RFI DETECTION AND MITIGATION PROCESSOR FOR THE COPERNICUS IMAGING MICROWAVE RADIOMETER SATELLITE

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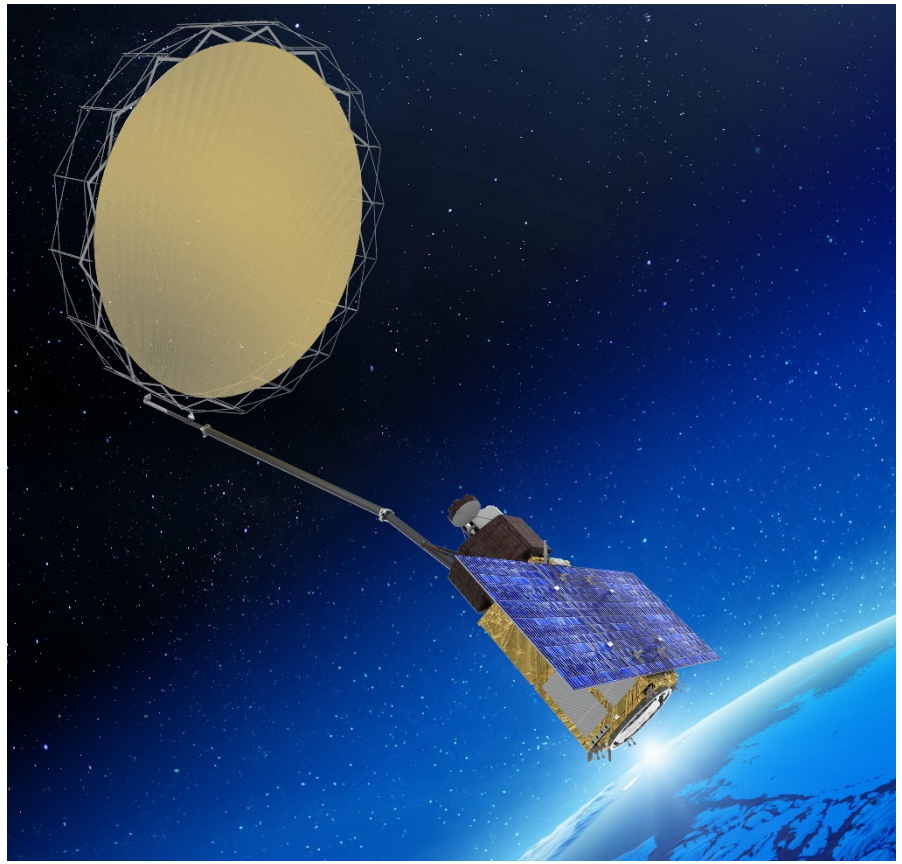
CIMR RFI processor: Introduction

- Five bands: L, C, X, Ku and Ka

- 25 channels fully polarimetric
  - L: 1 antenna horn
  - C and X: 4 antenna horns each
  - Ku and Ka: 8 antenna horns each

- RFI has been observed at all bands



https://www.esa.int/esearch?q=CIMR

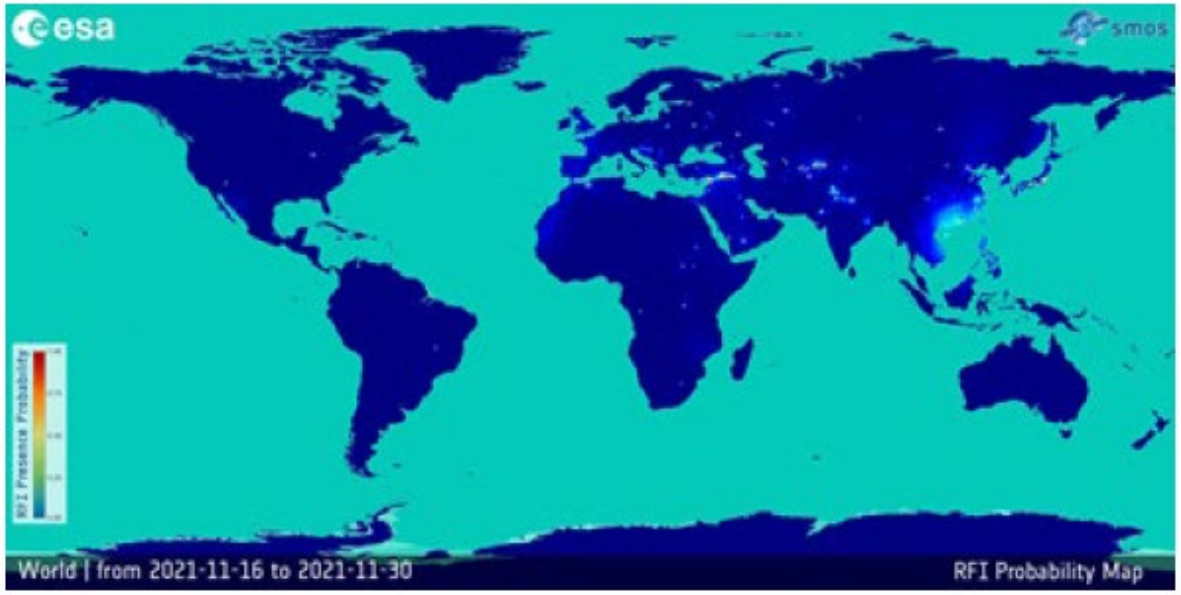
Background (historic snapshots)

- SMOS
  - Ground processing only
- SMAP
  - More data on-board and downloaded
- MetOp-SG
  - Additional processing on-board Expected launch 2024 (delayed)
- CIMR
  - Fully integrated processing
  - Expected launch 2026

DOSTAG #110, 25th January 2022:
Number of RFI sources

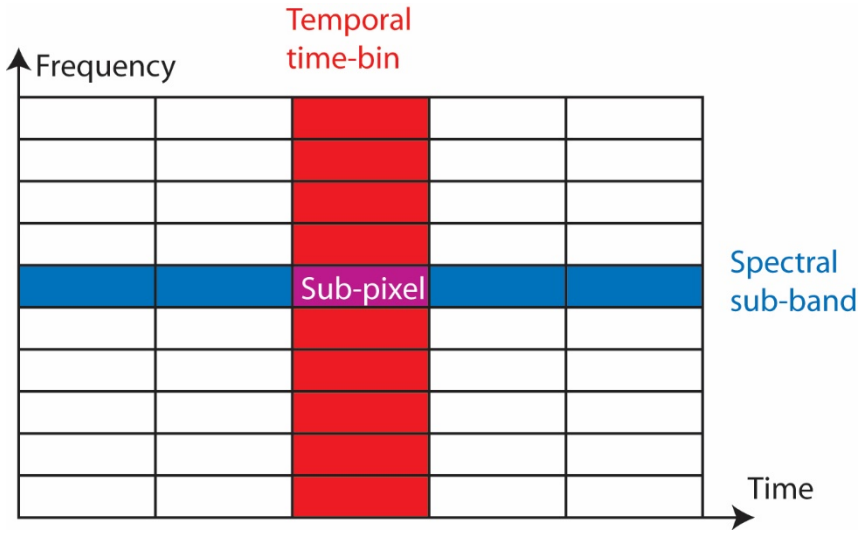
Continent	BT < 1000 K	1000 K ≤ BT< 5000 K	BT ≥ 5000 K	TOTAL
Africa	17	5	3	25
America	36	12	2	50
Asia	133	75	31	239
Europe	33	7	6	46
Middle East	38	19	11	68
Oceania	1	0	1	2
TOTAL	258	118	54	430

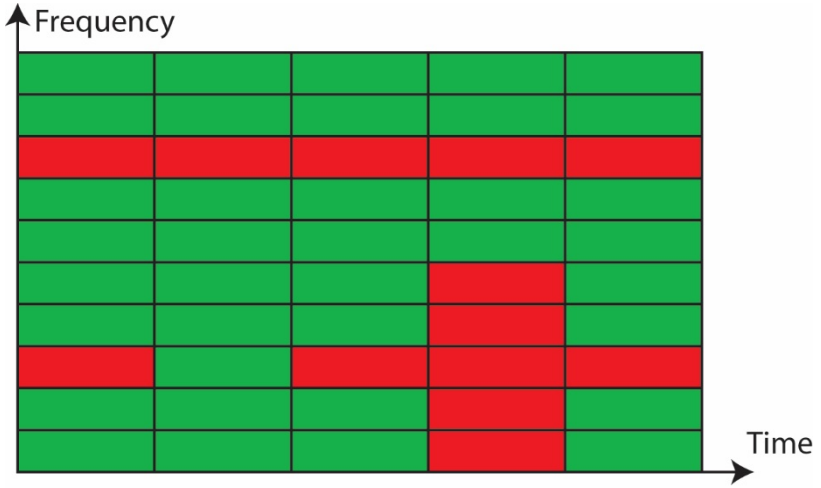
Table 1.1-1: Worldwide RFI strength distribution per continent (updated on 30 November 2021)

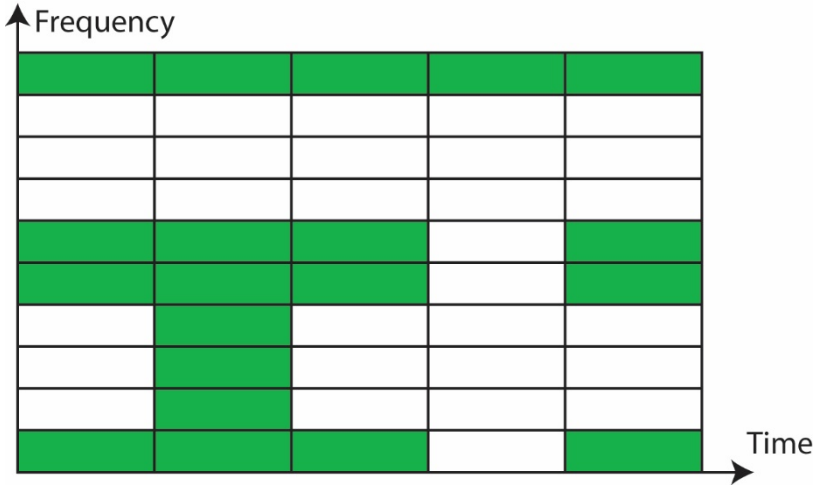


Global map showing the probability of SMOS persistent RFI occurrences during the period 16 November to 30 November 2021 (credits: SMOS RFI team at ESA ESAC)

Time bandwidth sub-pixel concept







- A continuous RFI in one spectral sub-band (third row from top)
- A pulsed RFI in one spectral sub-band (third row from bottom)
- A wideband RFI pulse in one temporal time-bin covering half the bandwidth (second column from right)

NEDT increase:

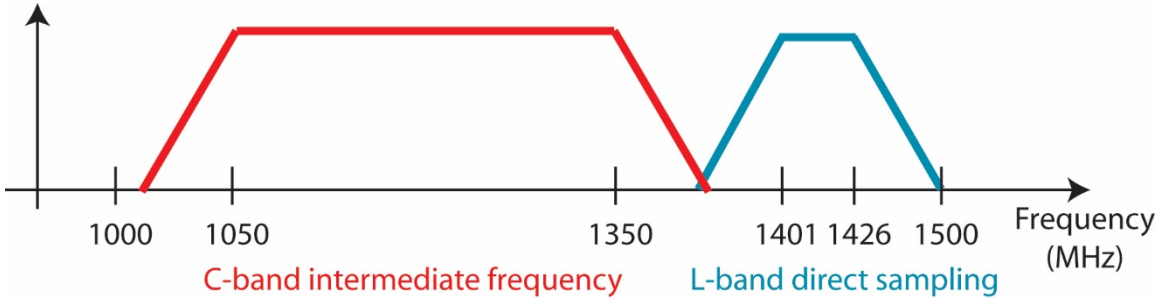
$$\sqrt{50/20} \cong 1.58$$

Algorithms

- Anomalous amplitude (Disastrous amplitude)
  – Input too large for natural sources
- Kurtosis
  – Input not Gaussian distributed (single statistic estimator)
- Cross frequency
  – Peak method
  – Variation method
- Polarimetry
  – Input too large for natural sources
- Glitch detector (currently optional)
  – Change too large for natural sources

- Architecture designed to accommodate more algorithms with ease

ADC input bandwidths have become wide enough to cover several radiometer bands



Full polarimetry can be handled by one dual channel ADC operating at 3 GSamples/s.

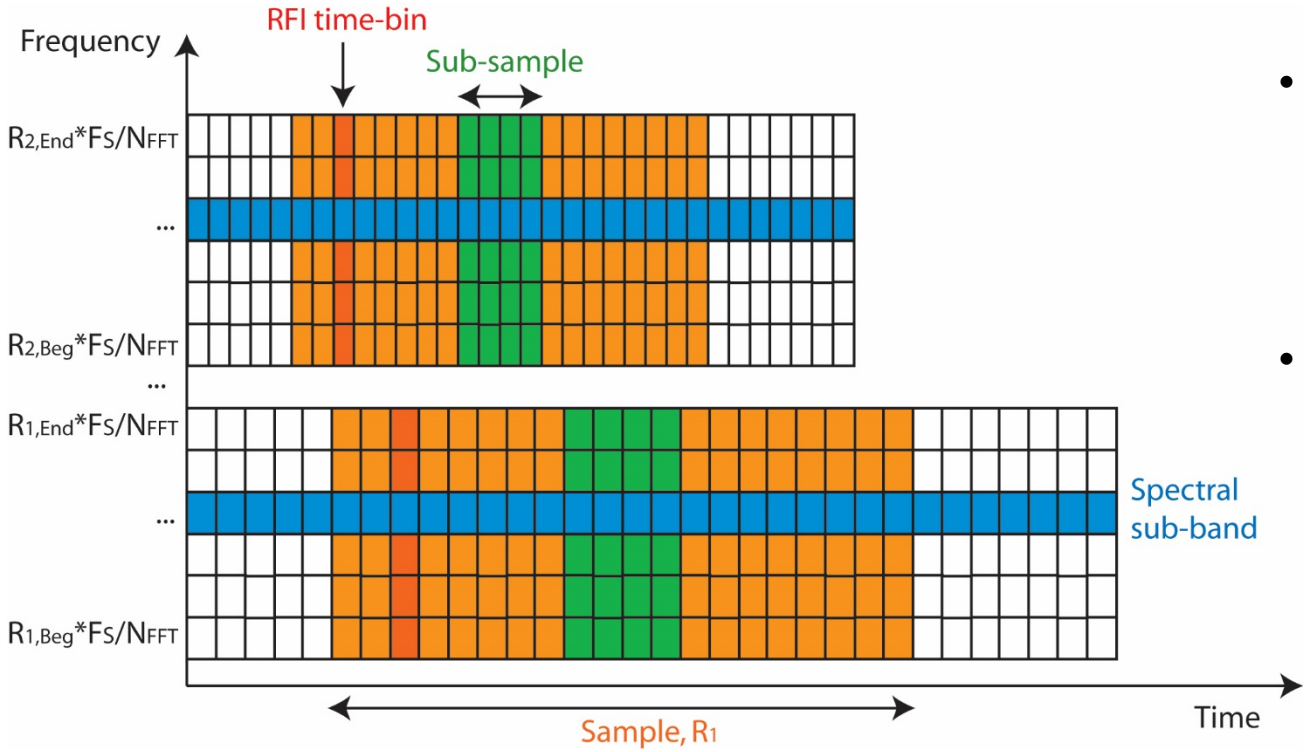
- Reasonable FFT length: 2048
  - Spectral sub-band width: 1.5 MHz

- 8 parallel FFTs: 375 MHz clock rate in the FPGA
- 16 parallel FFTs: 187.5 MHz clock rate in the FPGA

- Very high FPGA resource requirements – space qualified options?

Band	Bandwidth (MHz)
L	27
C	300
X	200
Ku	200
Ka	300
Transition	300 (6 x 50)
Total	**1327**

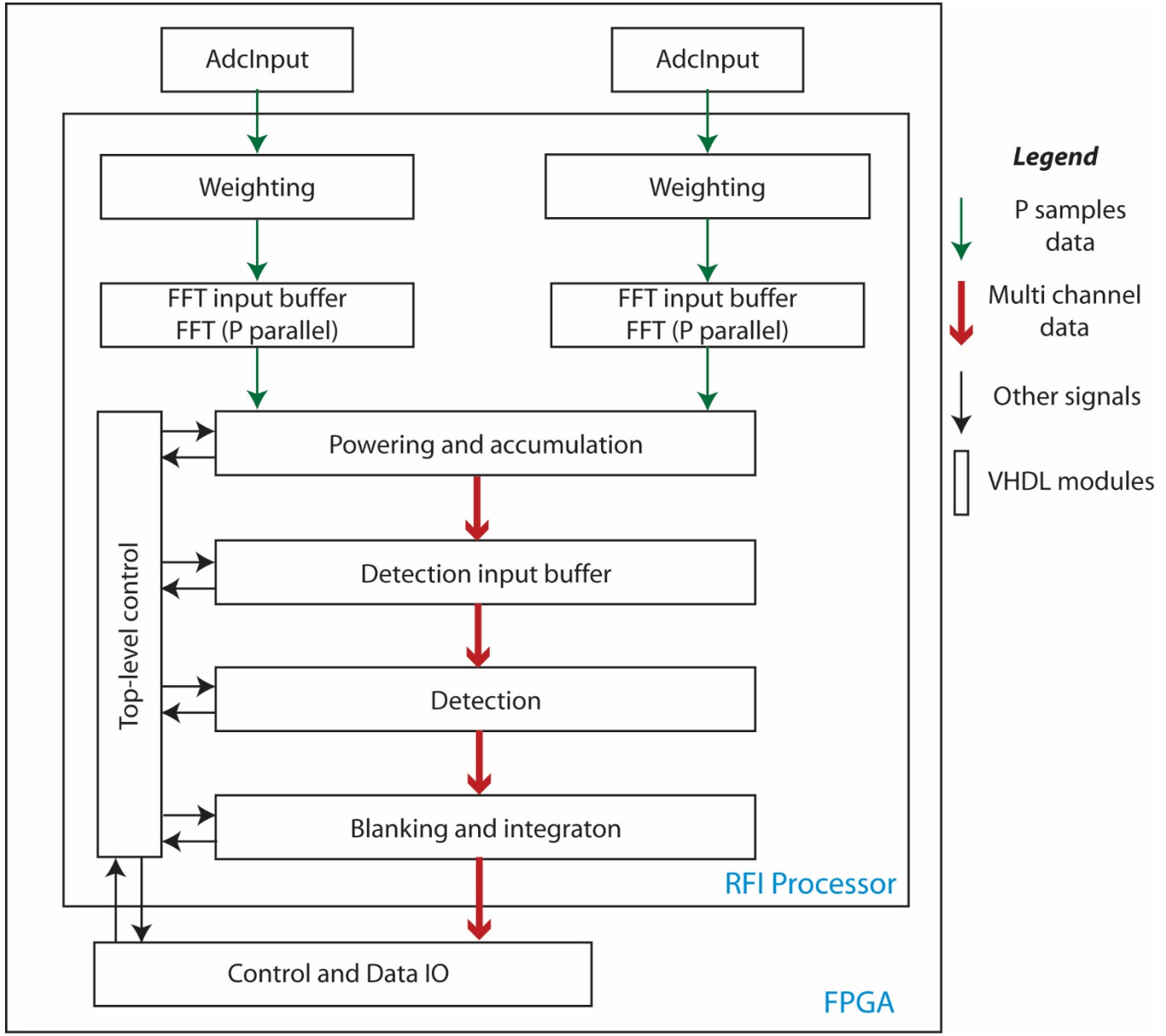
Time frequency matrices become more complicated



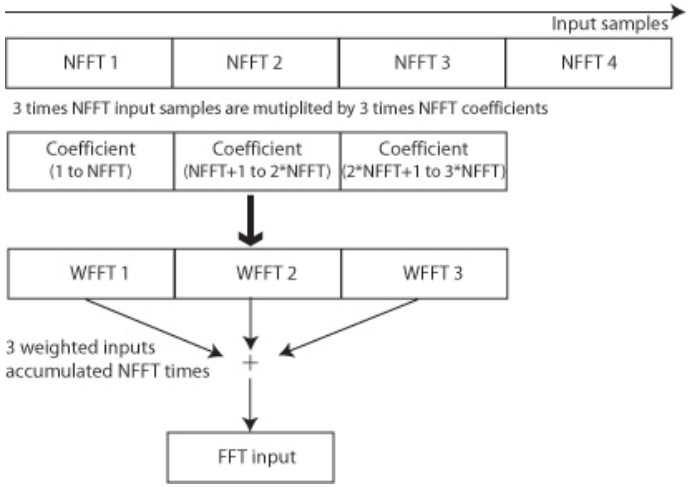
- RFI time-bin:
  - Multiple FFT outputs integrated
  - Minimum integration time
- Sub-sample:
  - Multiple RFI time-bins accumulated
  - Output sample (fraction of footprint)
- Sample equal to footprint
  - Multiple sub-samples

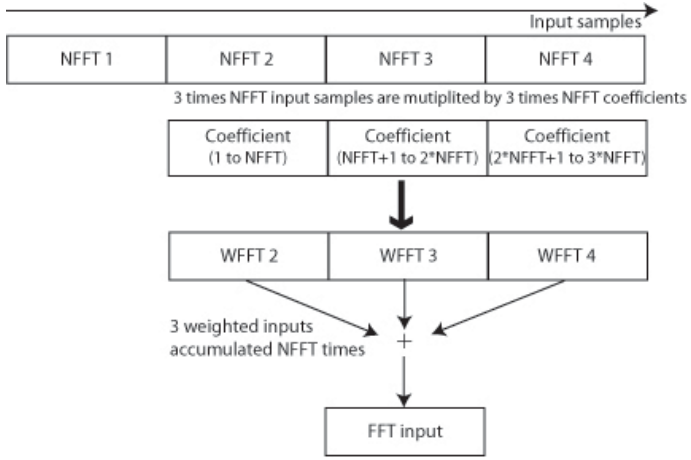
Processing FPGA overview

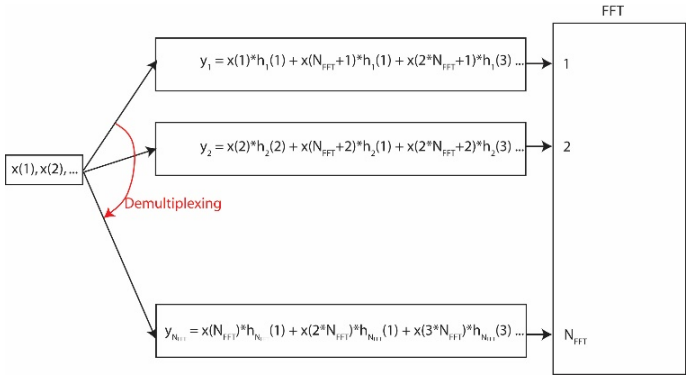
- Fully pipelined full clock speed processing until accumulation into detection input buffer
- Power and accumulation module holds the time frequency matrix for all spectral sub-bands
- Parallel processing of 8 or 16 ADC samples on each clock cycle
- Detection and subsequent processing done for each time-bin for each radiometer band.



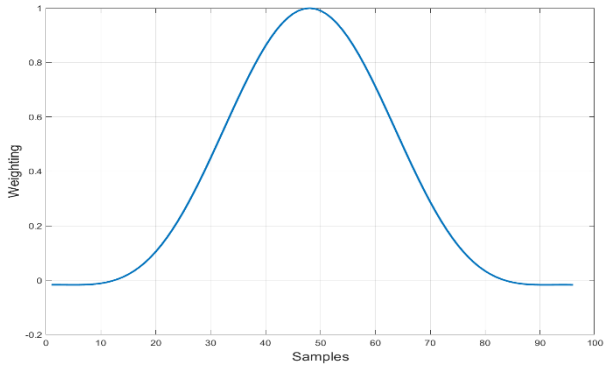
Weighting

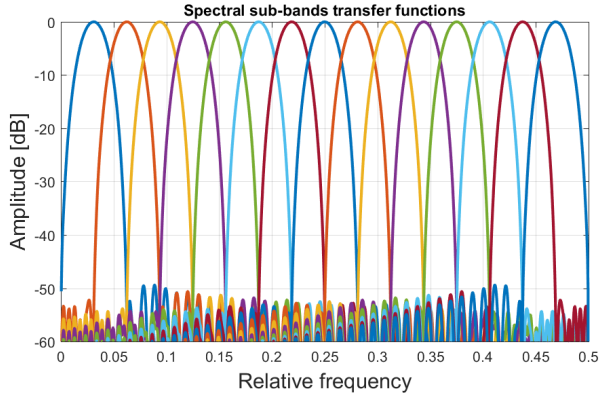






- Assumes stationary signal
- Needed to ensure:
  - Overlap between adjacent spectral sub-bands only
  - Sufficiently low side lobe level





Detection
FPGA overview

Input

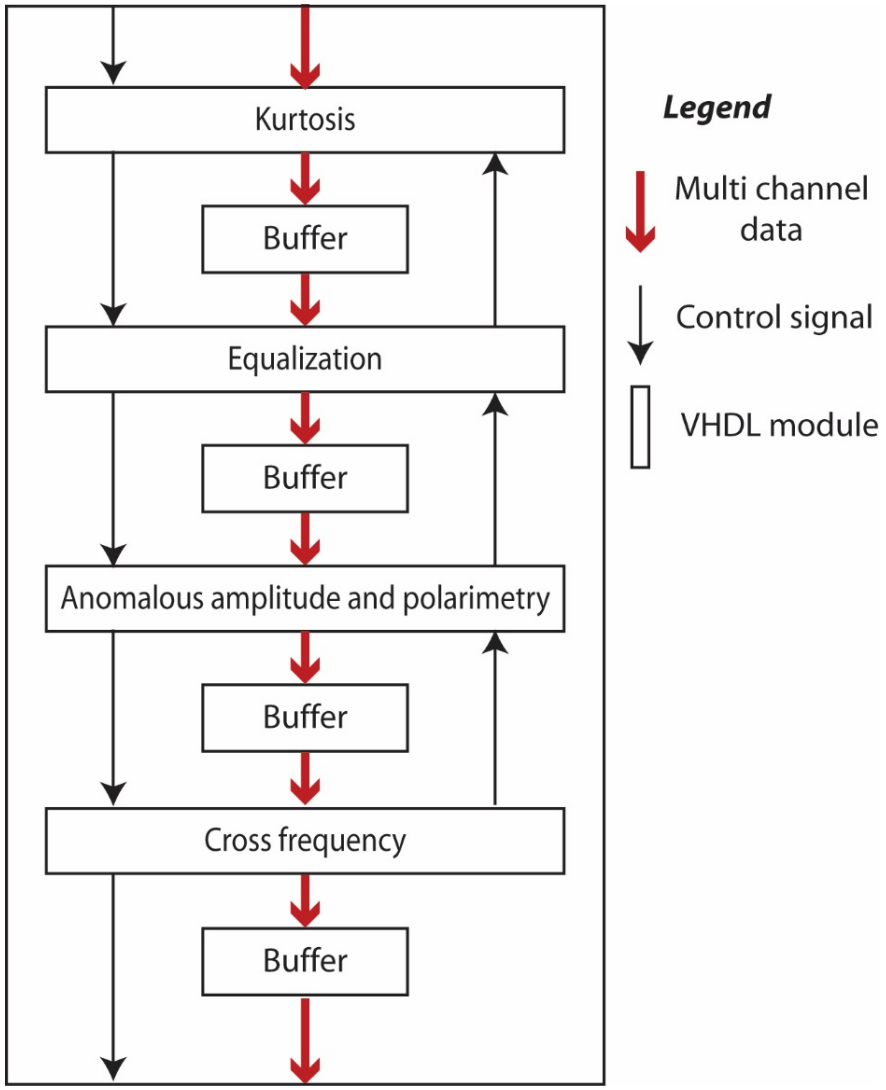
- Four modified Stokes accumulates
- Two fourth order accumulates
- Six accumulates for each spectral subband

Radiometer band is just a subset of spectral sub-bands

- User configurable

Pipelined processing

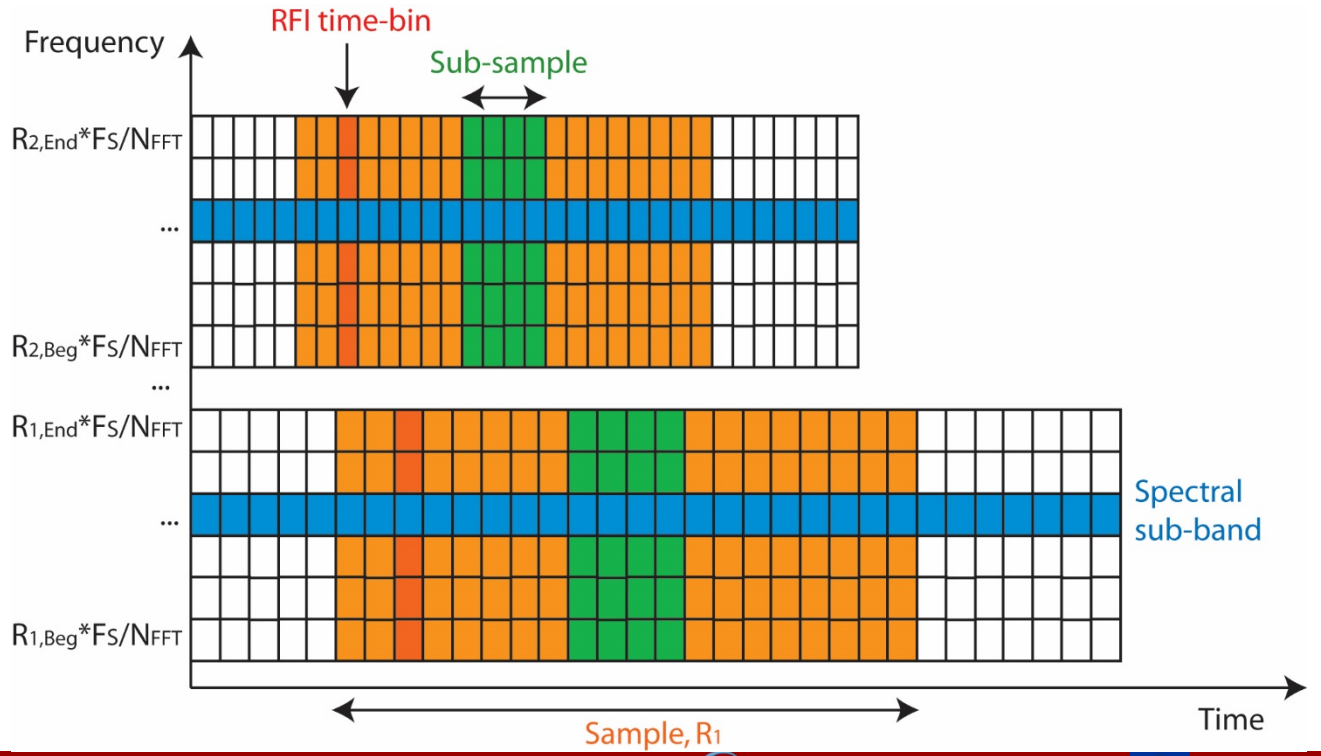
- No processing timing problem
- Easy to add new algorithms



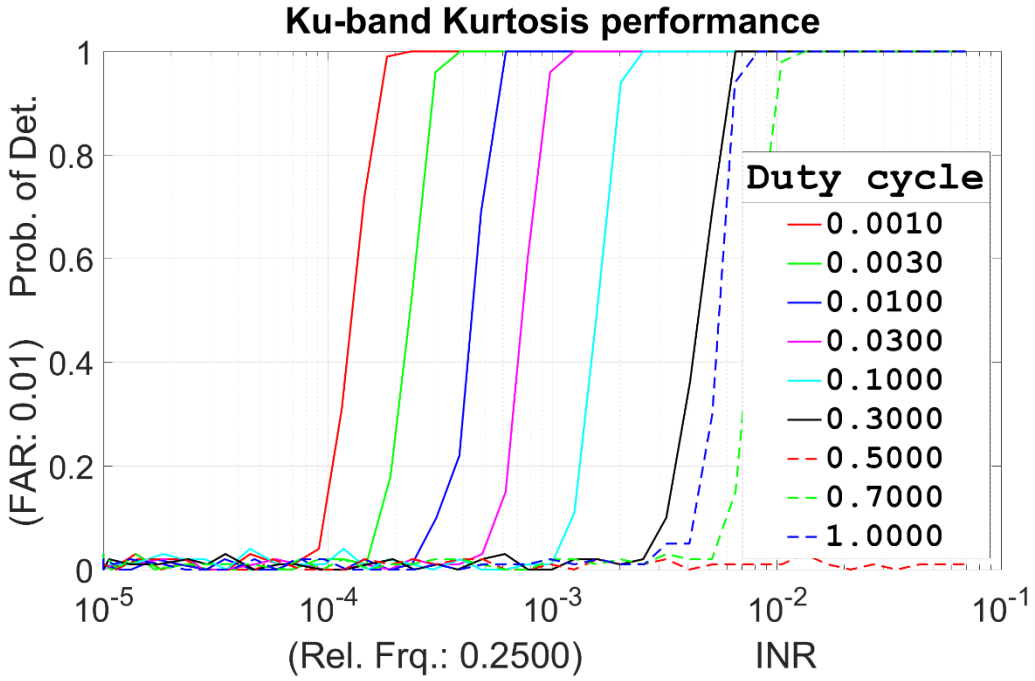
Processing output

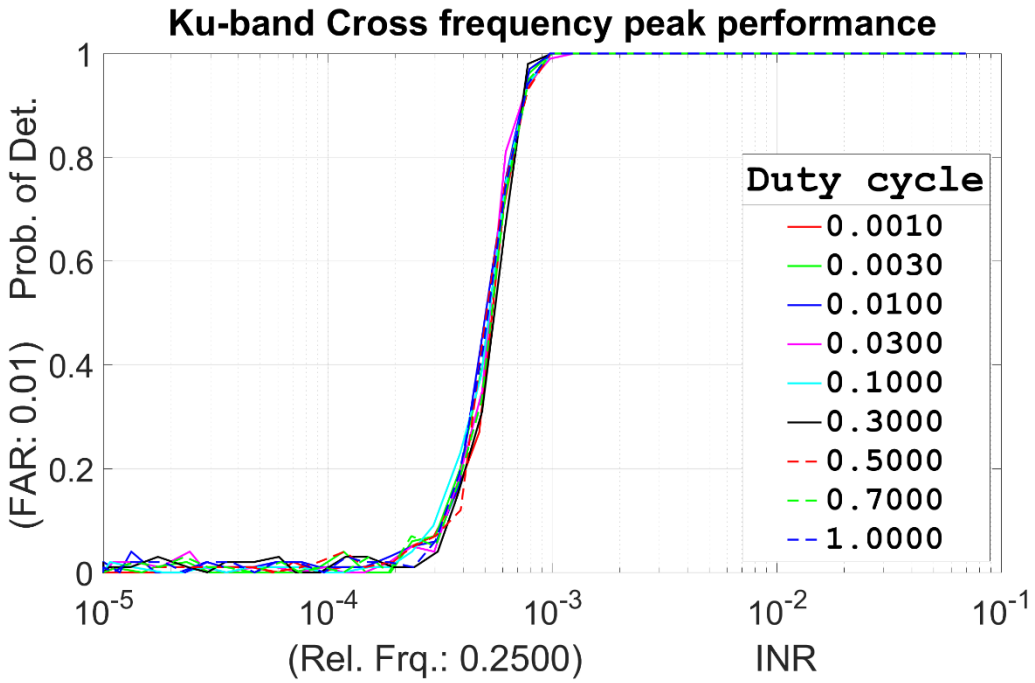
- Nominal output:
  - Accumulates of all sub-pixels
    - Filtered (sub-pixels where RFI has not been detected)
    - Not-filtered (all sub-pixels)
    - Number of sub-pixels where RFI has been detected
  - Low data rate

- Diagnostic data
  - All sub-pixels (input to detection)
  - High data rate
  - Needed for tuning thresholds

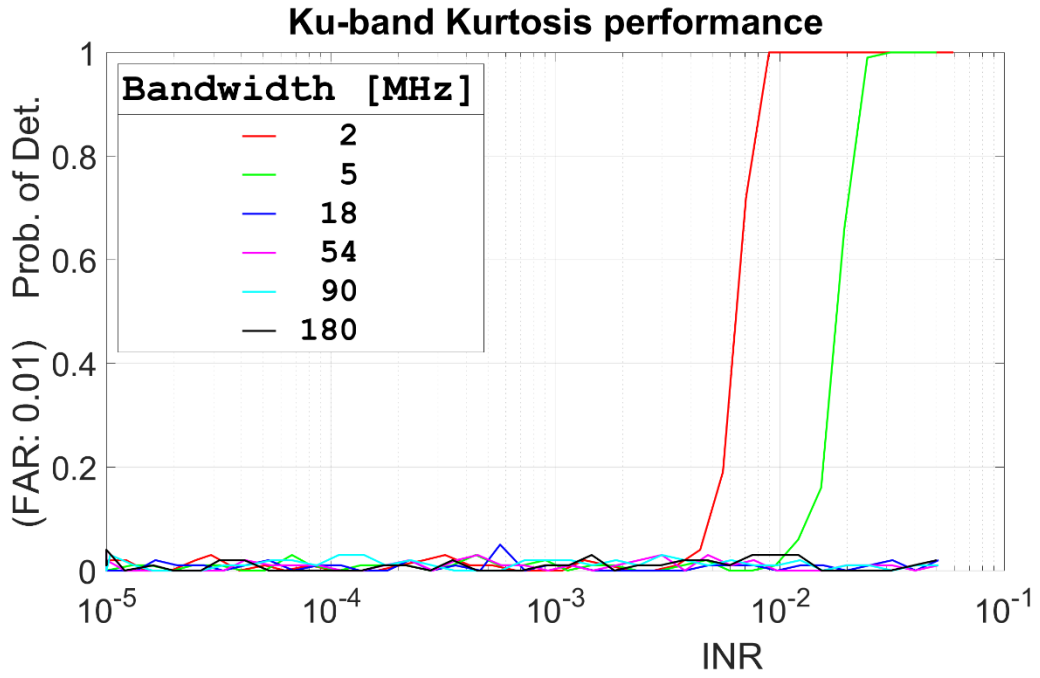


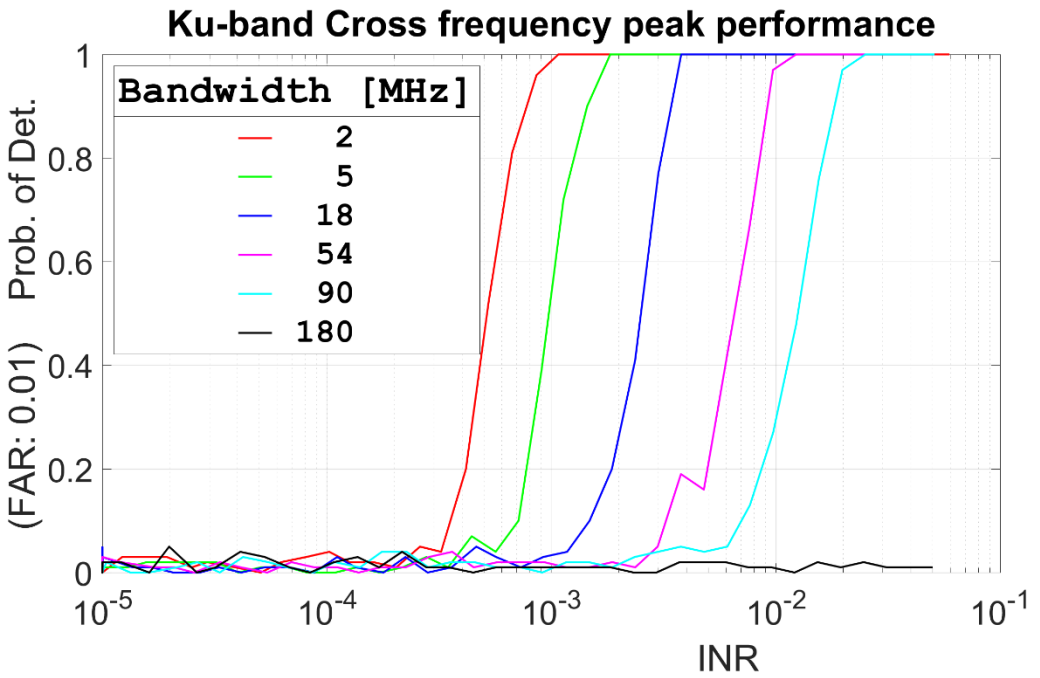
Performance simulation: sinusoidal RFI





Performance simulation: QPSK RFI





CIMR RFI processor: RFI and determining thresholds

- RFI
  - Inherently unknown
  - Amount will be location dependent
  - Type will be location dependent
  - Will change over time

- CIMR global coverage:
  - 95% of Earth each day
  - 5-6 coverings each week at the equator
  - 5-6 coverings at the poles every day
    - (not a lot of RFI there)

- Trial and error using nominal output
  - One test for each coverage
  - Way too time consuming
  - Cannot record and test simultaneously

- Monitoring using diagnostic output
  - Optimal thresholds can be found for each covering using ground processing
  - Can be tested at next covering
    - Not statistically reliable

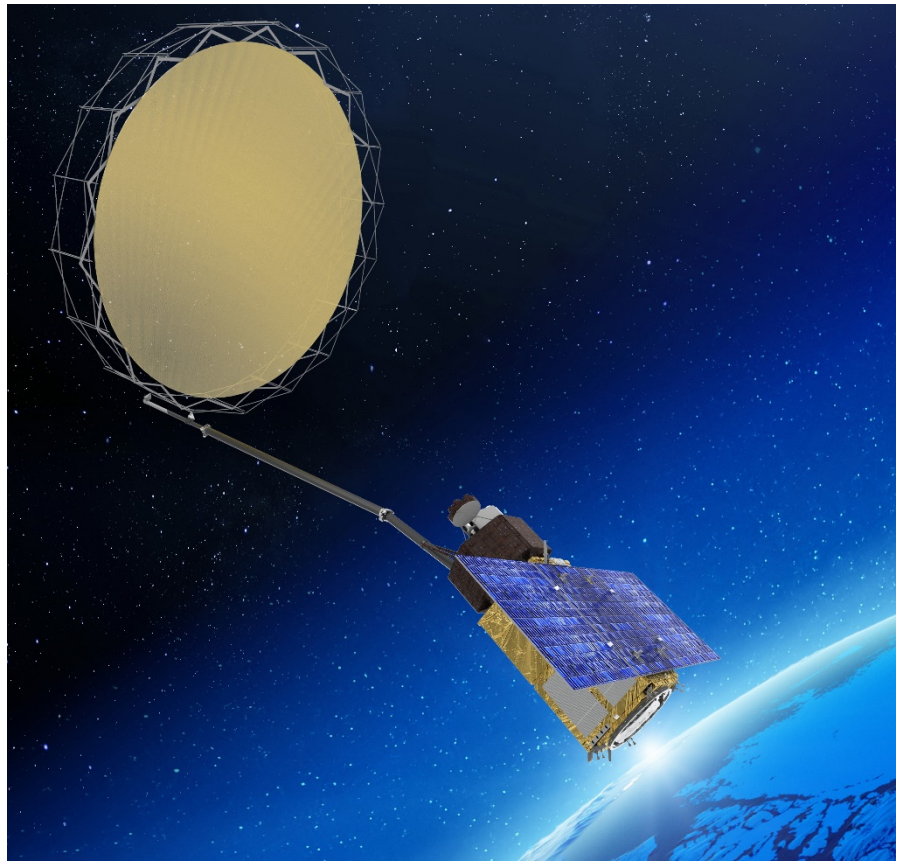
- We need a statistically reliable result
  - Multiple diagnostic outputs
    - Very difficult to say how many

- Constant monitoring of diagnostic data to keep detection thresholds updated to the changing RFI situation

- We want as much diagnostic output as possible

CIMR RFI processor: Conclusion

- ADC input at full bandwidth
- Fully digitized processing on-board
  - Full modified Stokes Vector (H, V, 3rd and 4th)
  - RFI detection and blanking
    - Both blanked and not blanked output
    - Diagnostic output
- All processing fully configurable (except FFT length)
  - One processor fits all



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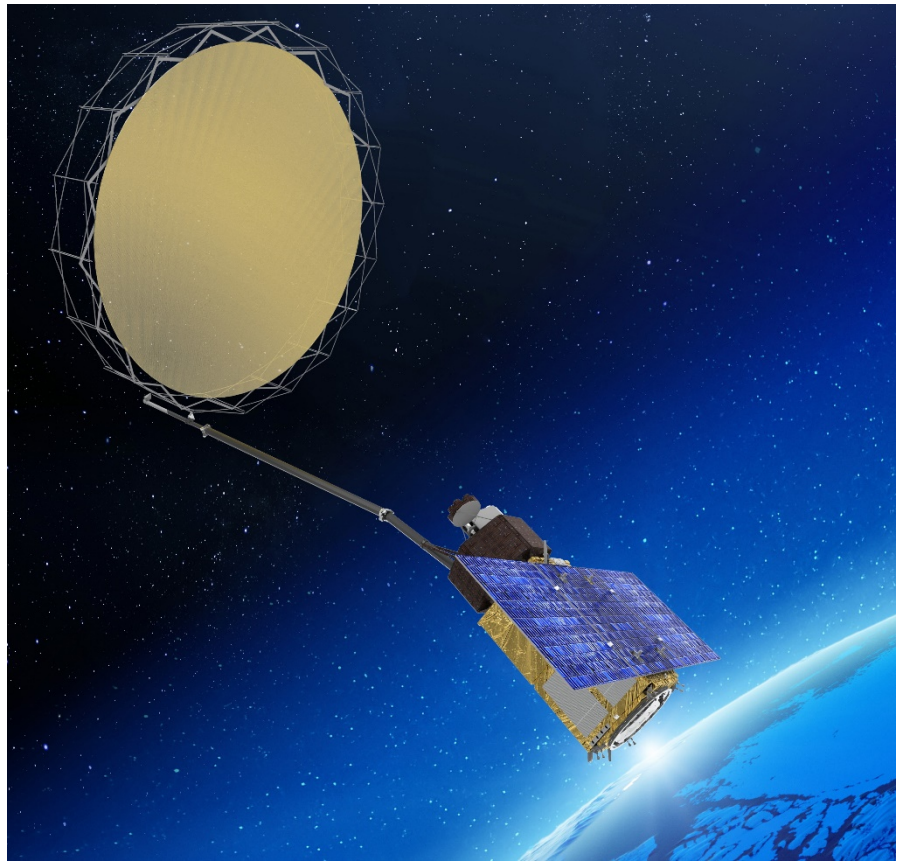
Thank you

- Questions?



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