Multiband Direct RF Sampling for 5G and Beyond MIMO Receivers

Presented by

Professor Timothy O'Farrell

Email: T.OFarrell@sheffield.ac.uk

with

Dr Stephen Henthorn, Dr Reza Mohammadkhani, Professor Lee Ford

Department of Electronic & Electrical Engineering,
University of Sheffield, UK

26 May 2021

Presentation Outline

- Introduction
- Conventional Multiband Receivers
- Direct RF Sampled Multiband Receivers
- Conventional MIMO Receivers
- Direct RF Sampled MIMO Receivers
- Conclusions

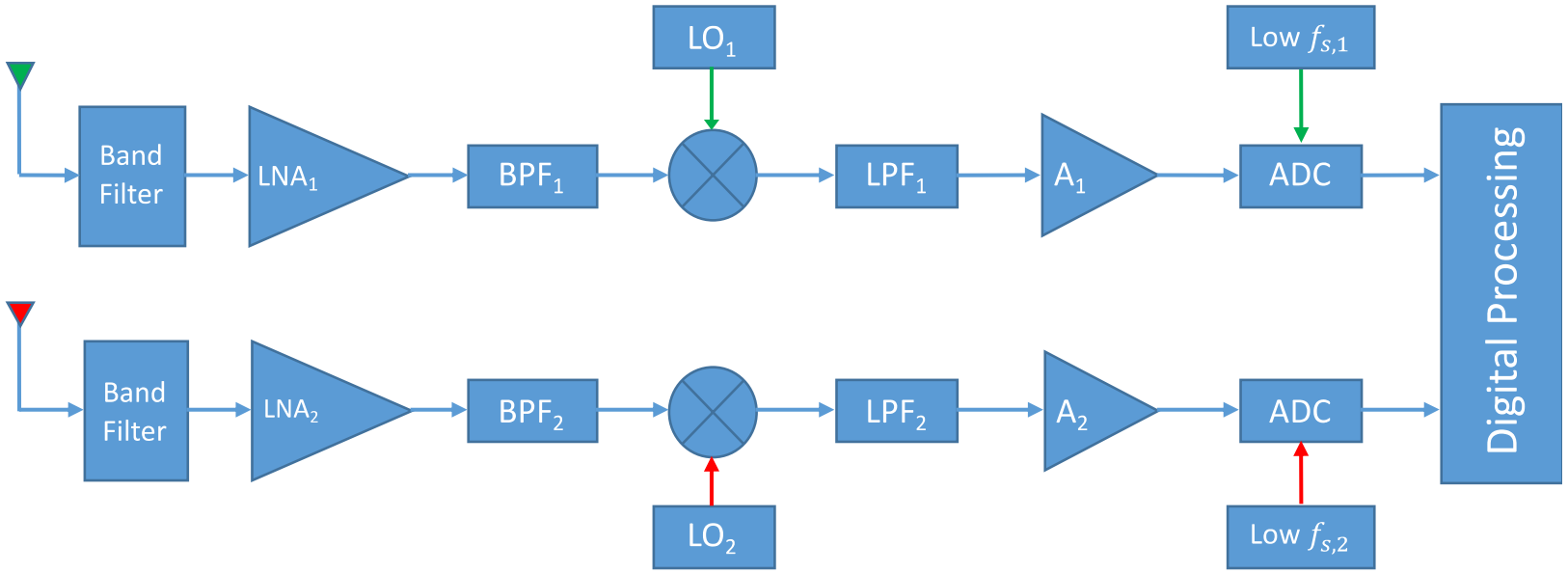
Introduction

- The work summarised here originates from 4 major projects
  - Green Radio (EPSRC/mVCE, EP/G064105/1, 2009-12)
  - Networks of Sensors (NERC, NE/I007148/1, 2011-15)
  - FARAD (EPSRC, EP/M013723/1, 2015-19)
  - DDmmMaMi (EPSRC, EP/S008101/1, 2019-2021)
- The work contains a significant RF hardware component.
- The work addresses complexity, cost and power consumption challenges in concurrent, multiband receivers.

Direct RF Sampling Multiband Receiver Concept

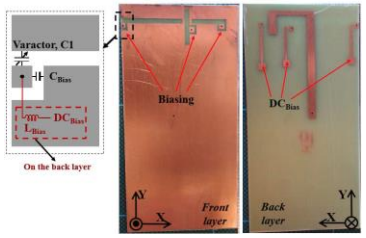
- AIM: To develop frequency agile, concurrent, multiband, direct RF sampling/subsampling receivers for use in LTE and 5GNR (e.g. support carrier aggregation, dual connectivity in HetNets or fully digital MIMO).
- Rationale: To reduce receiver cost, complexity and energy consumption by reducing RF and ADC component count.
- Solutions: Introduce direct RF digitisation using either Nyquist or sub-band sampling and frequency agility in the antenna and BPFs to realise software defined receivers. Specifically,
  - Concurrent, multiband, tuneable slot antenna;
  - Minimal RF circuitry to support concurrent, multiband signal conditioning;
  - Direct RF digitisation using wideband ADCs
  - Nyquist or sub-band sampling;
  - Digital downconversion (DDC) using NCO and comb filtering per channel;
  - BB processing per channel to recover data;
  - Demonstrated in a hardware-in-the-loop (HWIL) testbed.

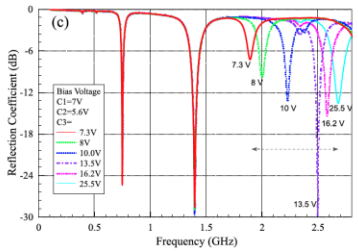
Conventional Multiband Receiver

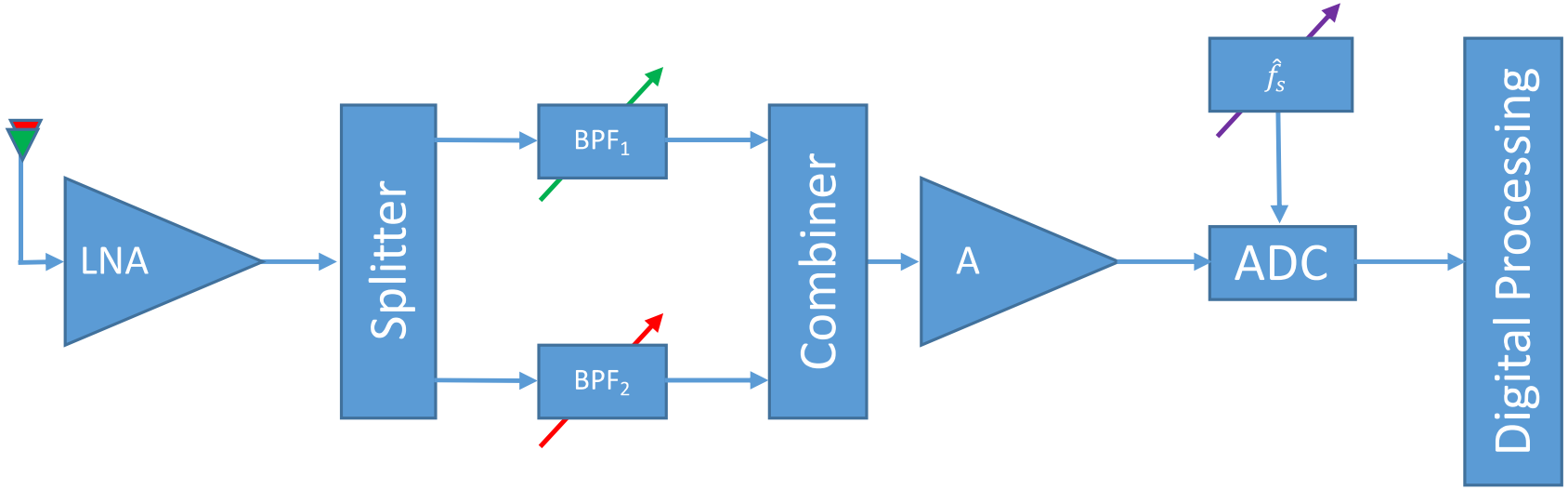


Direct RF Sampled Multiband Receiver

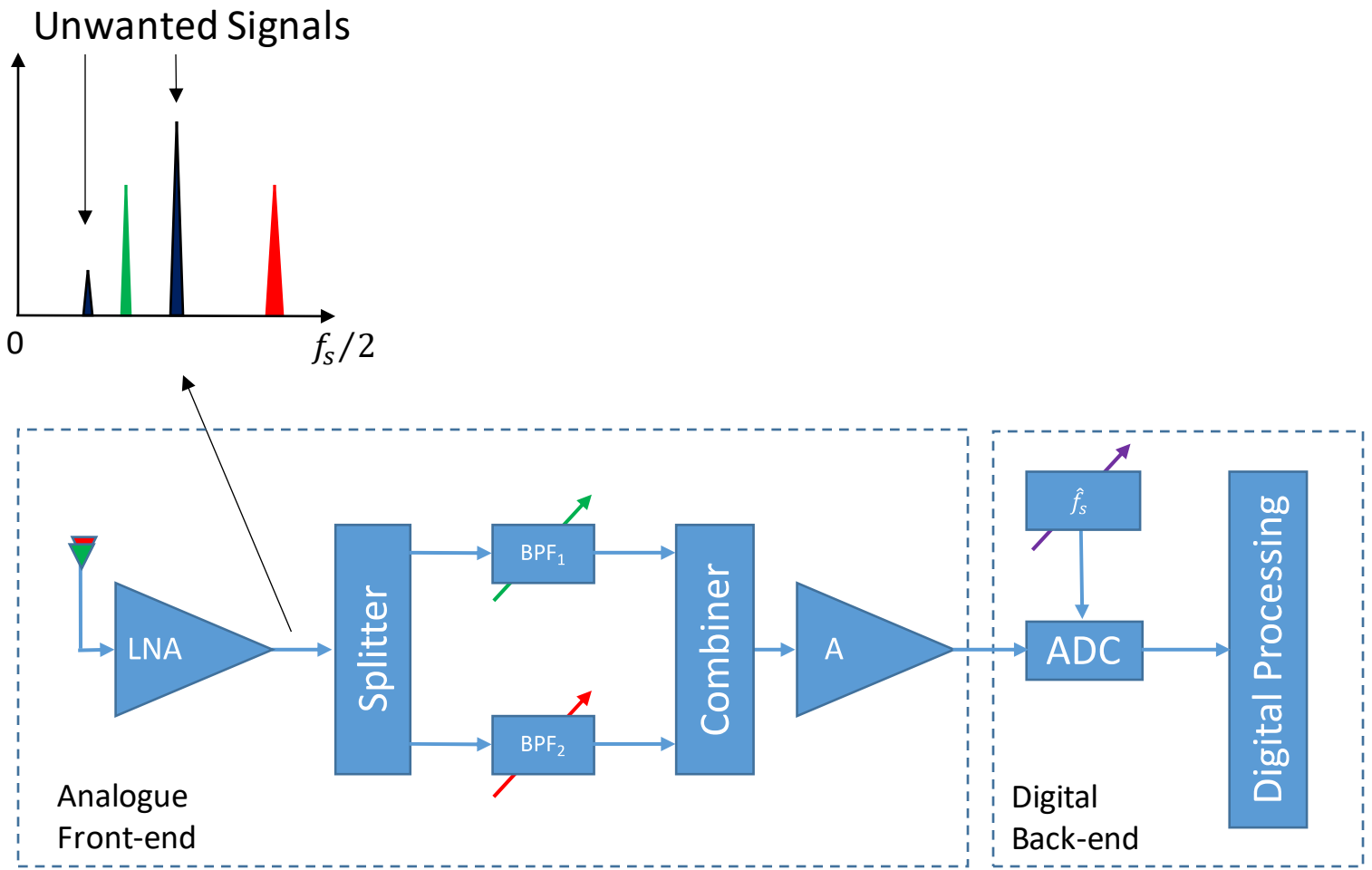
Tuneable Multiband Antenna



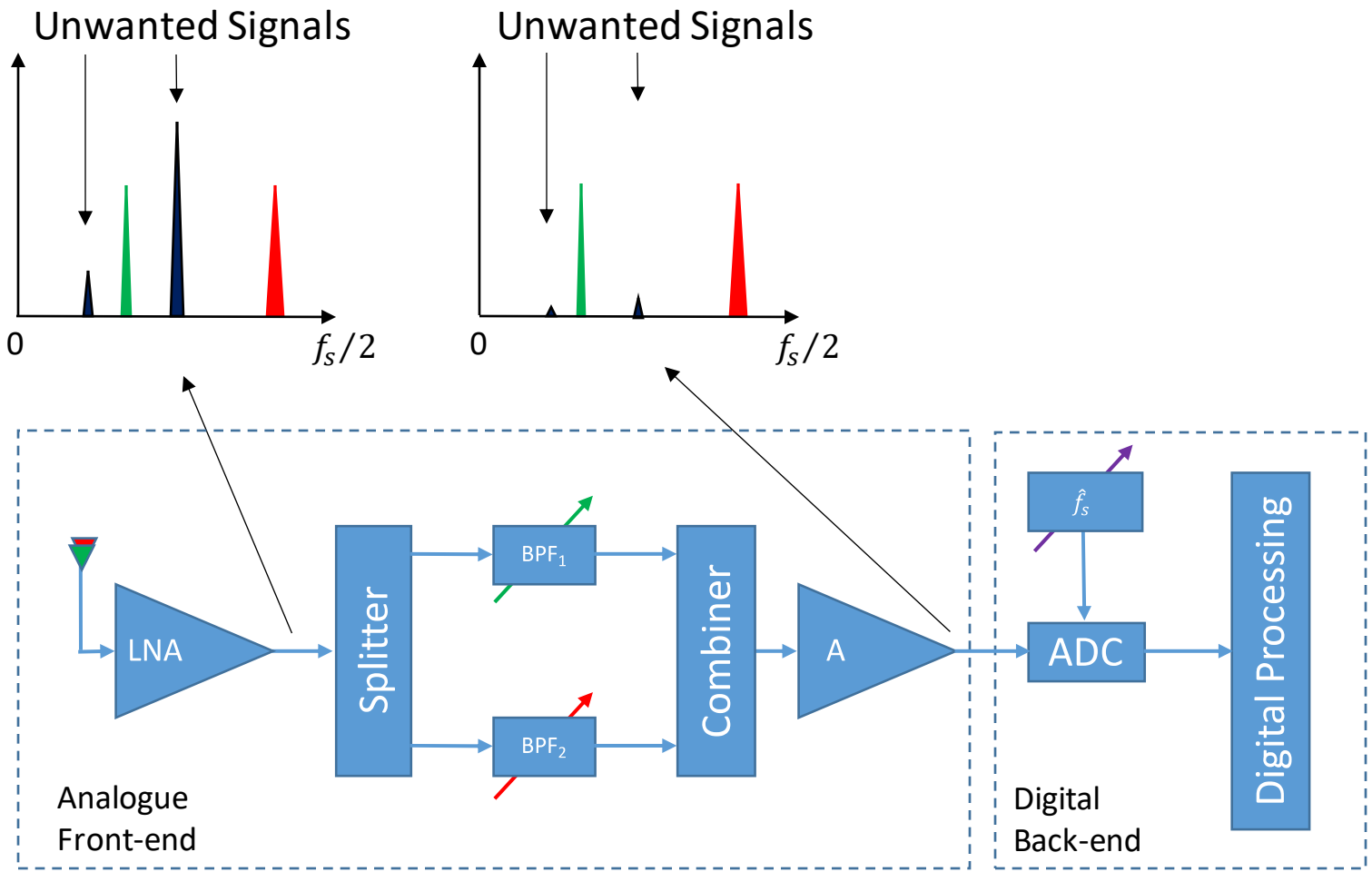




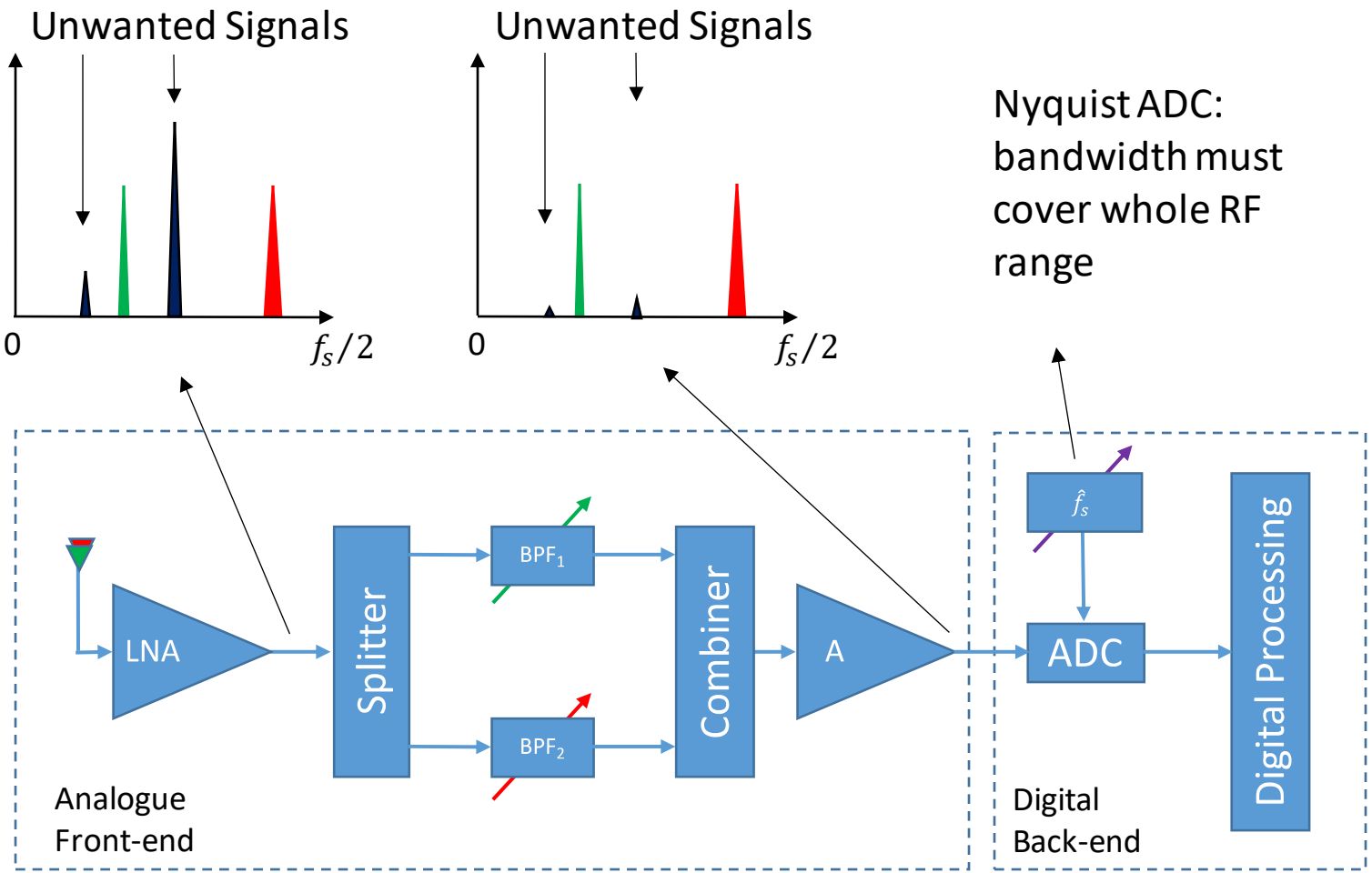
Nyquist Direct RF Sampling Multiband Receiver



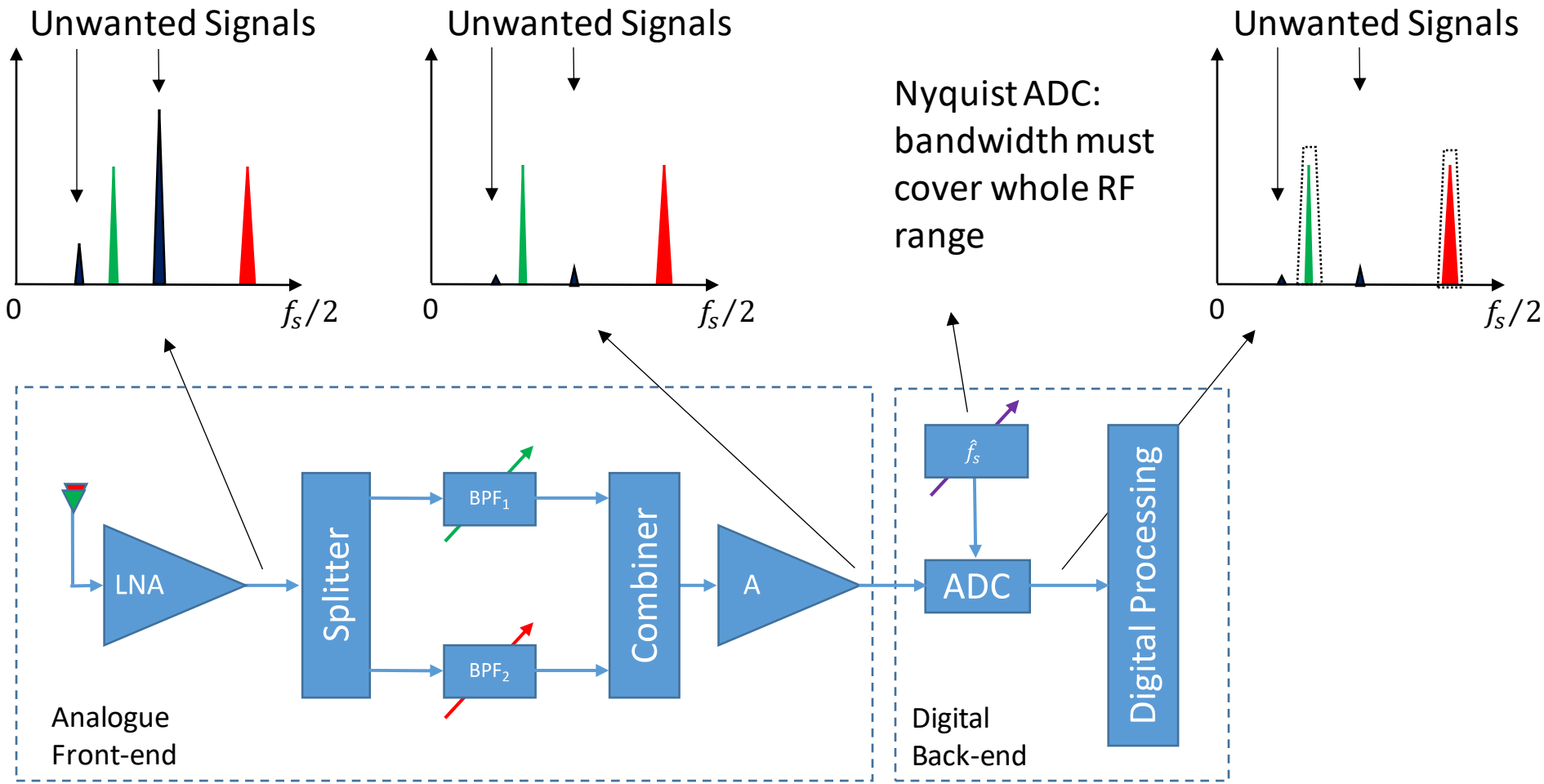
Nyquist Direct RF Sampling Multiband Receiver



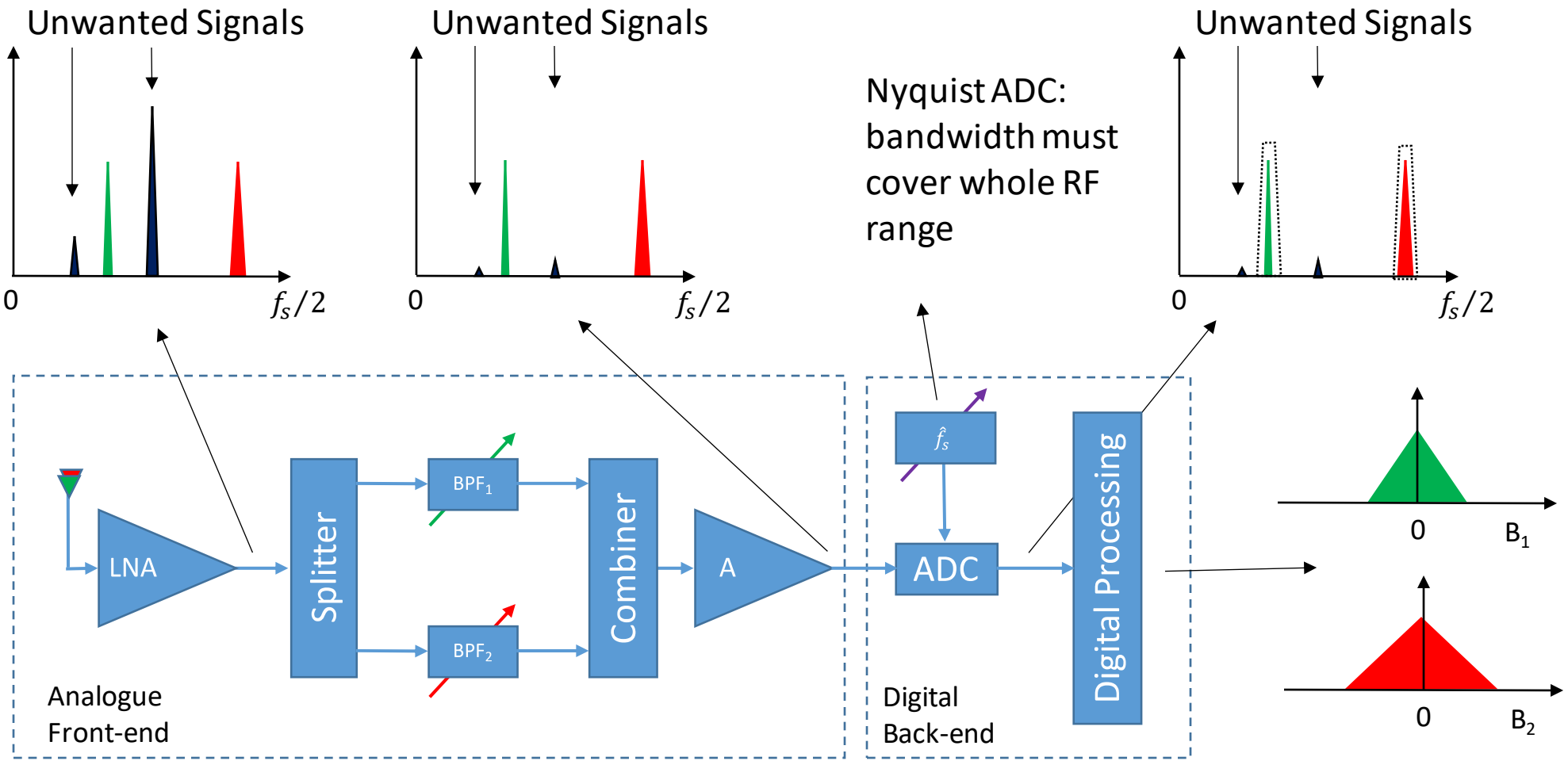
Nyquist Direct RF Sampling Multiband Receiver



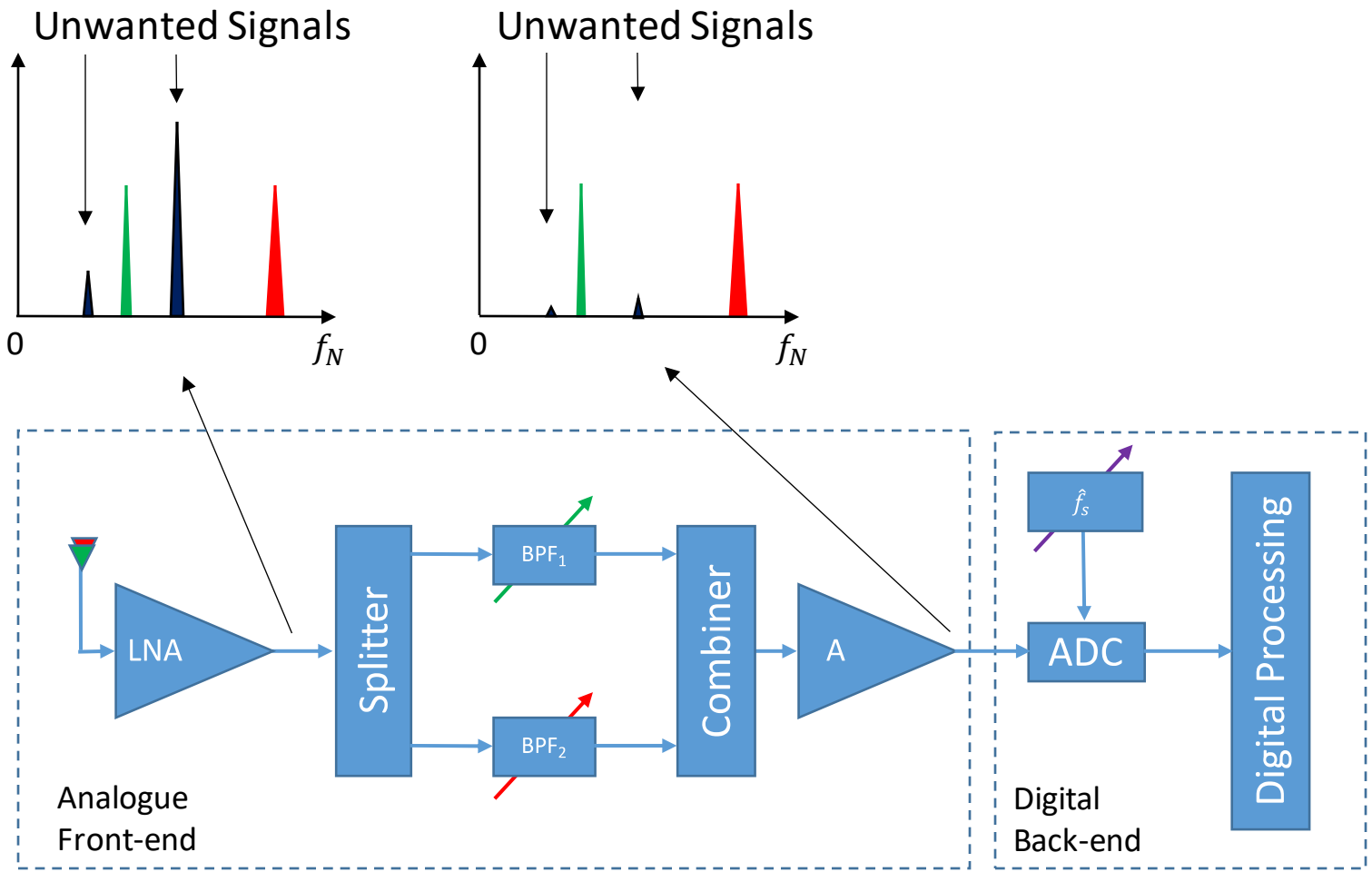
Nyquist Direct RF Sampling Multiband Receiver



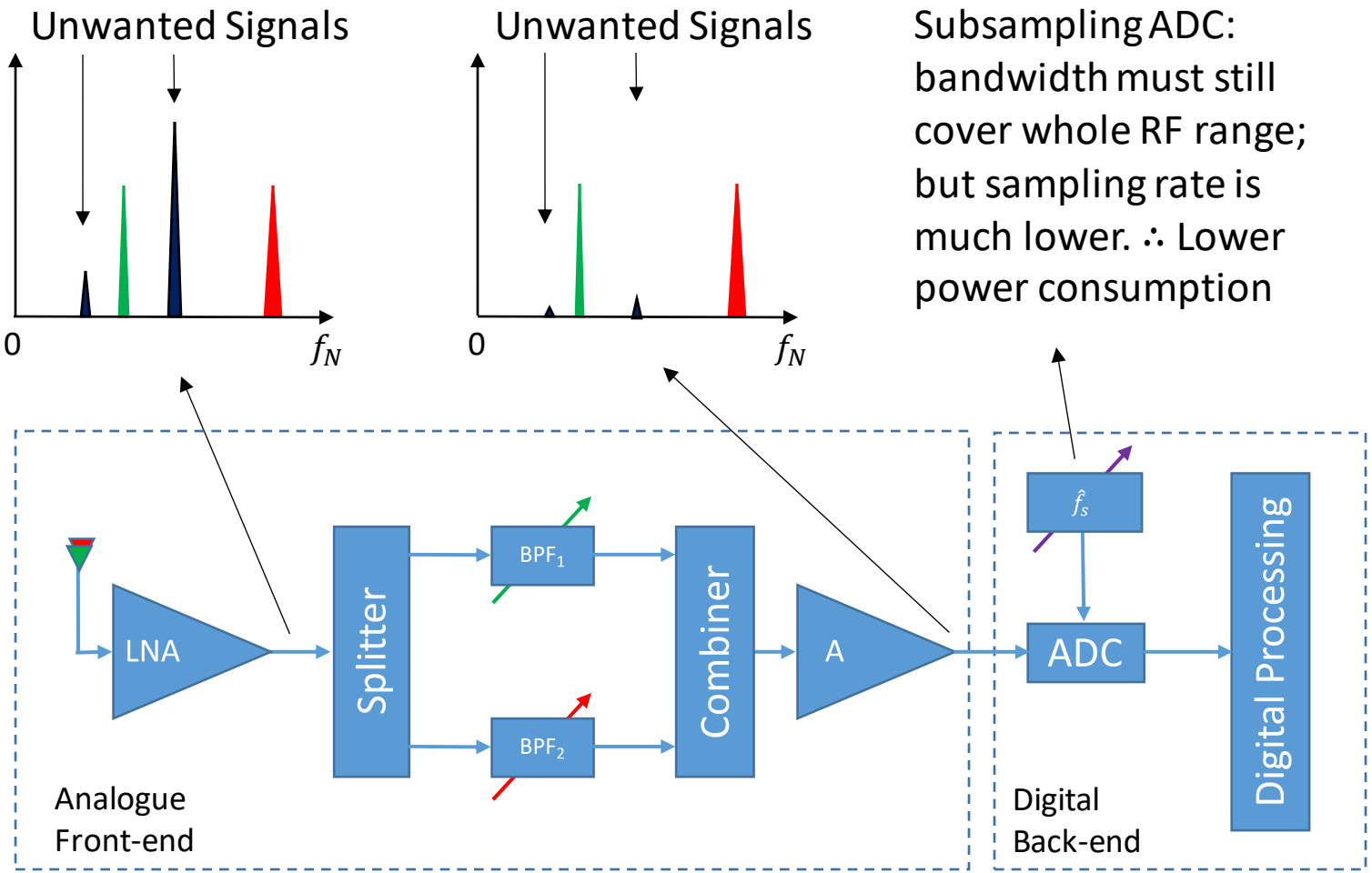
Nyquist Direct RF Sampling Multiband Receiver



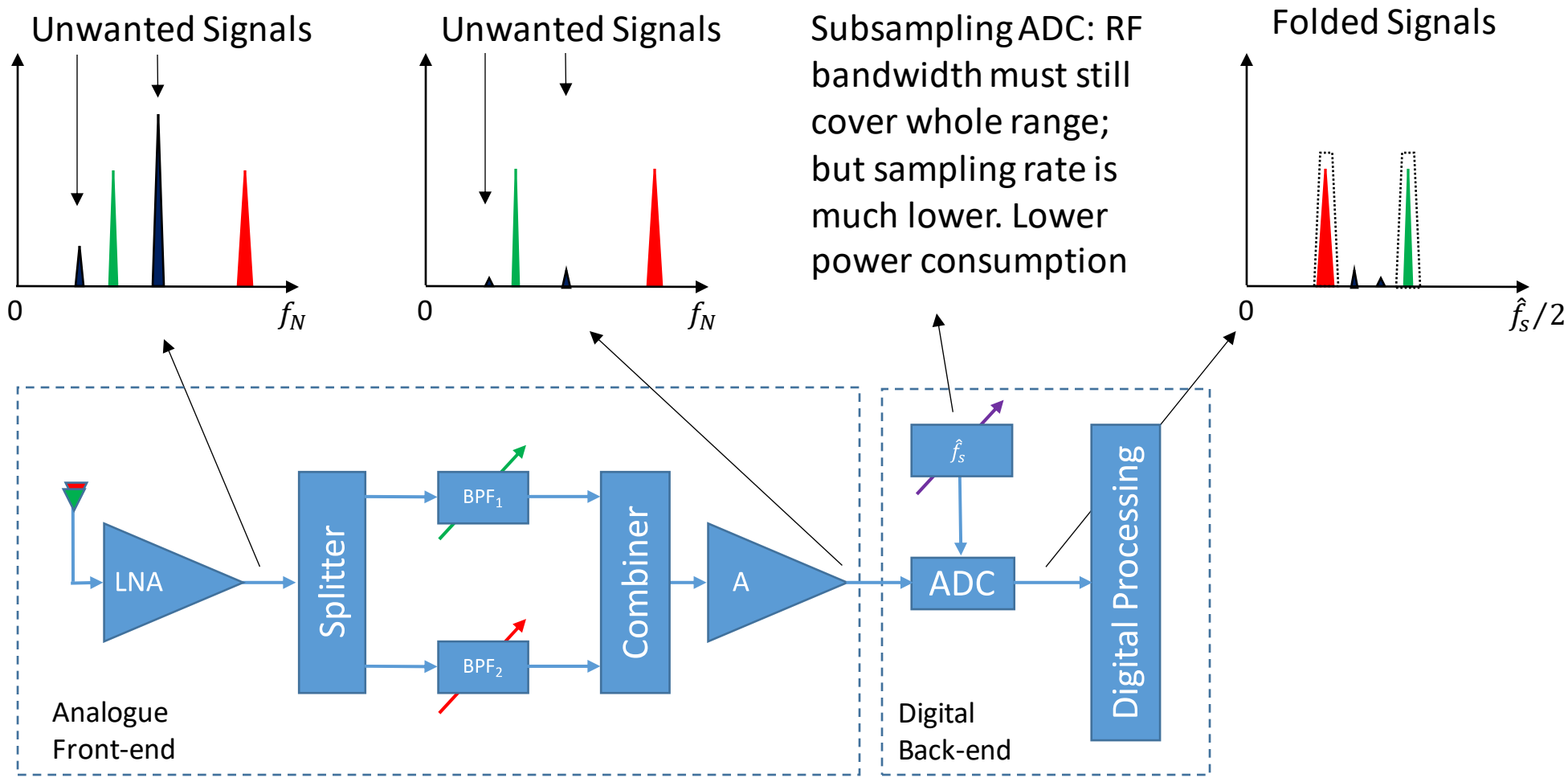
Sub-band Direct RF Sampling Multiband Receiver



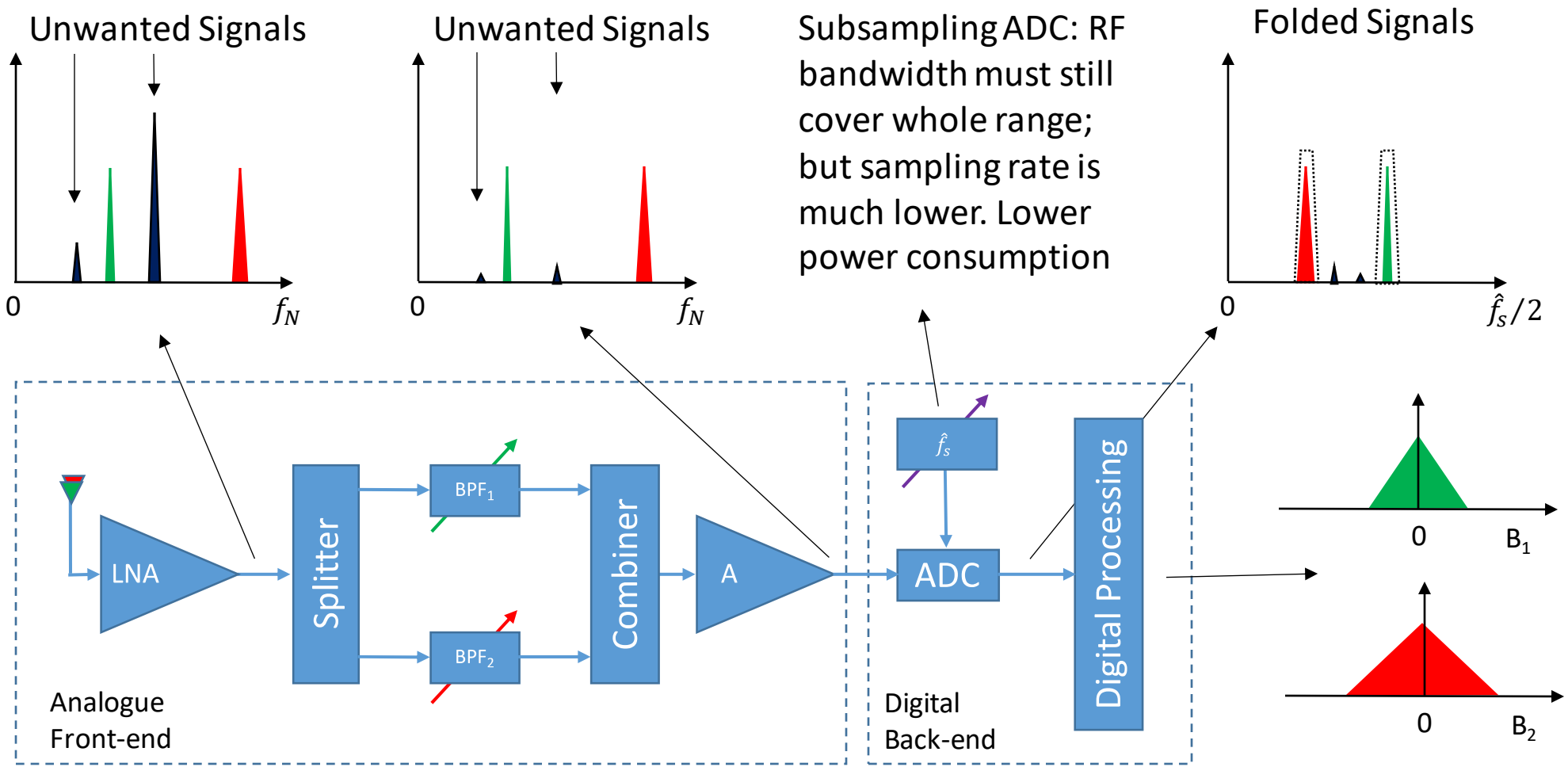
Sub-band Direct RF Sampling Multiband Receiver



Sub-band Direct RF Sampling Multiband Receiver



Sub-band Direct RF Sampling Multiband Receiver

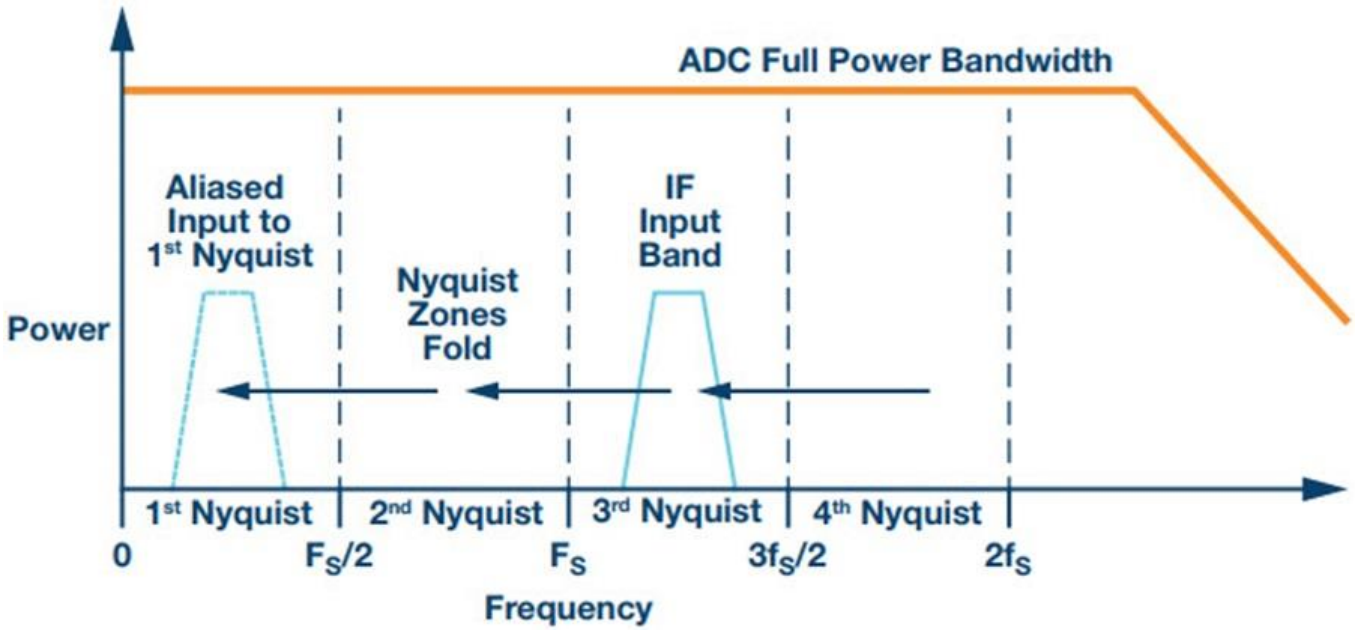


Sub-band Direct RF Sampling Multiband Receiver

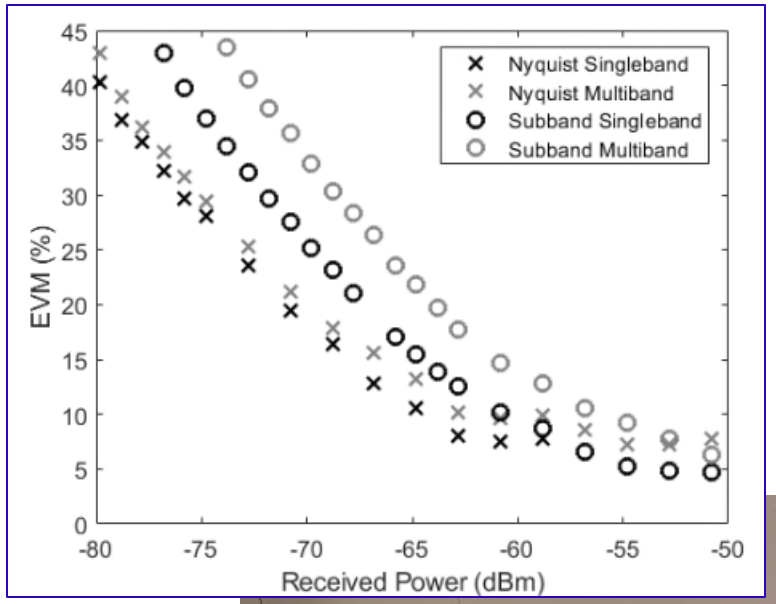
It's not just signals that are aliased into sampling bandwidth

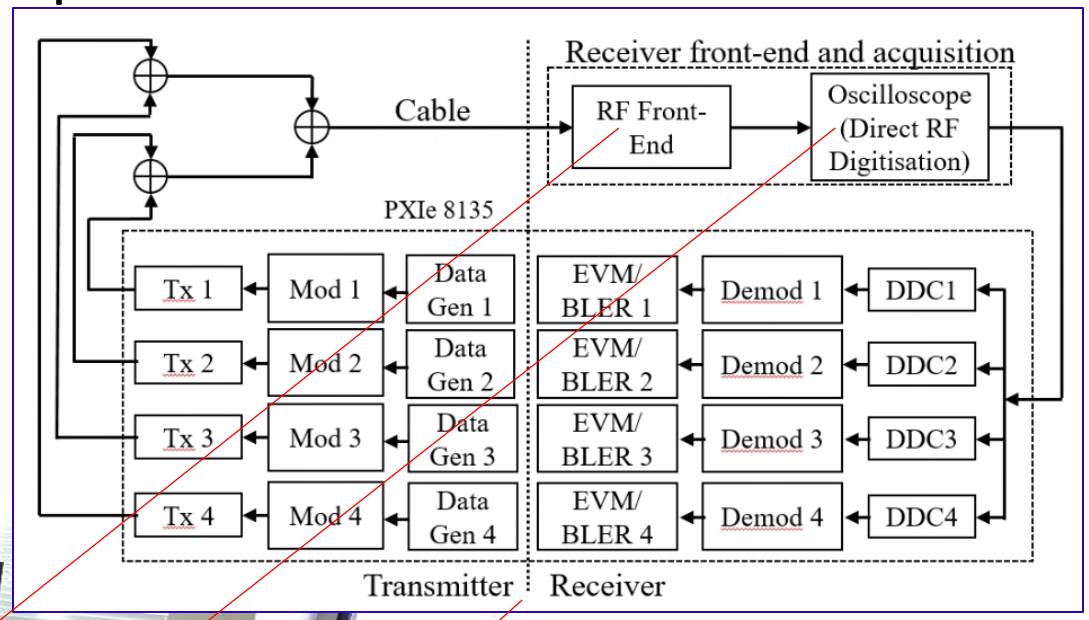
- Also Noise
- So increase in RF noise of up to m times, $m = \left(\left\lfloor \frac{2f_{max}}{\hat{f}_s} \right\rfloor - 1\right)$

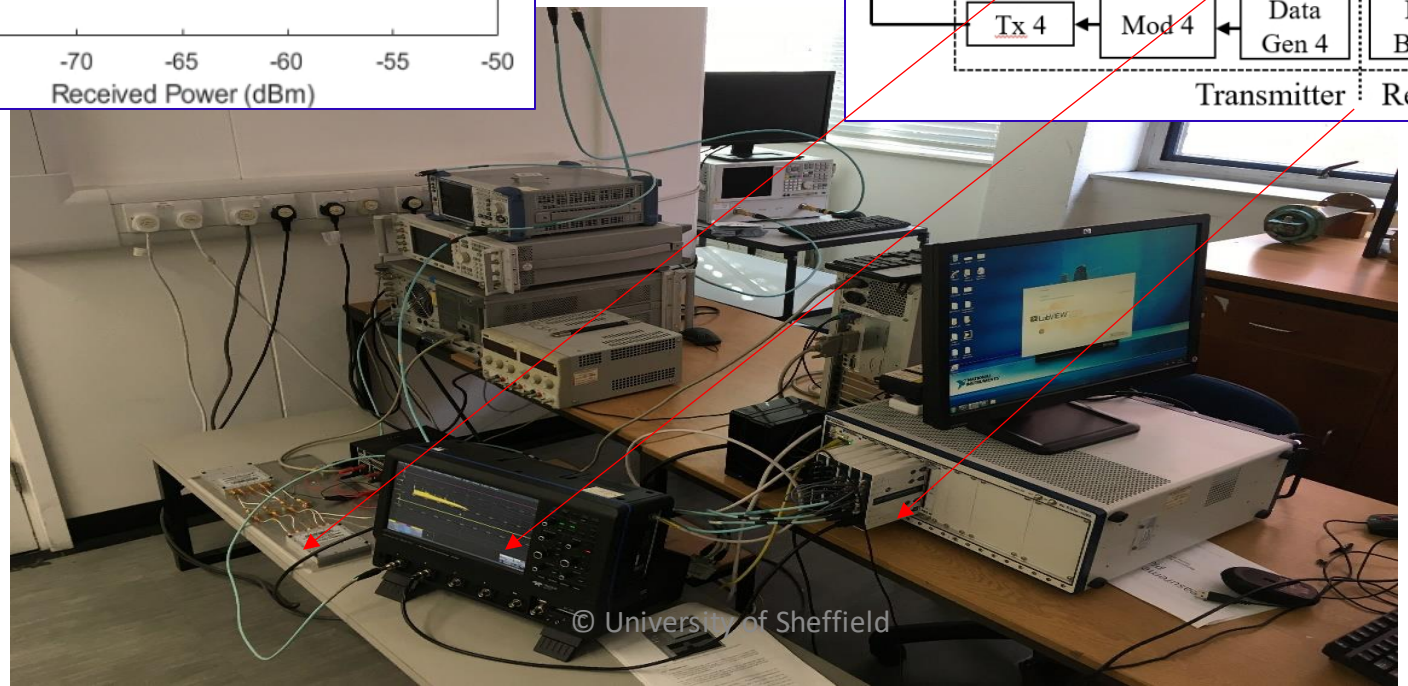
ADC RF bandwidth



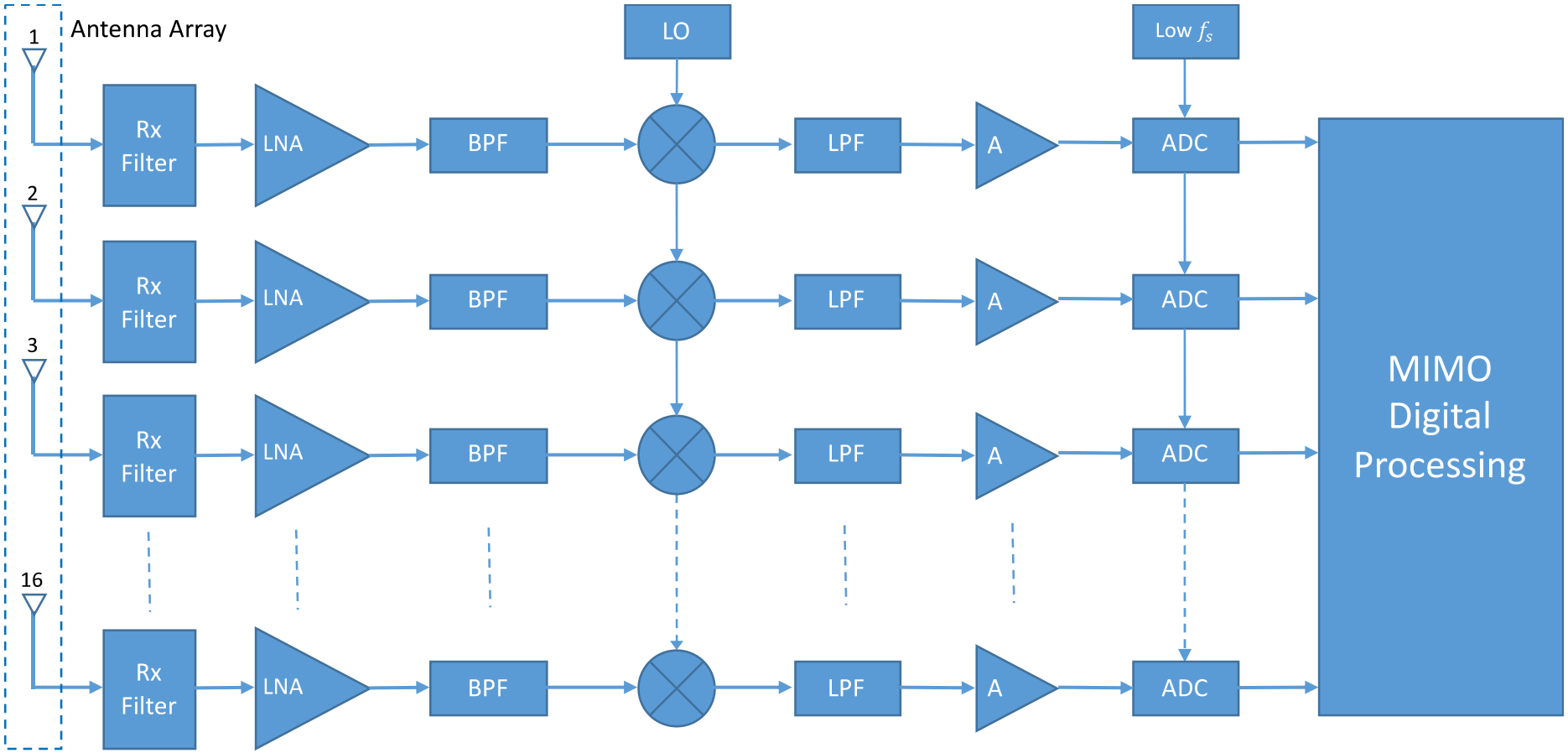
Multiband Hardware-in-the-Loop Testbed



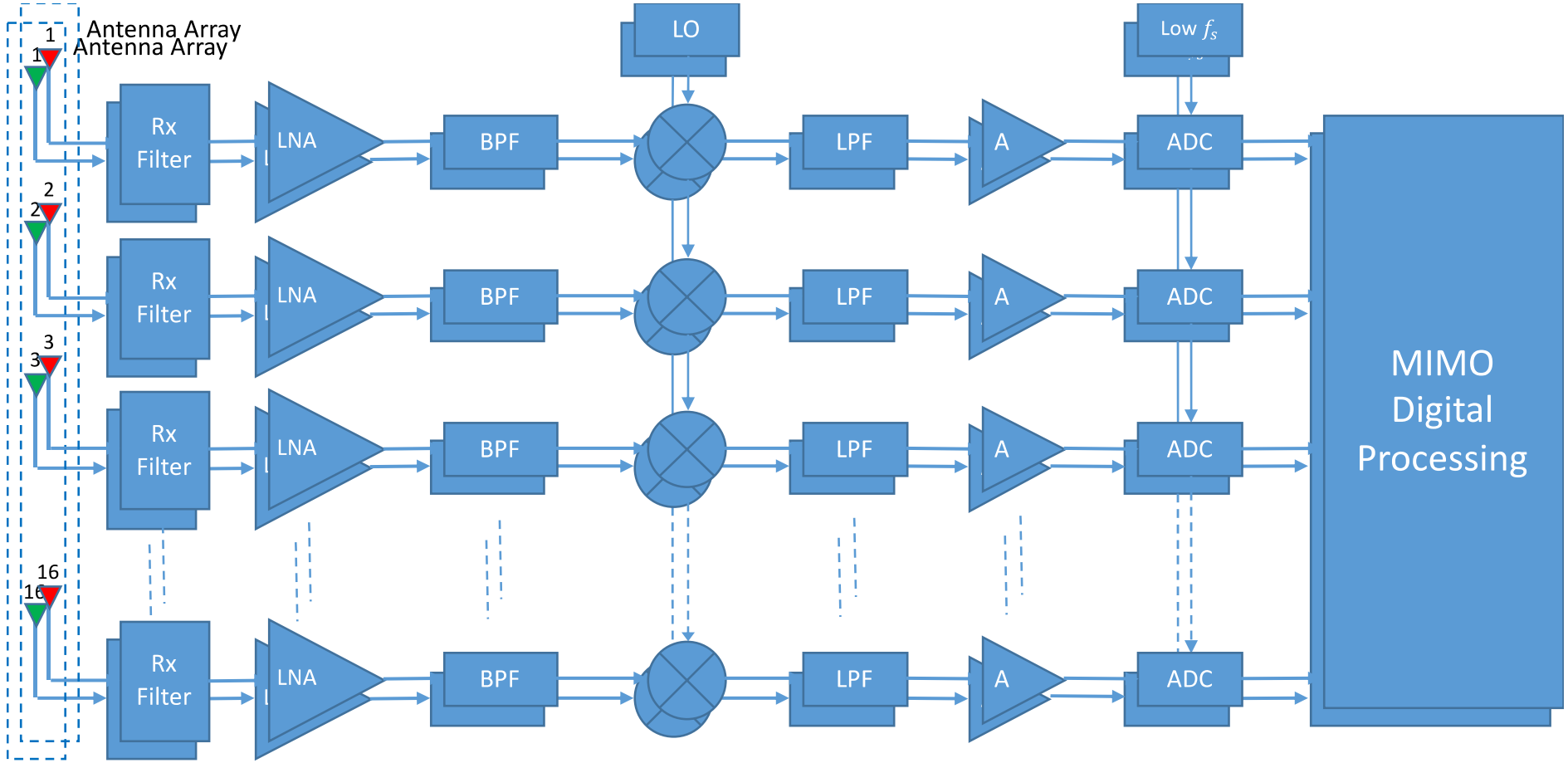




Conventional MIMO Receiver

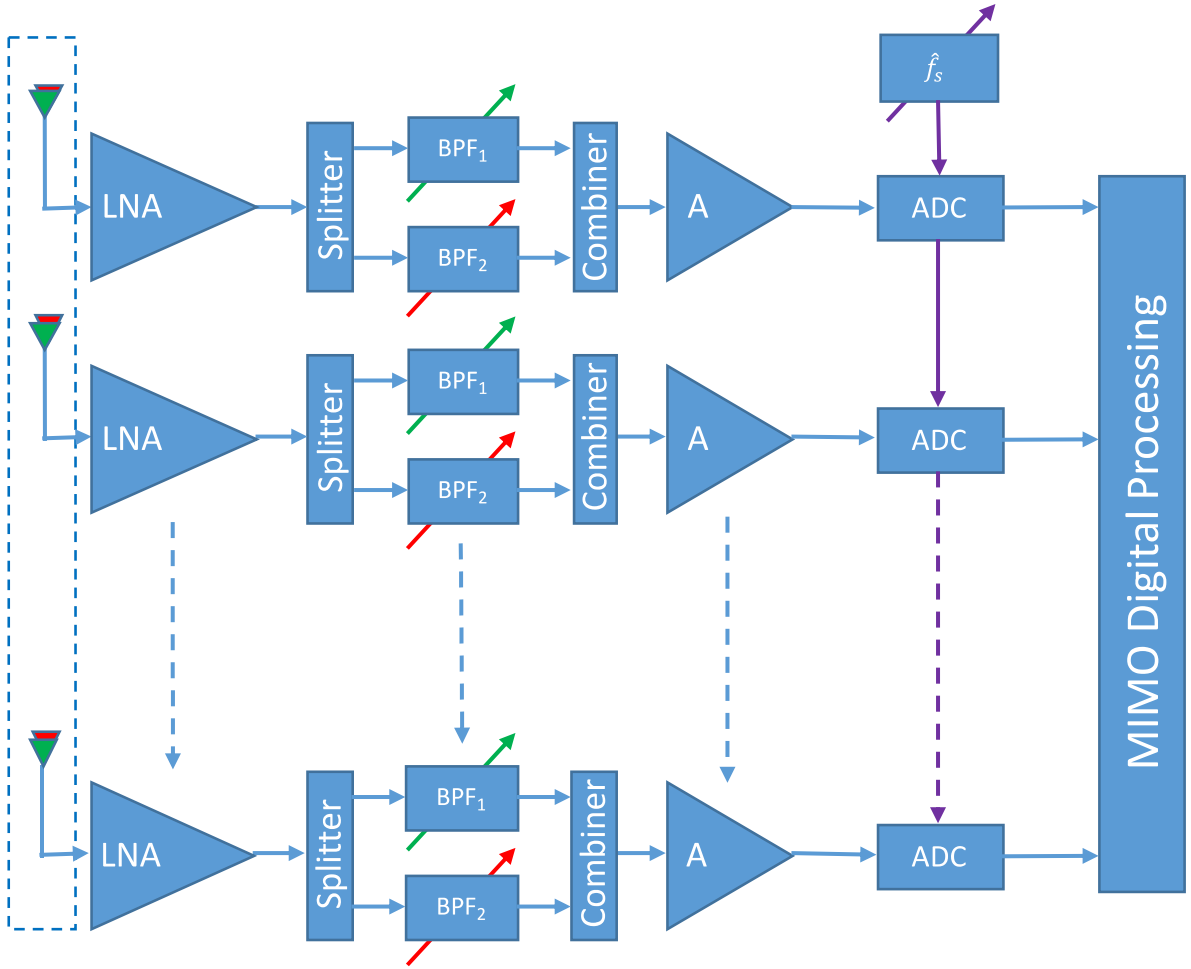


Conventional Multiband MIMO Receiver



Direct RF Sampled Multiband MIMO Receiver

Reconfigurable/ Tuneable Antenna Array with band limited elements



Conclusions

- Direct RF Sampling enables:
  - New concurrent, multiband SDR receiver architectures;
  - Low complexity, cost and power consumption;
  - Scalable RF solutions.
- Crucially, the work supports RF Skills development in the UK.
- The techniques can be migrated to 6G solutions as envisaged at higher frequency bands with appropriate technology changes.