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Water vapour assessment for the characterisation of radiowave propagation in Satellite Communication systems and Radio Science Experiments

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Radiowave propagation in the Earth's troposphere has a significant impact on several types of spatial systems and has to be taken into proper consideration in various phases of projects: including system planning, design, verification and mission operation. In this framework, among the atmospheric components, water vapor is particularly relevant for a wide range of systems.

In the case of Satellite communication system the increased use of higher frequency bands (currently Ka, Q and V bands with a future use of W band) combined with the interest on covering large service areas with a single satellite (which results in low elevation links at the edge of coverage) results in an increase of the relative impact of attenuation due to water vapor with respect to other components (typically rain but also clouds).
Areas of application include channel assessment techniques for controlling fade mitigation techniques and in orbit validation and testing of the actual payload performances (e.g. the actual radiated power). Another critical issue for Satellite Communication systems in which water vapour spatial distribution plays a major role at those frequency bands is the signal scintillation, determined by the turbulence at the atmospheric boundary layer, which affects in particular the higher order signal modulation schemes that are increasingly used. All this issues require on one hand an accurate characterization of water vapor distribution both in time and space and on the other hand the definition of propagation parameters to scale vapor affects at different frequencies. As an example with the forthcoming AlphaSat TDP5 scientific and Telecom experiment, the problem of assessing in real time atmospheric attenuation at Ka, Q and V band (i.e. 19.7, and 39.4 and 48 GHz) arises. To this end, measures of water vapour play a primary role and attenuation due to water vapour contents can be calculated through the use water vapour mass absorption coefficients which are frequency and site dependant. Techniques to retrieve integrated precipitable water vapour (PWV) from ground microwave radiometric (MWR) measurements and from the delay of radio signal of the Global Navigation Satellite Systems (GNSS) are here analysed.
GNSS data processing can provide excellent information on the PWV, practically equivalent to radiosonde profiles (RAOB) or ground-based multi-channel microwave radiometer observations (WVR). The rapid growth of GNSS ground networks and a drop in their unitary cost, together with their tested capability to operate in all-weather conditions and in different climates makes GNSS vapour estimation a very attractive technique.

Another area of application is on precise tracking of interplanetary spacecraft in space exploration missions. It is a crucial tool for mission operations (i.e. orbit determination and navigation) and for scientific applications (e.g. the experimental assessment of the dynamical model of the solar system, to probe planetary interiors and for testing of general relativity). As an example the ESA Bepi-Colombo mission to Mercury, will leverage on the experience gained with the successful JPL's Cassini mission, and will include an advanced accurate Doppler ranging system based on the use of radio links at Ka and X band. This system can remove the propagation effects of most of the media along the link with the exception of the tropospheric path delay. Therefore this type of Radio Science experiments must use a tropospheric media calibration system (MCS) to measure accurately the signal delay and delay-rate along the time-varying path to the satellite over observation periods which can extend up 10000 s. As a result the MCS must be characterised by a very high stability, usually expressed as Allan Standard Deviation of the observable, which implies the design and the implementation of very stable

MWR. In addition, due to MCS configuration and position, the presence of atmospheric turbulence along the path can degrade the stability of MCS observations. In this framework accurate modelling and the use of assessment techniques for propagation parameters related the atmospheric water vapour and turbulence will be discussed.