Efficiency improvements in wireless networks for future European communication needs

Reza Mahmoudi, Ulf Johannsen, Rob Mestrom

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Where innovation starts

Motivation

- Future communication needs in Europe require:
  - high capacity networks
  - access to wireless services everywhere

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  1. spectrum use
     - increase spectral efficiency (bits/Hz)
     - decreasing interference with adjacent systems
  2. multi-mode
     - multi-standard operation
     - dynamic reconfigurability

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     - dynamic reconfigurability
- In parallel: need for low power consumption

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For this, we have PANAMA

- Country in Central America
- Official language: Spanish
- Capital: Panama City
- Temperature: 24°-29° (Panama City)
- Famous for the Panama Canal

Info from www.wikipedia.com

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...but this is not what we mean

PANAMA project

- **P**ower **A**mplifiers a**N**d **A**ntennas for **M**obile **A**pplications
- European Catrene programme

PANAMA project

- **P**ower **A**mplifiers a**N**d **A**ntennas for **M**obile **A**pplications
- European Catrene programme
- January 2009 – December 2011
- 5 countries
  - France, Spain, Belgium, Israel, the Netherlands
- 22 project partners
  - e.g. ST, Agilent, NXP, Thales, TNO, universities

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PANAMA project partners

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- Focus of the project
  - future multi-band, multi-mode more efficient power amplifiers and transmitter systems
  - integrated, discrete and distributed systems

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PANAMA project

- Focus of the project
  - future multi-band, multi-mode more efficient power amplifiers and transmitter systems
  - integrated, discrete and distributed systems
- Target applications and standards
  - 3/4G mobile phones and their connectivity standards
  - 3/4G cellular base stations
  - avionics and mobile satellite communications
  - home networking

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PANAMA objectives

- Two main objectives of PANAMA:
    1. improve energy saving through better efficiency
    2. increase the capacity for each communication application

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- Two main objectives of PANAMA:
  1. improve energy saving through better efficiency
  2. increase the capacity for each communication application
- Innovations required in communication chain
  - improve the efficiency of each power amplification stage
  - take into account the overall transmit and receive chain

PANAMA innovation chain

- Common system approach and common architectures

Goals

- Energy saving through better efficiency
- More capability for each applications

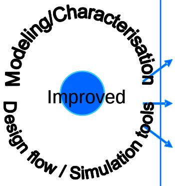
Same goals

System

- Novel reconfigurable architectures
- System level specification

Common approach

Enablers



+Technology evolution

Better tools for better design

Design

- Integrated PA
- Discrete PA
- Distributed PA & Antenna
- ADC

Proof of concepts

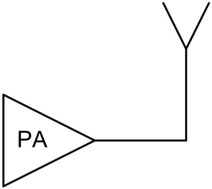
Applications

- Handsets
- BTS
- Avionics
- Satcom
- Home Networking

Market competitiveness

TU/e in PANAMA

- TU/e focuses on antenna systems and the interconnect to the PA



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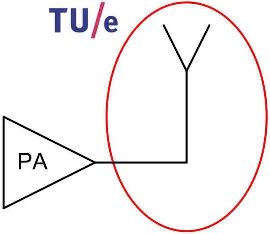

1. Direct matching from antenna to PA (MsM group)
2. Antenna-on-Chip (AoC) for mm-wave applications (EM group)
3. RF MEMS for adaptive antenna beamforming (EM group)

1. Direct matching from antenna to PA

Mixed-signal Microelectronics Group
Reza Mahmoudi

Matching at 60 GHz

- Transmission lines are widely used for matching
  - Quality-factors and lengths are important
  - PANAMA project: minimize losses in interconnect

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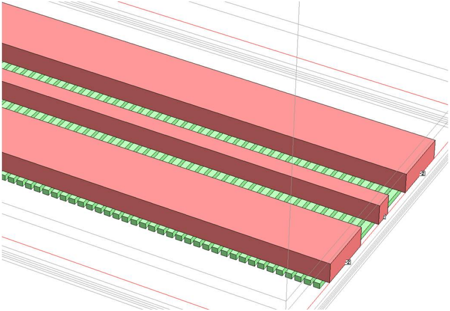
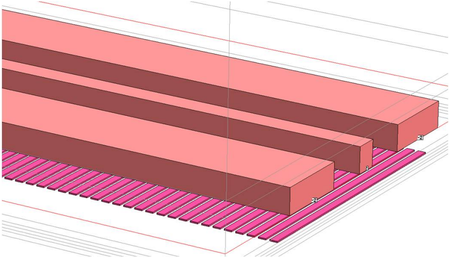
Matching at 60 GHz

- Transmission lines are widely used for matching
  - Quality-factors and lengths are important
  - PANAMA project: minimize losses in interconnect
- Method from literature: patterned shielding
  - How does this work?
  - Can this be used for matching?

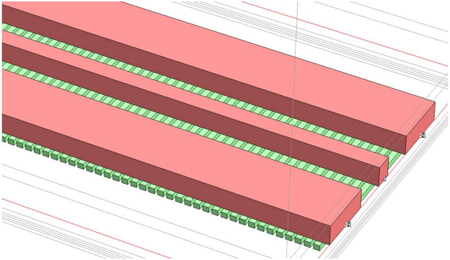


CPW with patterned shielding

- Effect of patterned shielding studied
  - Simulations using Sonnet
  - QUBIC4X process
  - Shielding in different layers of the stack



Shielding in layer M1



Shielding in layer M5

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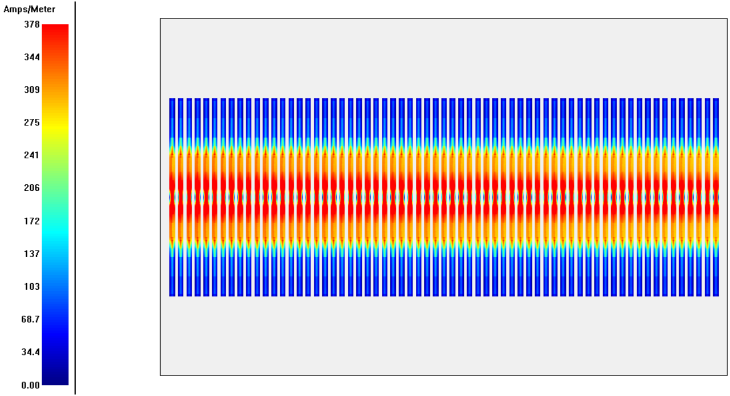
Patterned shielding working principle

- Shielding prevents current from flowing horizontally



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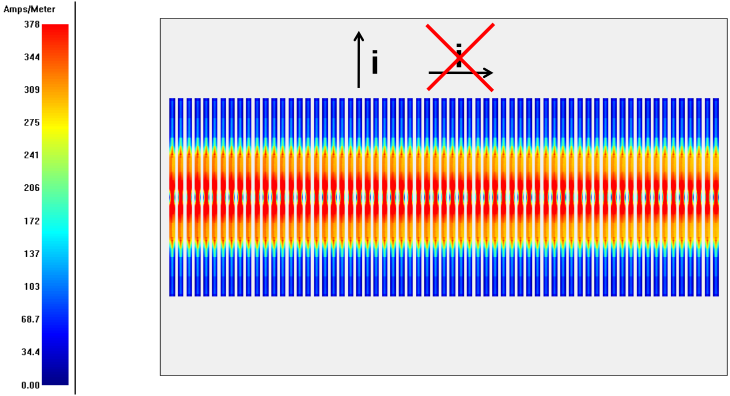

- Creates an anisotropic layer below the CPW

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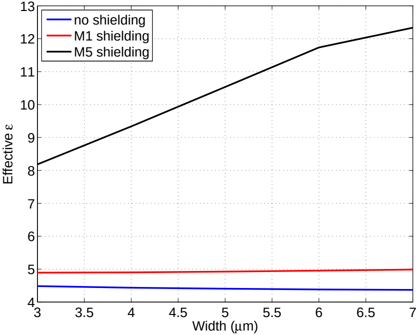
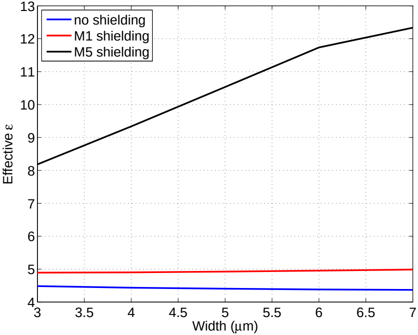
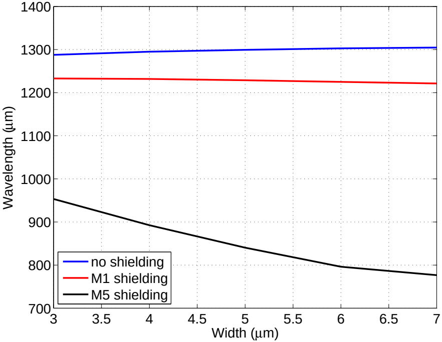
- Results for different widths of CPW line
  - shielding increases the effective permittivity



Patterned shielding simulation results

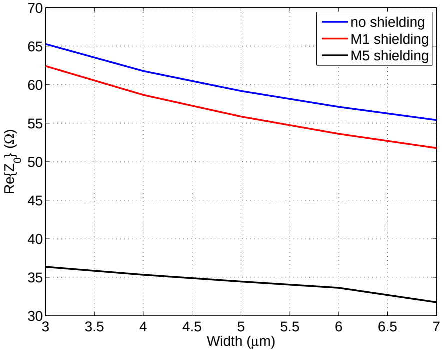
- Results for different widths of CPW line
  - shielding increases the effective permittivity
  - shielding decreases the wavelength





Patterned shielding simulation results

- Effect of patterned shielding
  - Freedom in characteristic impedance Z_0



Patterned shielding simulation results

- Effect of patterned shielding
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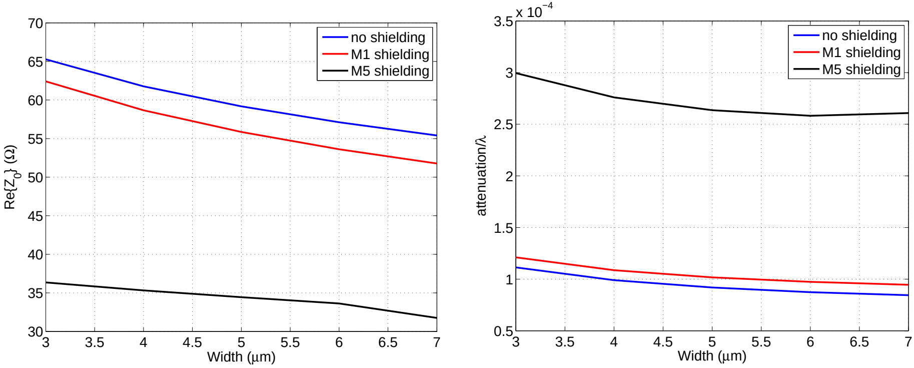
  - Increased loss per wavelength



2. Antenna-on-Chip for mm-wave applications

Electromagnetics Group

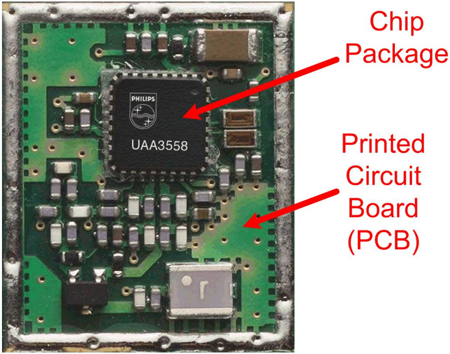
Ulf Johannsen

- What is an AoC?

Printed Circuit Board (PCB)

Antenna-on-Chip

- What is an AoC?



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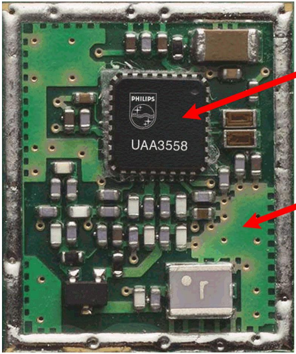

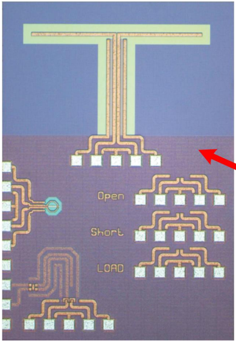

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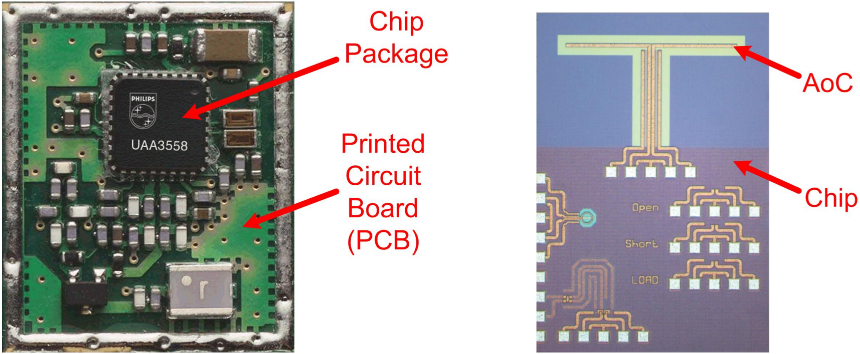

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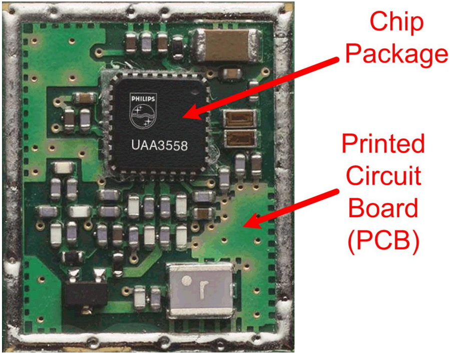
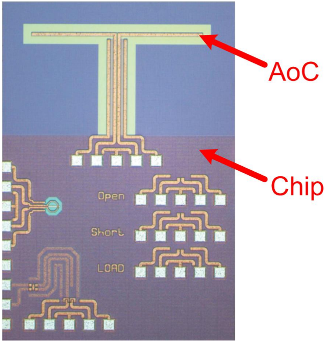
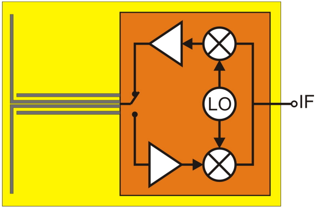




- Good option for evolving 60 GHz band

Why Antenna-on-Chip?



- No external mm-wave interconnect
- Direct matching of antenna and amplifier

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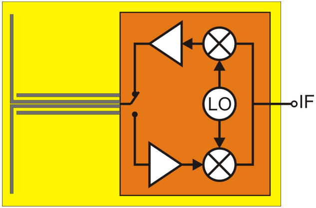

- No external mm-wave interconnect
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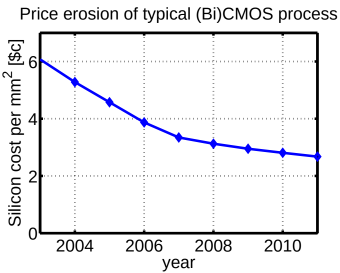
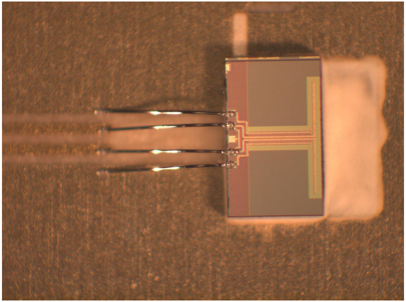
- Antenna size at mm-waves makes it affordable



Realization

- AoC bond-wired to differential transmission line
- GSSG infinity probe



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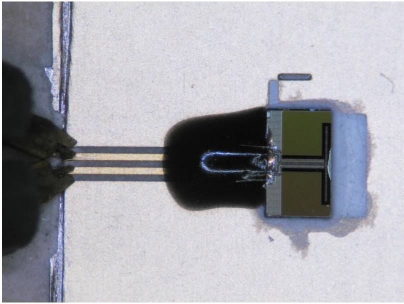

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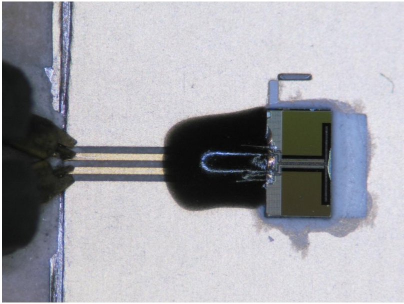
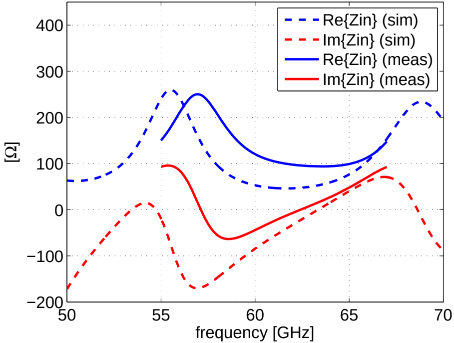
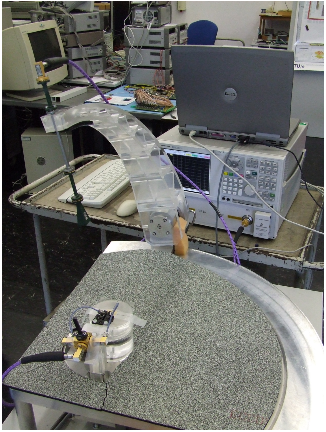


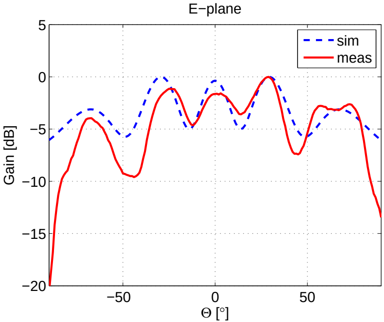


- Input impedance Z_{in}

Measurement results

- Radiation pattern measurements





- Good agreement in both principal planes

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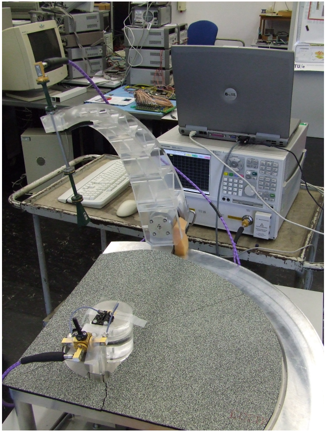
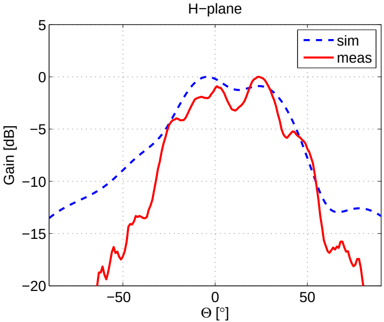




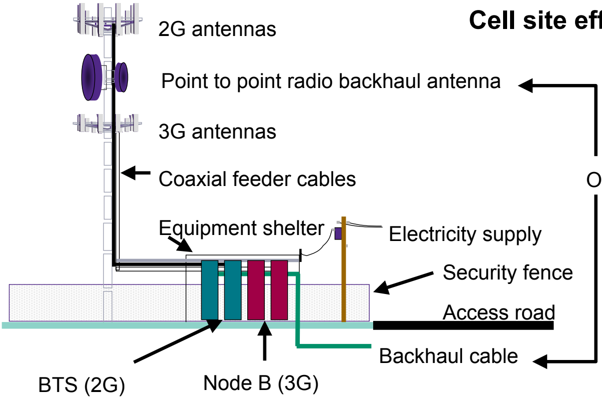
- Good agreement in both principal planes

3. RF MEMS for adaptive antenna beamforming

Electromagnetics Group

Rob Mestrom

W-CDMA cell site



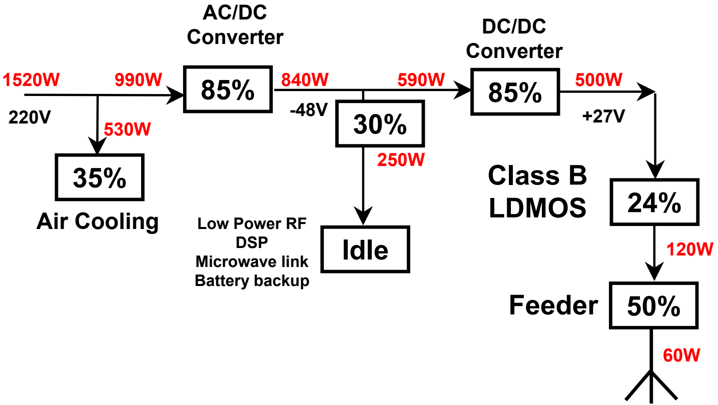
Cell site efficiency $= \frac{P_{RF}}{P_{DC}}$

< 4%

for Si-LDMOS

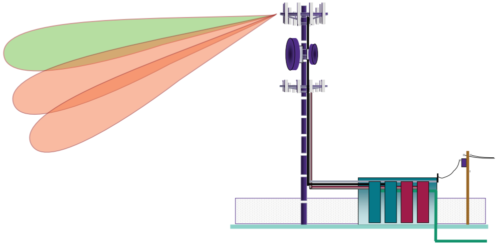
BTS power budget

Antenna radiates up to 60 W



Beamforming for BTS antennas

- Short-term demands for beamforming
  - (re-)calibration of elevation angle (0 – 10°)
  - evolution from mechanical tilt to remote electrical tilt



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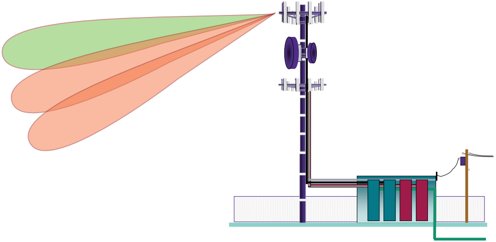
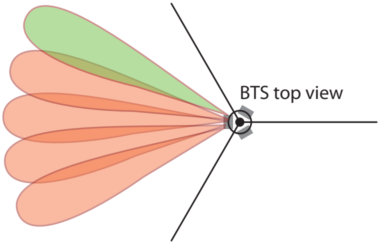


- Allows for
  - dynamic cell-breathing
  - reduction of near-far problem in CDMA

Beamforming for BTS antennas (2)

- Long-term demands for beamforming
  - horizontal beamforming



Beamforming for BTS antennas (2)

- Long-term demands for beamforming
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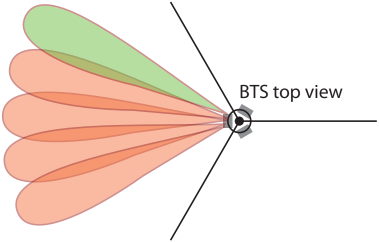

- Spatial separation of users
  - multiple simultaneous beams
  - adjustable gain or modulation per beam
  - beamforming per time slot possible (LTE)

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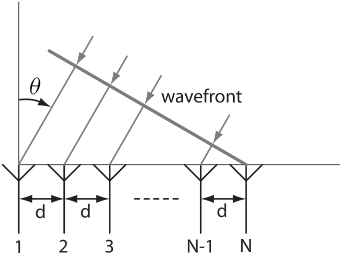
Approach

- Address demands by phased-array antenna
  - create phase shift between antenna elements using RF MEMS technology



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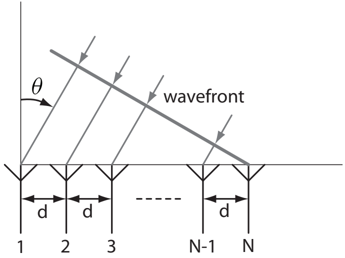

  - current BTS: 1D array for remote electrical tilt
  - future BTS: 2D array for adaptive beamforming

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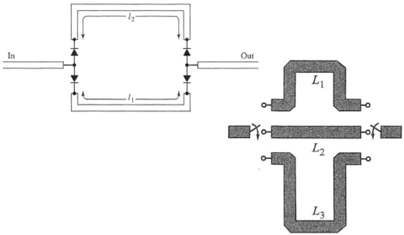
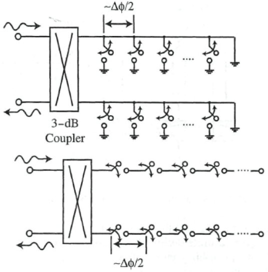
Beamforming

- Create phase shift between antenna elements using RF MEMS switches

Switched line



reflect-line



- Radio Frequency Micro-ElectroMechanical Systems

RF MEMS switches

- Radio Frequency Micro-ElectroMechanical Systems
- Why RF MEMS?
  - promising new technology
  - benefits from both mechanical and electrical disciplines
  - small size
  - integrability with IC technology

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RF MEMS switches

- Radio Frequency Micro-ElectroMechanical Systems
- Why RF MEMS?
  - promising new technology
  - benefits from both mechanical and electrical disciplines
  - small size
  - integrability with IC technology
- Alternatives are also considered
  - pHEMT switches
  - PIN-diode switches
  - electromagnetic relays

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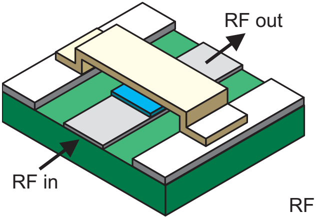
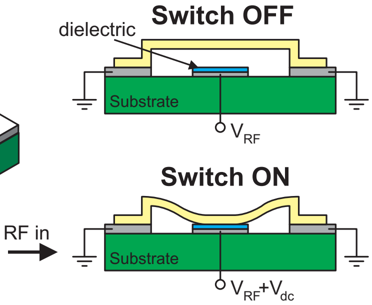
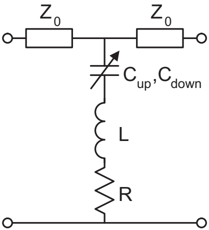
MEMS switches

- Two types of MEMS switches
  - capacitive (switch between two capacitance values)

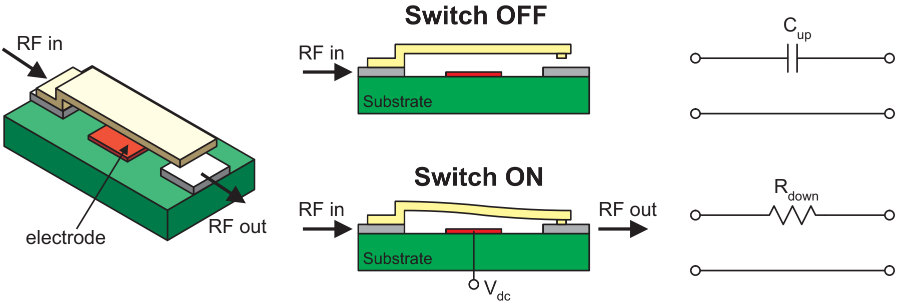






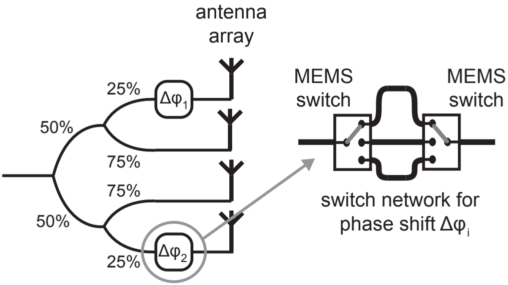
MEMS switches

- Two types of MEMS switches
  - capacitive (switch between two capacitance values)
  - ohmic (conventional on/off switch)



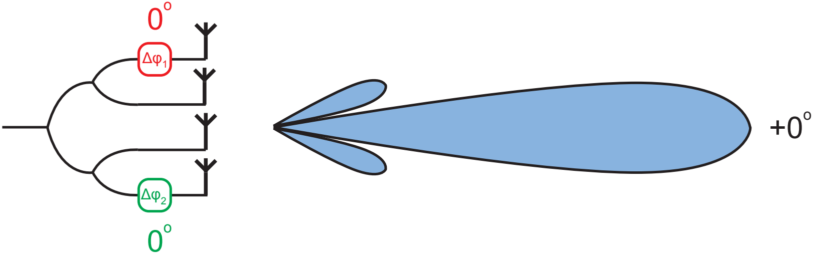
Phase shift array concept

- Power handling major challenge
- Phased-array feed network for antenna down-tilt
  - unequal power division to cope with power handling
  - phase shift in low-power branches only



feed network and power distribution

- Working principle
  - Beamforming by setting $\Delta\varphi_1 = -\Delta\varphi_2$
  - $\pm 5°$ beam steering by applying $\pm 30°$ phase shift



Summary

- PANAMA redefined
- Overview of 3 contributions from TU/e

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Thank you for your attention!

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