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Patch Antenna on a Thick Resin Layer Fed by Coaxial-Lines through a Hole in a Silicon Chip in the 60GHz Band

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***Abstract* - We have proposed to place a CMOS RF circuit and an antenna on each side of a silicon chip in the 60 GHz band, respectively, and to connect between them with low loss by a coaxial-line structure using a hole opening in the chip. To enhance the radiation efficiency, a patch antenna is placed on a thick resin layer. In this paper, we design a differential-feed square patch antenna on a silicon chip.**

***Index Terms* — patch antenna, millimeter wave, silicon chip, 60 GHz band, coaxial-line feeding, thick resin layer, differential antenna**

I. Introduction

There are many studies of antennas for the 60 GHz-band wireless personal area network. The antennas are categorized mainly in two types; on-chip and off-chip antennas. The on-chip antenna is placed on the same layer of an RF circuit on a silicon chip, and the off-chip antenna is placed separately from a silicon chip. The on-chip antenna has an advantage of a low connecting loss, however the radiation efficiency is quite low because of the thin (typically 5~10 μm) dielectric layer with the antenna. The off-chip antenna has an advantage of high radiation efficiency because the antenna height can be increased, however it has a large connecting loss between the antenna and the RF front-end (typically 1~2 dB). Thus, we proposed the configuration where an antenna is placed on the resin layer of about 200 μm thickness on the opposite side of a CMOS RF circuit as shown in Fig. 1 [1]. The thick resin layer can enhance the radiation efficiency. The antenna is directly fed through a hole in the silicon chip. Therefore the connection loss is expected to be small. We measured high a radiation efficiency of 75% by a reverberation chamber for a patch antenna placed on a thick resin layer [2]. Generally a CMOS circuit is driven differentially, and a differential-feed antenna is appropriate to integrate with the CMOS circuit. In this paper, we adopt rectangular patch antenna [3] and design a differential-feed patch antenna on a silicon chip.

II. Design

A. Antenna Design

Fig. 2 shows the configuration of the designed antenna chip. The size of the silicon substrate is a 5 mm square. To reduce the loss due to the silicon substrate, its surface is coated by copper. The resin is spread on the silicon chip with 200 μm thickness. The antenna is placed on the resin. The square patch antenna is differentially fed through a dual-core parallel coaxial line. The impedance of the coaxial line is adjusted to 50 ohm. The reflection is controlled by changing the size of the square patch.

The effective conductivity of the copper thin film is set to 2.0×10^7 S/m, which is a typical value of electro-deposited copper on a dielectric substrate at around 60.0 GHz [4]. The dielectric constant of the resin is 2.846 and the loss tangent is 0.0151. They are measured in the 50.0 GHz band. 150 μm diameter holes are opened in the resin-filled hole to insert copper pins as the cores of the coaxial line structure. The design frequency is 60.0 GHz.

B. Characteristics

Fig. 3 shows the designed frequency characteristics of the reflection. The designed result shows that the bandwidth for the reflection < -10 dB is 6.0 %.

Fig. 4 shows the designed radiation patterns at 60.0 GHz. -3 dB-down bandwidth is 76.4 degrees in the E-plane and 75.7 degrees in the H-plane. The designed directivity and gain are 7.9 dBi and 7.0 dBi, respectively. The radiation efficiency of the antenna is calculated to be 79 %.

C. Test Jig

The antenna chip is too small to connect with a measuring instrument directly. To connect the antenna chip to a V-band waveguide, we prepare a test jig. Fig. 5 shows the connection of the antenna chip, the test jig, and the V-band waveguide. Same two antenna chips are jointed, and these antenna patches are connected through pins which are the cores of the coaxial line. This jointed antenna chip is fixed between a washer and a fixing plate by screws. An electromagnetic wave is received in the antenna A and converted into a differential signal. The antenna B is fed this differential signal through the coaxial–line structure and radiates an electromagnetic wave.

This jig should be added to the analysis model of the antenna chip to consider the loss and the diffraction phenomena by it.

III. CONCLUSION

We design the patch antenna differentially fed by the coaxial-line structure through a hole in a silicon chip and a test jig.

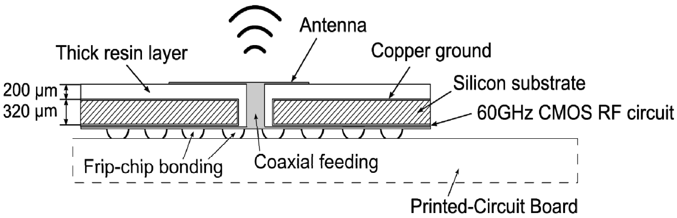
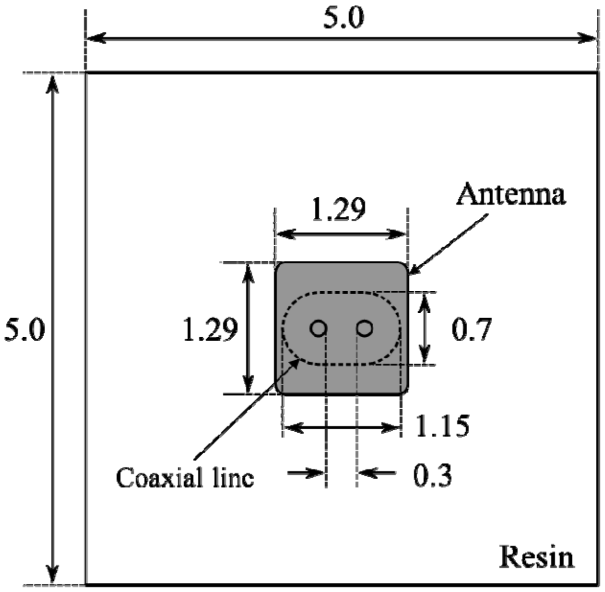
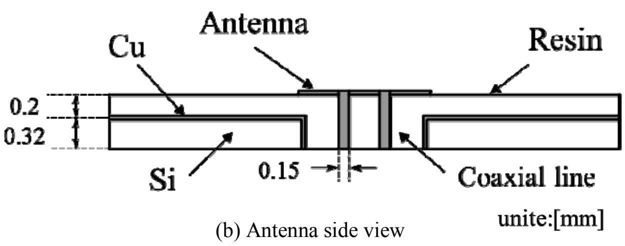


Fig. 1. Configuration of the proposed antenna on a silicon chip



(a) Antenna top view



(b) Antenna side view

Fig. 2. Antenna Structure

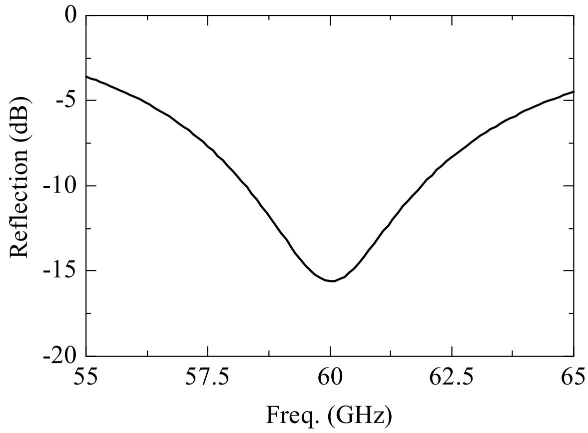


Fig. 3. Reflection

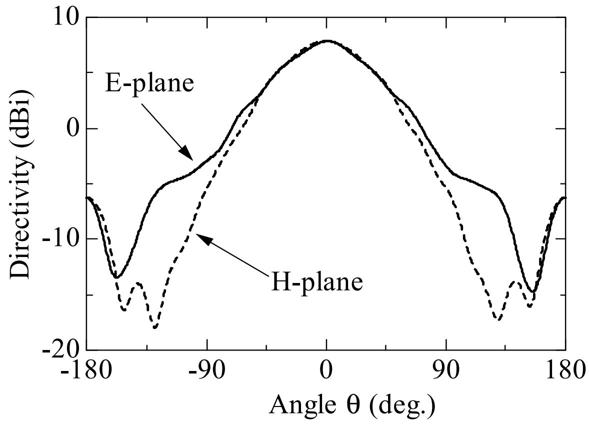


Fig. 4. Radiation pattern of the antenna

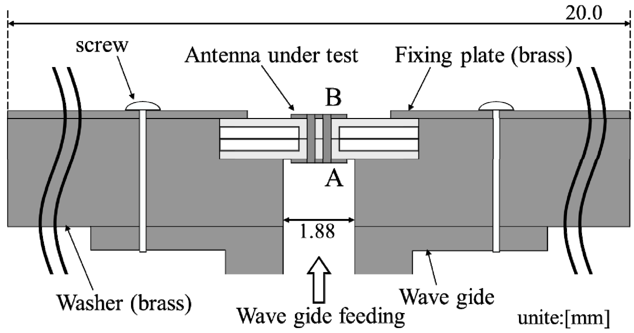


Fig. 5. Test jig

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