Tuning a Billion Control Loops

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Contents

- The Mobile Platform Business
- The Control Loops in 3G
- The LTE system (4G)

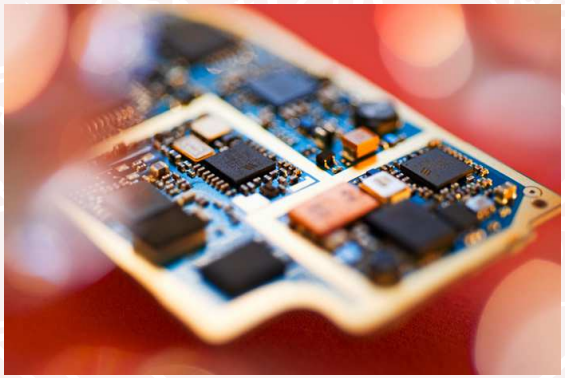
2001-2010 Expert in “Mobile System Design and Optimization”

Joint work with MANY other persons at Ericsson

The Mobile Platform Business

Ericsson in Lund since 1985, 4000 persons

- Sony Ericsson: mobile phones
- ST Ericsson: mobile platforms
- Ericsson: research, patents



Platform: HW, SW and IPR needed to make phones

Competitions: Qualcomm, Infineon, Broadcom, Freescale, . . .

The Mobile Platform Business

10^9 units/year

10^{12} CNY/year (1CNY≈1SEK)

Chinese holdings of US Treasury Securities: $\approx 10^{13}$ CNY

Extremely competitive market




Delays very costly (say 10^7 MCNY/week)

The Priorities

- Cost
- Size, Performance

$1\mathrm{mm}^2$ ASIC area approx 1CNY (100MCNY per 100Mphones)

Specialized HW or flexible processor?

Acceptable memory latency?

Bitwidths in calculations? . . .

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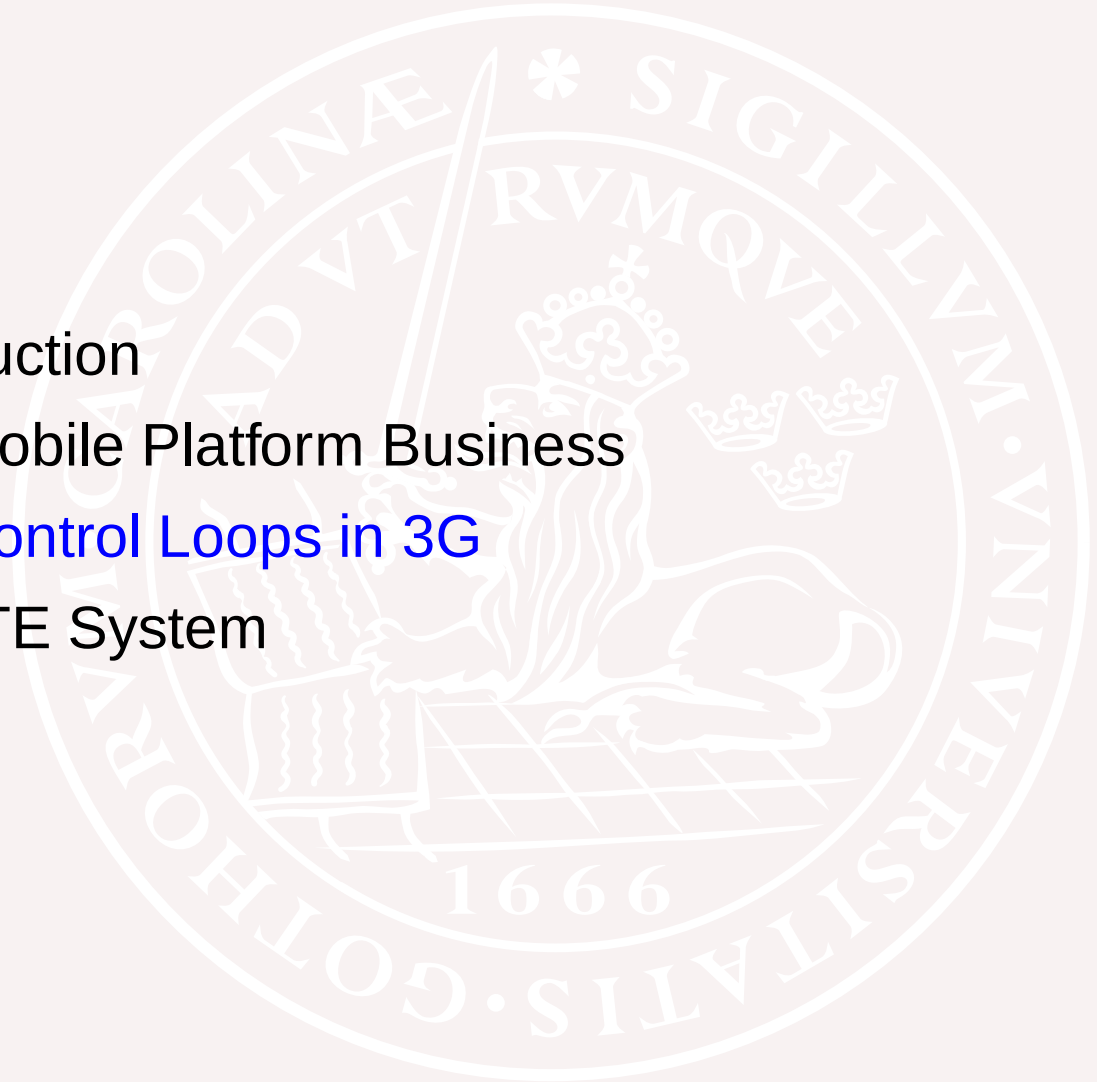
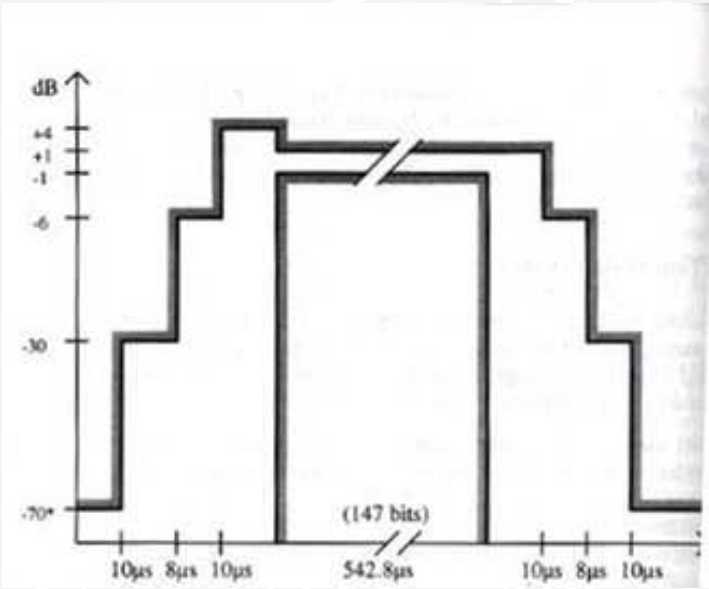


- Introduction
- The Mobile Platform Business
- The Control Loops in 3G
- The LTE System

The Control Loops in 3G

- Power Amplifier Control GSM
- Receiver Gain Control (AGC)
- Frequency Control (AFC)
- Phase-lock loop control (PLL)
- Power Control WCDMA
- (Thermal Control)
- (Antenna Weight Control)
- (Control of Computational Resources)
- (Timing Control LTE)

Power Amplifier Control GSM



PA single most power consuming part of radio, also possible large disturbance source. SAR.

Turn on and off 2W transmitter in 28 microseconds

Must not to disturb other GSM channels (200kHz grid).

GSM Design Problem

Power measurement not available, only PA current measured

I vs P map varies over temp, voltage, frequency and age

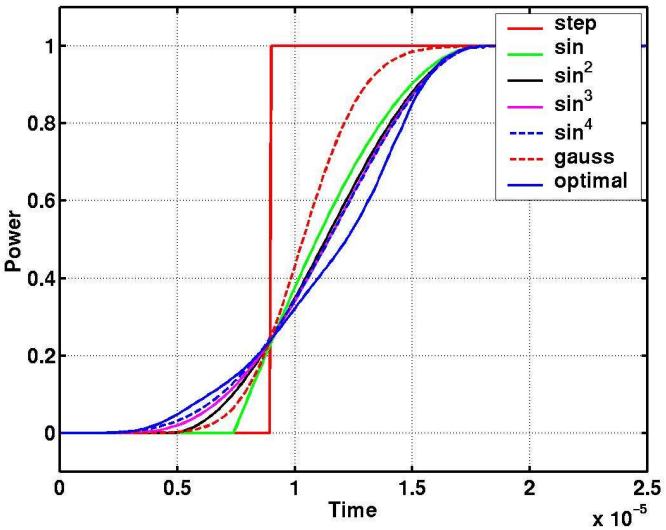
Customers could with short notice change PA

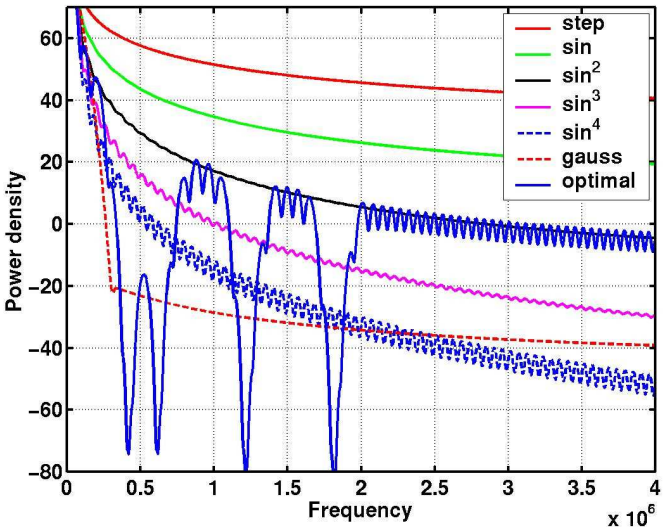
Calibration costly: Can affect build of new production plant

Remark: Resulting problem not noticeable for user of offending phone. “6-sigma” customer specs, very tough internal reqs.

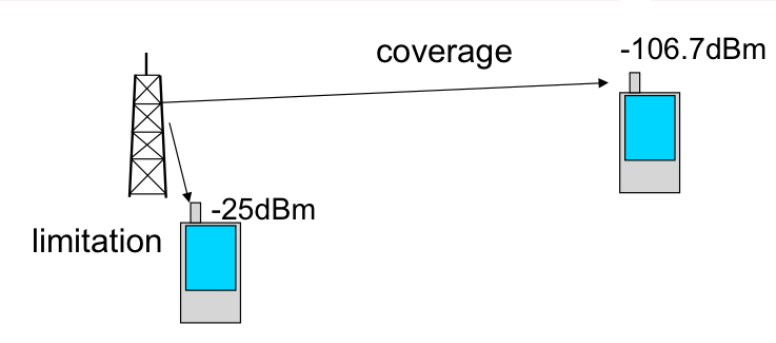
GSM Power Ramping

Choice of good ramp shape makes big difference





Receiver Automatic Gain Control (AGC)



Received power depends on distance to transmitter

WCDMA operating range between -110dBm and -25dBm

Would be extremely costly to design all blocks having >100dB dynamic range !

Solution: Dynamically adjust gains so internal levels are optimal

(Pedagogical Challenge: Find a visualization of 10^{-11}mW!)

Automatic Gain Control

Estimate received power by low pass filtering $I^2 + Q^2$

Minimize total effect of overflow and underflow

Accurate gain changes hard to implement in analog domain

Minimize gain changes in analog blocks

PI-control (in logarithmic domain) with antiwindup

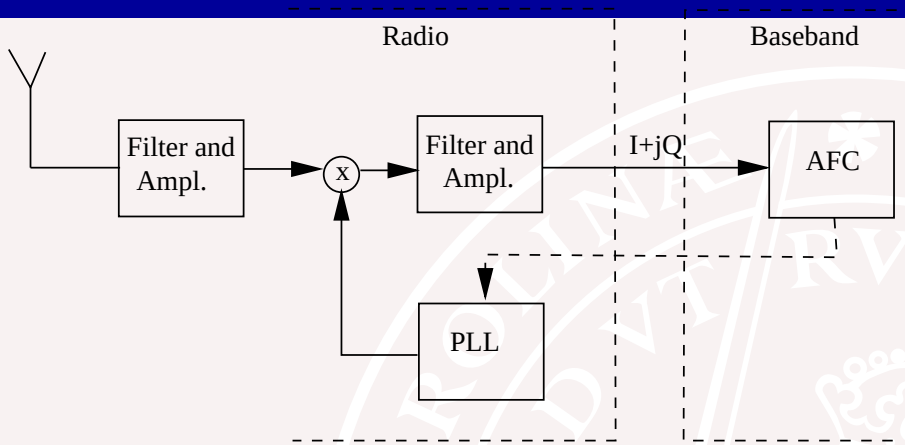
Automatic Gain Control

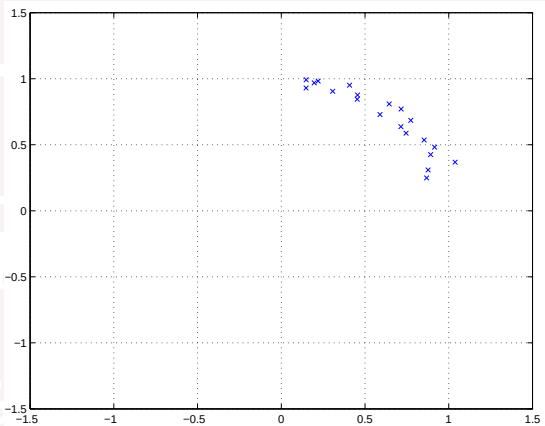
Speed of radio channel variations depend on UE velocity

Faster gain control needed when input power changes much

Easy to model, design and trim

Automatic Frequency Control





Accuracy requirement: A couple of ppb (say 10^{-8})

Achievable without control: 10ppm (10^{-5})

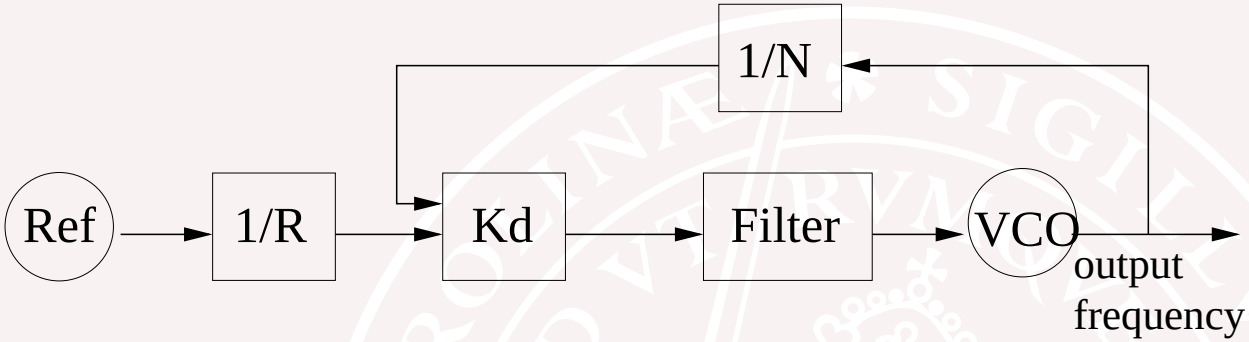
Use baseband signal to detect frequency error.

Fast filter needed to follow changes in frequency error (heating, UE speed changes, BS handover).

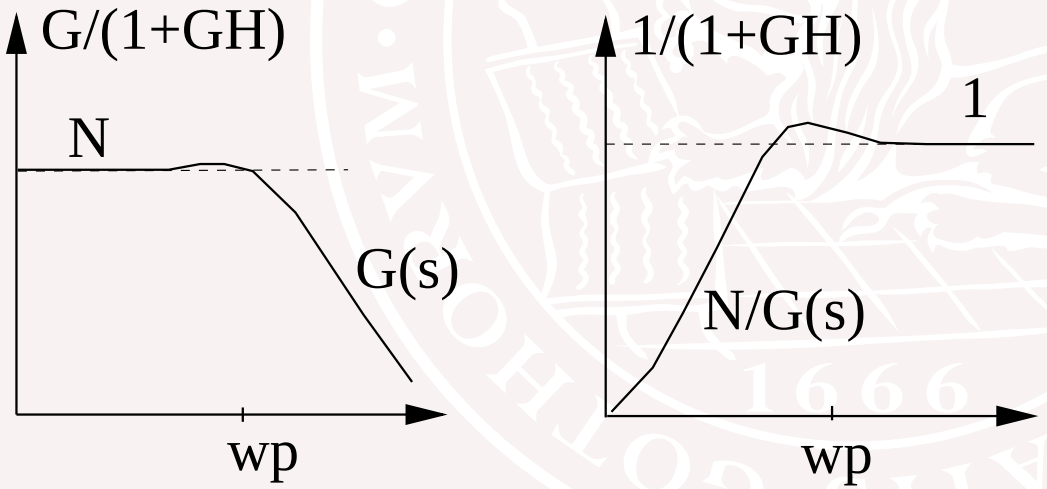
Slow filter needed to filter out effect of channel variations unrelated to frequency error (e.g. fast fading)

I control + filter + gain scheduling (idle vs connected mode)

PLL Control

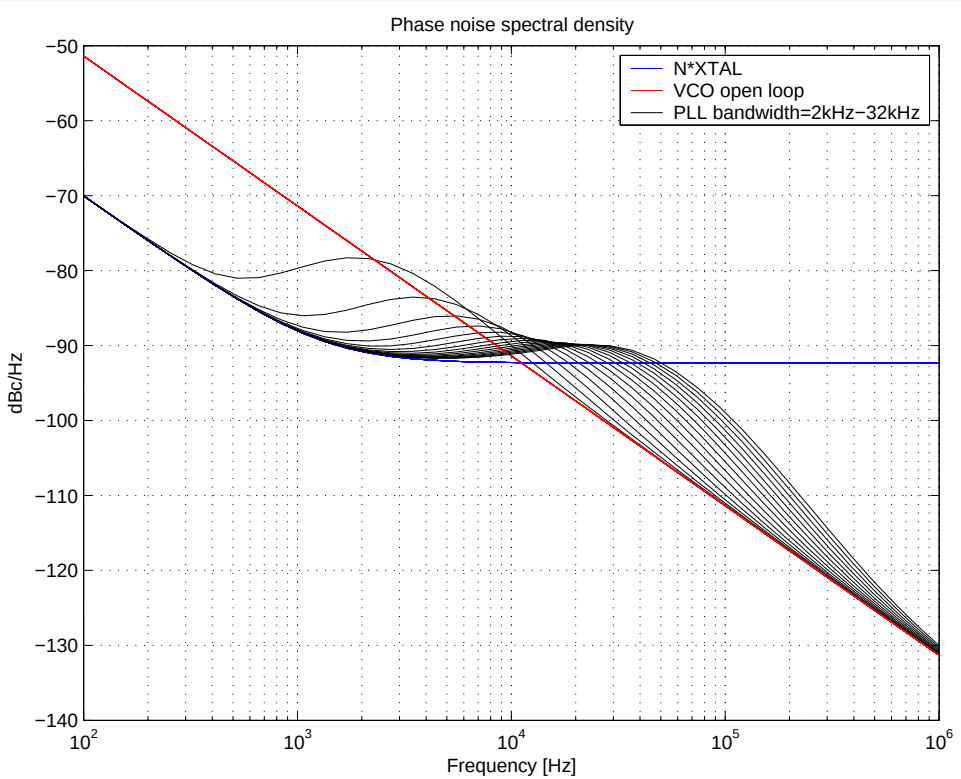


Output frequency = $\frac{N}{R} \cdot f_{ref}$



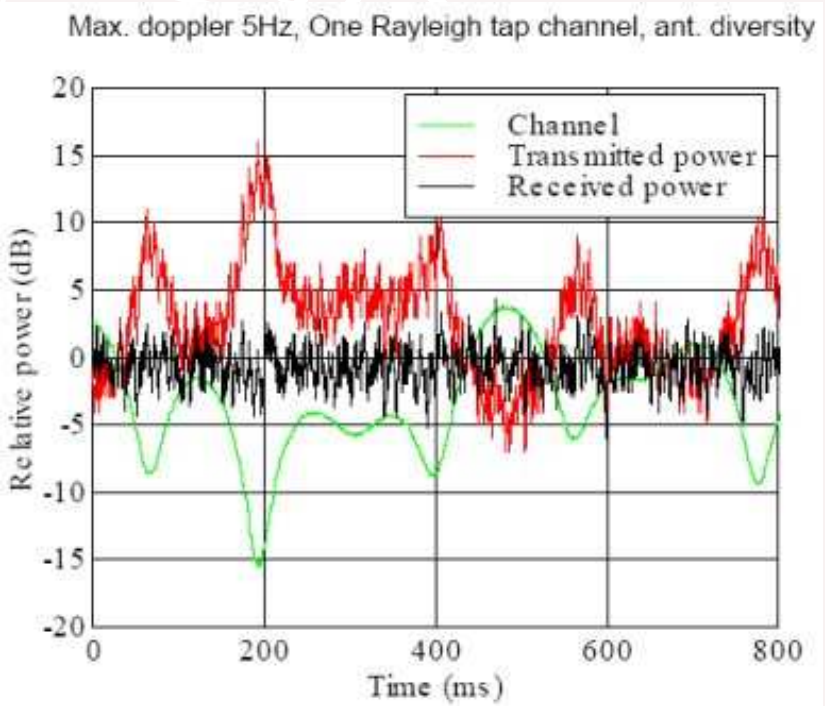
XTAL, R-div, N-div, Phase-detect VCO

Choice of Bandwidth



- Xtal reference and phase detector noise versus VCO noise
- Convergence time when changing frequency
- Spurs

3G Core Problem - Power Control

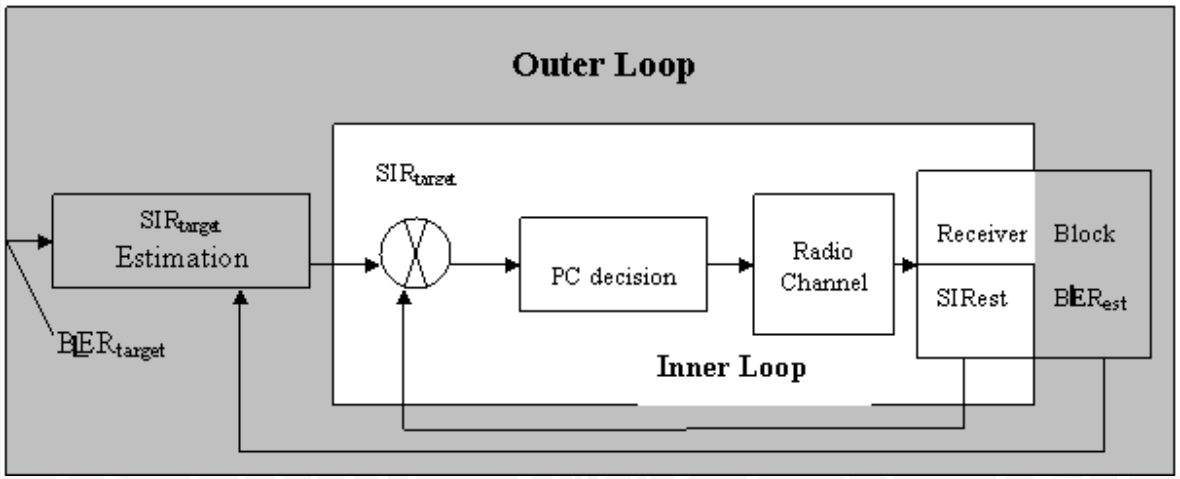


WCDMA - everyone share the same frequency

Uplink (UL) and Downlink (DL) power controlled at 1500Hz

Downlink Power Control

Not standardized, but everyone uses cascaded control



Major problem is how to estimate QoS level, for example at 0.1 percent block error rate.

Antiwindup mechanisms important (since basestation has only small operating power range, perhaps 25dB)

Many practical issues around startup, lost synchronization, compressed mode, change of transport formats . . .

Power Control

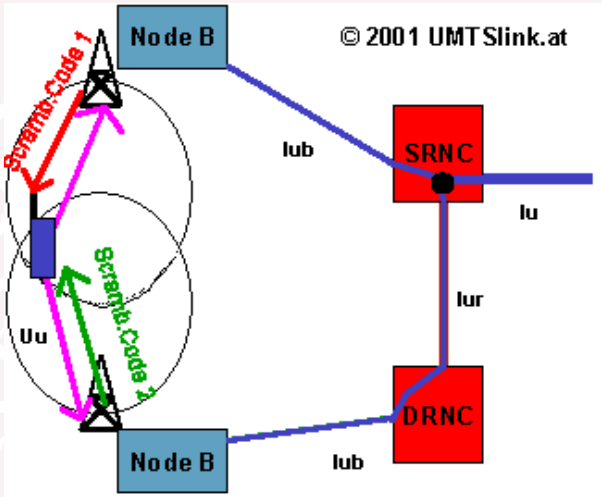
Bad UL power -> Unreliable DL control -> random DL power

Bad DL power -> Unreliable UL control -> random UL power

Hard to take loggs and locate problem

SW probes have limited logging rate, HW logging cumbersome

UE behavior in soft handover



UEs can connect to 6 base stations. Mandated behavior:

DL power: Signals from all basestations to be combined. A common power control command sent to all basestations.

UL power: Or-of-down rule. Command from each basestation should be detected separatly. If any basestation orders “down”, UE must decrease TX power !

All phones should follow the or-of-down rule !

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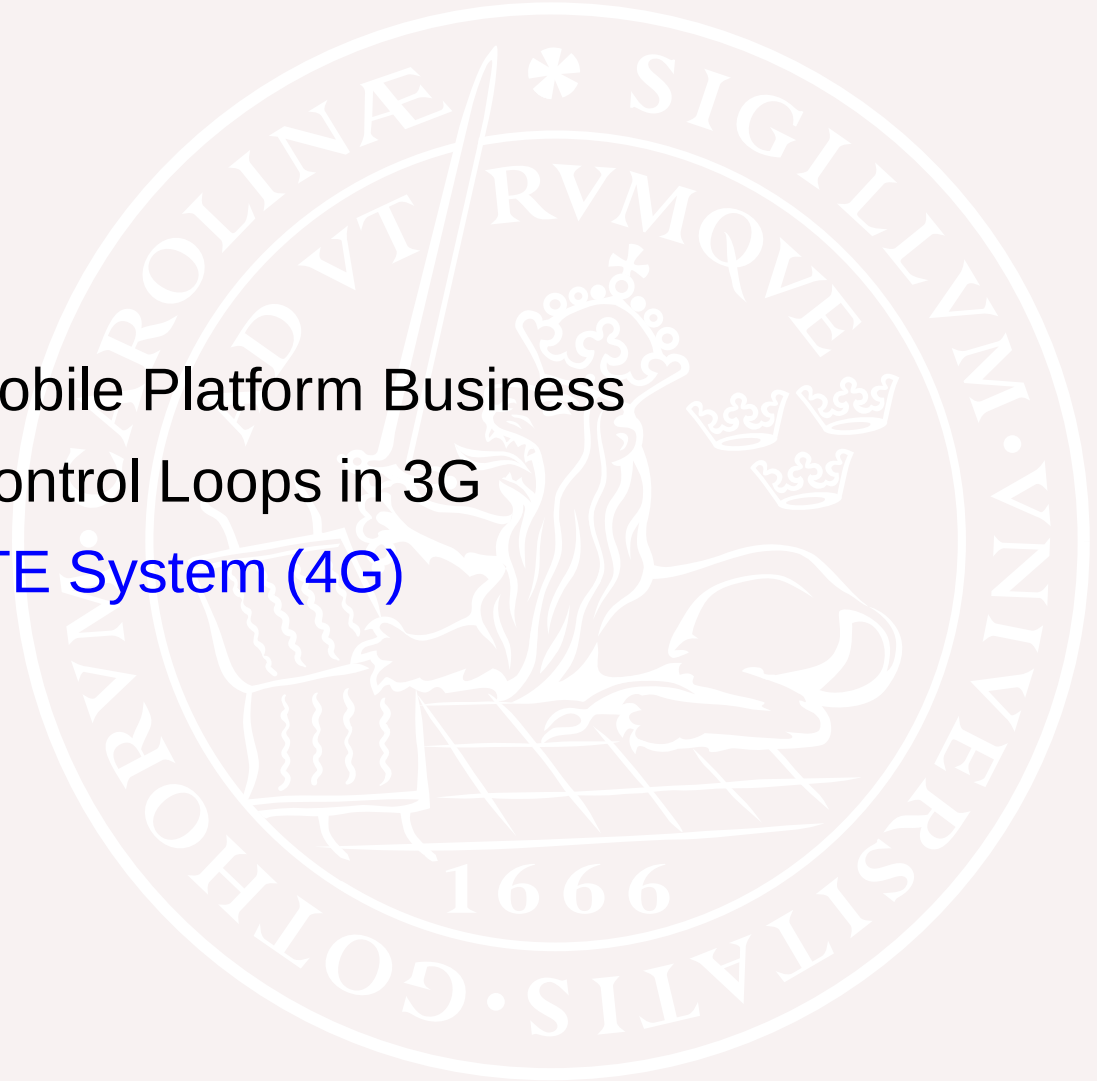

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Long Term Evolution

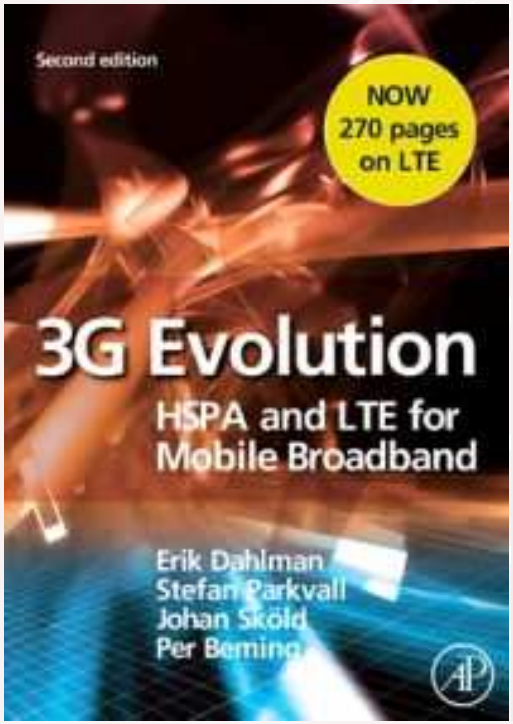
Both 3G and 4G designed with all companies in the market deciding on a joint standard

Same control problems as in 4G

LTE uses OFDM, not transmitting on the same frequency, user orthogonality better -> Power control not a big issue

New problems, but LTE launch seems to have fewer problems

LTE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3G Evolution
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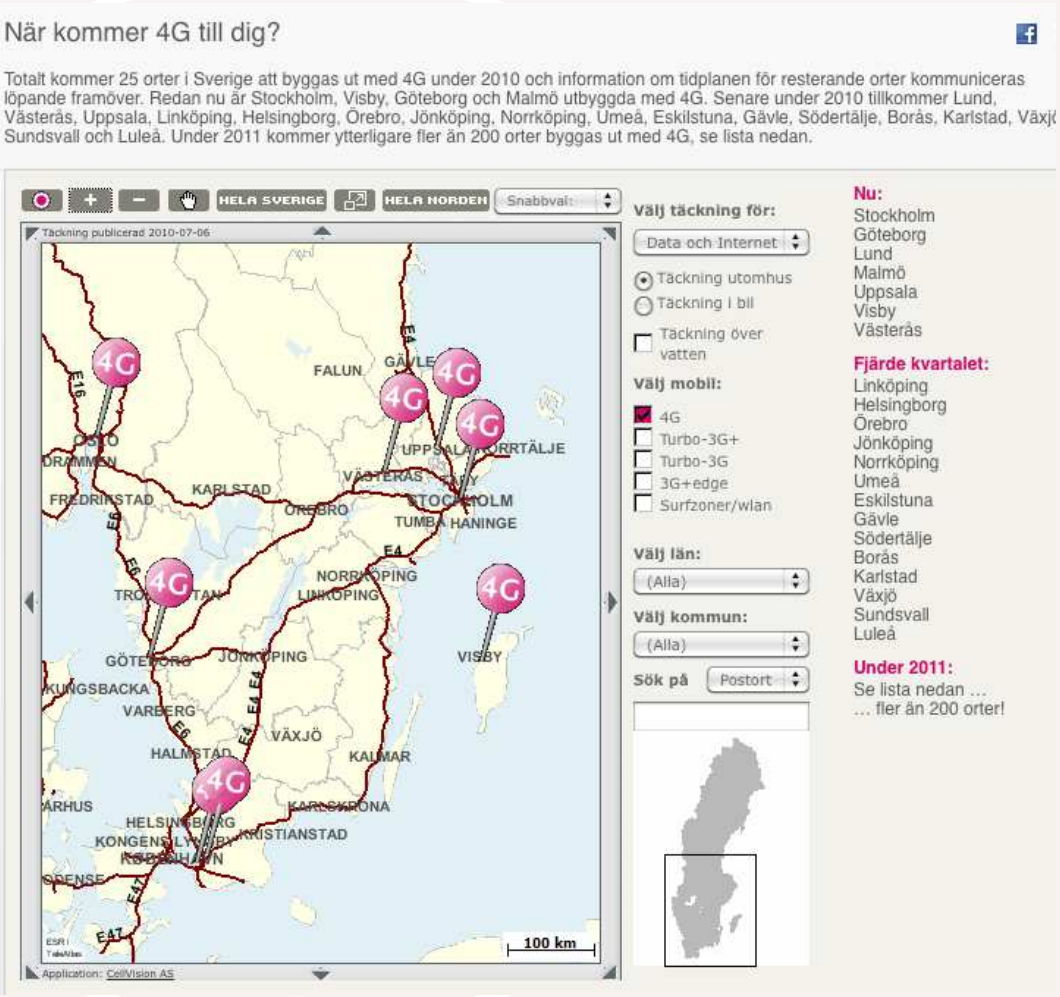
När kommer 4G till dig?
Totalt kommer 25 orter i Sverige att byggas ut med 4G under 2010 och information om tidplanen för resterande orter kommuniceras löpande framöver. Redan nu är Stockholm, Visby, Göteborg och Malmö utbyggda med 4G. Senare under 2010 tillkommer Lund, Västerås, Uppsala, Linköping, Helsingborg, Örebro, Jönköping, Norrköping, Umeå, Eskilstuna, Gävle, Södertälje, Borås, Karlstad, Växjö, Sundsvall och Luleå. Under 2011 kommer ytterligare fler än 200 orter byggas ut med 4G, se lista nedan.
HELA SVERIGE
HELA NORDEN
Snabbval:
Täckning publicerad 2010-07-06
FALUN
GÄVLE
UPPSALA
KARLSTAD
VÄSTERÅS
ÖREBRO
STOCKHOLM
TUMBA
HANINGE
NORRKÖPING
LINKÖPING
GÖTEBORG
JÖNKÖPING
VISBY
VÄXJÖ
KALMAR
KARLSKRONA
KRISTIANSTAD
100 km
Application: CellVision AS
Välj täckning för:
Data och Internet
Täckning utomhus
Täckning i bil
Täckning över vatten
Välj mobil:
4G
Turbo-3G+
Turbo-3G
3G+edge
Surfzoner/wlan
Välj län:
(Alla)
Välj kommun:
(Alla)
Sök på
Postort
Nu:
Stockholm
Göteborg
Lund
Malmö
Uppsala
Visby
Västerås
Fjärde kvartalet:
Linköping
Helsingborg
Örebro
Jönköping
Norrköping
Umeå
Eskilstuna
Gävle
Södertälje
Borås
Karlstad
Växjö
Sundsvall
Luleå
Under 2011:
Se lista nedan …
… fler än 200 orter!

Summary

For all problems, PI control was sufficient.

BUT none of the problems were straightforward PI

- antiwindup critical for power control
- feedforward often useful
- gain-scheduling
- nonlinear transformations (i.e. log domain)

Thank You