A 79 GHz Differentially Fed Grid Array Antenna

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***Abstract*— This paper presents a planar grid array antenna with a 100 Ω differential microstrip line feed on a single layer of standard soft substrate. The antenna operates in the 79 GHz frequency band for automotive radar applications. Its single row design offers a narrow beam in elevation and a wide beam in azimuth. Together with the differential microstrip line feeding, the antenna is suitable for differential multichannel MMICs in the frequency range.**

***Keywords-* grid array; microstrip antennas; millimeter-wave antennas; differential antenna feed**

I. Introduction

Millimeter-wave applications such as automotive radars have gained importance in recent years. Using cheap MMICs mass-market commercial applications such as collision warning, blind-spot detection and pre-crash vehicle preparation can be realized even for cars in the low-price market segment. The 77 GHz to 81 GHz frequency range is seen as the target spectrum for these radar applications. In highly integrated sensor designs using SiGe technology differential interconnects are of interest, since they offer reduced line loss on low resistance Si substrates and easier handling of thick substrates. Fully differential antenna feedings avoid the need of balun transformers or transitions which may cause spurious radiation and additional transmission loss. This paper presents a low-cost, easy producible and fully differentially fed grid array antenna on a single layer of Rogers RO3003 substrate.

II. Grid Array Antenna

The history of the grid array antenna goes back to 1964 when Kraus [1] proposed the wire grid antenna. Conti et al. [2] realized the grid with microstrip lines. The first numerical analysis and further optimizations were done by Nakano et al. [3] – [8]. Lately, LTCC versions of the antenna have been presented [9], one of them fed by a substrate integrated waveguide (SIW) [10]. A novel type of feeding using a differential microstrip line is investigated in this paper.

A. Design

The presented grid array antenna consists of a series of 10 rectangular microstrip line loop elements (c.f. Fig. 1). These are connected using $\lambda_g/2$ lines (λ_g is the guided wavelength at the center frequency) for in-phase radiation.

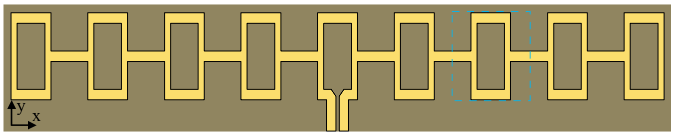

Figure 1: Top view of the grid array antenna.

The center loop is cut open at the radiating outer line. The 100 Ω differential microstrip line ends in a mitered bend and is directly connected to the grid.

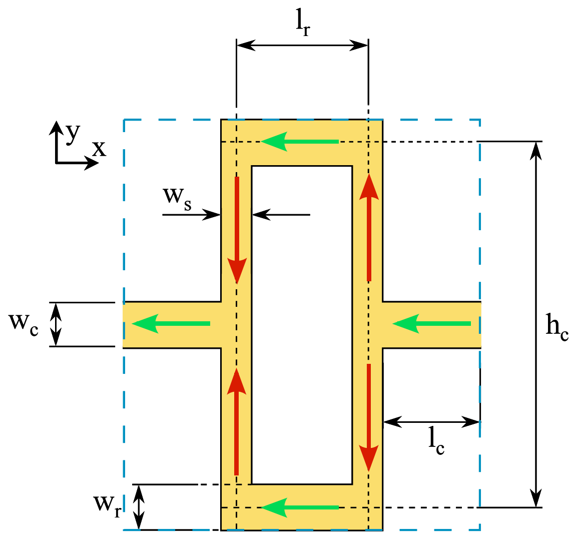

Figure 2: Current flow on a rectangular loop element.

The radiation properties of the antenna can be explained by analyzing the current flow on a single rectangular loop element. The radiating outer lines as well as the connecting half wavelength lines have even aligned current flow in the x-direction interfering constructively (c.f. Fig. 2). The microstrip lines in y-direction are phasing lines and have inversely flowing currents resulting in destructive interference. The single row of microstrip line loops results in a broadside beam which is narrow in the x-direction (elevation) and wide in the y-direction (azimuth).

B. *Simulation*

Modeling and simulations were carried out using CST Microwave Studio [11]. Initial designs were treated with the T-Solver – which implements a FDTD-Method – for fast results and then verified against the F-Solver – which uses FEM. The antenna geometry was optimized for Rogers RO3003 substrate with a height of 0.254 mm. This results in the dimensions shown in Table I.

TABLE I. ANTENNA DIMENSIONS

w_r	w_c	l_c	w_s	l_r	h_c
0.3 mm	0.3 mm	0.745 mm	0.18 mm	0.972 mm	2.675 mm

Fig. 3 shows the relative phase deviation of the rectangular loop elements starting from the center element to the 4th element on the left (c.f. Fig. 1). One can identify the different phase response of each element. Hence, the elements are only excited in-phase at the center frequency. This results in worse sidelobe suppression at the upper and lower range of the operating frequency band.

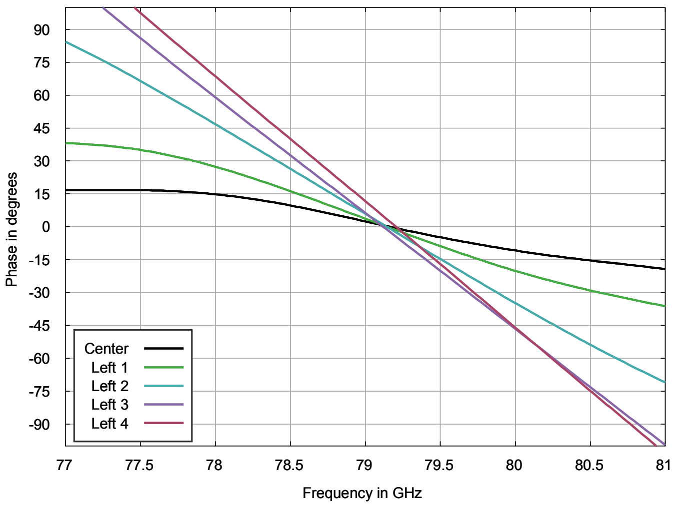

Figure 3: Simulated phase deviation of the rectangular loop elements.

C. *Transition*

For measuring the antenna with waveguide equipment, a transition from differential microstrip lines to WR12-waveguide is needed. The transition proposed in [12] offers a wide bandwidth and easy integration into the single layer antenna design. It was redesigned for the antenna's substrate properties. Figure 4 shows the top view and cross section of the transition - the corresponding dimensions are given in Tab. 2. The upper metallization layer of the substrate consists of two triangular flares. The TE_{10} waveguide mode is coupled to these flares and then converted to the connecting 100 Ω differential microstrip line. The vias extend the waveguide into the substrate and prevent the excitation of parallel plate modes.

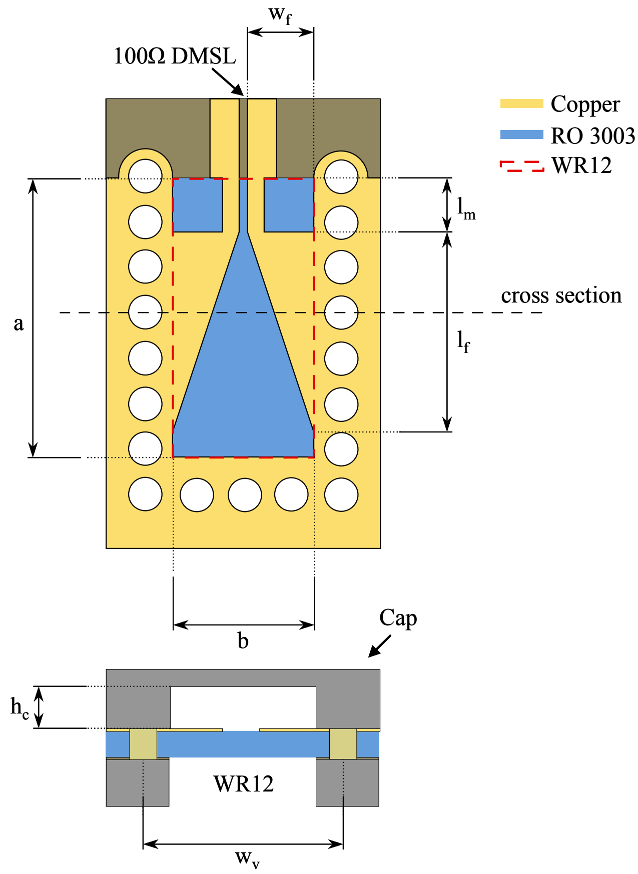

Figure 4: Top view and cross section of the transition.

TABLE II. DIMENSIONS OF THE TRANSITION

a	b	l_m	l_f	w_f	h_c	w_v
3.1 mm	1.55 mm	0.6 mm	2.25 mm	0.725 mm	0.42 mm	2.15 mm

III. MEASUREMENTS

The antenna was fabricated (c.f. Fig 5), and measurements were carried out in an anechoic chamber. Fig. 6 shows a good agreement between simulated and measured return loss of the antenna. The simulation includes the waveguide to differential microstrip line transition used in the measurements. A wideband impedance bandwidth is achieved.

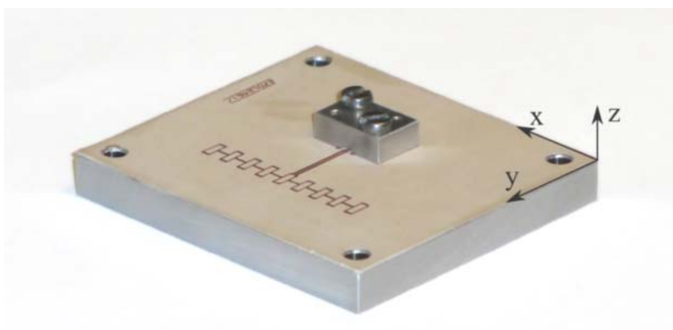

Figure 5: Photography of the fabricated antenna including mounting and the waveguide to differential microstrip transition.

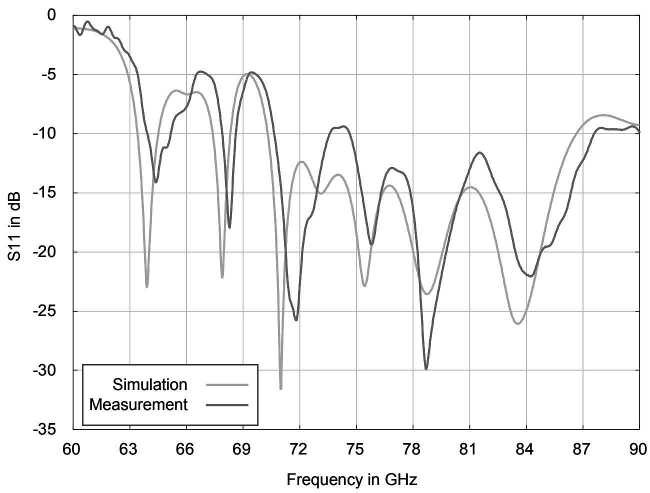

Figure 6: Simulated vs. measured return loss.

The measured and simulated radiation patterns in the E-plane are shown in Fig. 7 – Fig. 10. The antenna shows a good performance in terms of side lobe level, which is lower than −18 dB at 79.5 GHz. Deviations between measurement and simulation are most likely due to a reduced permittivity of the used substrate. Fig. 11 shows the radiation pattern in the H-plane at 79 GHz. The beam variation in the H-plane over the operating frequency range is insignificant. An asymmetry is observed for large angles due to a shadowing effect of the waveguide transition. A comparison between simulated and measured absolute gain can be found in Fig. 12. It shows that the antenna offers a high gain of 16 dBi including the transition loss in both, simulation and measurement.

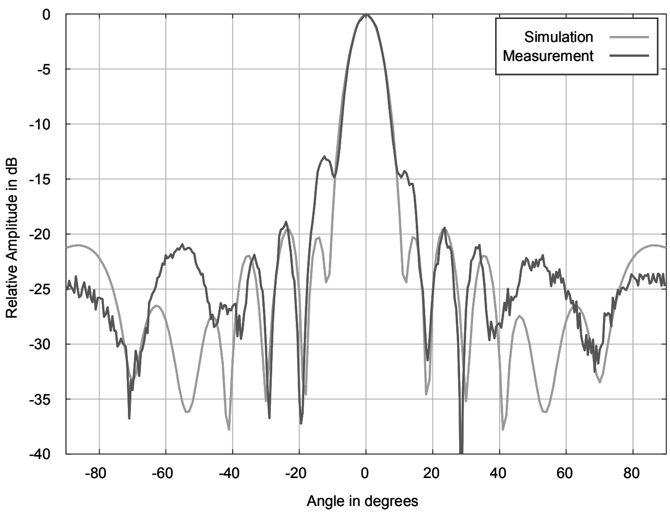

Figure 7: Radiation pattern in the E-plane at 78.5 GHz.

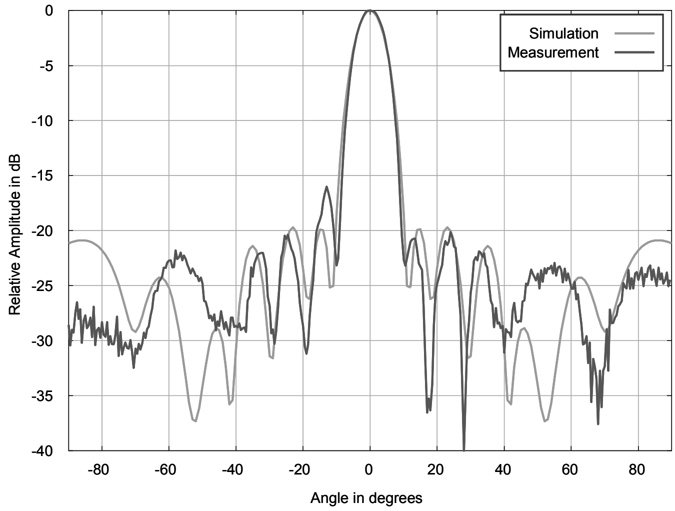

Figure 8: Radiation pattern in the E-plane at 79 GHz.

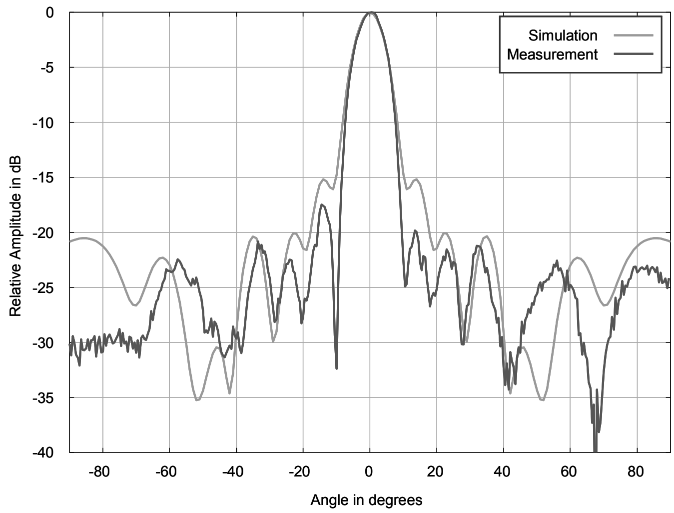

Figure 9: Radiation pattern in the E-plane at 79.5 GHz.

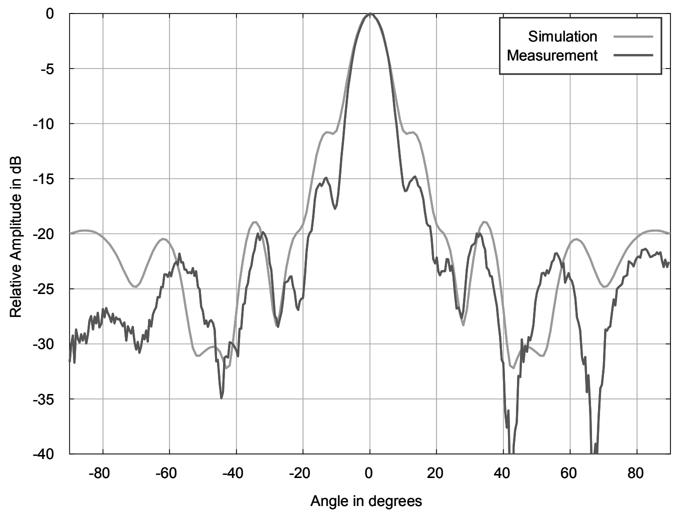

Figure 10: Radiation pattern in the E-plane at 80 GHz.

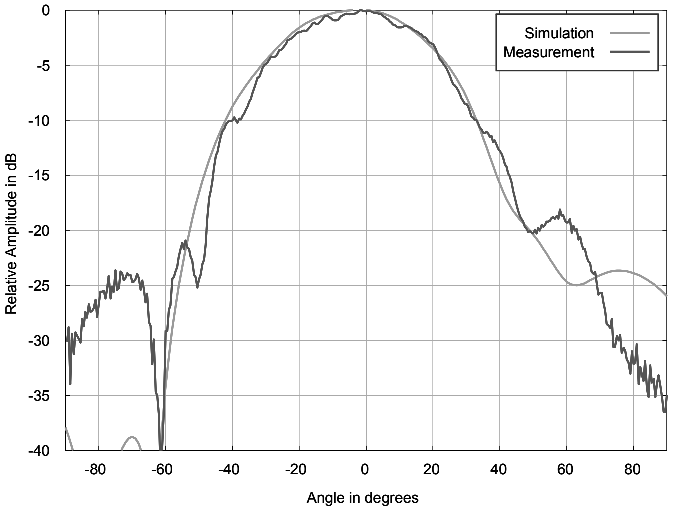

Figure 11: Radiation pattern in the H-plane at 79 GHz.

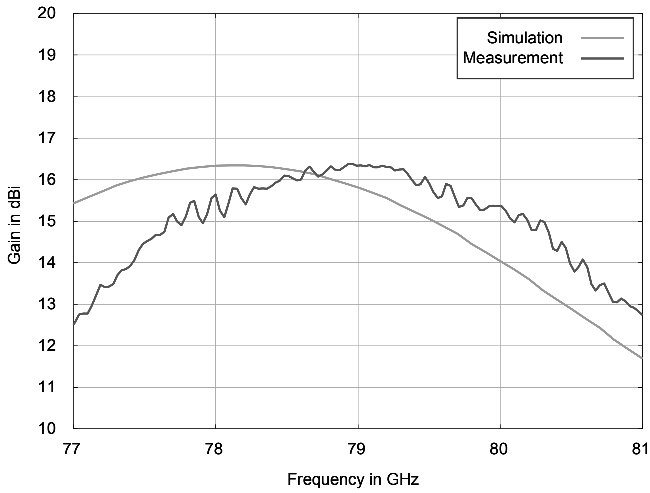

Figure 12: Broadband gain of the antenna (measured and simulated including the transition).

CONCLUSION

A microstrip grid array antenna fed by a differential microstrip line has been proposed. The antenna was realized on a single layer of Rogers RO3003 substrate. It offers a wideband impedance bandwidth. The measured far field patterns show a feasible frequency range of roughly 2 GHz and a maximum gain of 16 dBi.

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