

Interference of Digital Noise with Integrated Dipole Antenna for Inter-chip Signal Transmission in ULSI

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Introduction

To overcome the physical limit of global clock frequency in the conventional interconnects, a new concept of wireless interconnection using Si integrated antennas has been proposed [1-4]. In order to send ultrahigh-speed digital signals between ULSIs, UWB signals would be a candidate for short distance signal transmission [5]. However, one of the issues for on-chip Si integrated antennas is interference of signals. In this paper the interference of digital noise with integrated linear dipole antennas were investigated for inter-chip UWB communication in Si ULSIs. Gaussian monocycle pulse signals were transmitted from a linear dipole antenna fabricated on a Si substrate to a receiving antenna fabricated on a separate substrate. Rectangular pulses as digital noises for interference were radiated from a transmission line fabricated on the other Si chip which was inserted between transmitting and receiving antennas.

Experimental

Integrated dipole antennas and transmission lines were fabricated on Si substrates. Si substrate resistivities were changed from 10 Ω -cm to 2.29 k Ω -cm. 10 μ m wide and 4, 5 and 6 mm long aluminum dipole antennas were fabricated on SiO₂. A transmission line was fabricated on SiO₂, whose width, space and length were 20 μ m, 20 μ m and 25 mm, respectively. The antenna measurement setups for scattering (S)-parameters and interference are shown in Figs. 1(a) and 1(b), respectively.

Results and Discussion

Figures 2(a), 2(b) and 2(c) show waveforms of as received signal, differential signal and differential signal after 5.1 GHz high-pass filter with interference, respectively. Figures 3(a), 3(b) and 3(c) show FFT of these waveforms, respectively. Interference of 5 Gbps digital noise was observed in the frequency spectrum < 5 GHz. UWB signals were interfered by high-data-rate digital noise from a transmission line. Differential mode signals were not effective to suppress 5 Gbps digital noise. 5.1 GHz high-pass filter could recover Gaussian

monocycle pulses. Figures 4(a), 4(b) and 4(c) show BER versus number of inserted Si substrate, SNR and properties of Si substrate. BER increased with increasing the number of inserted Si substrate but it could be reduced by increasing the Si resistivity. BER of UWB with interference decreased as SNR with interference increased.

Conclusion

Gaussian monocycle pulses which were transmitted and received on one chip of ULSI was distorted by the digital noise which was radiated from the other chip. It is found that the differential mode of Gaussian monocycle pulses and high-pass filter could suppress the interference from the other chip. UWB communication in Si ULSIs could be possible using the differential mode signal transmission and high-pass filter.

Acknowledgement

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References

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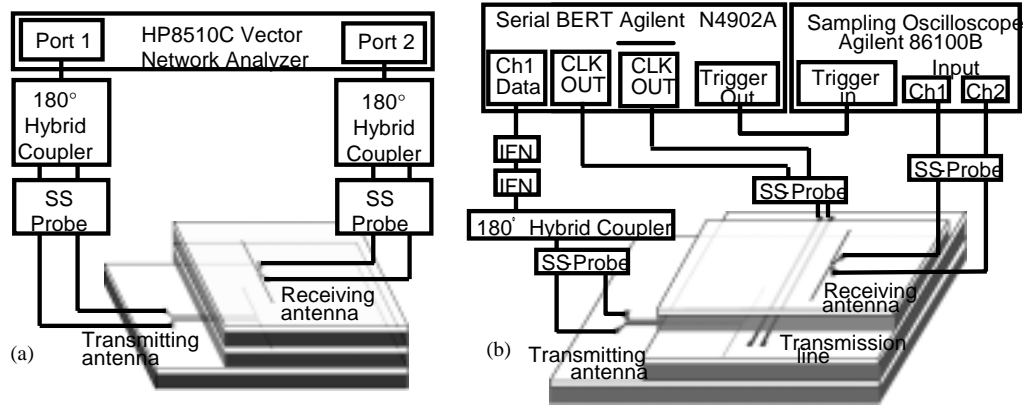


Fig. 1. Wafer level measurement set-up for inter-chip antenna transmission characteristics.
 (a) S-parameter measurement. (b) Interference measurement.

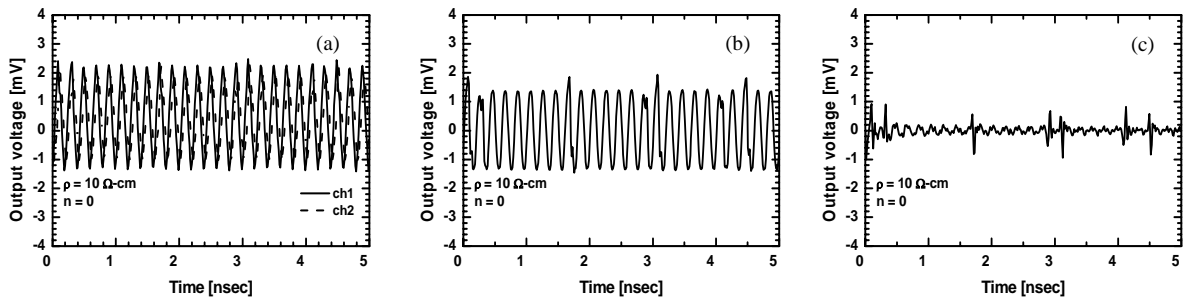


Fig. 2. Waveforms of data transmission with interference.
 (a) Received signal. (b) Differential signal. (c) Differential signal after 5.1 GHz high-pass filter.

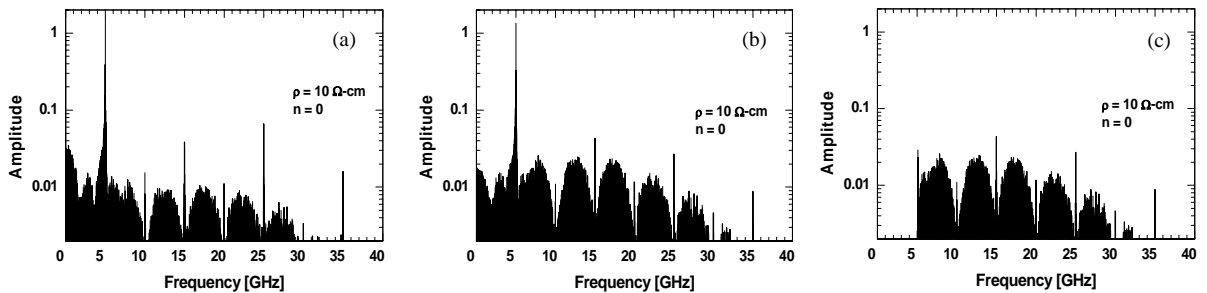


Fig. 3. FFT of Fig. 2
 (a) Received signal. (b) Differential signal. (c) Differential signal after high-pass filter.

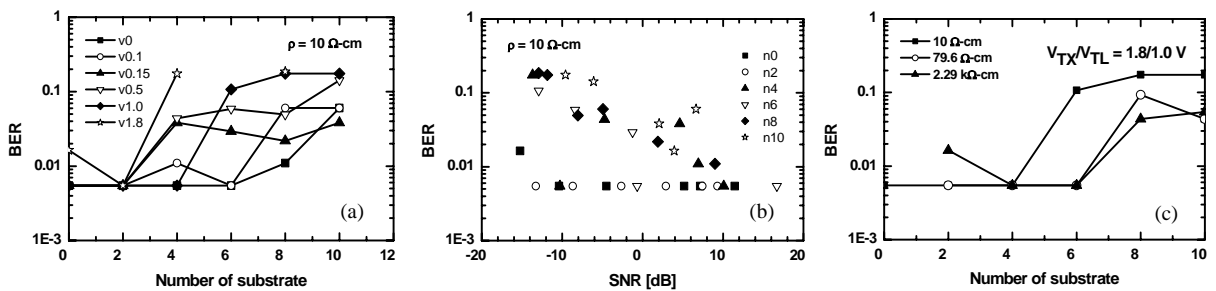


Fig. 4. Dependence of BER on each parameters.
 (a) Number of inserted Si substrates. (b) Signal to Noise Ratio. (c) Inserted Si resistivity.

Interference of Ultrawideband Signals for Inter-chip Signal Transmission with Integrated Dipole Antennas



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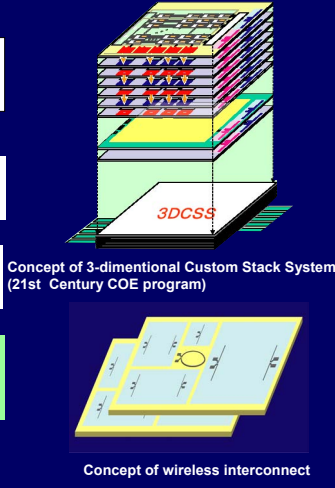
Background

3-Dimensional Custom Stack System is developed for Si-ULSI system integration.

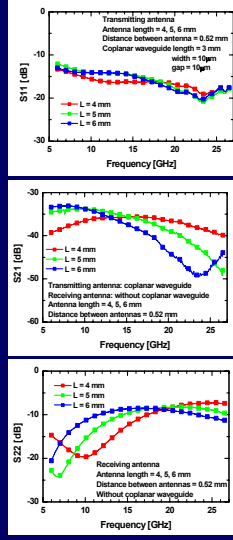
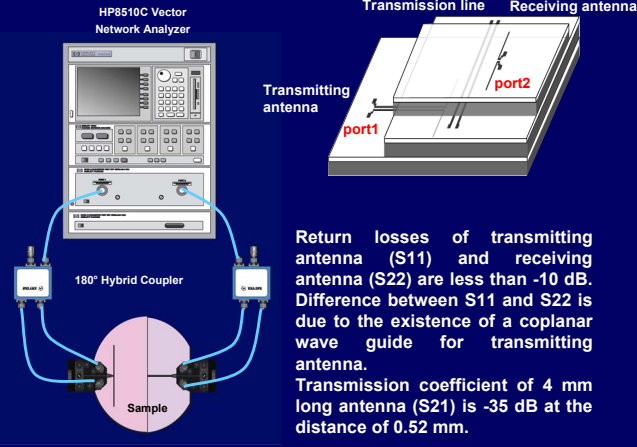
Wireless interconnection using Si integrated antennas has been proposed.

Signal interference by digital noise from ULSI metal interconnects causes error.

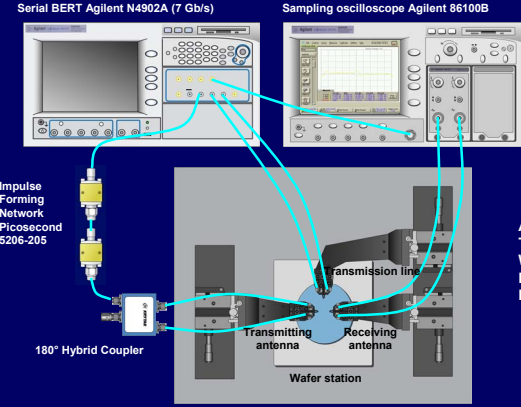
Interference of UWB signal transmission with digital noise in stacked chip packaging must be investigated.



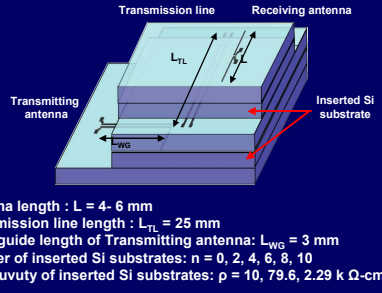
Frequency domain



Time domain



Sample structure



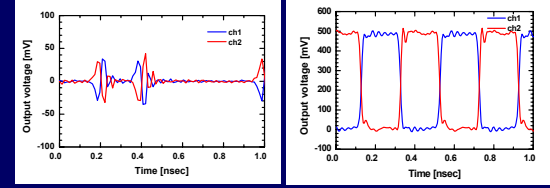
UWB and Interference signals

UWB signal radiated from a transmitting antenna

Gaussian monocycle pulse
Data rate = 5 Gbps
Output voltage (V_{TX}) = 70 mV
PRBS = 128 bits

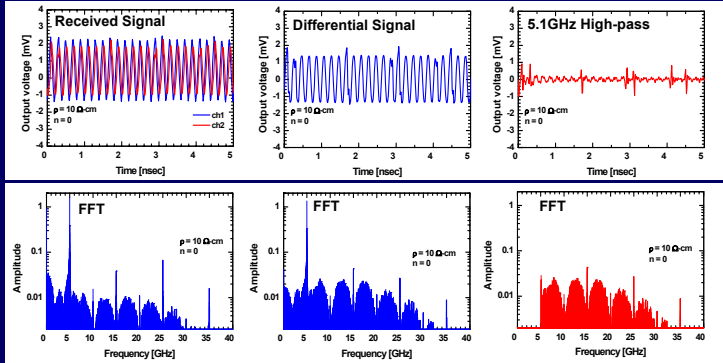
Interference signal radiated from a transmission line

Rectangular wave,
Repetition Frequency = 5 GHz
Generator voltage (V_{TL}) = 0, 0.1, 0.15, 0.5, 1.0, 1.8 V



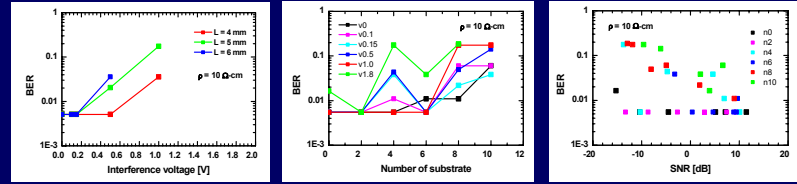
Interference of UWB Signal by 5 Gbps Digital Noise

$L = 4$ mm, $n = 0$, $V_{TL} = 0.5$ V, $V_{TX} = 70$ mV, Bit rate = 5 Gbps



Interference of 5Gbps digital noise was observed in the frequency spectrum < 5GHz. UWB signal was interfered by high-data-rate digital noise from a transmission line. Differential mode signal was not effective to suppress 5 Gbps digital noise. 5.1 GHz high-pass filter could recover Gaussian monocycle pulse.

BER of UWB versus Interference Voltage and Number of Inserted Si Substrate

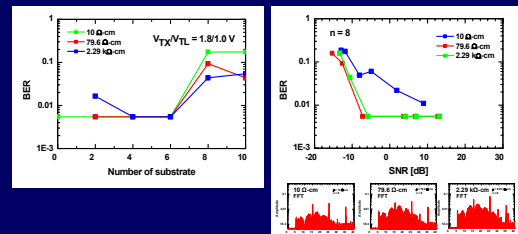


BER increased with increasing interference voltage.
BER decreased with decreasing antenna length in accordance with the transmission gains of antennas in the frequency range less than 10 GHz, where interference frequency was 5 GHz.

BER increased with increasing the number of inserted Si substrates.
BER decreased with increasing SNR, resulting in the lower limit of 128 bit PRBS, where SNR is defined as

$$SNR = 10 \log_{10} \frac{\int (UWB\text{signal})^2 dt}{\int ((Interference)^2 + WGN^2) dt}$$

BER versus Properties of Si substrates



BER increased with increasing number of Si substrates and decreased with increasing the resistivity of Si substrates.
BER decreased with increasing SNR including interference.

Summary

1. Interference of UWB signals in Si substrates with digital noise from transmission line was studied for the first time.
2. Interference could be suppressed by use of differential mode of signal transmission and high-pass filter.
3. BER increased with increasing the number of inserted Si substrates but it could be reduced by increasing the Si resistivity.
4. BER of UWB with interference decreased as SNR with interference increased.

Acknowledgements

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