High Performance On-Chip Array Antenna for Terahertz Integrated Circuits

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Abstract: In this letter a novel on-chip array antenna is investigated which is based on CMOS 20µm Silicon technology for operation over 0.6-0.65 THz. The proposed array structure is constructed on three layers composed of Silicon-Ground-Silicon layers. Two antennas are implemented on the top layer, where each antenna is constituted from three sub-antennas. The sub-antennas are constructed from interconnected dual-rings. Also, the sub-antennas are interconnected to each other. This approach enhances the aperture of the array. Surface waves and substrate losses in the structure are suppressed with metallic via-holes implemented between the radiation elements. To excite the structure, a novel feeding mechanism is used comprising open-circuited microstrip lines that couple electromagnetic energy from the bottom layers to the antennas on the top-layer through slot-lines in the middle ground-plane layer. Simulation results show the proposed on-chip antenna array has an average radiation gain, efficiency, and isolation of 7.82 dBi, 32.67%, and -33 dB, respectively.

I. Introduction

Recently, the electromagnetic spectrum in the terahertz (THz) band has attracted great interest because of its potential applications in imaging, radio astronomy, spectroscopy, security control and communications. In such systems an antenna plays an important component to interface the terahertz signal with free-space. Various THz antennas have been reported in the literature including dipole antenna, spiral antenna, graphene antenna, leaky wave antenna, on-chip antenna, Yagi-Uda antenna and butterfly shaped antenna. Close examination of these antennas reveals their limitations, particularly in the way they interact with electromagnetic waves for optimum impedance matching necessary for effective detection and their construction [1-3].

In this letter, proposed is an array antenna which is based on CMOS 20µm Silicon with properties of small dimensions, low profile, design simplicity and ease of implementation. The simulation results presented demonstrate that the antenna exhibits a wide impedance bandwidth with relatively high radiation gain and efficiency. In addition, the isolation between the array's radiation elements is high, which makes it suitable for integrated circuits. The proposed structure employs a novel feeding mechanism which is based on metasurface slot-lines.

II. On-Chip Array Antenna Design with a Novel Feeding Mechanism

Fig. 1(a) shows the proposed on-chip array antenna constructed of two 20µm Silicon layers that sandwich a 20µm ground plane (GND). Two microstrip antenna structures are implemented on the top Silicon layer. Each antenna structure is composed of three sub-antennas, which are made of interconnected dual rings of different diameters. The three sub-antennas are connected to each other to enhance the arrays radiation properties. With this approach it is shown later the effective aperture of the antenna is increased thereby enhancing its radiation characteristics. Surface waves and substrate losses in the structure are suppressed with metallic via-holes implemented between the radiation elements. The antennas are exciting using a novel feed mechanism based on electromagnetically coupling energy from bottom layer to top layer. Fig. 1(b) shows the bottom side of the on-chip array antenna with two open-ended microstrip lines. In the GND plane slot-lines are etched to facilitate electromagnetic coupling of energy from the bottom to the top layer. The slot-lines in the GND plane are based on metasurface technique.

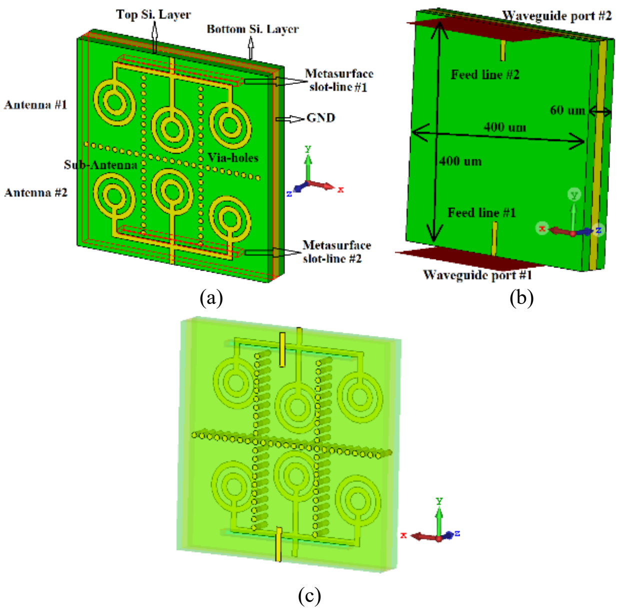

Fig.1. Proposed on-chip array antenna prototype.

S-parameter response of the proposed array antenna is shown in Fig. 2. The response covers the frequency range from 0.6 THz to 0.65 THz, which is corresponded to a fractional bandwidth of 8%. In addition, the isolation between the array elements is better than 20 dB over this frequency range, which illustrates the effectiveness of this array at detecting THz signals.

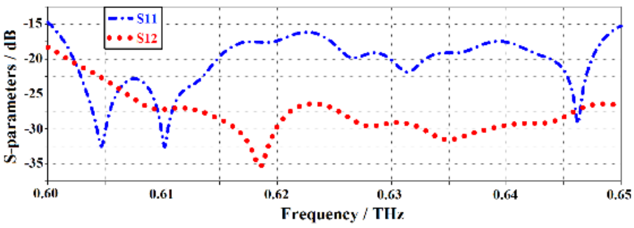

Fig.2. Reflection and transmission coefficients of the proposed on-chip array antenna.

The radiation gain and efficiency performance over the frequency range 0.6 THz to 0.65 THz is shown in Fig. 3. The maximum gain and efficiency observed at 0.63 THz are 8.1 dBi and 38.24%, respectively.

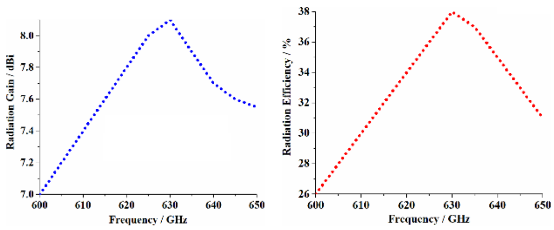

Fig.3. Radiation gain and efficiency plots.

III. CONCLUSION

Feasibility of an on-chip array antenna that exhibits high radiation gain and efficiency characteristics is demonstrated across a wide terahertz bandwidth between 0.60 THz to 0.65 THz. The array antenna is implemented on CMOS 20μm Silicon layers. Isolation between the sub-antennas constituting the array was increased by implementing metallic via-holes between the radiation elements. The array was excited electromagnetically using a novel feeding mechanism from the bottom layer. The results reveal the viability of the array antenna for THz integrated circuits.

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