Technologies in Support of Multimode and Flexible Transceivers

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Demand for Flexibility in Emerging Broadband Radio-Access Networks

- Flexibility in terminals and infrastructure is key to spectral efficiency in emerging broadband communications
  - Fragmentation of radio interface standards in all network topologies (cellular, P2MP, LAN, broadcast, short-range)
  - Fragmentation of worldwide spectrum (roaming issues)
  - Rapid increase in IP-based traffic
    - Convergence of voice, data and flat-rate broadcast services on mobile terminal
  - Multiplication of access-points/eNodeB (lower power) for coverage and EIRP reduction (public health concerns)
  - Spectral refarming and cohabitation of different access-networks on common spectrum
  - Ever-shortening development cycles
    - research/standardization/production
  - Support of legacy standards
- An increased (with respect to today) multimodality in both terminals and infrastructure is consequently inevitable in order to guarantee both high spectral efficiency and ubiquitous connectivity.

Demand for Flexibility in Emerging Broadband Radio-Access Networks

- Enabling technologies

Agile-RF	Broadband/Linear components/antennas, high dynamic range
Baseband DSP Architecture	Reconfigurable radio (SDR): reconfigurable MODEM blocks, efficient inter-processor communication media,
Heterogeneity in network and application layers	IP(v4/v6)-based mechanisms for inter-RAN handovers, QoS management, Reconfigurability Management
(Ultra)Wideband Radio Resource Management	Dynamic resource allocation, cognitive interference management

Cognitive Radio

- Cognitive radio's will require agile transceivers in order to opportunistically "park" on a particular frequency band
- In order to exploit existing systems in a cognitive sense, many radically different waveforms will have to be synthesized and or detected (multimodality)
  - Different carrier frequency rasters
  - Different baseband symbol times (sampling frequencies)
  - Different interference rejection requirements (narrowband vs. broadband systems, WLAN/WMAN vs. cellular, etc.)
- Concurrency of different radios (MODEMS + RF)
  - Sensing of new spectral opportunities
  - Dual radios during handovers
  - Uplink on one system, downlink on another, etc…
- <u>Question:</u> Compact and cheap agile and multimodal RF architectures are clearly very difficult to design. Would it be reasonable to assume that "cognitive" radios will have less stringent interference rejection requirements due to increased spectral agility? Put in other words, will cognitive radios be mostly lower-power short to medium range communications as opposed to high-power long-range?

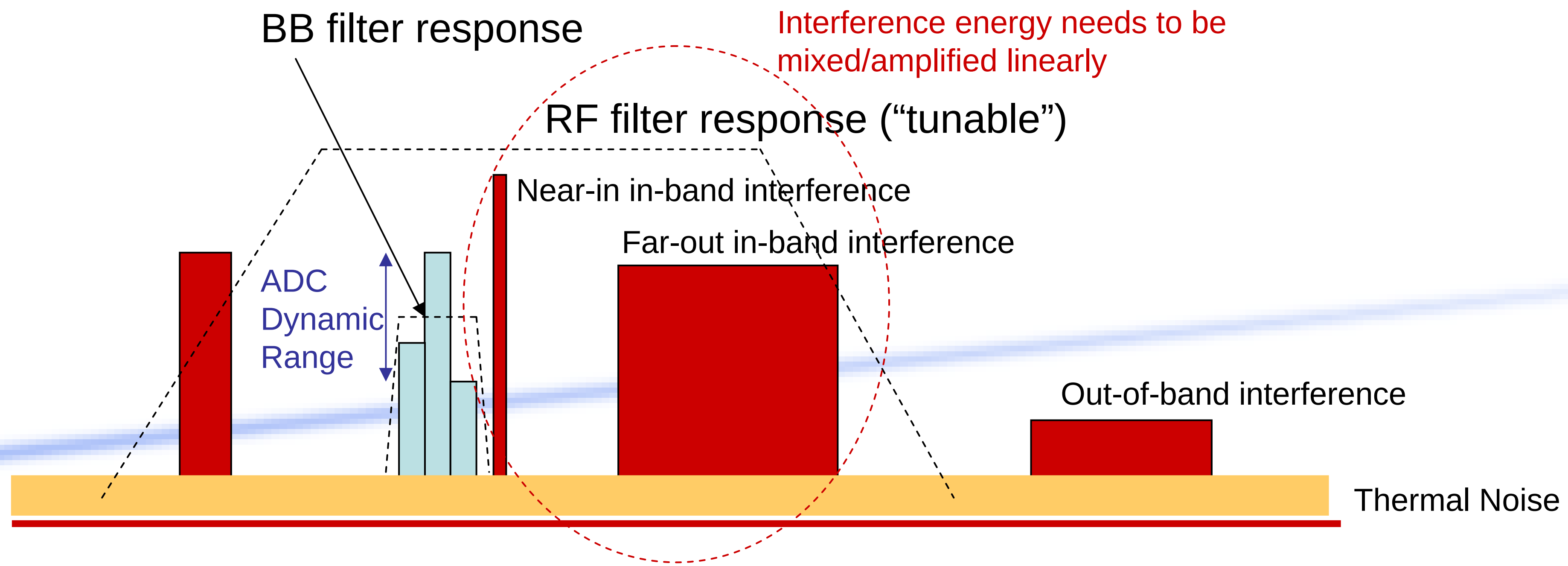
Idromel

- The French ANR (RNRT) IDROMEL Project address reconfigurable radio architectures on several fronts:
  - Agile RF architectures
  - Fully reconfigurable baseband DSP
    - Across the entire spectrum of systems (10kHz BW – 20 MHz BW) – i.e. forgetting some “niche” systems such as UWB or wideband satellite links
    - “developer-friendly” tools for MODEM development and validation
  - Real-time processing issues related to multimodality and concurrency of radio standards on a common processing architecture
  - Heterogeneity in networking protocols
- Primary goal: provide a demonstrator highlighting the challenges and difficulties in truly reconfigurable radio architectures
  - RF based on high-end discrete components
  - BB DSP based on state-of-the-art FPGA prototyping technologies
  - Open-source development (BB DSP)

Agile-RF

- Agile-RF
  - Ability to tune across large bandwidths (200 MHz – 6 GHz)
  - Support both TDD and FDD
  - Handle both narrowband (200 kHz) and wideband channels (20 MHz)
  - Technologies
    - broadband antennas
    - reconfigurable analog filters (e.g. MEMS) -> bandselection/interference rejection
    - Broadband **linear** amplifiers and image-reject (quadrature) mixers
    - Broadband VCO/PLL
    - High dynamic-range ADCs (to allow for digital interference rejection and advanced baseband processing)

Importance of Linearity over Large Dynamic Range



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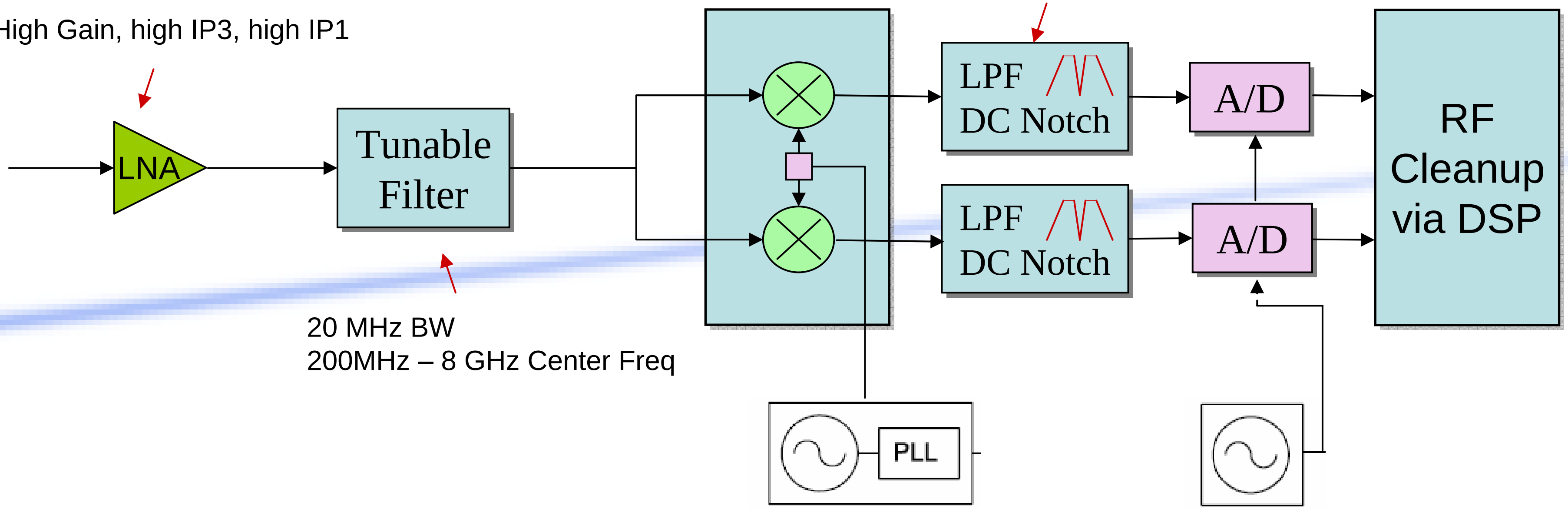
Target Broadband RF Receiver (IdroMel/E2R2)

END-TO-END RECONFIGURABILITY

High linearity quadrature (image-reject) mixer (high IP3, IP1)
Excellent I/Q balance over whole frequency range

Adjacent channel rejection
Carrier leakage rejection (ZIF receiver)

High Gain, high IP3, high IP1



20 MHz BW
200MHz – 8 GHz Center Freq

200MHz-8GHz synthesiszer

30 MHz TCXO

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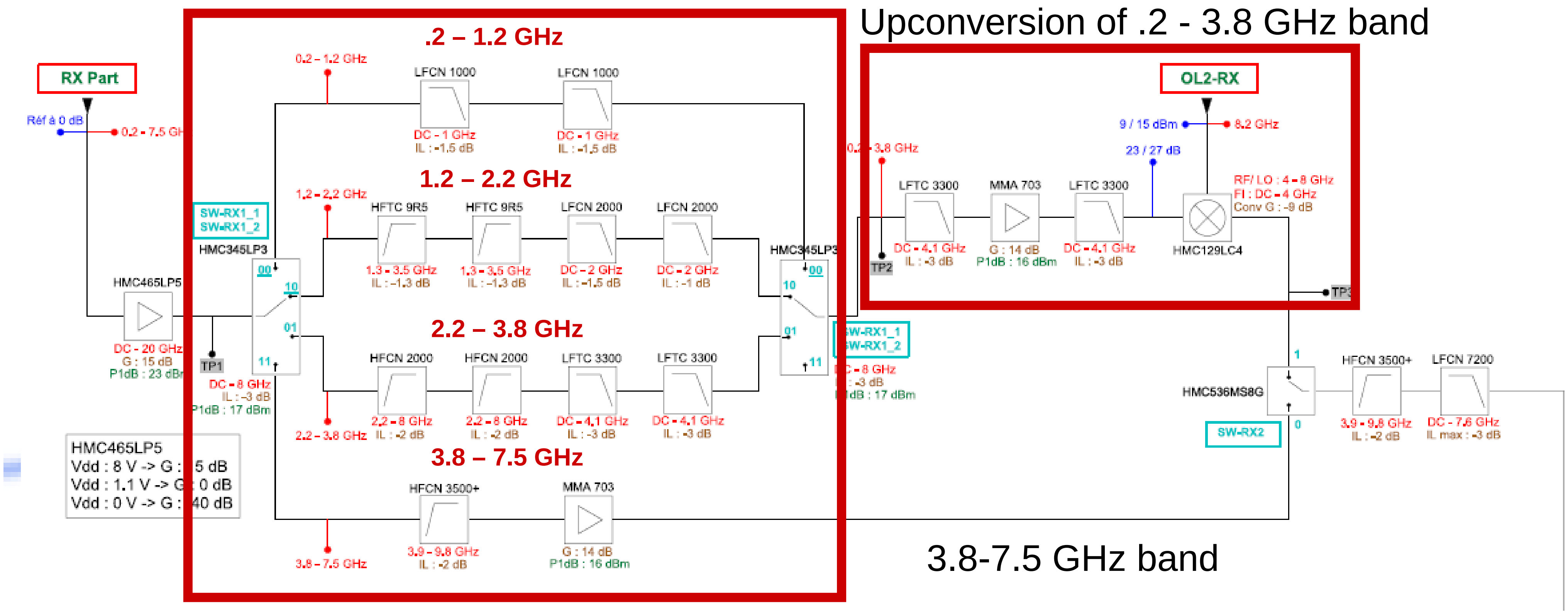
Difficulties

- Synthesizer
  - Broadband is hard to design (1.9-4.1 GHz is out there, but not cheap)
  - Large range comes with reduced frequency granularity (e.g. 500 kHz) -> requires digital frequency synthesis in baseband DSP to compensate
- Quadrature Mixer
  - Drive strength for LO input
- LNA
  - High IP3 to allow for interference mitigation in later stages of receiver
- Tunable filters
  - Still research topic in electronics community (MEMS-based technologies exist, but limited to tunability over small ranges)
  - Switched filter bank is not an “integrateable” technology and will consume space
- A/D
  - High resolution/low-power (modern sigma-delta is a good choice with high-end DSP behind). Resolution for near-in interference mitigation in DSP.
  - Fixed sampling clock for high-quality (low jitter/phase noise) requires retiming circuit in DSP to cover the plethora of radio standards in nature.

Adopted Approach for Prototype (IdroMel/E2R2)



Switched Filter Bank

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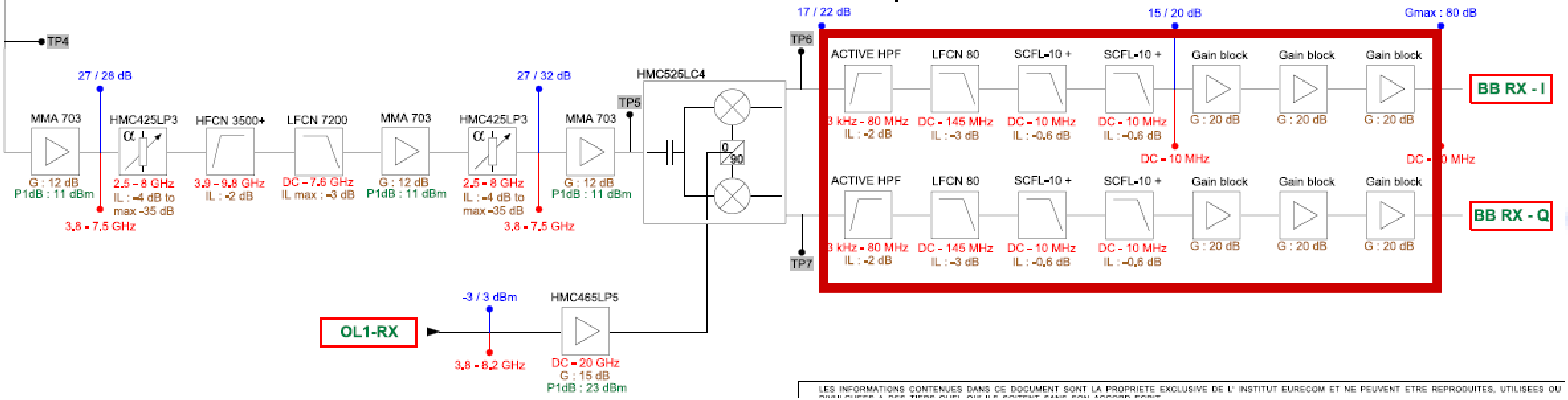
Adopted Approach for Prototype (IdroMel/E2R2)

Complex baseband filtering and amplification



END-TO-END RECONFIGURABILITY

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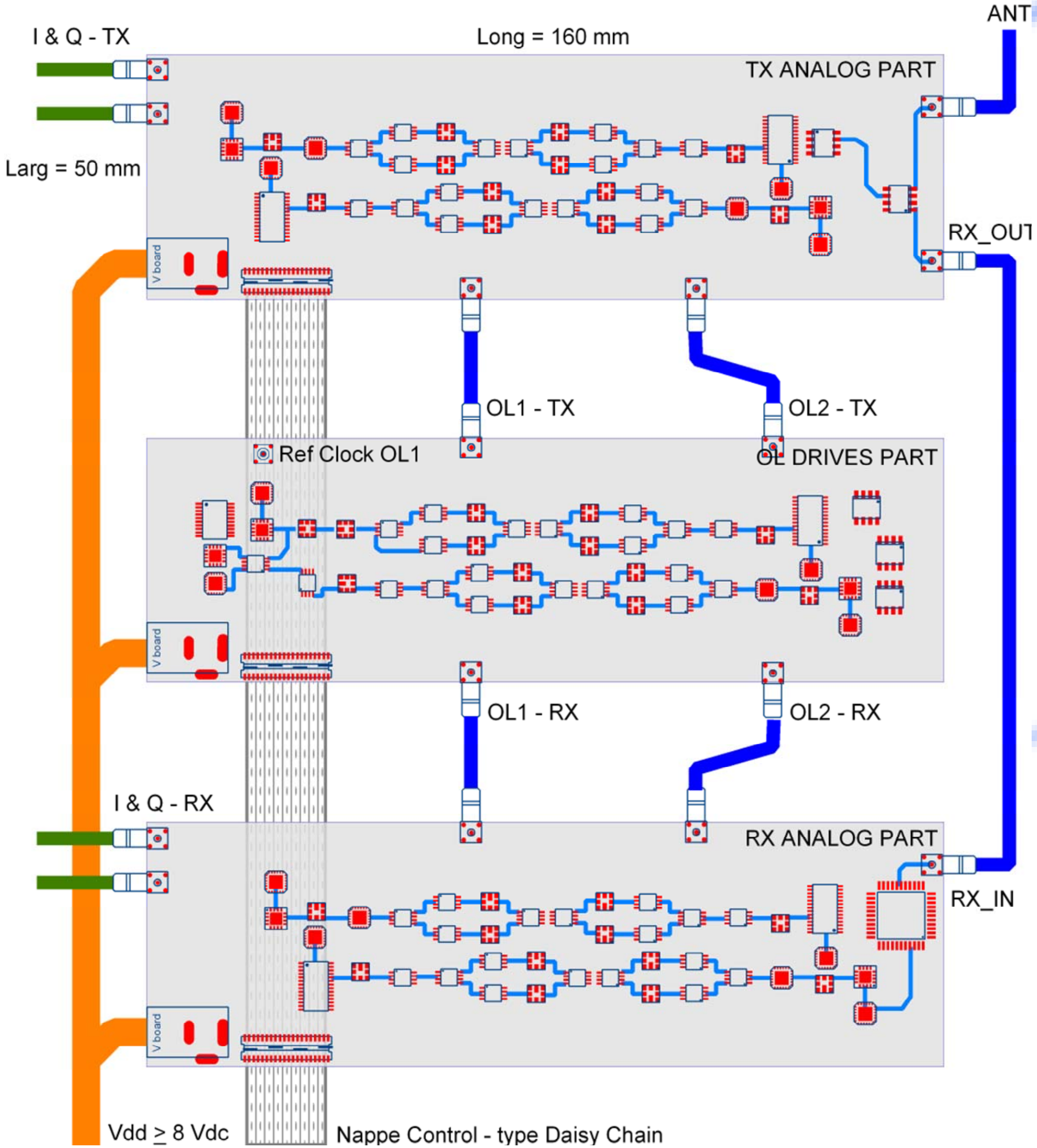


Idromel/E2R2 RF

- Characteristics:
  - Frequency band: 200 MHz – 7.5 GHz
  - 500 kHz raster
  - Baseband channel BW: 20 MHz
  - Tx : +15 dBm (35 dB ACLR)
  - Rx NF : 8 dB
- Cost is significant due to high-end components (amplifiers, broadband VCO/PLL)

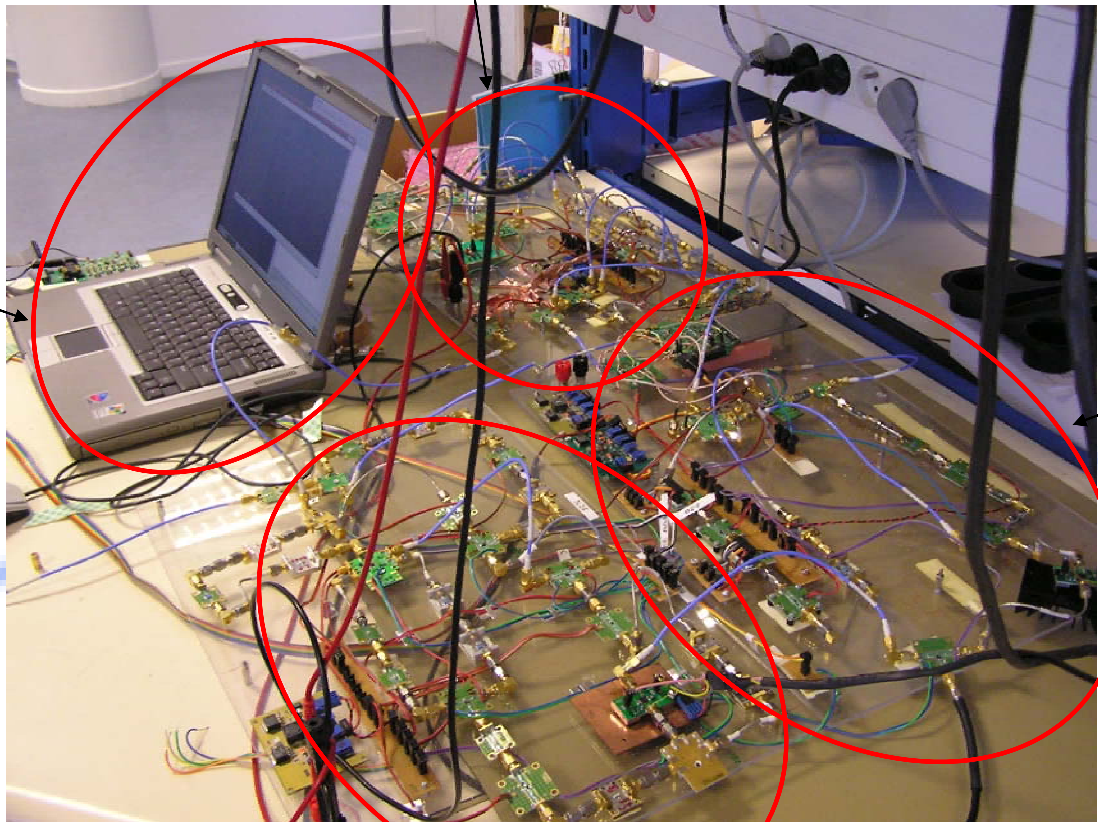
Prototyping …

LO DRIVES part

Laptop for control

TX ANALOG part

RX ANALOG part



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RF Cleanup

- Baseband DSP is used for
  - Channel selection (i.e. narrowband channelization of 20MHz sampling bandwidth)
  - Digital frequency offset correction (NCO + complex modulator)
  - Digital retiming
    - In order to provide baseband DSP with a properly timed waveform for the particular system in question.
    - Alternative would be a programmable VCO/PLL for sampling. Phase noise performance (jitter on sampling clock) would be prohibitive.

Baseband/RF Co-design

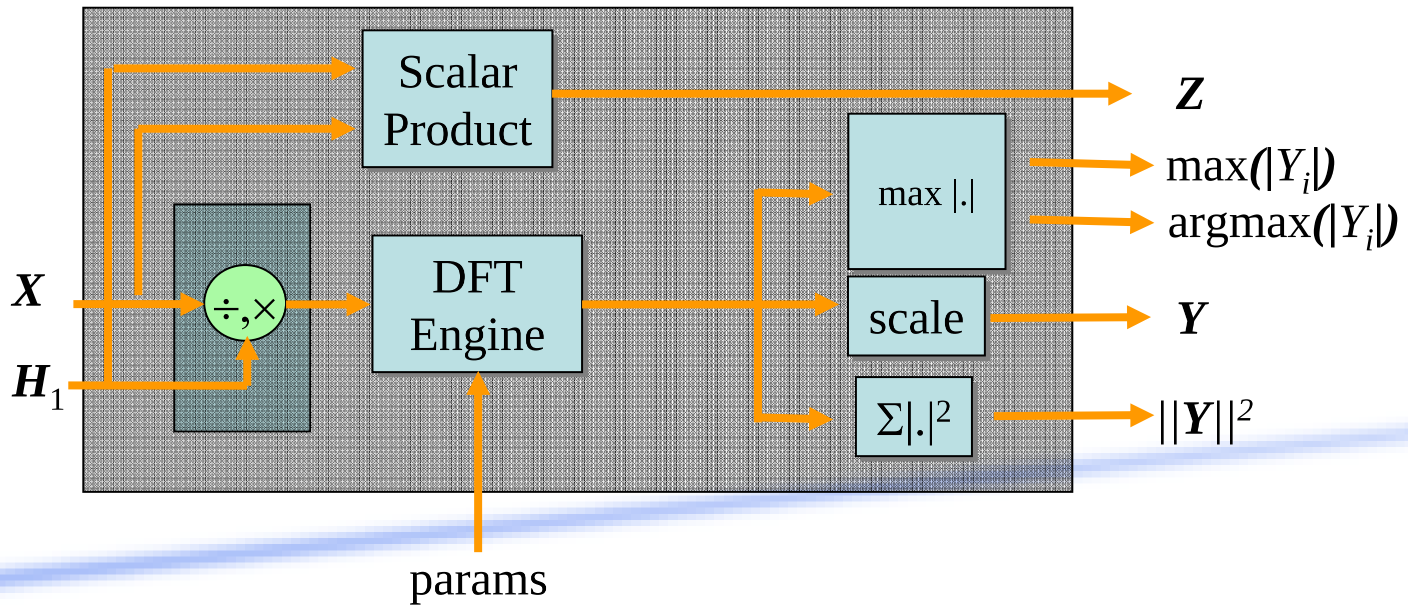
- In general, more effort in the area of Baseband/RF Co-design could be envisaged for CR
  - RF Flexibility will come with a price, and thus co-design between RF and baseband can be beneficial
  - In some sense we "improve" RF impairments through baseband DSP in order to enhance RF flexibility (dirty-RF concept), resulting in more flexible and cheaper RF components.
  - Examples:
    - phase-noise compensation through DSP and proper dimensioning of baseband waveforms (during standardization process)
    - amplifier linearization
    - Digital correction of I/Q gain/phase imbalance
    - PHY protocols for 2-way calibration.

Baseband DSP Architectures

- Desire for ideal software radio to accommodate all waveforms
  - adapting standards
  - Reuse of signal processing engines across standards
- PLATON and others showed the possibility of a true software radio with generic CPU/RTOS
  - Applicable to basestations (e.g. Vanu inc.), debatable for multi-antenna/sector/channel processing
  - Future LTE basestations will use a similar approach with high-end DSPs and RTOS.
- IDROMEL introduces hardware accelerators with tight SW control under a RTOS into the picture, in order to handle high throughput waveforms efficiently.
- Terminals?
  - bandwidth and processing power/power consumption constraints
  - Search for low-power SoC architectures, evolution of IDROMEL architectures with power consumption in mind (HW/SW optimizations and power management).

Reconfigurability Through Generic Macro-Operators

Example: Generic Front-End Processing



Uses: OFDMA : TX,RX,Ch Est,Frame Sync, Carrier phase offset compensation
MC-CP : TX,RX,Ch Est, Frame Sync, Carrier phase offset compensation
TD-SCDMA : RX,Ch Est, Frame Sync, MF synthesis, carrier phase offset
WCDMA : RX,
SC (e.g. GSM) : RX, Ch Est, Frame Sync, Equalization

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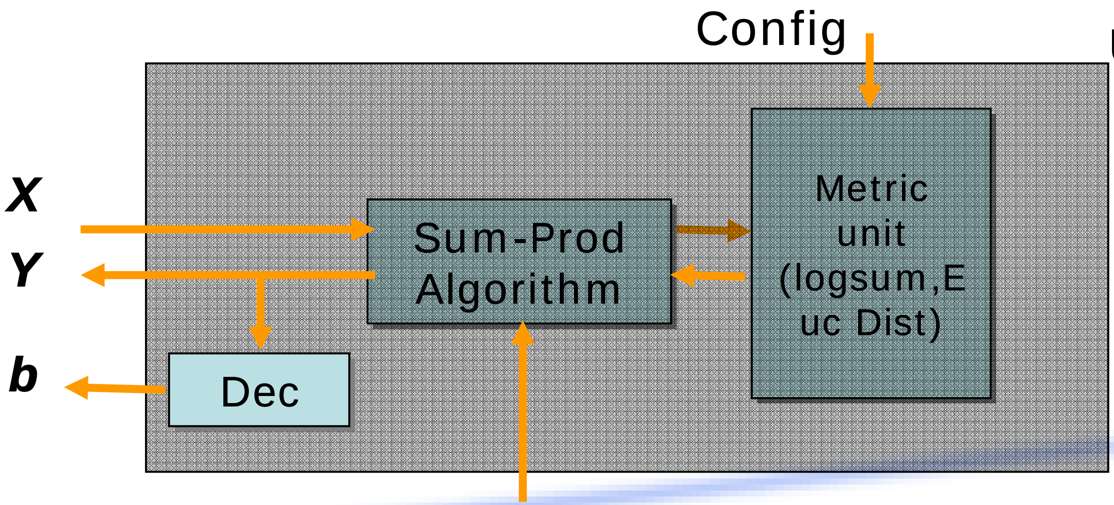
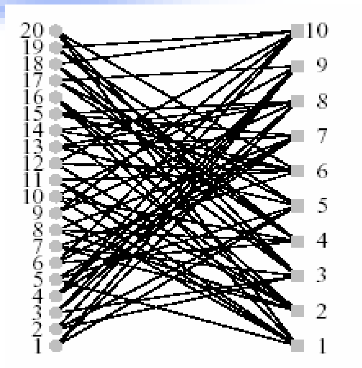
Reconfigurability Through Generic Operators (2)

Ex: Graph Processing (SPA Copro)

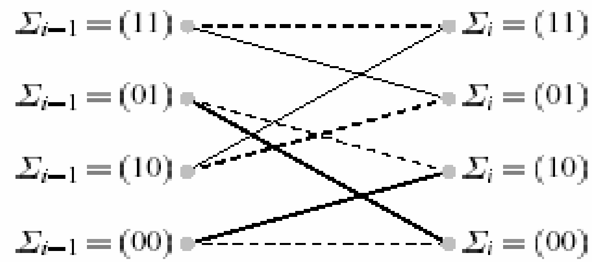


Generic Graph Description

Uses: BCJR (Turbo Decoder)
Viterbi
SP (LDPC Decoder)
Soft-output Equalizer
DFT?



Tanner (LDPC)



Trellis (C. Code, B. Code, T. Code, Channel w. memory)

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