Efficiency improvements in wireless networks for future European communication needs

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CWTe 2010 Fall Research Retreat
October 26, 2010
Motivation

Future communication needs in Europe require:

- high capacity networks
- access to wireless services everywhere

Two main challenges:

1. spectrum use
   - increase spectral efficiency (bits/Hz)
   - decreasing interference with adjacent systems

2. multi-mode
   - multi-standard operation
   - dynamic reconfigurability

In parallel: need for low power consumption
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PANAMA project

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

- Power Amplifiers aNd Antennas for Mobile Applications
- European Catrene programme
PANAMA project

- **Power Amplifiers aNd Antennas for Mobile Applications**
- 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
PANAMA project partners
PANAMA project

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

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  - future multi-band, multi-mode more efficient power amplifiers and transmitter systems
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- Target applications and standards
  - 3/4G mobile phones and their connectivity standards
  - 3/4G cellular base stations
  - avionics and mobile satellite communications
  - home networking
PANAMA objectives

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

**System**
- Novel reconfigurable architectures
- System level specification

**Enablers**
- Improved

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

**Applications**
- Handsets
- BTS
- Avionics
- Satcom
- Home Networking

Better tools for better design
Proof of concepts
Market competitiveness

Same goals
Common approach
Better tools for better design
+/Technology evolution
TU/e focuses on antenna systems and the interconnect to the PA
TU/e in PANAMA

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

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
Transmission lines are widely used for matching

- Quality-factors and lengths are important
- PANAMA project: minimize losses in interconnect
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

/department of electrical engineering
Patterned shielding working principle

- Shielding prevents current from flowing horizontally
Patterned shielding working principle

- Shielding prevents current from flowing horizontally

- Creates an anisotropic layer below the CPW
Patterned shielding simulation results

- 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 $Z_0$

![Graph showing the effect of patterned shielding on Re($Z_0$)](image)
Patterned shielding simulation results

- Effect of patterned shielding
  - Freedom in characteristic impedance $Z_0$
  - Increased loss per wavelength

![Graph](#)
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?

Chip Package

Printed Circuit Board (PCB)
Antenna-on-Chip

What is an AoC?

- Chip Package
- Printed Circuit Board (PCB)
Antenna-on-Chip

What is an AoC?

What is an AoC?

Good option for evolving 60 GHz band
Antenna-on-Chip

- What is an AoC?

- Good option for evolving 60 GHz band
Why Antenna-on-Chip?

- No external mm-wave interconnect
- Direct matching of antenna and amplifier
Why Antenna-on-Chip?

- No external mm-wave interconnect
- Direct matching of antenna and amplifier
- Antenna size at mm-waves makes it affordable

Price erosion of typical (Bi)CMOS process
Realization

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

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Input impedance $Z_{\text{in}}$
Measurement results

- Radiation pattern measurements

- Good agreement in both principal planes
Measurement results

- Radiation pattern measurements

- 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 (2G)  Node B (3G)

2G antennas
Point to point radio backhaul antenna
3G antennas
Coaxial feeder cables
Equipment shelter
Electricity supply
Security fence
Access road
Backhaul cable

/department of electrical engineering
BTS power budget

Antenna radiates up to 60 W

- Air Cooling: 35%
- AC/DC Converter: 85%, 530W
- Idle: 30%, 250W
- DC/DC Converter: 85%, 590W
- Class B LDMOS: 24%, 120W
- Feeder: 50%, 60W

220V, 990W, 840W, 500W, 1520W
Beamforming for BTS antennas

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

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  - (re-)calibration of elevation angle (0 – 10°)
  - evolution from mechanical tilt to remote electrical tilt

- 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
  - horizontal beamforming

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

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

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

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

- Create phase shift between antenna elements using RF MEMS switches

Switched line  

reflect-line
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
RF MEMS switches

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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

![Diagram of phased-array feed network and power distribution]

/department of electrical engineering
Feed network for antenna down-tilt

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

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

Overview of 3 contributions from TU/e

Thank you for your attention!