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60 GHz On-Chip Patch Antenna Integrated in a 0.18-μm CMOS Technology

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1. Introduction

Millimeter-wave CMOS RF circuits have been received substantial attention, motivated by the advance of CMOS process [1]. In the millimetre-wave band, the connection, such as wire bonding or flip chip bonding, between the RF circuit and off-chip antenna is not easy task because of the radiation loss and/or adding parasitic components. To overcome the problem, on-chip antennas, which do not suffer from the problem of connection, have been studied by many researchers [2][3]. Accurate and appropriate modelling in simulation is very important to obtain agreement with measurement.

In this paper, a 60 GHz on-chip patch antenna integrated in a 0.18-μm CMOS technology is investigated by simulation and measurement. Very good agreement for frequency characteristic of reflection coefficient is observed between simulation and measurement, which enables further investigation by simulation.

2. On-Chip Patch Antenna

The configuration of an on-chip patch antenna is shown in Fig. 1. Antenna dimensions are shown in Fig. 1 (a). Chip photo is shown in Fig. 1 (b). The patch antenna is fed by a nearly 50Ohm microstrip line (MSL). In the measurement, a 100μm pitch GSG pad is used to attach with a GSG probe. The configuration of the GSG pad and MSL [4] is shown in Fig. 1 (c). The bottom metal layer is used for the ground plane of the MSL and the patch antenna. The top metal layer is used for the signal line of the MSL and the patch. The height h between the bottom metal to the top metal is about 5 to 10μm, and metal thickness is about 0.5μm to 1μm in commercial CMOS technology. The metal of the metal is aluminium and the insulator between the metal is SiO_2. There is a line with 625μm-length and 30μm-width between the MSL and the patch antenna for impedance matching.

3. Results

The frequency characteristic of reflection coefficient is shown in Fig. 2. The reference plane is shown in Fig. 1 (b). In the measurement, the influence of the pad is removed by de-embedding technique using thru and line patterns [5][6]. The reflection is about -10 dB at design frequency 62.5GHz. The simulated result agrees very well with the measured one both in amplitude and phase. The finite element method (FEM) based commercial software Ansys HFSS ver.11 is used in this paper for the simulation.

The simulation model is shown in Fig. 3 (a). The excitation is modelled by the lumped port with 50 Ohm impedance at the edge of the MSL. Conductor loss of aluminium is considered while dielectric loss is neglected in the simulation. Calculated radiation pattern is shown in Fig. 3 (b). Calculated peak gain and radiation efficiency were -14.5 dBi and 1.0 %, respectively. Therefore, it is found that the conductor loss is dominant in degradation of radiation efficiency in the on-chip patch antenna because the height h is very thin (~2/1000 wavelength).

Figure 4 shows calculated radiation efficiency as a function of MSL height *h*. It is found that radiation efficiency becomes large enough when *h* is larger than 100μm (~2/100 wavelength).

4. Conclusion

A 60 GHz on-chip patch antenna integrated in a 0.18-μm CMOS technology is evaluated by simulation and measurement. The agreement between measurement and simulation was very good in the frequency characteristic of reflection coefficient. The calculated peak gain and radiation efficiency were -14.5 dBi and 1.0 %, respectively. It is found that the conductor loss is dominant in degradation of radiation efficiency in the on-chip patch antenna when the height is very thin (~2/1000 wavelength). The radiation efficiency becomes large enough when height is larger than 100μm (~2/100 wavelength). Experimental evaluation of radiation pattern and radiation efficiency is a future task. Improvement of radiation efficiency is also remaining as a future study.

Acknowledgments

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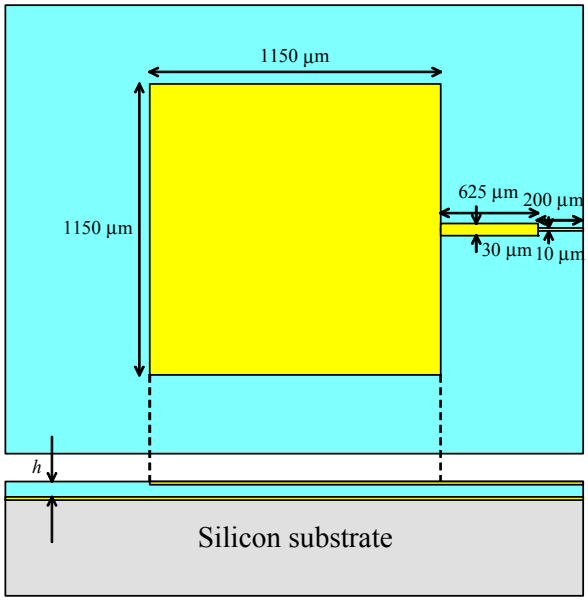
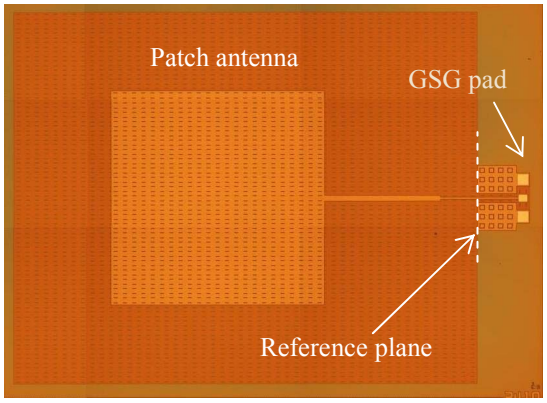
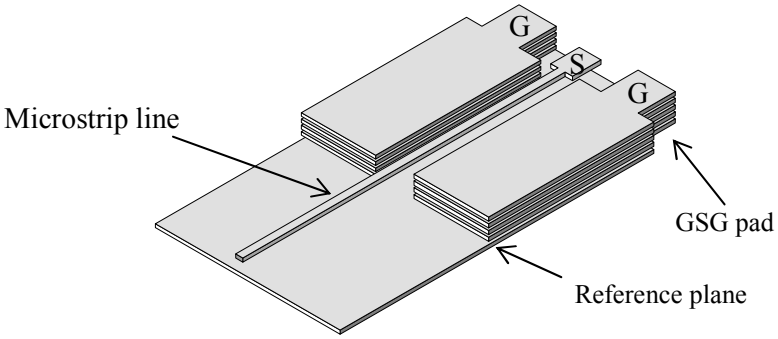


(a) Configuration of patch antenna



(b) Chip photo



(c) Configuration of GSG pad and microstrip line

Figure 1: On-chip patch antenna

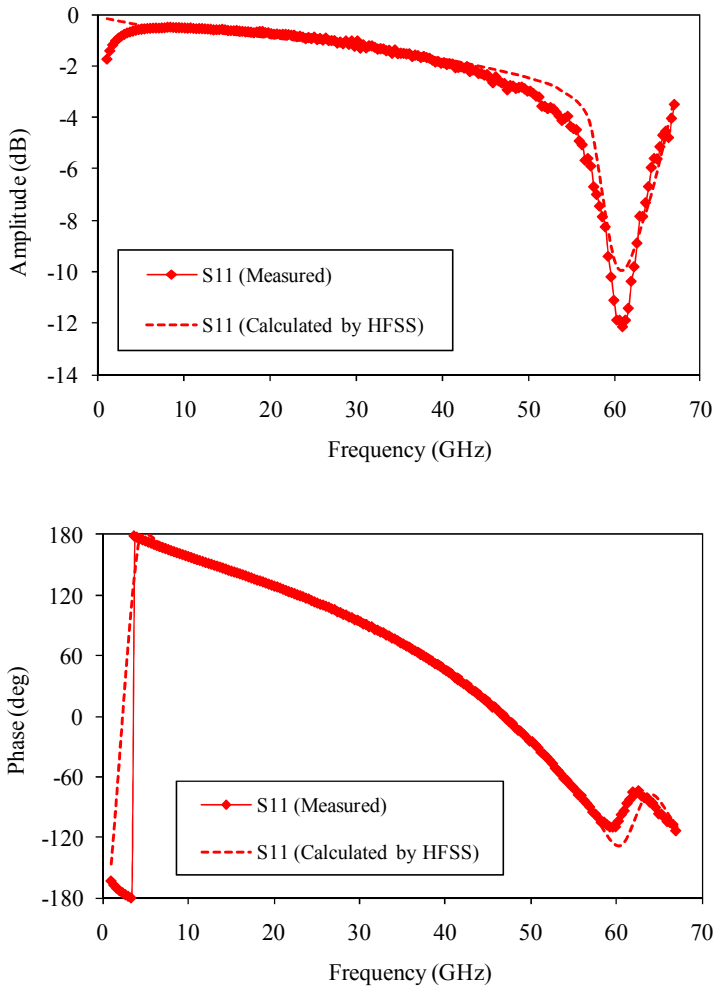
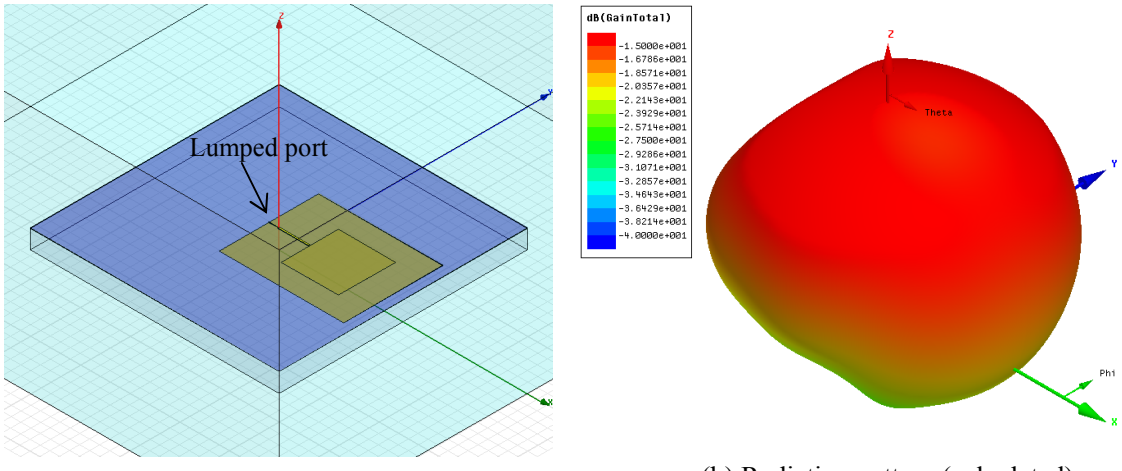


Figure 2: Frequency characteristic of reflection coefficient



(a) Simulation model

(b) Radiation pattern (calculated)

Figure 3: Simulation model and radiation pattern

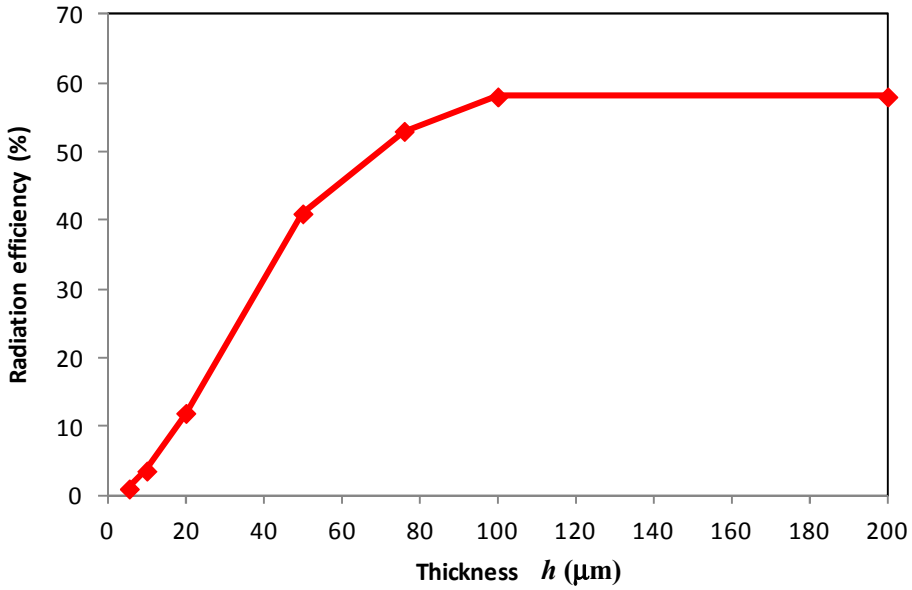


Figure 4: Radiation efficiency as a function of MSL height (calculated)

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