Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 47 (2011) 186–196
ADVANCES IN SPACE RESEARCH
(a COSPAR publication)
www.elsevier.com/locate/asr

The impact of microwave absorber and radome geometries on GNSS measurements of station coordinates and atmospheric water vapour

T. Ning *, G. Elgered, J.M. Johansson

Department of Radio and Space Science, Chalmers University of Technology, Onsala Space Observatory, SE-439 92 Onsala, Sweden

Received 25 January 2010; received in revised form 4 May 2010; accepted 13 June 2010

Abstract

We have used microwave absorbing material in different geometries around ground-based Global Navigation Satellite System (GNSS) antennas in order to mitigate multipath effects on the estimates of station coordinates and atmospheric water vapour. The influence of a hemispheric radome – of the same type as in the Swedish GPS network SWEPOS – was also investigated. Two GNSS stations at the Onsala Space Observatory were used forming a 12 m baseline. GPS data from October 2008 to November 2009 were analyzed by the GIPSY/OASIS II software using the Precise Point Positioning (PPP) processing strategy for five different elevation cutoff angles from 5° to 25°. We found that the use of the absorbing material decreases the offset in the estimated vertical component of the baseline from ~27 mm to ~4 mm when the elevation cutoff angle varies from 5° to 20°. The horizontal components are much less affected. The corresponding offset in the estimates of the atmospheric Integrated Water Vapour (IWV) decreases from ~1.6 kg/m^2 to ~0.3 kg/m^2. Changes less than 5 mm in the offsets in the vertical component of the baseline are seen for all five elevation cutoff angle solutions when the antenna was covered by a hemispheric radome. Using the radome affects the IWV estimates less than 0.4 kg/m^2 for all different solutions. IWV comparisons between a Water Vapour Radiometer (WVR) and the GPS data give consistent results.

Keywords: GNSS antennas; Multipath; Microwave absorbing material; Radome; Atmospheric water vapour; Water Vapour Radiometer

1. Introduction

After decades of continuous development, Global Navigation Satellite System (GNSS) data have been used successfully in many applications. For example, continuously operating Global Positioning System (GPS) stations provide accurate estimates of the atmospheric Integrated Water Vapour (IWV). The formal uncertainty is in the order of 0.5 kg/m^2 and Root-Mean-Square (RMS) difference seen in comparisons to other instruments, such as radiosondes and microwave radiometers, typically ranges from 1.2 and 2.8 kg/m^2 (Wang et al., 2007). Based on the precise orbit information and consistent Earth orientation parameters, the accuracy of horizontal position estimates from the GPS data are at the millimetre level (Hill et al., 2009). However, the characteristic of GNSS also makes it vulnerable to some errors. For example, the GNSS antennas have low directive gain (hemispheric coverage) in order to simultaneously track as many satellites as possible. As a result, site-dependent systematic effects, i.e. scattering and multipath reflections of the signal observed, cannot be neglected and need to be carefully investigated and mitigated to improve the performance.

Multipath occurs when satellite signals are reflected by objects, such as huts, walls and trees. Due to multipath, the antenna receives the signal sent by a given satellite from different directions. The reflected signals always travel a longer path than the direct one, and the superposition of the signals causes errors in the measurements. In order to avoid the reflected signals from positive elevation angles, antennas from continuously operating stations are mounted far away from big buildings. In addition, the

* Corresponding author.
E-mail addresses: tong.ning@chalmers.se (T. Ning), kge@chalmers.se (G. Elgered), jmj@chalmers.se (J.M. Johansson).

0273-1177/$36.00 © 2010 COSPAR. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.asr.2010.06.023

antennas are equipped with a choke ring assembly designed to reject the reflected signals arriving from negative elevation angles. However, most GNSS antennas are required to receive signals from low positive elevation angles. Therefore, the gain of the antenna at negative elevation angles is too high to completely eliminate these reflected signals.

The effects of multipath on geodetic estimates of the site position have been investigated (e.g. Elósegui et al., 1995; Jaldehag et al., 1996). These studies found that the scattering from the reflecting structures within the near-field region (less than a few metres from the antenna), can produce errors of a centimetre or greater in the estimated vertical coordinate, but no significant effects in the horizontal coordinates. The top surface of the pillar and the metal structures to support the antenna are possible sources of the near-field multipath. King and Watson (2010) showed that a model of time-constant multipath effects is insufficient. The development of a mitigation approach is therefore highly desirable.

To avoid the accumulation of snow, and for a general protection, many GNSS antennas are equipped with radomes. Offsets in the order of centimetres in the vertical component were found due to the installation of a radome on a GNSS antenna (Williams, 2003). Different shapes of radomes (mainly conical and hemispherical) yield different impacts on the phase of the signal. Investigations of such systematic errors have shown that the hemispherical radome design is preferred (e.g. Johansson et al., 1998; Emardson et al., 2000).

Here we address the influence of the implementation of microwave absorbing material and a hemispherical radome on the estimates of the relative site coordinates, and the IWV. In Section 2, we describe the experiment setup and the processing of the GPS data. Sections 3 and 4 present results regarding the use of antenna phase centre corrections, and impacts of the antenna environment, respectively. The conclusions and suggestions for future work appear in Section 5.

2. Experimental setup and data analysis

An experimental pillar (ONTE) was constructed for a flexible mounting of GNSS antennas over a reference marker at the Onsala Space Observatory. A Leica AT504GG antenna is mounted on a circular concrete pillar with a beveled top surface and a height of 1 m (see Fig. 1a). The continuously operating IGS station ONSA is 12 m away from the ONTE antenna. In addition to what is seen in Fig. 2a the 20 m telescope is located 54 m to the left of ONTE and a small measurement hut is 23 m to the right of ONSA.

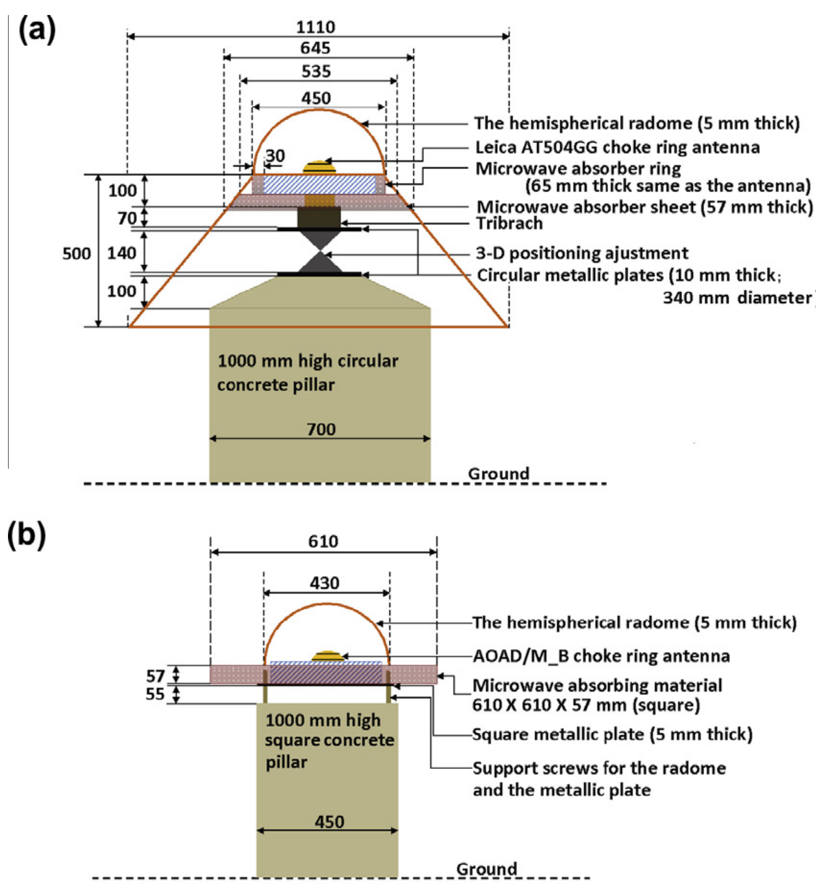

Fig. 1. (a) The experimental station ONTE and (b) the IGS station ONSA. All values are given in millimetres.