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CMOS Circuit Design Techniques for Millimeter-wave Applications

Ryuichi Fujimoto[1], Toshiya Mitomo[2], Hiroaki Hoshino[2] and Yoshiaki Yoshihara[1]

[1]Toshiba Corporation, Semiconductor Company
580-1, Horikawa-Cho, Saiwai-Ku, Kawasaki 212-8520, Japan
Phone: +81-44-548-2722 E-mail: ryuichi.fujimoto@toshiba.co.jp
[2]Toshiba Corporation, Corporate Research & Development Center
1, Komukai Toshiba-Cho, Saiwai-Ku, Kawasaki 212-8520, Japan

1. Introduction

Recently, millimeter-wave LSIs and its applications attract considerably attentions. As shown in Fig.1, wide frequency range of over 7 GHz near 60 GHz can be used as an unlicensed band, and such wide frequency range is very attractive for high data rate communications. On the other hand, automotive radars have been introduced in markets; however, it is still an expensive option for the luxury models. To spread these millimeter-wave applications widely in the world, low-cost millimeter-wave LSIs are necessary.

In this paper, CMOS circuit design techniques for millimeter-wave applications are presented. Measured results of the fabricated millimeter-wave LSIs are also presented and some issues are discussed.

2. Circuit Design Techniques

Thanks to advanced CMOS [1] and SiGe BiCMOS [2] processes, many millimeter-wave LSIs were published [3]-[8]. One of the major issues for the millimeter-wave LSI is serious influence of the parasitic elements.

Fig. 2 (a) and (b) show typical single-ended and differential LNAs, respectively. The single-ended LNA in Fig. 2 (a) is very sensitive to parasitic elements due to layout designs, bonding wires and so on. The performances of the single-ended LNA are degraded by such the parasitic elements. On the other hand, the differential LNA in Fig. 2 (b) is robust to the parasitic elements. It is because common-mode nodes such as points A, B and C in Fig.2 (b) are act as a ground node for differential signals. And, parasitic elements at these common-mode nodes do not affect to the differential performances. Therefore, differential configurations are suitable for the millimeter-wave LSIs.

To adopt differential configurations, there is an issue how convert single-ended signals to differential signals. One of the solutions is to use Marchand baluns shown in Fig. 3. The Marchand baluns are composed of four $\lambda/4$-transmission lines, and two pairs of the transmission lines are coupling with each others. It is required relatively low coupling constant for the Marchand baluns, they are suitable for fabricating using CMOS processes: however, careful design considerations are required for realizing low-loss performances.

Another solution to convert single-ended signals to differential signals is adopting differential antennas. Fig. 4 shows an example using an on-chip differential antenna in receiver. By adopting the on-chip differential antenna, the fully differential configuration is realized in the LSI; however, due to large parasitic capacitance to Si-substrate and a resistivity loss in Si-substrate, it is difficult to realize large antenna gains by using on-chip antennas.

3. Measured Results and Discussions

A millimeter-wave receiver [6] with a synthesizer [7] and the power amplifier [8] are fabricated using 90-nm CMOS process. The block diagram and die photograph of the receiver are shown Figs. 4 and 5, respectively. Fig.6 shows schematic and layout diagrams of the LNA in the receiver, and Fig. 7 shows measured S-parameters of the LNA. In the differential mode, good impedance matching and high gain performances are realized, on the other hand, the gain is low in single-ended mode. The gain degradation is due to parasitic elements at ground and voltage-supply lines. These measured results show merits of the differential circuit configurations in millimeter-wave LSIs.

The block diagram and die photograph of the PA are shown in Figs. 8 and 9, respectively. Fig. 10 shows measured S-parameters of the PA. By adopting the Marchand balun based power combiner, good impedance matching in both differential- and single-end modes, high-gain performances are realized at 60-GHz band.

4. Conclusions

The CMOS circuit design techniques for millimeter-wave applications are presented. The measured results of the fabricated LSIs show merits of the differential circuit configurations in millimeter-wave LSIs. To spread the millimeter-wave applications widely, continuously developments of the CMOS millimeter-wave LSIs are necessary.

References

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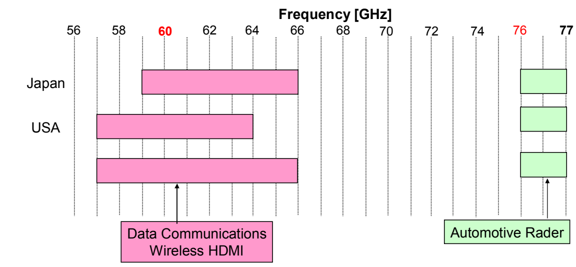

Figure 1: Millimeter-wave applications

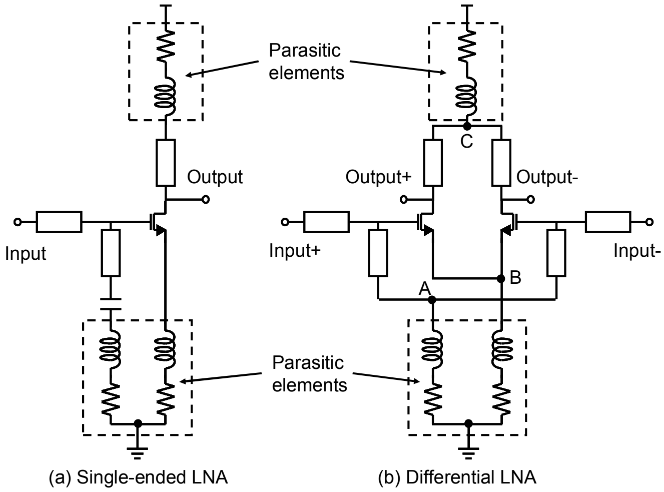

Figure 2: Circuit configurations and parasitic elements

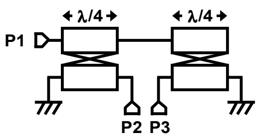

Figure 3: Marchand BALUN

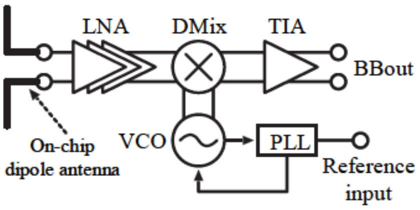

Figure 4: Block diagram of the receiver

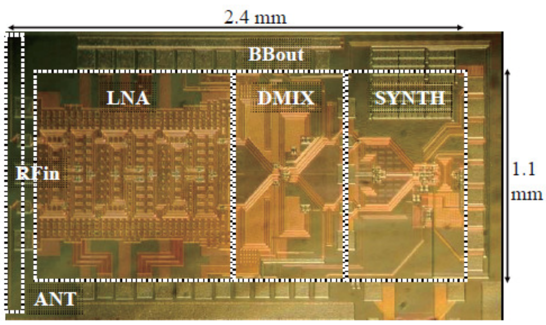

Figure 5: Die photograph of the receiver

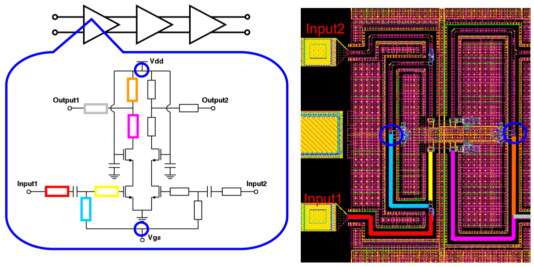

Figure 6: Schematic and layout of the differential LNA

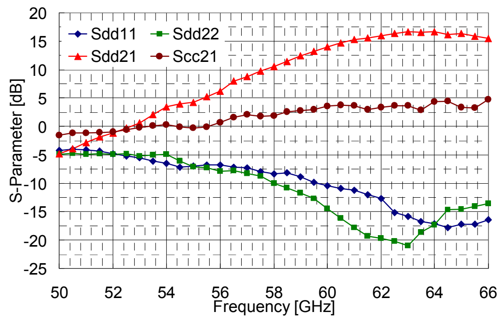

Figure 7: Measured S-parameters of the differential LNA

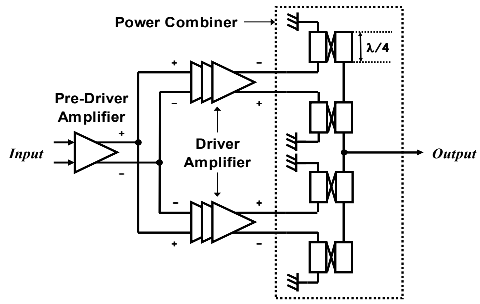

Figure 8: Block diagram of the PA

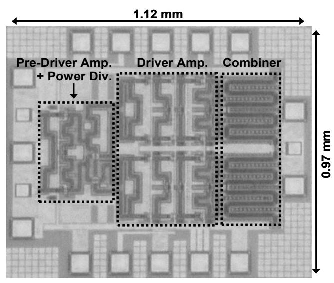

Figure 9: Die photograph of the PA

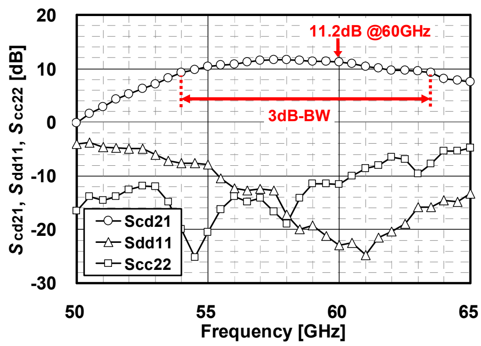

Figure 10: Measured S-parameters of the PA