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Inter-chip Transmission Characteristics of Meander Dipole Antennas Integrated in 0.18 µm CMOS UWB Transceiver Chips

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1. Introduction

For future ultra-large scale integrated circuits (ULSI), three-dimensional (3D) integrated packaging technology is needed to overcome the limits in clock and data signal transmission between chips [1]. One of the problems in conventional 3D integrated packaging is resistance-capacitance (RC) delay in metal wiring. Wireless interconnection using integrated antennas is a candidate to solve this problem. We have proposed integrated antennas for inter-/intra-chip wireless communication using ultra wideband (UWB) which has been paid more attention for short distance and high-speed signal transmission [2-5].

In this study, we investigated inter-chip transmission characteristics of integrated meander dipole antennas fabricated by 0.18 µm CMOS technology and demonstrated transmitting and receiving UWB signals using Gaussian monocycle pulse generated by on-chip transmitter circuits.

2. Sample structure and Measurement

Figure 1 shows a photograph of an UWB transceiver chip fabricated by 0.18 µm CMOS technology with integrated meander dipole antennas for transmitting and receiving. The total length of meander antenna designed is 22.32 mm and its width is 10 µm as shown in Fig. 2.

A schematic diagram of transmitting and receiving antennas with stacked Si chips for inter-chip signal transmission is shown in Fig. 3. The horizontal distance between transmitting and receiving antennas is 2.65 mm. Si chips with resistivities greater than 50 MΩ·cm and thickness of 0.64 mm per chip were inserted between the transmitter and receiver chips in which integrated antennas and circuits were fabricated. The vertical distances of the antennas were 0.26-6.66 mm. The line of sight (LOS) distance between antennas was changed from 2.6 mm to 7.2 mm by increasing the number of inserted Si chips. The antenna transmission characteristics of the inter-chip stacked structure was investigated by vector network analyzer (HP8510C) in the frequency range of 1-12.4 GHz. Figure 4 shows measurement setup for inter-chip transmission characteristics of Gaussian monocycle pulse (GMP) generated by on-chip GMP transmitter circuits. The received signals of Gaussian monocycle pulse were observed by a real time oscilloscope (Agilent infiniium 12 GHz, 40 Gsa/s) via an amplifier (GaAs FET; SHF810, +30 dB). The on-chip transmitter circuits were consisted of voltage controlled oscillator (VCO), GMP generator, amplifier (Amp.), and source follower.

3. Results and Discussion

Figures 5 and 6 show reflection coefficient (S_{22}) for receiving antenna and transmission coefficient (S_{21}), when the LOS distance between transmitting and receiving antennas was changed from 2.6 mm to 7.2 mm by inserting Si chips with resistivites over 50 MΩ·cm. This integrated antenna has a resonance frequency at 4 GHz. S_{22} did not change with increasing the distance, but S_{21} decreased with the distance in the frequency range from 1 to 10 GHz.

Figure 7 shows the dependence of S_{21} on the LOS distance between antennas at 4 GHz. S_{21} decreased with $1/d^n$ in near-field range (n~3; d<3.5 mm at 4 GHz).

Figure 8 shows transmitted Gaussian monocycle pulse trains generated by the on-chip transmitter circuits, whose peak-to-peak voltage was 10 mV and data rate was 1 Gbps. Its frequency spectrum was shown in Fig. 9. The center frequency was 2.5 GHz.

Figure 10 shows the received peak-to-peak voltages as a function of distance for the signals transmitted through Si chips having high (ρ>50 MΩ·cm) and low (ρ=10 Ω·cm) resistivites, respectively. The received waveforms of Gaussian monocycle pulse at the distances of 2.6 mm and 7.2 mm are also shown in the Fig. 10. The peak-to-peak voltages at 2.6 mm and 7.2 mm distances were 32.4 mV and 4.9 mV via an amplifier. The waveform received at the distance of 2.6 mm was similar to that of the transmitted signal. On the other hand, the waveform received at the distance of 7.2 mm was the first derivative of the transmitted signal. This is attributed to the fact that the distances of 2.6 mm and 7.2 mm are corresponding to the near-field and far-field conditions, respectively. The received peak-to-peak voltages decreased with $1/d^{3.2}$ in the near-field (d<3.5 mm) and $1/d^{1.2}$ in the far-field (d>3.5 mm). The signal received via 10 Ω·cm Si chips showed steeper attenuation than that via 50 MΩ·cm Si chips due to the conductive loss of the Si chips. Consequently, the signal could be propagated with low attenuation in the far-field range beyond 3.5 mm with high resistivity Si chips.

4. Conclusion

The inter-chip wireless signal transmission using UWB signal generated by on-chip 0.18 µm CMOS circuits with meander antennas was demonstrated for 3D stacked Si chips.

Acknowledgements

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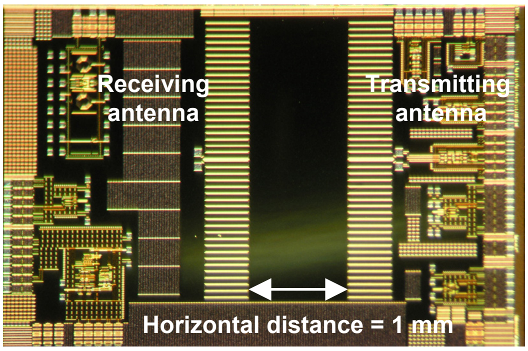

Fig. 1. Chip photograph of UWB transceiver circuits and meander dipole antennas using 0.18 μm CMOS technology.

Fig. 2. Schematic diagram of integrated meander dipole antenna (total antenna length = 22.23 mm, antenna width = 10 μm).

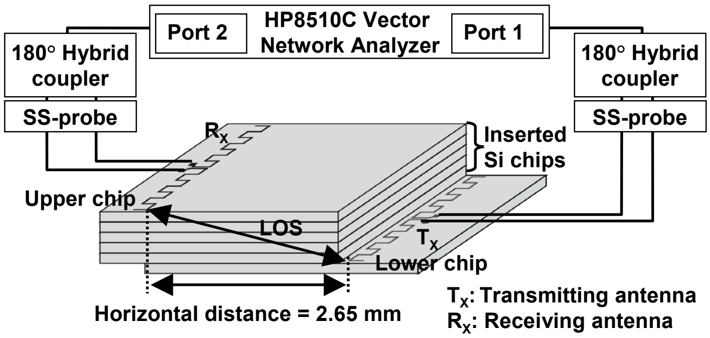

Fig. 3. Schematic diagram of transmitting and receiving antennas with stacked Si chips for inter-chip transmission measurement.

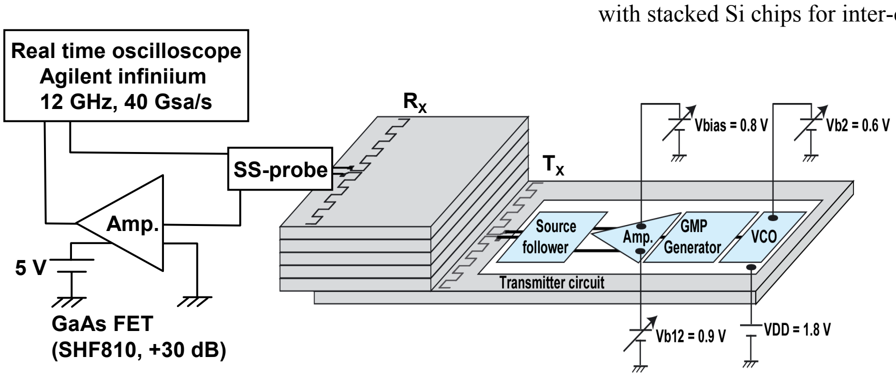

Fig. 4. Measurement setup for inter-chip transmission characteristics of Gaussian monocycle pulse (GMP) generated by on-chip GMP transmitter circuits.

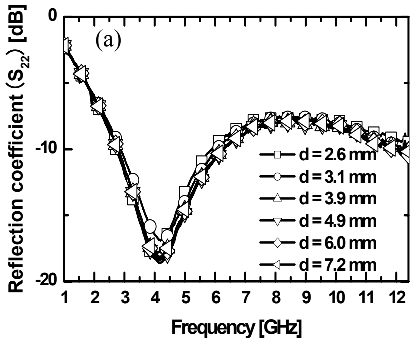

Fig. 5. Effect of the number of inserted Si chips with resistivities greater than 50 MΩ·cm on reflection coefficient (S_{22}) at the receiving antenna.

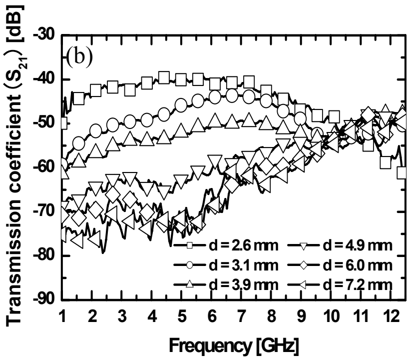

Fig. 6. Effect of the number of inserted Si chips with resistivities greater than 50 MΩ·cm on transmission coefficient (S_{21}).

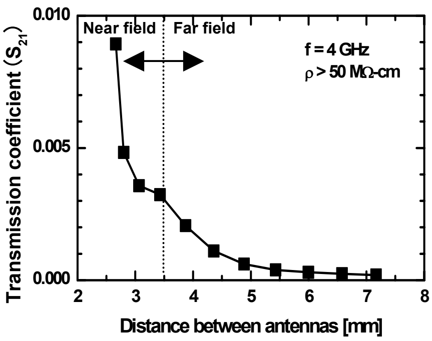

Fig. 7. Transmission coefficient (S_{21}) versus LOS distance between transmitting and receiving antennas at 4 GHz.

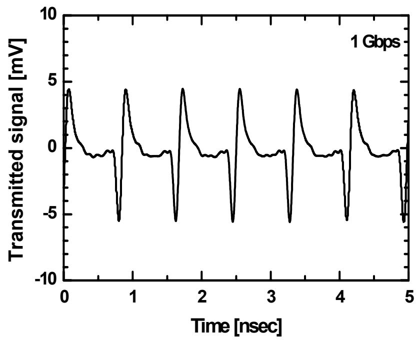

Fig. 8. Transmitted signal of Gaussian monocycle pulse train generated by the on-chip transmitter circuits (peak-to-peak voltage = 10 mV, data rate = 1 Gbps).

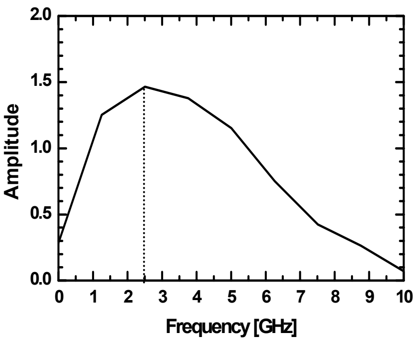

Fig. 9. Frequency spectrum of a Gaussian monocycle pulse (center frequency = 2.5 GHz).

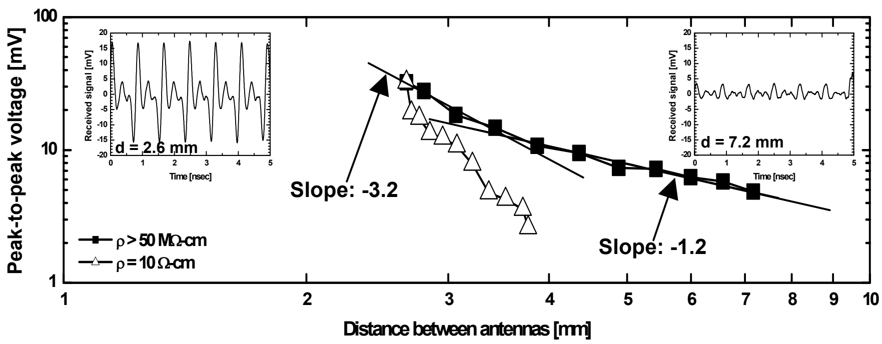

Fig. 10. Peak-to-peak voltage of the received signal via an amplifier (+30 dB) as a function of distance between transmitter and receiver antennas.