URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020

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

Apostolos Z. Papafragkakis (1), Charilaos I. Kourogiorgas (2), Athanasios D. Panagopoulos (3)
(1) National Technical University of Athens, School of Electrical and Computer Engineering, Athens, Greece; email: apapafrag@mail.ntua.gr
(2) National Technical University of Athens, School of Electrical and Computer Engineering, Athens, Greece; email: harkour@mail.ntua.gr
(3) National Technical University of Athens, School of Electrical and Computer Engineering, Athens, Greece; email: thpanag@ece.ntua.gr

Abstract

The ongoing migration of satellite communication services to higher frequency bands such as Ka and Q has recently triggered a great interest to conduct new propagation measurements across the globe. In this paper, an ongoing triple frequency diversity experiment campaign conducted in Attica, Greece is outlined. The frequency bands examined are Ku, Ka and Q. Such a campaign should provide useful insight on a practically realizable frequency diversity scheme as well as assist in more precise modelling on frequency scaling effects. The first (1-year) results are presented and discussed along with the remarks for the planned future work.

1 Introduction

As already discussed in numerous previous works [1], there is a massive interest in conducting new satellite propagation measurements across the globe. This can be attributed to the fact that new satellite systems are going to utilize higher frequency bands such as Ka and Q, where atmospheric propagation effects (and more particularly rain precipitation) could seriously deteriorate signal, possibly jeopardizing the system availability and performance [2], [3]. At the National Technical University of Athens (NTUA), there is an ongoing propagation campaign making use of available satellite beacons to measure the attenuation levels which in turn should allow for better channel modelling and pave the way for more efficient application of Fading Mitigation Techniques (FMTs) [4]. In this particular work, part of the campaign is presented focusing on frequency effects on signal propagation across Ku, Ka and Q bands. The results from one full year of the campaign are presented providing useful insight on the different effects faced at different frequencies.

2 Measurement Setup

The frequency diversity campaign consists of three collocated receivers, deployed at the NTUA campus in Attica Greece (37.98º N, 23.79º E, 210 m above mean sea level). They are based mainly on off-the-shelf components and their design and development has been done fully in-house [5]. All of them follow the Software Defined Radio paradigm making use of the popular open-source GNU Radio framework. Their main building blocks are the Ettus' USRP B210 units, undertaking the task of sampling, quantizing and digitizing the received satellite beacon signals before they are fed to a single-board computer for Fast Fourier Transform (FFT) power estimation. Collocated with the receivers are also ancillary meteorological instruments, including tipping bucket rain gauges. A photo of the actual receivers (outdoor part/front-end) can be found in Fig 1. Following the storage of the raw measurement data, a rigorous pre-processing routine takes place where the data are consolidated and stored for further use with timestamps and necessary meta-tags. All receivers are time synchronized and share common oscillators to ensure consistent behavior and sample time alignment; to this end high performance GPS Disciplined Oscillators (GPSDOs) have been employed. The receivers offer a dynamic range in excess of 40 dB for the Ka-band

Fig 1. The NTUA beacon receivers
(from left to right: Q-, Ku- and Ka-band)

and approximately 35 dB for Ku and Q bands.
As already mentioned in the introduction, three bands are examined, namely Ku, Ka and Q. For the Ka and Q bands the beacons originating from ALPHASAT's (25.0ºE) [6] are used at 19.701 and 39.402 GHz respectively, while for the Ku band a telemetry beacon transmitted by Badr 5 26.0°E at 11.699 GHz is exploited. Considering the very slight deviation across the two orbital positions, one can practically consider it the same satellite without loss of

generality. The full details on the received beacons can be found in Table I. For more details on the ALPHASAT experiment conducted at NTUA as well as beacon-based attenuation measurement campaigns the interested reader is pointed to [1],[5],[7]-[10].

TABLE I. SATELLITE BEACONS USED

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

3 In-Excess Attenuation Statistics

In the following the very first results from a full year of the campaign, i.e. January to December 2018 are presented. In Fig. 2 the Complementary Cumulative Distribution Functions (CCDFs) for the three frequency bands are presented; the receivers data availability has been 99.07 %, 96.63 % and 98.82 % for Ka, Q and Ku band respectively. As expected, Q-band exhibits the worst performance as it is very prone not only to rain precipitation but also to great extent to clouds and fog; Ka-band does not appear to be very sensitive to clouds, however, it is still heavily affected by rain. On the other hand, Ku-band seems to be more robust to atmospheric phenomena, with rare cases of in-excess attenuation levels exceeding 10-15 dB. It becomes obvious from the above that the sole use of a fade margin, particularly in the Q-band case is not sufficient.

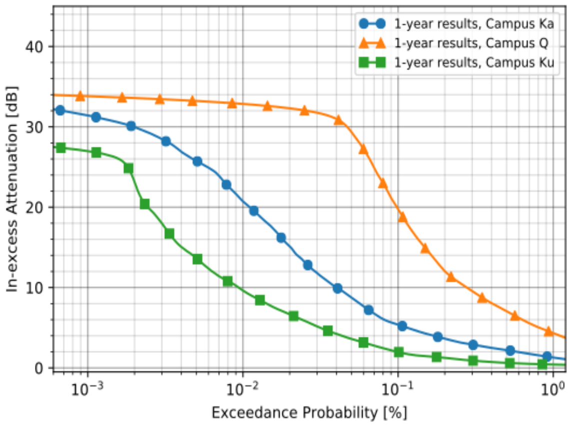

Fig. 2. Overall (one-year) in-excess attenuation statistics for the three frequency bands.

In Figs. 3-5 the seasonal statistics for each frequency band are presented, making clear that the south Mediterranean climate of Greece is quite unique. As can be seen, the worst season in terms of attenuation (at least for the year 2018) was summer, and more particularly June and July where very strong attenuation events (even beyond the available dynamic range of the receivers) were recorded.

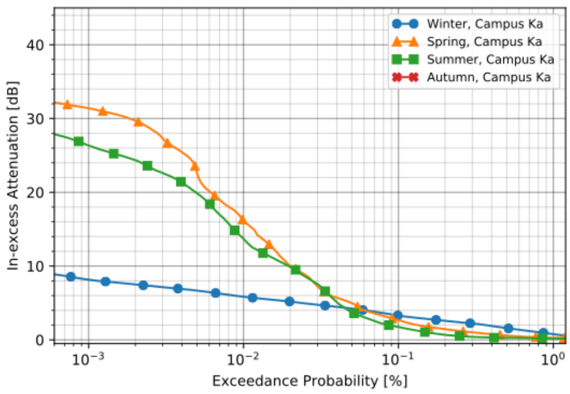

Fig. 3. Seasonal in-excess attenuation statistics for Ka-band

4 Correlation Statistics

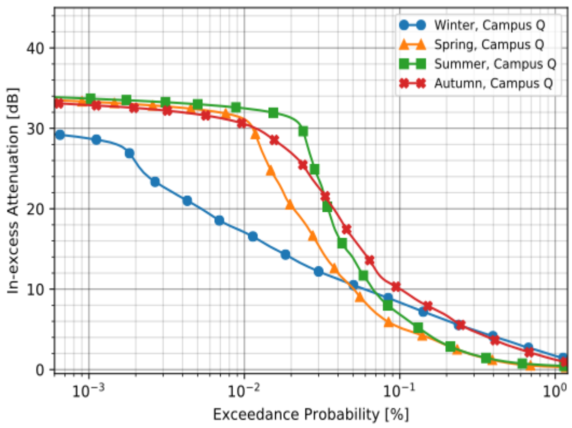

Fig. 4. Seasonal in-excess attenuation statistics for Q-band.

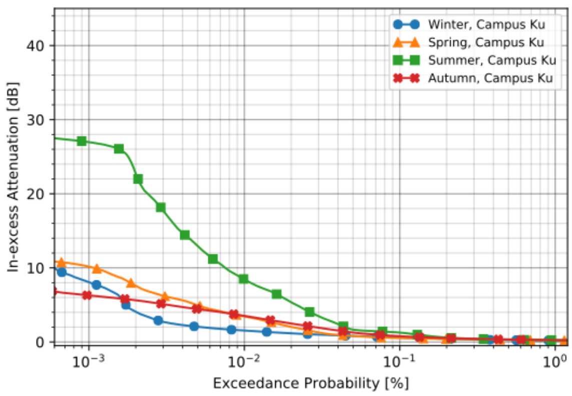

Fig. 5. Seasonal in-excess attenuation statistics for Ku-band.

To give a basic insight on the correlation between attenuation across the three frequency bands, the scatter plots between Ka-Ku, Q-Ka and Q-Ku are depicted in Figs. 6-8 respectively. It is worth noting that since only one year of measurements has been included the results are not conclusive, however, a general tendency can still be obtained. The vertical tendency in Figs. 7 and 8 is attributed to the lower dynamic range that the Q-band receiver offers.

5 Frequency Diversity Examples

In Figs. 9-10 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 and could be employed to keep a service operational, yet at lower performance.

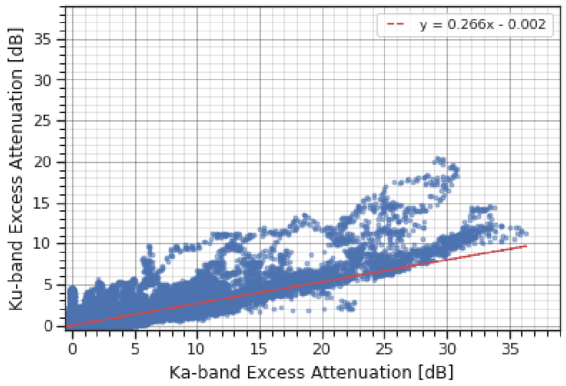

Fig. 6. Ka vs Ku band in-excess attenuation.

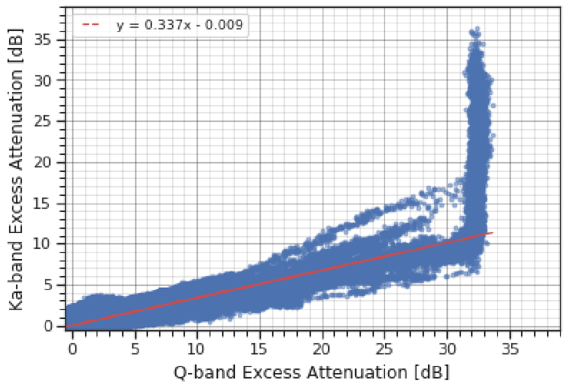

Fig. 7. Q vs Ka band in-excess attenuation.

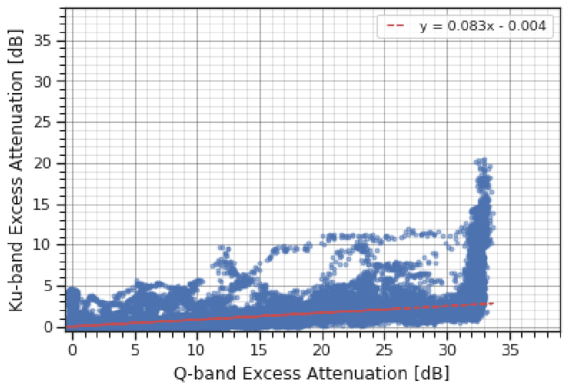

Fig. 8. Q vs Ku band in-excess attenuation.

6 Summary and Future Work

In this paper the first results from a year of concurrent operation of the ongoing frequency diversity campaign conducted in Attica, Greece are presented. Interesting observations have been made and as more results are collected and processed a more elaborate analysis will follow. Among others it would be interesting to verify how frequency scaling models perform as well as to possibly attempt to improve them by exploiting the actual measurement data acquired.

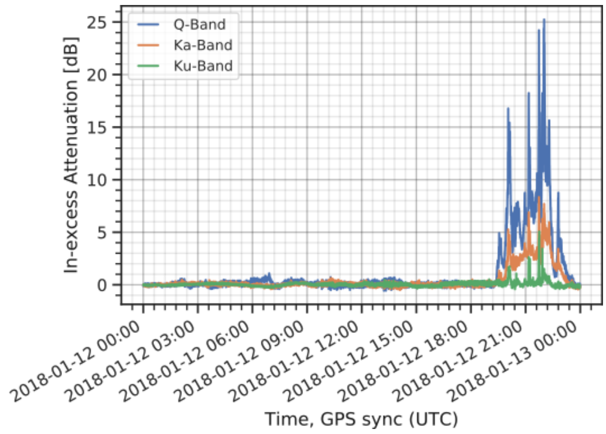

Fig. 9. In-excess attenuation timeseries for 12 January 2018.

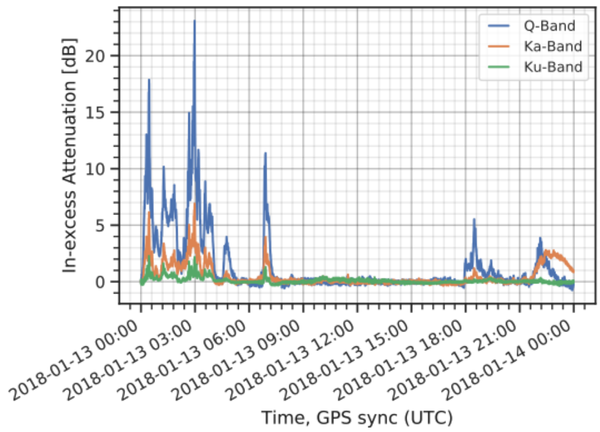

Fig. 10. In-excess attenuation timeseries for 13 January 2018.

7 References

[1] S. Ventouras et al., "Large scale assessment of Ka/Q band atmospheric channel across Europe with ALPHASAT TDP5: The augmented network," in 2017 11th European Conference on Antennas and Propagation (EuCAP), March 2017, pp. 1471–1475.

[2] R. K. Crane, Propagation handbook for wireless communication system design. CRC press, 2003.

[3] L. J. Ippolito, Satellite Communications Systems Engineering: Atmospheric Effects, Satellite Link Design and System Performance, John Wiley, 2008.

[4] A. D. Panagopoulos, P.-D. M. Arapoglou and P. G. Cottis, "Satellite Communications at Ku, Ka and V Bands: Propagation Impairments and Mitigation Techniques." IEEE Communication Surveys and Tutorials, 2004.

[5] A. Z. Papafragkakis, A. D. Panagopoulos, and S. Ventouras, "Combined beacon and noise satellite propagation measurements using software defined

radio," in 2017 11th European Conference on Antennas and Propagation (EuCAP), March 2017, pp. 2356–2360.

[6] T. Rossi, M. De Sanctis, M. Ruggieri, C. Riva, L. Luini, G. Codispoti, E. Russo and G. Parca. "Satellite Communication and Propagation Experiments Through the Alphasat Q/V Band Aldo Paraboni Technology Demonstration Payload," IEEE Aerospace and Electronic Systems Magazine, Vol.31(3), part I of II, pp.18-27, March 2016.

[7] J. M. Riera, D. Pimienta-del-Valle, P. Garcia-del-Pino, G. A. Siles and A. Benarroch, "Alphasat propagation experiment in Madrid: Results on excess and total attenuation," in 2017 11th European Conference on Antennas and Propagation (EuCAP), March 2017, pp. 1-4.

[8] A. Rocha, S. Mota, F. Jorge, "Propagation campaign at Q-band and Ka-band using the Alphasat and Ka-Sat satellites," in 2018 12th European Conference on Antennas and Propagation (EuCAP), IET Conference Proceedings, 2018, pp. 904-909.

[9] F. Machado, F.P. Fontán, V. Pastoriza, and P. Mariño, "The Ka- and Q-band Alphasat ground station in Vigo," in 2015 9th European Conference on Antennas and Propagation (EuCAP), Lisbon, 2015, pp. 1–4.

[10] J. Nessel, G. Gousetis, M. Zemba. and J. Houts, "Design and Preliminary Results from Edinburgh, UK Alphasat Q-band Propagation Terminal", in 22nd Ka and Broadband Communications Conference, Cleveland, Ohio October 2016.