TELERAD

Aeronautical and Maritime Radiocommunication Systems

TELERAD RF and digital architectures for VHF/UHF radio equipment

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rapid

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Summary

1. Introduction
    1. **Telerad presentation**
    2. **Context and goals of project**
2. Digital architectures
    1. **Receiver architecture**
    2. **Transmitter architecture**
3. Electronically tunable cavity filters

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WHO ARE WE ?

Company introduction and context presentation

TELERAD key features

- TELERAD SA – Private Company established in 1950
- Registered Capital: 700 000 €
- Located in Anglet, France

- Our mission
  - Design, manufacture, commissioning and marketing of radio sy and maritime communications
  - World market, both civil and military

- Number of employees : 78 persons
  - 40% technicians and engineers

- Turnover
  - 10.4 M€
  - Exportation: 60-70 %
  - Defense Market: 15-20%

- 10% of the annual turnover invested in R&D every year

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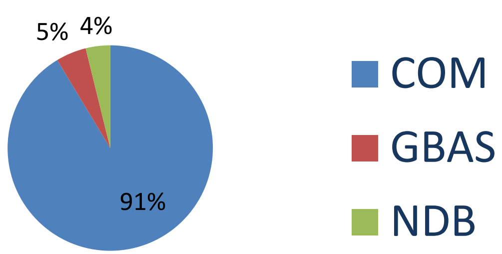
TELERAD Products

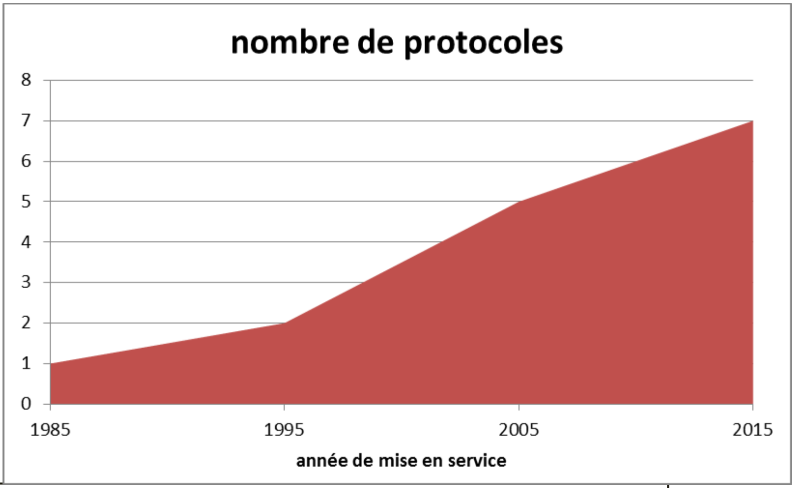
- Developing and building VHF radio units since 1950.
- First software radio architecture in mid-1990
- Product portfolio (summary):
  - **Multimode VHF/UHF receivers and transmitters :**
    - Air Traffic Control (ATC)
    - Marine Infrastructures
    - Military control stations
  - **Multimode VHF/UHF transceivers :**
    - Custom military products
  - **Normal/standby switching units, remote controls and supervision systems**
  - **NAVAIDS (GBAS + NDB)**

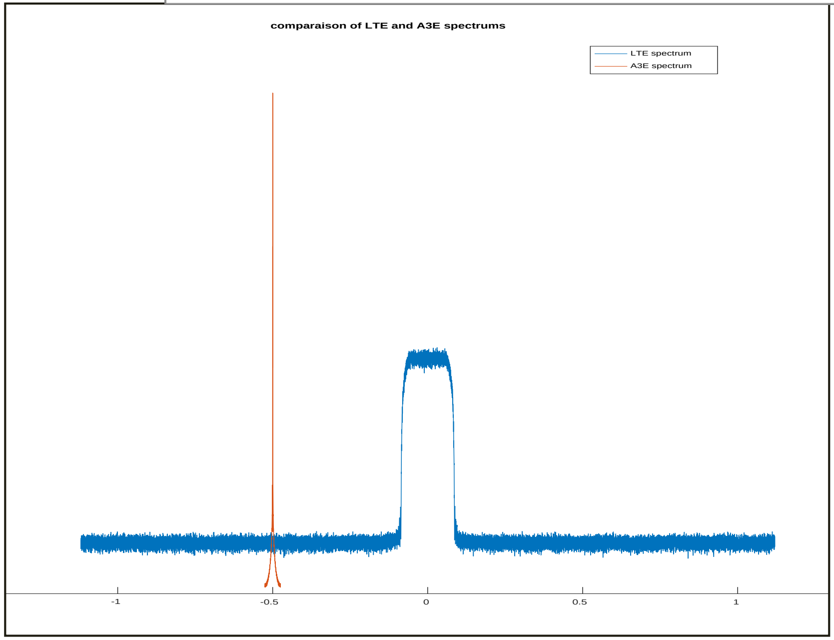
Sales revenue 2015



Project context (1/2)

- Market trends :
  - Increasing number of protocols (A3E – ACARS – VDL2 – VDL 3 & 4 – F3E – G3E….)
  - Lower prices : prices of radio units + maintenance cost
  - Standardization of radio units (Single European Sky)
- Technical trends – radio development are now driven by consumer technologies
  - Low cost / high quantity
  - High bandwidth
  - Short lifecycle
  - High integration
  - Digital modulations
- Our technical requirements
  - Both analog and digital modulations
  - Low bandwidths (25kHz)
  - High dynamic range (120dB)
  - Very high ACR / very low ACP
  - High longevity (MTBF + lifecycle)
  - Low quantity (~hundreds)





Project context (2/2)

- Product longevity :
  - Active production: 10 years
  - Lifetime (MTBF): around 11years
  - Reparability: 10 to 15 years




1985 | 1995 | 2006 | 2012 | 2014 | 2016

reparability | Life time | Production

life | Prod.



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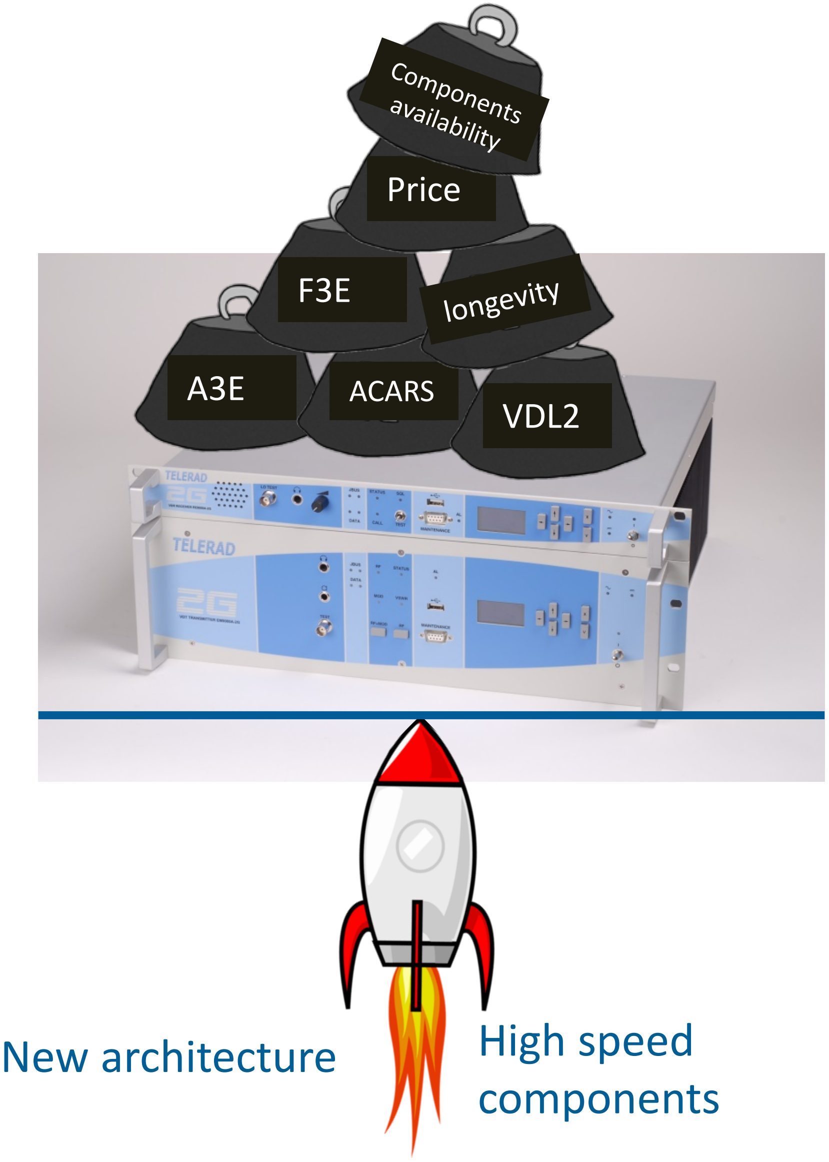
Project goals

- Develop new architectures / adapt architectures to our context
- VHF / UHF convergence
- Lower cost / make cost “resistant” to evolutions
- Ease integration of new protocols
- Develop a method to specify key components characteristic (RF – digital co-design).



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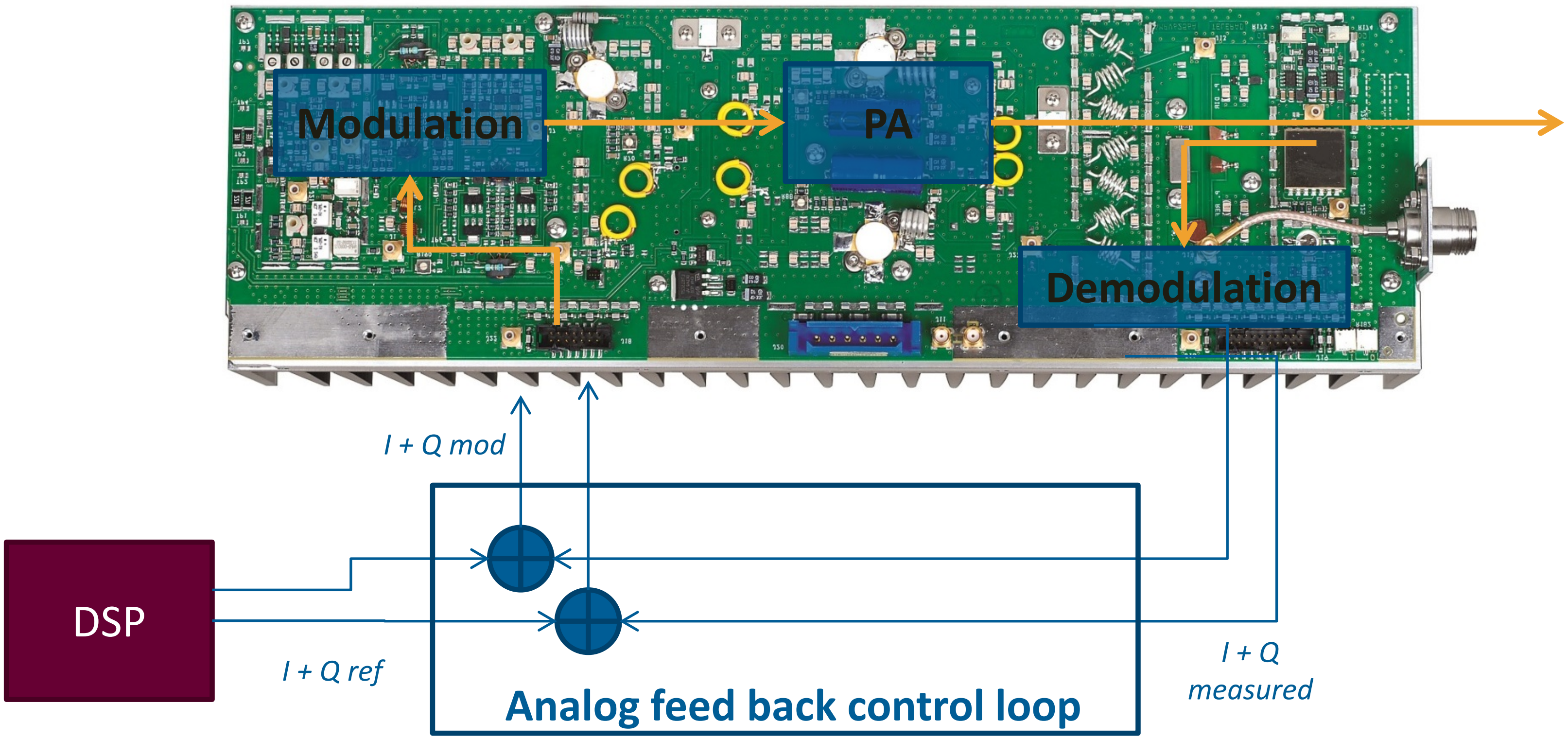
DIGITAL ARCHITECTURES

Adding flexibility and simplifying RF architectures

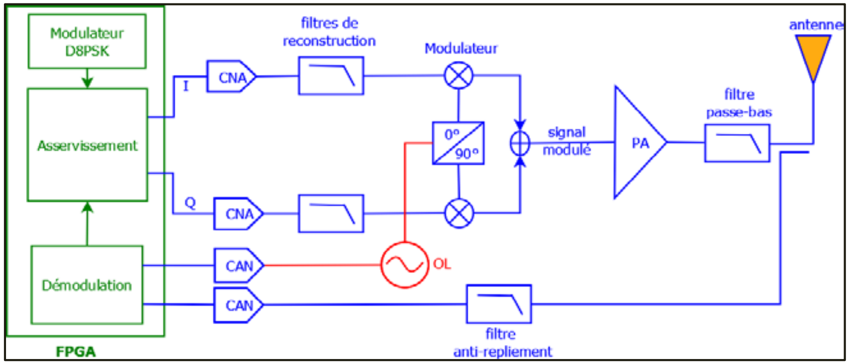
Transmitter Current architecture

- Current architecture : full analog Cartesian loop :

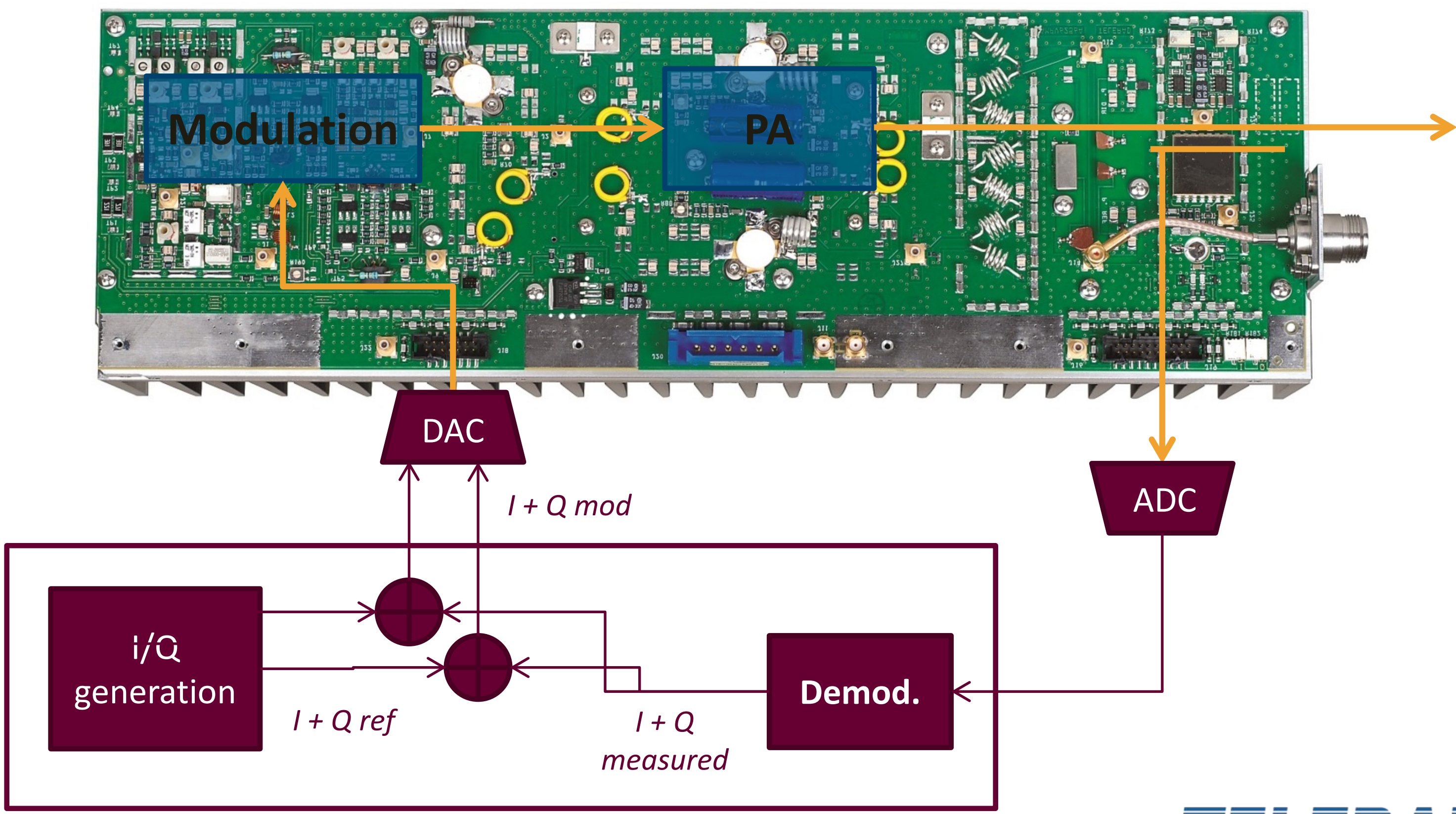


- Several drawbacks :
  - **Very difficult to tune**
  - **difficult to adapt to different waveforms**

New Transmitter architecture



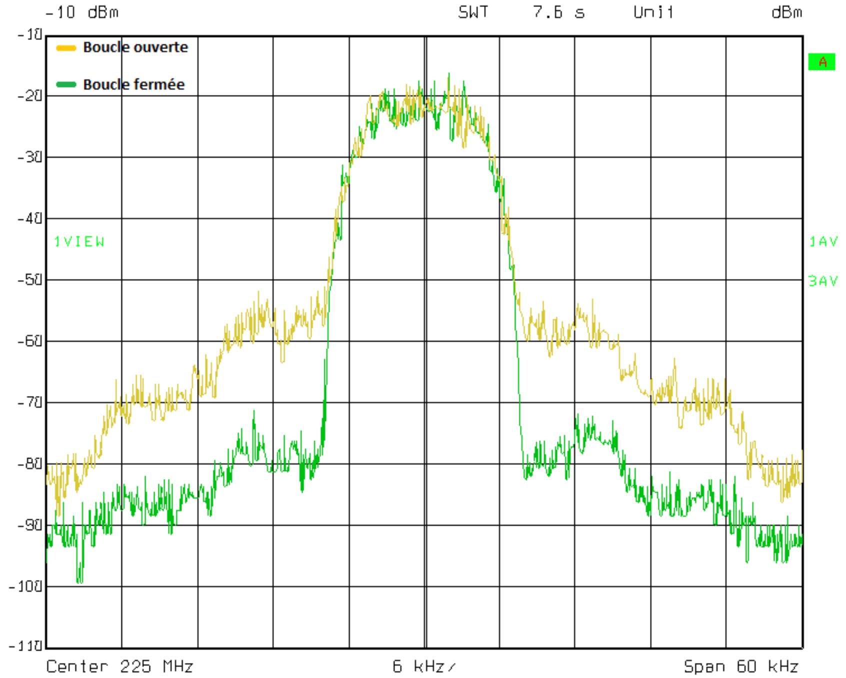
- State of the art :
  - Cartesian and polar loop
  - Digital Predistortion : LUT and parametric
- Implementation of a fully digital Cartesian Loop

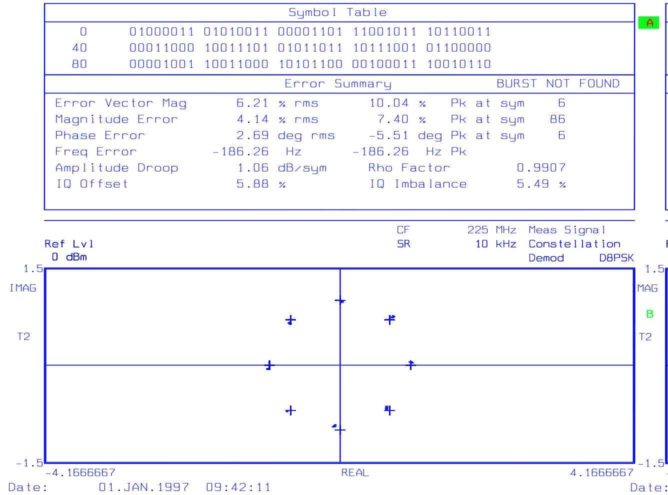


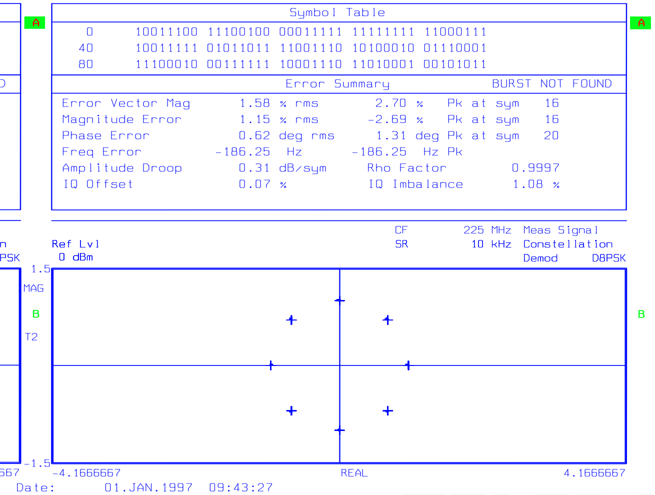
FPGA control loop

Transmitter performances

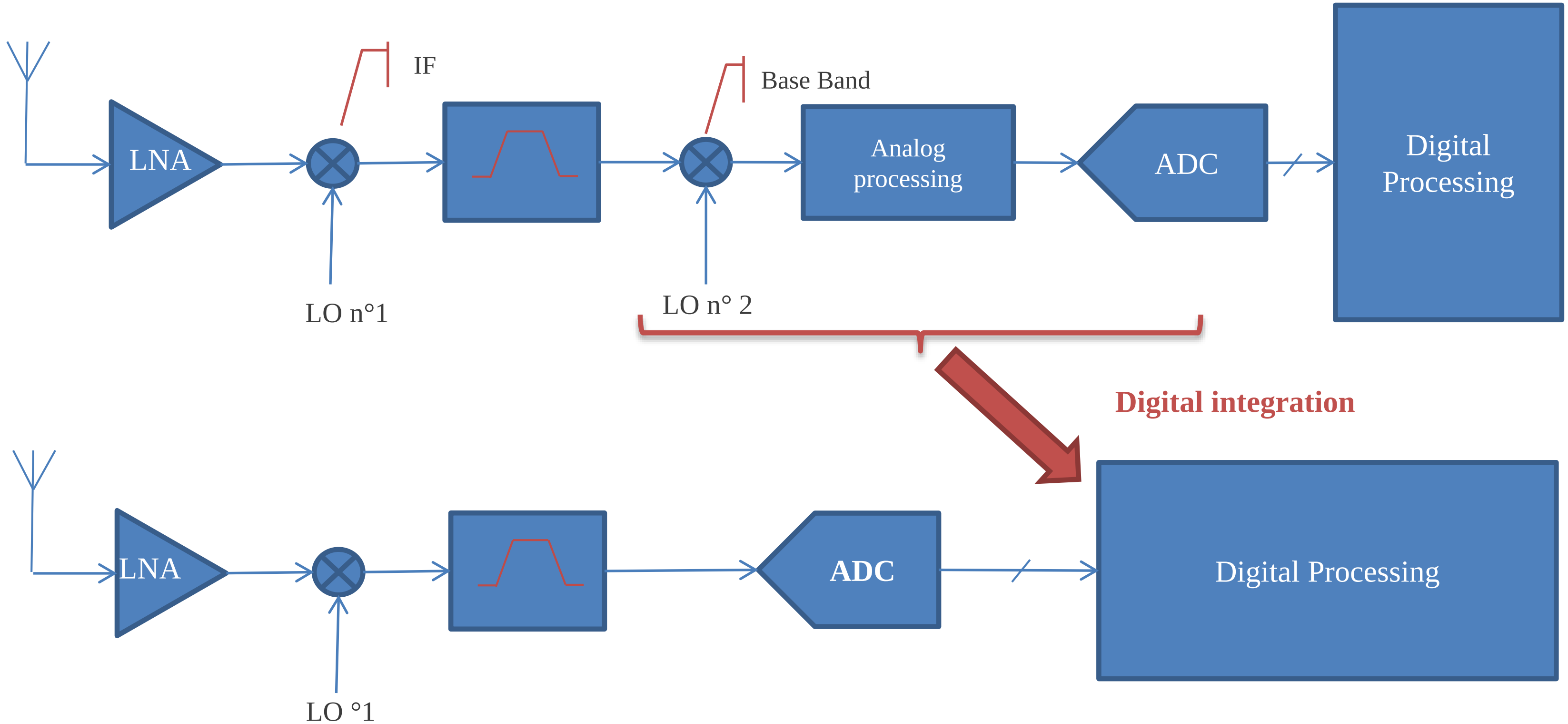
- ACP :
  - Open loop : -37dBm
  - Closed loop : -58dBm
- EVM :
  - Open loop : 6.5%
  - Closed loop : 1.6%
- Work still in progress:
  - Limited bandwidth
  - high order modulations
  - Comparison with DPD ?







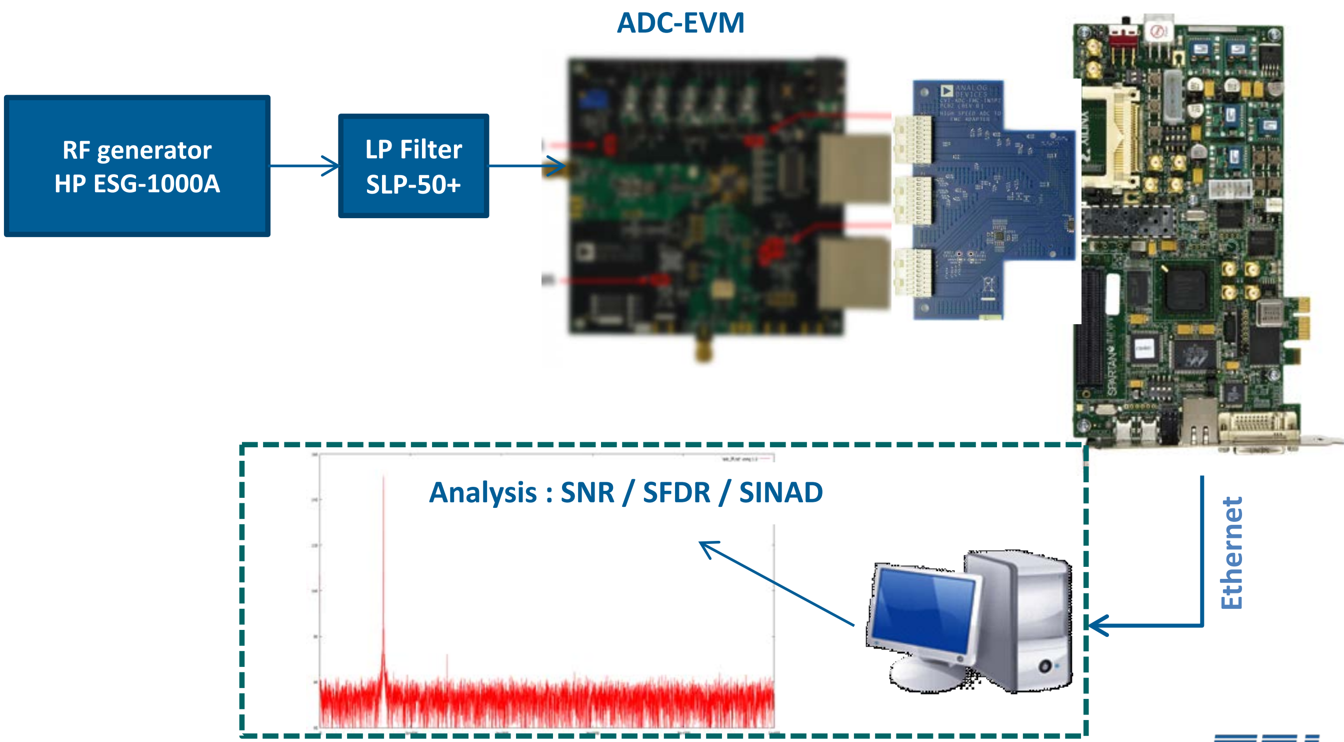
Receiver Architecture



- Legacy Architecture :
  - Digital components speeds (2000-conception)
  - High dynamic and high rejection
  - IF filters need to be duplicated for each supported bandwidth
  - Analog processing hard to tune and duplicated for each supported protocols
- Target Architecture :
  - Now possible due to evolution (speed and price) of digital components
  - Only 1 IF filter
  - No analog baseband processing

Analog to Digital Converters (1/2)

- Central component in new architecture
- Complete evaluation of component needed : raw performances and impact on specific radio performances
- Protocol :
  1. **Selection of component**
  2. **Raw performances evaluation (SINAD, SNR, SFDR)**
  3. **Radio performances evaluation (sensibility, distortion, ACR)**
- Raw performances evaluations testbench

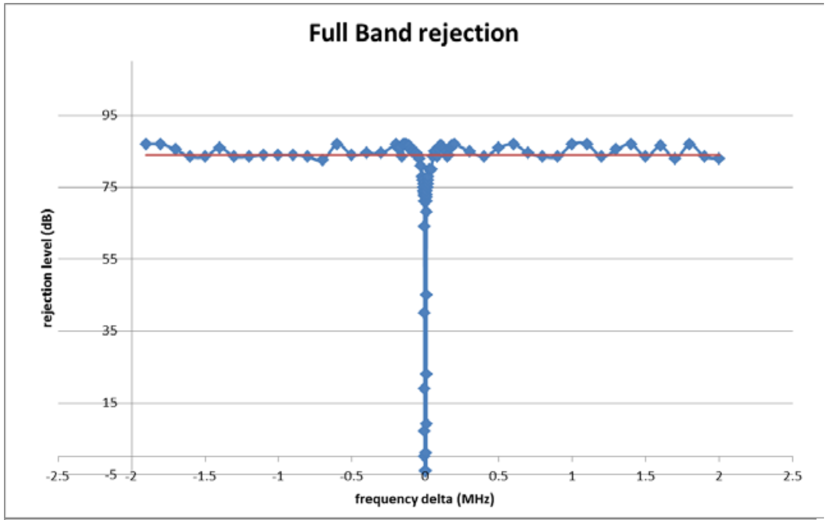


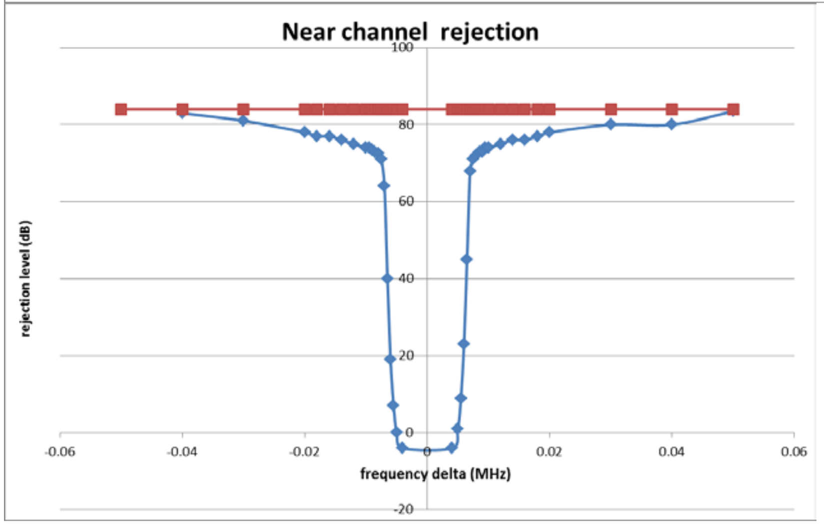
Analog to Digital Converters (2/2)

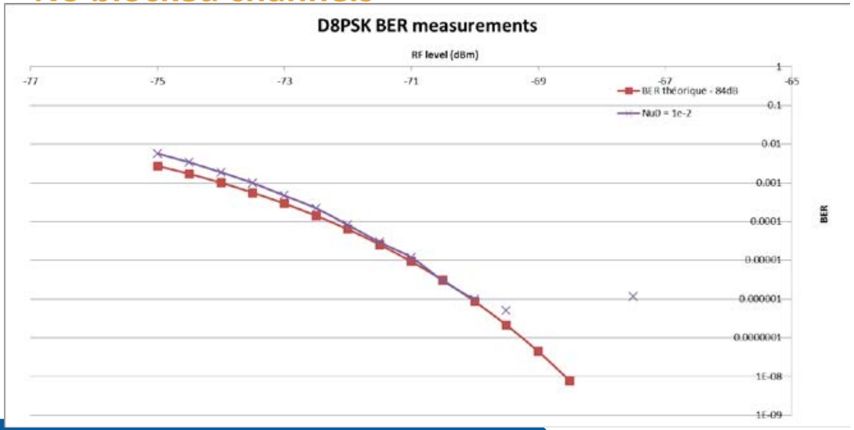
- Raw performances :
  - **72 dB SNR**
  - **95 dB SFDR**
- Expected performances in A3E :
  - $G_{filt} = 10\log_{10}\left(\frac{20.10^6}{3{,}4.10^3}\right) \approx 37.6dB$
  - $P_{demod} = 10\log_{10}\left(\frac{m^2}{2+m^2}\right) \approx 13.6dB$

  $\Rightarrow$ **Sensibility at 84dBFs / ACR = 84dB**
- Expected Performances in D8PSK :
  - $G_{filt} = 10\log_{10}\left(\frac{20.10^6}{10{,}5.10^3}\right) \approx 32.7dB$
  - $G_{demod} = -3dB$

  $\Rightarrow$ **Sensibility at 83.5dBFs**
- Measures :
  - **A3E : sensibility 84dBFS – ACR at 84dB.**
  - **D8PSK : sensibility at 84dBFS**
  - **No blocked channels**







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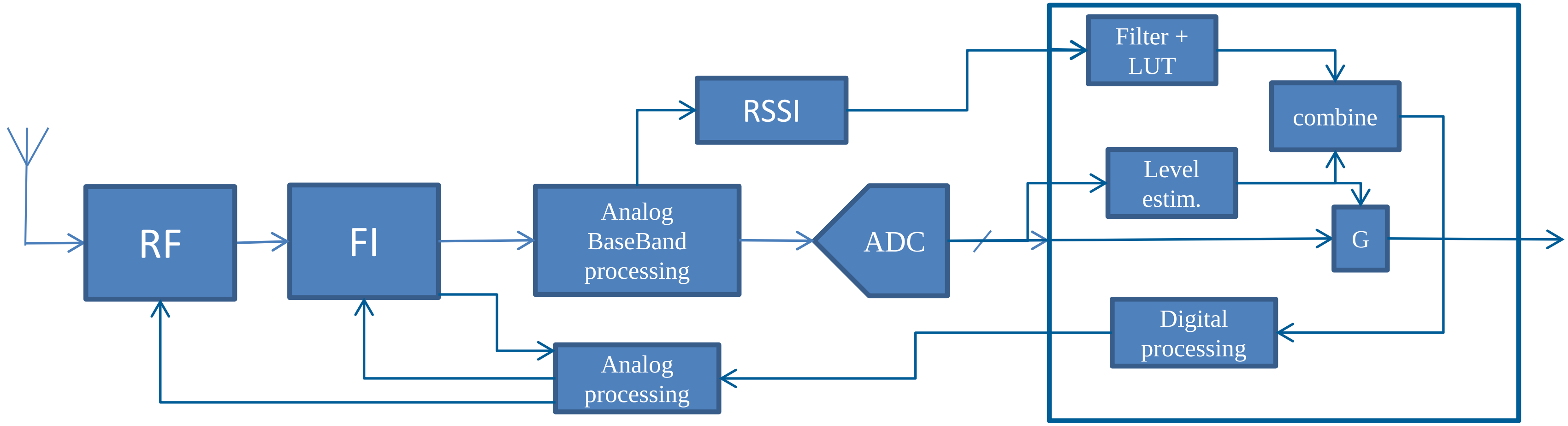
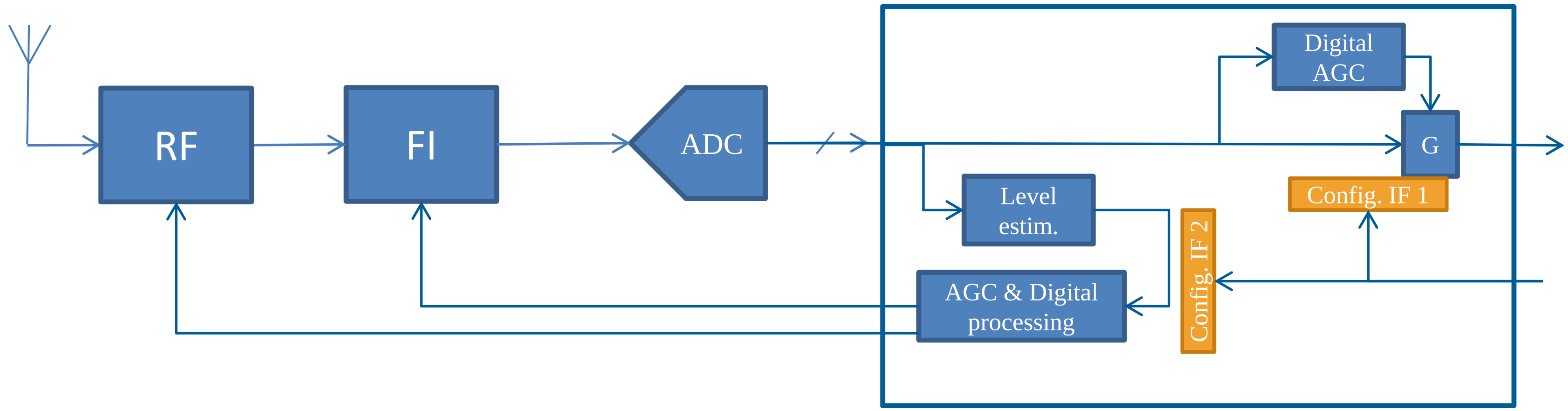
new AGC

- New architecture takes advantages of high speed digital components
- Simpler / more reliable / more performant
- Easier tuning & adaptation

Legacy arch.



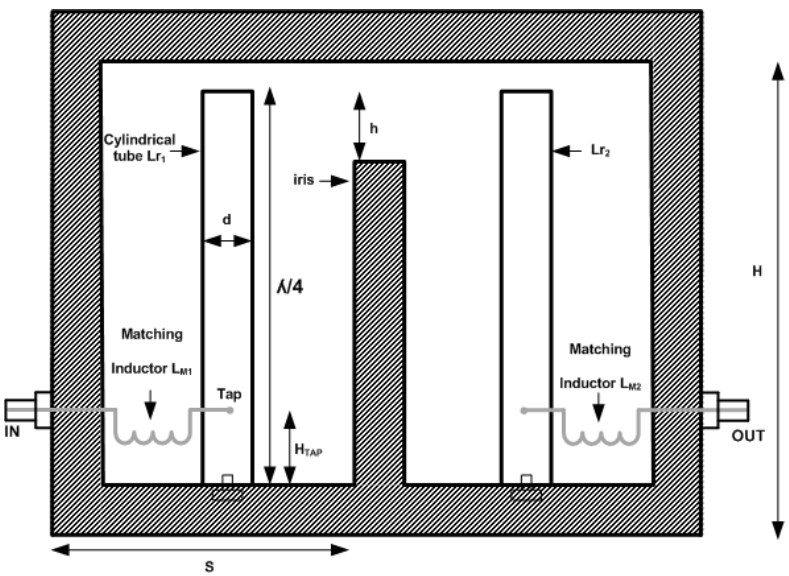
New arch.

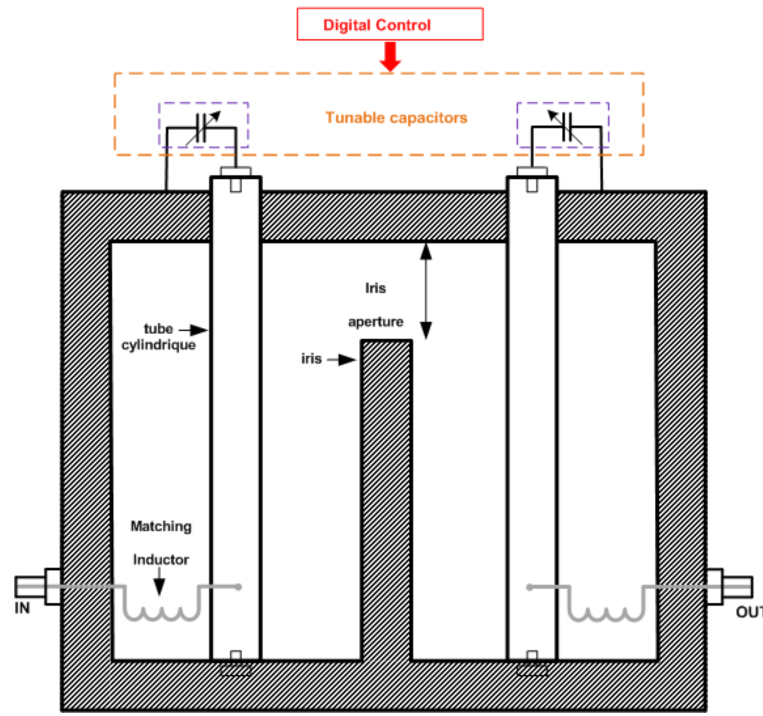


ELECTRONICALLY TUNABLE CAVITY FILTERS

- Goals :
  - Cover a frequency wideband (108MHz-512MHz)
  - Meet the requirements of military applications
  - Reduce the design costs vs state of the art architectures

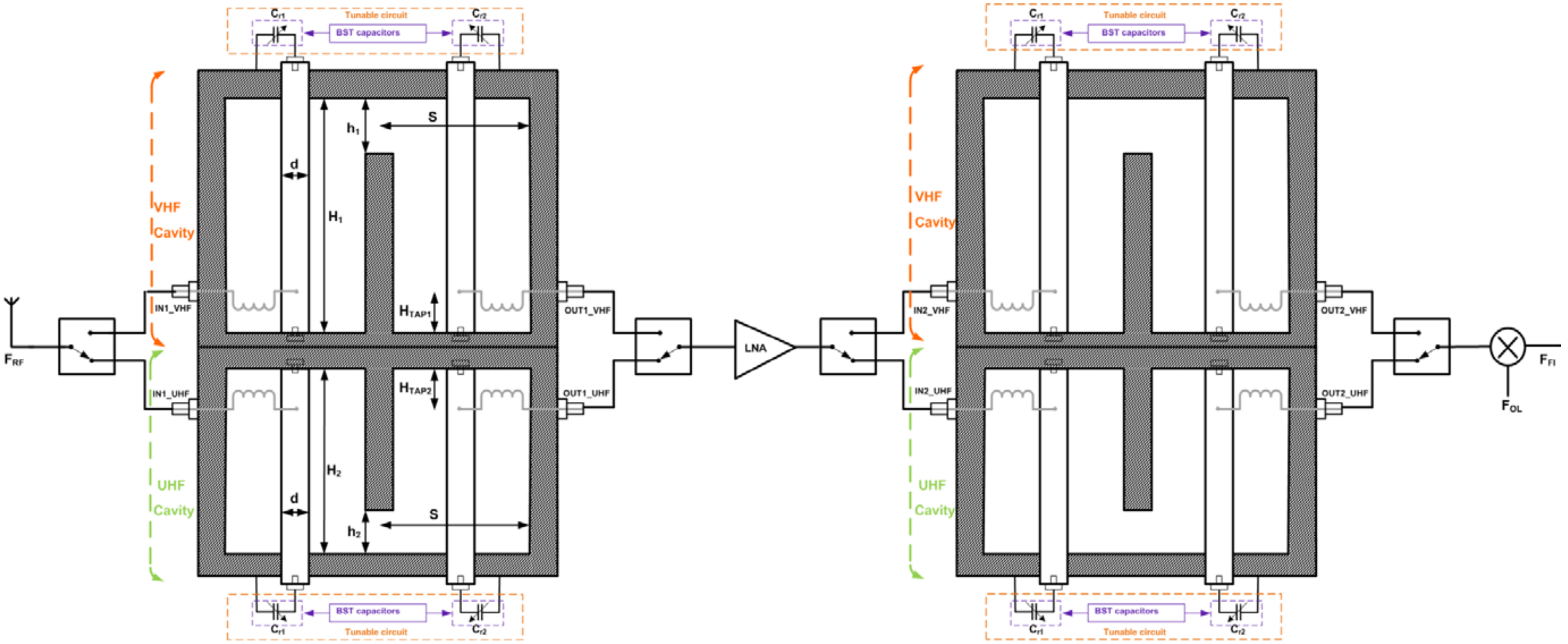
- Tunable bandpass cavities :
  - High selectivity
  - High linearity
  - Reconfigurable architecture





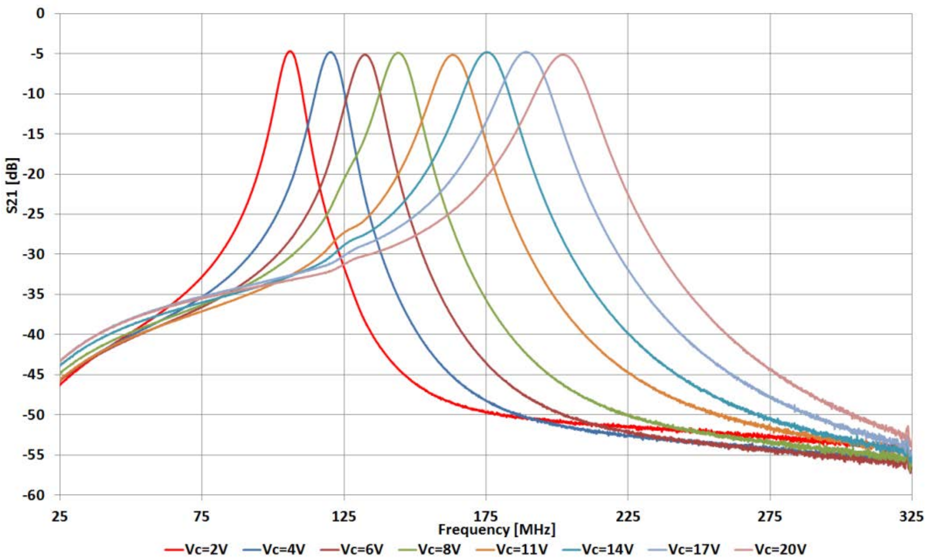
Tunable bandpass cavities

- Design choices :
  - Parallelized architecture (VHF/UHF)
  - BST capacitors implemented to improve linearity
  - Aluminum structure : tradeoff between price vs performance
- Design Methodology :
  - Cavity sizing based on iterative process
  - Characterization of the BST technology
  - CAD (Solid Edge) used to draw the mechanical part of the cavities

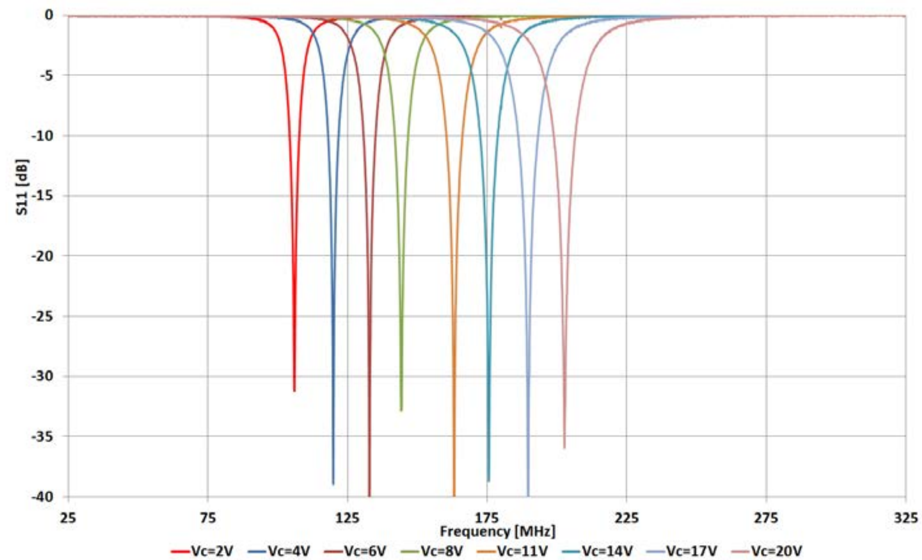


VHF Cavity Performances

- Cover band : 108MHz – 220MHz
- 10 BST capacitors implemented
- Control voltage variation : 2V – 20V
- Cavity performances :
  - **Insertion losses : 4.7dB to 5.2dB**
  - **% Bandwidth -3dB : 5.4% to 5.8%**
  - **S11<-30dB**



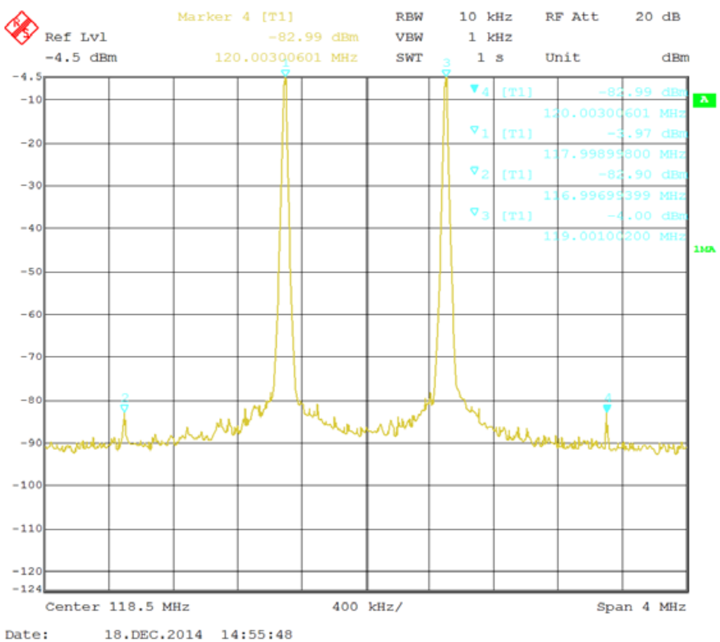
Measured S21 parameters



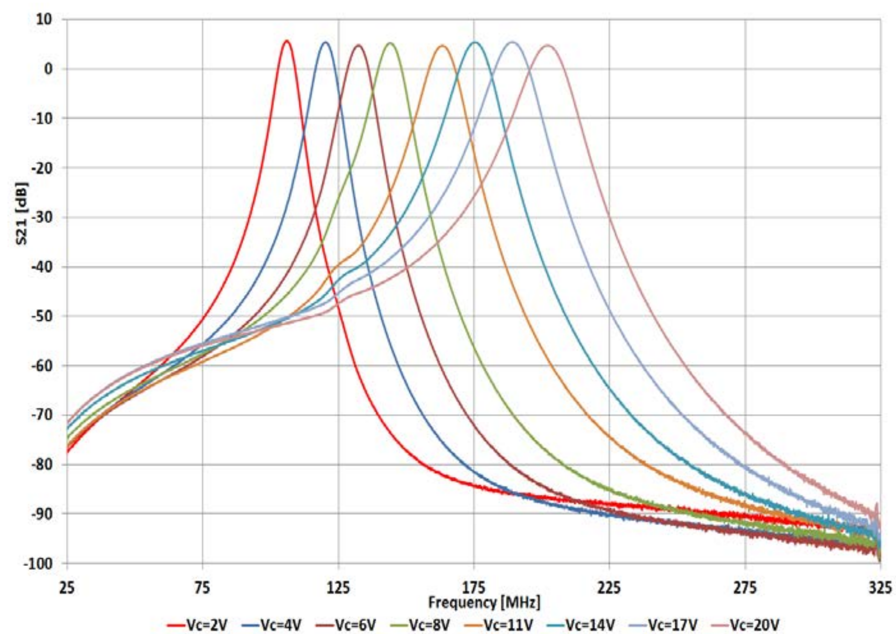
Measured S11 parameters

VHF Cavity Performances

- Cavity linearity performances : IP3>40dBm
- Overall performances
  - **Gain variation: 4.5dB (@108MHz) to 5dB (@220MHz)**
  - **@ +/-40MHz of tuning frequency : 51dB (@220MHz) to 79dB (@108MHz) of rejection**
  - **Noise Figure<6dB**
  - **Power handling : 36dBm**



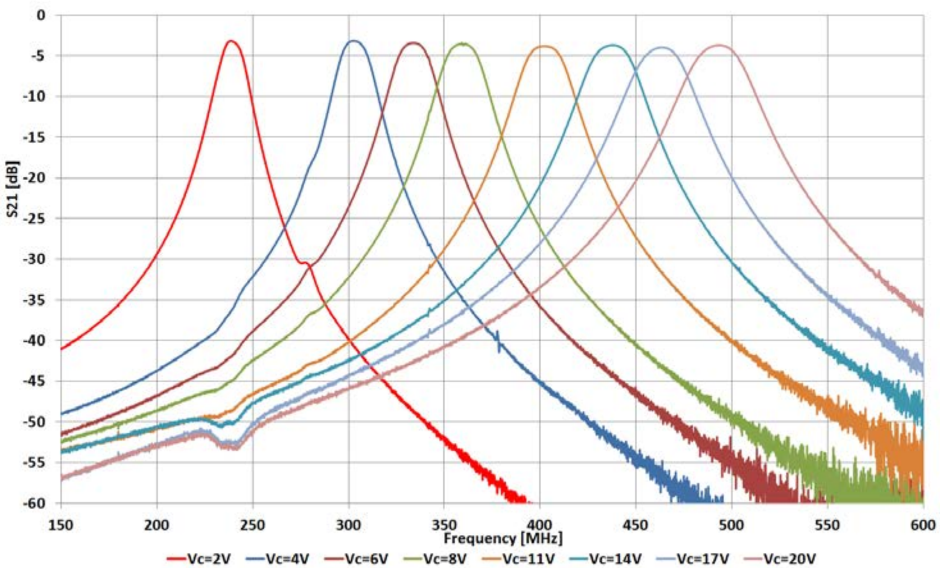
Measured cavity IP3 @ 118MHz



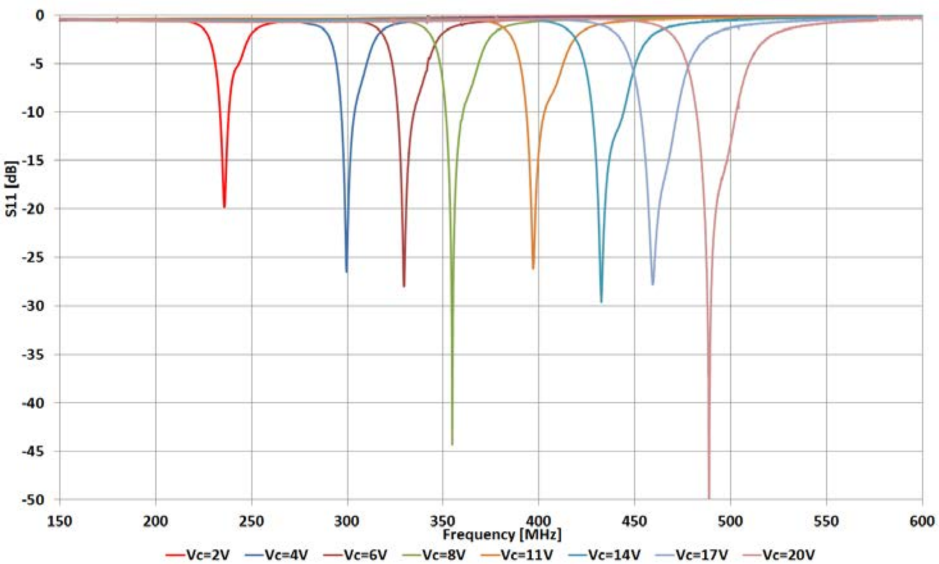
Measured VHF channel S21 parameters

UHF Cavity Performances

- Cover band : 220MHz – 512MHz
- 3 BST capacitors implemented
- Control voltage variation : 2V – 24V
- Cavity performances :
  - **Insertion losses : 3.5dB to 4dB**
  - **% Bandwidth -3dB : 5.3% to 5.7%**
  - **S11<-20dB**



Measured S21 parameters



Measured S11 parameters

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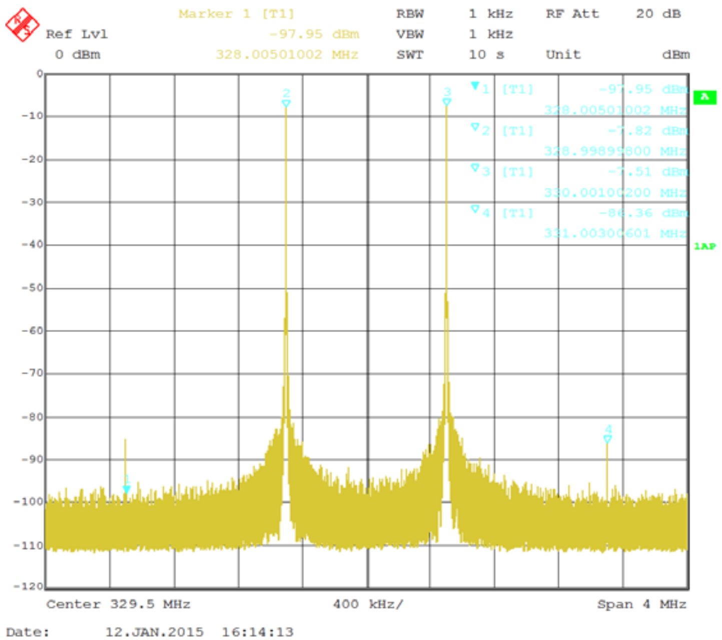
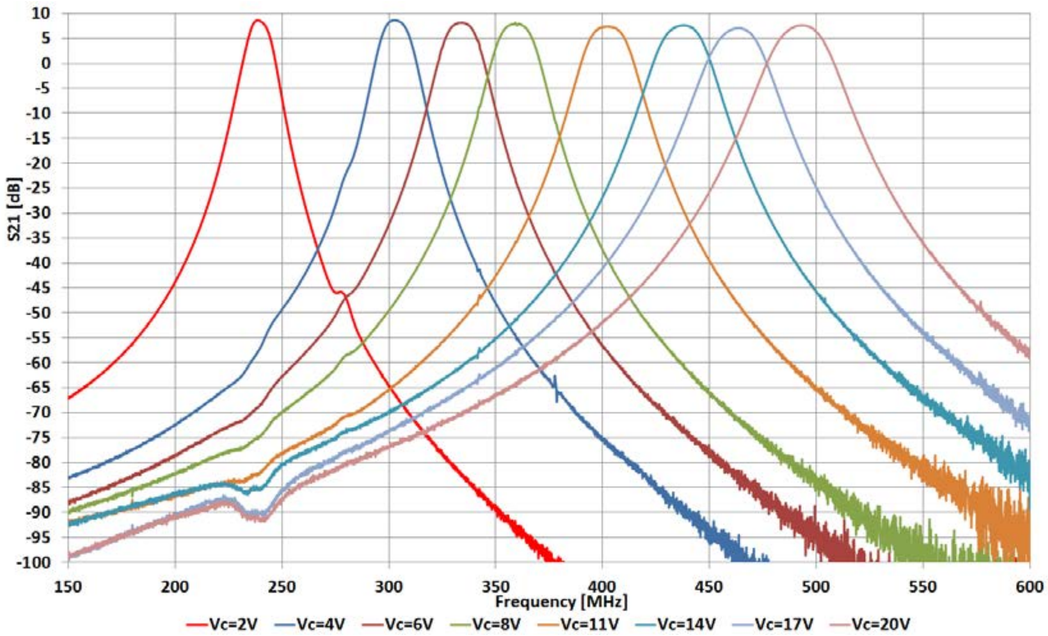
UHF Cavity Performances

- Cavity linearity performances : IP3>35dBm
- Overall performances
  - **Gain variation: 7.6dB (@400MHz) to 8.3dB (@512MHz)**
  - **@ +/-40MHz of center frequency : 32dB (@512MHz) to 54dB (@220MHz) of rejection**
  - **Noise Figure<5dB**
  - **Power handling : 36dBm**



Measured cavity IP3 @ 329.5MHz



Measured UHF channel S21 parameters

Tunable bandpass cavity

- Conclusion :
  - World's first implementation of tunable bandpass cavities using BST technology capacitors
  - Bandwidth covered : 108MHz – 512MHz
  - High selectivity and linearity achieved

- Prospects :
  - Build reconfigurable matching networks to maintain constant gain in the bandwidth covered
  - Commute BST capacitors in the tunable circuits to increased the covered bandwidth
  - Realization of an architecture composed of one channel VUHF

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Thank you for your attention.

Questions ?

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