The Future View from RF Perspective

Zdravko Boos
Intel European Research & Innovation Conference
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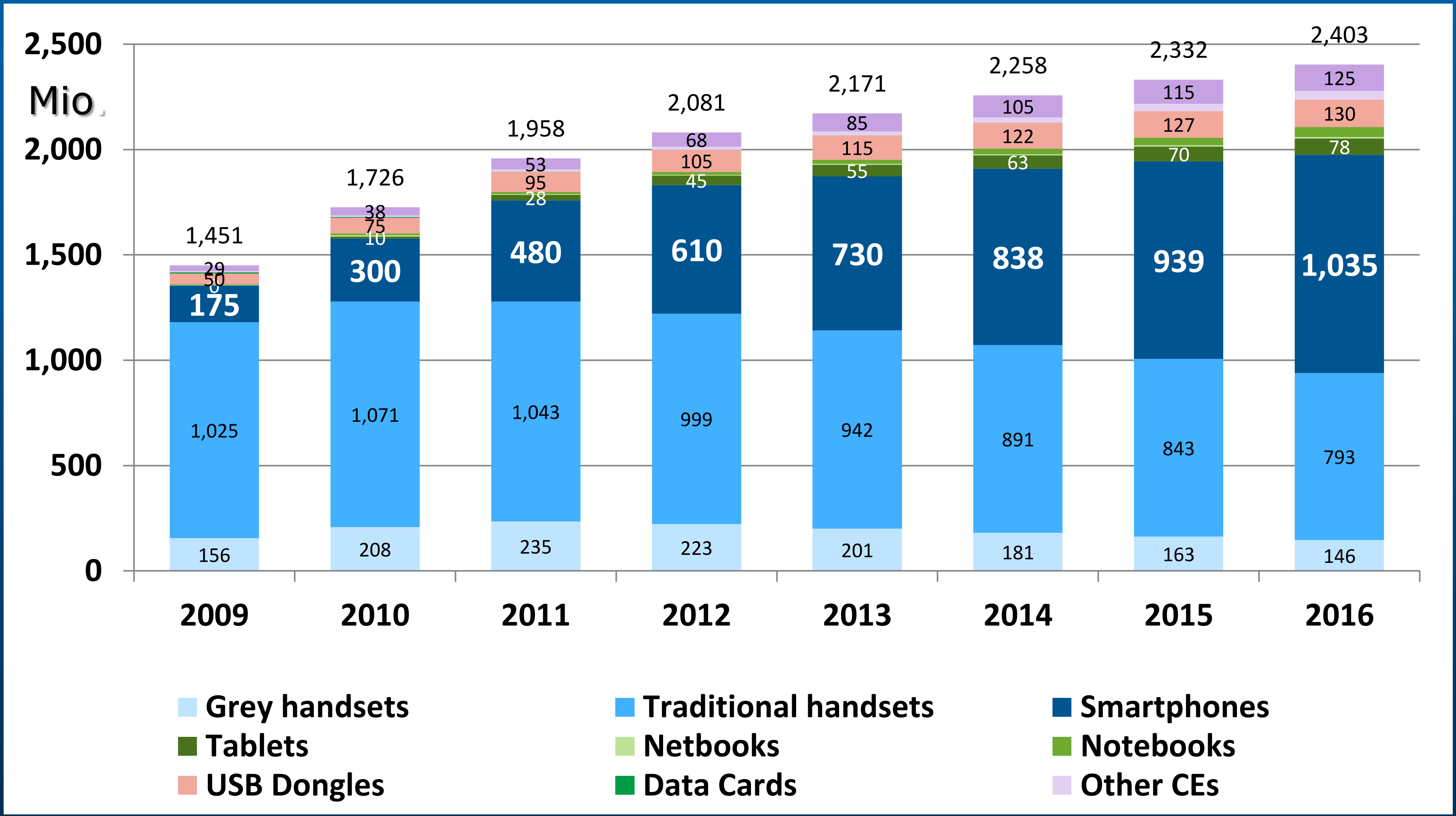
Outline:

- RF Challenges
- 2G/3G/4G Solutions
- 5G requirements
- Future View

Total Cellular Device Market by Application



RF Challenges

- Multiple RATs (2G, 3G, 4G, BT, GNSS, WiFi…)
- Frequency bands (4 in 2G, -> 40 in 4G, ? 5G)
- Carrier aggregation (DL, UL, inter/intra, ….)
- MIMO (2x2 -> 8x8)
- Power consumption (< 40 mA in UMTS 0 dBm)
- Chip area (cost)
- PCB area (cost)
- Component height
- Number of antennas

RF Transceiver Requirements

How to come there?

Moore`s Law of Multiradio Integration: The SMARTi TRX Evolution

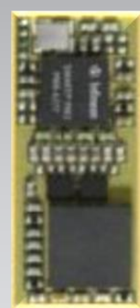
2000

- SMARTi+

- 650mm² PCB Area
- Single Mode
- 3 Band GSM/GPRS
- 0.35µm BiCMOS

2005

- SMARTi PM2



- 200mm² PCB Area
- Dual Mode
- 4 Band GSM/EDGE
- 130nm CMOS

2008

- SMARTi 3GE

- 550mm² PCB Area
- Triple Mode
- 4 Band GSM/EDGE
- 3 Band UMTS/HSPDA
- 130nm CMOS

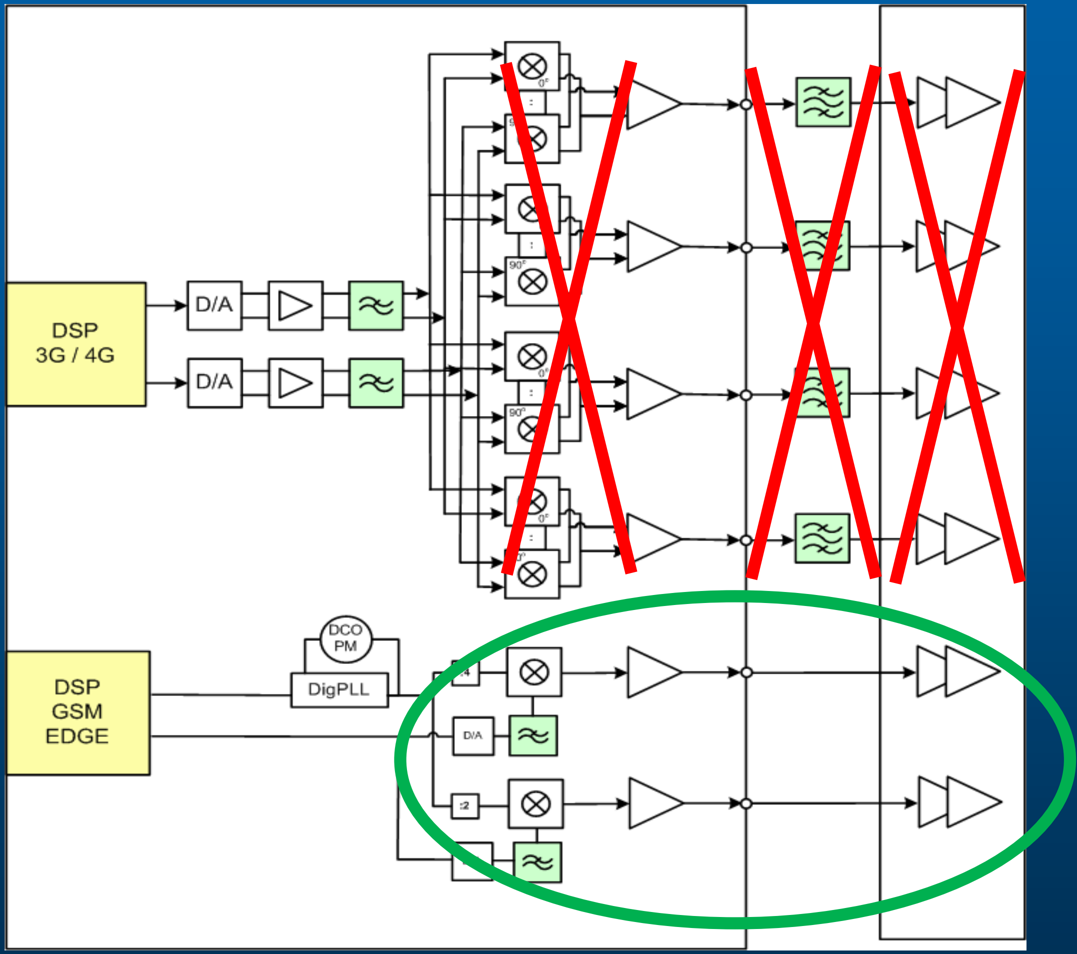
2011

- SMARTi UE2

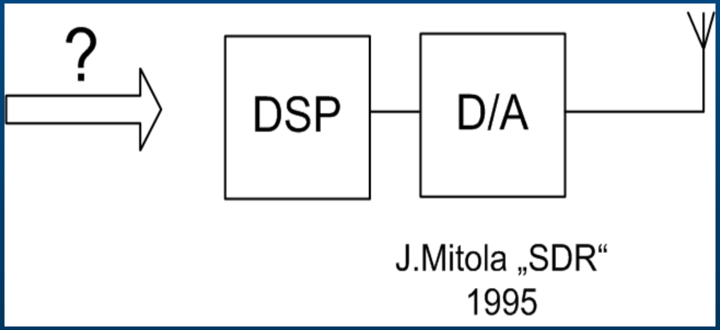
- 280mm² PCB Area
- Triple Mode
- 4 Band GSM/EDGE
- 5 Band UMTS/HSPA+
- RX Diversity
- 65nm CMOS

Triplication of # of bands and # of modes in a decade @ 1/3 of the space

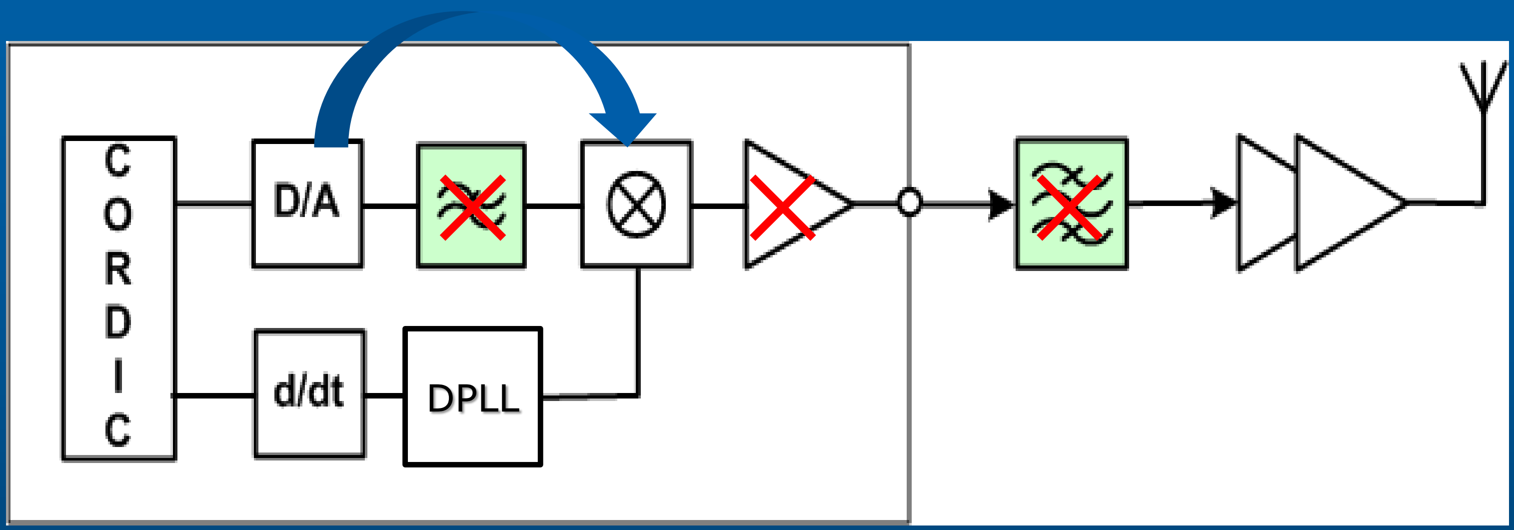
Block Diagram of the Analog Multimode Multiband Transmitter



Supported modes:
- GSM
- EDGE
- EDGEEvo
- WCDMA
- HSPA+
- LTE…



TX concept evolution from Analog to Digital

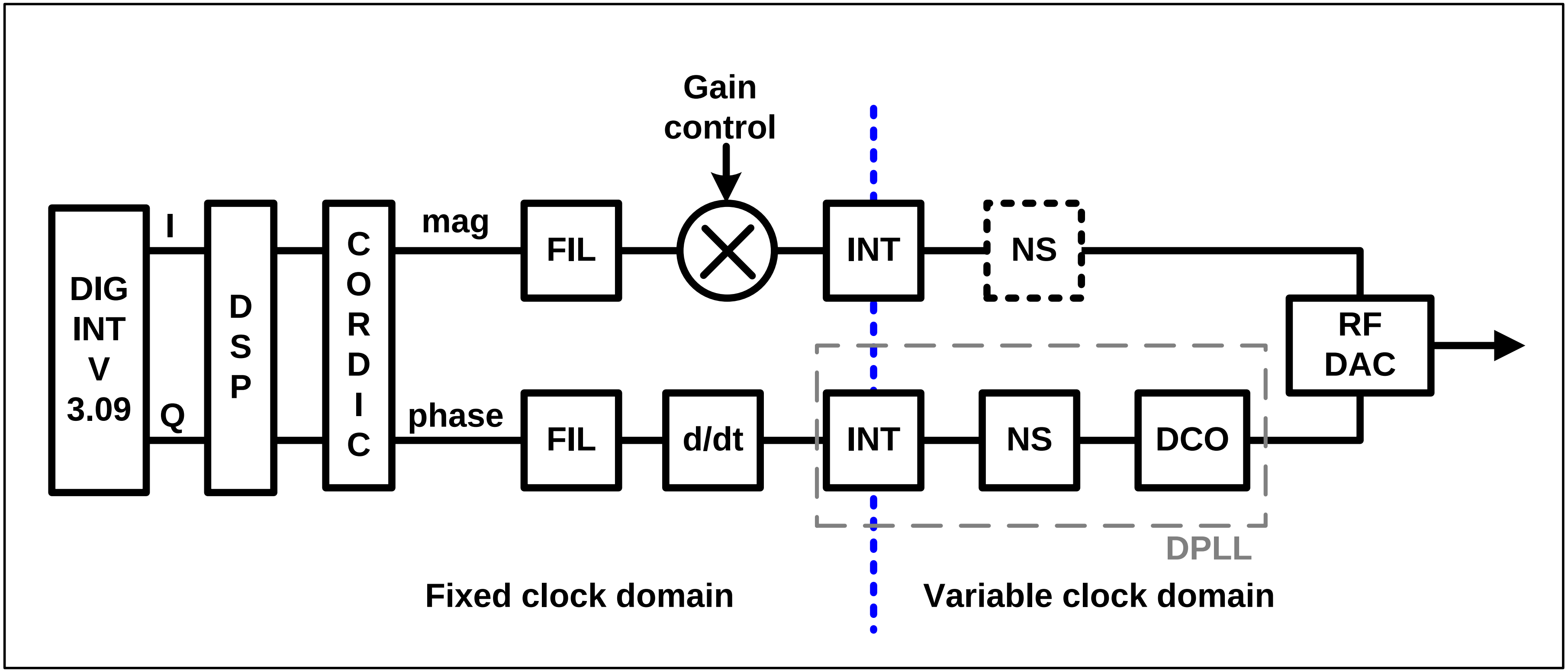


- Reconstruction filter removed
- D/A combined with mixer
- PA driver removed
- APLL replaced with DPLL
- External TX SAW omitted

=> 17b RFDAC requirement

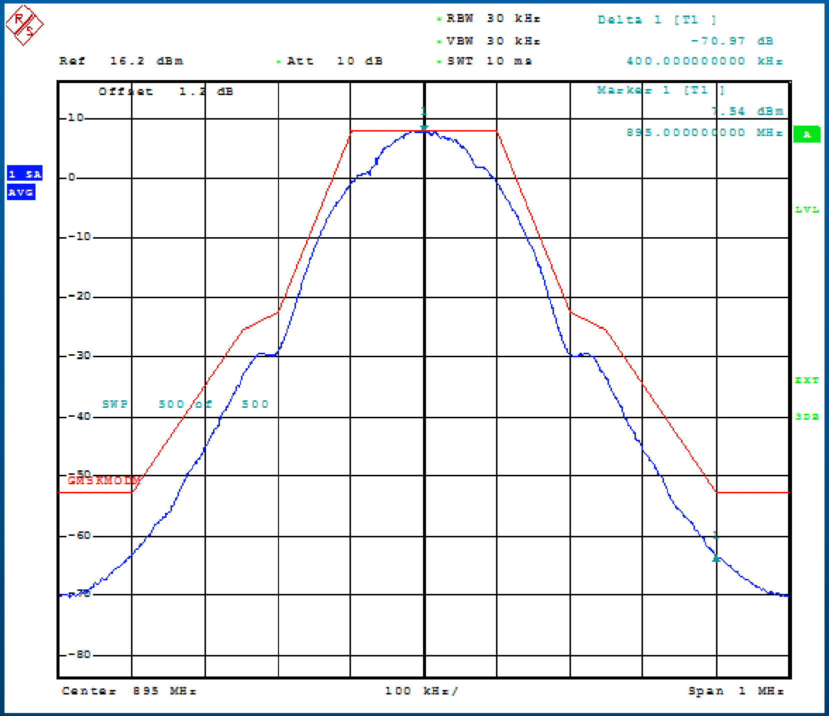
(as in audio but at 100000 times higher freq.)

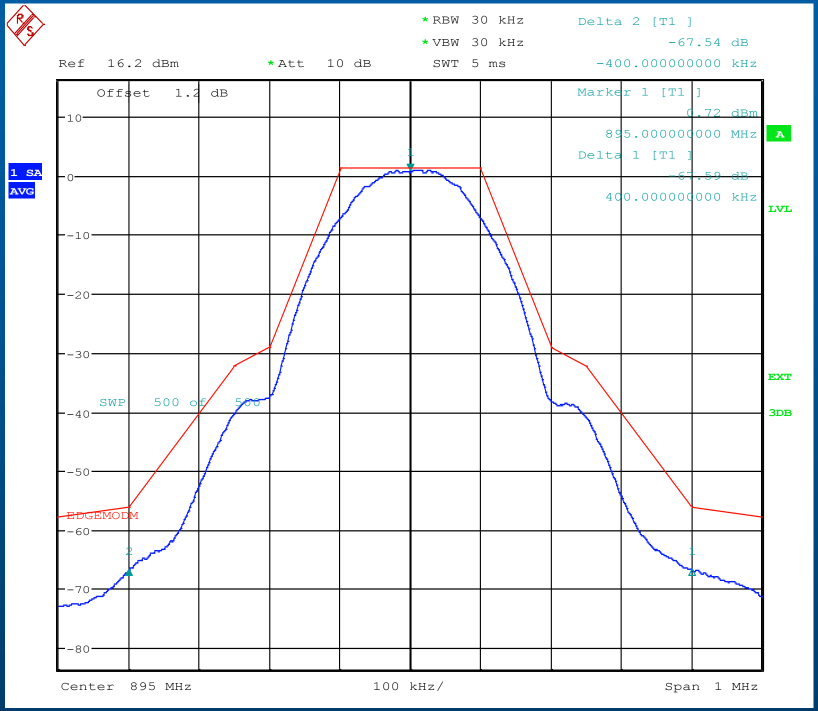
Digital Transmitter Block Diagram



For an highly competitive digital cellular transmitter 65 nm was a breakeven technology

Measurement results
Modulations masks GSM, EDGE @ 895MHz

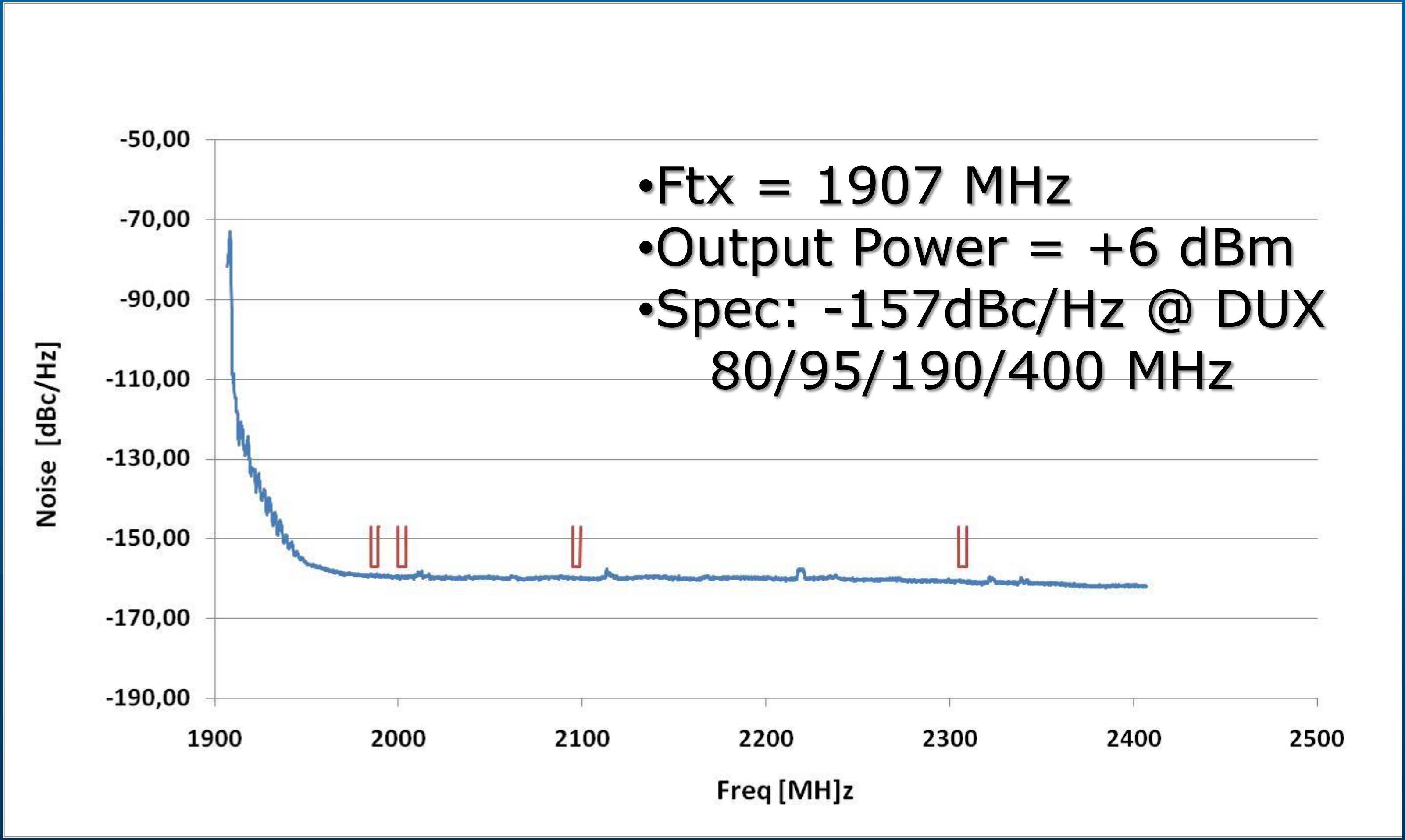




GSM
Power = +15,5dBm
Phase Error = 0,8°
Noise in GPS Band
= -180 dBc/Hz

EDGE (without pre-distortion)
Power = +8,5dBm
EVM = 1,46%
Noise in GPS Band
= -166dBc/Hz

Measured TX far off noise in High Band / WCDMA



A fully digital solution free of spurious

Intel Is Leading In RF CMOS Integration
CMOS RF SoC With Integrated 3G PAs

XMM™ 6255 w/ SMARTi™ UE2p
World smallest 3G modem

260mm²

- M2M
- Internet of Things
- Entry Smartphones

ES available
Ramp Up E 2013

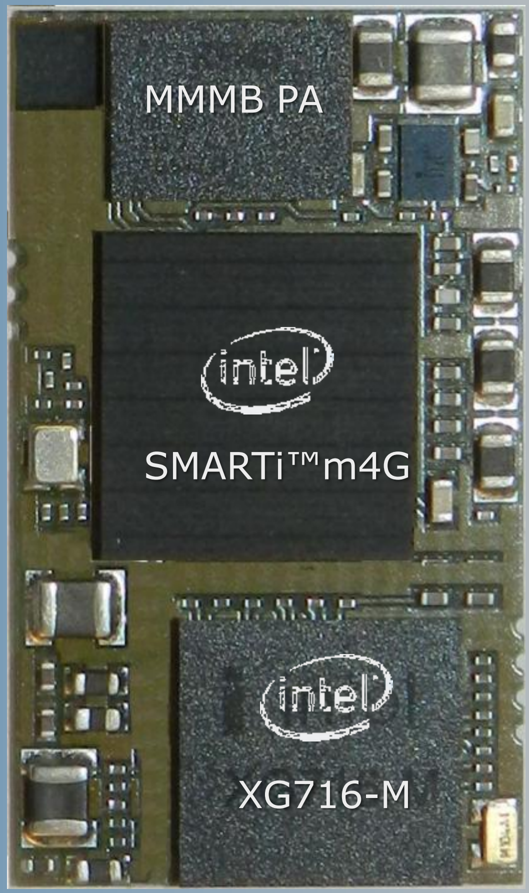
The World's Smallest LTE Solution In 2013

XMM™ 7161 Multi-Mode Multi-Band LTE Modem

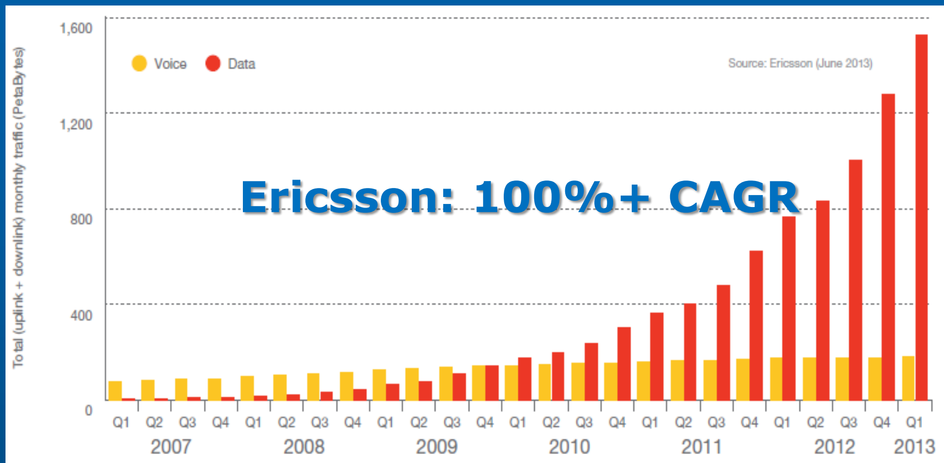
World‘s smallest LTE Solution
- PCB area <400mm²

SMARTi™ m4G RF Module
- Including RF Transceiver, Filters, Duplexer, Coupler and Antenna Switches

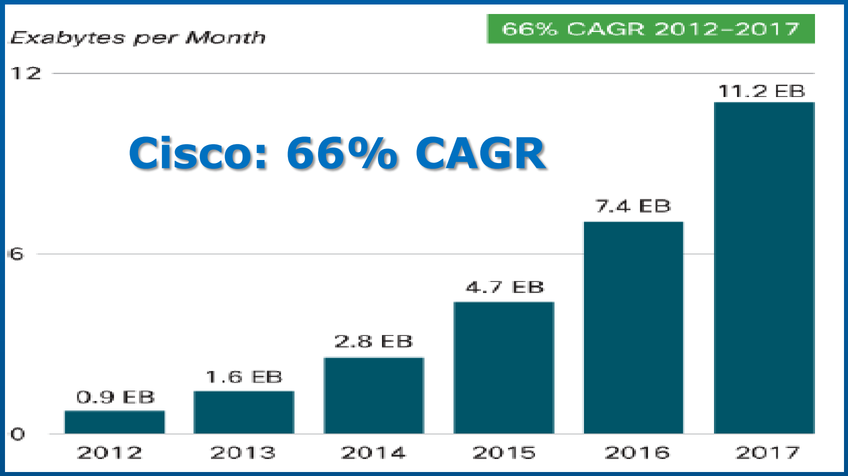
7 x 5mm Multi-Mode-Multi-Band PA



Towards 5G: Mobile Data Traffic Growth



Ericsson Mobility Report, June 2013
Excludes WiFi, VoIP, MTC



Cisco Visual Networking Index, Feb.`13

- **System Capacity Requirements**
  - Network traffic load increasing by **65-100% CAGR**
  - Requires up to **2x increase** in network capacity per annum
  - > 100 higher traffic until 5G introduction in 2020

Note 1: Assumes 85% CAGR in traffic.

Trends in Spectrum Availability

Example: Emerging U.S. Auctions

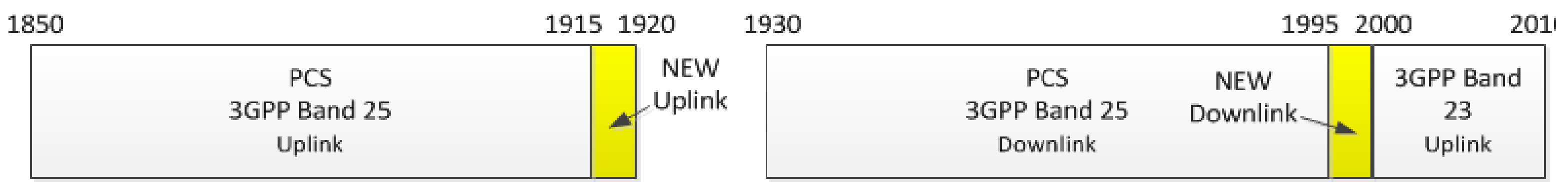
AWS Extension#1
2x15MHz

1. Most likely downlink – opposed by NAB.

Limitations: Limited number (18) of exclusion zones
Likely Date of Auction: Q4-2014
Likely Bidders: T-Mobile, Verizon, AT&T

AWS Extension#2
2x15MHz

Limitations: Limited number (18) of exclusion zones
Likely Date of Auction: Q4-2014
Likely Bidders: T-Mobile



Limitations: None
Likely Date of Auction: Q4-2013
Likely Bidders: Sprint, Dish Networks

PCS Extension ('H')
2x5MHz

U.S. 3.5GHz Spectrum Access System (SAS)

Managed Spectrum Sharing

- U.S. Strategic National Objectives
  - #1 – Release new spectrum potentially with new licensing regime
  - #2 – Deploy high-capacity technologies – including small cell
- FCC Proposal – **Citizens Broadband Service** (CBS)

Band Status	Band	Bandwidth
Proposed	3350-3650 MHz	100 MHz
Potential	3650-3700 MHz	50 MHz

intel

mm-Wave Frequency Allocations

International 60GHz plus U.S. LMDS Bands

BTA[1] License	Band (GHz)	BW (MHz)	BW (GHz)
A	27.5–28.35	850	1.150
	29.1–29.25	150	
	31.075–31.225	150	
B	31.0–31.075	75	150
	31.225–31.3	75	

U.S. Allocations 28-31GHz LMDS Fixed Point-Point Service

Band (GHz)	BW (GHz)	Jurisdiction	Licensing
57-64	7.0	USA	Unlicensed
57-64	7.0	Canada	Unlicensed
59-66	7.0	Japan	Unlicensed
57-64	7.0	S. Korea	Unlicensed
57-66	9.0	Europe	Unlicensed

International 60GHz Allocations

Band (GHz)	BW (GHz)	Licensing
71-76	5.0	1. **Licensing**: database registration, non exclusive. 2. **Allocation**: 1.25GHz aggregable blocks 3. **Services**: point-point fixed services.
81-86	5.0	
92-94	2.0	
94.1-95	0.9	
57-66	9.0	

U.S. Allocations 70-80-90GHz Bands

Band (GHz)	Structure
38.6-40	14 x 50MHz Pairs (100MHz Total)

U.S. Allocations 39GHz Fixed Point-Point Service

Note 1: BTA – Basic Trading Area

mm-Wave System Design

Historical Perspective

1993

5 Conclusions

Future mobile radio systems must use ever higher radio frequencies as spectral congestion effectively removes lower frequencies from availability. Future broadband mobile services (eg MBS) will use mm-wave frequencies and utilise a microcellular architecture. The limitations of fibre/radio for these applications are outlined and a novel solution, based on optical heterodyning, is proposed in this paper. A RACE funded research programme is investigating this approach and this paper describes the demonstrator that will be built. Applications for MODAL type systems are discussed and some of the most significant results achieved to date are summarised.

In summary, this paper has outlined a novel solution to the problem of providing a connection between a base station and a remote antenna for a mobile access system operating at mm-wave frequencies. Optical technology has been adopted to remove the need for mm-wave signal sources whilst optical fibre is used to interconnect the base station and the antenna thereby ensuring both low installation and maintenance costs.

J.J. O'Reilly, et al, "MODAL: an Enabling Technology for Wireless Access", 1993. 4th-IEE Conf. Telecomm.

1995

EVOLUTIONARY PATHS IN PCN

<u>3rd Framework Research - RACE and ESPRIT</u>

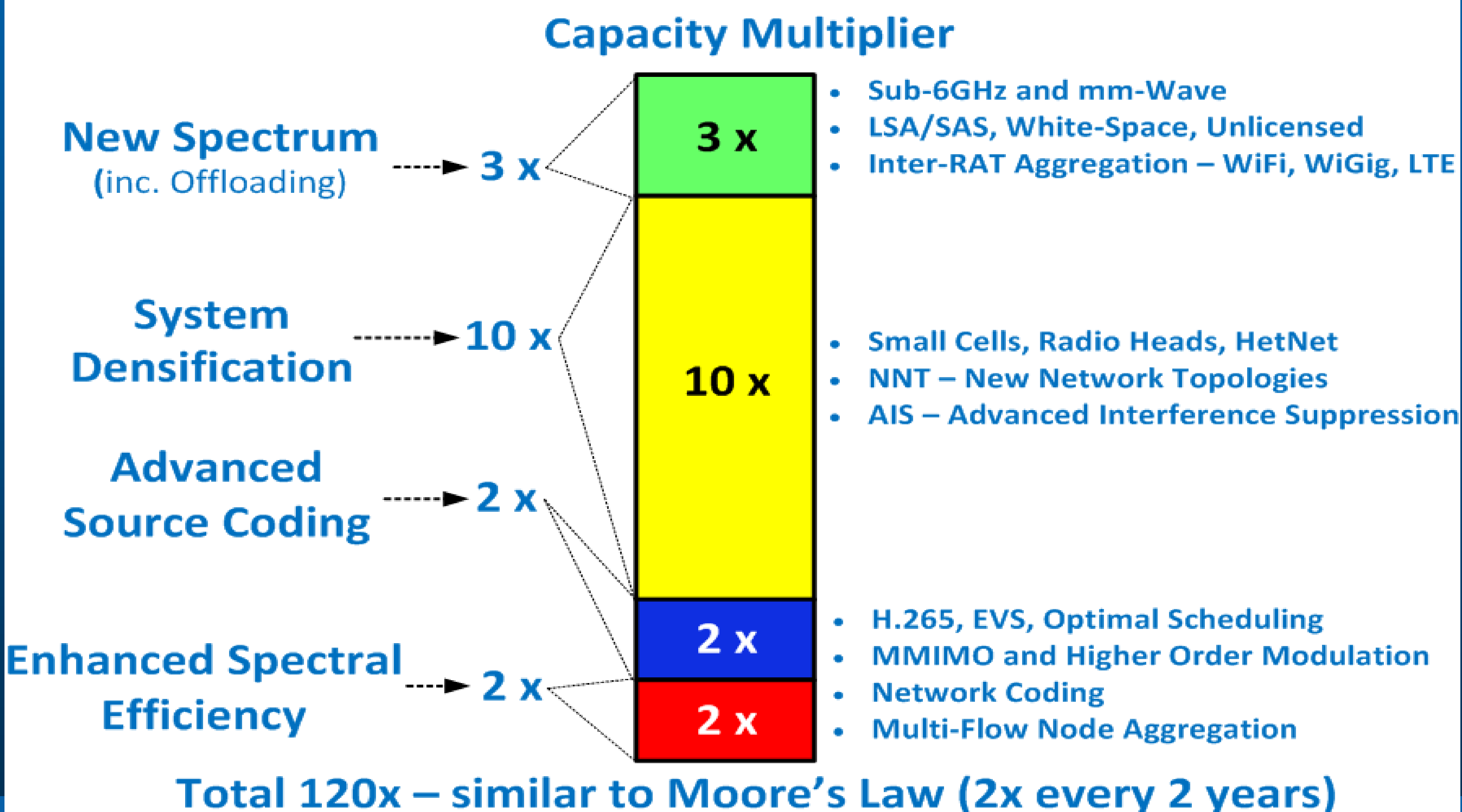
CODIT - exploring the potential of code-division multiple access for UMTS, and considering such issues as radio interface parameters, fast and soft handover etc;

ATDMA - the time-division multiple access equivalent of CODIT with emphasis on the concept of an adaptive terminal which can access different air-interfaces according to the local radio environment and required services;

MBS - targeting the frequency allocation for broadband wireless pico-cell networks in the 62-63GHz and 65-66GHz bands, and paying particular attention to low cost transceiver technology based on GaAs P-HEMT MMICs;

J. Gardiner, "Microwave and mm-WAVE Technology Requirements…European 4th-Framework…", Microwave Symp. Digest, 1995

Network Capacity Enhancement
Relative Contribution – 2013-2020

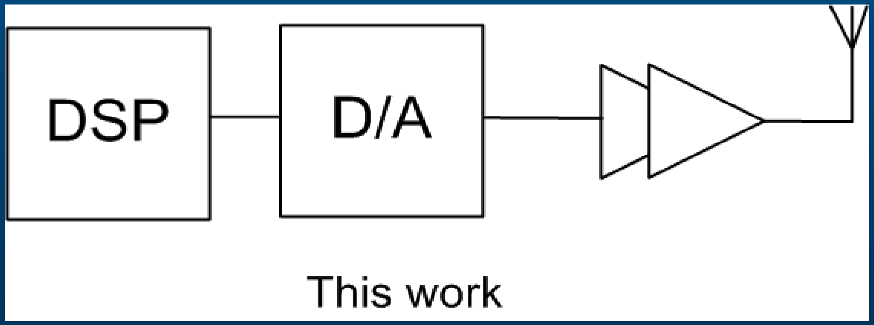


Hypothetical 5G Device – 2020

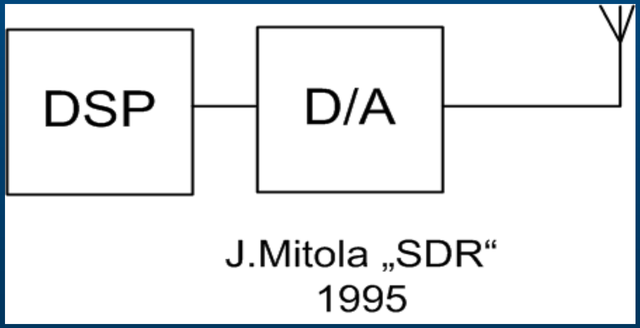
- **5G Era Devices – 2020**
  - Multi-RAT support including evolution of LTE and WiFi (WiGig)
  - Support for 1 or more possible "new" 5G RAT's
  - Flexible resource-aggregating "cellular" transceivers, accessing >150MHz with up to antenna 8 ports
  - New access to sub-6GHz spectrum and new aggregation modes

Summary

- Exponential mobile data traffic growth is a key driver for the 5th generation mobile networks
- Even with 5G definition just started it is clear that the best 3G/4G solution is prerequisite and enabler for the coming 5G mobile network



2G/3G/4G



5G