Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.308-309

D-5-3

Analysis of Transmission Characteristics of Gaussian Monocycle Pulse for Silicon Integrated Antennas

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1. Introduction

According to the scaling rule for silicon ultra-large scale integrated circuits (ULSI),[1] operation frequency and power consumption of ULSIs can be reduced by reducing the feature sizes of the metal-oxide-semiconductor (MOS) transistors.[2] However, conventional metal interconnects will have limitation in global clock frequency of ULSI for high speed operation at 3-4 GHz due to parasitic RC (resistance-capacitance) delay.

In order to overcome this problem, a new concept of wireless interconnection using Si integrated antennas has been proposed to send signals by electromagnetic wave so that both parasitic capacitance and resistance can be eliminated.[3,4] The conceptual diagram of ULSI intra-chip wireless interconnection using integrated antenna is shown in Figure 1. Si integrated antennas are fabricated on Si-ULSI so that the ultra-wideband (UWB) signals can be sent from a transmitting antenna on a chip having a function and received by a receiving antenna on another chip having different function by electromagnetic wave propagation.

In this study, we analyzed transmission characteristics of Gaussian monocycle pulses as a UWB signal for Si integrated antennas.

2. Experimental

P-type (100) Si wafers with resistivities of 10 and 2290 Ω·cm were prepared as substrates which thickness of 260 μm. The Si surface was oxidized by pyrogenic oxidation at 1050˚C to form 0.3 μm thick field SiO_2. A 1.0 μm thick aluminum layer was deposited on the SiO_2 layer by direct current (DC) magnetron sputtering, and then integrated dipole antenna patterns were formed using HL-700 electron-beam lithography. Figure 2 shows the fabricated integrated dipole antennas. The antenna lengths (L) were changed from 3 to 6 mm, its width was 10 μm and distance between antennas (d) was fixed to 5 mm. A wafer level measurement set-up for Scattering parameter (S-parameter) in frequency domain is shown in Fig. 3. It consists of HP8510C Vector Network Analyzer, 180° Hybrid Couplers (6-26.5 GHz), probe station and Signal-Signal (SS) probes. Wafers were measured on wood (2.6 mm thick) on the metal chuck of the probe station. The relative dielectric constant of wood was 2.15 at 1 GHz.[4] From measured S-parameters, reflection coefficient (S_{11}) and transmission coefficient (S_{21}), antenna transmission characteristics were investigated in the frequency domain. Figure 4 shows a measurement set-up for antenna transmission characteristics in the time domain. It is composed of Agilent N4902A Serial BERT, two impulse forming networks, and Agilent 86100B sampling oscilloscope.

Analysis of the transmission characteristics was carried out. S-parameters of antennas were calculated by 3-dimensional electromagnetic field simulator MW-Studio (CST). Transient waveform simulation was carried out by HSPICE using the calculated S-parameters. Measured time domain waveforms were compared with HSPICE simulation.

3. Results and Discussion

Figure 5 shows S_{11} versus frequency. Calculated results S_{11} (solid line) were consistent with the measured data. Figure 6 shows S_{21} versus frequency. Calculate results of S_{21} (solid line) fit well in the frequency from 6 to 10 GHz. However, measured S_{21} were lower than the calculated values in the resonant frequency range (10-20 GHz) due to the lower Q of antenna caused by the loss in the 10 Ω·cm Si substrate. Figure 7 shows calculated antenna impedance versus frequency. Calculated impedance fit well with the measured results. Figure 8 shows equivalent circuit schematic diagram of a measurement set-up. In order to improve received voltage amplitude, load impedance R_L should be increased compare to antenna impedance. Figure 9 shows comparison of calculated Gaussian monocycle pulse waveform with measured results at the receiver antenna on the 10 Ω·cm Si substrate. The received waveform was simulated very well. Figure 10 shows the effect of load impedance on the received voltage waveform. The peak-to-peak voltage versus load impedance is shown in Fig. 11. Voltage gain was improved approximately 5 times by increasing the load impedance from 50 Ω to 100 kΩ.

4. Conclusion

Transmission characteristics of Gaussian monocycle pulse for Si integrated antennas were analyzed. It is found that the received antenna voltage gain can be improved 5 times by increasing the load impedance from 50 Ω to 100 kΩ.

Acknowledgements

This work is supported by the Ministry of Education, Culture, Sports, Science and Technology under the 21st Century COE program and the Grant-in-Aid for Scientific Research.

References

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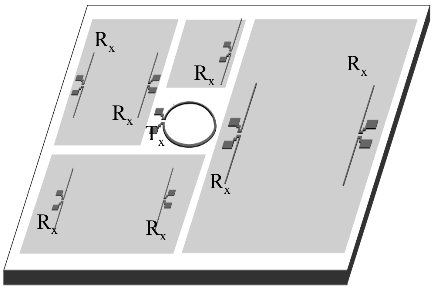


T_x : Transmitting antenna, R_x : Receiving antenna

Fig.1. Concept of intra-chip wireless interconnect using dipole antennas integrated in multiple Si ULSI chips.

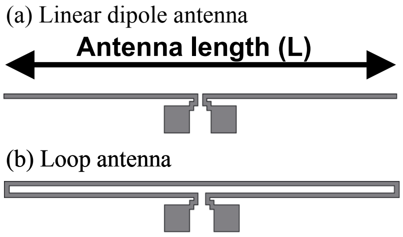


Fig. 2. Structure of integrated antennas (a) Linear dipole antenna, (b) Loop antenna

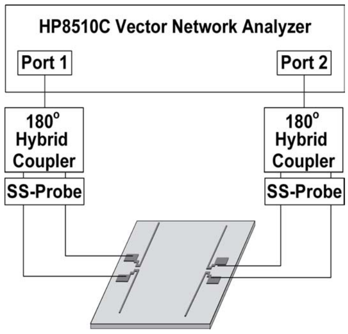
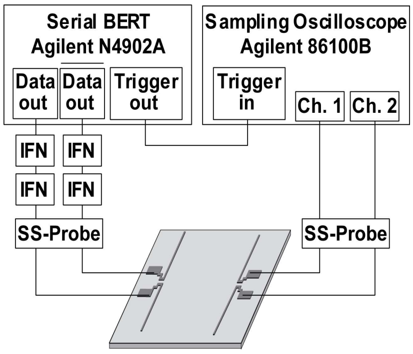


Fig. 3. Measurement set-up for antenna transmission characteristics in frequency domain.



IFN : Impulse Forming Network

Fig. 4. Measurement set-up for signal transmission characteristics in time domain.

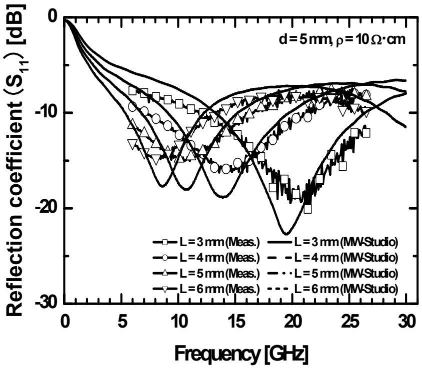


Fig.5. Reflection coefficient (S_{11}) versus frequency. (d=5 mm, ρ=10 Ω·cm)

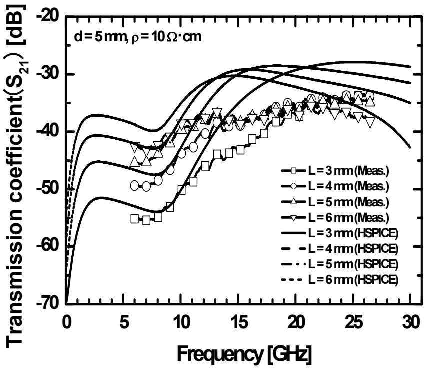


Fig.6. Transmission coefficient (S_{21}) versus frequency. (d=5 mm, ρ=10 Ω·cm)

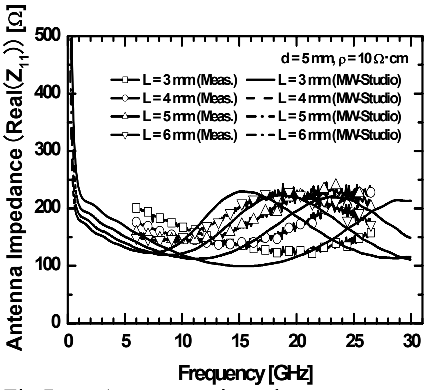


Fig.7. Antenna impedance versus frequency. (d=5 mm, ρ=10 Ω·cm)

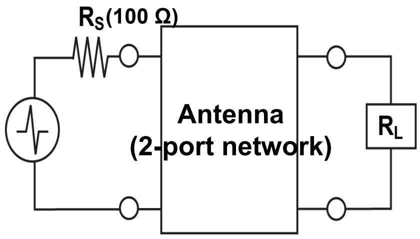


Fig.8. Equivalent circuit schematic diagram of a measured set-up.

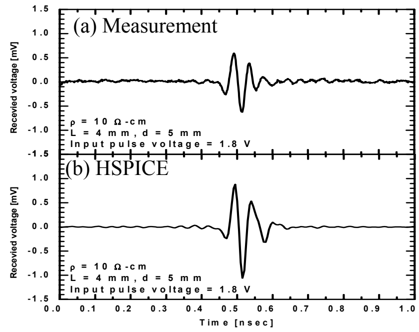


Fig.9. Comparison of calculated Gaussian monocycle pulse with measured received waveform. (L=4 mm, d=5 mm, ρ=10 Ω·cm)

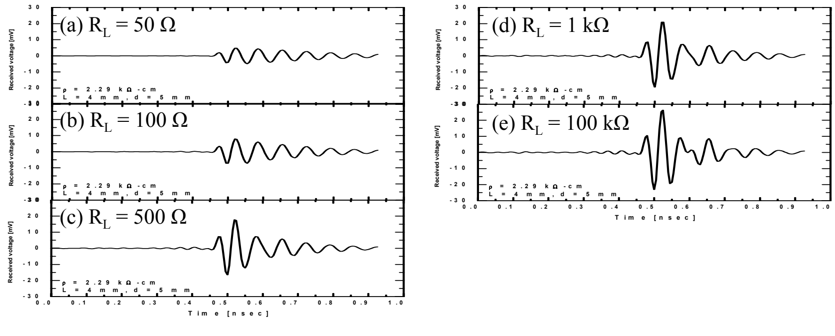


Fig.10. Effect of load impedance (R_L) on the received voltage waveform. (L=4 mm, d=5 mm, ρ=2.29 kΩ·cm)

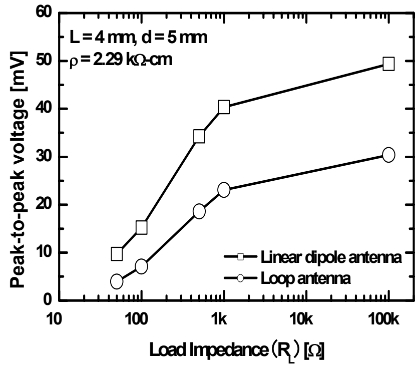


Fig. 11. Peak-to-peak voltage versus load impedance. (Antenna: L=4 mm, d=5 mm, ρ=2.29 kΩ·cm)