E-band SiGe Beamsteering Transmitter Building Blocks

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Tobias Tired

Electrical and Information Technology Lund University
Presentation outline

• E-band wireless backhaul

• Beam forming concept
  - Linear timed and phased arrays

• Transmitter architecture

• Designed building blocks
  - 28 GHz QVCO with I/Q phase error tuning and detector
  - 28 GHz to 1.75 GHz Divider
  - PA version 1
  - PA version 2
  - PA version 3: diploma thesis

• Conclusions
E-band wireless backhaul

• The E-band at 71-76 GHz and 81-86 GHz: wireless point-to-point communication
  • 5 GHz of spectrum ⇒ data rates of Gb/s

• Costly optical fiber backhaul ⇒ wireless data link

• Heterogeneous networks: macro, pico and femto cells ⇒ large number of base stations

A wireless backhaul is highly advantageous
Beamsteering concept

- Beamsteering $\Rightarrow$ equal to spatial filtering of radio signals
- Array of antennas $\Rightarrow$ steered to block transmission to certain directions and to provide antenna gain to a desired direction

Applications:
- Radio communication
- Surveillance
- Radar
- Sonar
- Audio
Linear timed arrays

- Linear equally spaced array with 8 TX antenna elements
- Wave plane at transmit angle $\alpha$

Different time of departure $\Delta t$

$$\Delta t = \frac{(n-1)d \sin \alpha}{c}$$

$c =$ light speed, $d =$ element spacing

- Beamforming transmitter: aligns the signals to the antenna elements in time

$$\Rightarrow \text{Coherent combination to one direction and suppression to other directions}$$

Use a small fractional BW $\Rightarrow$ Realization of time delay with fixed phase shift $\Rightarrow$ Linear phased array
E-band transmitter architecture

Unpublished material
28 GHz QVCO plus phase error detector and tuner

Unpublished material
QVCO phase error detector

Unpublished material
28 GHz QVCO with phase error detector and tuner

Unpublished material
Divide by 16

Unpublished material
Beam steering implementation with PLL

Unpublished material
Power amplifier architecture

50 Ω antenna impedance transformed to 12.5 Ω ⇒ lower VCC

Stage 1 and 2
Version 1

Stage 1
Version 2

Capacitive cross coupling with diode connected devices to neutralize base collector capacitance
Power amplifier transformers

- **50 Ω antenna impedance transformed to 12.5 Ω single ended ⇒ lower VCC for same CP_{1dB}**
- **Tuning capacitors: reduce imbalance for improved power combination**
- **Input transformer: 50 Ω antenna impedance to 100 Ω differential for each amplifier**
Transformer simulation results and chip layout

- Chip area: 0.87 mm\(^2\)

- Output transformer loss: two transformers back to back ⇒ \( G_{\text{max}} = -2.67 \) dB ⇒ 1.34 dB loss for one transformer
Power amplifier simulation results

Version 1

Unpublished material
Power amplifier simulation results

Version 2 – gain versus varactor voltage

Unpublished material
Power amplifier diploma thesis

Version 3 by Manuel Beljano

- Cascode architecture
- VCC = 3.5 V
Power amplifier simulation results

Version 3: diploma thesis

VCC = 3.5V
Gain = 16 dB
PAE = 7.5 % at $CP_{1dB}$
$CP_{1dB} = 14.1$ dBm
$P_{sat} = 18$ dBm
Conclusions

- Project status September 2014

- Designed TX blocks: 28 GHz QVCO
  Three power amplifiers
  Divider
  PLL with phase control

- Remaining TX blocks: 28 GHz I/Q mixer
  84 GHz mixer

- Complete beam steering transmitter to be taped out in December 2014