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CMOS-based THz detector with on-chip amplifier for imaging applications

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The non-ionizing nature of terahertz radiation together with the ability to penetrate through common packaging materials have sparked significant interest in THz non-destructive imaging applications. There is a huge need for low-cost and compact THz systems, which will grow with the further discovery of potential THz wave applications. A natural solution to this issue is the usage of mainstream semiconductor technologies, such as complementary metal-oxide-semiconductor (CMOS) lines. The understanding of device properties and the performance of CMOS-based detectors are constantly improving, resulting in high sensitivity, low noise, and broadband devices.

Mentioned detector improvement stimulates the research aimed at the readout circuits addressed to these devices. The integration between CMOS-based detector and on-chip readout electronics seems to be a natural solution. This attitude is optimal from the system performance point of view: the path between detector output and readout input is minimized. This opens up the way for the possibilities in the field of THz systems development and miniaturization.

In this study, we concentrate on a lower range of THz frequencies - the vicinity of 300 GHz. Two different types of integrated antennas have been implemented: a patch-type antenna for the front-side radiation coupling and a slot dipole antenna for the coupling with the substrate or booster lens. Furthermore, we extend our research toward the on-chip integrated amplifier. These solutions are not mutually exclusive and can be combined to achieve the best performance.
Although the best practical performance is achieved with substrate lens coupled devices, patch antenna coupling brings the advantage of a strong reduction in packaging complexity. The disadvantage of patch-antenna coupled detectors is the relatively small effective area of the antenna, which limits its total efficiency compared to a backside-illumination solution with the slot antenna. This shortcoming can be improved by an additional dielectric lens attached to the top of the patch.

The output signal amplifies can be realized by using an integrated amplifier implemented on the same chip. Noise-optimized design and minimized distance between the detector output and amplifier input results in cost-efficient devices without the deterioration in the SNR (signal-to-noise ratio). This work uses an integrated circuit based on a differential pair loaded by two resistors to achieve a voltage gain of 20V/V (26dB).

Described above solutions enable to increase of the output signal (and the practical SNR) by a total factor of approx. ~160 (at 275 GHz of radiation frequency for patch antenna detector), where the factor x8 is related to the increased effective area as well as improved efficiency of the antenna and the factor of x20 - due to the amplifier circuit.

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