Challenges for SoC Integration of Multistandard-RF-Circuits

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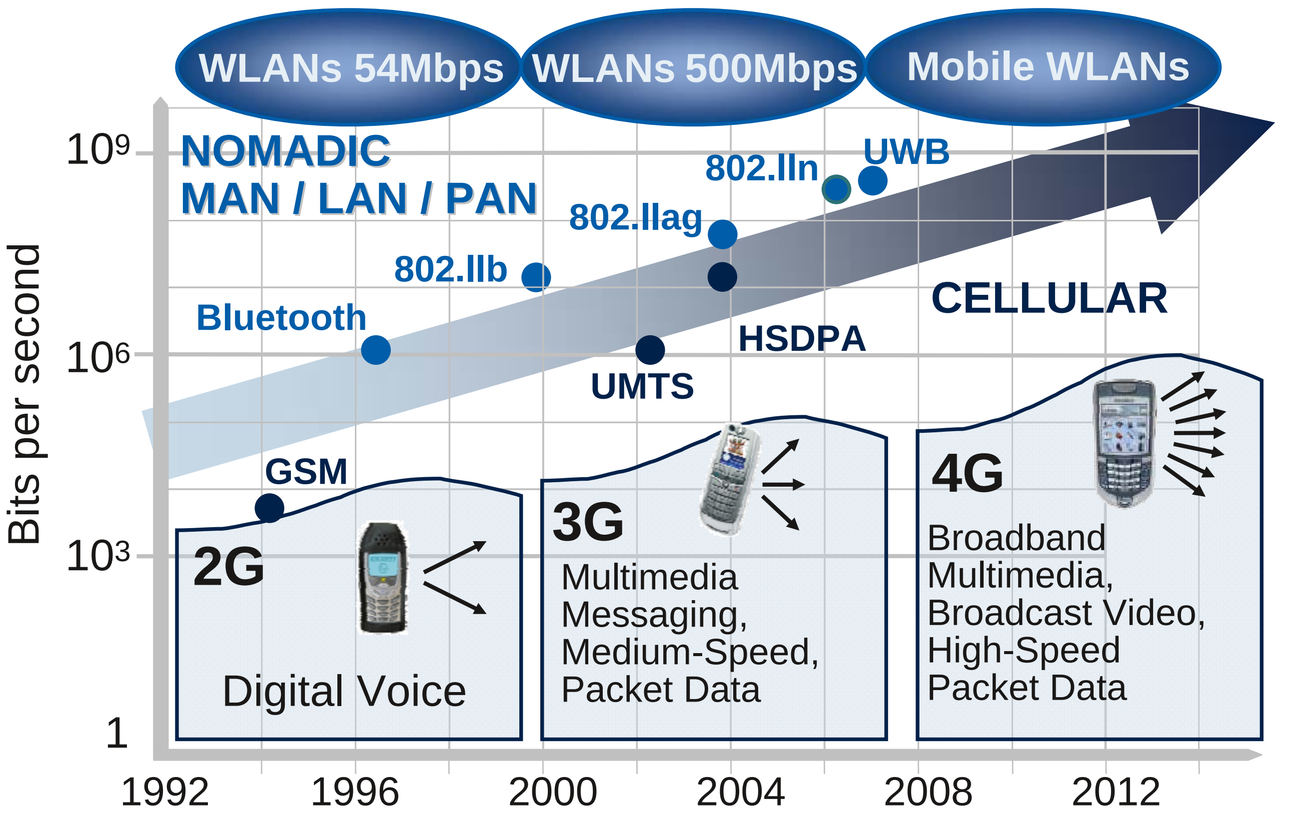
Never stop thinking

Outline

- **Introduction**
- Cellular RF SoC - State of the Art
- Multistandard RF Requirements
- Issues to solve
- Conclusions

The Wireless Evolution requires advanced RF-SoC Integration



Requirements Multimode Terminals

Standard		Uplink			Downlink		
3GPP/GSM	T-GSM 380	380	-	390	390	-	400
3GPP/GSM	T-GSM 410	410	-	420	420	-	430
3GPP/GSM	GSM 450	450	-	460	460	-	470
3GPP/GSM	GSM 480	479	-	486	489	-	496
3GPP	US	728	-	746	698	-	716
3GPP/GSM	GSM 750	747	-	762	777	-	792
3GPP	US	777	-	792	747	-	762
3GPP/GSM	Band XVIII	824	-	849	869	-	894
3GPP	Band XIX	830	-	840	875	-	885
3GPP/GSM	Band XX	880	-	915	925	-	960
3GPP	JP	1428	-	1448	1476	-	1496
3GPP/GSM	Band XXII	1710	-	1785	1805	-	1880
3GPP	Band XXIII	1710	-	1755	2110	-	2155
3GPP	Band XXIV	1750	-	1785	1845	-	1880
3GPP/GSM	Band XXV	1850	-	1910	1930	-	1990
3GPP	Band I	1920	-	1980	2110	-	2170
WiMAX		2300	-	2400	2300	-	2400
WiFi	ISM 2400	2400	-	2483	2400	-	2483
Bluetooth	ISM 2400	2400	-	2483	2400	-	2483
WiMAX		2496	-	2690	2496	-	2690
3GPP	Band I	2500	-	2570	2620	-	2690
WiMAX		3300	-	3800	3300	-	3800
WiFi	ISM 5800	5725	-	5875	5725	-	5875

Recommended:

- At least 3 UMTS bands
- At least 4 GSM bands

Optional:

- WiFi 2.4 (5.8)
- WiMax 2.3, 2.5 (3.4)

Parallel Operation:

- GSM/UMTS same receiver
- WiFi / WiMAX same receiver
- BT / BT ULP same receiver

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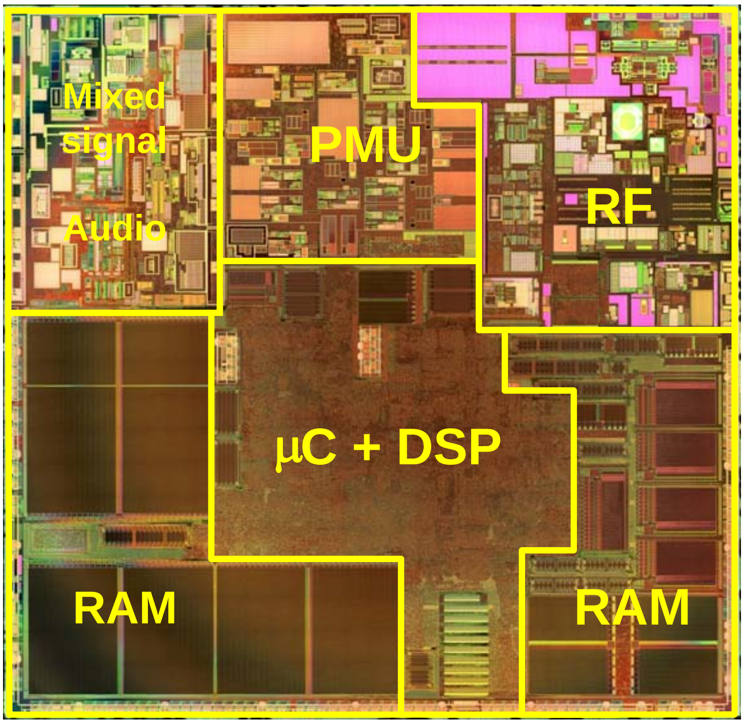
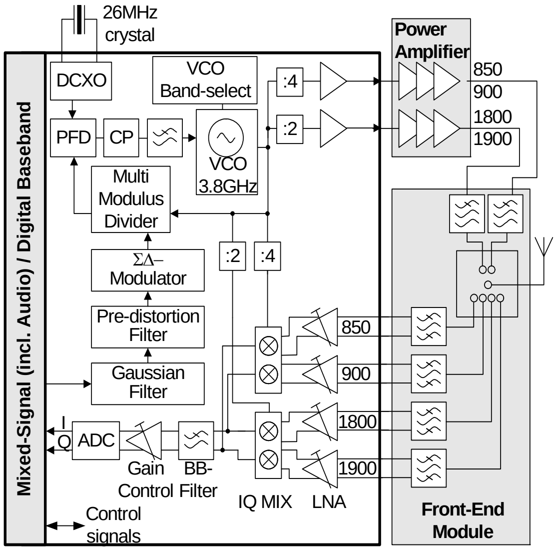
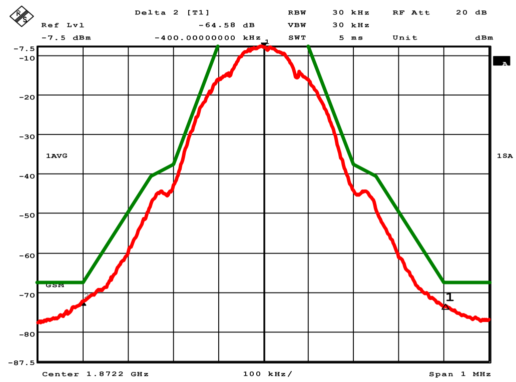
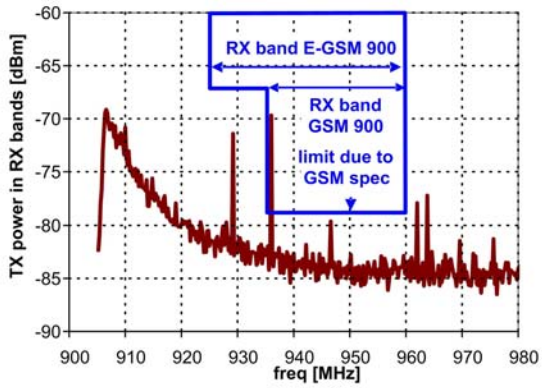
Infineon Ultra Low Cost Mobile



RF-SoC without Performance Loss







- Noise figure: 2.6dB
- Sensitivity: -113dBm

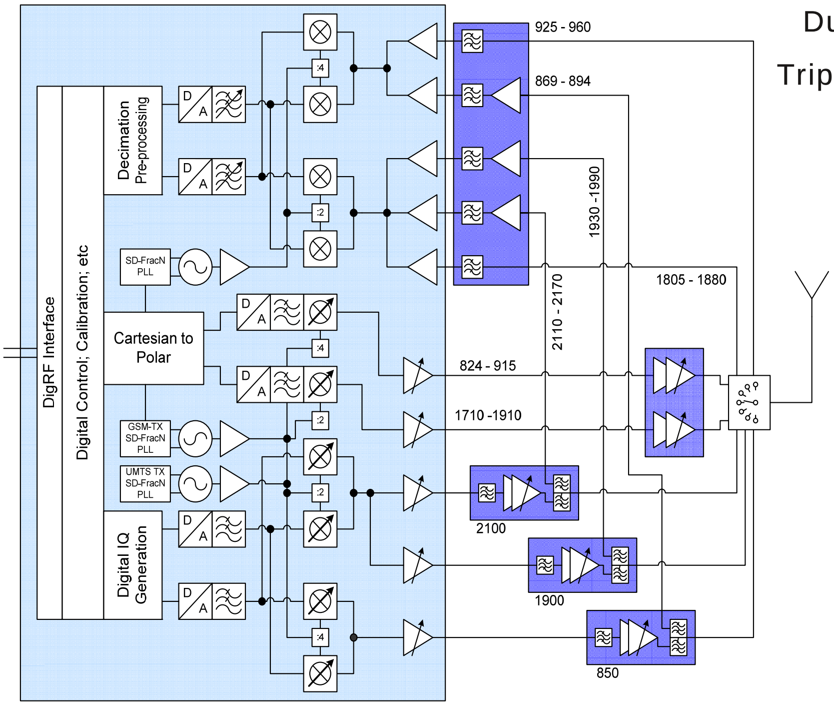
Multi Standard RF SoCs in nanoscale CMOS

- RF–BB co-integration enabling high volume
- Only linear shrink for RF and analog
- One CMOS technology for RF and Digital
- 65nm CMOS is state of the art today

Solution for nanoscale CMOS:

- **Increase Digital Signal Processing**
- **Avoid Analog Processing**

State of the Art UMTS/GSM Transceiver



Dual band GSM

Tripple band UMTS

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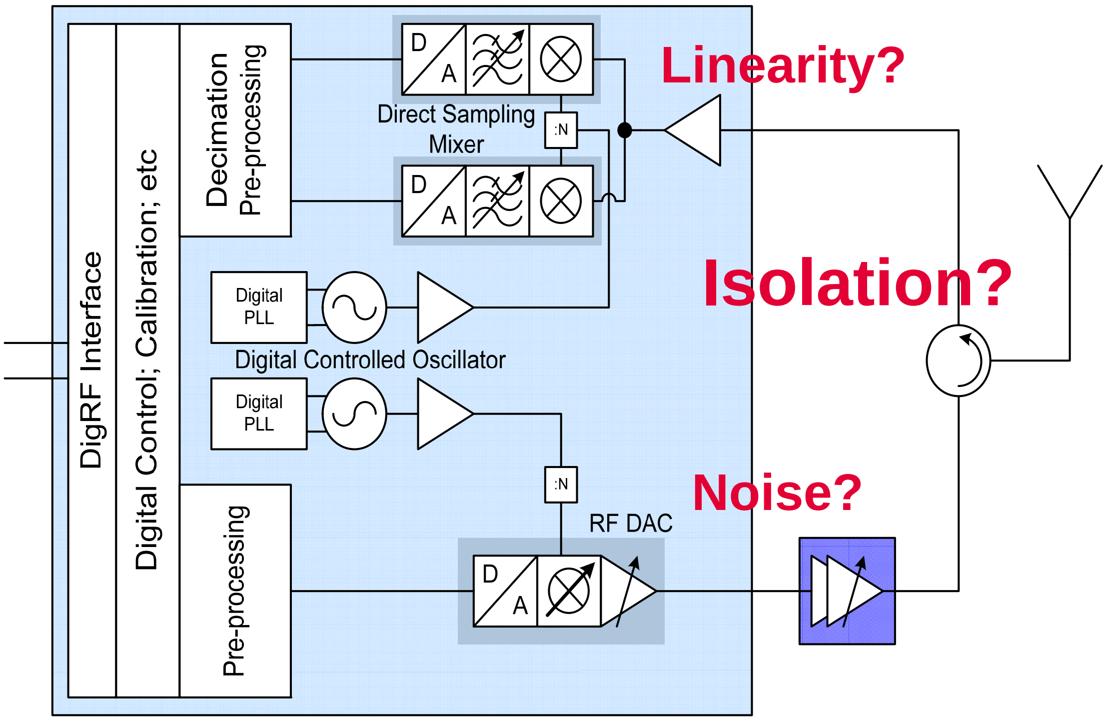
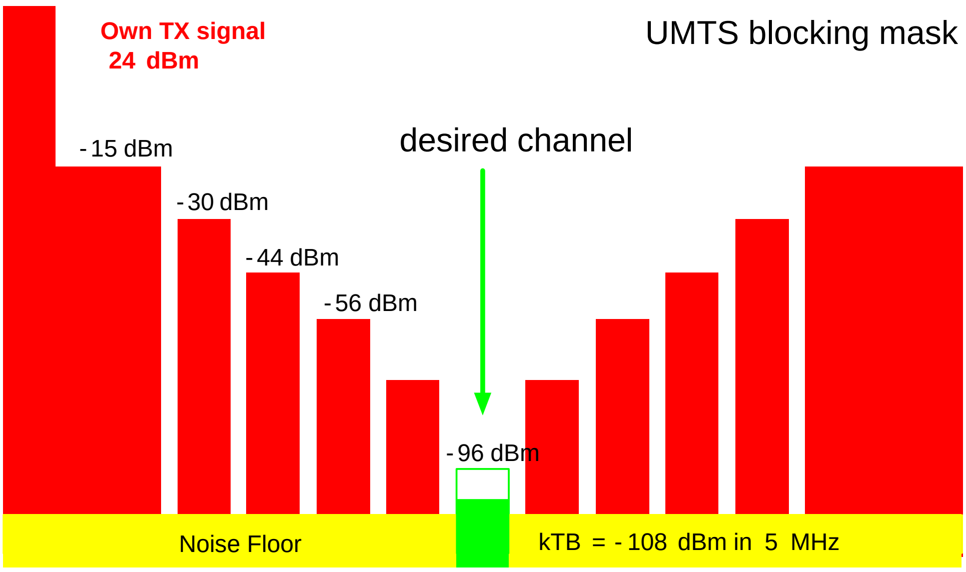
RF Transceiver for Software Defined Radio?

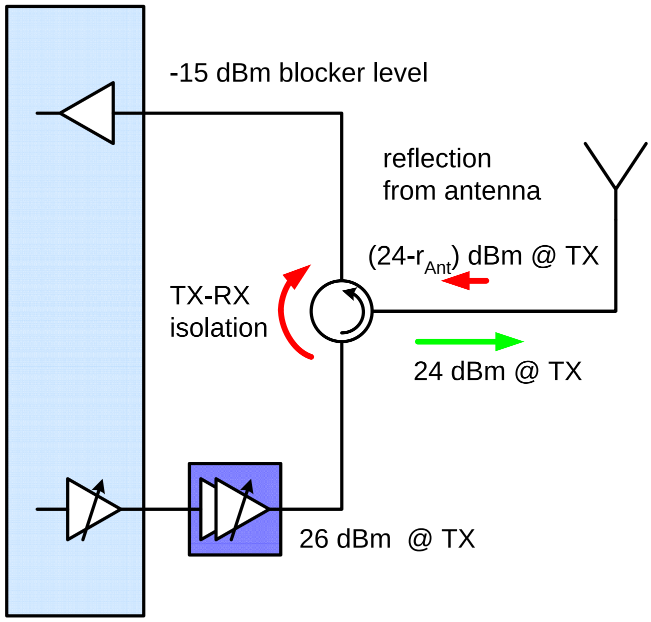


UMTS Interference - Blocking



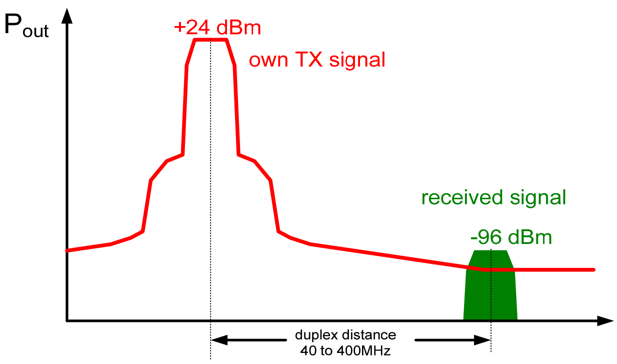
- 5th adjacent channel to be attenuated by about 90dB
- dynamic range distributed to analog filter and ADC
- TX signal is a real issue

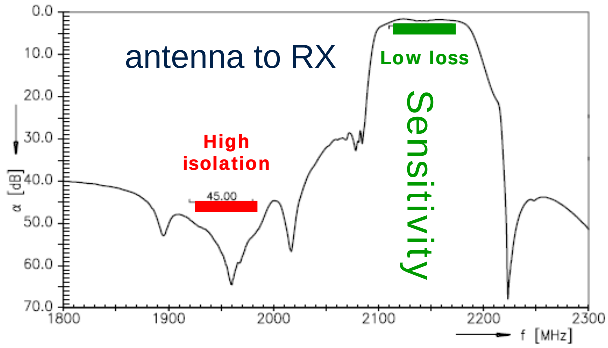
UMTS – TX leakage in FDD Systems

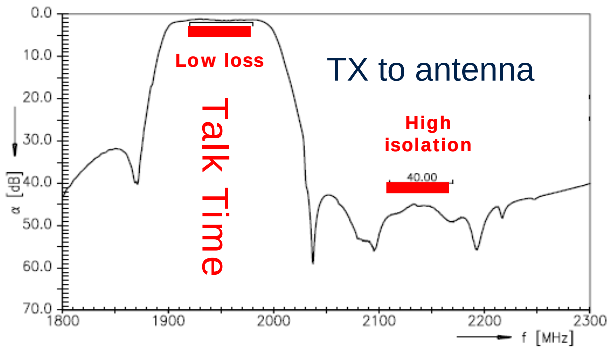


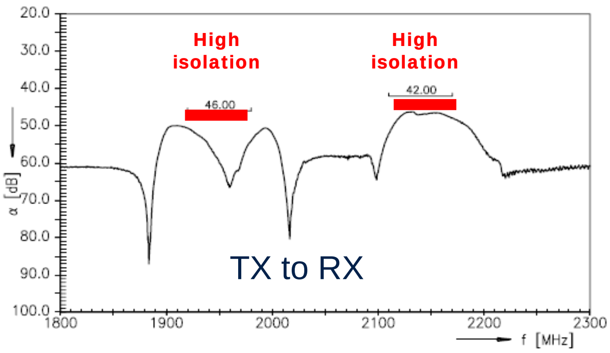
- Circulator has no selectivity
- RX-TX Isolation
  - At least 40dB
- Reflection from antenna
  - r_{Ant} above 40dB?
  - Antenna tuner?
- IP3 requirements?
  - Blocker and TX leakage are present at LNA

UMTS - FDD and Duplex Filter

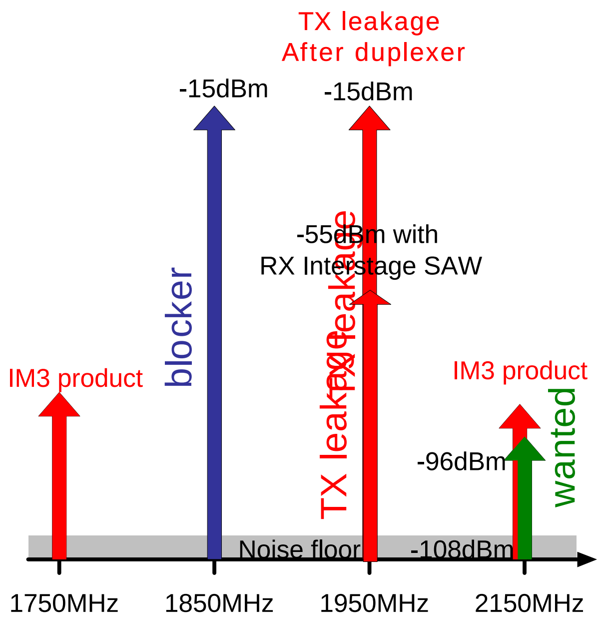






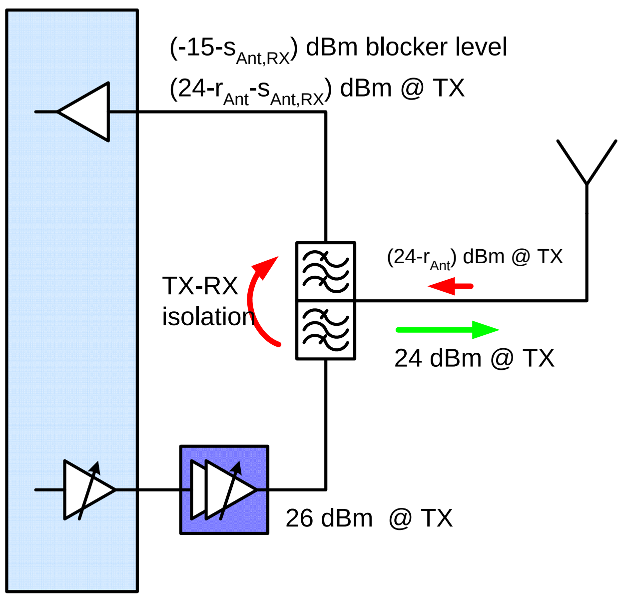


UMTS – IP3 & TX leakage in FDD Systems



- Blocker and TX leakage are present at LNA
- IM3 product 10dB below noise floor
- IIP3 of 36dBm feasible?
- Circulator not feasible
- Duplex filter required!

UMTS – IP3 & TX leakage in FDD Systems



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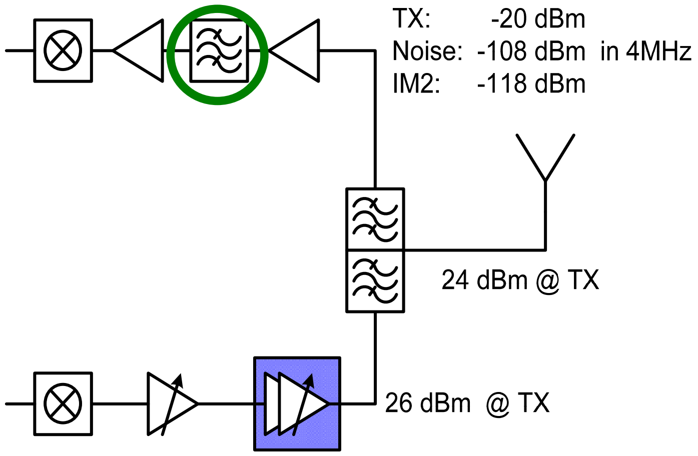
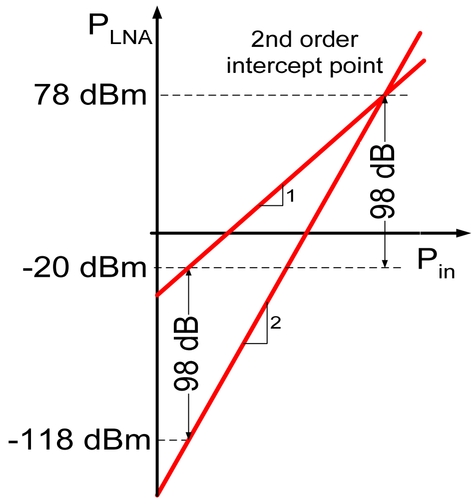
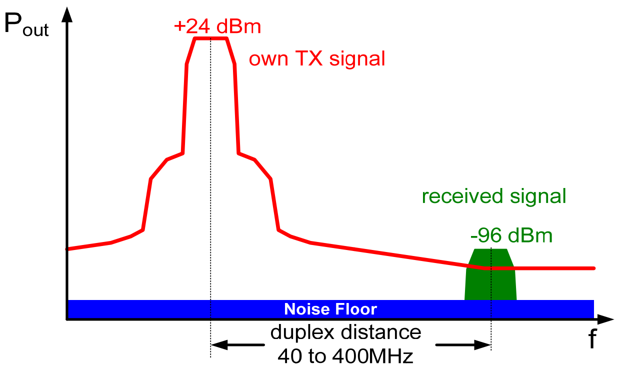
UMTS - FDD requires RX Interstage Filter

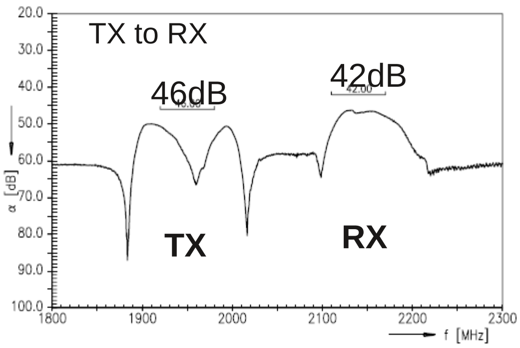




- 2nd order nonlinearity generates IM2 product at DC
- DC IM2 product has to 10dB below the noise floor referred to LNA
- RX interstage filter attenuates TX signal
- 1 dB attenuation reduces 2nd order intercept point by 2 dB

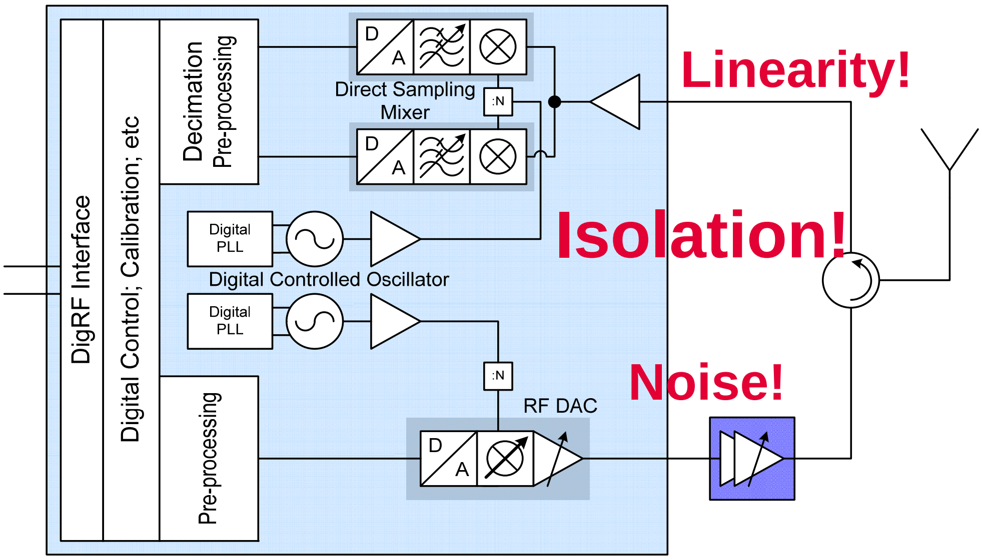
UMTS - TX Interstage Filter





- TX noise contribution at the RX input 6dB below thermal noise
  - -180 dBm/Hz equivalent to -204 dBc/Hz@24dBm output power
- -162dBc/Hz noise floor at duplex frequency
- Solutions
  - passive TX interstage filter
  - Higher duplexer isolation
  - reduce noise VCO and driver by increasing power and area

SDR the RF View!



- TX leakage for FDD systems can not be handled.
- TX noise in RX band will limit sensitivity
- Blocker requirements for GSM can not be handled.

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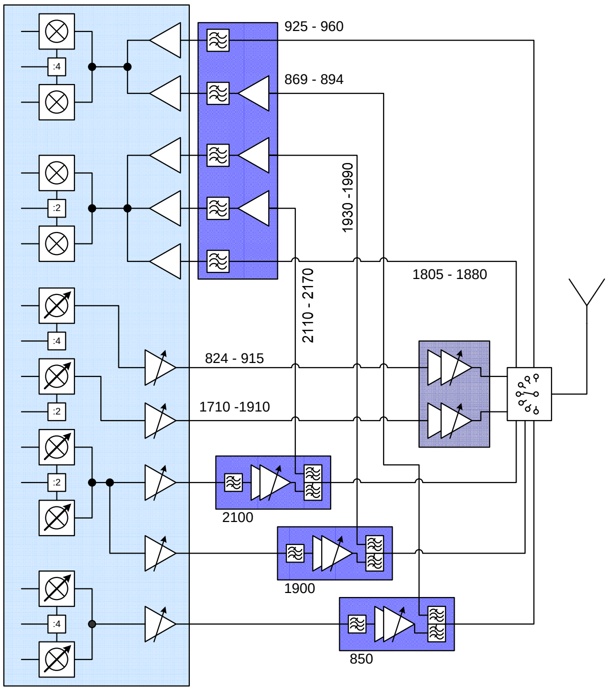
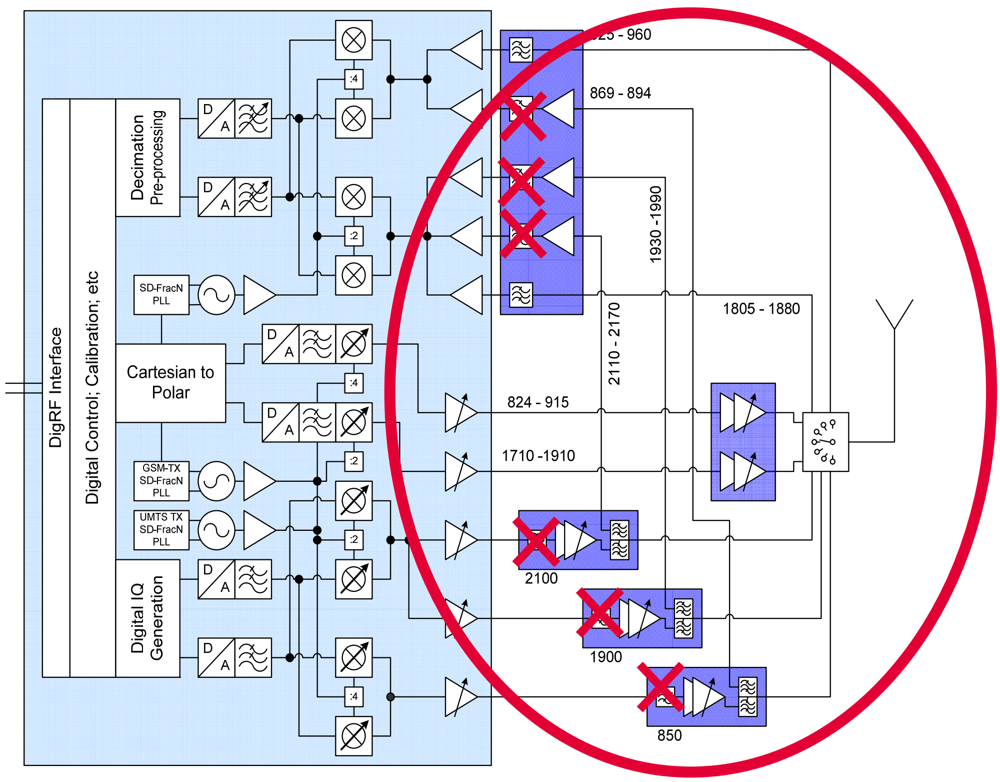
UMTS/GSM
Multistandard RF Frontend



- Wide-band front end not feasible
  - power
  - linearity
  - noise
- Duplex filter required
- TX interstage filter required
- Fixed passive filters
  - 3 UMTS front ends
  - 2 GSM front ends
  - switched to one antenna

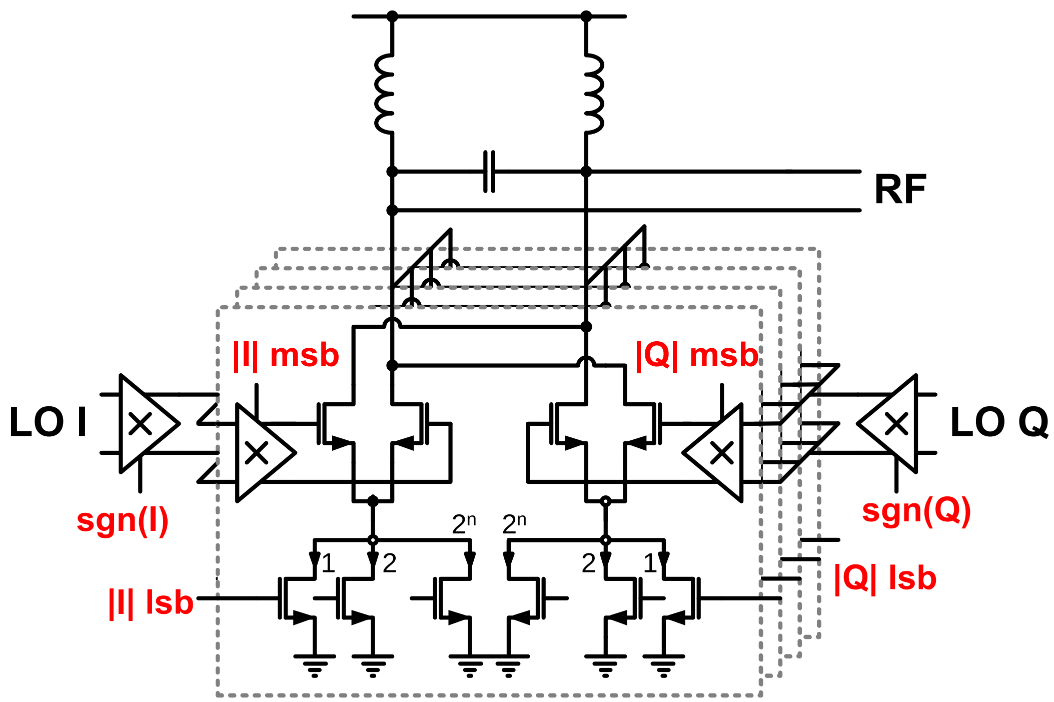
The Real Challenge for Multistandard RF: Remove Interstage Filters



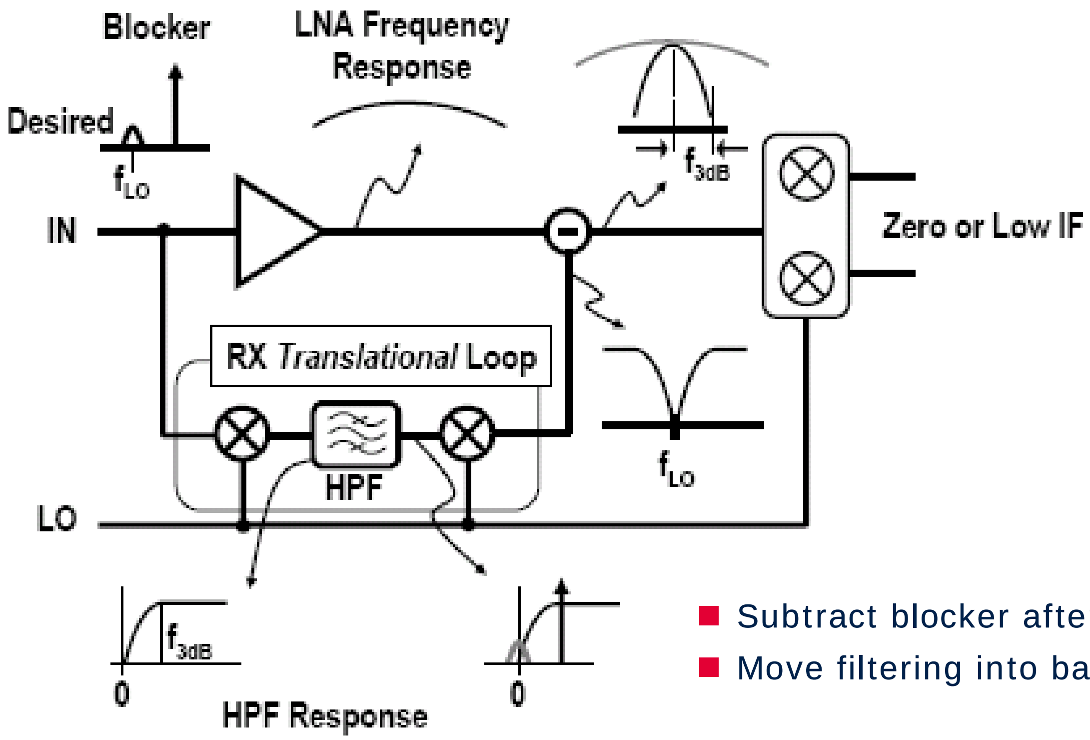
Challenges – Flexible RF Architectures

- **Remove external interstage filter**
  - high dynamic range transceiver frontend
  - increase IP2 and IP3: filter, calibrate or cancel
- **Reconfigurable Circuitry**
  - reuse die area consuming blocks in different modes
  - Reuse coils – switch between different frequency bands

IQ-RF DAC using fully switched Transistors



Broadcom ISSCC 2007: Blocker Cancellation



- Subtract blocker after LNA
- Move filtering into baseband

Challenges – Flexible RF Architectures

- **Remove external interstage filter**
  - high dynamic range receiver
  - increase IP2 and IP3: filter, calibrate or cancel
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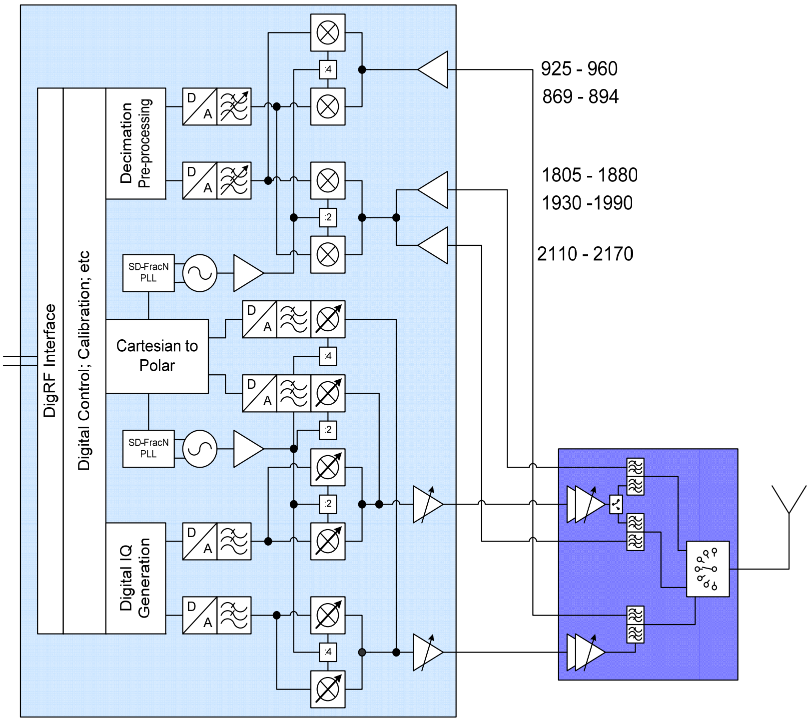
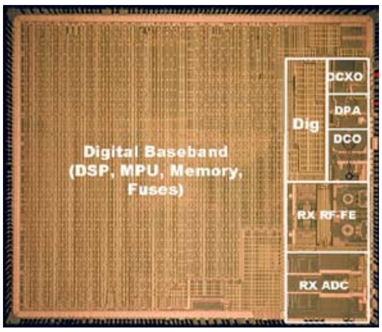
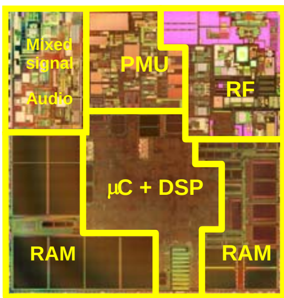
Target: Multistandard RF Transceiver



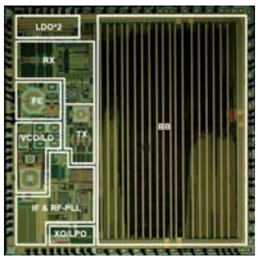
SoC Partition: Distribution of RF, Mixed-Signal, PMU, Digital, Memory



TI 90nm GSM SoC:
24mm2/3.8mm2
ISSCC 2008



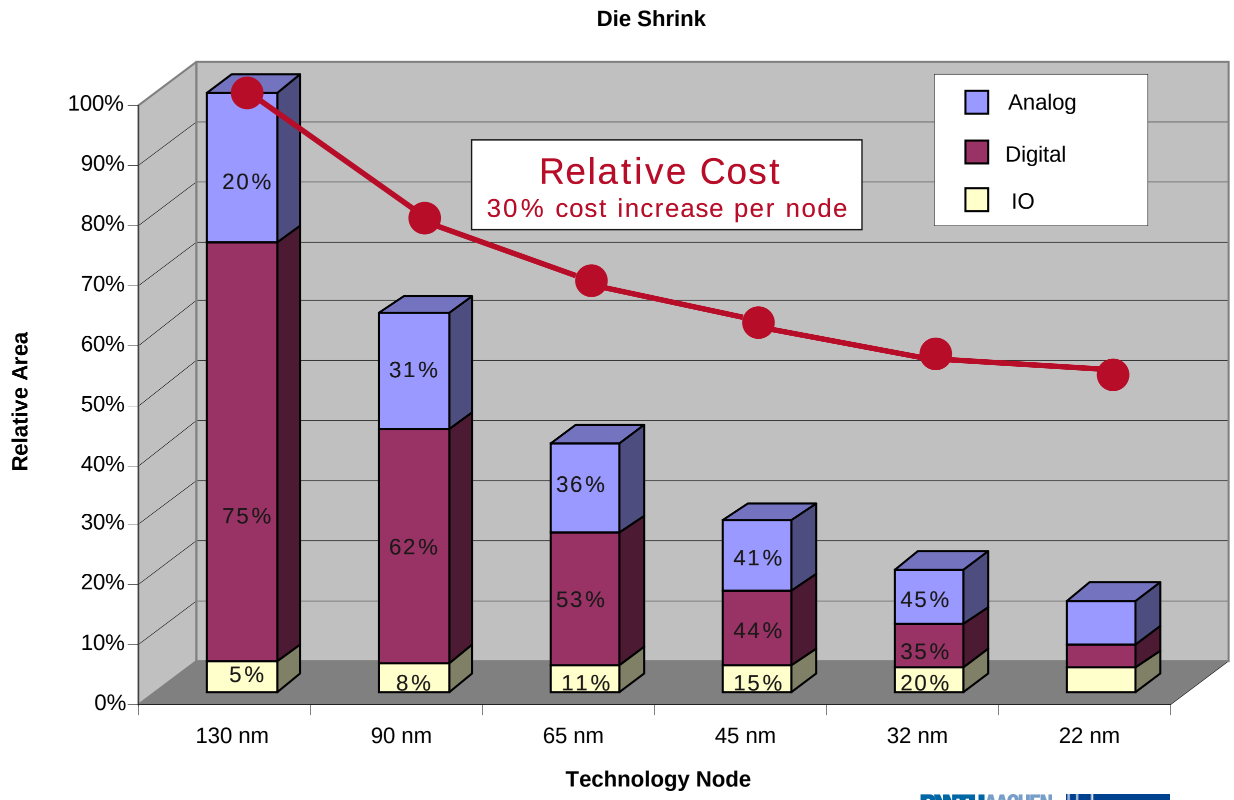
IFX 130nm GSM SoC:
X mm2
ISSCC 2006



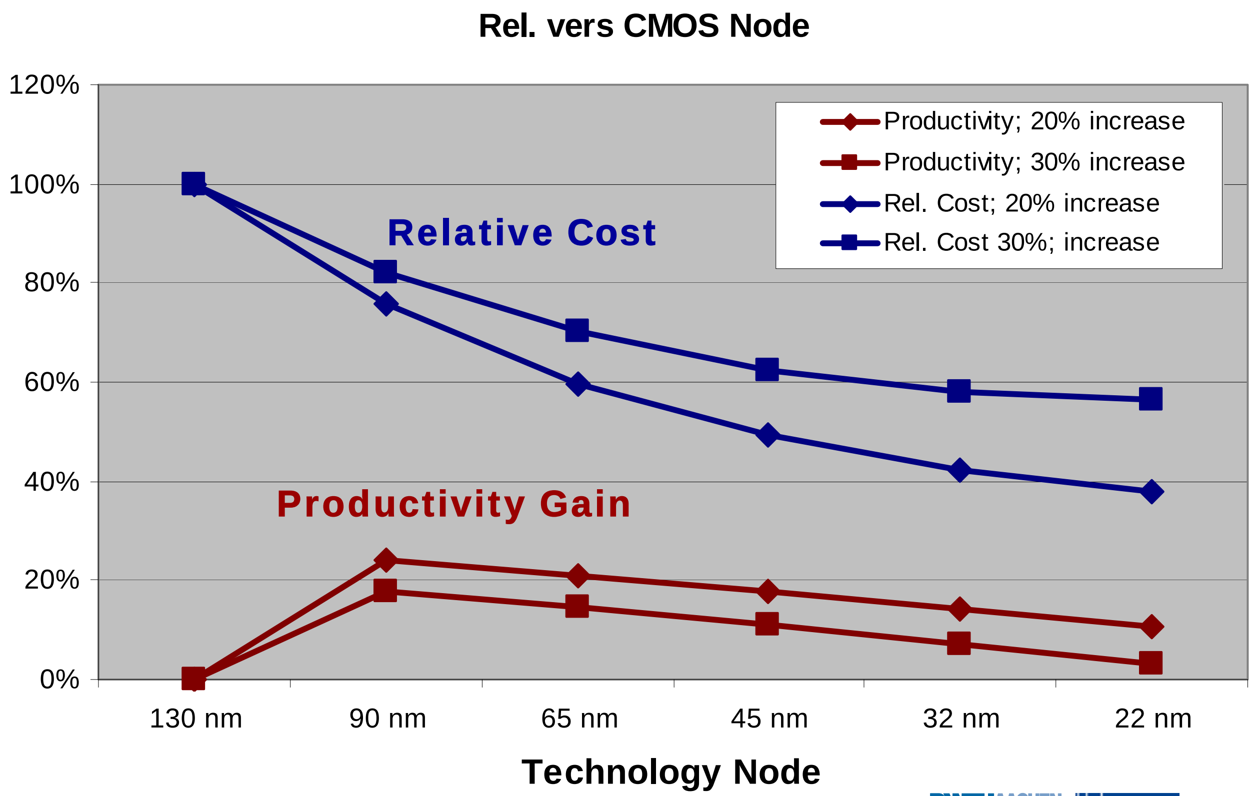
Broadcom 130nm
BT EDR SoC:
11.8mm2
ISSCC 2007

- Best Case: linear area reduction for Analog
- Real world application have only limited digital content
- Example: Smart Phone GSM/EDGE/UMTS
  - Start in 130nm
  - 70% digital; 25% analog&RF; 5% IO

Commercial Issues for RF SoC Integration



Productivity vers. Technology Node



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Conclusions – Challenges for Multistandard RF SoCs

- High Dynamic Range
  - Low supply voltage
  - High 1/f noise
- Transistors are good high speed switches
  - Use “fully switched” transistors
- Replace RF / analog processing by digital techniques
- Complexity – Multi-standard RF SoC
- Commercial Feasibility
  - Reuse RF blocks
  - Smart reconfigurable frequency agile RF transceiver
- Spurs, Spurs, Spurs, ….