LABORATOIRE DES TECHNOLOGIES SPATIALES, SYSTÈMES EMBARQUÉS, NAVIGATION ET AVIONIQUE

Design of Integrated Mode S Transponder, ADS-B and Distance Measuring Equipment Transceivers

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Track 4:

Surveillance & Situational Awareness

Session F:

Surveillance Systems and Technologies II

Outline

1. Introduction
2. Receiver Design
3. Transmitter Design
4. Antenna/Duplexer Design
5. Conclusion

1. Introduction

Benefits of SDR for Aviation

- Minimization of SWaP-C requirements
  - GHG emissions reduction
  - Design, development and installation time and cost
  - Maintenance, repair and modernization time and cost
- Reprogrammability & reconfigurability
  - Seamless transition to new standards
- Scalability
- Reduced number of parts
  - Increased reliability

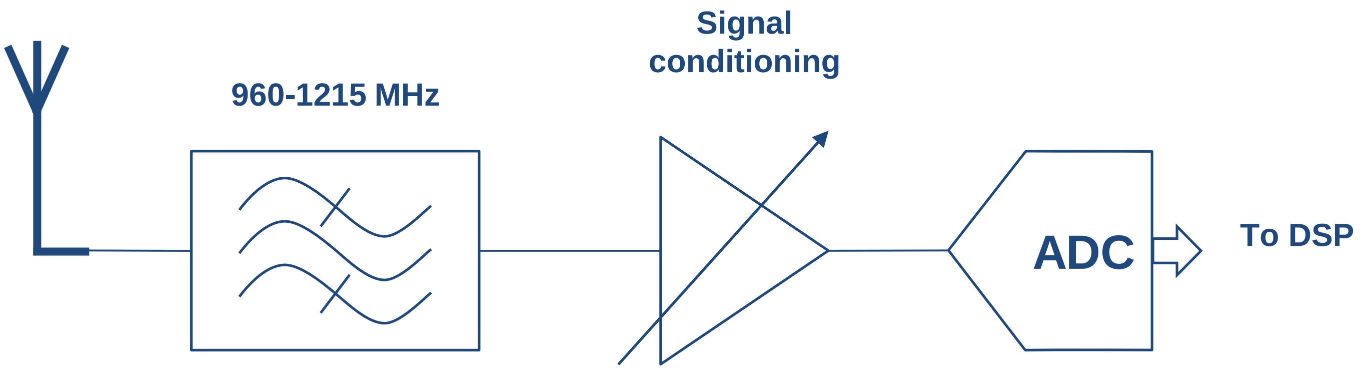
1. Introduction

Context of the Work

AVIO-505 project

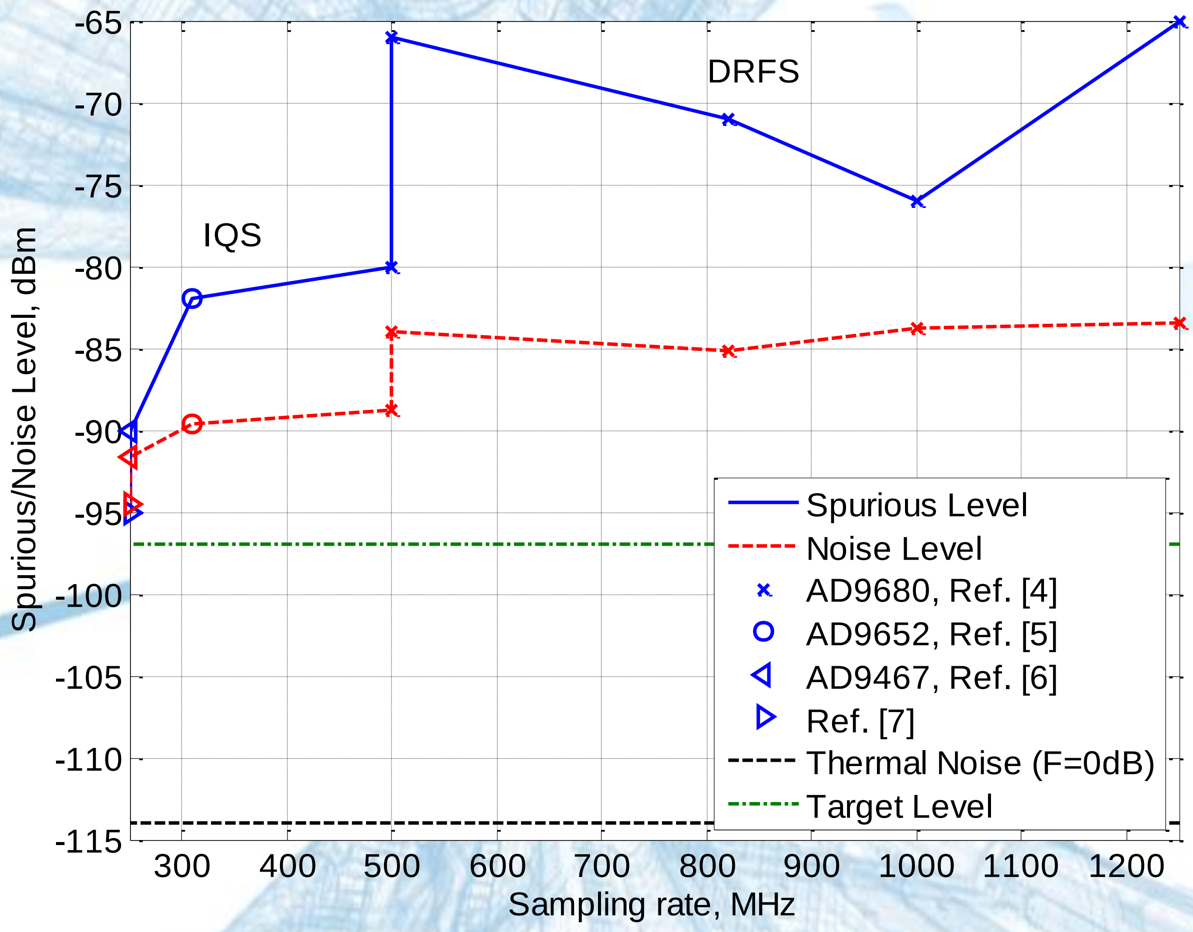
- "Software defined radios for highly integrated system architecture"
- Objectives:
  - Integration of navigation, communication and surveillance systems under a single universal reconfigurable platform
  - Demonstrate the capabilities and performance of SDR in aerospace
  - Address new regulatory initiatives (NextGen)
- Partners:
  - Academic: ETS Montreal, Ecole Polytechnique Montreal, UQAM
  - Industrial: Bombardier, MDA, Marinvent Corporation

SDR: ADC next to the Antenna

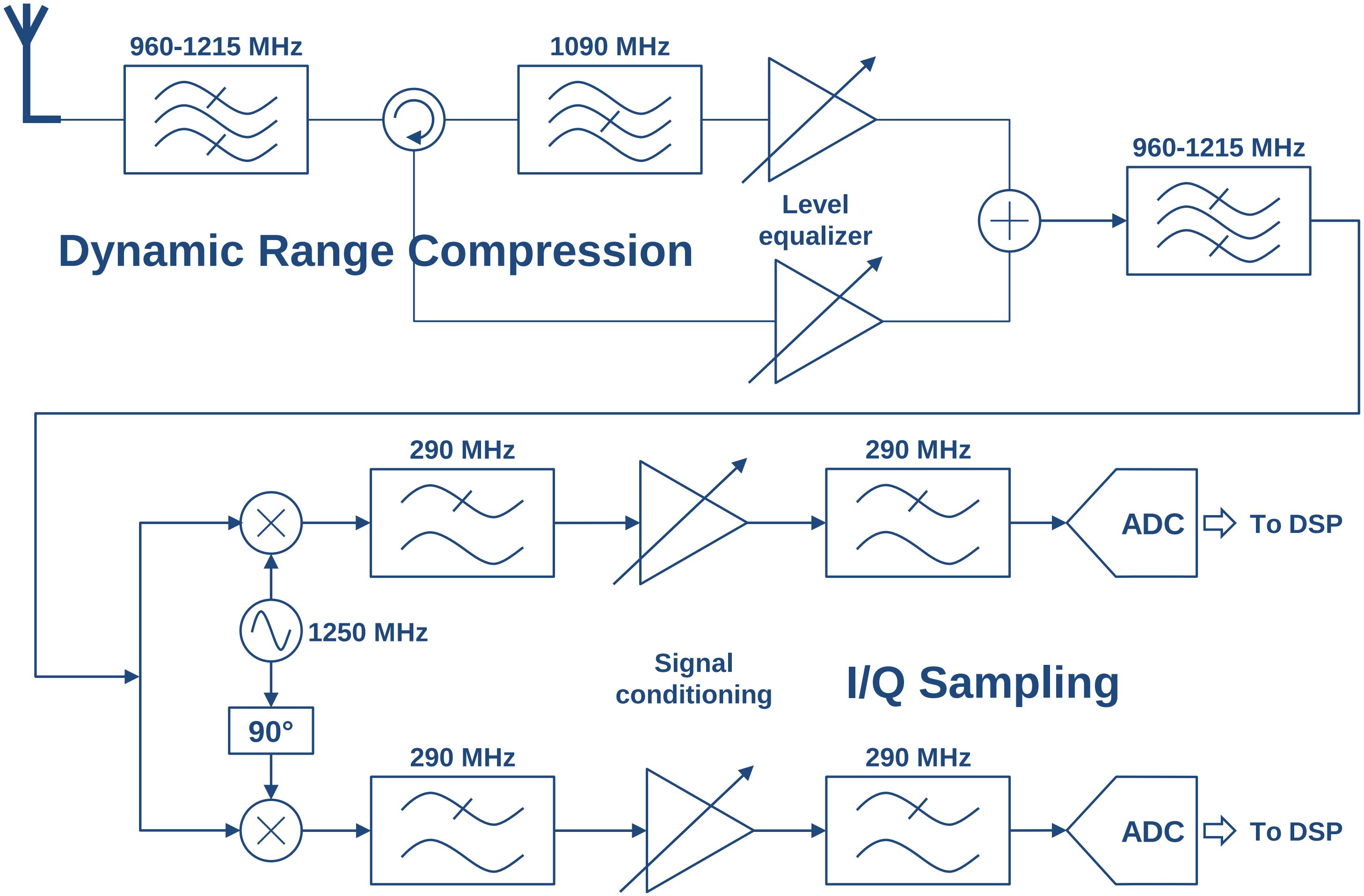


- Required dynamic range
  - 100 dB (3 dBm to -97 dBm)
- Minimum sampling frequency
  - DRFS: 607.5 MHz
  - I/Q sampling: 255 MHz

ADC State-of-the-Art



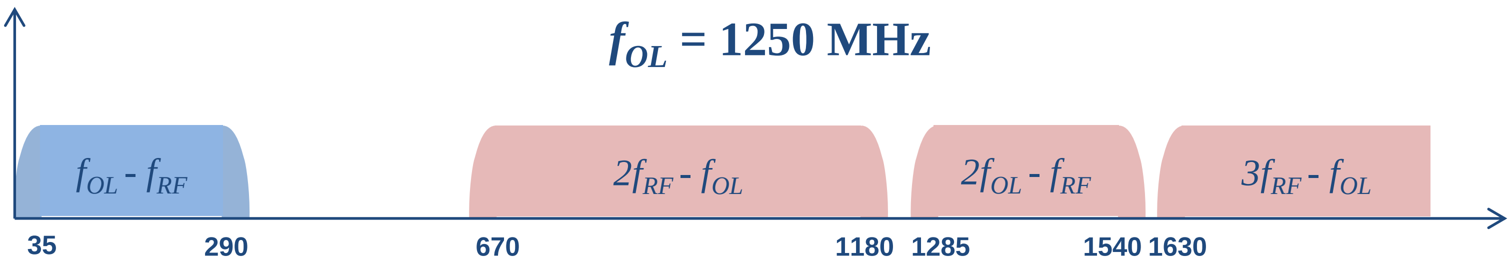
Architecture



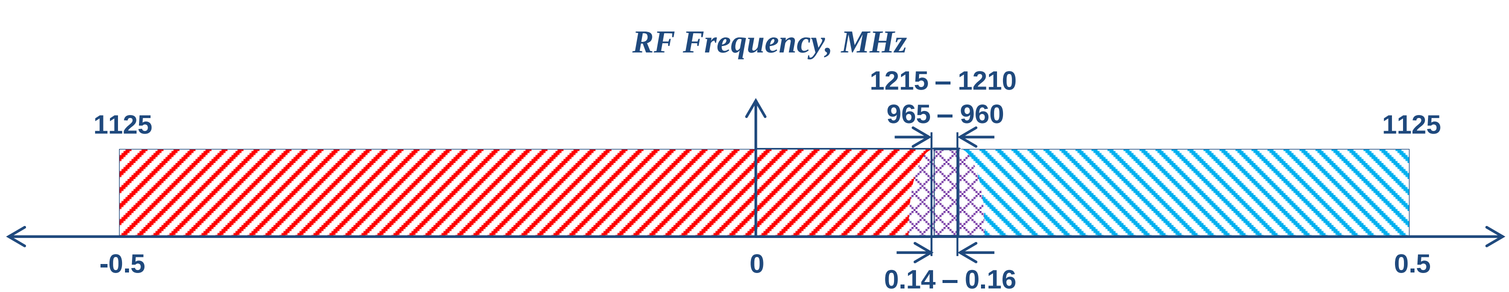
2. Receiver Design

Down Conversion

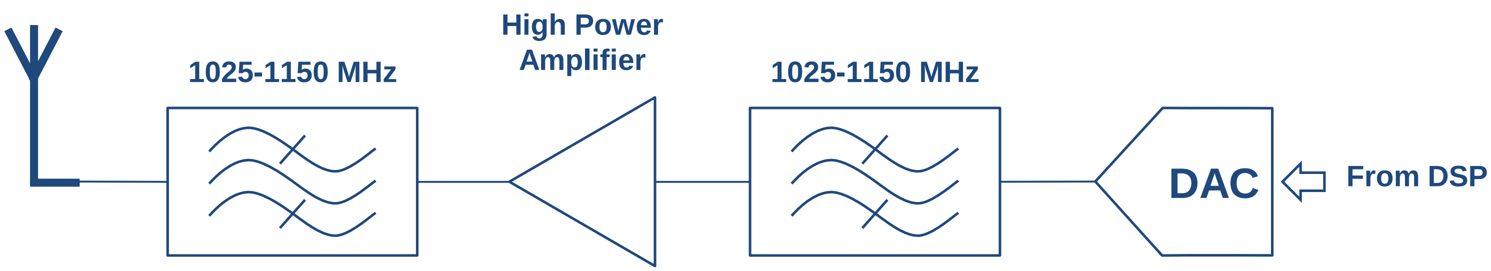
f_{OL} = 1250 MHz



f_s = 250 MHz



Architecture



- Spurious emission level
  - 60 dBc
- TDMA technique
  - Only one subsystem at a time

3. Transmitter Design

TDMA Feasibility

"First-come, first-served"

Subsystem	Successful Transmission Rate	PRF
Mode S	100.0 %	50-75 Hz
ATCRBS	99.5 %	1000-1200 Hz
ADS-B	99.4 %	5-10 Hz
DME	92.3 %	125-150 Hz

4. Antenna/Duplexer Design

Requirements / TDD

- Tx/Rx signals cannot be separated in the frequency domain
- Required Isolation
  - 61 dB
  - Antenna separation: 88 m
  - *(Promising experimental works based on Tx signal cancellation [1]-[3])*
- Time-Domain Division (TDD)
  - Antenna switches to **Tx mode IF** in **Rx mode AND**:
    - After successfully receiving an ATCRBS / Mode S interrogation
    - A DME interrogation begins
    - An ADS-B message (Mode S ES) begins
  - **Otherwise** transmission is aborted
  - Antenna switches to **Rx mode**:
    - At the end of current transmission

4. Antenna/Duplexer Design

TDD Feasibility

Subsystem	A	B	C	D	E
Mode S	99.1 %	99.4 %	98.9 %	98.9 %	91.6 %
ATCRBS	99.1 %	99.1 %	99.2 %	99.1 %	97.7 %
ADS-B Out	99.5 %	99.4 %	99.3 %	99.5 %	99.3 %
ADS-B In	97.6 %	97.3 %	95.0 %	90.8 %	90.0 %
DME	99.5 %	99.5 %	95.4 %	92.2 %	99.5 %

A. Only interference between DME and other subsystem considered (Results referred to most common installation)

B. A + interference between ADS-B In and other subsystem (Results referred to isolated ADS-B In installation)

C. B + Non-rotating Mode-S SSR antenna (Peak interrogation)

D. C + Non-rotating ATCRBS SSR antenna (Peak interrogation)

E. B + interference between any subsystem with each other (raw successful rate)

Conclusion

- Software Defined Radio benefits to aviation
  - Reduced operation costs
  - Open the door to multi-standard scenario for CNS modernization
- Current ADC technology
  - Cannot implement DRFS
  - Dynamic Range compression in the analog domain
- Current DAC technology enables DRFS
- TDMA techniques allows for HPA sharing
- Antenna sharing feasible through TDD

Future work

- Implementation of the analog front-end with COTS parts
- Integration with fast prototyping SDR platforms
- Lab Tests
- Flight Tests

References

1. S. K. Hong et al., "**Applications of self-interference cancellation in 5G and beyond**," in *IEEE Communications Magazine*, vol. 52, no. 2, pp. 114-121, February 2014.

2. O. N. Alrabadi, A. D. Tatomirescu, M. B. Knudsen, M. Pelosi and G. F. Pedersen, "**Breaking the Transmitter–Receiver Isolation Barrier in Mobile Handsets With Spatial Duplexing**," in *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 4, pp. 2241-2251, April 2013.

3. W. G. Lim, H. L. Lee and J. W. Yu, "**Transmitter and Receiver Isolation by Concentric Antenna Structure**," in *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 10, pp. 3182-3188, Oct. 2010.

4. Analog Devices, **"AD9680 14-Bit, 1.25 GSPS/1 GSPS/820 MSPS/500 MSPS JESD204B, Dual Analog-to-Digital Converter,"** *Data Sheet*. 2015.

5. Analog Devices, **"AD9652 16-Bit, 310 MSPS, 3.3 V/1.8 V Dual Analog-to-Digital Converter (ADC),"** *Data Sheet*. 2013.

6. Analog Devices, **"AD9467 16-Bit, 200 MSPS/250 MSPS Analog-to-Digital Converter,"** *Data Sheet*. 2013.

7. A. M. A. Ali *et al.*, **"A 16-bit 250-MS/s IF Sampling Pipelined ADC With Background Calibration,"** in *IEEE Journal of Solid-State Circuits*, vol. 45, no. 12, pp. 2602-2612, Dec. 2010.

Questions?

Thank you

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