PHOTONIC RF FILTERING

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Introduction

- **RF filtering** is a basic function in **communication satellite payloads**
- RF filtering offering **central frequency tuneability and passband BW adjustability** would provide flexibility in allocation of spectral resources
- Today **no commercial products** exist with these characteristics
- The feasibility of **Photonic RF Filtering** has been assessed
- **Brillouin Scattering** in Highly Non-Linear Fibres Technique
- **Method**: optical comb generation stimulating multiple Brillouin gain in non-linear medium
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  - *DAS Photonics*
  - *Thales Alenia Space France*
  - *Thales Research and Technology*
The evolution of broadband communication satellites:

• **efficient** use of the spectral resources

• **dynamic allocation of bandwidth** according with the dynamic needs of the traffic

Today, agile filters are not available in space equipments.

Traditional payload based on fixed filters (xMUX) with eventually switching capability

![Ku Band Switchable IMUX (6 channels)](image1)

![Ka-Band IMUX (YAHSAT 1A)](image2)
Introduction

Remarkable advances in introducing bandwidth flexibility by alternative means:

- **Agile up/down conversions with fixed filters** [POR12]

- **Mechanically tuned filters** [JON12] or **electrically tuneable filters** based in MEMs

- **Digital Processing on-board** [VOI12]

References:


[EST08] A. Esteves et al., ESA Flexible Payload Workshop 2008, ESA/ESTEC Noordwijk
Photonics for RF Filtering technologies

A number of photonic techniques & technologies investigated during last years

- **Discrete time delay schemes** → limited performance

- **Fiber Bragg Gratings** → limited performance (bw, tuning, reconfiguration)
Photonics for RF Filtering technologies

- Microphotonic based on coupled cavities

Bandwidth: 1 GHz

Reconfigurable central frequency

Photonics for RF Filtering technologies

- **Microphotonic based on coupled cavities**
  - Promising technology for size, mass reduction
  - Requires complex control (trimmers).
  - Fundamental limitation: *Optical propagation losses*!

Waveguide propagation losses = 0.002 dB/cm

Waveguide propagation losses = 0.19 dB/cm
Photonics for RF Filtering technologies

- **Brillouin-based Photonic Filtering**
  - uses non-linear effects in the fibre to generate spectral regions with gain based on the Brillouin effect

**Small bandwidth affordable**
**Potentially tuneable and reconfigurable**

Photonic RF Filtering Architecture

Concept: narrow-band Brillouin optical amplifier
The filter bandwidth is adjusted by modifying a multitoned baseband signal (Ntones, frequency, amplitude, phase) in digital domain.

The filter center frequency is adjusted by a synthesizer generating LO frequencies $f_{LO} = f_c - f_B$. For $f_c$ within the Ku-band (10.7-12.75 GHz), $f_{LO} = 1-3.05$ GHz, can be addressed by a synthesizer chipset for a stand-alone filter.
**Optoelectronic module**: Optical devices and control electronics assembled in a PCB with mechanical, electrical (RF, TM/TC, power supply), and optical interfaces.
Breadboard Test Results

Gain and Group delay for 72 MHz bandwidth

0.2dB In-band Flatness
40 dB Out-of-band rejection

2ns In-band Group-Delay Flatness
Breadboard Test Results

Gain and Group delay for 54 MHz bandwidth

→ Return loss is lower than -10dB for the frequencies of interest
Breadboard Test Results

Gain and Group delay for 36 MHz bandwidth
Breadboard Test Results

Wide bandwidth tested (170 MHz)

Gain Test

BW @ 3 dB = 170.4 MHz
BW @ 20 dB = 234.4 MHz

Shape factor = 1.37

Note: limited by Filter Pump power.
Breadboard Test Results

Wide bandwidth tested (170 MHz)

Gain Test

4 GHz span
Breadboard Test Results

Wide bandwidth tested (170 MHz)

Group Delay Test

4 ns ripple
Breadboard Test Results

Center frequency tuning
LO from 0.907 to 3.007 GHz with 100 MHz step

Ku-band, from 10.7 to 12.75 GHz
Minimum Noise Figure: 50 dB @ pump power of 18.5 dBm
Breadboard Test Results

Power Handling

Trade-off: NF vs Gain
Breadboard Test Results

Linearity

OIP3: -7 dBm
Conclusion

- Photonic RF Filter experimentally demonstrated
  - Performance partially comply with narrow-bandwidth (<72 MHz)
  - Promising specs for broader bandwidth (>125 MHz)

- **2 GHz Tunable center frequency** in the Ku-band (10.7-12.75 GHz) tested
  - Applicable also for Ka and Q/V

- **Adjustable bandwidth up to 170 MHz tested**
  - *Roadmap to increase beyond 1 GHz*

- Potential multichannel filtering within the same non-linear fibre

- Promising alternative either as
  - stand-alone filter
  - Integrated in future telecom optical payloads
THANK YOU

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