Low-cost SiGe Circuits for Frequency Synthesis in Millimeter-wave Devices

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List of Abbreviations

List of the acronyms and abbreviations used in this thesis.

AC	Alternating Current
ACC	Autonomous Cruise Control
amp	Amplitude
BER	Bit Error Rate
BiCMOS	Bipolar Complementary Metal Oxide Semiconductor
BiCMOS6HP	IBM 0.25μm SiGe BiCMOS technology (6 metal, $f_t = 47$GHz)
BiCMOS7WL	IBM 0.18μm SiGe BiCMOS technology (7 metal, $f_t = 60$GHz)
BiCMOS7HP	IBM 0.18μm SiGe BiCMOS technology (7 metal, $f_t = 120$GHz)
BiCMOS8HP	IBM 0.13μm SiGe BiCMOS technology (8 metal, $f_t = 200$GHz)
BJT	Bipolar Junction Transistor
BOM	Bill Of Materials
BT15G	Base-tuned 15GHz single-ended VCO
B-tuned	Base-tuned
BW	Bandwidth
CAD	Computer Aided Design
C-B	Collector-Base
CML	Current Mode Logic
CMOS	Complementary Metal Oxide Semiconductor
CP	Charge Pump
DC	Direct Current
DFF	Data Flip-Flop
DHBT	Double HBT
Diff	Differential
D-latch	Data-Latch
ECC	European Communications Committee
ECL	Emitter Coupled Logic
E^2CL	Double ECL
EF	Emitter-Follower
EM	Electromagnetic
ET15G	Emitter-tuned 15GHz single-ended VCO version 1
ET15G_V2	Emitter-tuned 15GHz single-ended VCO version 2

ET15G_V3	Emitter-tuned 15GHz single-ended VCO version 3
ETH/Z	Swiss Federal Institute of Technology / Zürich
E-tuned	Emitter-tuned
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
FMCW	Frequency Modulated Continuous Wave
FOM	Figure Of Merit
f_t	Transition Frequency
GaAs	Gallium Arsenide
Ge	Germanium
GHz	Gigahertz
GND	Ground
HBT	Heterojunction Bipolar Transistor
HP	Hewlett-Packard
IF	Intermediate Frequency
IfE	Institute for Electronics
IMPATT	IMPact ionisation Avalanche Transit-Time
InP	Indium Phosphide
ISM	Industrial Scientific and Medical
LC	Inductor Capacitor
LNA	Low Noise Amplifier
LO	Local Oscillator
LPF	Low Pass Filter
LRR	Long Range Radar
LTI	Linear Time Invariant
MHz	Megahertz
MIM	Metal Insulator Metal
MMIC	Monolithic Microwave Integrated Circuit
mm-wave	Millimeter-wave
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPW	Multi Project Wafer
NPN	n-type p-type n-type semiconductors
PCB	Printed Circuit Board
PFD	Phase Frequency Detector
PHEMT	Pseudomorphic High Electron Mobility Transistor
PLL	Phase Locked Loop

PSD	Power Spectral Density
PSK	Phase Shift Keying
PSS	Periodic Steady State
Q	Quality Factor
QAM	Quadrature Amplitude Modulation
RBW	Resolution Bandwidth
RF	Radio Frequency
RLC	Resistor Inductor Capacitor
RMS	Root Mean Square
Rx	Poly-Si
SARA	Strategic Automotive Radar frequency Allocation
SCV	Sub-Clutter Visibility
SDIV6	1/6 Synchronous Static Frequency Prescaler
S-End	Single-Ended
Si	Silicon
SiGe	Silicon Germanium
SMA	Sub-Miniature version A
SoC	System-on-Chip
S-parameters	Scattering Parameters
SRR	Short Range Radar
Ti	Deep Trench Isolation
TUD	Technical University of Dresden
UWB	Ultra Wideband
VBW	Video Bandwidth
VCO	Voltage Controlled Oscillator
VLSI	Very Large Scale Integration
WLAN	Wireless Local Area Network
XC24G	24GHz cross-coupled differential VCO

Abstract

Advances in Silicon Germanium (SiGe) Bipolar Complementary Metal Oxide Semiconductor (BiCMOS) technology has caused a recent revolution in low-cost Monolithic Microwave Integrated Circuit (MMIC) design.

This thesis presents the design, fabrication and measurement of four MMICs for frequency synthesis, manufactured in a commercially available IBM 0.18μm SiGe BiCMOS technology with f_t = 60GHz. The high speed and low-cost features of SiGe Heterojunction Bipolar Transistors (HBTs) were exploited to successfully develop two single-ended injection-lockable 15GHz Voltage Controlled Oscillators (VCOs) for application in an active Ka-Band antenna beam-forming network, and a 24GHz differential cross-coupled VCO and 1/6 synchronous static frequency prescaler for emerging Ultra Wideband (UWB) automotive Short Range Radar (SRR) applications.

On-wafer measurement techniques were used to precisely characterise the performance of each circuit and compare against expected simulation results and state-of-the-art performance reported in the literature.

The original contributions of this thesis include the application of negative resistance theory to single-ended and differential SiGe VCO design at 15–24GHz, consideration of manufacturing process variation on 24GHz VCO and prescaler performance, implementation of a fully static multi-stage synchronous divider topology at 24GHz and the use of differential on-wafer measurement techniques.

Finally, this thesis has illustrated the excellent practicability of SiGe BiCMOS technology in the engineering of high performance, low-cost MMICs for frequency synthesis in millimeter-wave (mm-wave) devices.

Statement of Candidate

I certify that the work in this thesis entitled "Low-cost SiGe Circuits for Frequency Synthesis in Millimeter-wave Devices" has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of this thesis itself have been appropriately acknowledged.

In addition, I certify that all information sources and literature used are indicated in this thesis.

The research presented in this thesis has not required the approval of Macquarie University Ethics Review Committee.

Signed

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30 June 2009

Date

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