60GHz 帯の回路設計における伝送線路間のカップリングに関する研究

A research on the coupling of transmission lines in 60 GHz circuit design

ヌルル ファジュリ　　河合　誠太郎　　岡田 健一　　松澤 昭
Nurul Fajri　　Seitarou Kawai　　Kenichi Okada　　Akira Matsuzawa

東京工業大学大学院理工学研究科電子物理工学専攻
Department of Physical Electronics, Tokyo Institute of Technology

1. Introduction

In 60 GHz circuit design, transmission lines are mainly utilized for designing matching blocks [1]. In many cases, the demand on reducing the circuit area causes transmission lines need to be arranged very close each other. Therefore, the signal coupling between transmission lines cannot be ignored since it may result in undesirable circuit performance degradation.

In this paper, the signal coupling between transmission lines is investigated. Furthermore, the signal coupling between transmission lines in the input and output sides of 1-stage amplifier circuit and its effect on amplifier circuit performance are studied.

2. Transmission Lines Coupling

The structure of transmission line is shown in Fig. 1. It has a 4 µm signal-line width and a 15 µm ground-to-ground gap. This structure and its dimensions are optimized to reduce insertion loss and to obtain a characteristic impedance of 50 Ω. The ground side-wall has a 5 µm width and can be overlap-arranged so that the minimum distance between two transmission lines is 16 µm.

As shown in Fig. 2, 4-port S-parameters simulation is used to investigate the signal coupling between two transmission lines which are *d* µm separated by ground side-wall. Here, S_{14} (or S_{41} = S_{23} = S_{32}) shows the power of the signal which is coupled between transmission lines. In this paper, S_{14} is analyzed with respect to the distance between two transmission lines. Simulation is conducted using electromagnetic field solver software.

3. Simulation Results and Analysis

Fig. 3 shows the simulation results of S_{14} depending on the distance. According to the simulation results, it shows that the closer distance between transmission lines the more signal is coupled, with the maximum value is -40 dB when both transmission lines are 16 µm separated. These results mean that transmission lines can be closely arranged when the signal travelling through them is relatively weak. However, the signal coupling cannot be ignored if the signals power are different such as the signal coupling between the input and output sides of amplifier.

A 1-stage amplifier, as shown in Fig. 4, is designed to investigate the effect of the signal coupling between the input and output sides to circuit performance. Fig. 5 shows the amplifier simulation result. The peak power gain of amplifier designed with considering the signal coupling is shifted in lower frequency compared to conventional design which is not considering the signal coupling. From this result, it is confirmed that the signal coupling is one of the crucial factors affecting the circuit performance and has to be taken into account in circuit design.

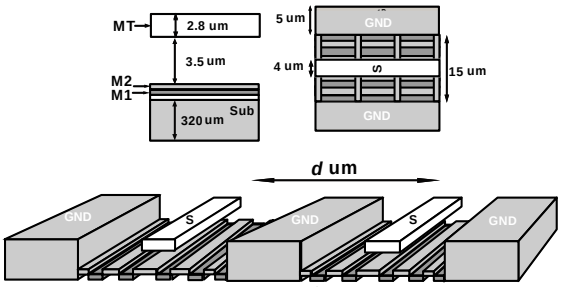

Figure 1: The structure of transmission line

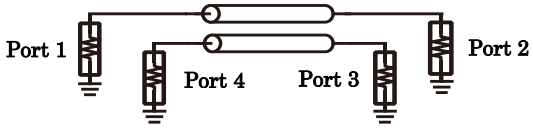

Figure 2: Schematic of coupled TL model for simulation

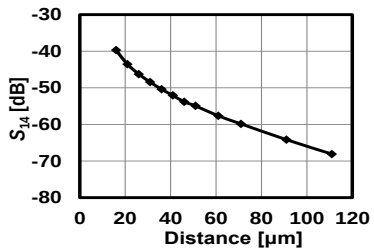

Figure 3: Signal Coupling depending on distance between TLs

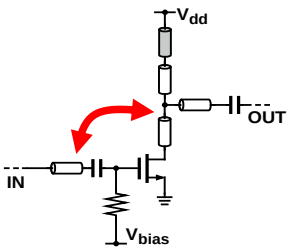

Figure 4: 1-stage Amplifier

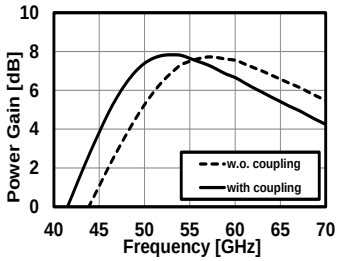

Figure 5: 1-stage Amplifier Power Gain

4. Conclusion

The simulation results of signal coupling between transmission lines are presented in this paper. Afterwards, the effect of the signal coupling to amplifier circuit performance is confirmed in term of power gain peak is shifted in frequency.

Acknowledgements

This work was partially supported by MIC, SCOPE, MEXT, STARC, Canon Foundation and VDEC in collaboration with Cadence Design Systems, Inc., and Agilent Technologies Japan, Ltd.

References

[1] K. Okada, *et al.*, *IEEE Journal of Solid-State Circuits*, Vol. 48, No. 1, pp.46-65, Jan. 2013