Chapter 6 Summary and Future Works

6.1 Summary

A silicon carrier with high-Q cross-membrane micro-machined inductors has been successfully developed for realizing the SOP scheme for RFIC applications. By means of the integration of the carrier and a proposed LNA chip fabricated using standard 0.18μm COMS process [10], the proposed tunable LNA can be used for the design of high performance UWB mode-2 transceiver. According to the simulation listed in Table 3, the developed LNA circuit will have wider frequency tuning range, lower noise performance, and lower power consumption characteristics. The comparison of simulation performance is made by the LNA circuit switched with MIM capacitors and that with MEMs inductors, respectively [10].

Furthermore, in order to realize the high-performance UWB tunable LNA based on the SOP scheme, a novel package-integration technique, Au-Au thermocompression bonding, is utilized to assemble the silicon carrier with the LAN circuit. Without using solder balls, the novel flip chip technique can have the advantages of low insertion loss and low parasitic effects. Meanwhile, by synthesizing the proposed methodologies of Greenhouse's formula [7], physics-based closed-form inductance expression [8], and distributed capacitance model [8], an exactly physic-based equivalent model for the optimized design of cross-membrane micro-machined inductors is developed from 1GHz to 10 GHz application range. This model will present a prediction of inductor's electromagnetic behavior as accurately as commercial 3-D electromagnetic simulator, but with less computational resource required for the calculation.

Performance	***Tunable LNA without micro-machined inductors***	***Tunable LNA with micro-machined inductors***
Technology	0.18um TSMC CMOS Standard	
Supply voltage	1.5V	
Center Frequency tuning range	3.1 ~ 8 GHz	
$S_{21(range)}$	6.5~11.1 dB	11.7~13.2
S_{11}	< -9.5 dB	<-10 dB
S_{22}	<-12 dB	<-14 dB
S_{12}	<-38 dB	<-36 dB
$NF_{(average)}$	6.2 dB	3.5 dB
$IIP3_{(average)}$	~ 0 dBm	~ -5 dBm
Power consumption	21.5 mW	10.5 mW
*FOM (at worse case)	0.156	0.302

$$*FOM_{LNA} = \frac{Gain[abs] \cdot IIP_3[mW] \cdot freq[GHz]}{(NF-1)[abs] \cdot P_D[mW]}$$

Table 6-1 The summary of simulation performance between the LNA circuit switched with MIM capacitors and with MEMs inductors [9].

6.2 Future works

The proposed model of micro-machined inductor is developed for 0.5nH~5nH from 1GHz to 10 GHz in the thesis. In order to enhance the application in RF ICs, the parasitic effect of micro-machined inductor which occurs dominantly at higher frequencies must be considered. For example, the capacitive coupling effect of sandwich membrane and residual silicon substrate will dominate the performance of inductors as operating frequency approaches the self-resonance frequency. Therefore, the equivalent model of micro-machined inductor can not be simplified as figure 2-6 at all and the substrate tank can not be indispensable.

In addition, the SOP scheme is not only for the incorporation of micro-machined inductors but also other useful MEMs passive components, such as switch, resonators, and antenna…etc.. All of the high performance passive components can be developed and built in the silicon carrier to achieve a specified multi-functional RF circuit in the future.