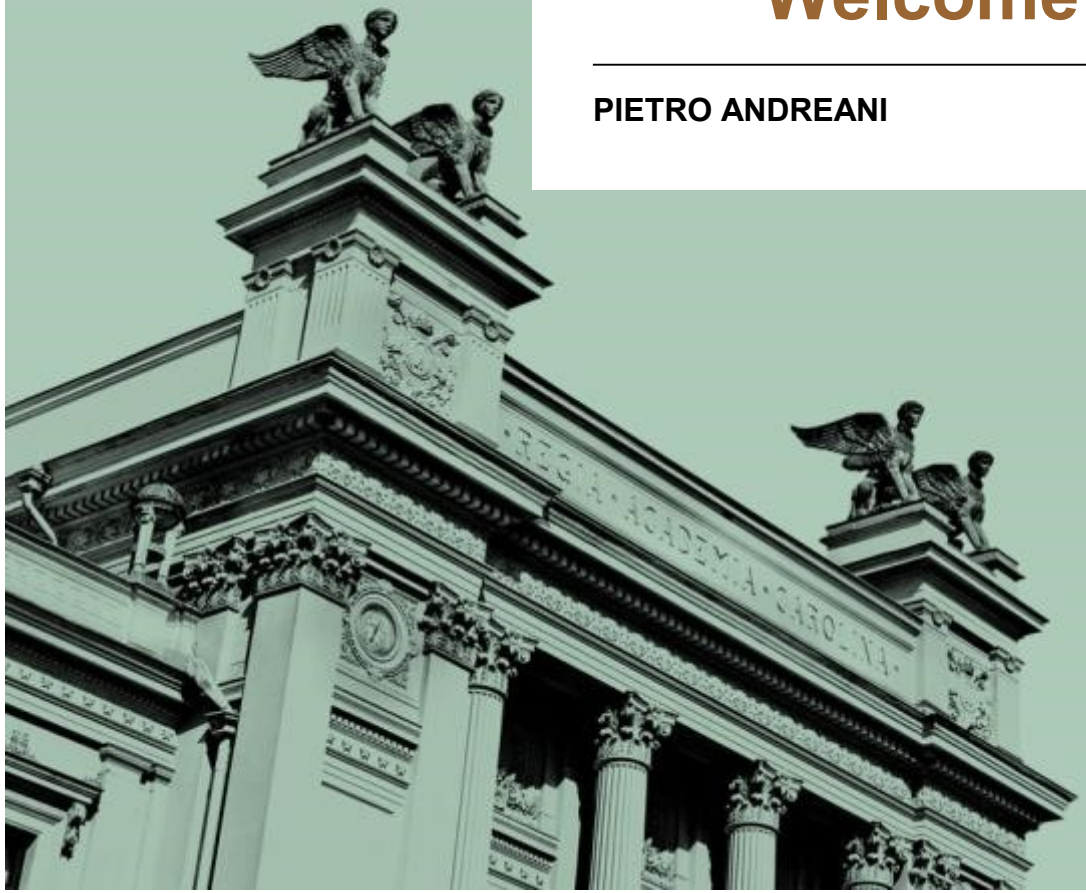
2016 Lund Circuit Design Workshop
Welcome and Introduction

PIETRO ANDREANI

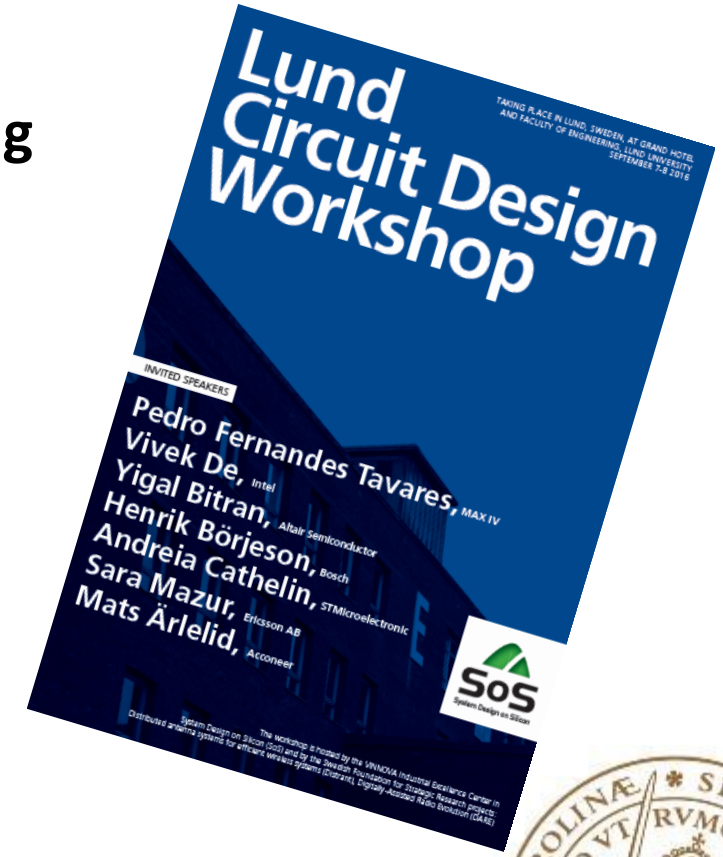


Welcome to two exciting days with SoS!

Together with 150 colleagues!

You have received a folder containing

- **Workshop program**
- **Invited speakers**
- **Senior researchers**
- **PhD students**
- **International Advisory Board**
- **SoS Board**



Thematic Sessions

Day 1

- **Session 1: Energy-Aware ICs**
- **Session 2: Cellular Communication**
- **Session 3: New Directions – Technologies and ICs**

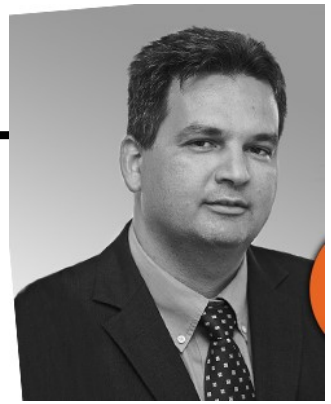
Day 2

- **Session 4: Future Technologies**
- **Session 5: 5G**
- **Conclusion**

Invited Speakers, day I (a)

- **Vivek De**, Intel, Portland, OR
  Energy Efficient Computing in Nanoscale CMOS

- **Yigal Bitran**, Altair Semiconductor, Israel
  Taking LTE to the extremes



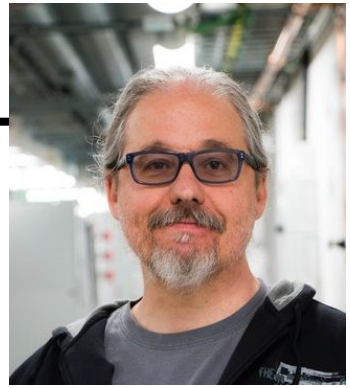
Invited Speakers, day I (b)

- **Henrik Börjeson**, Bosch, Lund
  From consumer to commercial: connectivity solutions for the automotive industry

- **Andreia Cathelin**, STMicroelectronics, Crolles, France
  FD-SOI Technology – Advantages for Analog/RF and Mixed-Signal Designs

Invited Speakers, day I (c)

- **Pedro Fernandes Tavares**, MAX IV, Lund
  Status and Future Development Plans for the MAX IV Light Sources



Invited Speakers, day II

- **Mats Ärlelid**, Acconeer, Lund
  60GHz radar for consumer products

- **Sara Mazur**, Ericsson AB, Stockholm
  5G for the Networked Society

Important people in SoS

The SOS Board

Sven Mattisson, Chairman
Ericsson

Andreia Cathelin
STM

Franz Dielacher
Infineon

Peter Karlsson
Sony

Anton Klotz
Cadence

Klas Malmqvist
LTH

?

Peter Olanders
Ericsson

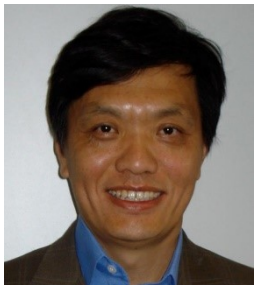
Per Runeson
Computer Science, LTH

Important people in SoS

The International Advisory Board

Mike Faulkner
Victoria University, Melbourne

Qiuting Huang
ETH, Zurich



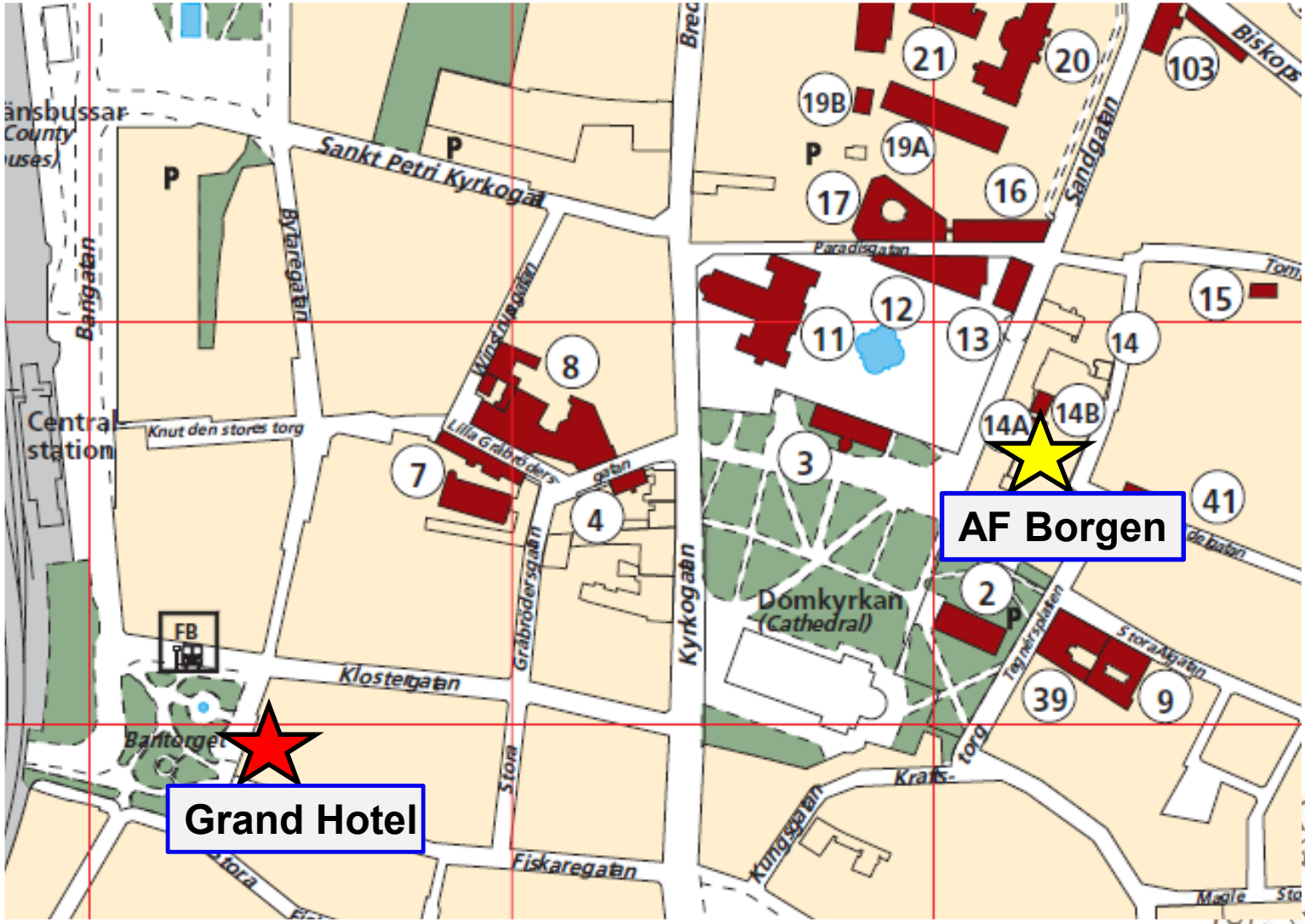
Jan Rabaey
UC Berkeley, CA

Some Logistics

- **Today we are at Grand Hotel, including lunch**
- **Dinner is in Lilla Salen, AF Borgen, at 7pm**
- **Tomorrow we are at the Faculty of Engineering, LU**

Dinner: AF Borgen

Dinner: AF Borgen

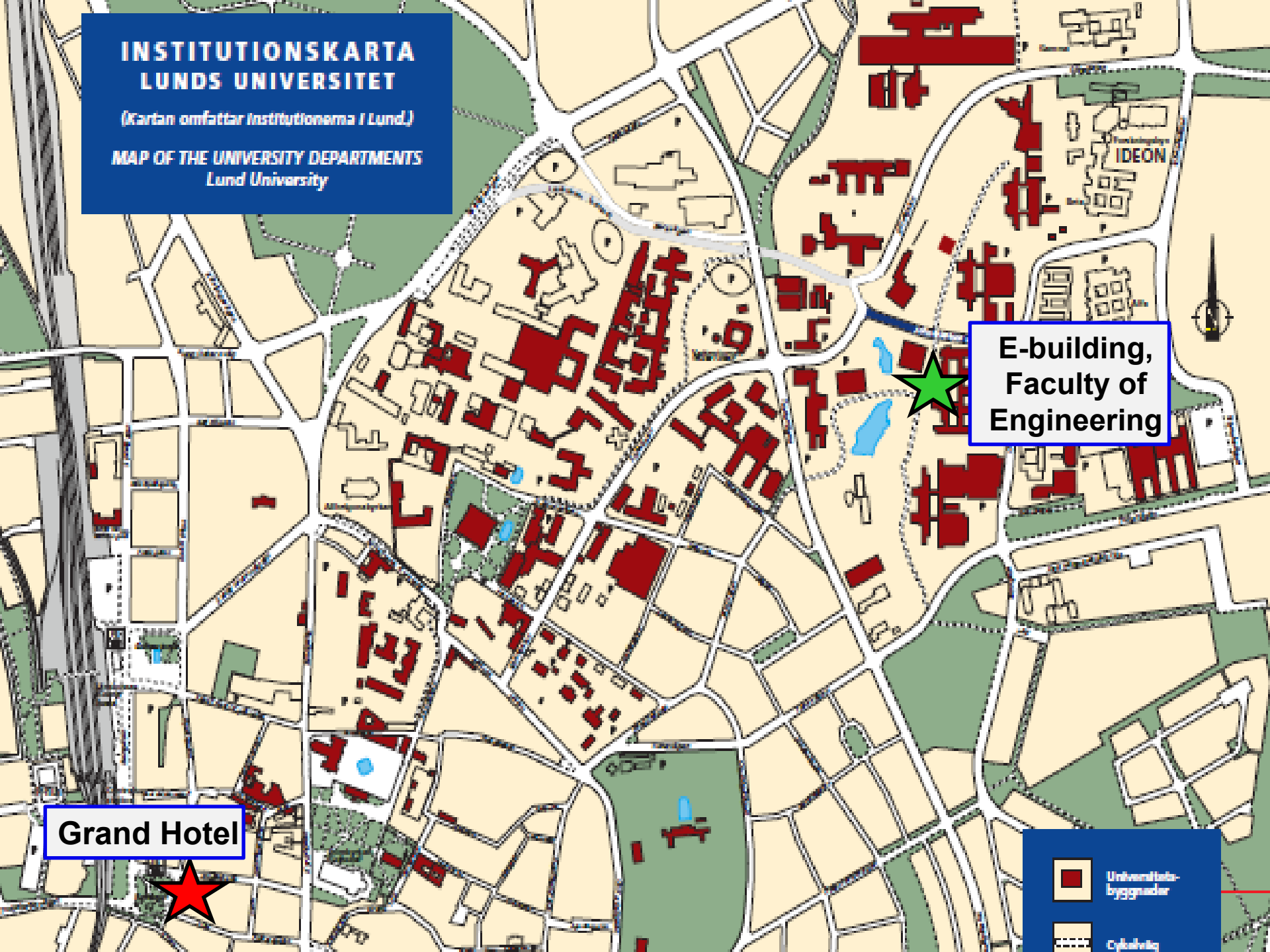


Some Logistics

- Today we are a[illegible] lunch
- Dinner is in Li[illegible]7pm

- **Tomorrow we are at the Faculty of Engineering, LU**
  - **E-building**
  - **A 25-minute walk from Grand Hotel**

Room E:1406


INSTITUTIONSKARTA
LUNDS UNIVERSITET
(Kartan omfattar institutionerna i Lund.)
MAP OF THE UNIVERSITY DEPARTMENTS
Lund University
IDEON
E-building, Faculty of Engineering
Grand Hotel
Universitets-byggnader
Cykelväg

The Hosts

Industrial Excellence Center in

System Design on Silicon

The Hosts: the SSF programs

DARE

Digitally-Assisted Radio Evolution

Pietro Andreani

2011-2015/16

Swedish Foundation for Strategic Research

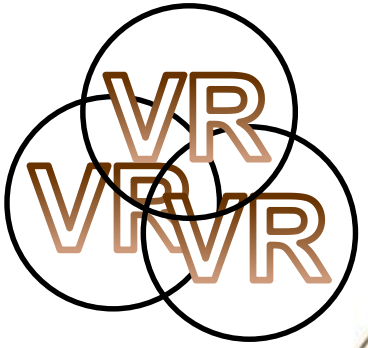
Distrant

Systems

Fredrik Tufvesson

More programs

Swedish Foundation for Strategic Research



Strategic Research Area (SFO)

New Projects – Smartare Elektroniksystem

Prototype system for massive MIMO in new 5G frequency band

2.1 MSEK over two years: August 2016 to July 2018

EIT: Liang Liu, Fredrik Tufvesson, Ove Edfors

Project Partner: Sony Mobile

New Projects – 5G lab

Funding for 5G lab equipment

1.2 MSEK over 5 years (LTH)
200 kSEK (Crafoord)

Fredrik Tufvesson

LTHs Infrastrukturmedel

The Crafoord Foundation
ESTABLISHED BY HOLGER CRAFOORD IN 1980

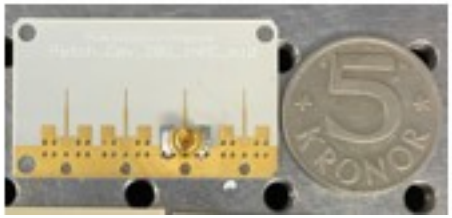
Ongoing Projects - Multi-antenna mm-wave systems

28GHz real-time MIMO Channel Sounder

Fredrik Tufvesson, Carl Gustafson

ERICSSON
TAKING YOU FORWARD

SONY



New Projects – Intel SRC Project

Coordination in Distributed Multi-User High-Performance Dense Networks

375 KUSD over three years: May 2016 to Apr 2019

EIT: Liang Liu, Ove Edfors

Project Partner: Intel

Ongoing Projects – MAMMOET, FP7

Mission of MAMMOET:

Advancement of Massive MIMO for radio access

Project Partners:

1 Technikon Forschungs- und Planungsgesellschaft mbH (Austria)

2 Interuniversitair Micro-Electronica Centrum VZW (Belgium)

3 Ericsson AB (Sweden)

4 Infineon Technologies Austria AG (Austria)

5 Katholieke Universiteit Leuven (Belgium)

6 Lunds Universitet (Sweden)

7 Linköpings Universitet (Sweden)

8 Telefónica Investigación y Desarrollo SA (Spain)

Ongoing Projects – Vetenskapsrådet (VR)

Future communications, Massive MIMO, efficient signaling

1 PhD position funded by VR

Project Manager: Viktor Öwall

Ongoing Projects – Vetenskapsrådet (VR)

High Efficiency Millimeter Wave Transmitters using CMOS technology

1 PhD position funded by VR

Project Manager: Markus Törmänen

Ongoing Projects – Smartare Elektroniksystem

TX front-end building practices for 5G Massive MIMO systems

3 MSEK over two years: August 2015 to July 2017

Project Manager: Markus Törmänen

Project Partner: Ericsson Research

Ongoing Projects – H2020

Flex5Gware

Two years: July 2015 to July 2017

Project Manager at LTH: Henrik Sjöland (60GHz LO generation)

Project Partner: Ericsson Research

Horizon 2020

ERICSSON

TAKING YOU FORWARD

SoS: 2008 – 2017

- SoS will close its very successful 10-year mission at the end of next year (2017)
- VINNOVA opened a call for existing Centers in 2015
- 5 Centers out of the existing 30 will be funded for 5 more years
- SoS applied for a continuation/evolution → SoS++

The SoS++ application

Three-pronged research proposal

- Wireless and massive MIMO
- Low-power transceivers in Si CMOS
- III-V CMOS for near antenna-array electronics

Reviewed by VINNOVA experts (anonymous) in spring 2016

The future of SoS/SoS++

- We will continue in the spirit of the SoS++ application
  - Protect SoS brand and competence, although at a lower activity level
  - Lund Circuit Design Workshop
  - Next VINNOVA center call in three years → our target
- We will form an independent center
  - OK from LTH, but no LTH/VINNOVA money
  - Partner cooperation as stated in the SoS++ application

Faces in SoS

Peter Nilsson

Recent graduates

- Anders Nejdel, ”*Flexible Receivers in CMOS for Wireless Communication*“, Nov. 2015.
  Now at Mellanox, Roskilde, DK.

Recent graduates

- Iman Vakili, ”*Time-Domain Antenna and Scattering Analysis for Micro- and Millimeter-Wave Applications*“, Nov. 2015.
  Now at Volvo Car.

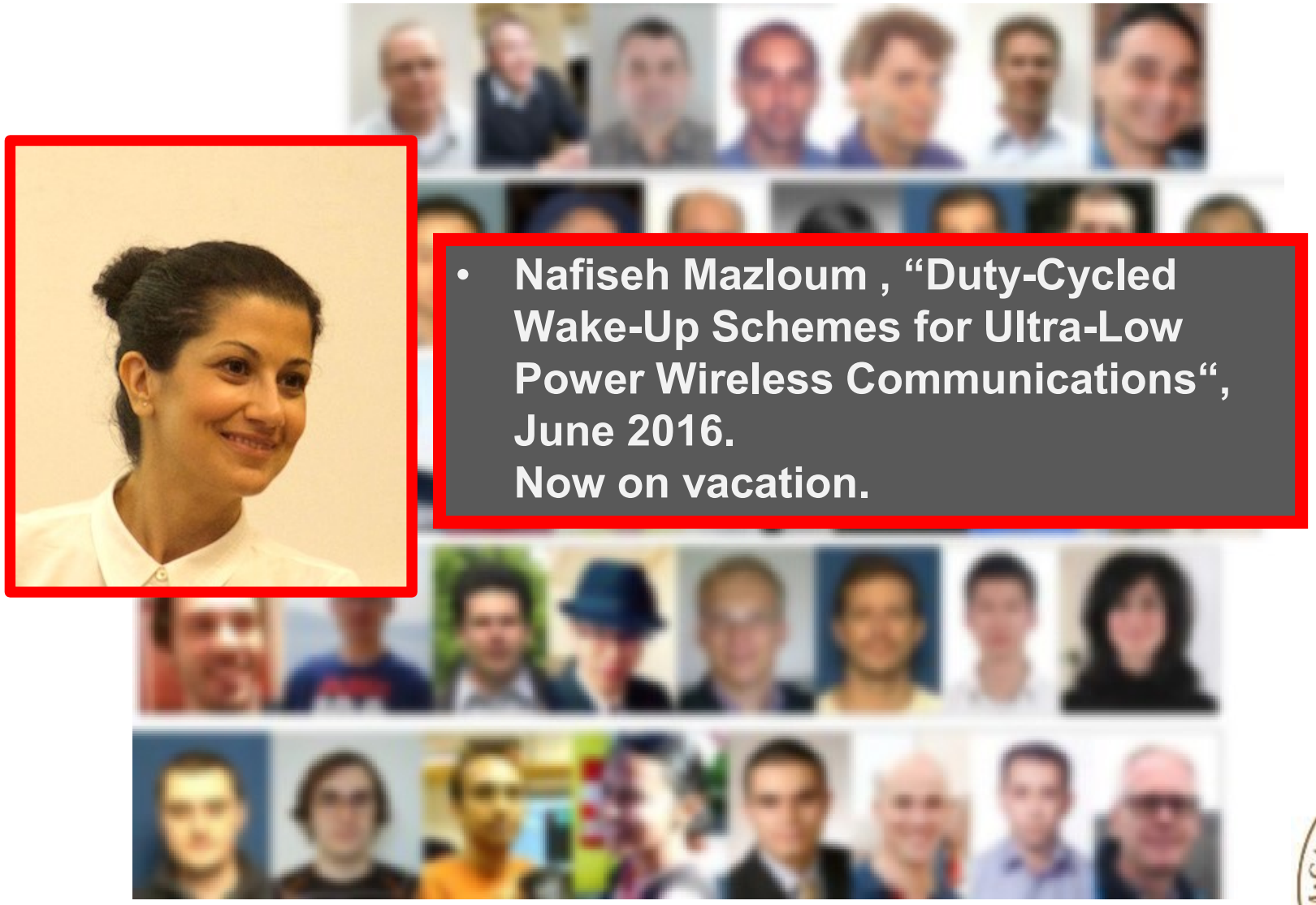
Recent graduates

- Xiang Gao, "Massive MIMO in real propagation environments“, Feb. 2016.
  Where is she?

Recent graduates

- **Mohammed Abdulaziz, “Linearity Enhancements of Receiver Front-End Circuits for Wireless Communication“, June 2016.**
  Now postdoc with us.

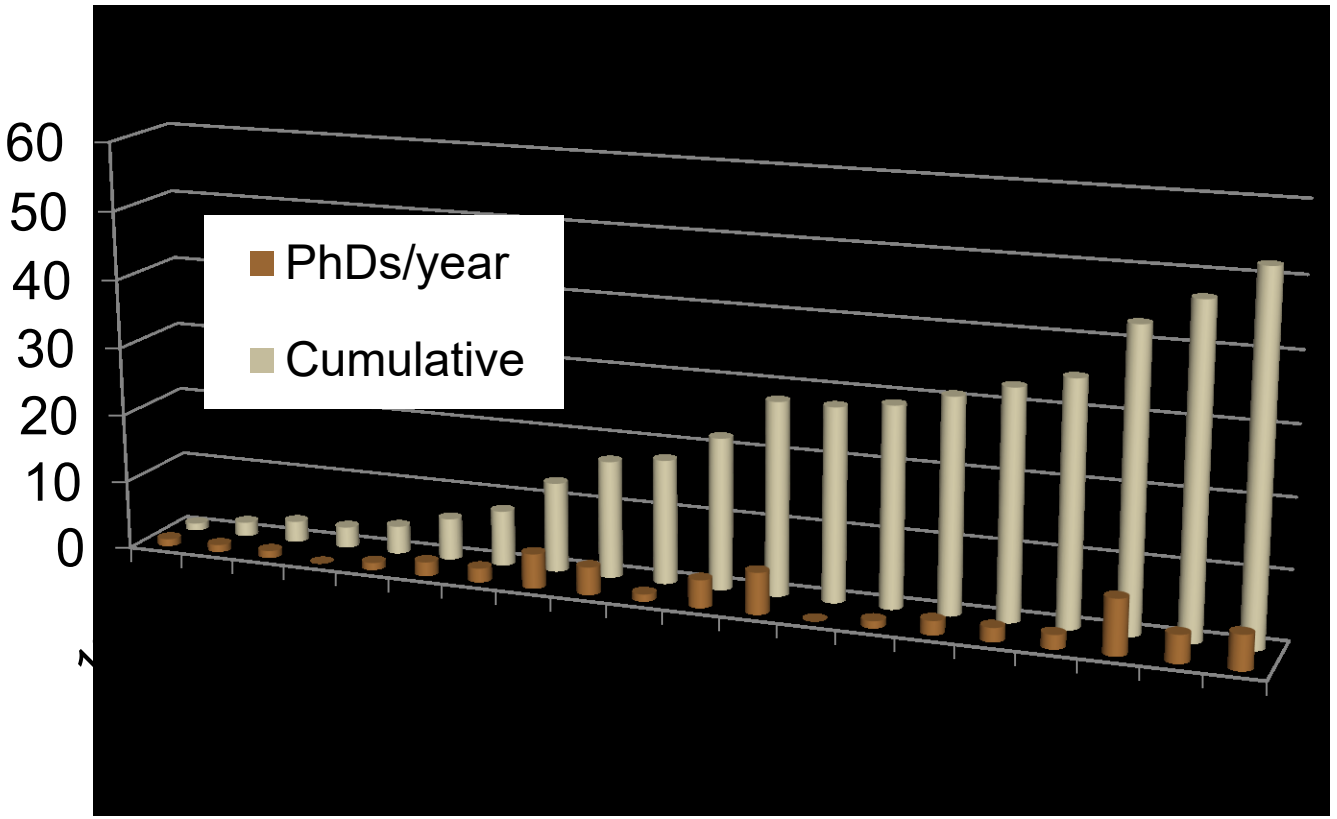
Recent graduates



- Nafiseh Mazloum , “Duty-Cycled Wake-Up Schemes for Ultra-Low Power Wireless Communications“, June 2016.
  Now on vacation.

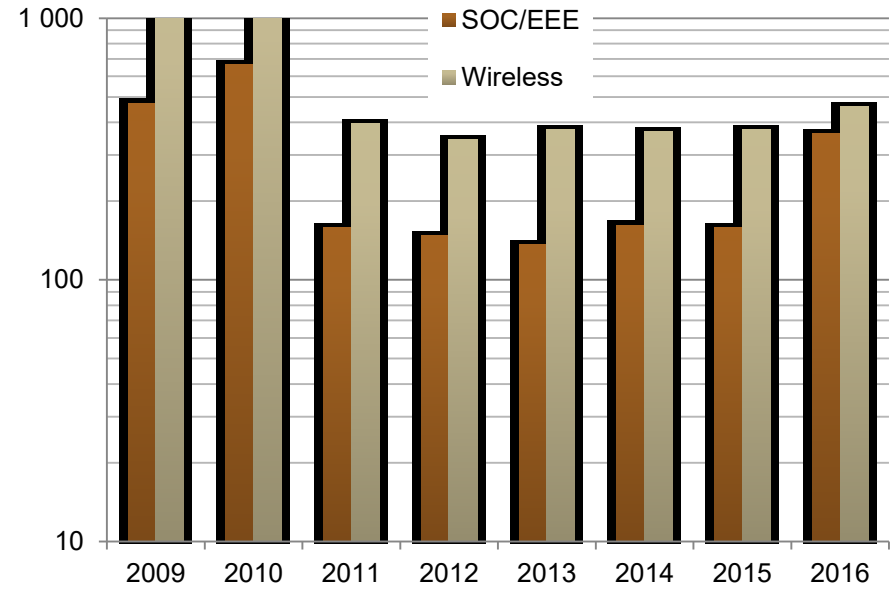
PhDs graduated since the start of CCCD

52 PhDs since 1997

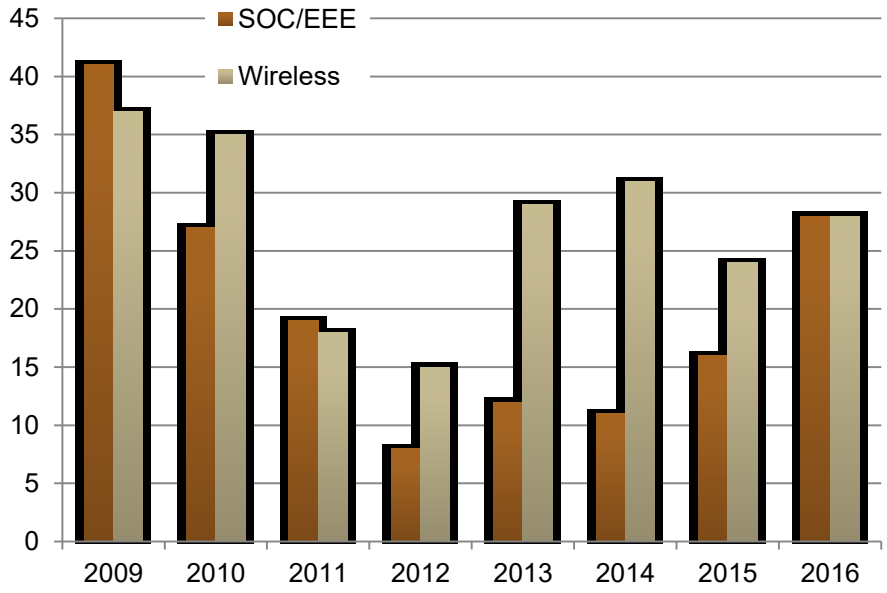


Master Programs

- Wireless and Embedded Electronics Engineering (EEE, replacing the SOC program)
- 28 students admitted (22♂, 6♀ for EEE) – twice as many as in 2015!



Applicants



Admitted

Some Research Highlights

IoT network and OpenDoor at EIT

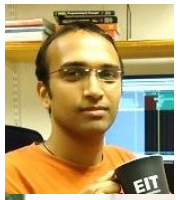
EIT operates an open LoRa IoT network

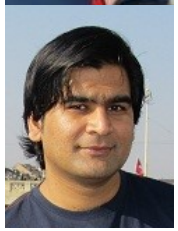
Inaugurated at the IoT conference in Lund tomorrow

Moreover, EIT opens the electronics lab ("OpenDoor") to regional start-ups

Short briefing later by J. Rodrigues

Internships





- Hemanth Prabhu at Xilinx, Cork, Ireland
- Steffen Malkowski at
  National Instruments, Austin, Texas
- Waqas Ahmad at
  Qualcomm, San Diego, California

Massive MIMO out-door mobility test

Collaboration with
University of Bristol
–
Outdoors
measurements with
mobile UEs

World Record in 5G!!

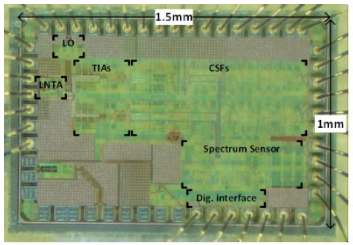
145.6 bits/s/Hz on a 20MHz channel

1 paper + 1 workshop presentation at RFIC 2016

S. Francisco, CA, May 22-26

1 paper + 1 workshop presentation at RFIC 2016

- M. Abdulaziz, W. Ahmad, A. Nejdel, M. Törmänen, and H. Sjöland, ”*A Cellular Receiver Front-End with Blocker Sensing*”



- P. Andreani, ”*Harmonic Integrated Oscillators*”, workshop presentation

1 paper at APMC 2015

- T. Forsberg, H. Sjöland, and M. Törmänen, ”*A Two-Stage mm-wave PA with 18.5% PAE in 65nm CMOS*”

Best Student Award
Asia-Pacific Microwave Conference 2015

1 paper at ESSCIRC 2016

B. Mohammad, O. Andersson, J. Nguyen,
L. Ciampolini, A. Cathelin, J. Rodrigues,
"*A 128 Kb Single-Bitline 8.4 fJ/Bit 90MHz at 0.3V 7T Sense-Amplifierless SRAM in 28 nm FD-SOI*"

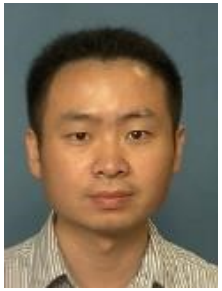
Lausanne,
September 12-15

1 paper at ASSCC 2016

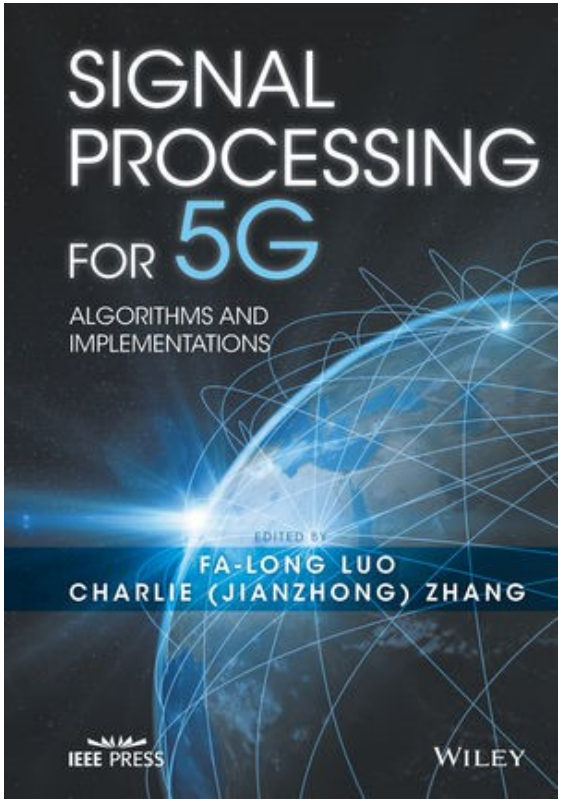
B. Mohammadi, O. Andersson, X. Luo, M. Nouripayam, J. Rodrigues, "*An Area Efficient Single-Cycle xVDD Sub-Vth on-Chip Boost Scheme in 28 nm FD-SOI*"

Noteworthy publications

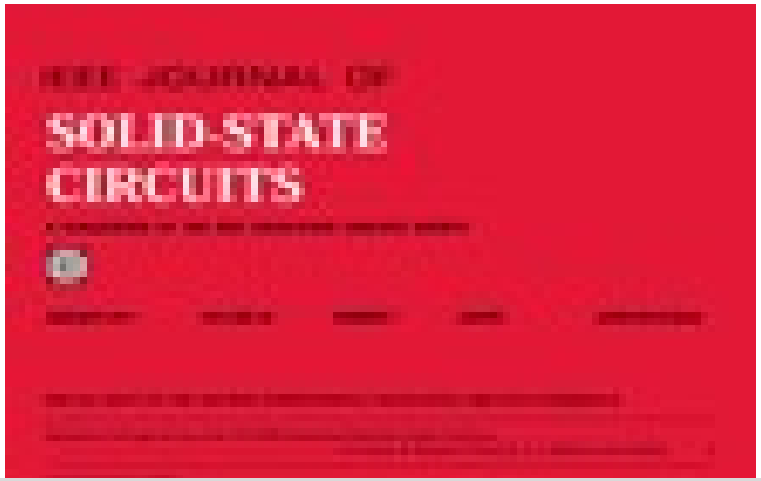
Wiley 5G book chapter


O. Edfors, L. Liu, F. Tufvesson, N. Kundargi and K. Nieman: "Massive MIMO for 5G: Theory, Implementation and Prototyping"

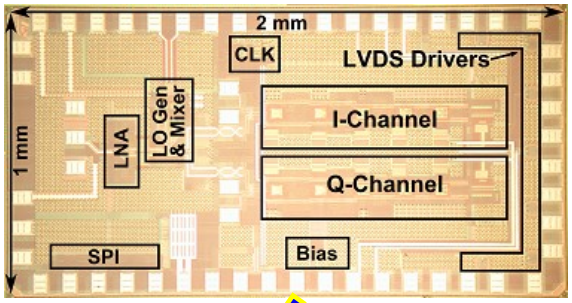


IEEE JSSC special issue on ESSCIRC 2015

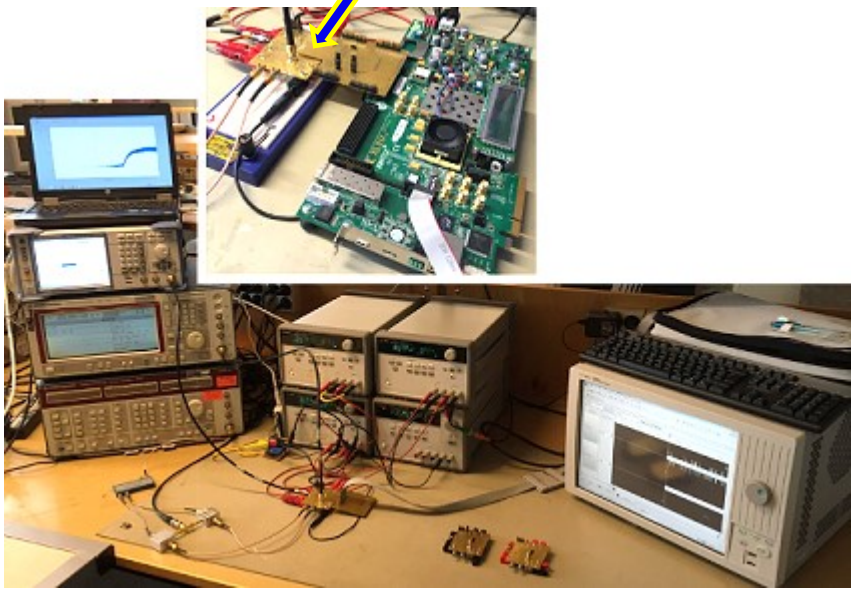


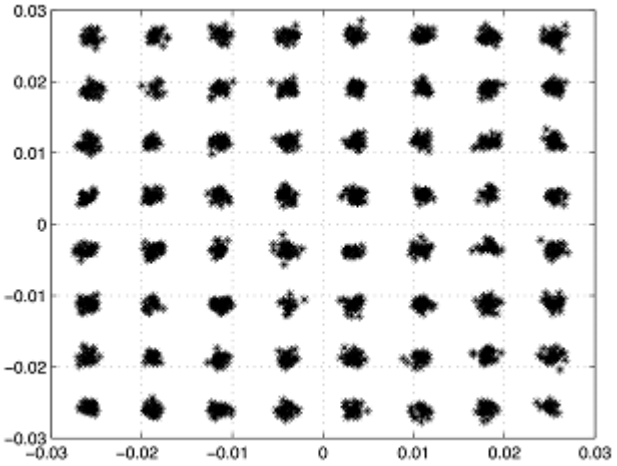
X.Liu, A. Nejdel, M. Palm, L. Sundström, M. Törmänen, H. Sjöland and P. Andreani, "*A 65 nm CMOS Wideband Radio Receiver with ΔΣ-Based A/D-Converting Channel-Select Filters*", IEEE J. of Solid-State Circuits, Vol. 51, No. 7, pp. 1566-1578, July 2016.

Demonstrator of complete radio RX



From antenna to constellation!



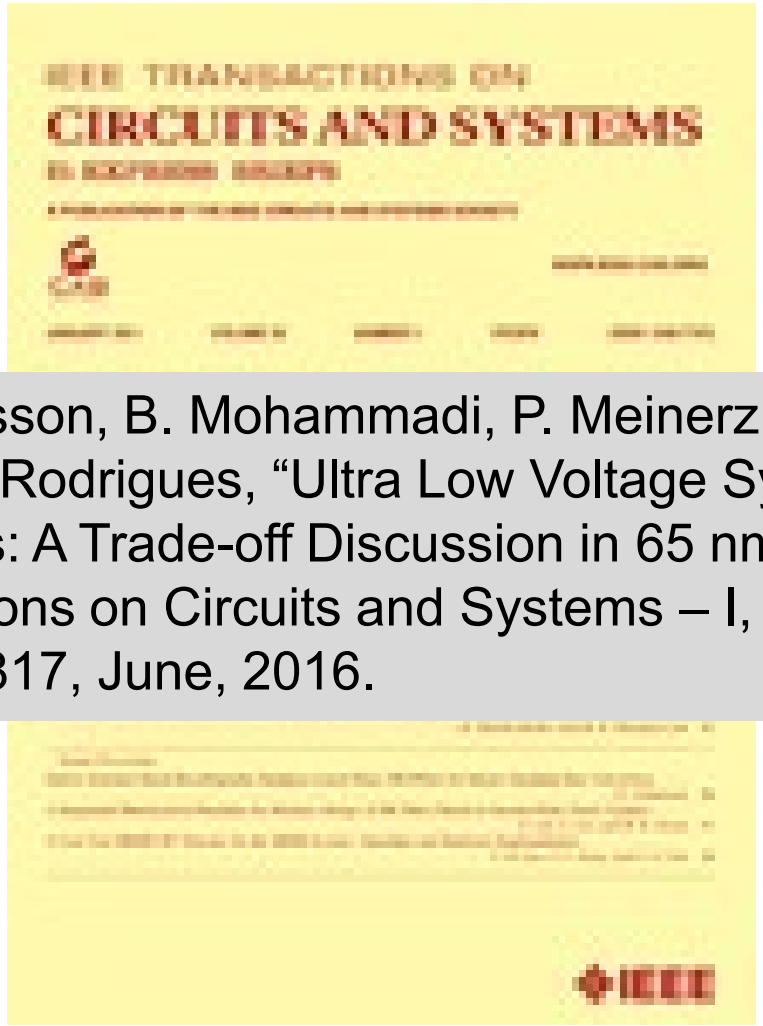


SSF DARE project

IEEE T-MTT paper

I. Vasilev, J. Lindstrand, V. Plicanic, H. Sjöland, and B. K. Lau: "*Experimental investigation of adaptive impedance matching for a MIMO terminal with CMOS SOI tuners*", IEEE Transactions on Microwave Theory and Techniques, Vol. 64, No. 5, pp. 1622-1633, 2016.

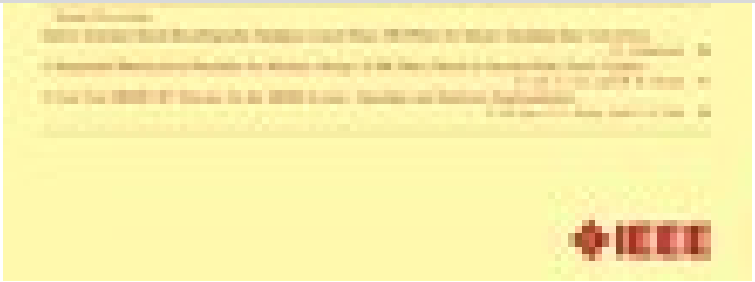
IEEE TCAS-I paper



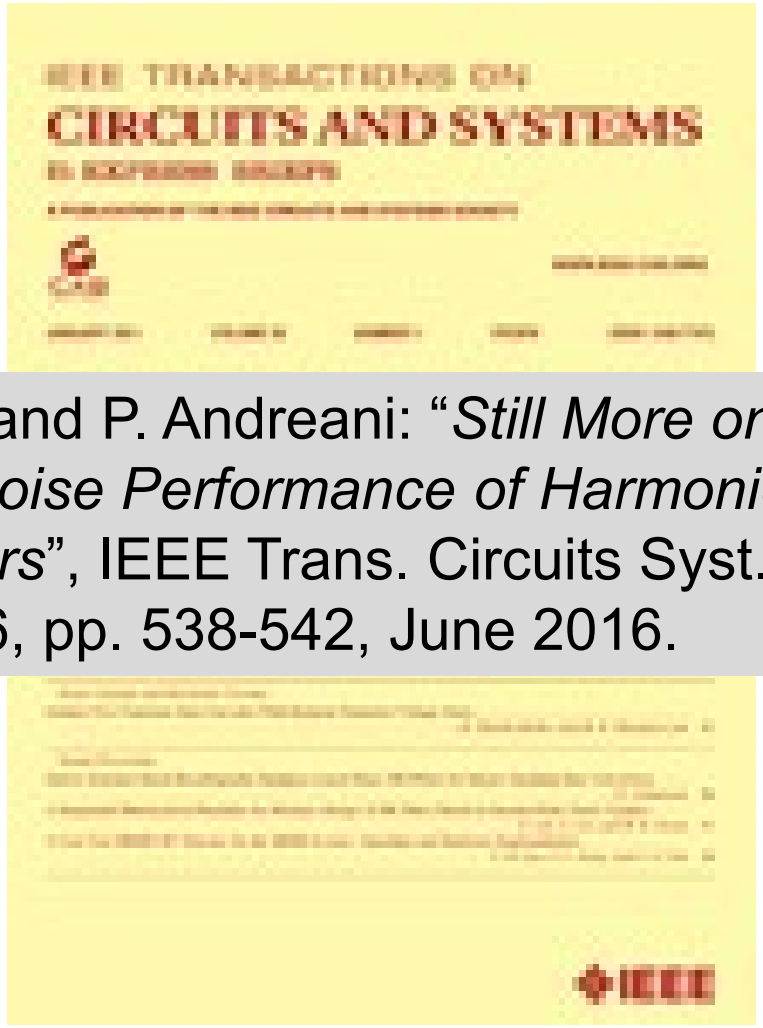
O. Andersson, B. Mohammadi, P. Meinerzhagen, A. Burg, and J. N. Rodrigues, “Ultra Low Voltage Synthesizable Memories: A Trade-off Discussion in 65 nm CMOS,” IEEE Transactions on Circuits and Systems – I, vol. 63, no. 6, pp. 806–817, June, 2016.

IEEE TCAS-II paper

R. Gangarajaiah, M. Abdulaziz, H. Sjöland, P. Nilsson, and L. Liu,: "*A Digitally Assisted Nonlinearity Mitigation System for Tunable Channel Select Filters*", IEEE Trans. Circuits Syst. – II, Vol. 63, No. 1, pp. 69-74, Jan. 2016.

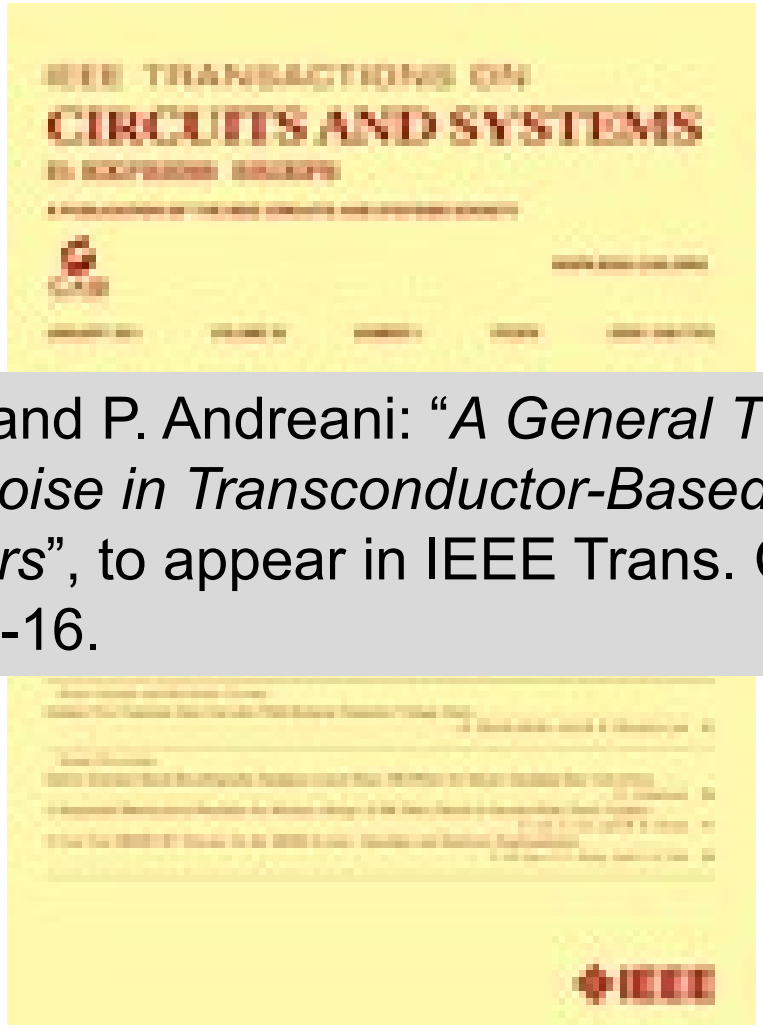


IEEE TCAS-II paper



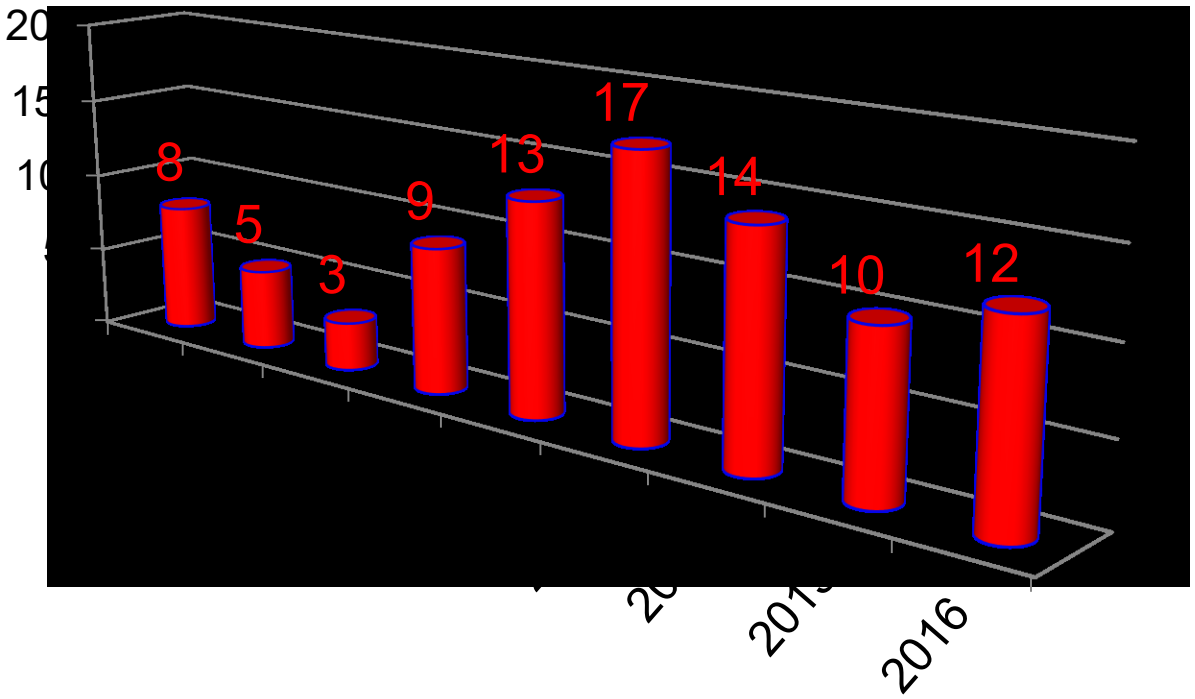
F. Pepe and P. Andreani: "*Still More on the 1/f² Phase Noise Performance of Harmonic Oscillators*", IEEE Trans. Circuits Syst. – II, Vol. 63, No. 6, pp. 538-542, June 2016.

IEEE TCAS-I paper



F. Pepe and P. Andreani: "*A General Theory of Phase Noise in Transconductor-Based Harmonic Oscillators*", to appear in IEEE Trans. Circuits Syst. – I, pp. 1-16.

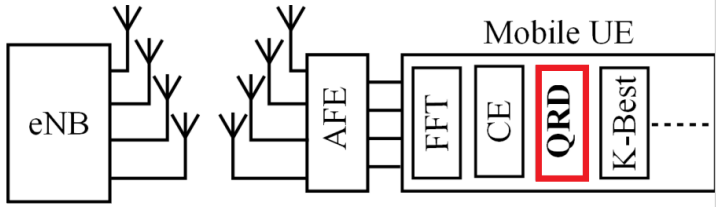
Journal publications in circuit design



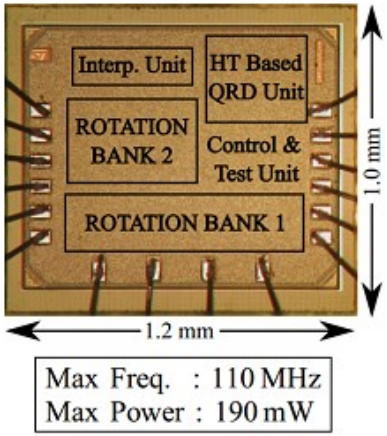
… and some unpublished results

Adaptive QR Matrix Decomposition for LTE-A MIMO

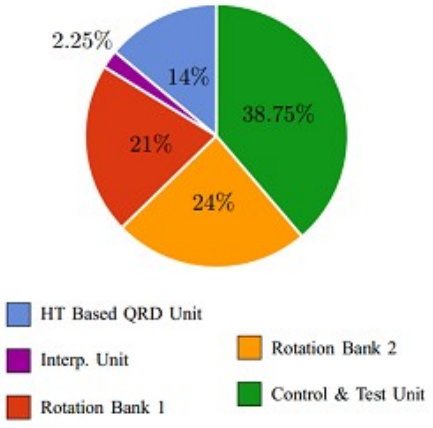
SSF DARE project



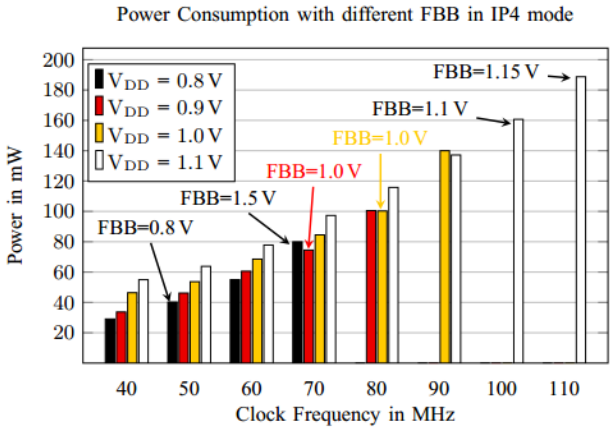
A typical LTE-A MIMO system with a QRD unit



Chip microphotograph



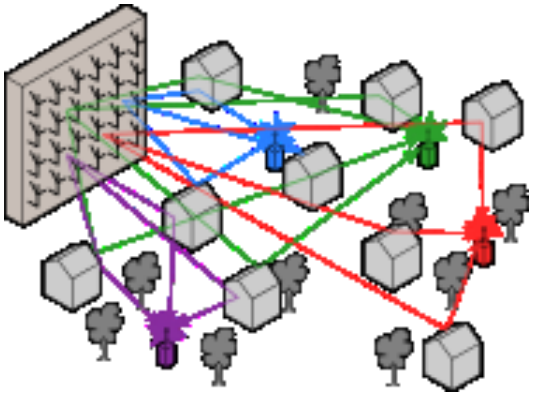
Area Breakdown



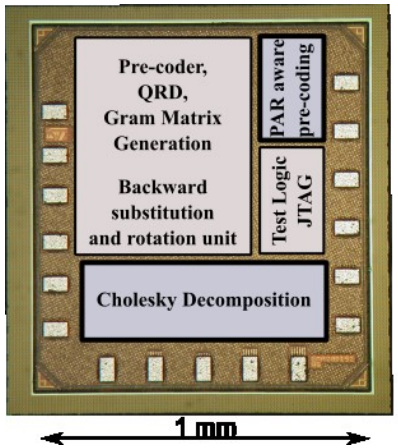
STM 28nm UTBB FD-SOI CMOS

FBB = forward body bias

Massive MIMO Baseband Processing



MAMMOET FP7 project



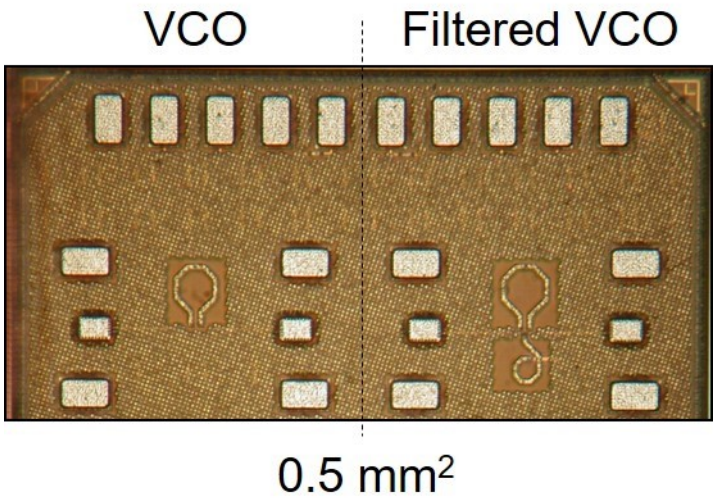
8x128 Massive MIMO Pre-coder	
Gate Count (QRD)	138 K
Max. Freq	300 MHz
Clock Cycles	64 or 128
Power	33 mW

8x8 Cholesky Decomposition	
Gate Count	79.7 K
Max. Freq	300 MHz
Clock Cycles	325
Power	20 mW @ 0.9V

STM 28nm UTBB FD-SOI CMOS

- Adaptive downlink pre-coding based on approximate QR decomposition
- Linear/non-linear uplink detection based on LU decomposition

Two mm-wave VCOs



VR project

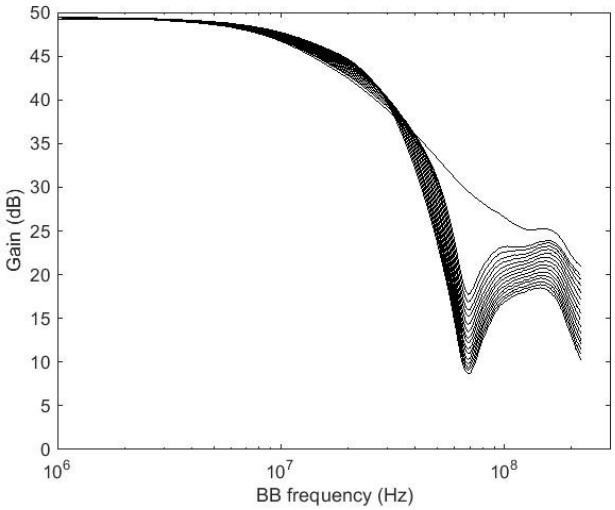
- Tuning range of 11% (60 – 67 GHz)
- Lowest power consumption at 3.15 mW
- State-of-the-art FOM of -187 dBc/Hz for filtered VCO

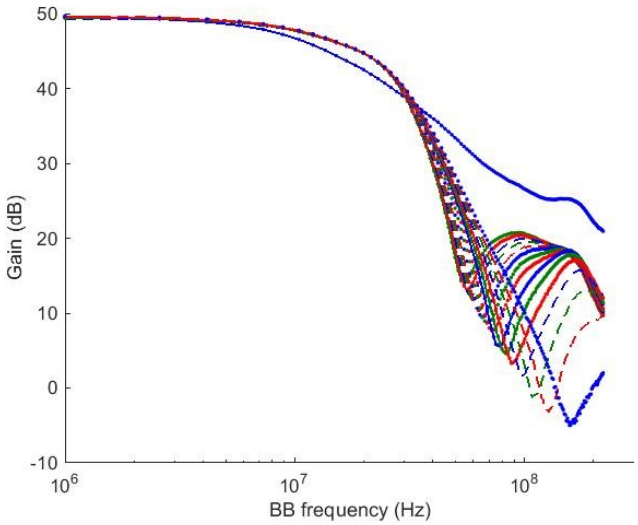
STM 28nm UTBB FD-SOI CMOS

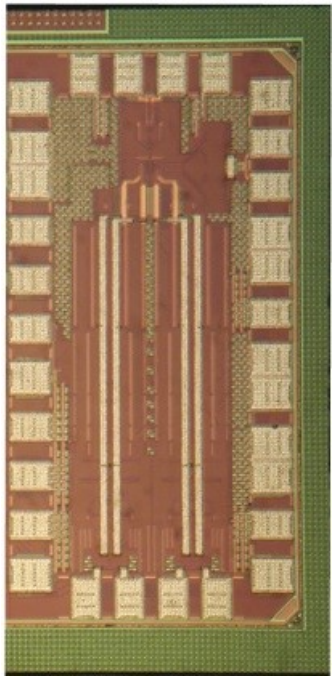
A Blocker-Tolerant Front-End

SSF DARE project

Improved gain compression
and NF vs. blocker



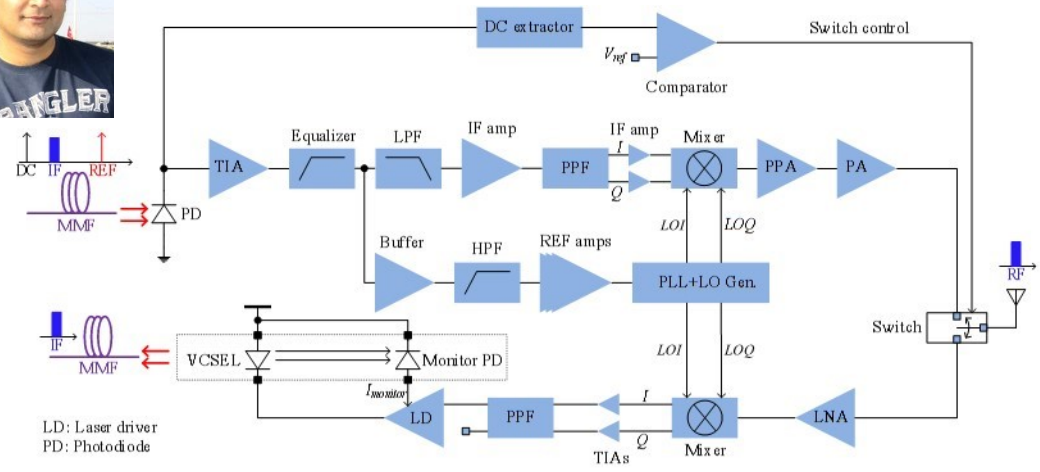


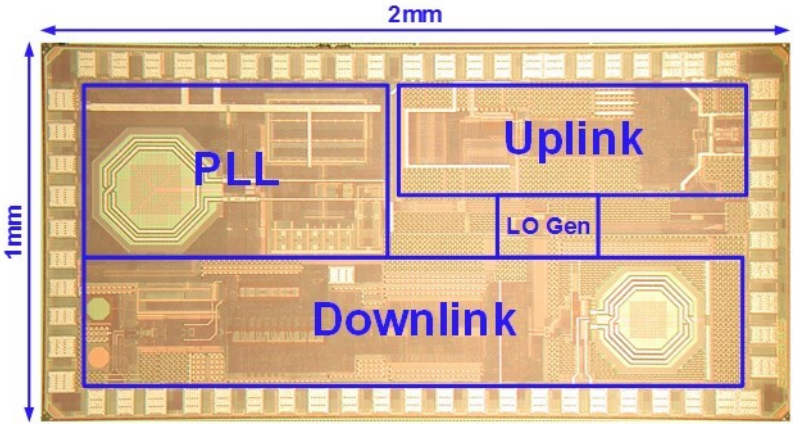


STM 65nm CMOS

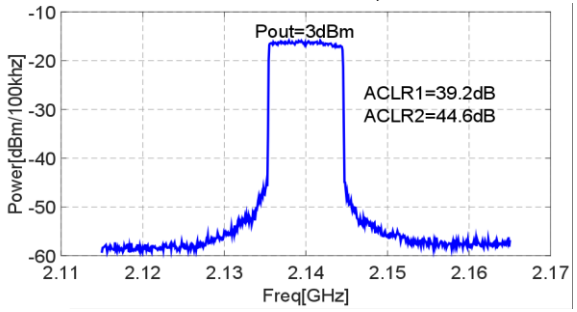
CMOS RAU for Fiber-Fed Distributed MIMO

SSF DISTRANT project

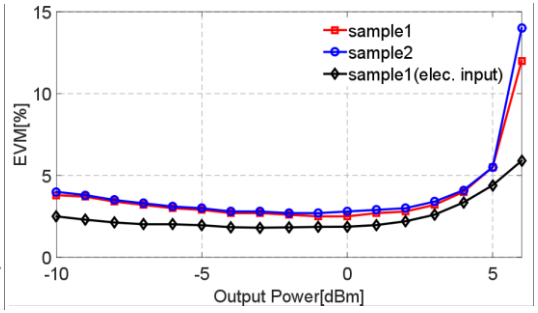




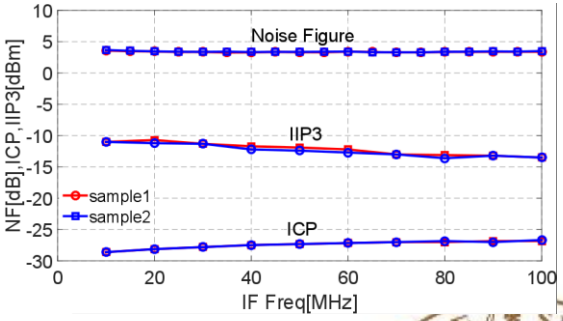
Downlink ACLR: 16-QAM, 10 MHz LTE



Downlink EVM: 16-QAM, 10 MHz LTE



Uplink continuous wave measurements

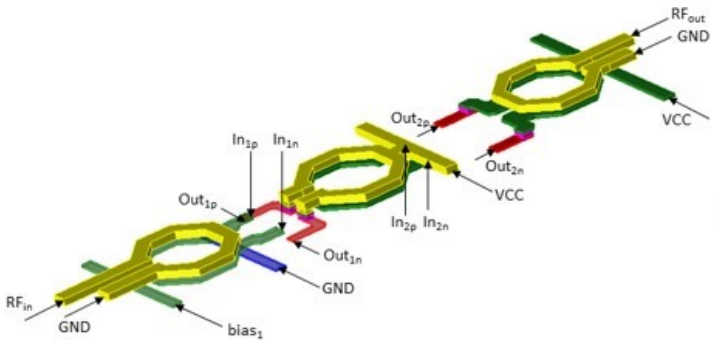


STM 65nm CMOS

Submitted to T-MTT

mm-wave Power Amplifiers

SoS project

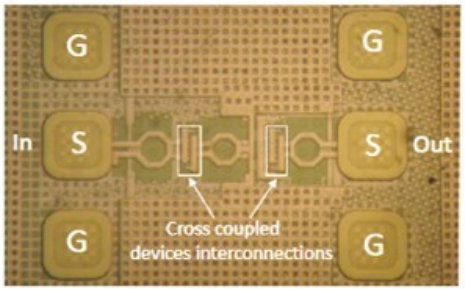


Infineon b7hf200 SiGe process

2-stage, cross-coupled

G = 10dB @ 93GHz

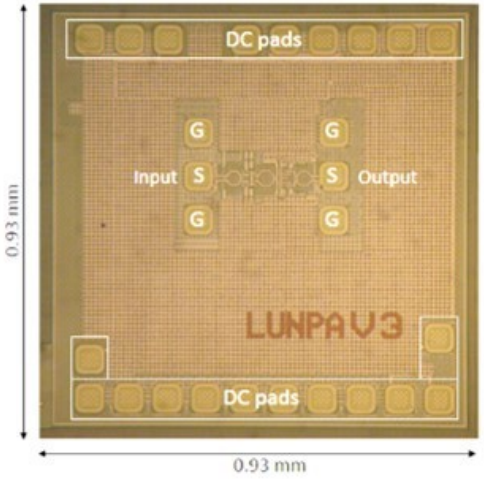
P_{sat} = 15dBm



2-stage, cascode

G = 16dB @ 92GHz

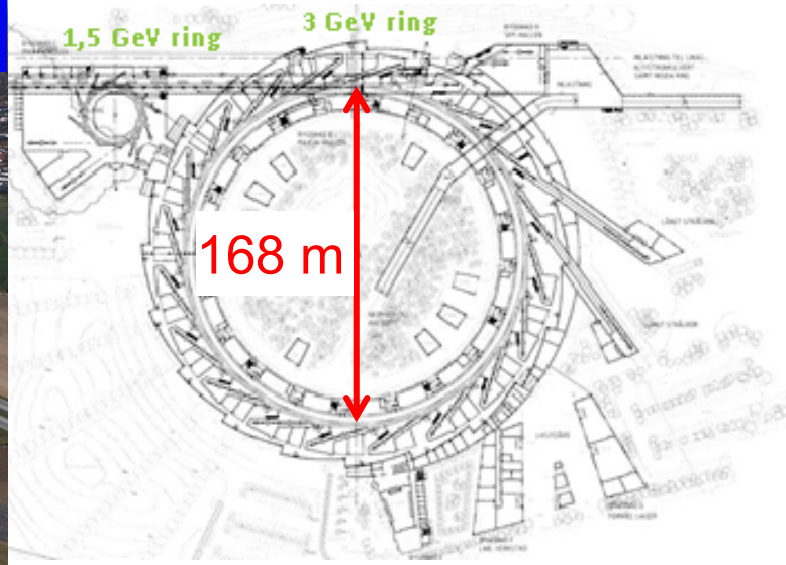
P_{sat} = 17dBm



Our Neighbors

MAX IV

The most modern synchrotron light facility in the world



Later today a presentation by
Pedro Fernandes Tavares from MAX IV

European Spallation Source (ESS)

ESS – aerial photo from Feb. 2016

ESS – progress of constructions

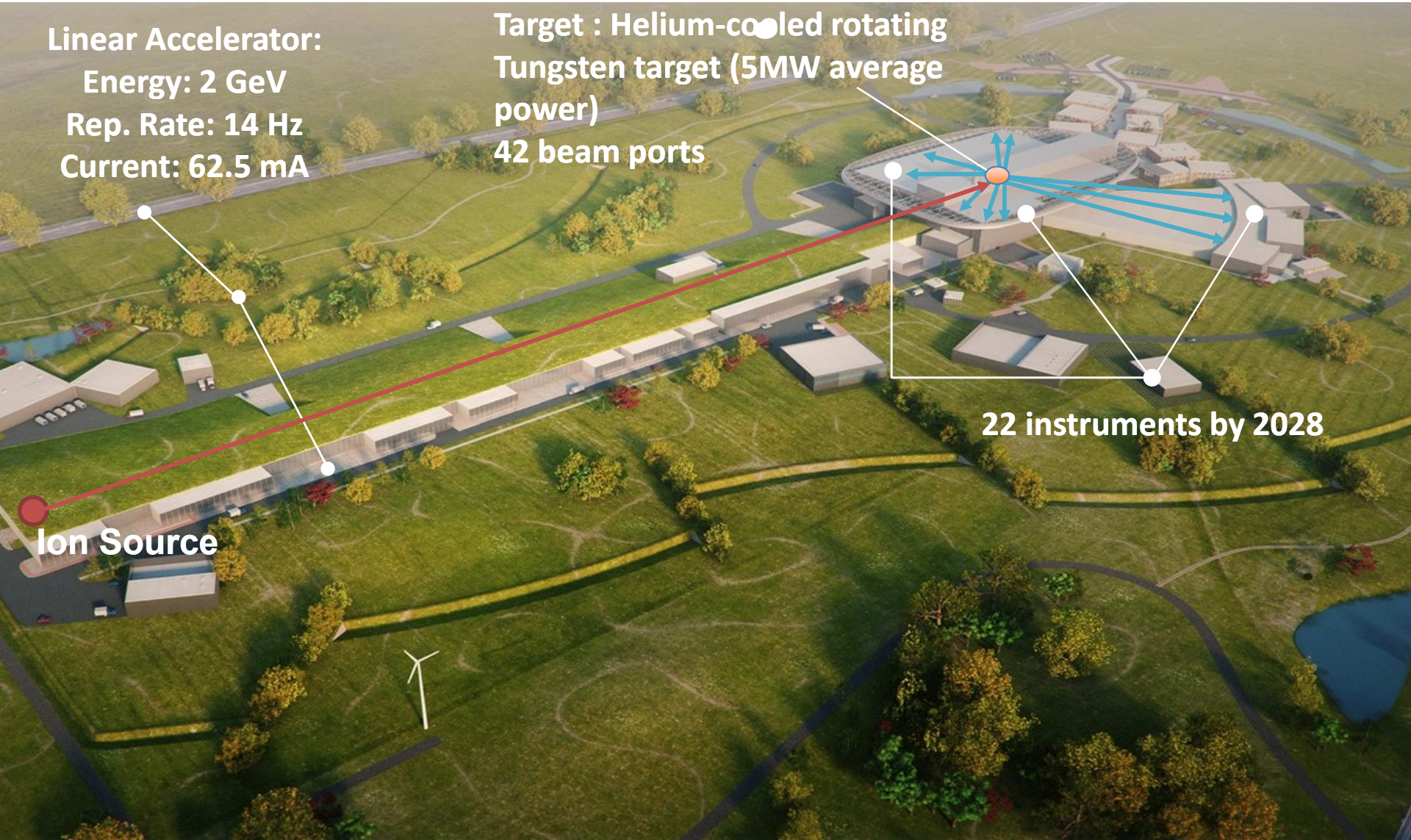
Test hall for modulators and klystrons

Accelerator tunnel

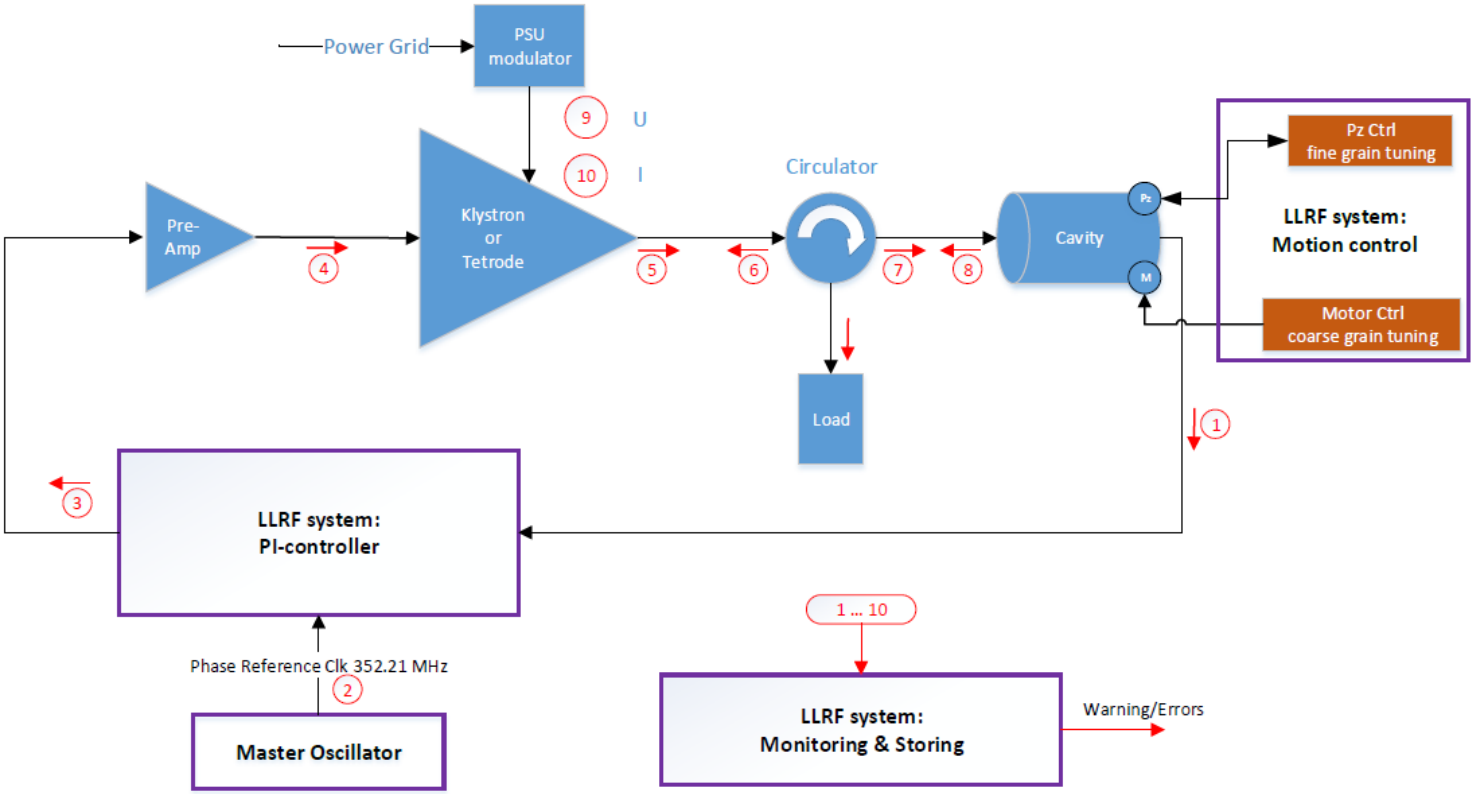
Accelerator gallery

Bulding hosting the target

ESS – the way it will be



LTH activities for the ESS accelerator



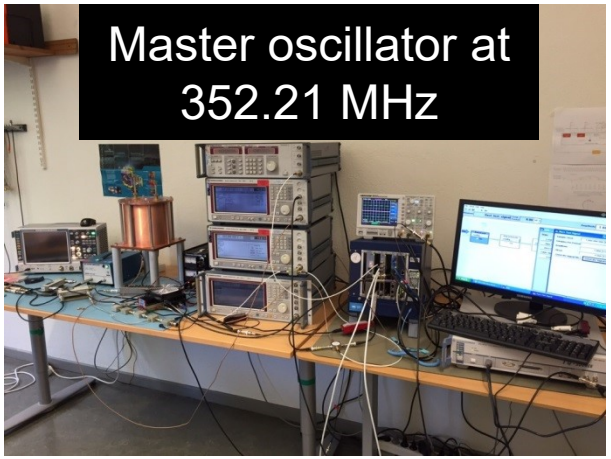
Lund University will design part of the low-level RF (LLRF) system for the linear accelerator

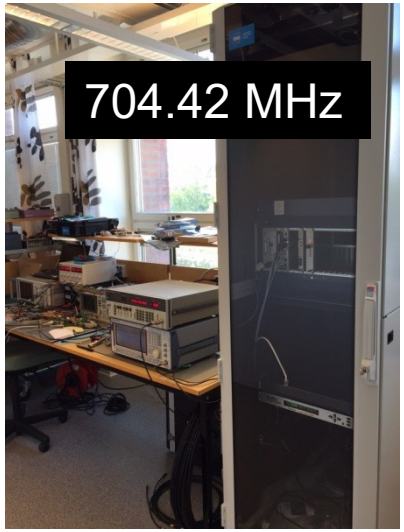
The LLRF system controls phase and amplitude of the electric field at the accelerating cavities to within 0.1° and 0.1% (the klystron PA delivers 1 MW to one cavity)

LTH activities for the ESS accelerator – II

120 kV power-supply modulator

- pulsed @ 14 Hz
- 5% duty cycle



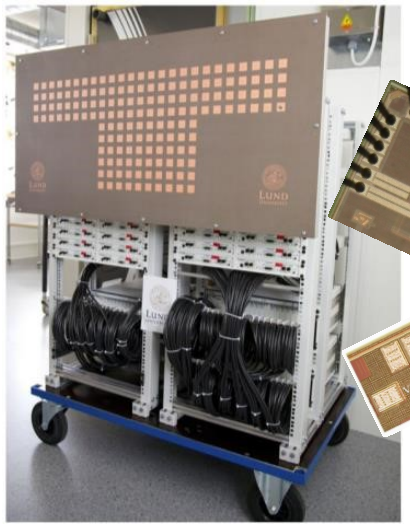


What's next?

We are one of the few groups that actually design and test ICs…

… and we want to continue!

The IC!



MAX IV and ESS

Low Power Connectivity