From sub-V_T RF to mm-wave CMOS Circuits

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Outline

- Introduction
- Beamforming Circuits
- Circuits for Cellular Applications
  - LNAs
  - Channel Filters
- Sub-V_T RF
  - LNA + Mixers
  - Antennas
- Conclusions

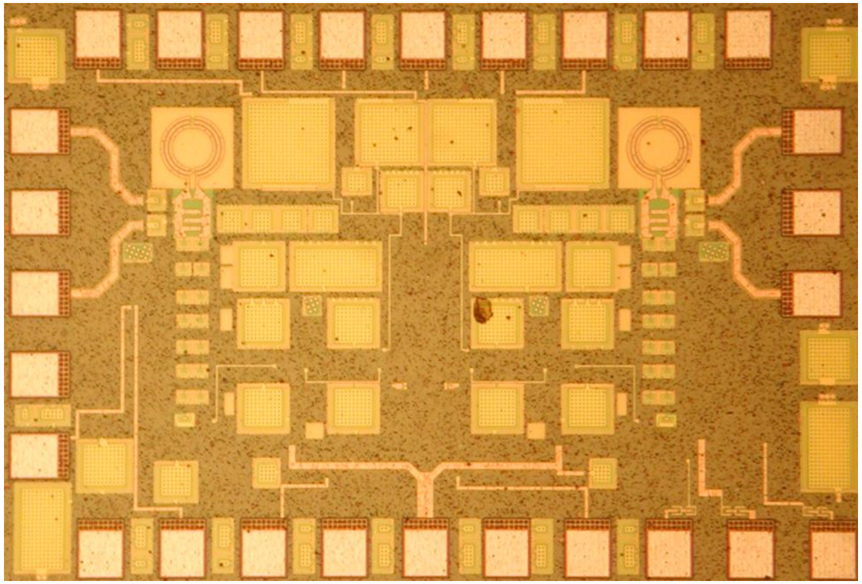
Introduction

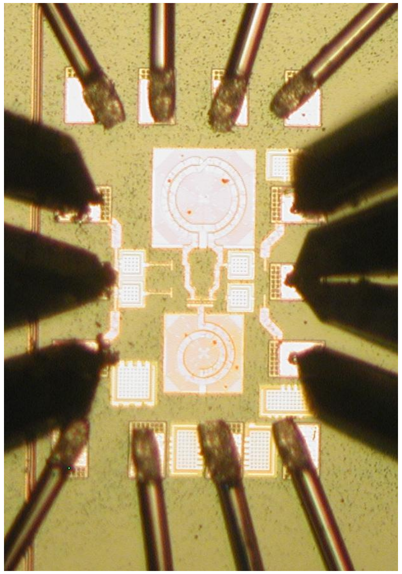
CMOS scaling =>

- Faster devices
  - μ-Wave & mm-Wave CMOS
- More devices per chip
  - Beamforming
- Weak inversion RF
  - Micropower radio
- Less voltage
  - System-on-package
  - MEMS
  - Devices with thick oxide and/or extended drain

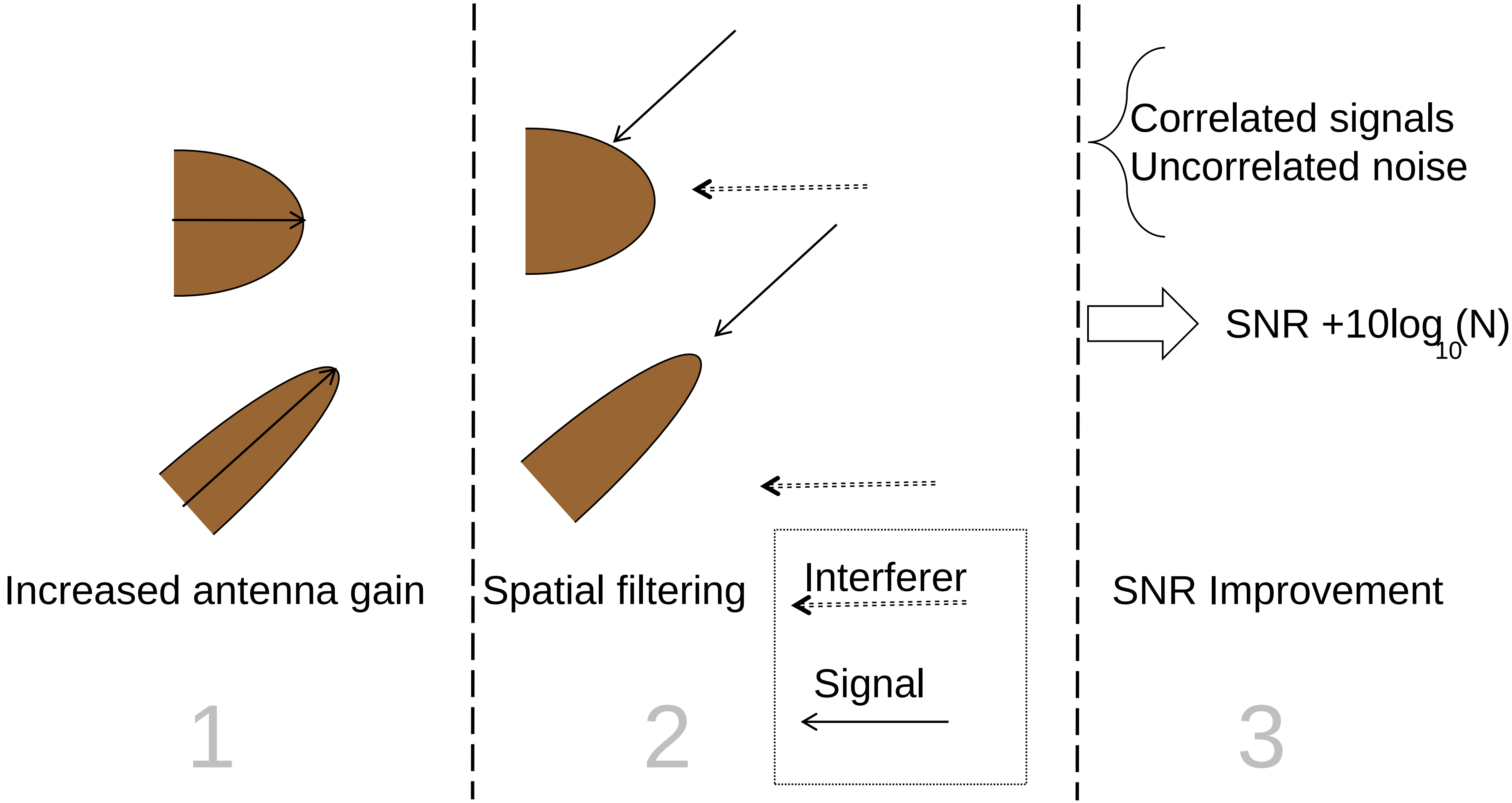
Beamforming Circuits

Andreas Axholt





Beamforming Benefits



Beamforming Architectures

1. RF path
   - True delay line
   - Reflection coupler

Substrate losses

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2. Analog baseband
   - Cartesian vector combination

Quad LO distribution & area/current overhead

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3. Digital baseband

Quad LO distribution & area/current overhead

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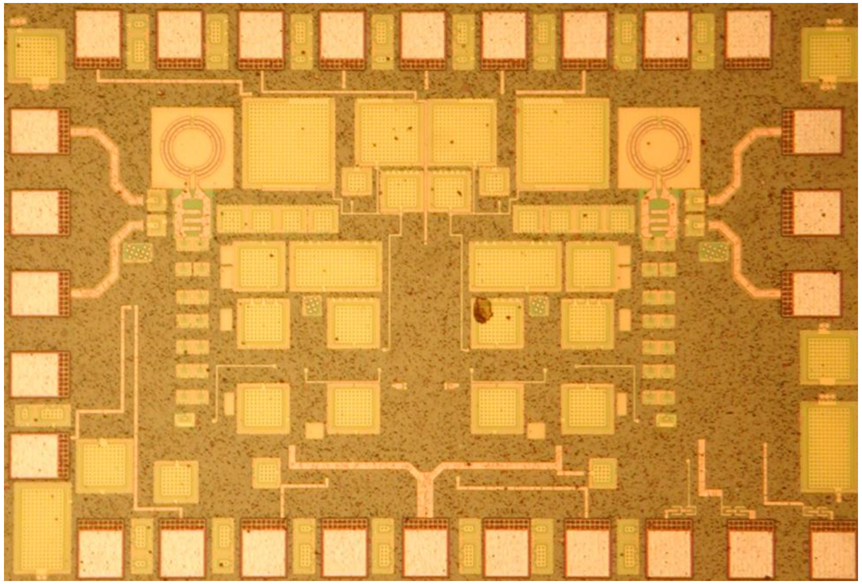
4. LO path
   - Cartesian LO vector combination
   - Injection Locked VCO →
   - PLL →

Quad LO distribution
Injection Signal distribution
area/current overhead, NO signal variation versus phase setting

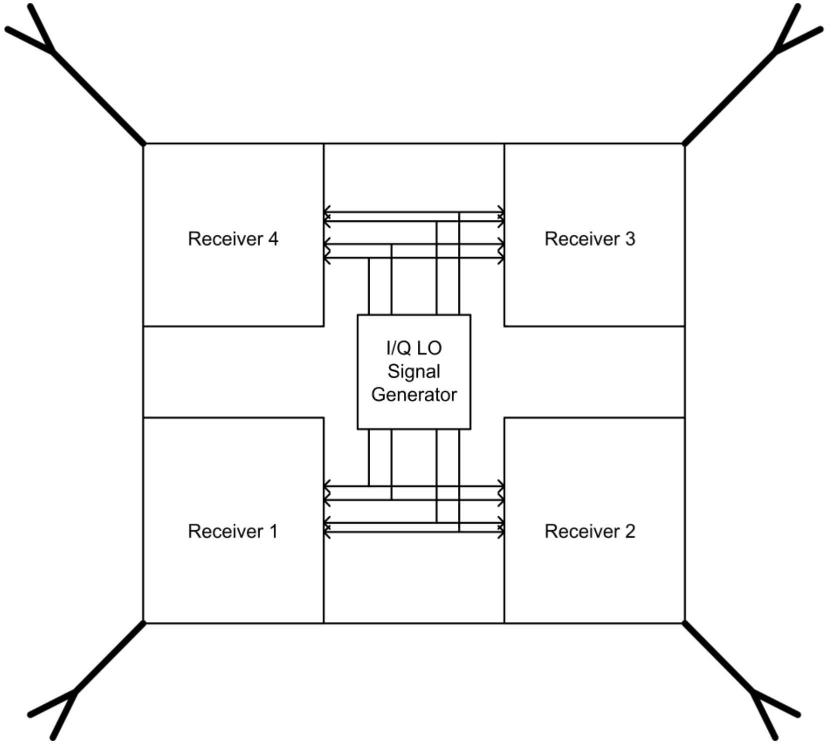
Beamforming Circuit 1:

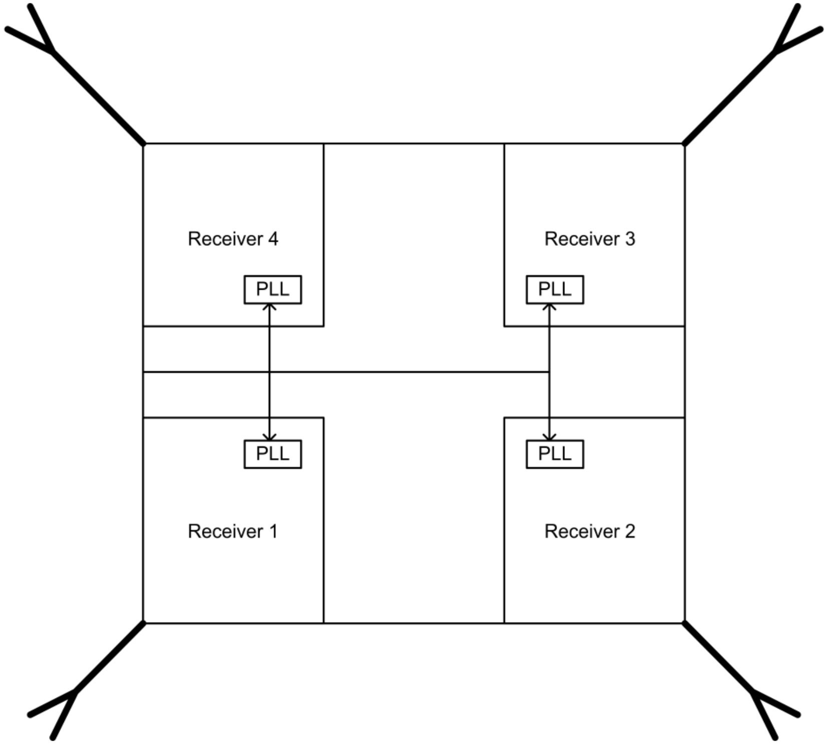
A PLL based 12GHz LO Generator with Digital Phase Control



Received the APMC Prize

LO Routing Problem



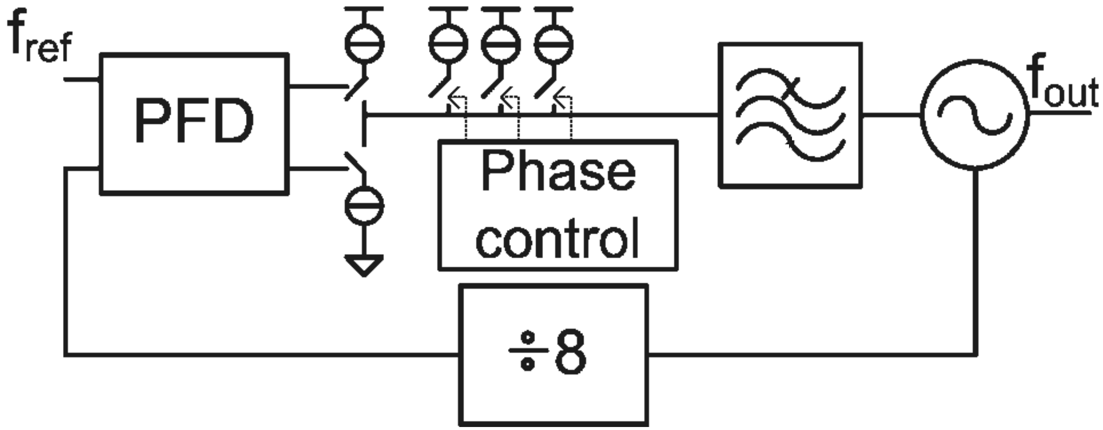


I/Q routing is complex
Everything must be symmetric

Single-ended "low" frequency routing

PLL with Phase Control

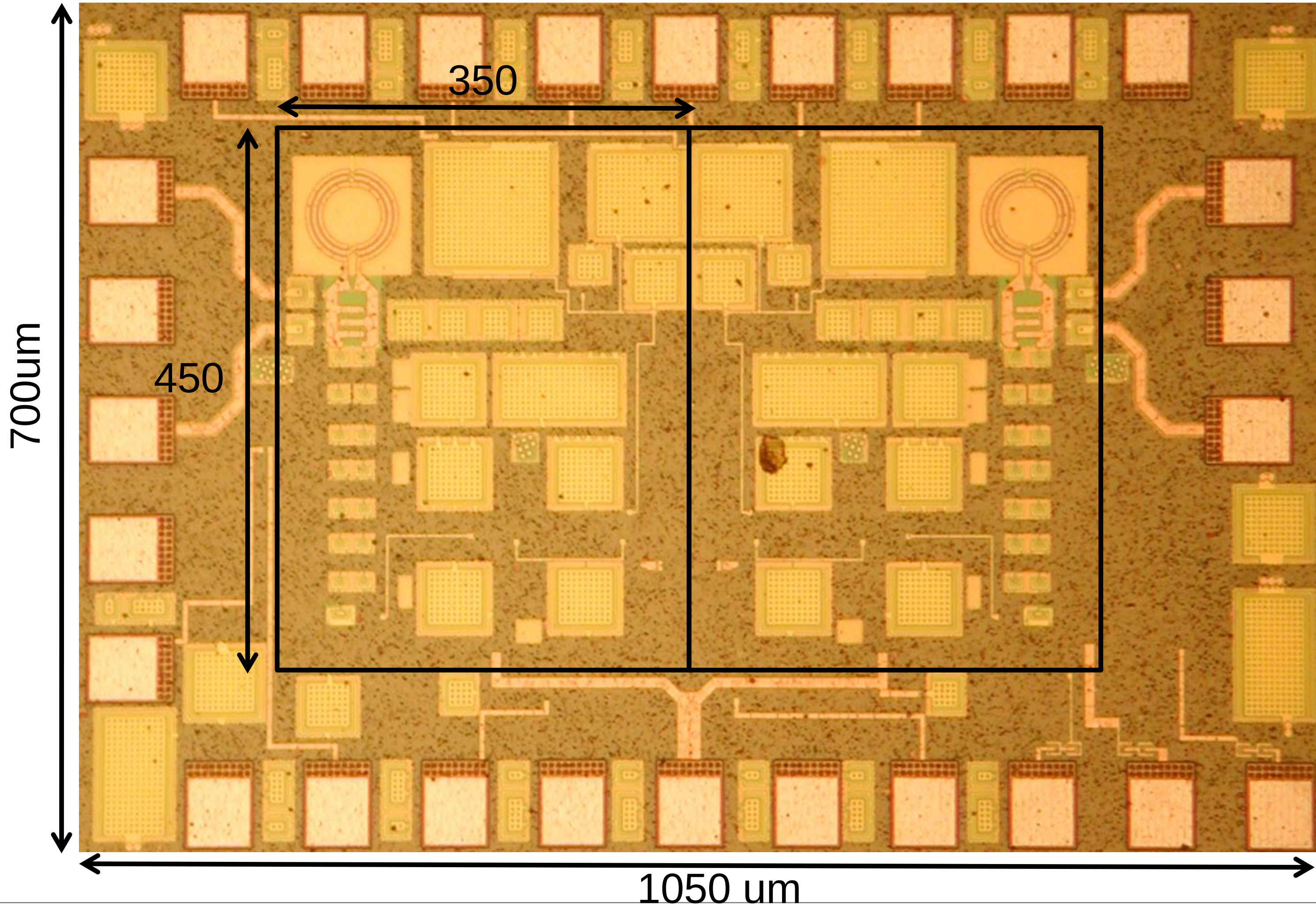
1.5 GHz



12 GHz

$$\Delta\phi = 2\pi \cdot N \cdot \frac{I_{inj}}{I_{cp}}$$

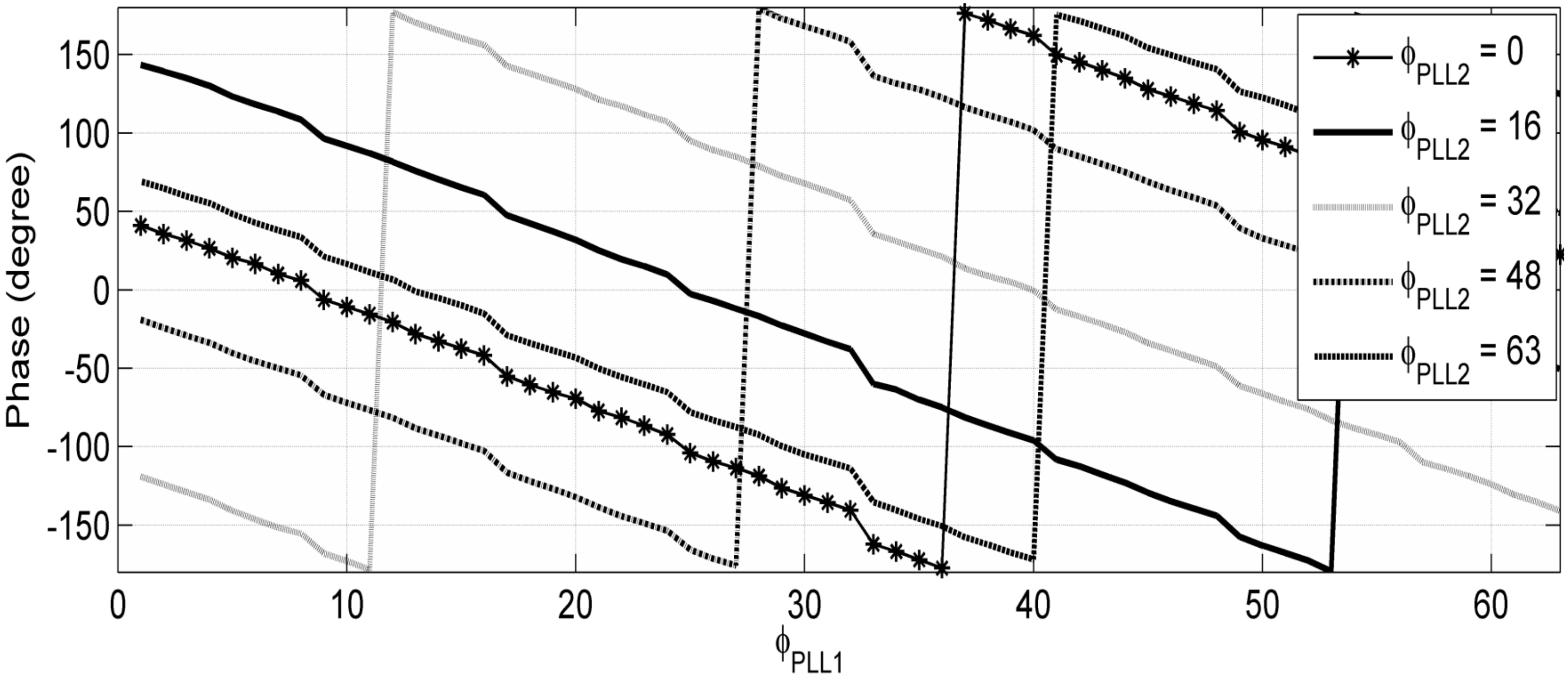
Chip with 2 PLLs



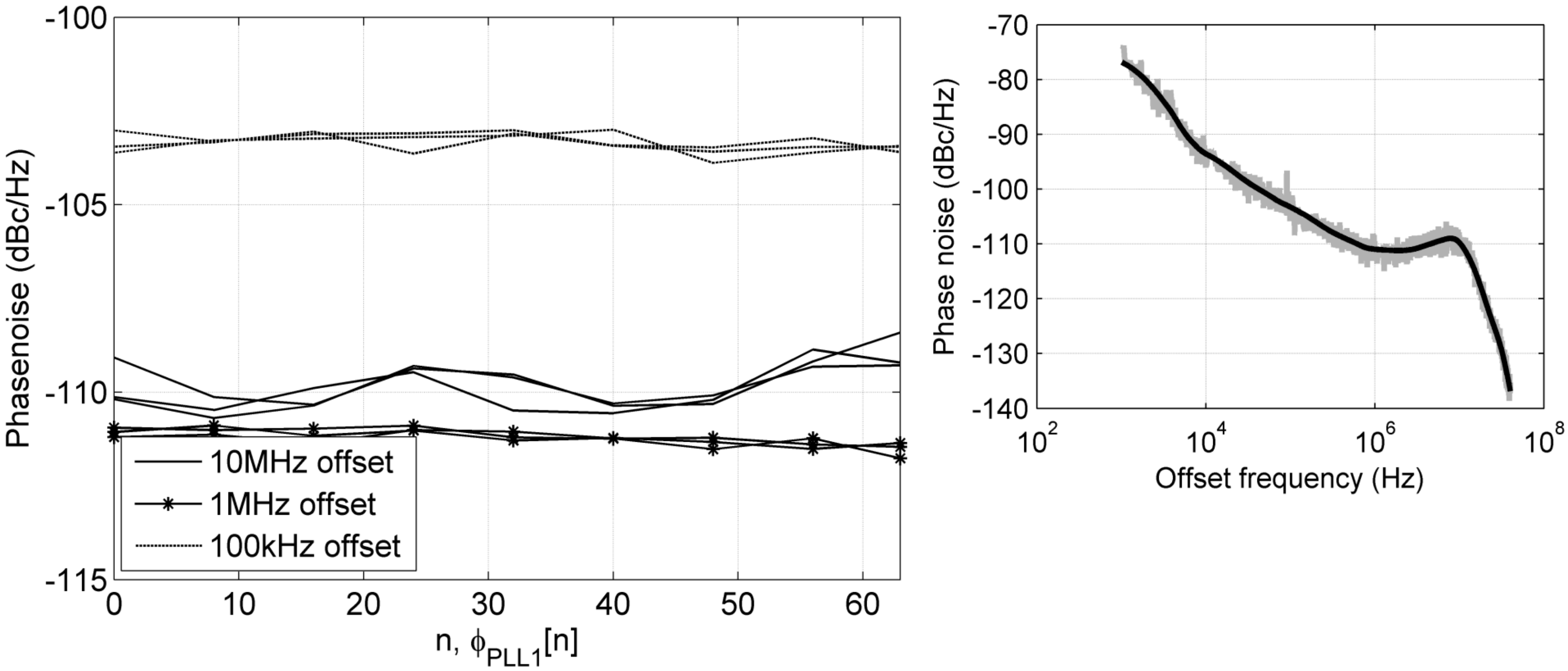
15 mA x 2
1.2 V supply

90nm
CMOS

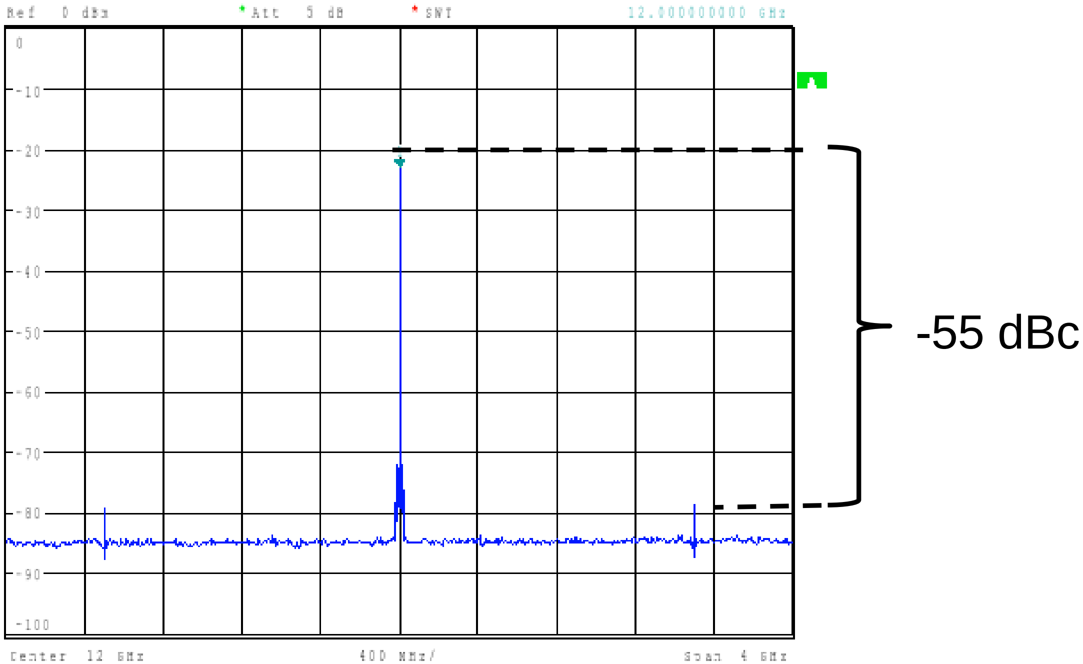
Measurement: Phase control



Measurement: Phase noise

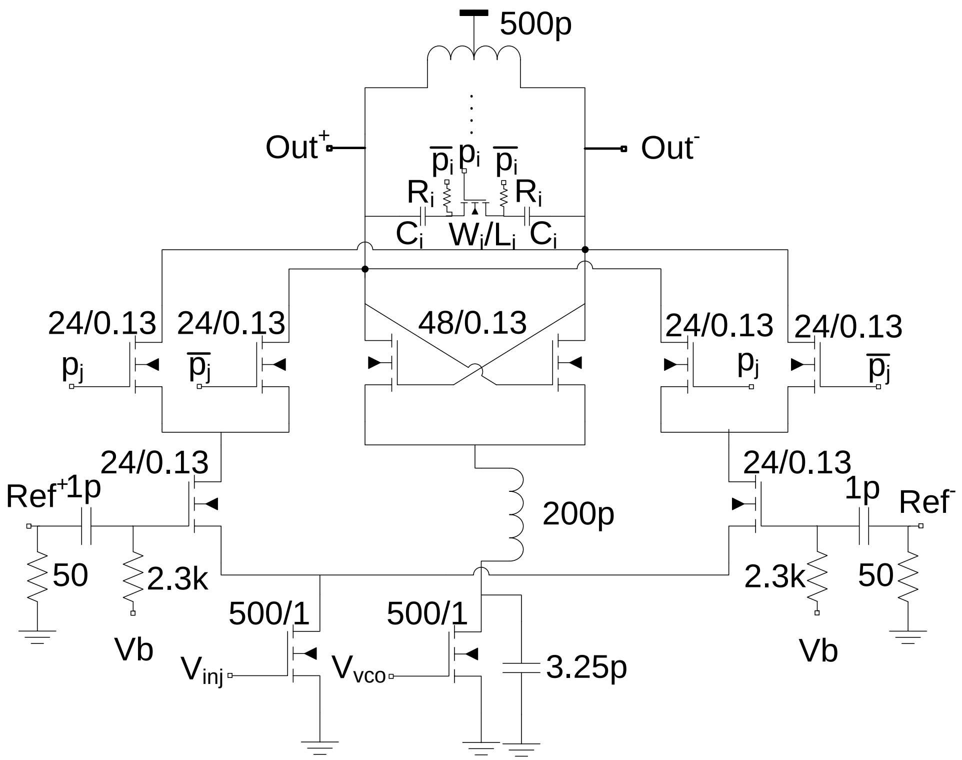


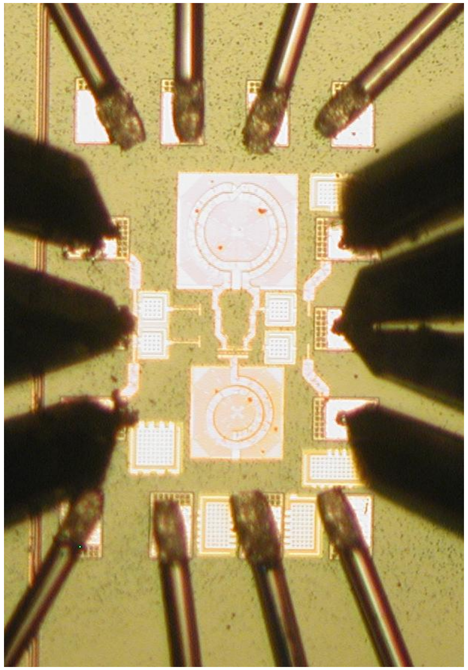
Measurement: Spectrum



Beamforming Circuit 2:

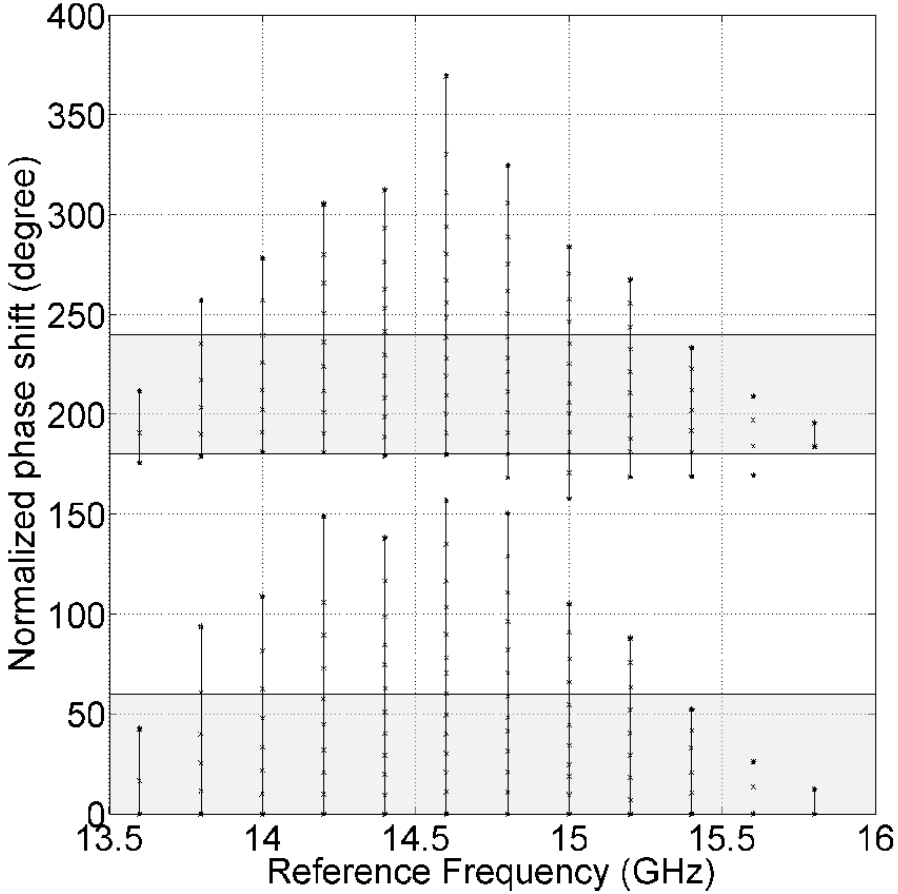
A 14.5 GHz Injection Locked LO Generator with Digital Phase Control





IMS 2010

Measured Phase Control Range



Full 360º coverage with 3rd order sub-harmonic mixer

Beamforming Circuit 3:

A 24-GHz 90-nm CMOS Beamforming Receiver Front-End with Analog Baseband Phase Rotation

To be shown in the next presentation!

ESSCIRC 2010

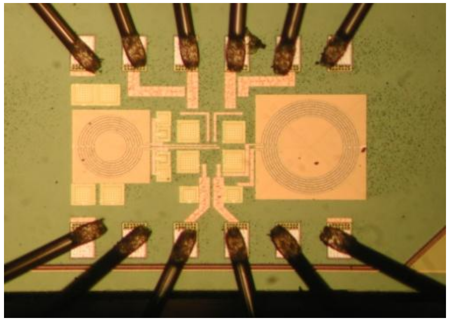
Beamforming Circuits 4 and 5

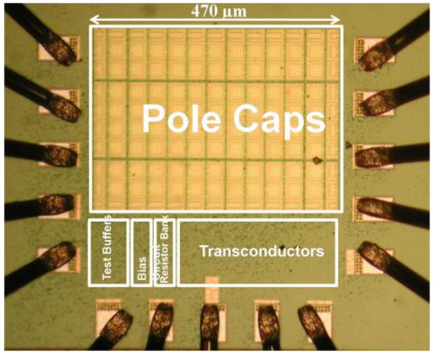
Circuit 4: New architecture, in measurement
Circuit 5: PLL based receiver at 60GHz, in fabrication

More about these at the LCD Workshop 2011

Circuits for Cellular Applications

- LNAs
- Channel Select Filters
- Ongoing work: Power amplifiers

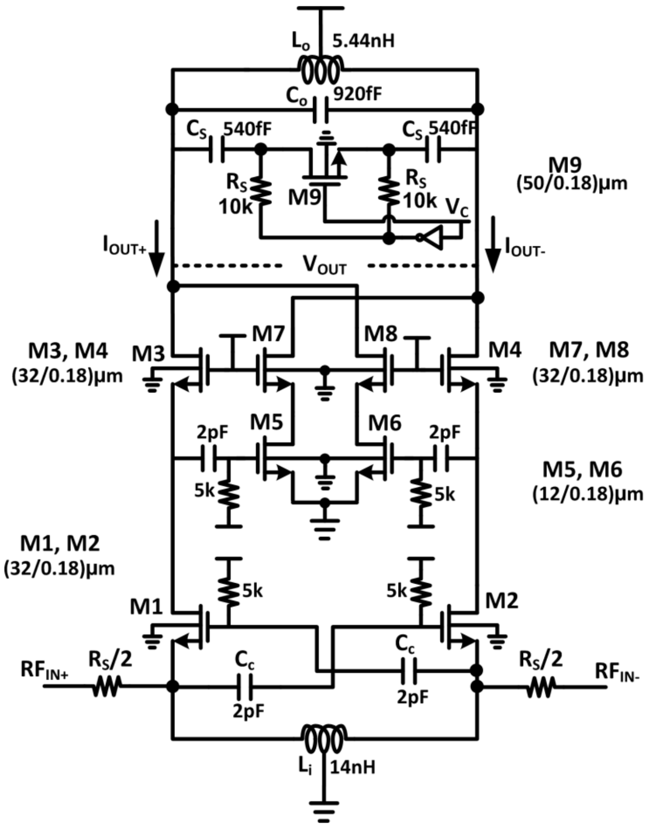


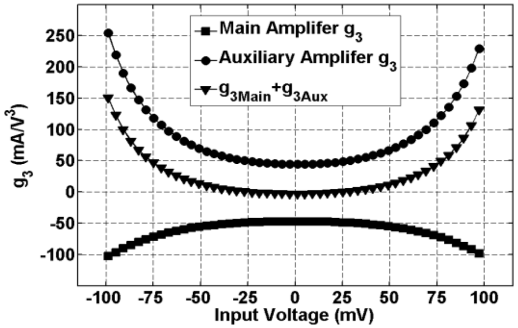


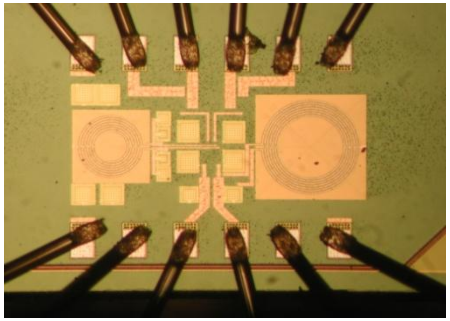
Low Noise Amplifier 1

Gholamreza Zare Fatin

Visit from Univ. of Tabriz, Iran



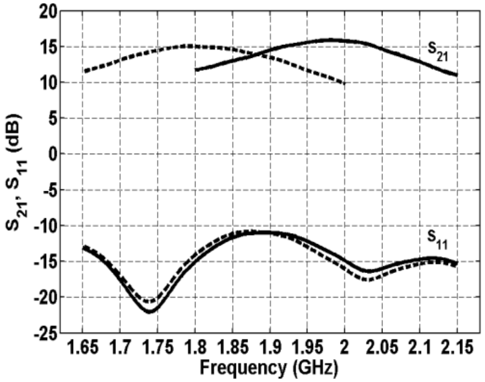


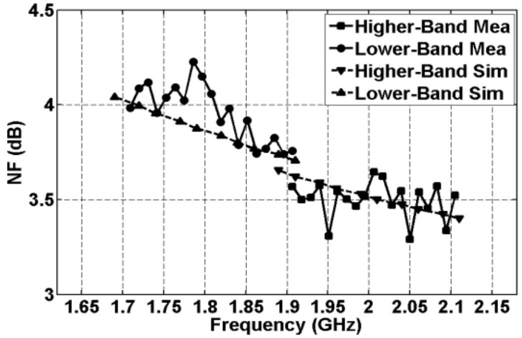


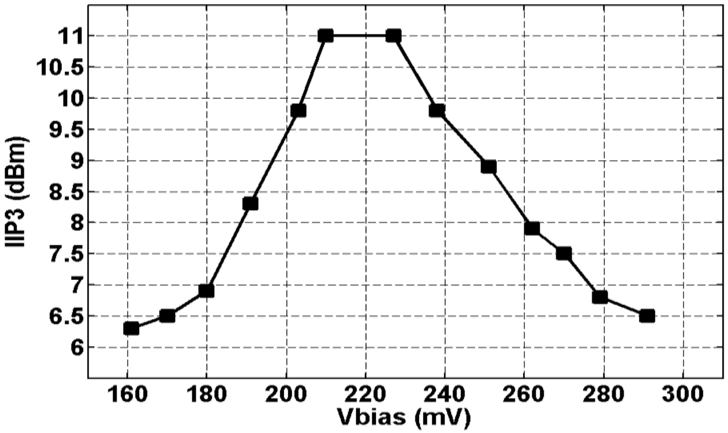
90-nm CMOS

IEEE Microwave and Wireless Components Letters 2010

Measurements



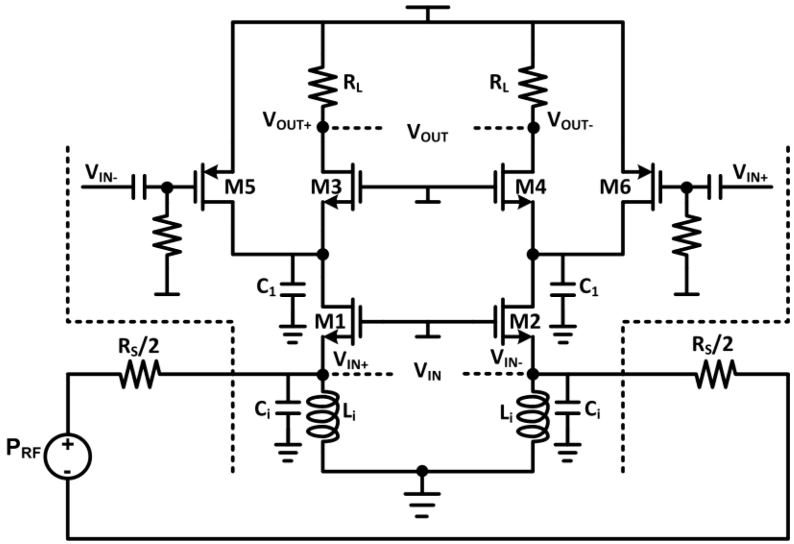


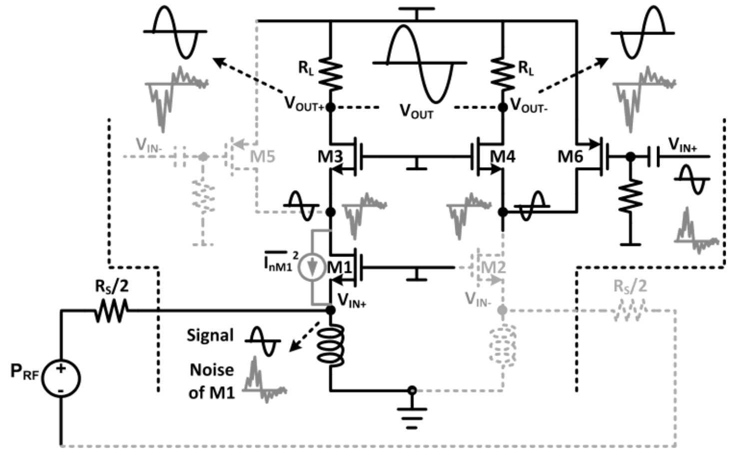


Low Noise Amplifier 2

Gholamreza Zare Fatin

Visit from Univ. of Tabriz, Iran



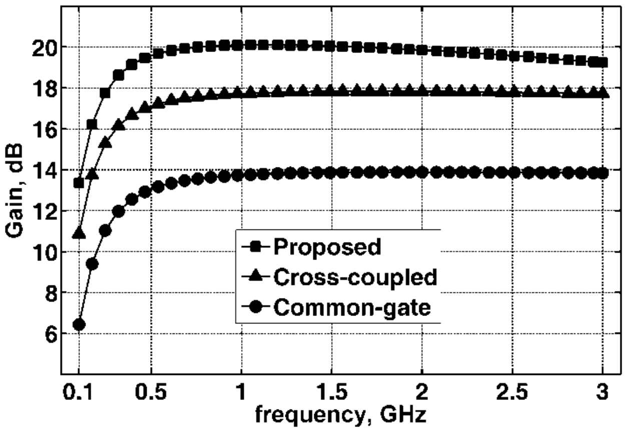


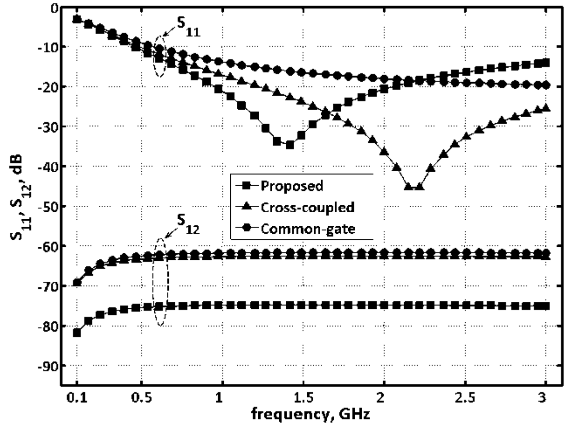
90-nm
CMOS

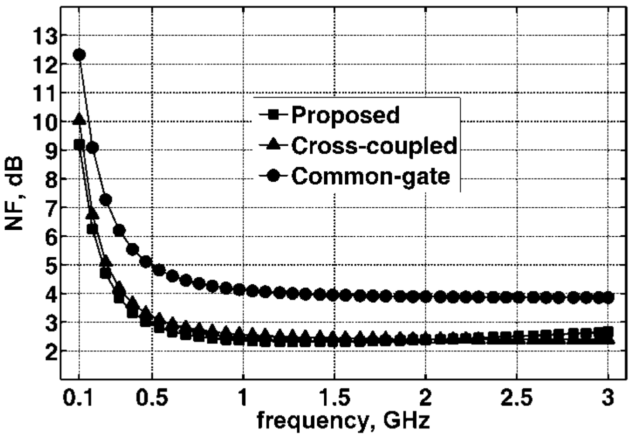
Springer Journal on Analog Integrated Circuits and Signal Processing 2010

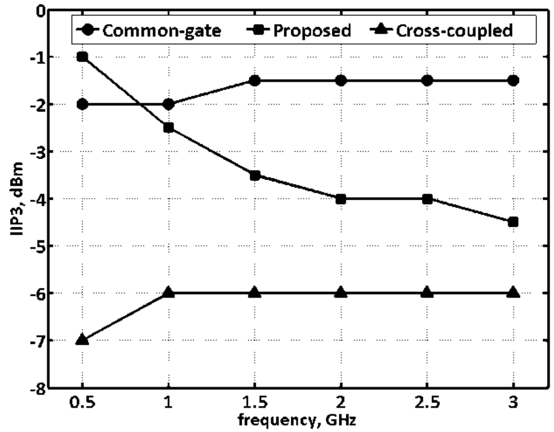
Simulation:

Comparisons to CG and CC CG LNAs





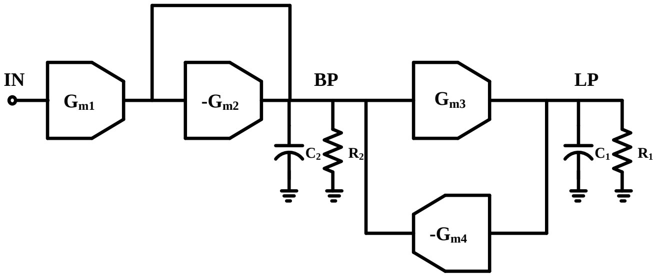


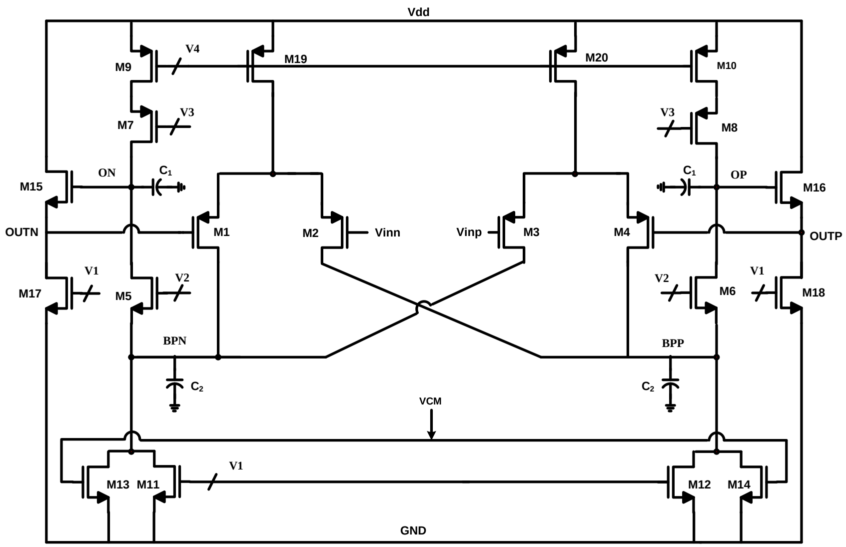


WLAN/WiMax Channel Select Filter

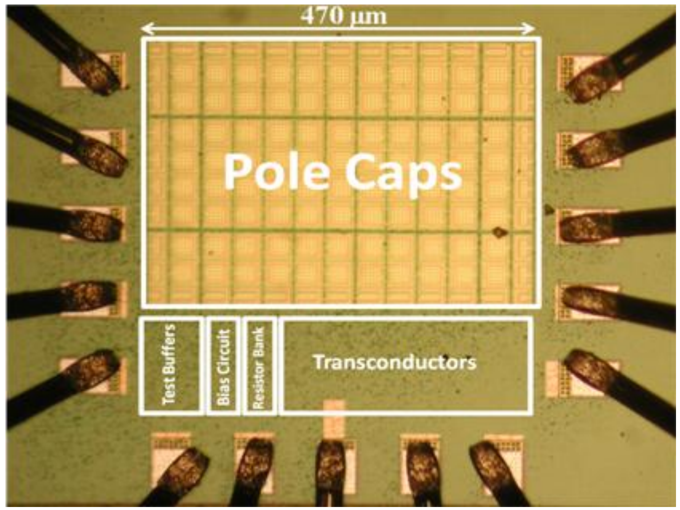
Mostafa Savadi Osgooei

Visit from Univ. of Tehran, Iran





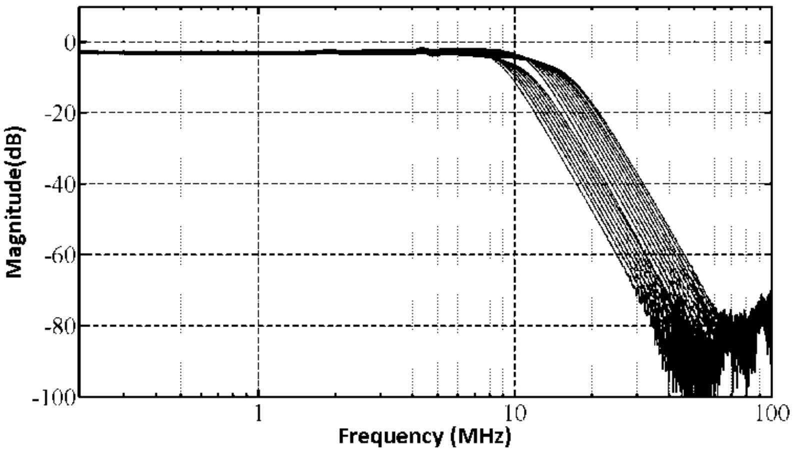
Gm-C biquad with improved linearity

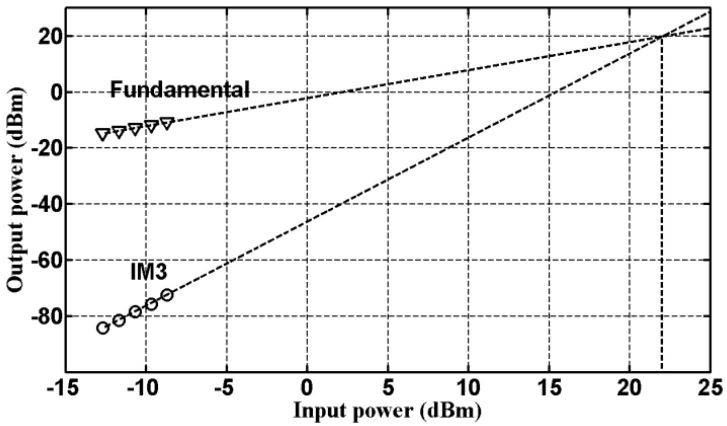


6th order filter in 90-nm CMOS

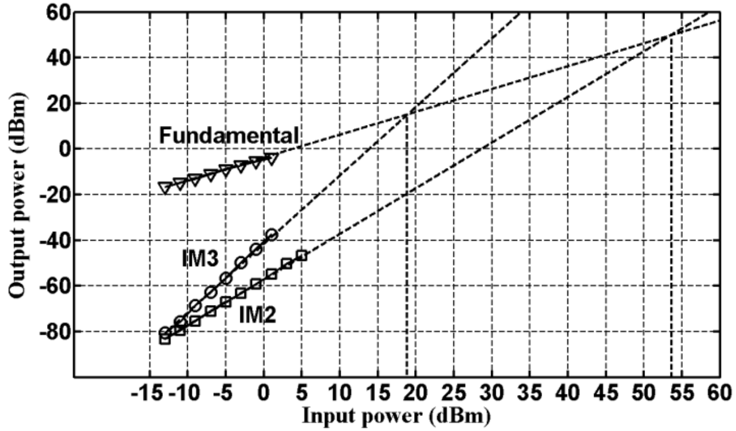
RFIC 2010

Measurements





In band linearity



Out of band linearity

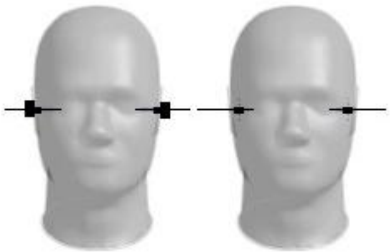
A 175µW 150MHz-2GHz inductorless receiver front-end in 65nm CMOS

Carl Bryant

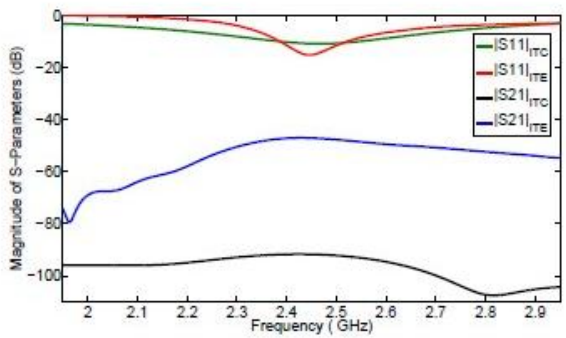
Not yet published

Antennas for Link between Hearing Aids

Rohit Chandra



Placement of Antennas, left: ITE, right: ITC



Simulated return loss(S_{11}) and the coupling between the antennas (S_{21})

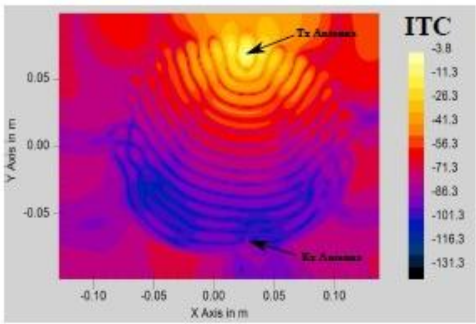
SEMCAD simulations

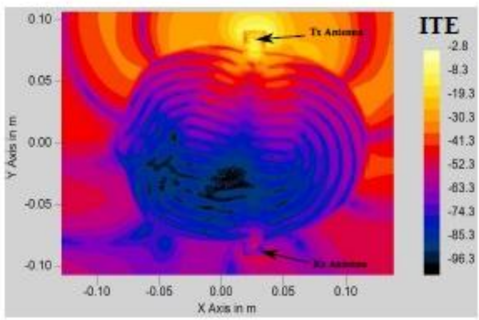
Parameter	ITC	ITE
f_{res}(GHz)	2.46	2.44
$S_{11_{res}}$(dB)	-11.0	-15.3
BW(MHz)	174	139.4
$S_{21_{peak}}$(dB)	-91.7	-47.1
$S_{21_{2.45GHz}}$(dB)	-91.7	-47.2
$S_{21_{res}}$(dB)	-91.8	-47.1

SAR Limitation	ITC	ITE
$1.6W/Kg$ over $1g$	$5.5mW$	$18.4mW$
$2W/Kg$ over $10g$	$37.3mW$	$80.1mW$

Maximum Accepted Power by ITC and ITE antennas

ITC = In The Canal
ITE = In The Ear





Real modulus of electric field at 2.45 GHz sliced at the level of the antennas

EMBC 2010

Conclusions

- Activities in different fields:
  + µWave & mm-Wave CMOS
  + Cellular
  + Micropower radio
  + Nanowires for RF
  + MEMS starting up
  + …
- Enabled by
  + Centers
  + Cooperation