# MULTI-BAND NDSA MEASUREMENTS BETWEEN TWO COUNTER-ROTATING LEO SATELLITES FOR ESTIMATING THE TROPOSPHERIC WATER VAPOR PROFILE

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## 1. INTRODUCTION

NDSA (Normalized Differential Spectral Absorption) is a differential measurement method to estimate directly the total content of water vapor (IWV, Integrated Water Vapor) along a tropospheric propagation path between two Low Earth Orbit (LEO) satellites [1].

The NDSA approach is based on the conversion of a spectral parameter called "spectral sensitivity" into the total content of water vapor along the propagation path between the two LEO satellites. In [1] we showed the potential of spectral sensitivity in providing direct estimates of integrated water vapor along LEO-LEO tropospheric propagation paths in the 15-25 GHz range. This analysis was carried out for tangent altitudes (the distance of the path with respect to the Earth) up to 11 km and at global scale accounting for more than 8000 radiosonde observations related to 20 lunch sites in the Northern Hemisphere. A basic result in [1] is the presentation of the coefficient conversions (linear and quadratic) from the spectral sensitivity to the integrated water vapor for 17,19 and 21 GHz in the 1-11 km tangent altitude range.

In [2] we focused on the measurement accuracy of the spectral sensitivity parameter. Specifically, we examined this accuracy at 17, 19 and 21 GHz for two models of atmospheric structure. We achieved this objective both by providing an approximate theoretical expression, function of main propagation and disturbance parameters, and by developing a simulator based on more detailed atmospheric and disturbance models.

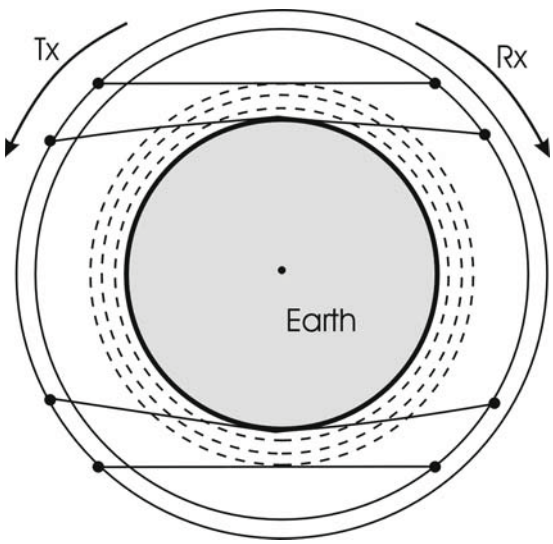


Fig. 1 Sketch of the measurement geometry with two counter-rotating LEO satellites on two different orbits

A basic result was that the spectral sensitivity measurement accuracy can be estimated through the theoretical approximation as far as the averaged signal-to-noise ratio (SNR hereafter) keeps above 20 dB, and that below such level measurements are not reliable. This can be considered true as far as the integration time used for measurements keeps smaller than the decorrelation time of the scintillation.

In [3] we presented a complete simulation tool for the study of the NDSA measurement performance at global scale for single and multiple global atmospheric profiles assuming spherical symmetry for the atmospheric structure. Realistic LEO satellites' orbit configuration, link budget, and disturbances sources are accounted for. In [4] we analyzed for the first time the use of M band for NDSA measurements (specifically, 179 and 182 GHz), proposing them as good candidates for water vapor estimates at tangent altitudes higher than 10 km with respect to those in $K_u$/K band.

## 2. MULTI-BAND NDSA CONVERSION ALGORITHM

In this paper we present the multi-band approach to convert the simultaneous $K_u$, K and M spectral sensitivity measurements into an integrated water vapor profile up to 14 km tangent altitude. In particular we present the processing algorithm developed for the optimal use of 5 simultaneous measurement channels (17, 19, 21, 179 and 182 GHz). This algorithm is based on the estimate of the SNR at the receiver, so as to exploit adaptively at every tangent altitude the optimal channel, based on actual signal conditions.

The algorithm version used in this work is the following:

- Below 5 km: use 19 GHz (quadratic relationship) if the estimated SNR exceeds a given preset threshold, otherwise use 17 GHz with linear relationship
- From 5 to 7 km: use 19 GHz (linear relationship)
- From 7 to 11 km: use 21 GHz (linear relationship)
- From 11 to 12 km: use 179 GHz (linear relationship)
- Above 12 km: use 179 GHz (linear relationship ) is the estimated SNR falls below a preset threshold, otherwise use 182 GHz (linear relationship)

The coefficients used to convert spectral sensitivity into integrated water vapor for the M band were computed using high-resolution yearly radiosonde profiles related to a single (Gibraltar) radiosonde site.

The algorithm has been tested simulating the transmission between two counter-rotating LEO satellites, using global atmospheric profiles based on the ECMWF high-resolution weather analysis field of July 15, 2007, and on true high-resolution radiosonde profiles. The counter-rotating LEO satellites simulation tool has been developed based on the results described in [1]-[5]. It accounts for scintillation impairments, thermal noise at the receiver and defocusing. The atmospheric propagation at microwaves is computed based on the MPM93 model [6]. The main system specifications for the simulations are shown in Table 1 and Table 2, showing the satellite orbit settings and the system (link budget) parameters respectively.

Simulation results and processing algorithm performance are presented and discussed. In particular, we discuss the effect of increasing the number of frequency bands on the estimate performance of the integrated water vapor profile.

Table 1 LEO satellites settings

| | Tx | | Rx | |
|---|---|---|---|---|
| Satellite Height | 800 km | | 650 km | |
| Satellite Inclination | 98.63° | | 97.95° | |
| Right Ascension of the Ascending Node | 243.60° | | 63.60° | |
| Eccentricity | 0.0001 | | 0.0001 | |
| Argument of Perigee | 90.00° | | 90.00° | |
| Mean Anomaly | 0° | 180° | 0° | 80° |

Table 2. Values of the link power budget parameters, for each of the 5 channels utilized in the simulations

| $f_o$ [GHz] | Tx Power [dBW] | Tx and Rx Antenna Gain [dB] | System noise temperature [dBK] |
|---|---|---|---|
| 17.00 | 3.0 | 26.9 | 25.3 |
| 19.00 | 3.0 | 27.8 | 25.8 |
| 21.00 | 3.0 | 28.5 | 26.3 |
| 179.00 | 3.0 | 34.8 | 23.8 |
| 182.00 | 3.0 | 34.9 | 23.8 |

## 3. REFERENCES


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