C-1-5

Extended Abstracts of the 2009 International Conference on Solid State Devices and Materials, Sendai, 2009, pp68-69

A 3.5-4.5 GHz CMOS UWB Receiver Frontend LNA with On-chip Integrated Antenna for Inter-chip Communication

A. Azhari[1], K.Kimoto[1], N. Sasaki[1] and T. Kikkawa[1]

[1] Research Institute for Nanodevice and Bio Systems, Hiroshima University,
1-4-2 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8527, Japan
Phone: +81-82-424-6265; Fax: +81-82-424-3499; E-mail: {afreen-azhari,kikkawat}@hiroshima-u.ac

1. Introduction

Chip to chip UWB wireless interconnection is essential to reduce RC delay in wired interconnection and 3-Dimentional (3D) highly integrated packaging [1-6]. Previous works on inter-chip signal reception involves low gain amplification of received signal using low noise amplifier (LNA) in UWB range. The investigated system is required for the future single chip transceiver front end, integrated with on chip antenna for 3D mounting on PC Board. In this paper, we demonstrated wireless inter-chip signal transmission between two on-chip meander antennas on PCB for different transmission distance where the low power gain due to lossy Si substrate has been amplified with a low noise amplifier (LNA).

2. Integrated Antenna and Low Noise Amplifier

Figure 1 shows a die photograph for wireless inter-chip signal transmission on RT5880 PCB in transverse electromagnetic (TEM) coupling mode by integrated meander antenna and differential LNA using 180 nm CMOS technology on a typical Si substrate of resistivity of 10 Ω·cm. Figure 2 shows a schematic of 2.98 mm long sample structure of on-chip Si integrated meander dipole antennas. Figure 3(a) shows a schematic of a 3.6 mm^2 2-stage differential-ended LNA exploiting a three section reactive input networks to match with the on-chip antenna. Cascode topology with shunt peaking inductive load has been designed to improve the gain and reverse isolation of LNA. Source follower (Fig.3(b)) based buffer is added after LNA for 50 Ω output impedance matching with measurement equipment. Figure 4 shows a schematic of measurement setup for S-Parameters of on chip meander antenna integrated with LNA for different transmission distance, D. Figure 5 shows the measurement setup for chip to chip transmission of Gaussian Monocycle Pulse (GMP). During fabrication of the PCB no ground plane was kept below the region of chip to prevent the gain loss of antenna. A low k (k=1.03) interposer of Styrofoam was also placed between the PCB and metal stage of measurement setup for the same reason.

3. Results and Discussion

Figure 6 shows the measured S-parameters of the LNA and antenna. The measured transmission coefficient, S_{21} of LNA is 26dB at 4GHz. The input reflection coefficient, S_{11} of LNA and antenna both are < -10dB at the center frequency of 4GHz. Also Fig.7 shows close values of measured input impedances of the LNA and antenna at 3.9 GHz, which is differential 100Ω. Both the S_{11} of Fig.6 and Z_{11} of Fig.7 of LNA and antenna reveal good matching between antenna and LNA at 4GHz. Figure 8 shows the noise figure (NF) of the LNA which is less than 4dB from 3.5 to 5 GHz according to the post layout simulation result. The minimum NF is 3.8dB at 4GHz.

Figure 9(a) shows a peak-to-peak 6.2mV voltage (Vp-p) and 120ps pulse width input Gaussian Monocycle (GM) Pulse to the LNA. The signal is amplified to a peak-to-peak 17.6mV by the LNA (Fig.9(b)). The bandwidth (BW) of the GM Pulse is 1.3-4.2 GHz with the center frequency of 2.75GHz. Some ringing comes at the end of the amplified GM pulse as the center frequency of the GMP is different from that of LNA and also for the variable LNA gain in the BW of GM Pulse. A maximum rate of pulse train that can be used is 400MHz as the ringing dies out within 2.5ns without affecting the successive pulse.

Figures 10 to 12 shows the measured transmission coefficients, S_{21}, and time domain GMP signal for chip to chip communication. Without LNA the S_{21} of the antenna is -46dB at 4.2GHz in D=1mm, which increased to -20dB by the LNA with 1.8V power supply (Fig.10). Fig.11 shows the improved S_{21} of antenna with LNA at different values of D = 1, 6, 12.3 and 20 mm which are -20,-35,-43 and -48 dB, respectively, at 4.2 GHz. The transition between far and near field is 12.3 mm.

The measured value of received and amplified GMP signal at the end of LNA integrated with antenna by chip to chip wireless communication at 6mm distance is obtained 75mV(p-p), shown in Fig.12.

4. Conclusion

A chip to chip wireless UWB transmission has been demonstrated on PC Board in 3.5-4.5 GHz both in near and far field regions while the receiving on-chip antenna is integrated with an LNA using 180nm CMOS technology. The measured result shows that the LNA performs 26dB of improvement of the antenna power gain at 4.5 GHz on a lossy Si substrate.

References

[1] A. Iwata et al., IEEE Int. Solid-State Circuits Conf.(2005) 262.
[2] T.Kikkawa et al., IEEE J. Solid-State Circuits, 43(2008) 1303.
[3]K.Kimoto et al., Jpn. J. of Appl. Phys, 44 (2005), 2761.
[4] N.Sasaki et al., IEEE J. Solid-State Circuits, 44(2009).
[5] Kenneth K. O et al., IEEE J. Solid-State Circuits, 42(2007)1678.
[6]N.Behdad et al.,IEEE Radio Frequency Integrated Cir. Sym.(2007) 441

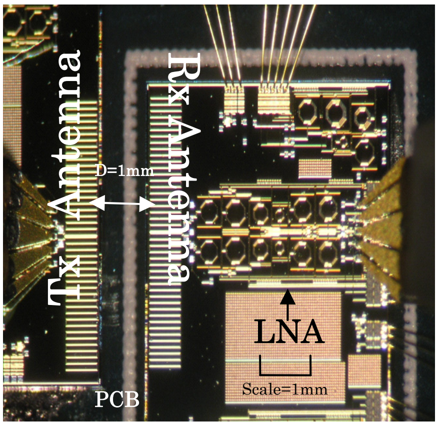

Fig. 1 Chip Photograph of UWB wireless inter-chip communication on PCB by integrated meander dipole antenna and differential LNA using 180nm CMOS Technology. D=transmission distance

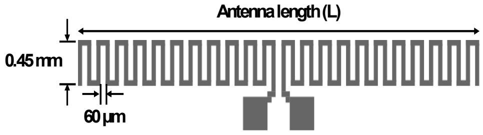

Fig. 2 Schematic of Meander Dipole Antenna

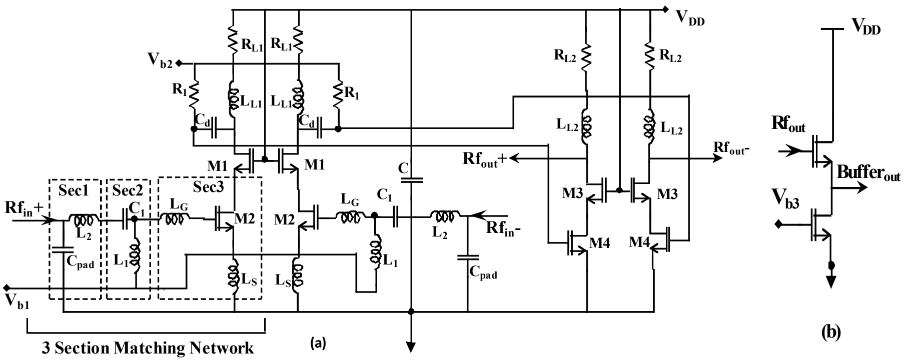

Fig. 3 Schematic of Circuits. (a) Differential LNA. (b) Buffer.

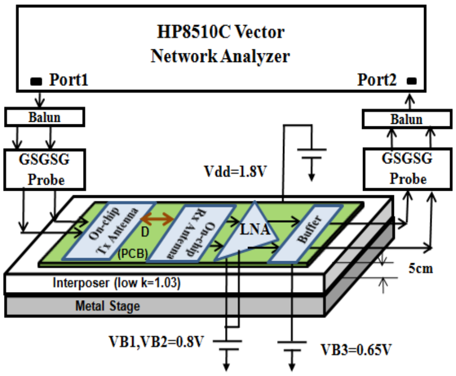

Fig.4 Setup for the measurement of S-parameters of wireless inter-chip transmission characteristics with on chip integrated antenna and LNA. D=transmission distance.

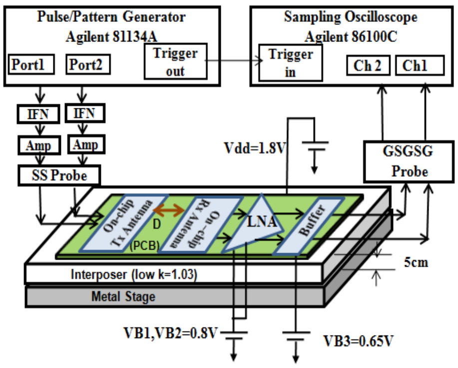

Fig.5 Measurement setup for wireless transmission and amplification of GM Pulse for chip to chip communication. IFN=Impulse Forming Network Amp=Power Amplifier

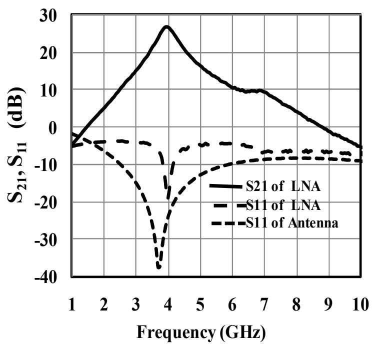

Fig.6 Measured S_{21} , S_{11} of LNA and S_{11} of antenna

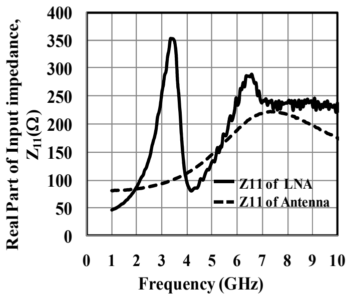

Fig. 7 Measured Z_{11} of the LNA and Antenna

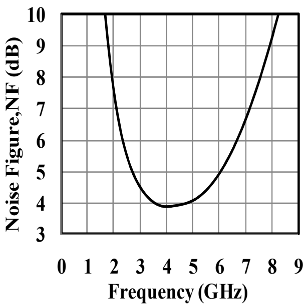

Fig. 8 Post layout simulation of Noise Figure (NF)

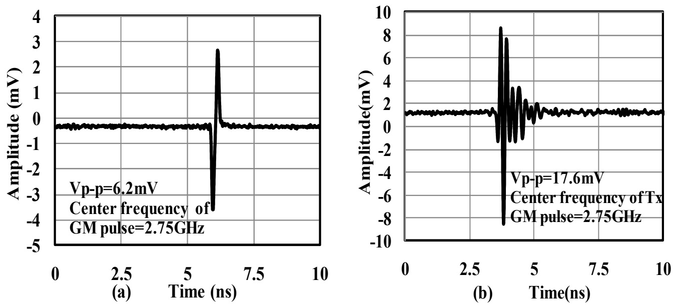

Fig.9 LNA characteristics . (a) Generated time domain GM Pulse. (b) Measured amplified GMP at the end of buffer of the LNA including antenna impedance at the LNA input.

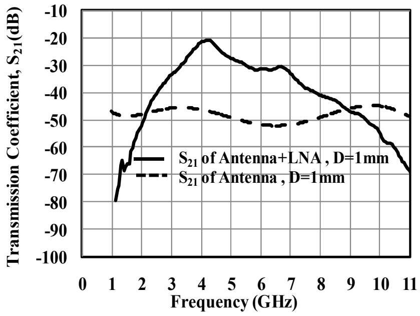

Fig.10 Measured S_{21} of Antenna with and without LNA (D= 1mm)

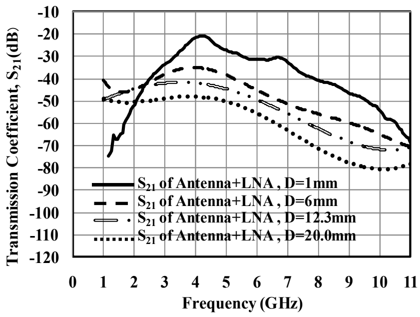

Fig.11 Measured S_{21} of Antenna with LNA at different distances, D= 1, 6, 12.3 and 20.0mm

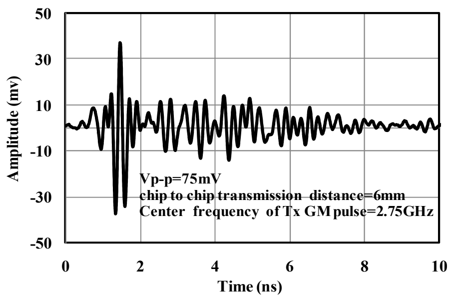

Fig. 12 Received and amplified GM Pulse at the end of on chip LNA integrated with on-chip antenna at the distance of 6mm between two chips.