300-GHz Antenna-in-Package in LTCC

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***Abstract*—This paper presents a 300-GHz differential microstrip grid array antenna, aiming at its integration in low-temperature co-fired ceramic (LTCC) as an antenna-in-package module. The antenna has a size of 2460×1260×95 μm^2. It has achieved excellent performances: 14.9% impedance bandwidth, 12.3% gain bandwidth, and 13.7-dBi gain at 300 GHz.**

I. INTRODUCTION

AN antenna or array plays a crucial role in a THz radiation source. Most conveniently, an on-chip antenna or array is used that is directly integrated with the THz signal-generation circuit on the same substrate. However, the substrate will inevitably create surface wave modes that result in poor radiation of the on-chip antenna into the air. This problem has been attacked by antenna designers in different ways for many years with their effort early focused on gallium arsenide and recently turned into silicon substrates. Perhaps the most unusual way is to take the advantages of substrate radiation by coupling energy through a lens on the back of the substrate. The lens should have the same dielectric constant as the substrate and the minimum radius for acceptable operation being one free-space wavelength for silicon. The lens also requires a matching layer to reduce reflection losses at the air-dielectric interface. The technology of quarter-wavelength matching layers is not well developed [1]. In this paper, we propose not to integrate the THz antenna with the THz circuit in the same chip but integrate the THz antenna in the package that carries the THz chip [2]. In Section II, we present an antenna-in-package design for applications at 300 GHz in LTCC. We summarize the paper in Section III.

II. RESULTS

Fig. 1 shows the microstrip grid array antenna. The radiator on the top layer has 11 optimized rectangular loops on Ferro's LTCC substrate backed by a metallic ground. The long sides of the loops are operated as transmission lines and the short sides of the loops are operated as both radiators and transmission lines. The lengths of the long and short sides of the loops are about one guided wavelength and half guided wavelength, respectively. The antenna has a size of 2460×1260×95 μm^2.

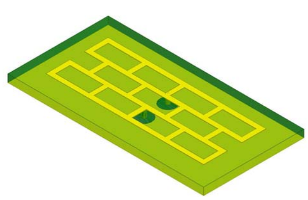

Fig. 1. The microstrip grid array antenna.

Fig. 2 displays the simulated current distributions on the microstrip grid array radiator at 300 GHz. The instantaneous currents on the long sides are out of phase, leading to a weak cross polarization radiation. The currents on the short sides are almost in phase which result in a main beam in the broadside direction.

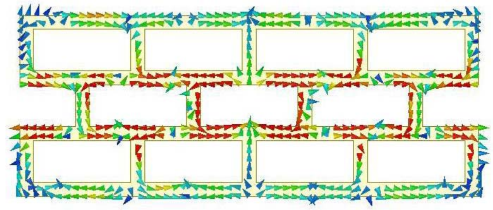

Fig. 2. Current distribution on the microstrip grid array antenna at 300 GHz.

The simulated $|S_{d11}|$ versus frequency is shown in Fig. 3. The measured 10-dB impedance bandwidth is 44.6 GHz from 286.1 GHz to 330.7 GHz (or 14.9% at 300 GHz). The simulated peak realized gains versus frequency is also shown in Fig. 3. The simulated maximum realized gain is 13.7 dBi at 301.9 GHz and the simulated 3-dB gain bandwidth is 39.7 GHz from 275.6 GHz to 315.3 GHz (or 13.2% at 300 GHz).

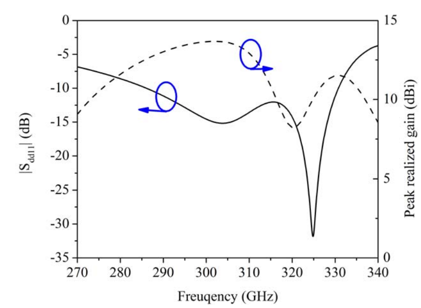

Fig. 3. Simulated $|S_{11}|$ and peak realized gain versus frequency.

The simulated radiation patterns are shown in Fig. 3. Both the E-plane and the H-plane patterns have the main beam of radiations in the broadside direction. The simulated half-power beamwidths of the radiation beam are 60° and 30° in the E-plane and the H-plane, respectively.

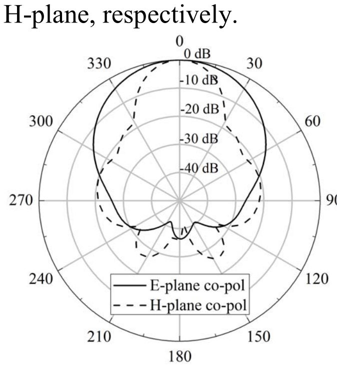

Fig. 4. Simulated radiation patterns at 300 GHz.

REFERENCES

[1]. Y. P. Zhang, "THz on-chip antennas," in Proc. *Int. Workshop on Antenna Technology,* Seoul, Korea, 4-6 March 2015.

[2]. Y. P. Zhang, D. Liu, "Antenna-on-chip and antenna-in-package solutions to highly-integrated millimeter-wave devices for wireless communications," *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 10, pp. 2830-2841, October 2009..