Triple Frequency Diversity and Frequency Scaling Experimental Campaign in Attica, Greece: Preliminary Results

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Agenda

- Introduction
- Campaign details
- In-excess Attenuation Evaluation
- Frequency Correlation Statistics
- Frequency Diversity Examples
- Conclusions & future work

Introduction

- Current situation:
  - Demand for very high data rate services
  - Constant, ubiquitous coverage is essential
  - Low latency and high availability vital to meeting high QoS

Introduction

- Migration to higher frequency bands for feeder links
  (Ka, Q/V):
  - Massive bandwidth available (5 GHz for V-band)
  - Signal propagation severely impaired by atmospheric phenomena
    - Gases, clouds, **<u>rain</u>** and tropospheric turbulence
    - Sole use of fade margins not suffice
    - Fade Attenuation > 20 dB for non-negligible percentage of time
  - Fading Mitigation Techniques (FMTs) required:
    - Uplink Power Control, not always effective
    - Site Diversity
    - Lack of accurate propagation models
  - New measurement campaigns necessary

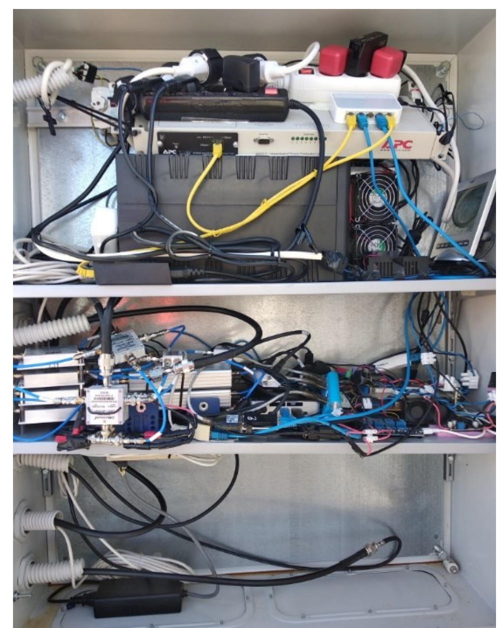
Campaign Details

- Propagation Measurements:
  - Non-trivial task
    - High cost
    - Long duration
    - Dependent on geographic location
    - Multiple measurement sites required
  - Use of satellite beacons to assess signal attenuation
  - ESA made available ALPHASAT TDP #5
  - Software Defined Radio solutions available
  - Currently many measurement campaigns ongoing across Europe

Campaign Details

- Receivers located in Attica, Greece
- Concurrent measurements using ALPHASAT's beacons and Badr 5 telemetry beacon
  - Ku-band: **11.699 GHz**, vertical pol (Badr 5)
  - Ka-band: **19.701 GHz**, vertical pol (Alphasat)
  - Q-band: **39.402 GHz**, 45º pol (Alphasat)

Freq. Band	Satellite	Orbit. Pos	Frequency	Pol.
Ku	Badr 5	26.0ºE	11.699 GHz	V
Ka	Alphasat	25.0ºE	19.701 GHz	V
Q	Alphasat	25.0ºE	39.402 GHz	45º



Campaign Details

- Results presented for the first one year of measurements
- Coordinated measurements since July 2017 for the three bands
- Truly concurrent, common format measurements (netCDF files, metatags)
- Ancillary equipment also installed:
  - Weather stations, rain gauges etc.
  - Weather data available from local meteo offices

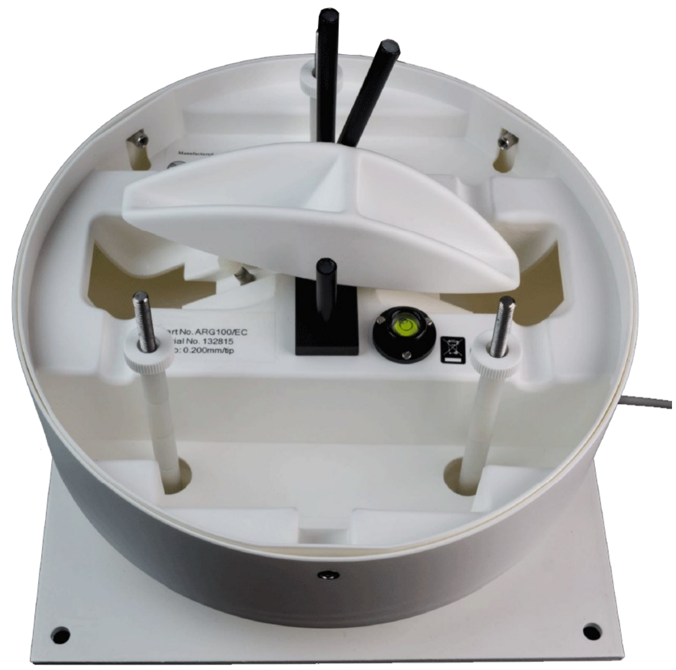
Campaign Details

- NTUA Receivers:
  - Cost-effective solution
  - Based on Software Defined Radio (SDR)
  - Antennas:
    - 1.2 m offset for Ku-band
    - 1.2 m offset for Ka-band
    - 0.6 m shrouded parabolic for Q-band
  - FFT based power estimation
  - Developed around GNU Radio framework
  - Elevation Tracking for Ka- & Q-band (developed in-house)
  - 10 Hz output data sampling rate
  - Dynamic Range:
    - > 30 dB for Ku-band
    - > 40 dB for Ka-band
    - > 35 dB for Q-band

Campaign Details

- EML ARG 100 tipping bucket rain gauge installed
  - Accuracy of 0.2 mm of rainfall per tip
  - Sampling rate of 1 Hz

outside view



inside view

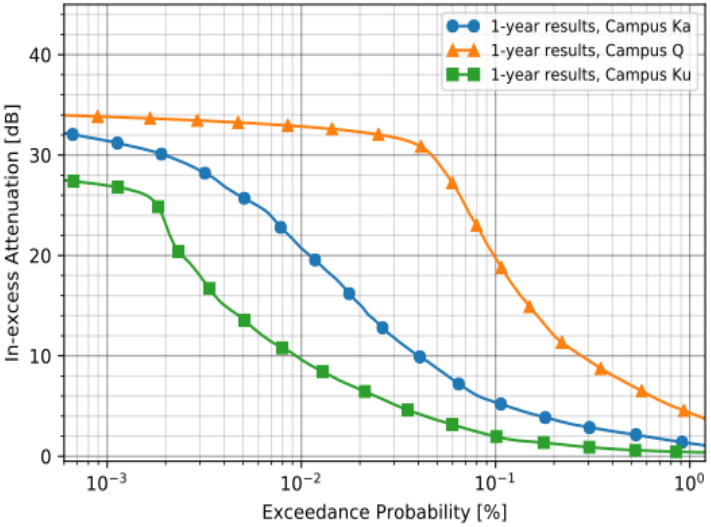
Campaign Details

- 12 months of fully coordinated operation are presented (January to December 2018)
- Campaign still ongoing; expected to last as long as ALPHASAT’s Ka- and Q-band beacons are available
- Power spectral analysis is performed on a daily basis
  - Check the quality of the received signals

In-excess Attenuation Evaluation

- Complementary Cumulative Distribution Functions (CCDFs) for the three frequency bands are presented
- Q-band exhibits the worst performance
  - very prone to rain precipitation, also affected by to clouds and fog
- Ka-band does not appear to be very sensitive to clouds
  - still heavily affected by rain
- Ku-band seems to be more robust to atmospheric phenomena
  - rare cases of in-excess attenuation levels exceeding 10-15 dB
- A fade margin to compensate for propagation losses is insufficient and could lead to frequent service disruption
  - Utilization of more sophisticated FMTs required

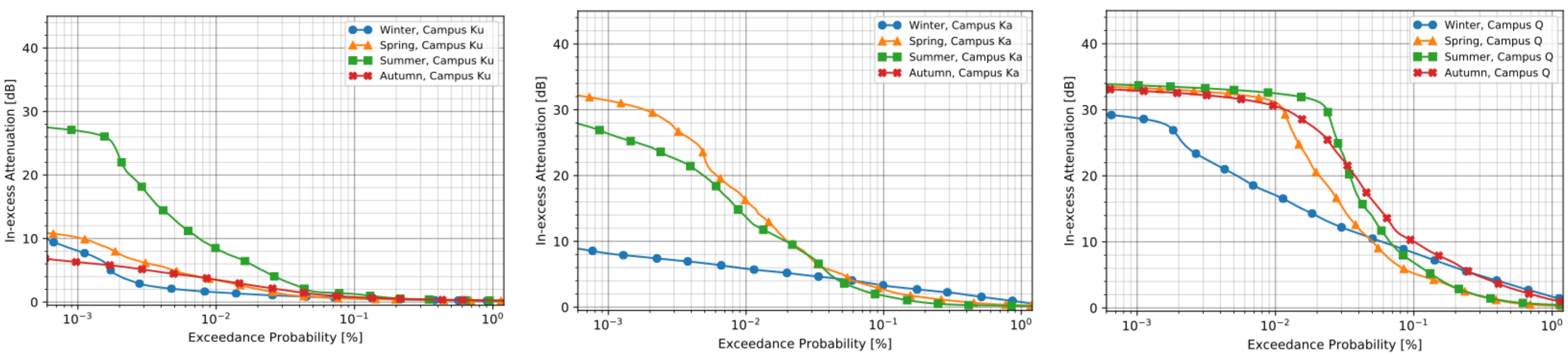
Frequency Band	Data Availability
Ku-band	98.82 %
Ka-band	99.07 %
Q-band	96.63 %



Overall (one-year) in-excess attenuation statistics for the three frequency bands

In-excess Attenuation Evaluation

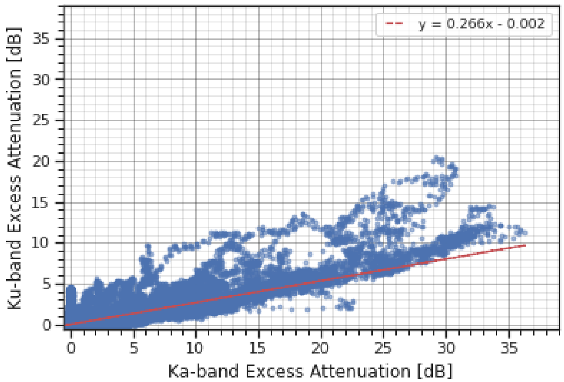
- Seasonal CCDFs of In-excess Attenuation
- The south Mediterranean climate of Greece is quite unique;
- The worst season in terms of attenuation (at least for the year 2018) was summer
  - more particularly June and July where very strong attenuation events (even beyond the available dynamic range of the receivers) were recorded.



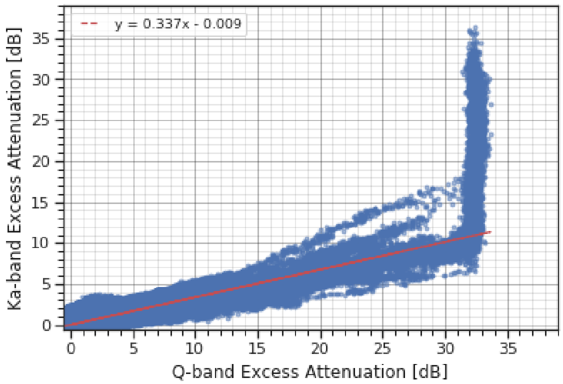
Seasonal in-excess attenuation statistics for Ku-, Ka- and Q-band for 2018

Frequency Correlation Statistics

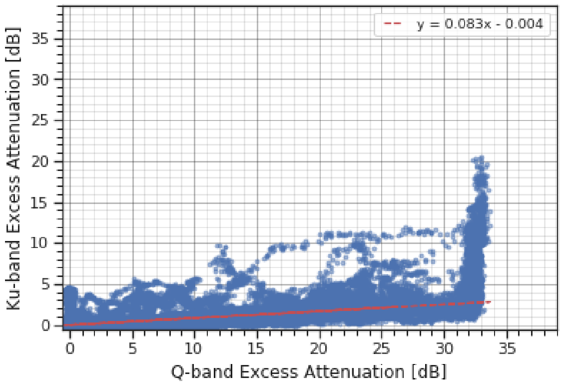
- The scatter plots between Ka-Ku, Q-Ka and Q-Ku are depicted below
- Only one year of measurements has been included
  - the results are not conclusive
  - a general tendency can still be obtained.
- The vertical tendency in the two rightmost figures is attributed to the lower dynamic range that the Q-band receiver offers



Ka vs Ku band in-excess attenuation



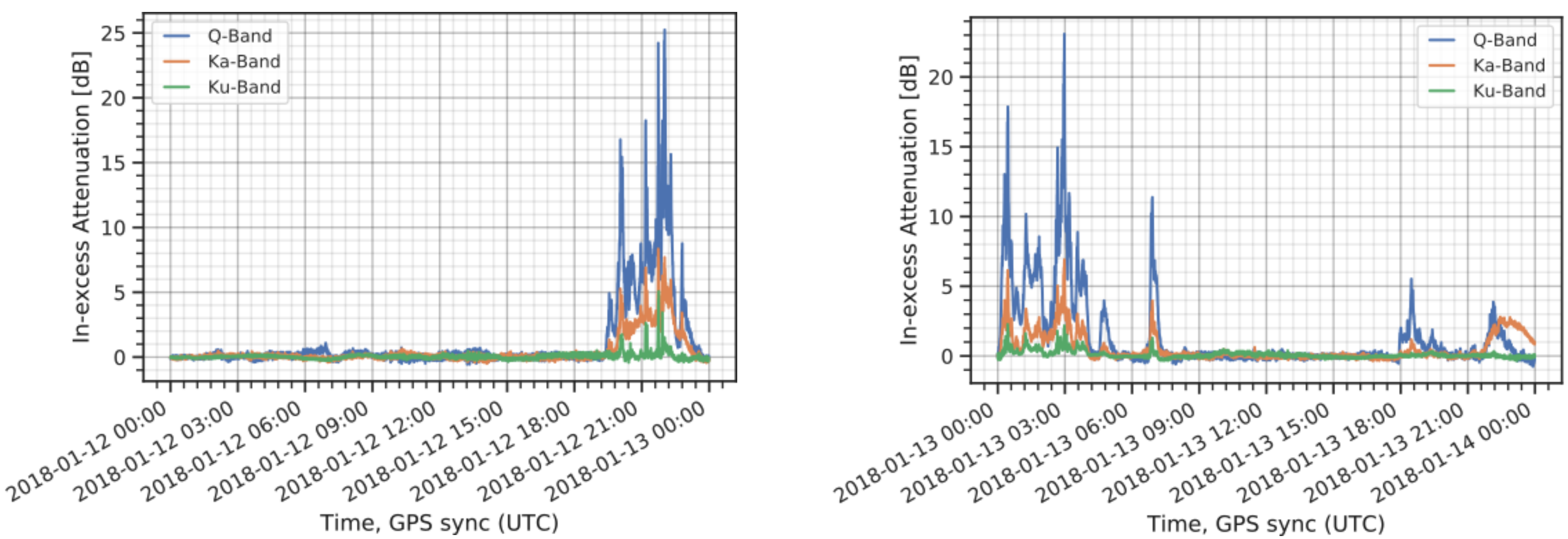
Q vs Ka band in-excess attenuation



Q vs Ku band in-excess attenuation

Frequency Diversity Examples

- Time series for two days in January 2018 (12-13/01/2018) are shown;
- The difference in attenuation magnitude across the three bands
  - is quite pronounced
  - could be employed to keep a service operational, yet at lower performance.



In-excess attenuation timeseries for 12 & 13 January 2018

Conclusions & future work

- Ongoing measurement campaigns in Greece have been presented
- As more results are collected and processed a more elaborate analysis will follow.
- It would be interesting to:
  - verify how frequency scaling models perform
  - to possibly attempt to improve them by exploiting the actual measurement data acquired
- In general, the collected data shall:
  - populate scientific databases (e.g. ITU-R SG3)
  - assist the development and validation of
  - new propagation models
  - FMTs
  - small/large site diversity techniques

Thank you very much for your time and attention!

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