

Unique Origin
Unique Future

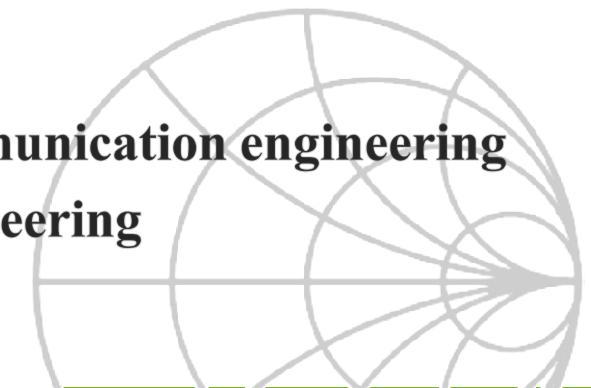
Analog / RF Circuit and System Research Center

2016.6

Sungkyunkwan University

College of Information & communication engineering

Electrical and Electronic Engineering



SUNG KYUN KWAN
UNIVERSITY

Professors and laboratory



Kangyoон Lee: Analog / RF / Power in Integrated Circuit
Integrated Circuits Lab (IC Lab)



Munkyo Seo: Millimeterwave / Terahertz IC Integrated Circuit
Millimeterwave / Terahertz Integrated Circuits Lab (MMIC Lab)



Keum Cheol Hwang: Antenna / Electromagnetic Analysis
Antenna Analysis and Design Lab (AADL)



Youngoo Yang: RF / Power amplifier / IC
Microwave Circuits and Systems Lab (MCS Lab)

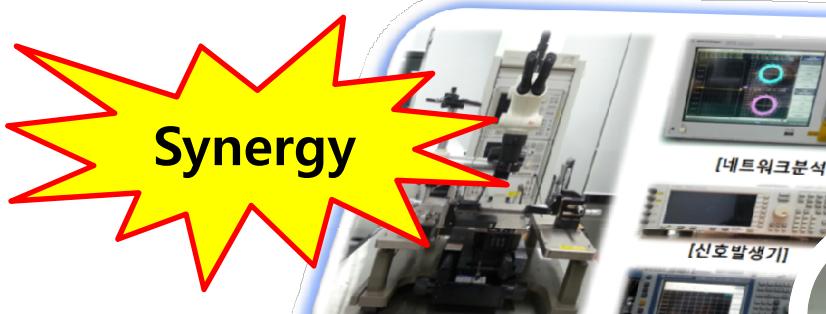


Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

Operation of Research Group

- ✓ Open Lab
 - ✓ Resource Sharing



Members

2019. 10

Course	MCS Lab.	IC Lab.	MMIC Lab.	AAD Lab.	Total
Professor	1	1	1	1	6
Researcher	1	2	1	1	2
Ph.D	6	17	4	2	16
Master & Ph.D combine	-	4	2	7	30
Master	4	24	2	3	49
Bachelor	4	22	-	1	12
Total	16	70	10	15	111



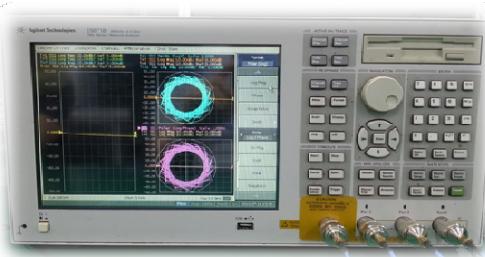
Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

Measurement Equipment



[Digital serial analyzer]



[4-port network analyzer]



[Oscilloscope]



[Spectrum analyzer]



[2-port network analyzer]



[Wire & antenna training system]



[Wire bonding machine]



[DC power supply]



[Signal generator]

Measurement Equipment



[Probe station]



[Network analyzer Deck]



Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

Equipment list

Category	Type	Num.	Purpose
Spectrum Analyzer	HP8563E	2	9KHz~26.5GHz spectrum measurement
Spectrum Analyzer	E4440A	1	9KHz~26.5GHz spectrum measurement
Spectrum Analyzer	FSV	1	9KHz~13.6GHz spectrum measurement
Spectrum Analyzer	11970W	1	spectrum measurement
Spectrum Analyzer	PSA-3000	1	9kHz~3GHz spectrum measurement
Spectrum Analyzer	FS300	2	9kHz~3GHz spectrum measurement
Vector Signal Generator	Agilent E4438C	2	250kHz~4GHz – 2tone
Vector Signal Generator	Agilent E8241A	1	250kHz~20GHz RF – 1tone
Vector Network Analyzer	Agilent 8753ES	1	RF signal measurement
Vector Network Analyzer	Agilent E8364B	1	RF signal measurement
Vector Network Analyzer	ME7838A	1	100GHz RF signal measurement
Vector Network Analyzer	E8241A	1	RF signal measurement
Network Analyzer	Agilent E5071B	1	300kHz~8.5GHz
Network Analyzer	Agilent E5061B	1	5Hz~3GHz
Network Analyzer	Agilent 8510C	1	45 MHz ~ 110 GHz
Noise Figure Analyzer	Agilent N8975A	1	RF signal measurement
PARAMETER ANALYZER	Agilent 4156C	1	RF signal measurement



Equipment list

Category	Type	Num.	Purpose
Digital serial analyzer	Tektronix DSA 71254C	1	12.5GHz measuring Input/Output signal
Mixed Signal Oscilloscope	Tektronix MSO 4054	1	500MHz/ 2.5GS/s measuring Input/Output signal
Digital Storage Oscilloscope	Tektronix TDS 2022	1	200MHz/2GS/s measuring Input/Output signal
Oscilloscope	Wavepro 7300	1	Quad 10 Gs/s
RF Signal Generator	Agilent N9310A	1	9kHz~3GHz RF injection signal
Arbitrary/Function Generator	Tektronix AFG 3022	2	25MHz / 250MS/s injection signal
Arbitrary/Function Generator	Tektronix AFG 3101	1	100MHz / 1Gs/s injection signal
Function Generator	Tektronix TDS2024B	1	200MHz / 2Gs/s injection signal
Function Generator	VB8000	1	
DC Power Supply	Topward 6303D	3	Injection Voltage source
DC Power Supply	Agilent E3631A	5	6V / 5A, 25V / 1A Injection
DC Power Supply	HP 6626A	1	Injection Voltage source
DC Power Supply	Agilent 6674A	2	60V / 35A injection
DC Power Supply	SM3004-D	1	350V / 4A injection
DC Power Supply	ED-333T	1	30V / 3A, 5V / 3A injection
Multi meter	Agilent U1251A	2	Measuring current & voltage
Multi meter	Agilent 34401A	1	



Equipment list





Kangyoон Lee :
IC Lab

IC Lab - 이강윤 교수

▪ Professor, Kang-Yoon Lee



- ✓ B.S., M.S., Ph.D. all in School of Electrical Engineering, Seoul National University
- ✓ 1998 – 2005: One of Founders & Design Manager of Analog Division, GCT Semiconductor Inc.
- ✓ 2005 – 2012: Associate Prof., Konkuk Univ.
- ✓ 2012 – recent : Associate Prof., Sungkunkwan Univ.

▪ Distinctions

- ✓ 60편 이상의 해외저널, 72편 이상의 해외 학회 논문 보유
- ✓ 60건 이상의 특허 보유
- ✓ 산업통상자원부장관표창 2015년도 반도체산업발전 유공자 포상 수상

▪ Integrated Circuits Lab (IC Lab, <http://iclab.skku.ac.kr>)

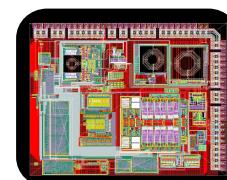
- ✓ 상용화를 포함한 산업체와의 과제 수행.
- ✓ 총 45 명의 연구원 (연구교수: 1, 박사과정: 18, 석사과정: 26)

▪ Project

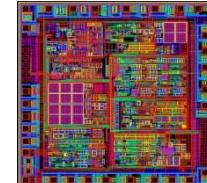
- ✓ 45개의 산업체 협력 과제 수행 (지난 5년 간)
- ✓ 27개의 정부 참여 과제 수행 (지난 5년 간)

연구 분야	특허	기술 이전
Wireless Power Transfer (Active Rectifier, DC-DC converter)	10	2
Ultra low power transceiver and system	32	1
Total	42	3

업체 명	대표 상용화 내용
삼성전기	DVBS2용 PLL 및 Base Band 회로 설계
삼성전자	LED TV BLU 용 Power IC 상용화 DC-DC Converter + LED Driver IC 설계
삼성전자	EMR 방식의 Pen Touch 시스템 개발
GCT Semi.	PHS Transceiver



RF Transceiver
핵심 부품 개발



LED TV BLU 용 DC-DC
Converter + LED Driver IC



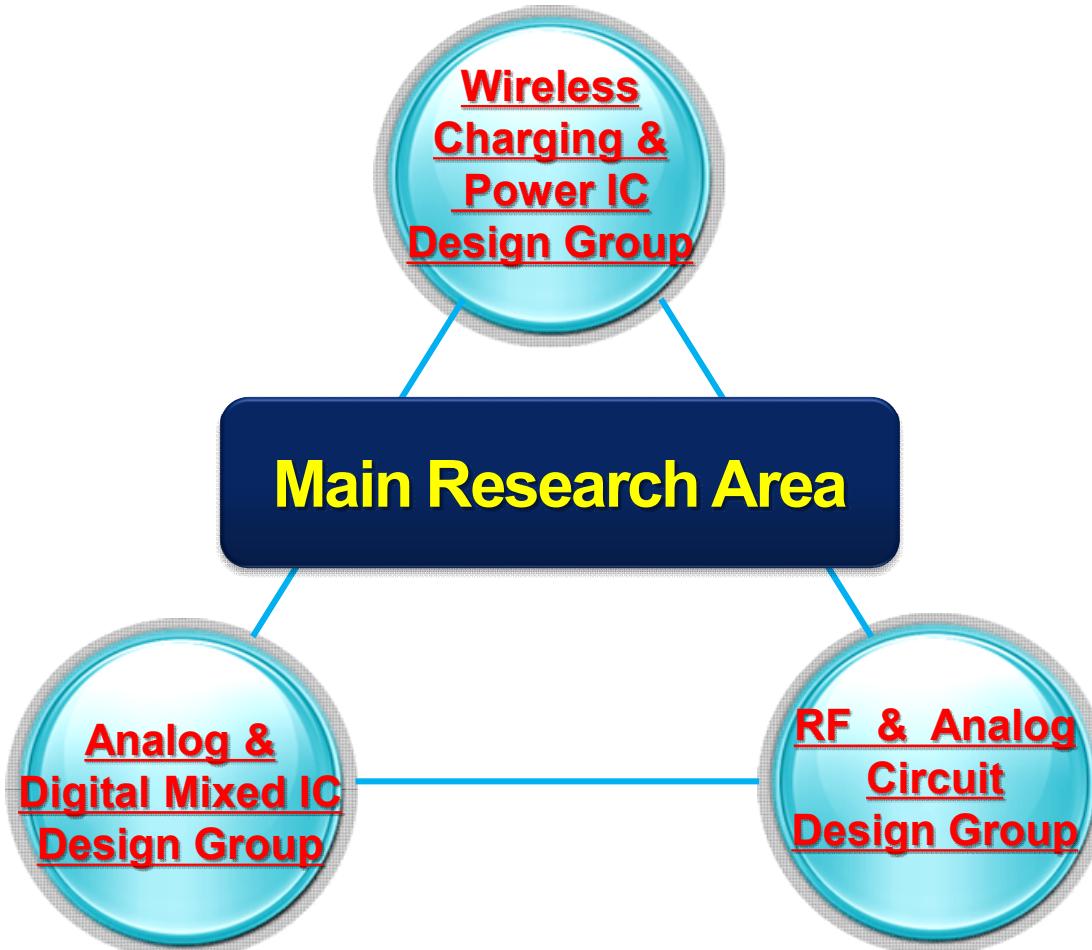
Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea



Kangyoон Lee :
IC Lab

IC Lab - 이강윤 교수



Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

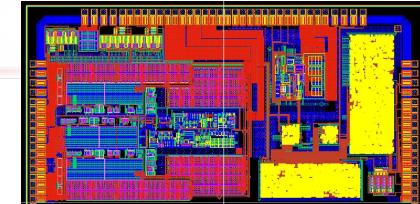


Kangyoон Lee :
IC Lab

IC Lab - 이강윤 교수

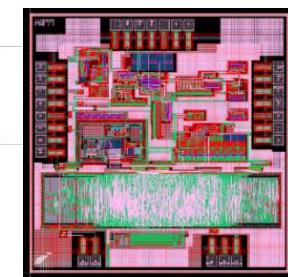
Wireless Charging & Power Management IC

- Wireless Power Receiver & Transmitter
- RF Energy Harvesting Circuit
- LLC Resonant Controller IC



RF & Analog Circuit IC

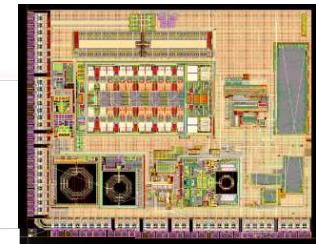
- Signal Conditioning IC for Automotive Pressure Sensor
- 60GHz PLL/VCO
- 10Gbps 4CH VCSEL Driver



<Pressure Sensor>

Analog & Digital Mixed IC

- MR-FSK Transceiver
- DigRF M-PHY System



<MR-FSK Transceiver>

AI IC

- Neuromorphic IC



Research Group on Analog/RF circuit and Systems

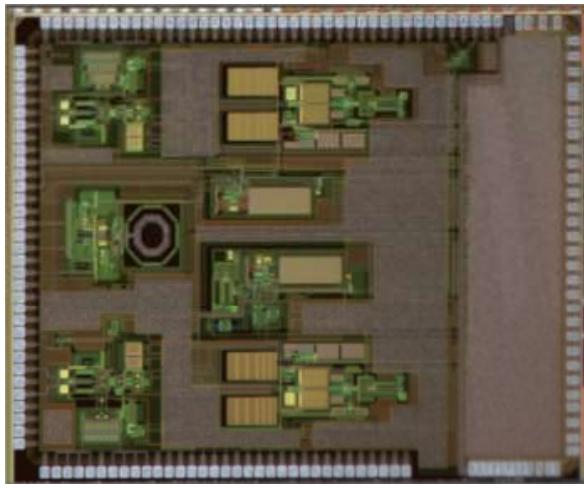
Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea



Kangyoong Lee :
IC Lab

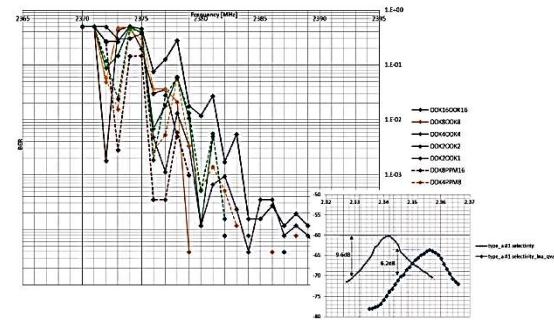
Analog IC Circuit Design

RF Transceiver System

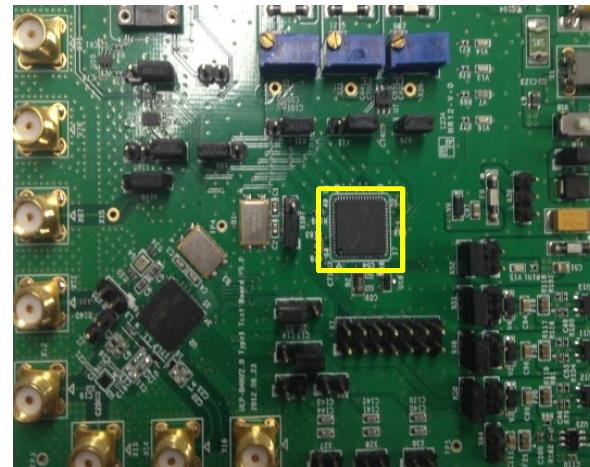


<Chip>

- Chip size: 3.0 mm x 4.0 mm
- Average Power in Active Period : 177uW
- Data Rate : 1Mbps
- Applications
 - Bio-Monitoring System
 - Medical Instrument



< BER Measurement Results >



< Test Board >



Research Group on Analog/RF circuit and Systems

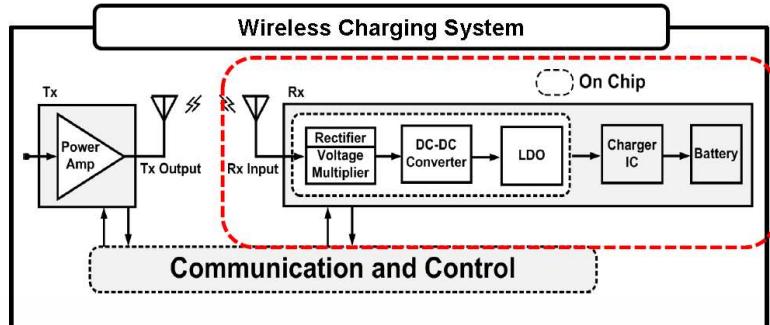
Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea



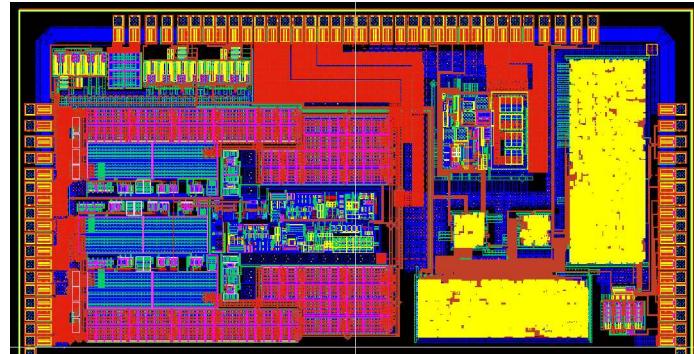
Kangyoong Lee :
IC Lab

Analog IC Circuit Design

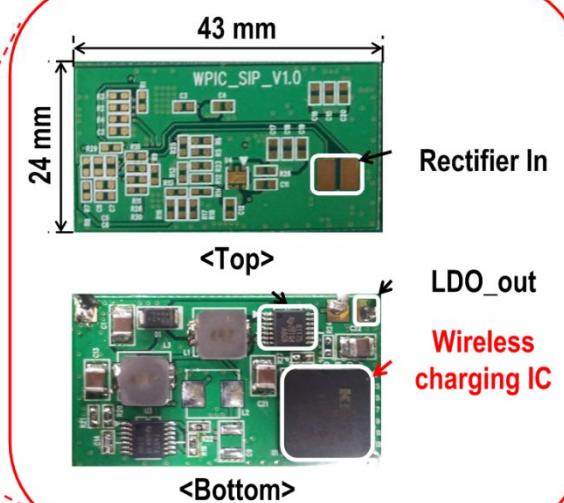
Wireless Charging System



Block Diagram



Layout



Test Board



Kangyoong Lee :
IC Lab

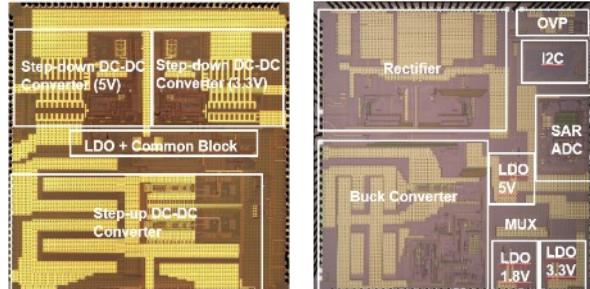
IC Lab - 이강윤 교수

1

Wireless Charging System



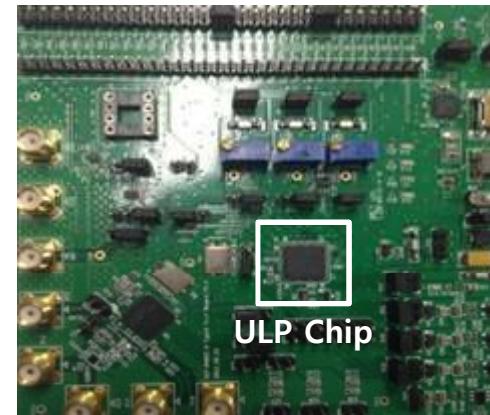
< Wireless Charging Test board >



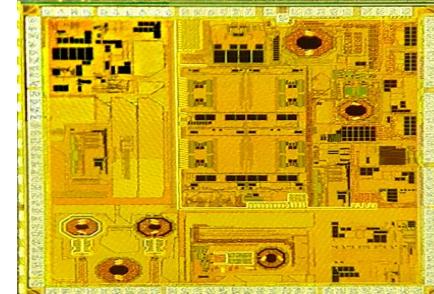
< Die Micrograph >

2

Ultra Low Power Transceiver



< ULP Transceiver Test board >



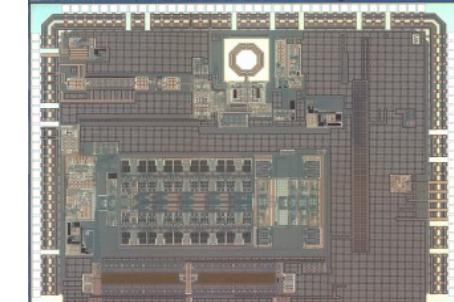
< Die Micrograph >

3

ADPLL based FSK Transceiver



< FSK Transceiver Test board >



< Die Micrograph >

안테나 해석 설계 연구실(Antenna Analysis and Design Laboratory)



담당교수

황금철 교수님
안테나 및 전파공학 전공

연구실적:

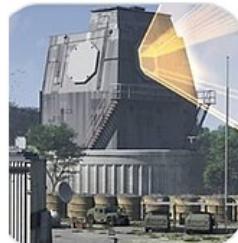
- SCI급 국제 논문 130편
- 국내 논문 14편
- 국내외 학술대회 논문 103편
- 국내외 특허 38편 등록 외 다수 출원 및 심사 중

연구실 위치

- 교수실: 산학협력센터 85670호
- 연구실: 산학협력센터 85669호
- 장비실: 산학협력센터 85633호

Homepage: <http://aadl-skku.net>

연구 분야



- Multi-band Array/Subarray Optimization
- Wide-beam Scanning Array
- Waveguide Slot Array



- Compact Antennas for Wireless Terminal
- Broadband CP Antennas
- Fractal Antennas



- Theoretical Electromagnetics
- Scattering/Radiation from Various Wedges
- Twist Reflectors/Polarization Filters

안테나 해석 설계 연구실(Antenna Analysis and Design Laboratory)

● 연구원



Trinh Van Son
(Post Doc.)



이종민



이성우



송찬미



윤주호



임홍준



권오현



박원빈



Manzoor Elahi



김상일



성영훈



이영표



방재식



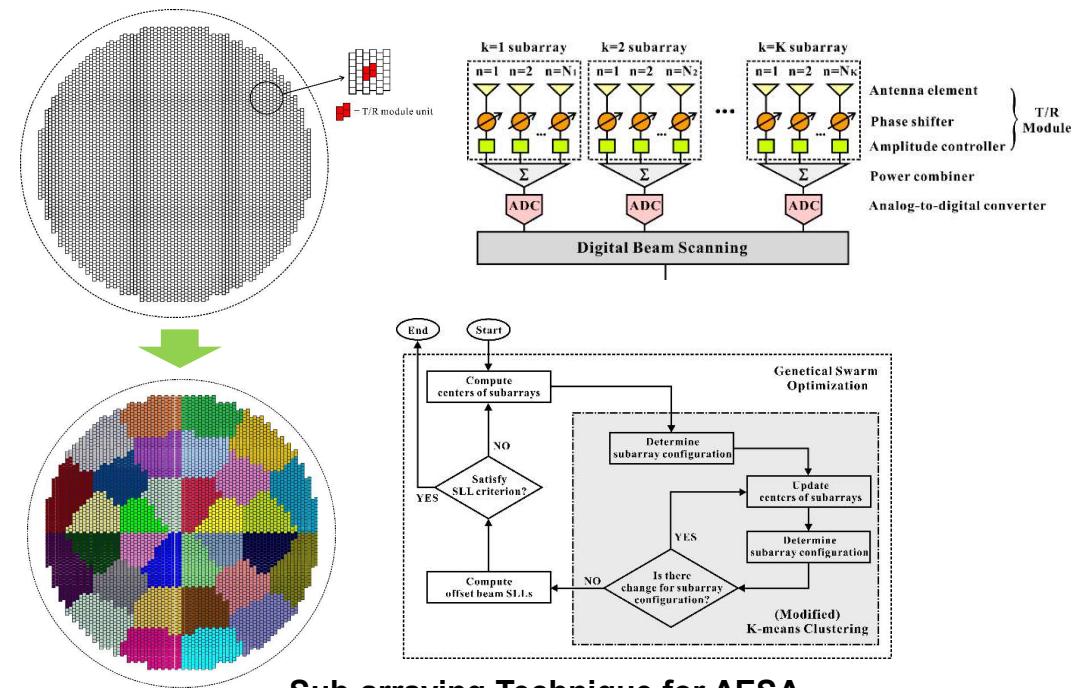
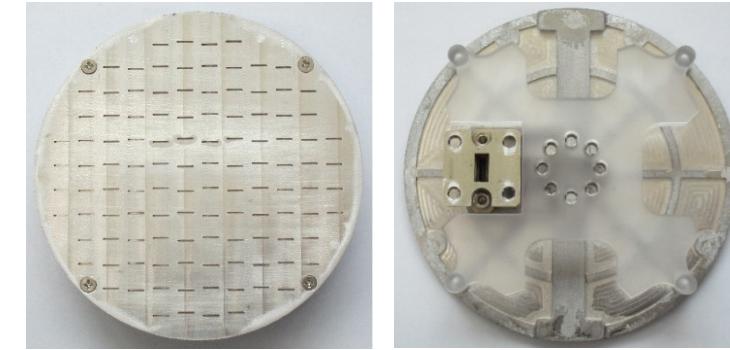
정태용

● 연구 프로젝트 현황

- 5G/mm-Wave 전자파 측정 분석 방법 개발 (2019.01 ~ 2019.11, 삼성전자)
- 5G 단말기용 다중 대역 패치 안테나 개발 (2019.08 ~ 2020.07, 삼성전기)
- 28GHz대역 5G用 소형 패치 안테나 개발 (2018.04 ~ 2019.03, 삼성전기)
- 5G 이동통신 단말기용 배열 안테나 최적 설계 (2018.05 ~ 2018.12, 삼성전자)
- 5G 통신용 다중빔 배열 안테나 최적 설계 (2017.07 ~ 2017.12, SK텔레콤)
- 79 GHz Radar 안테나 및 모듈 설계 해석 연구
(2017.04 ~ 2018.12, 한국전자통신연구원)
- 저피탐 안테나의 성능 최적화를 위한 알고리즘 연구 (2018.03 ~ 2019.02, 한화시스템)
- High-squint SAR 송수신부 및 배열 안테나 연구 (2017.08 ~ 2020.07, 한화시스템)
- 미래 전투체계네트워크 기술 특화연구센터 (2016.11 ~ 2022.10, 방위사업청)
- 신호정보 특화연구센터 (2015.10 ~ 2020.12, 방위사업청)
- 무선에너지하비스팅 통신융합연구센터 (ERC)
(2014.05 ~ 2021.04, 과학기술정보통신부)
- RF 무선전력전송 기술 개발 (2017.04 ~ 2017.11, 삼성전자)
- 저전력 IoT 기기용 이중대역 적응형 RF 무선전력전송 시스템 개발
(2018.03 ~ 2021.02, 과학기술정보통신부)
- 웨어러블 디바이스용 무구속 멀티모달 무선에너지공급 기술 개발
(2017.06 ~ 2019.12, 산업통상자원부)

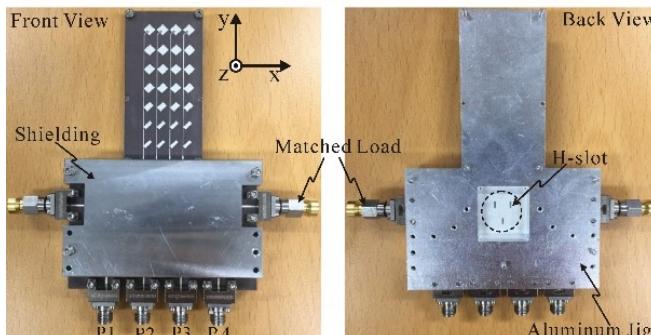
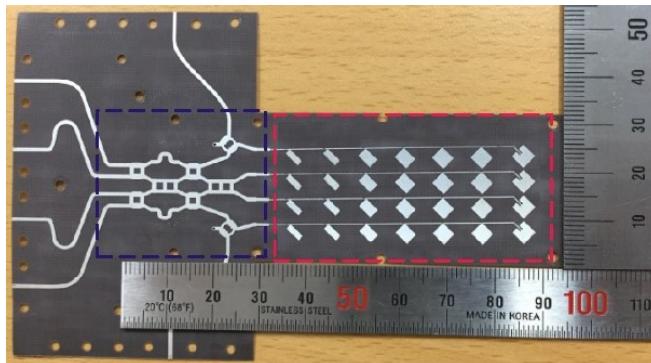
안테나 해석 설계 연구실(Antenna Analysis and Design Laboratory)

● 연구내용 (레이이다 안테나)

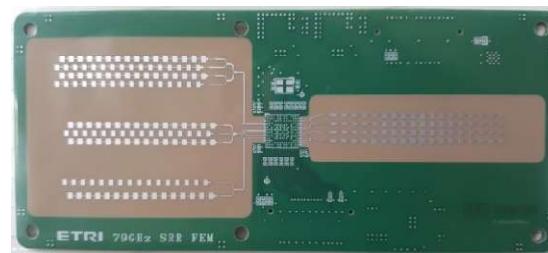


안테나 해석 설계 연구실(Antenna Analysis and Design Laboratory)

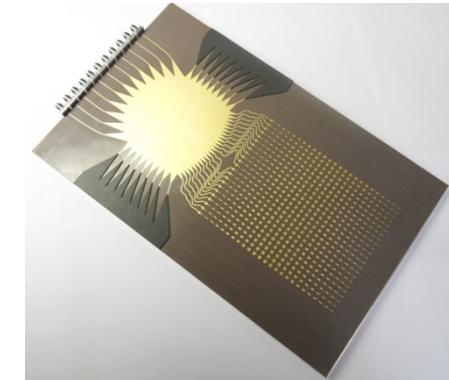
● 연구내용 (통신용 안테나)



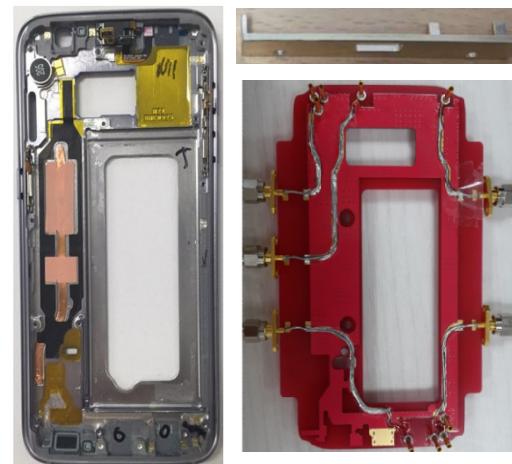
mm-wave 5G Array Antenna



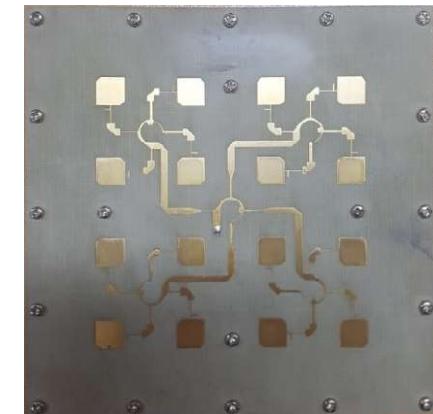
79 GHz car radar antennas



30 GHz Multi-beam Array



Smartphone Metal-frame Antenna



Satellite Antenna

Millimeterwave and Terahertz Electronics



Munkyo Seo:
MMIC Lab

EDUCATION:

- Ph.D. in Electrical Engineering, University of California, Santa Barbara, CA USA, 2007
- MSEE in Electrical Engineering, Seoul National University, Seoul, Korea, 1996
- BSEE in Electrical Engineering, Seoul National University, Seoul, Korea, 1994

EXPERIENCE

- Associate Professor, Sungkyunkwan University, Suwon, Korea, 2013-present
- Senior Engineer, Mixed-Signal IC Design Group, Teledyne Scientific Company, Thousand Oaks, CA USA, 2009-2013
- Assistant Project Scientist, ECE Department, University of California, Santa Barbara, CA USA, 2007-2009
- Summer Internship, Logic Technology Group, Intel Corporation, Hillsboro, OR USA, 2006
- Senior Engineer, Mobile Handset Group, LG Electronics, Seoul, Korea, 1997-2002



Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

Millimeterwave and Terahertz Electronics



Munkyo Seo:
MMIC Lab

RESEARCH INTERESTS

- RF/Millimeter-wave circuit design
- Terahertz electronics
- Applied signal processing techniques
- IoT / Wireless sensor network

PROFESSIONAL ACTIVITIES

- IEEE MTT-S Seoul Chapter Vice Chair, 2015-present
- IEEE Senior Member, 2011-present



Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

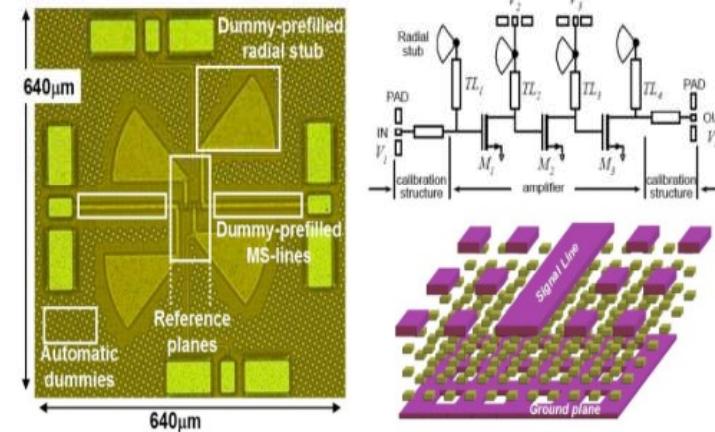
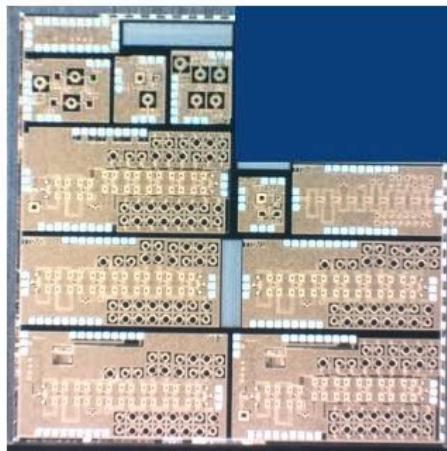
Millimeterwave and Terahertz Electronics



Munkyo Seo:
MMIC Lab

Research Goal:

Explore innovative circuit- and system-level techniques to enable 10-1,000 GHz future wireless systems.



Circuits for X-band (6-18 GHz) phased-array systems in 0.18 um CMOS

- Programmable True-time delay (TTD) IC
- Programmable attenuator IC
- Broadband amplifier

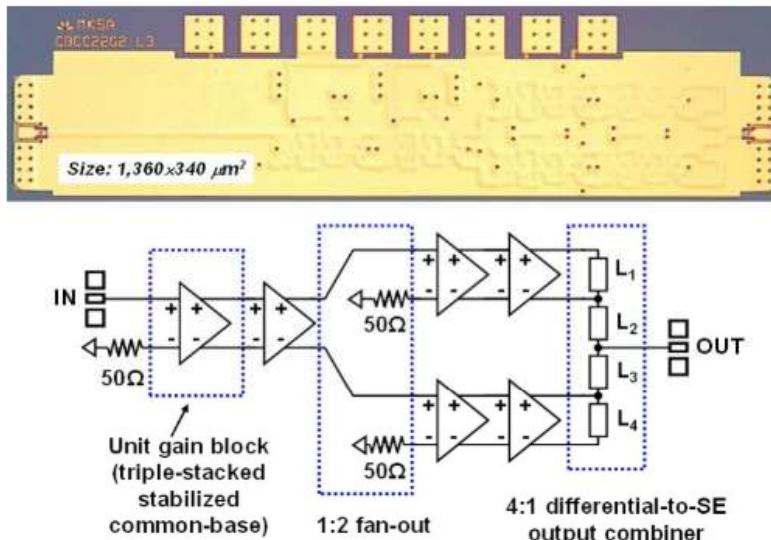
A 150 GHz amplifier in 65nm CMOS

- Three-stage common-source stages with minimum matching losses
- Dummy-prefilled microstrip lines for design-rule compliance

Millimeterwave and Terahertz Electronics



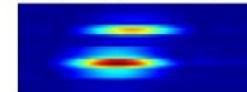
Munkyo Seo:
MMIC Lab



60-GHz Up/Down Converter



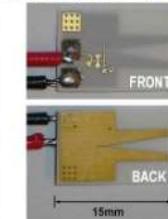
Image map (two sensors)



Entire collector system



60 GHz antenna + modulator



60 GHz reflection sensor



A 600 GHz 30 dB gain, 2 mW Psat amplifier in InP-HBT process

- Among the fastest amplifier reported with a record output power
- 12-stage common-base for high-gain
- Cross-coupled feedback stabilization
- 4:1 differential-to-SE output combiner for high saturated output power

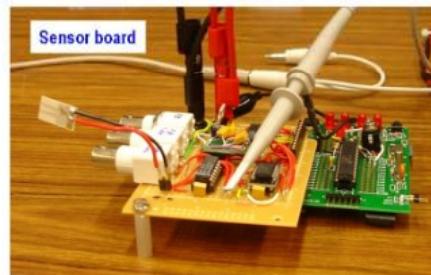
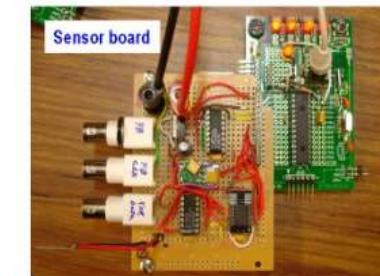
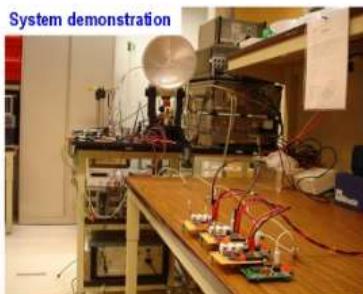
Millimeter-wave (60 GHz) sensor network experimental prototype

- Simultaneous sensor localization and data read-out
- 3D sensor localization using a narrow pencil beam and radar ranging techniques
- Reflection-type sensor prototype using a slot antenna and PIN-diode modulator

Millimeterwave and Terahertz Electronics

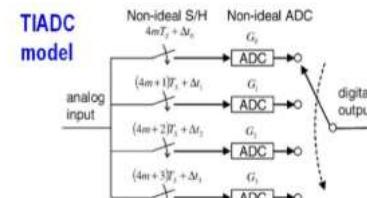


Munkyo Seo:
MMIC Lab

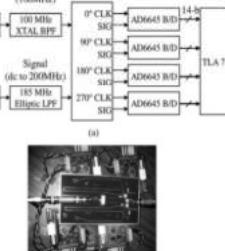


Experimental prototype (60 GHz) for sensor network based on a distributed phased array

- Local sensors collaborate to combine their RF carrier power to reach far-out reader.
- Feedback-based approach to synchronize sensor phase/frequencies in distributed fashion.

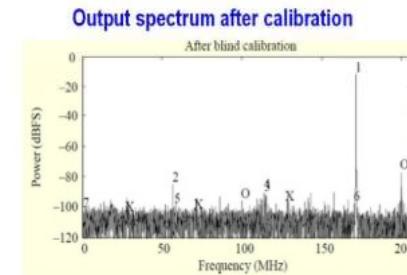
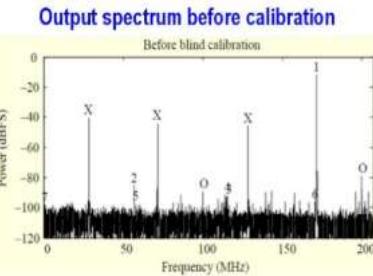


Prototype system



Signal processing techniques for mismatch error corrections in time-interleaved ADCs (TIADC)

- Time-interleaving enables much higher sampling frequencies than a single A-D converter
- However, signal-to-noise ratios of TIADCs are significantly affected by mismatch errors
- Various foreground/background signal processing techniques are developed to correct such mismatch errors



Introduction

Microwave integrated Circuits and Systems Lab. (MCS Lab)

- Professor: Youngoo Yang
- Established in 2005



Research Areas

- 5G and IoT transmitters/receivers
- Broadband multi-function ICs
- Wireless power transfer systems
- High power / high efficiency / broadband Doherty PAs
- High linearity/efficiency power amplifier ICs for RF and mm-wave applications

Members	Ph.D. Candidates	M.S. Candidates	Research Staff	Undergraduate	Total
6	4	1	4	15	

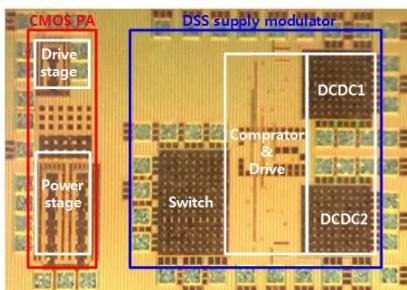


Research Group on Analog/RF circuit and Systems

Research Group on Analog/RF Circuit and Systems
Sungkyunkwan Univ. Natural Sciences Campus
2066, Seobu-ro, Jangan-gu, Suwon-si, Gyeonggi-do, Korea

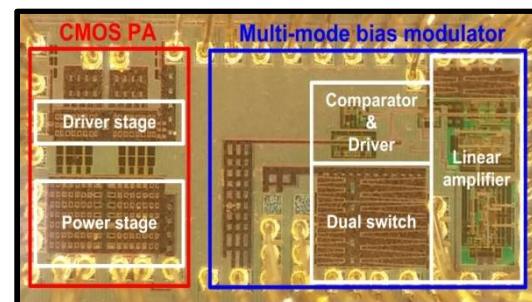
Supply Modulators / Power Amplifier ICs

- Efficiency enhancement techniques at average power level
- With DSS (Dynamic supply switching) and ET (Envelope tracking)
- Handset power amplifier for wireless communications



[DSS PA CMOS IC]

- 0.18 um CMOS process
- 2-stage single-ended CMOS PA
- Single-chip DSS PA
- 1.75 GHz, LTE 5MHz



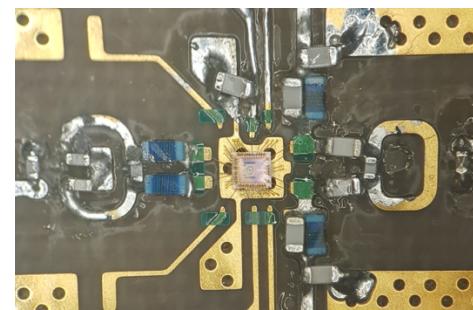
[ET PA CMOS IC]

- 0.18 um CMOS process
- 2-stage balanced CMOS PA
- Single-chip ET PA
- 0.78 GHz, LTE 5MHz



[Boost converter PA]

- With Boost DC-DC converter
- High drain voltage
- No output matching network
- 1.88 GHz, LTE 5MHz

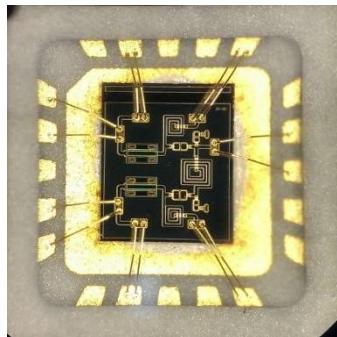


[Dual mode CMOS PA]

- 55 nm CMOS process
- 2-stage differential CMOS PA
- LPM, HPM using load impedance modulation
- 0.92 GHz, LTE 5MHz

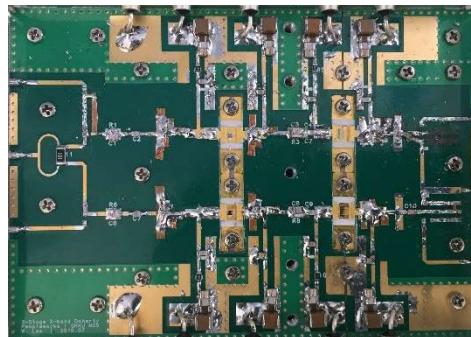
Doherty Power Amplifiers

- Efficiency enhancement and load modulation techniques
- Various applications (high efficiency, high-power, broadband, and MMIC)



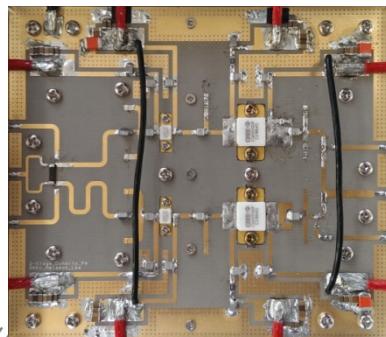
[GaN-HEMT Doherty PA IC]

- 0.4 um process
- Compact load network
- QFN packaging
- For LTE small-cell base stations
- 2.655 GHz, LTE 10 MHz



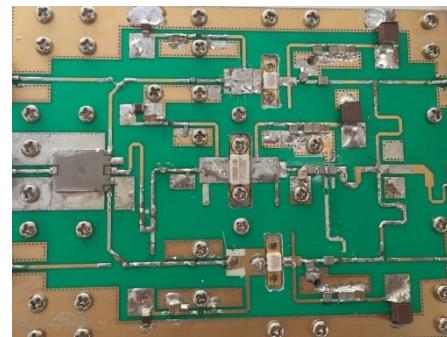
[X-Band Doherty PA]

- X-Band (8.2 GHz)
- 2-stage structure
- Ceramic packaging
- For military communications



[High-Power 2-Stage Doherty PA]

- More than 200 W
- 2-stage structure
- Current optimization
- For LTE RRH systems
- 2.655 GHz, LTE 10 MHz

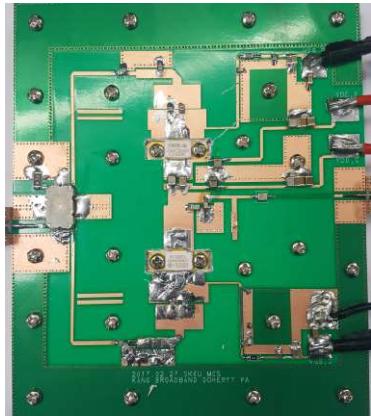


[3-Way Uneven Doherty PA]

- 3-way structure
- Arbitrary cell ratio
- Linearity improvement
- For base stations
- 2.14 GHz, LTE 10 MHz

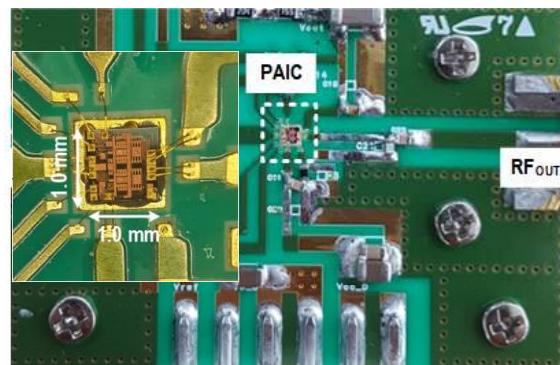
Broadband Power Amplifiers

- Broadband multi-function ICs



- More than 100 W
- Octave bandwidth
- Optimized susceptance using MRC
- Post matching structure
- 0.9 - 1.8 GHz, LTE 10 MHz

[Broadband Doherty PA]



- 2- μ m InGaP/GaAs HBT process
- Cascode structure for high R_{OPT} and low C_{OUT}
- Single L-section matching network
- 1.55~2.65 GHz, LTE 10 MHz

[GaAs HBT Cascode PA IC]

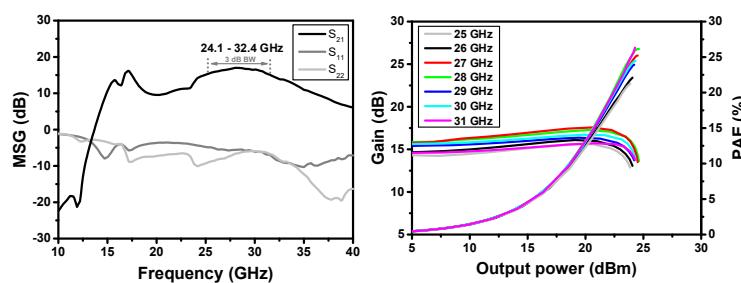
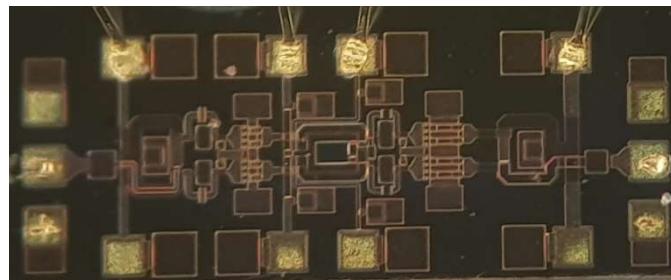


- 0.15- μ m GaAs pHEMT process
- Two-stage structure for high gain
- Dual frequency selective impedance matching for broadband
- 6~18 GHz, CW

[GaAs pHEMT broadband PA IC]

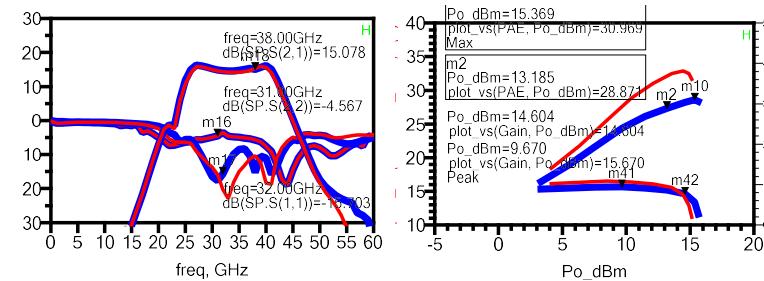
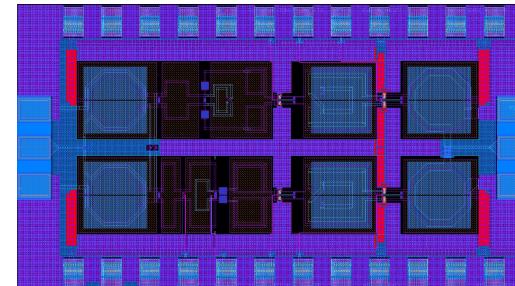
mm-wave PA ICs

- High linearity / efficiency mm-wave power amplifier IC (GaAs pHEMT / CMOS)



- 0.15- μ m GaAs pHEMT process
- 2-stage differential structure PA
- 2nd harmonic control at gate to source
- 25 - 31 GHz, CW measurement

[Ka-band differential GaAs PA]



- 28 nm Bulk CMOS process
- 2-stage differential broadband Doherty PA
- Varactor based input phase compensation
- 25 - 40 GHz, CW simulation

[mm-wave broadband Doherty CMOS PA]

WPT using RF

- RF energy transmission and data communication
- For wireless power transfer, IoT, and low power sensor systems

