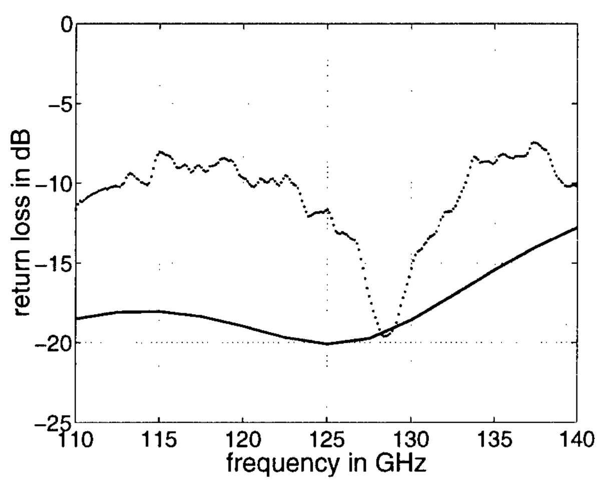

Figure 7: Simulated and measured return loss of a microstrip probe micromachined horn antenna.

Conclusions

Transmission line structures on thin dielectric membranes are a promising technique for applications at D-band frequencies. The simulated results presented in this paper promise low-cost and reproducible fabrication of antennas which may contribute to effective power combining array arrangements for D-band frequencies.

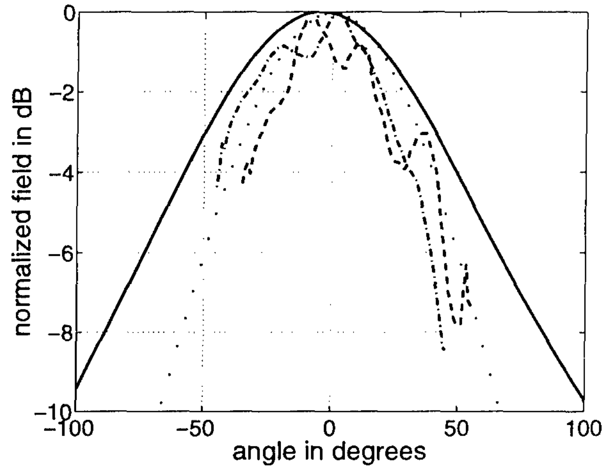

Figure 8: Simulated and measured radiation pattern of a microstrip probe micromachined horn antenna: E-Plane (solid line, dashed line) and H-Plane (dotted line, dash-dotted line)

Acknowledgement

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References

[1] N. I. Dib, W. P. Harokopus Jr., P. B. Katehi, C. C. Ling, and G. M. Rebeiz, "Study of a Novel Planar Transmission Line", *IEEE MTT-S Digest*, 1991, pp. 623-626.

[2] K. Duwe, S. Hirsch, R. Judaschke, J. Müller, "Micromachined Planar Antennas for D-Band Frequencies", *this conference.*

[3] W. Menzel, W. Grabherr, "A Microstrip Patch Antenna with Coplanar Feed Line", *IEEE Microwave and Guided Wave Letters*, 1991, vol. 1, no. 11, pp. 340-342.

[4] R. Q. Lee, R. N. Simons, "Coplanar Waveguide Aperture-Coupled Microstrip Patch Antenna", *IEEE Microwave and Guided Wave Letters*, 1992, vol. 2, no. 4, pp. 138-139.

[5] S. Hirsch, K. Duwe, R. Judaschke, "A Transition from Rectangular Waveguide to Coplanar Waveguide on Membrane", *25th International Conference on Infrared and Millimeter Waves*, Sept. 2000, Beijing, China.

[6] K. Duwe, S. Hirsch, R. Judaschke, J. Müller, "Micromachined Coplanar Waveguides on Thin HMDSN-Membranes", *25th International Conference on Infrared and Millimeter Waves*, Sept. 2000, Beijing, China.

[7] S. V. Robertson, L. P. B. Katehi, and G. M. Rebeiz, "Micromachined W-Band Filters", *IEEE Trans. Microwave Theory Tech.*, April 1996, vol. MTT-44, pp. 598-606.