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On-Chip Folded Dipole Antennas for Inter-Chip UWB Signal Transmission

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Abstract

On-chip folded dipole antenna was developed for inter-chip UWB signal transmission. Impedance matching and bandwidth increase of folded dipole antennas were achieved by increasing the number of parallel dipoles The bandwidth and the transmission gain of the antennas were also improved by inserting the interposer underlying the chips.

1. Introduction

Issues of conventional metal interconnect technologies are delay time and power consumption for high-speed signal transmission due to parasitic capacitances and interconnect resistances. Wireless interconnect technologies have been developed to substitute metal interconnects. Both capacitive and inductive couplings can be used for local wireless interconnects in the near field transmission where the distance is shorter than a few hundred μm. On the other hand, electromagnetic wave propagation can be applied to global wireless interconnects for longer distances than a few mm in the far field transmission by use of on-chip antennas [1-3].

In this paper, impedance matching of on-chip ultra-wide-band (UWB) dipole antenna is studied.

2. Experimental

P-type (100) Si wafers with resistivity (ρ) of 10 Ω·cm were prepared as substrates, whose thicknesses was 260 μm. On the surface of Si wafer 6.3-μm-thick field SiO_2 was deposited by atmospheric pressure CVD. 0.4-μm-thick aluminum was deposited on the SiO_2 layer by direct current magnetron sputtering and the antenna patterns were formed by maskless lithography. After wet etching and photo resist stripping, On-chip dipole antennas were fabricated on the Si substrate. Figure 1 shows a measurement set-up for antenna transmission characteristics in the frequency domain. S-parameter of antennas were measured by a vector network analyzer HP8510C, 180° hybrid couplers(1-12.4 GHz and 6-26.5 GHz) and signal-signal (SS) probes. The chip was placed on a interposer as a dielectric slab waveguide. The dielectric constant and thickness of interposer were 38 and 1.0 mm, respectively. The distance between antennas was 10 mm. Antenna characteristics were simulated by structure simulator (CST Microwave Studio). The dummy metals were necessary in the area of the antenna because of copper damascene fabrication yield. The total dummy metal size and the space between antenna and metal were 1475x260 μm^2 and 100 μm, respectively. Effects of the dummy metals, the width between lines and the thickness of interposer were investigated. Simulation was carried out for the structures where thickness of SiO_2 and aluminum were 8.825 and 1.17 μm, the width between lines g were 10, 40, 90 and 190 μm and the thickness of interposer t were 250, 500, 750, 1000, 1250 and 1500 μm, respectively.

3. Result and discussion

Due to the size limit of the on-chip antenna, the line width, the horizontal and the vertical lengths were chosen as 10 μm, 3.6 mm and 1.8 mm, respectively. The dipole antenna was folded in double and triple as shown in Figure 2. Figure 3 shows input impedance versus frequency of single, double and triple folded dipole antennas. It is found that the impedance matching to the transmission line characteristic impedance was achieved by increasing the number of parallel dipoles. Figure 4 shows the S-parameters of the single, double and triple folded dipole antennas. The bandwidths were improved as 5 GHz (5.0 - 11.0 GHz) and 16 GHz (4.0 - 20.0 GHz) for double and triple folded antennas, respectively.

Figure 5 shows the effect of dummy metals which are placed with a spacing of 100 μm from the antenna on S-parameters. S_{21} decreased 1.5 dB at 10 GHz, but S_{11} did not change very much. Figure 6 shows the effect of the spacing between parallel dipoles, g, on S-parameter. As the spacing between dipoles increased, the resonance frequency and the bandwidth increased. The effect of the interposer thickness, t, on S-parameter is shown in Fig. 7. The bandwidth and the gain increased with decreasing the thickness of the interposer.

4. Conclusion

The input impedance matching and the bandwidth were improved by folding dipole antennas. The bandwidth and gain were also improved by thinning the interposer thickness. The optimum thickness of interposer was 500 μm.

Reference

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[2] T. Kikkawa et al., "Gaussian Monocycle Pulse Transmitter Using 0.18 um CMOS Technology With On-Chip Integrated Antennas for Inter-Chip UWB Communication," IEEE J. Solid-State Circuits, Vol. 43, No. 5, May 2008, pp. 1303-1312.

[3] N. Sasaki and T. Kikkawa, "Bit Error Rate Measurement of IR-UWB CMOS Transmitter and Receiver, "2009 Asia-Pacific Microwave Conference, 2009, pp. 249-252.

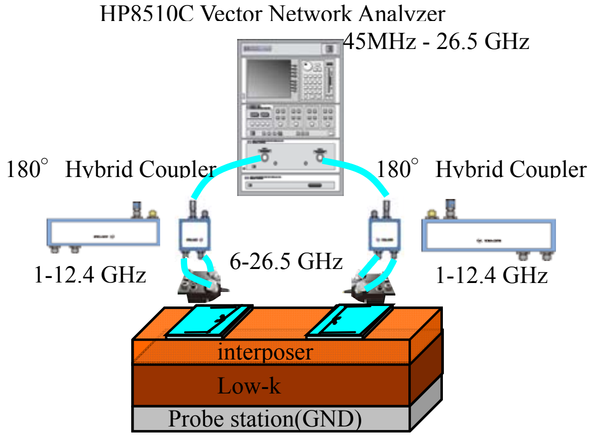

Fig. 1. Measurement set-up for antenna characteristics.

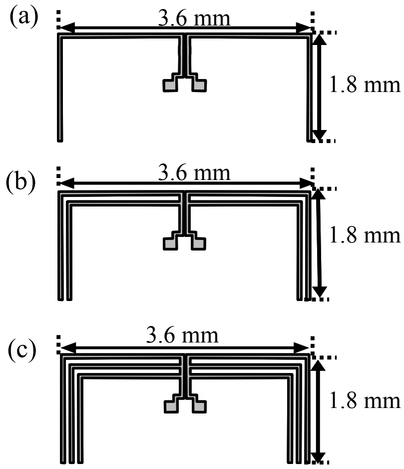

Fig. 2. Schematic structure of folded dipole antenna. (a) Single folded dipole antenna. (b) Double folded dipole antenna. (c) Triple folded dipole antenna.

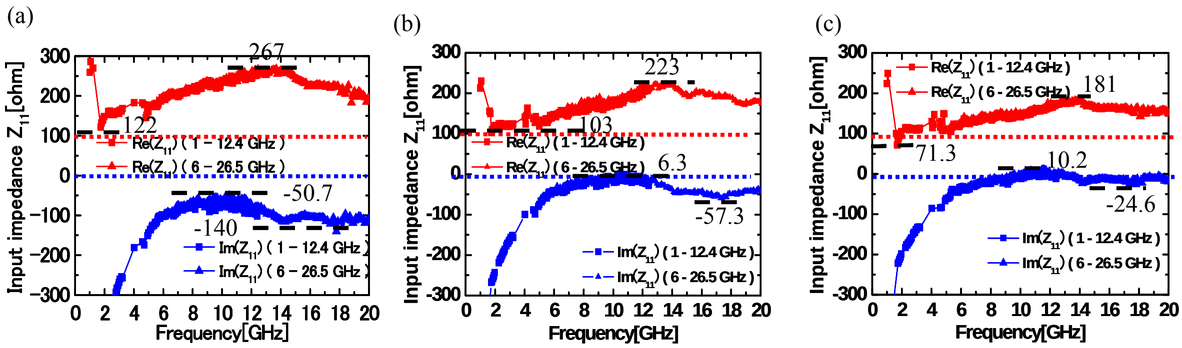

Fig. 3. Input impedance of dipole antennas versus frequency. (a) Input impedance of single folded dipole antenna. (b) Input impedance of double folded dipole antenna. (c) Input impedance of triple folded dipole antenna.

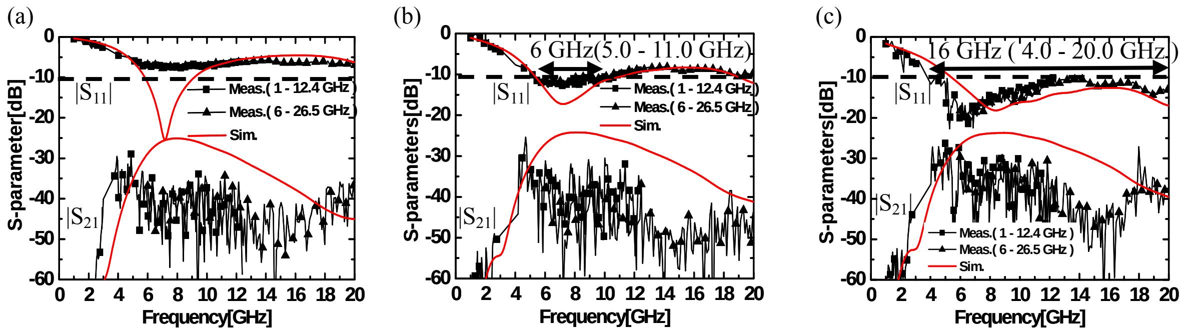

Fig. 4. S-parameters of folded dipole antennas versus frequency. (a) S-parameter of single folded dipole antenna. (b) S-parameter of double folded dipole antenna. (c) S-parameter of triple folded dipole antenna.

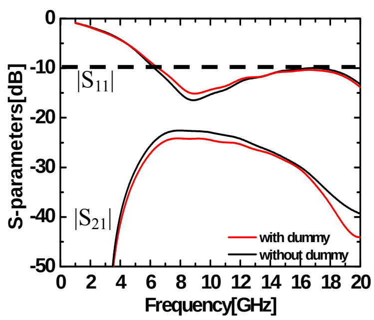

Fig. 5. S-parameter versus frequency for the triple folded dipole antenna with and without dummy metals for Cu damascene.

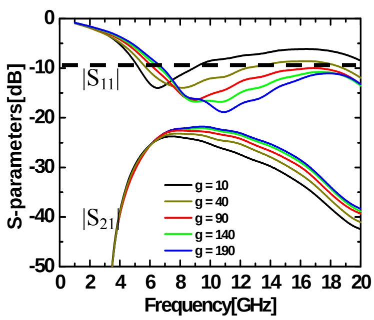

Fig. 6. S-parameter versus frequency for the triple folded dipole antenna as a parameter of spacing of parallel dipoles.

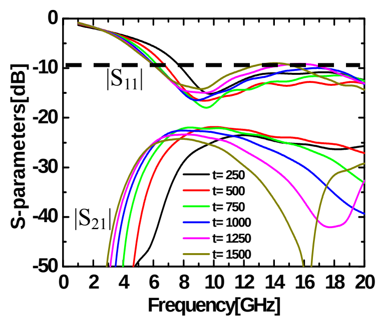

Fig. 7. S-parameter versus frequency for the triple folded dipole antenna as a parameter of interposer thickness.