Benefits and Constraints of SMPS Integration in Wireless Multi Media Terminals

D. Chesneau
F. Hasbani

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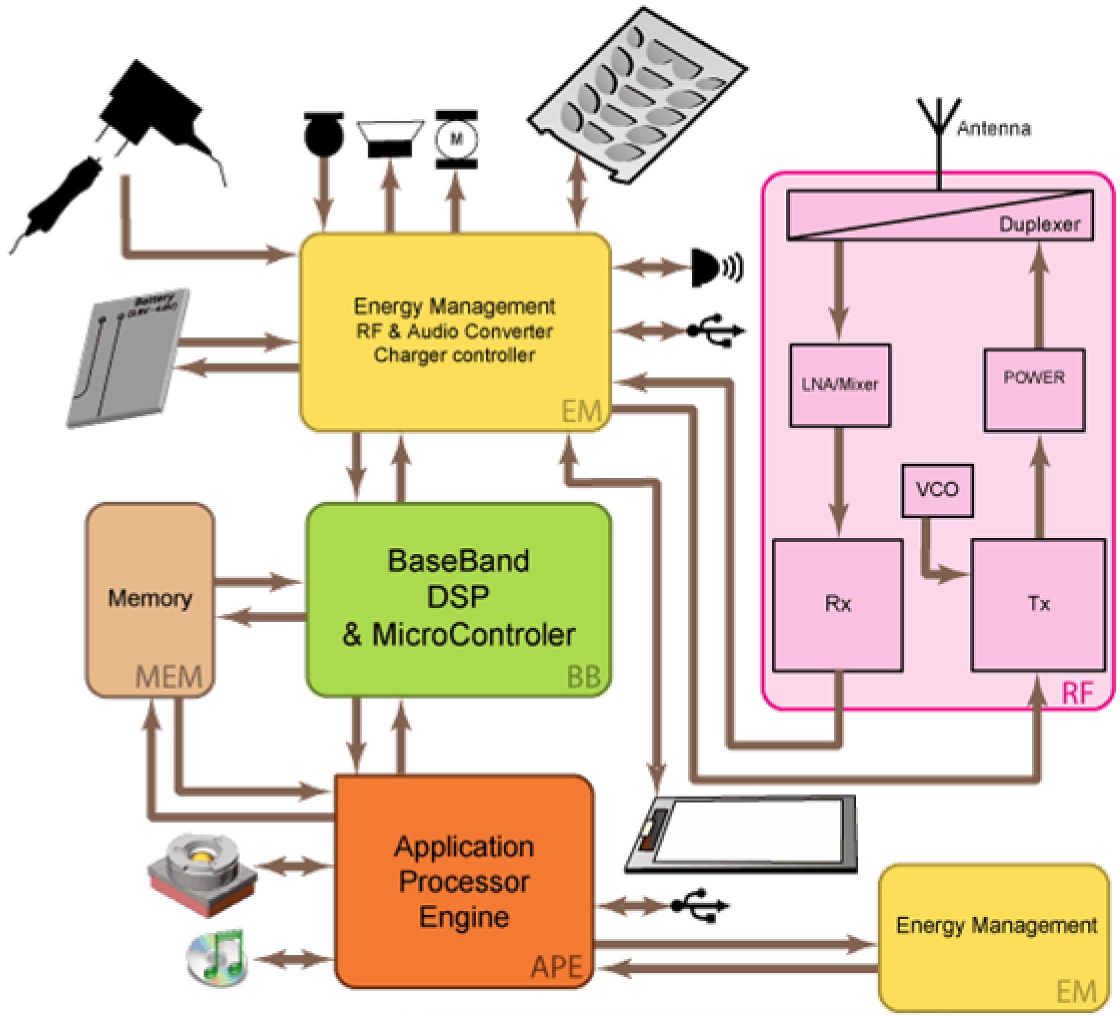
Power SoC 08

$200mm^2$

2/3

Introduction: Mobile Terminal Typical Content



Introduction: The Problem

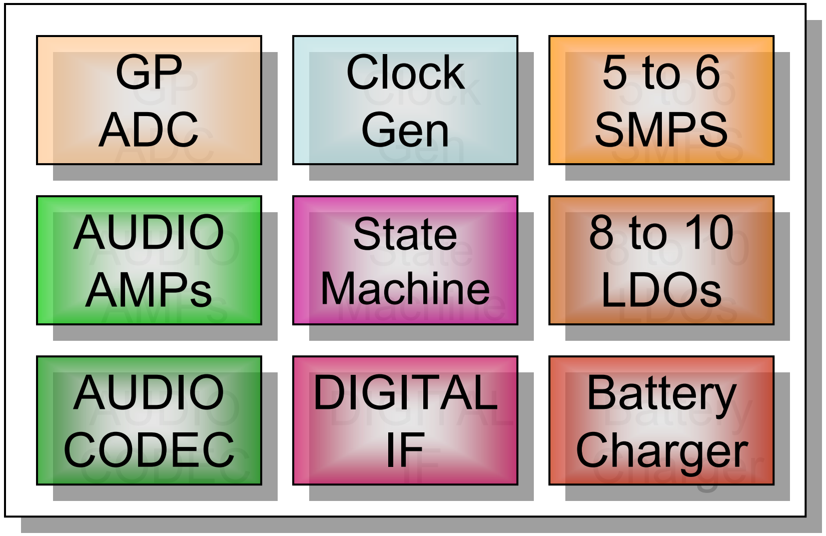
- More and more functions in mobile terminals
- Need massive integration
- Power consumption increases drastically
- But users still request large autonomy

- How to achieve
  - High Efficiency
  - Low Volume
  - Low Cost

Outline

I.0: Power Management Units Context

- Companion chip of DBB
- Complex IC
- Many IOs (200 to 300)
- Low Cost CMOS (5V compliant)
- BGA package



I.1: SMPS for DBB Requirements

High Efficiency
Power Supply

$$\frac{MHz}{\left(mW \bullet mm^2\right)}$$

I.1: SMPS for DBB Requirements
High Efficiency Power Supply

- At light and medium loads
  - Low quiescent current
  - Low switching losses
  - Low AC losses in coil magnetic core

- At heavy loads: Low ohmic losses
  - In Power Transistors ⇨ Low RDSON
  - In Package ⇨ Low parasitic resistance
  - In power coil ⇨ Low DC resistance

I.1: SMPS for DBB Requirements

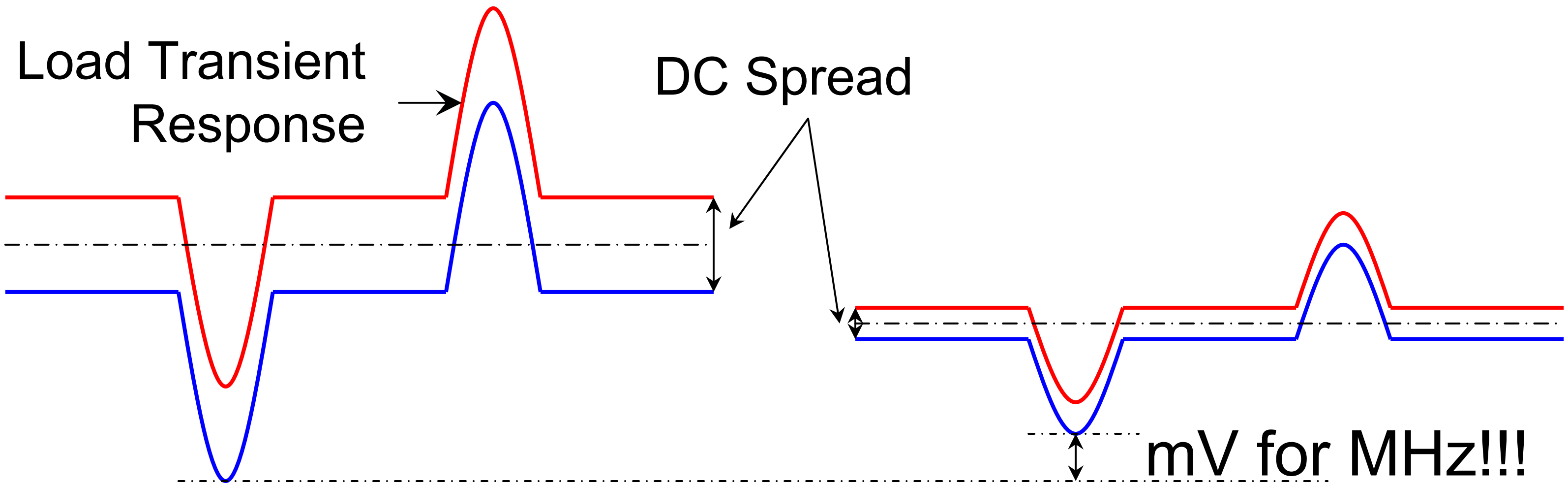
High Efficiency Power Supply

$$\frac{MHz}{\left(mW \bullet mm^2\right)}$$

DC & Transient Accuracy

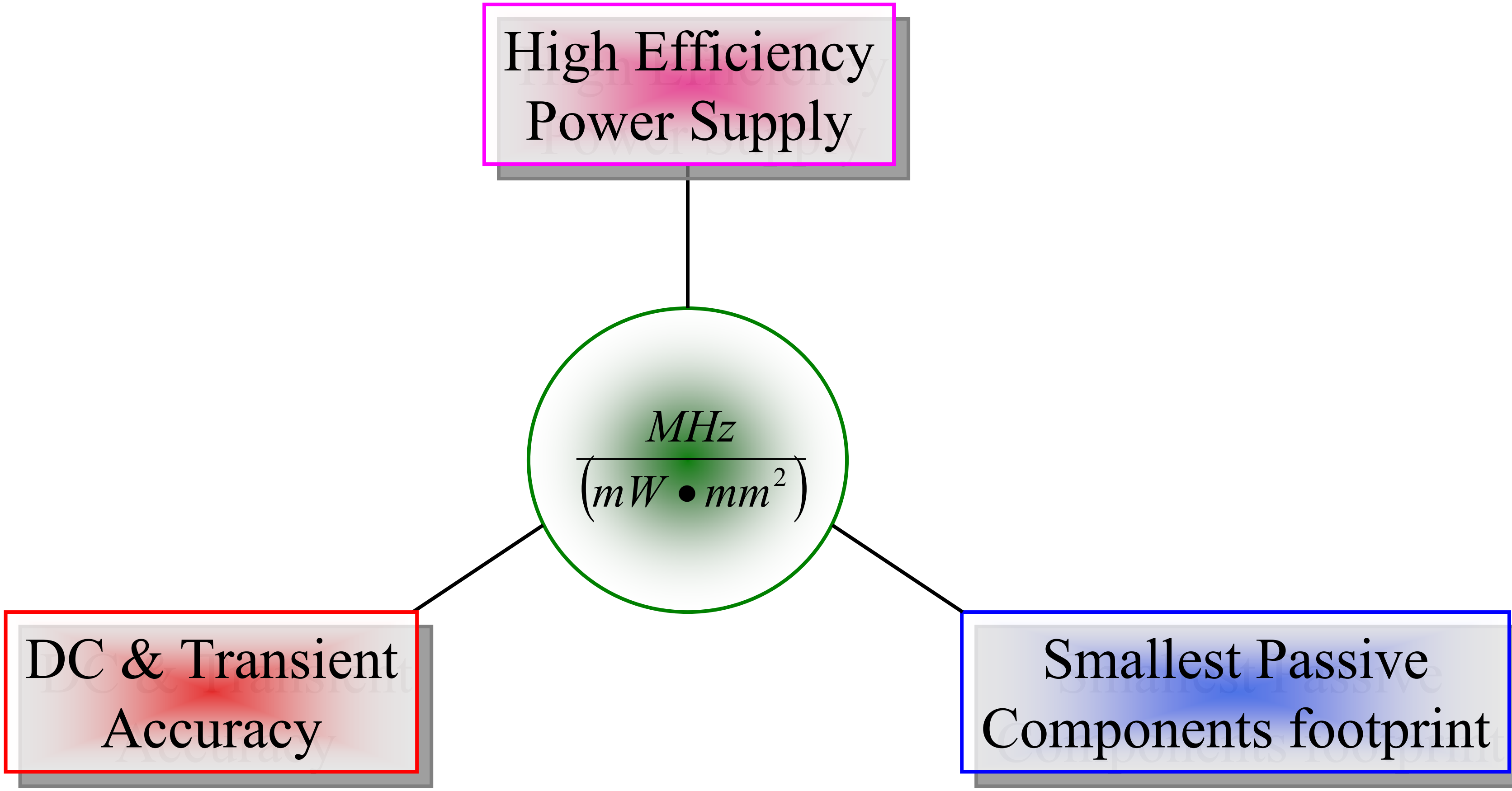
I.1: SMPS for DBB Requirements

DC & Transient Accuracy

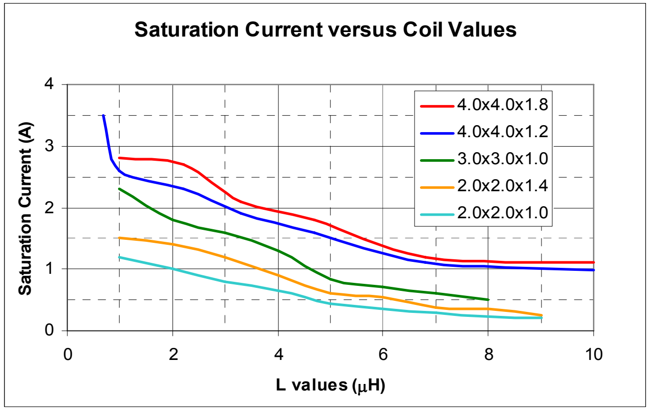


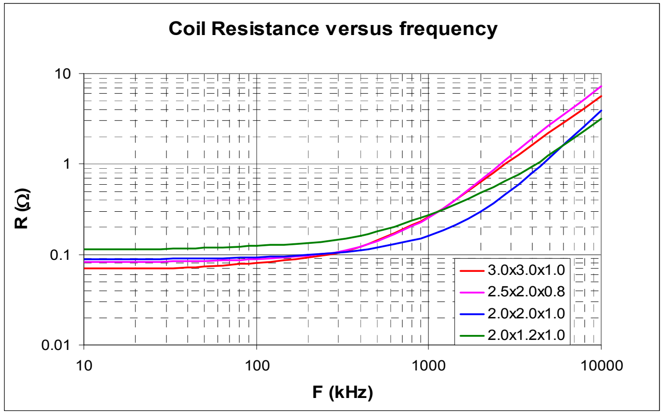
- Better DC & Transient accuracy helps to
  - Reduce static voltage & keep higher min voltage
  - Reduce buffering
  - Reduce silicon area
  - Reduce routing capacitance
  - Achieve more MHz for less mW and less area

I.1: SMPS for DBB Requirements

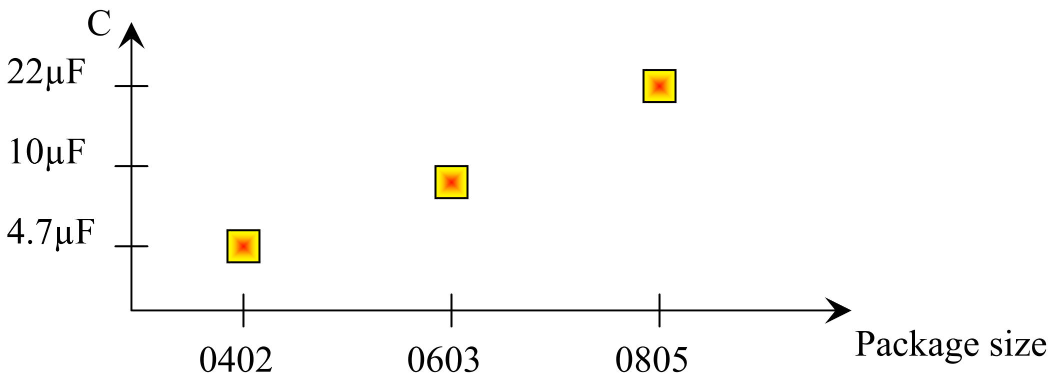


I.1: SMPS for DBB Requirements
Smallest Passive Components Footprint





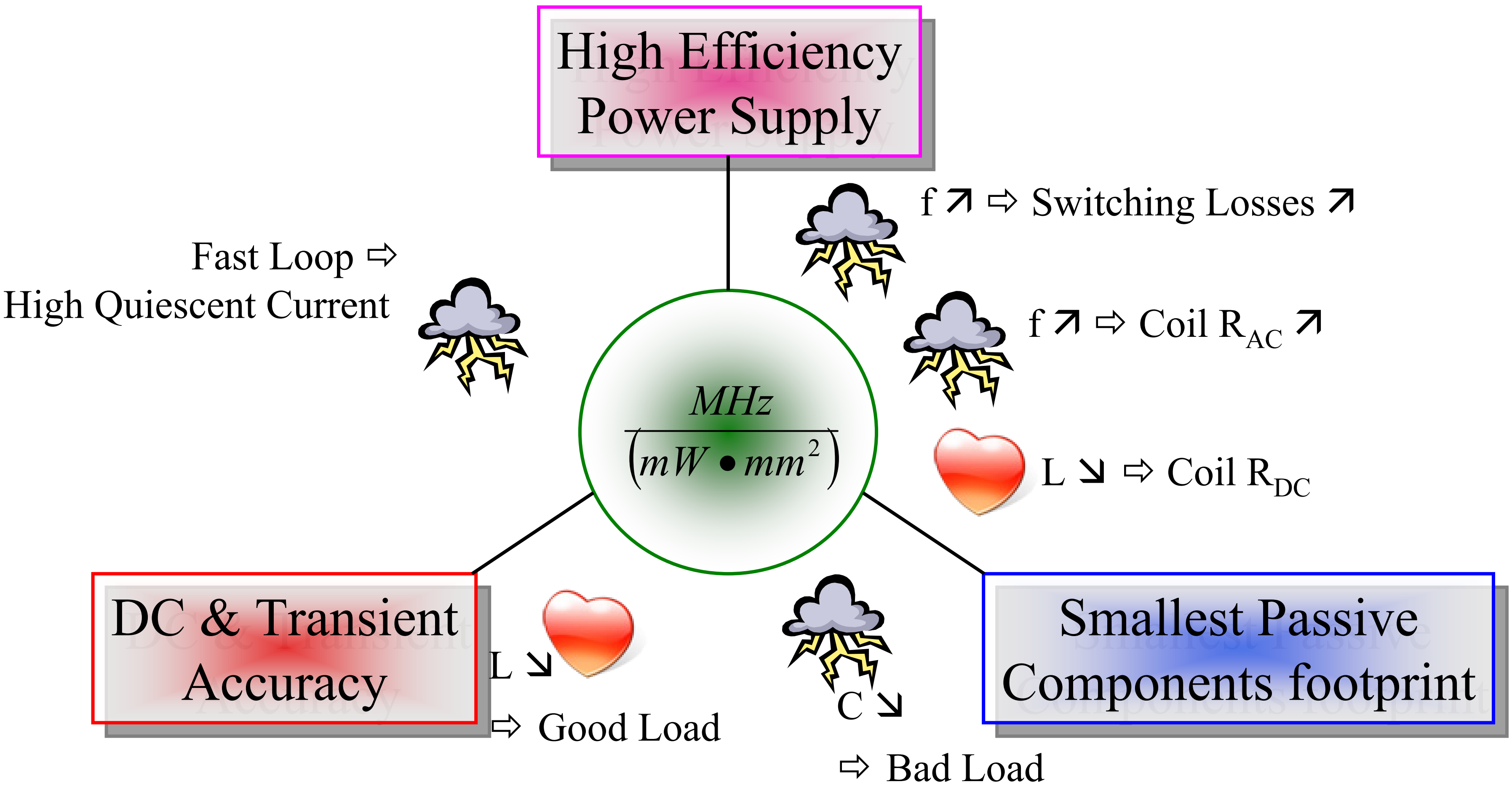
Must reduce L value and increase f …but not too much!!!



Must reduce C value …but not too much!!!

I.1: SMPS for DBB Requirements

Compatibility



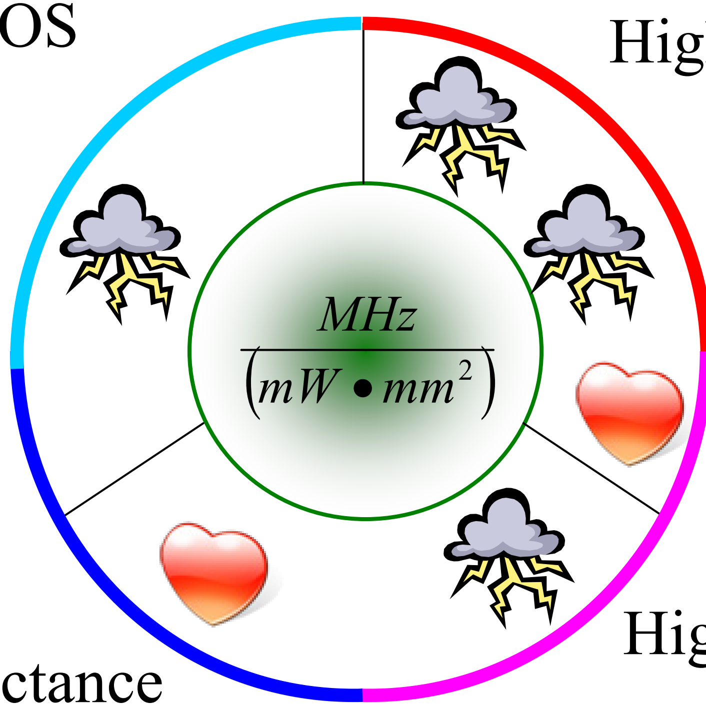
I.2: SMPS for DBB Constraints

Low Cost CMOS

Reliability
vs
overshoots

High Current (>1A)

High Volume Coil



5 to 6 SMPS

High Thermal Dissipation

BGA Package

High Bonding Inductance

So What ?

I.3: Possible integration solutions

- Select a low cost process
- Select a package with low parasitic inductance
- Select a mid range frequency and coil value

And …

- Keep External components outside…

Or

- Split Power Management in 2, 3,… power modules
  - 2/3 Coil
  - 4/6 Capacitors

Outline

Introduction

I SMPS for Digital Base Band and Memories

II SMPS for Audio and Low Power RF functions

- ➢ Requirements / Compatibility
- ➢ Constraints
- ➢ Possible Solutions

III SMPS for RF Power Amplifier

Conclusion

II.0: Audio & Low Power RF Context

- Audio functions
  - Inside PMUs
    or
  - In stand alone ASSP
    - < 50 IOS BGA or WLCSP
  - Low cost CMOS (0.13µm – 5V Compliant)

- Low Power RF functions
  - In dedicated RF chips
  - 0.65µm CMOS process
  - WLCSP

I.1: Audio and Low Power RF Requirements

High Efficiency
Power Supply

$$\frac{SNR}{\left(mW \bullet mm^2\right)}$$

Low Noise
Low Ripple

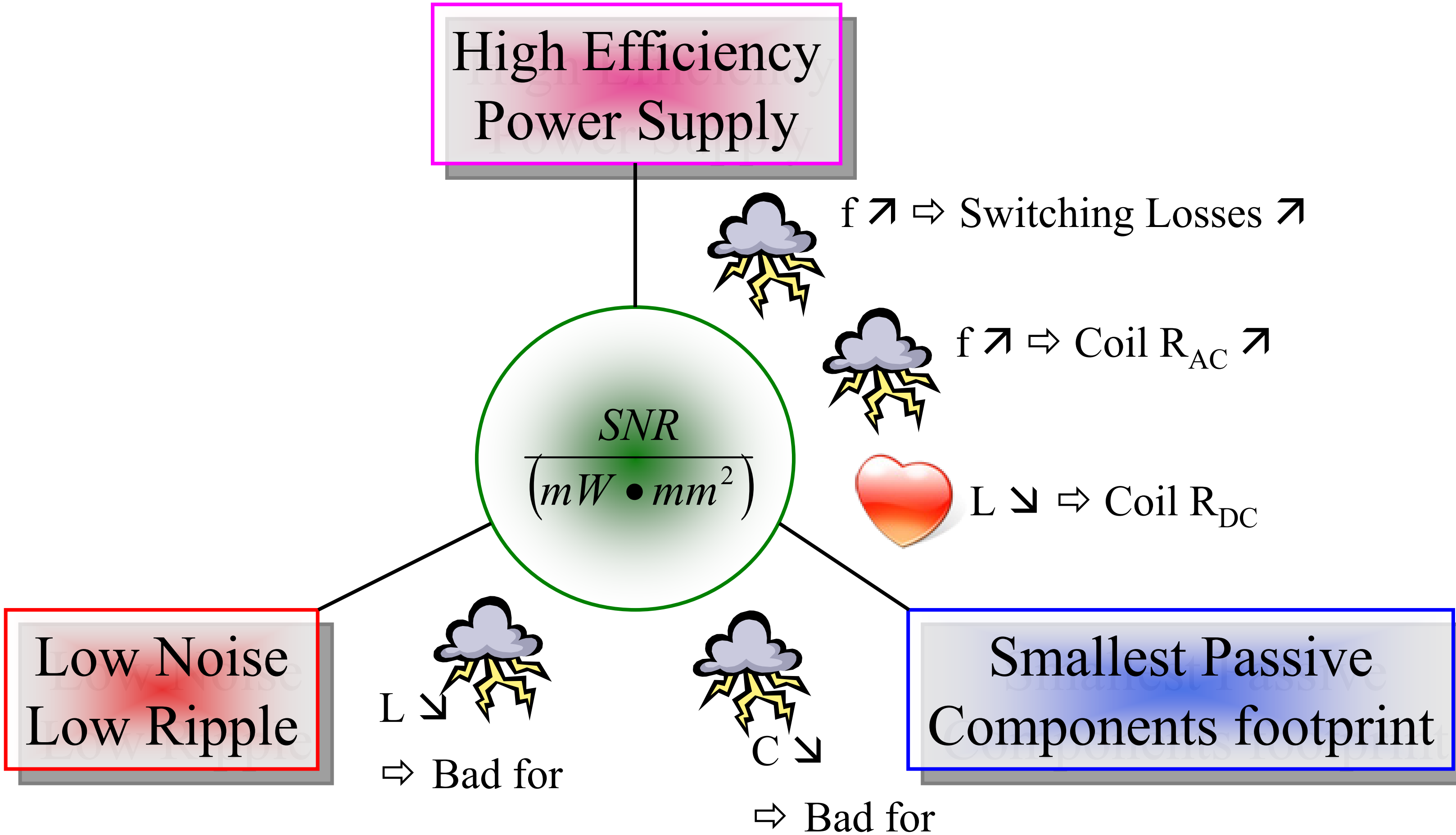
Smallest Passive
Components footprint

I.1: Audio and Low Power RF Requirements
Low Noise / Low Ripple

- Low Noise
  - Fixed frequency
  - Compatible with Audio or RF constraints

- Low Ripple
  - Relatively high coil value
  - Relatively high capacitor value
  - Medium Switching frequency

I.1: Audio and Low Power RF Requirements
Compatibility



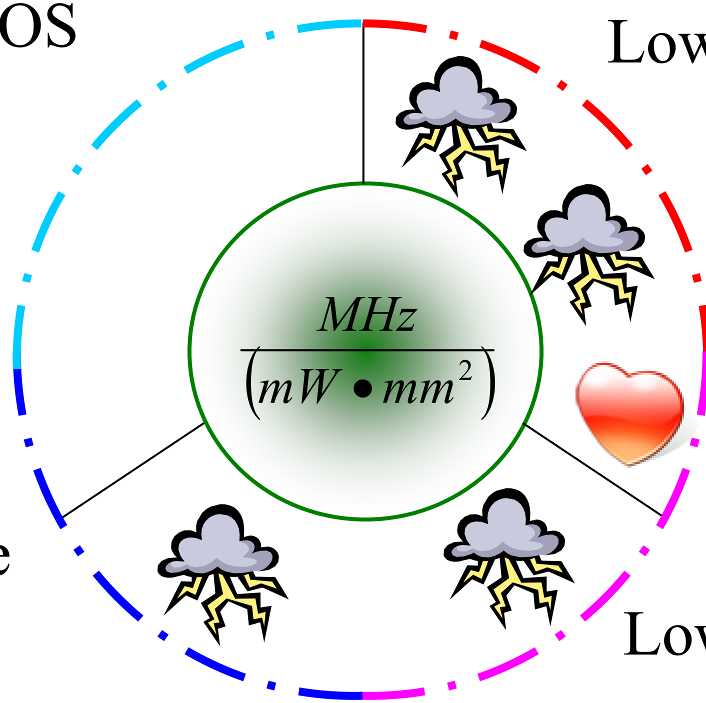
II.2: SMPS for Audio and Low Power Constraints

Low Cost CMOS

Reliability
vs
overshoots

WLCSP Package

Low Inductance



Low Current (<200mA)

Low Volume Coil

1 to 2 SMPS

Low Thermal Dissipation

II.3: Possible integration solutions

- Low current requirement
  - OK for coil volume
  - OK for WLCSP
  - OK for medium frequency

- Possibility to build modules with
  - Stand alone ASSP
  - May be also with PMUs (1 coil)

Outline

Introduction

I SMPS for Digital Base Band and Memories

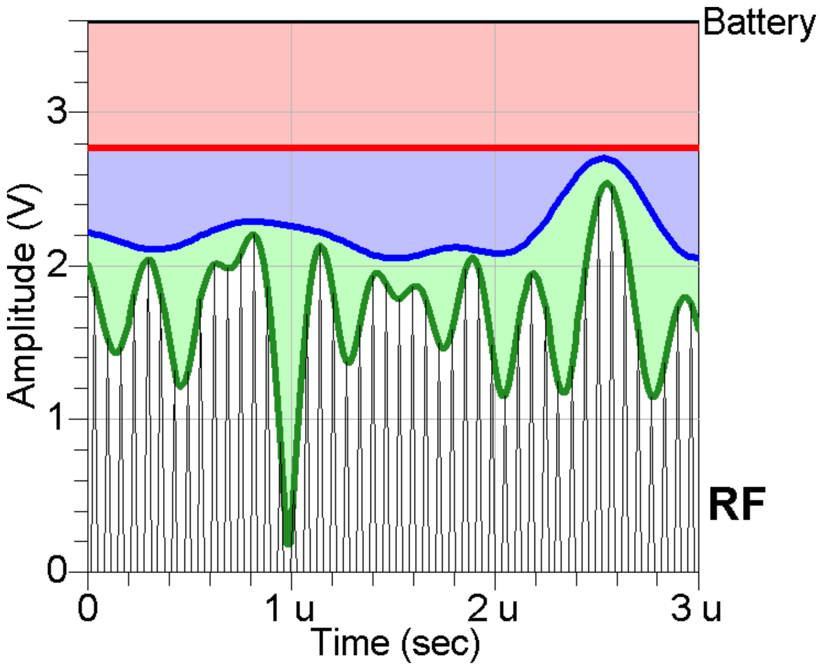
II SMPS for Audio and Low Power RF functions

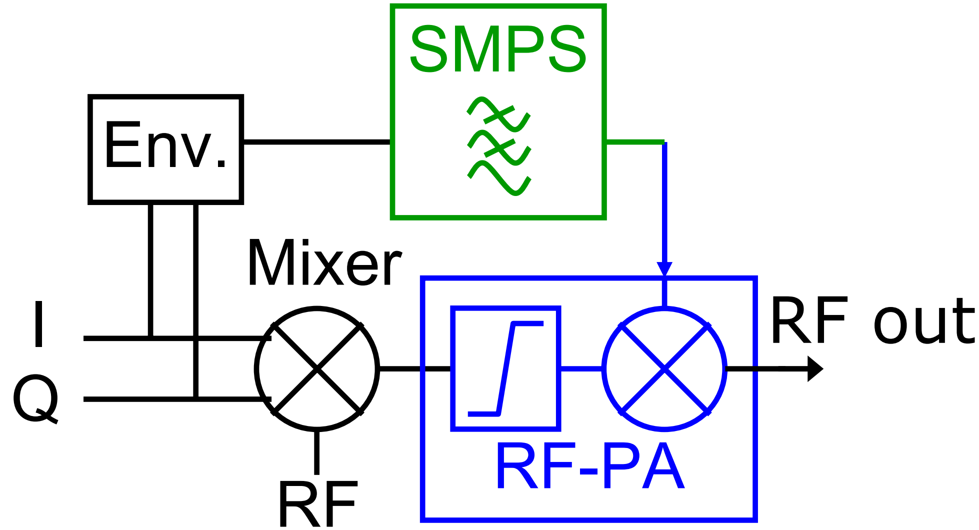
III SMPS for RF Power Amplifier

- Requirements / Compatibility
- Constraints
- Possible Solutions

Conclusion

Power supply of an Envelope Reconstruction RF PA





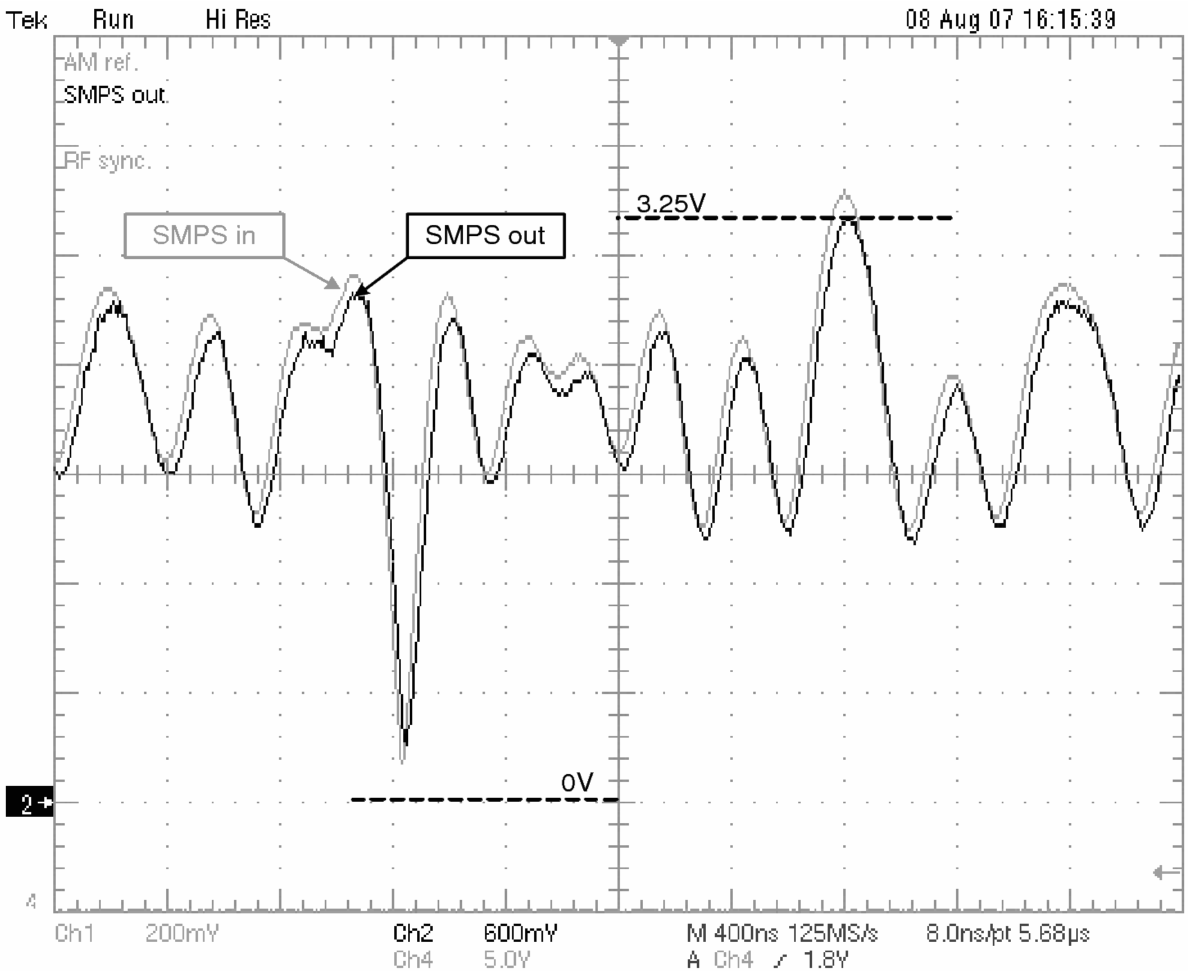
EER

- The PA operates in saturation
- The SMPS provides the envelope signal
- The full RF signal reconstructs at the output

SMPS in the signal path

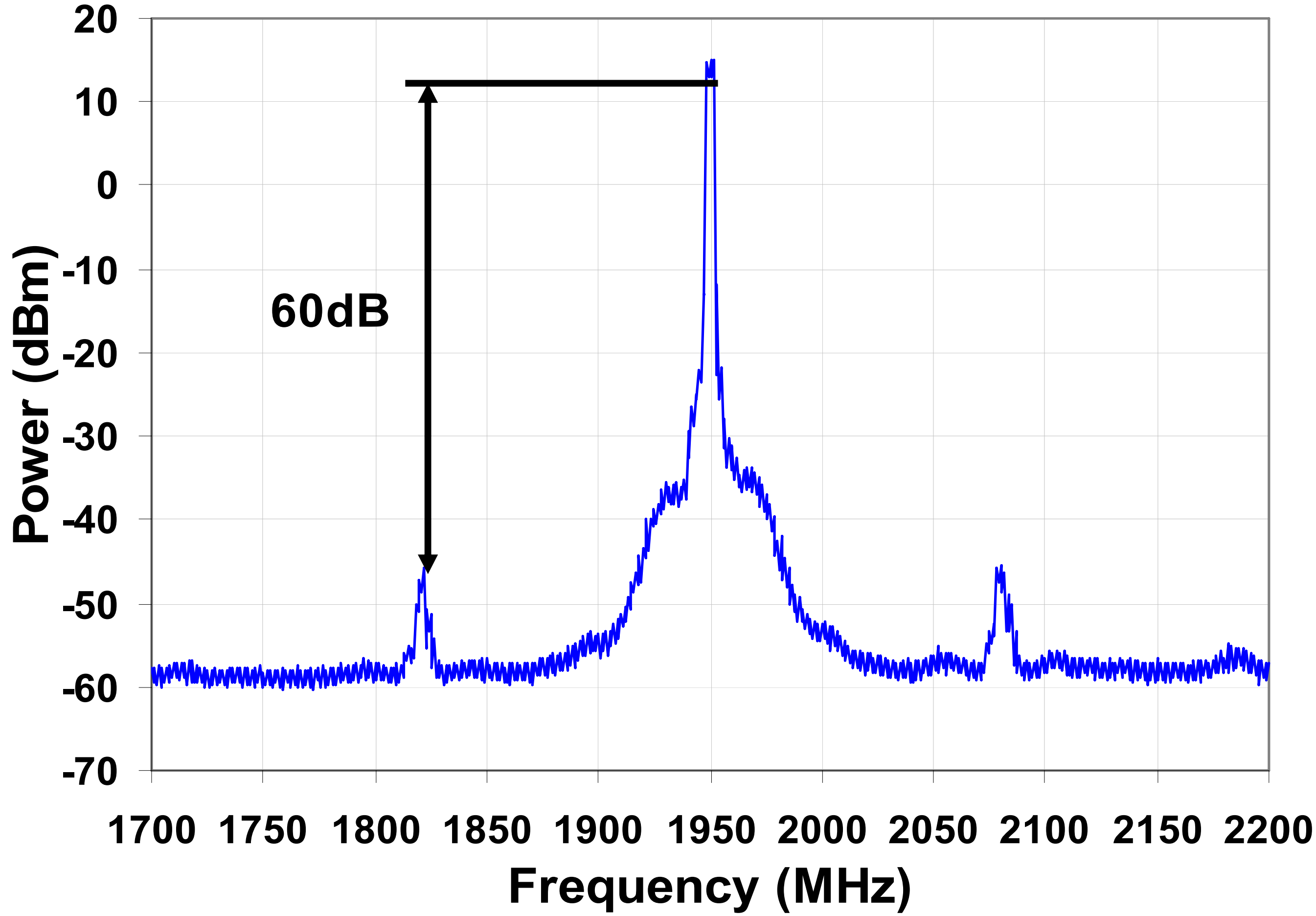
From Analog …	… to SMPS specification
Signal AC BW	Switching frequency
Large signal rate	Output filter cutoff freq.
Linearity	large BW close loop control
Spurious & Noise	Fixed freq, output filter mask
Stability	Load modeling
Low Z_out over full BW	Low Z_in over full BW

SMPS accuracy : WCDMA envelope tracking



Symbol rate : 3.84MHz
Peak output power : 2.2W
V battery : 3.6V
PAPR : 3.5dB

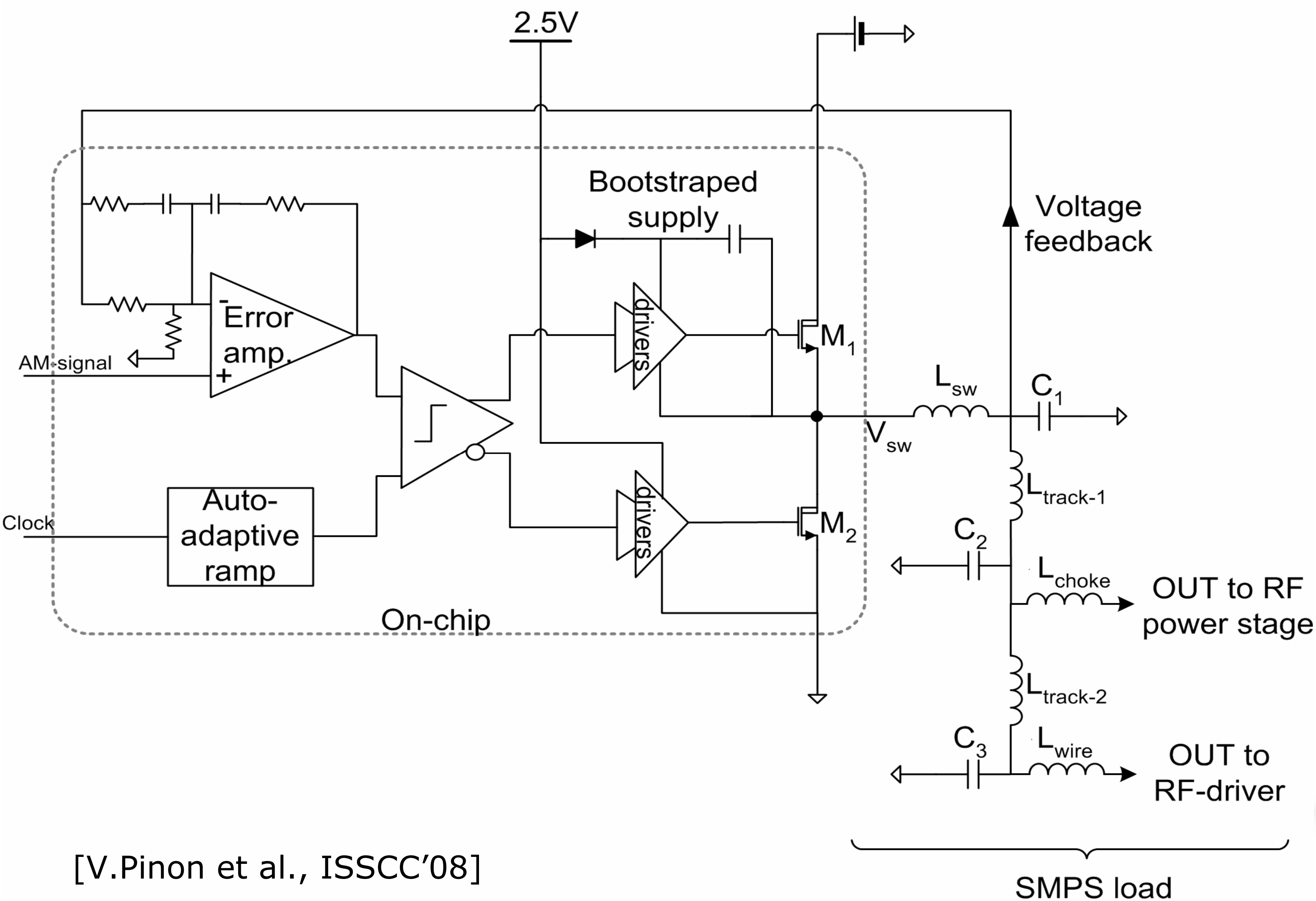
Spurs filtering



Convergent technology requirements

- RF PA
  - driver stage : high-voltage bipolar (high Gm)
  - output stage : NLDEMOS (gain @ large I, high voltage tolerance, no thermal runaway, efficiency)
- SMPS
  - Power switches : NLDEMOS (low Ron, low Cgate)
  - Controller : bipolar (high Gm)
- Integration on a single chip!

Implementation example in ST BiCMOS 0.25

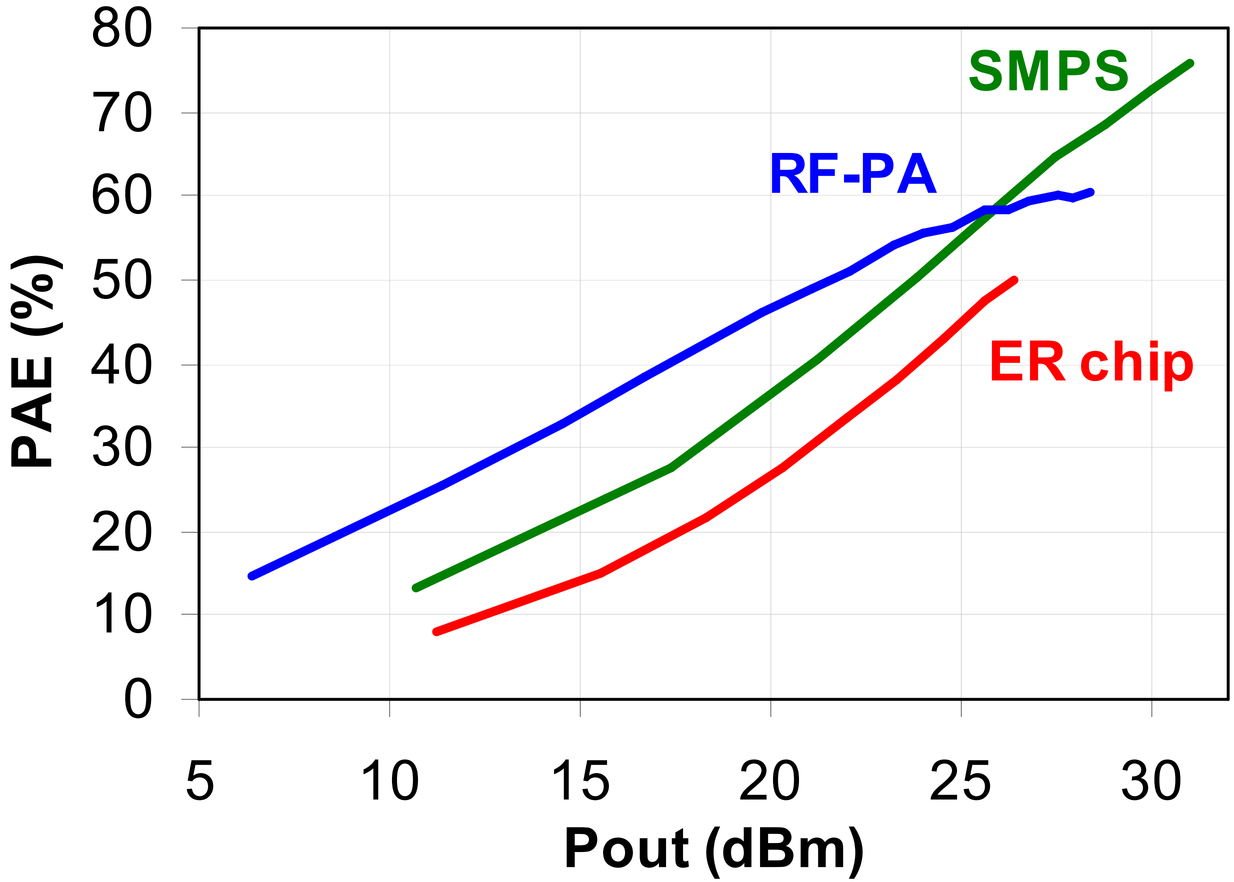


[V.Pinon et al., ISSCC'08]

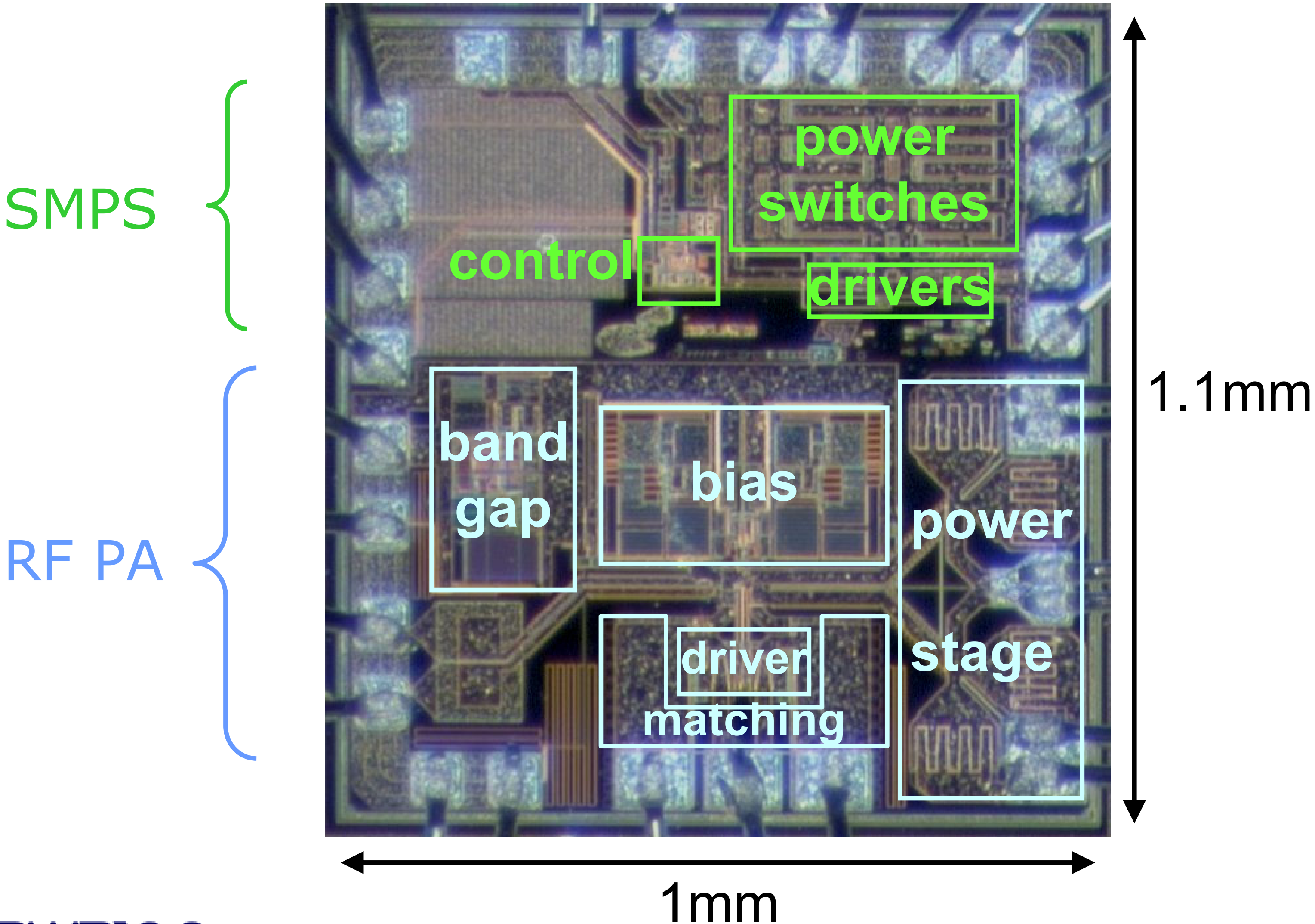
SMPS test results	
Max Out power @ 3.6V battery	2W
Peak efficiency @ 3.6V battery	83% @2W
AC BW	15MHz
Fs	130MHz
Area (with pads)	0.5 mm^2

1.95GHz WCDMA EER chip test results	
Chip efficiency	46% @ 27dBm RF out power
ACLR 1/2	-39/-47dBc
Peak switching noise	-60dBc
Battery range	2.9V – 4.3V
Chip area	1.1mm^2

Measured efficiencies vs. output power



ST BiCMOS 0.25 die



Outline

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Conclusion

- For DBB:
  - Integration in PMUs is difficult
    - High number of coils (5 to 6)
    - High current / High Power dissipation
    - Process and Package versus high frequency

- Possible solution with new partitioning
  - Solve passive components congestion
  - Solve power dissipation issue
  - Is it cost competitive ? (multiple packages)

- Analog solution still the most cost effective?

Conclusion

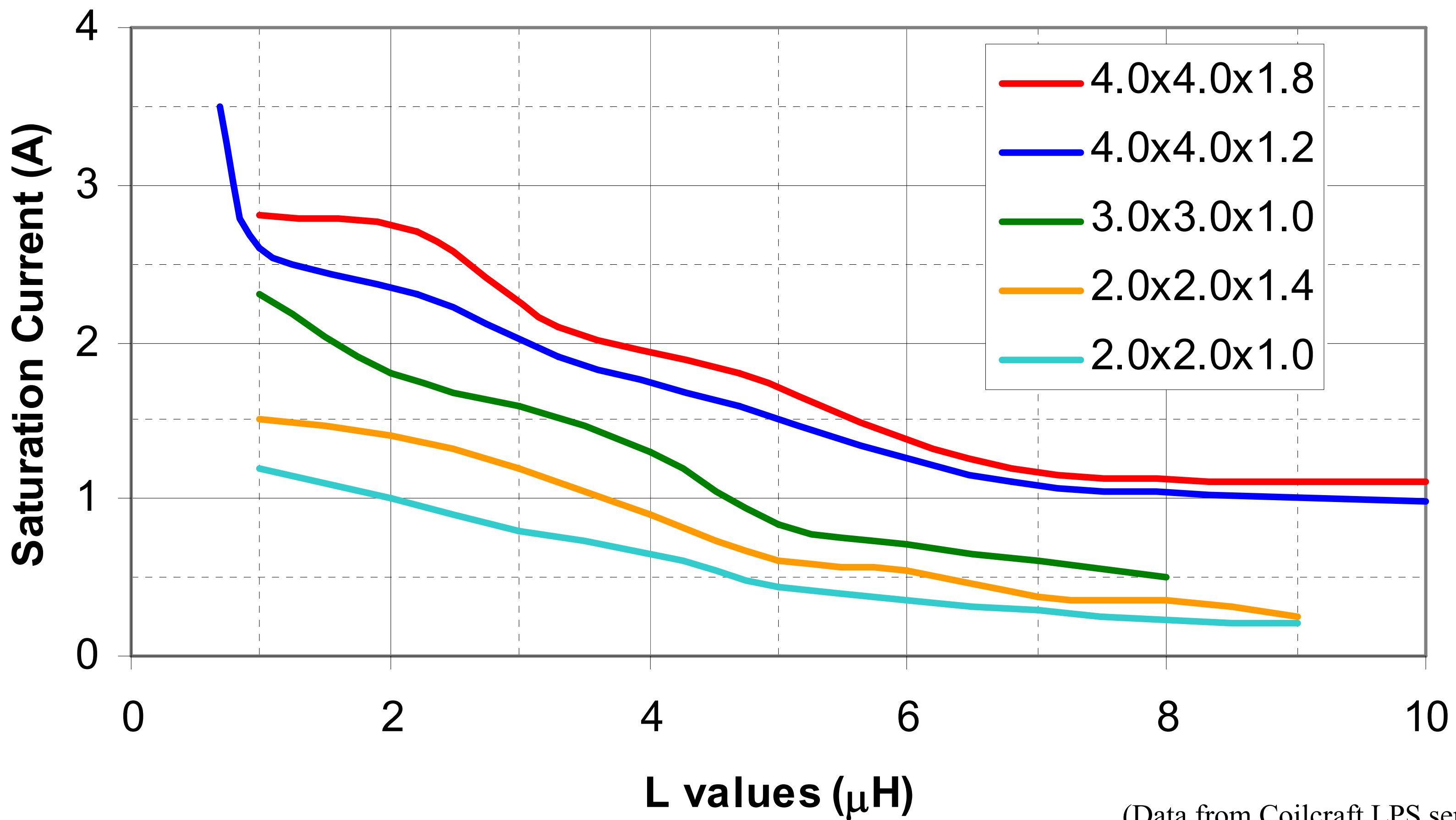
- For Audio and Low Power RF:
  - Good Candidates for integration
    - Can be outside of PMUs
    - Less Ios than PMUs = WLCSP
    - 1 to 2 coils required
    - Medium current (200mA)
    - Do not require very high frequency

- Mixed mode architecture for time to market

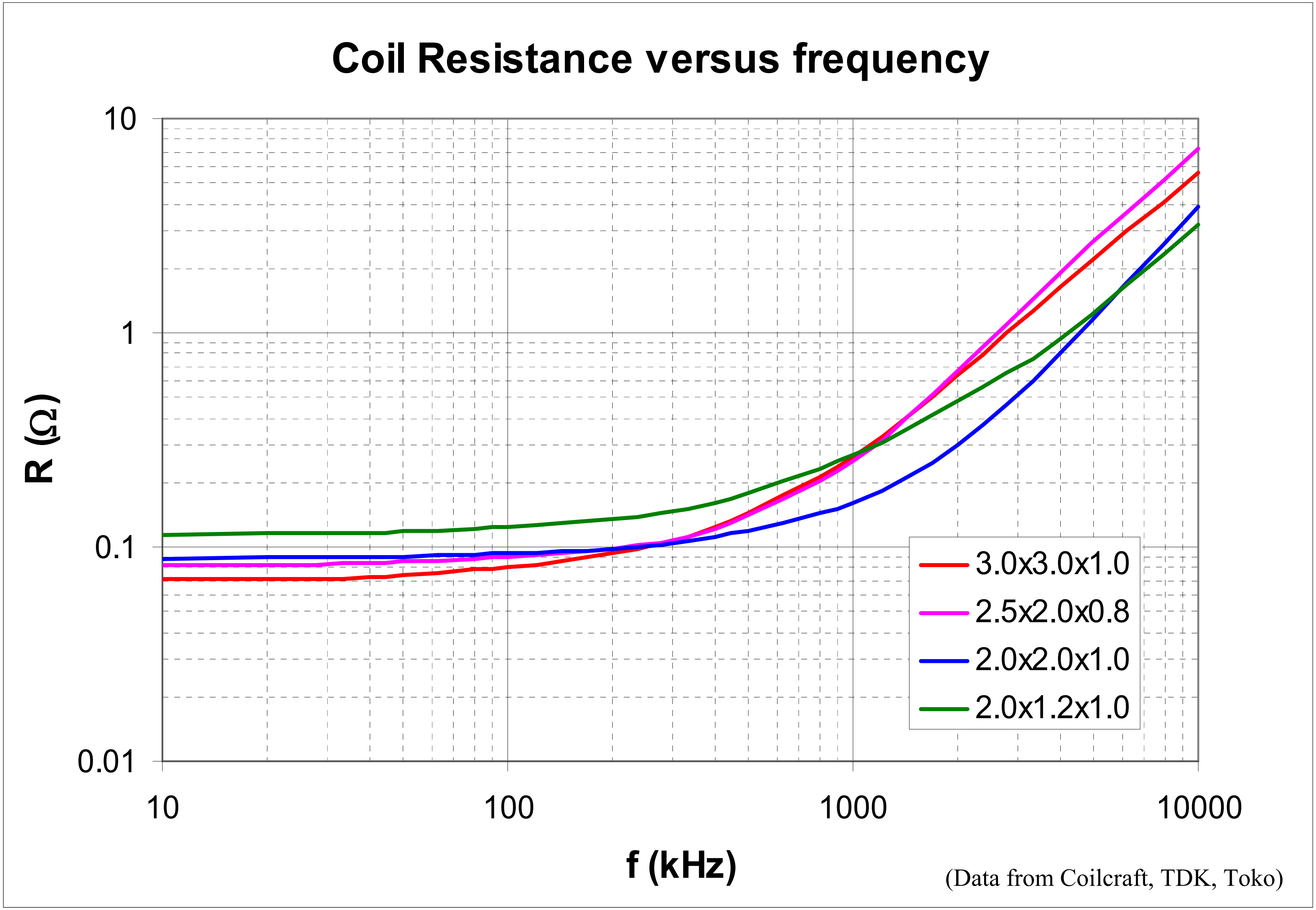
Conclusion

- For RF PA
  - A real need for high frequency SMPS
    - Saves a lot of power in a EER system
    - Saves coil area on PCB…
    - … and goes towards full integration
  - SMPS + PA common integration
    - SMPS and RF PA technology requirements are totally compatible
    - Gives a new degree of freedom for platform partitioning

Saturation Current versus Coil Values



(Data from Coilcraft LPS series)


Coil Resistance versus frequency
10
1
0.1
0.01
R (Ω)
10
100
1000
10000
f (kHz)
3.0x3.0x1.0
2.5x2.0x0.8
2.0x2.0x1.0
2.0x1.2x1.0
(Data from Coilcraft, TDK, Toko)