GPS Solut
DOI 10.1007/s10291-013-0322-z

ORIGINAL ARTICLE

Dynamic multipath in structural bridge monitoring: an experimental approach

Fanis Moschas · Stathis Stiros

Received: 10 July 2012 / Accepted: 8 March 2013

Abstract Vehicles such as passing trains produce significant short-term biases in coordinates of nearby GPS stations, preventing these coordinates from being used for structural monitoring of bridges. In order to study this problem, we carried out experiments with receivers recording at 100 Hz and located on both sides of a rail next to passing trains. The experiments focused on trains with similar characteristics and velocity. The analysis of the data revealed a short-duration bias in coordinates with amplitude up to 10 cm and high spectral frequencies. This bias is not due to wrong integer ambiguity fixing, software defects, and changing geometry of satellites and it does not significantly improve with the addition of GLONASS satellites. It is partly due to temporary blocking of certain satellites by passing vehicles and a dynamic multipath due to fast-moving, near-field reflective surfaces. This dynamic multipath seems to depend on the geometry of satellites and to be characterized by a shift of coordinates during the whole interval of the vehicle passage, as well as by very short-period coordinate fluctuations which are related to specific morphological characteristics of the train reflective surfaces. The amplitude of the dynamic multipath is smaller in the horizontal coordinates, which are also characterized by a clearer pattern than the vertical coordinates. On the basis of the above results, certain strategies for the modeling of the dynamic multipath are proposed.

F. Moschas · S. Stiros (✉)
Laboratory of Geodesy and Geodetic Applications,
Department of Civil Engineering, University of Patras,
Patras, Greece
e-mail: stiros@upatras.gr

F. Moschas
e-mail: fmoschas@upatras.gr

Keywords Structural monitoring · 100-Hz ultra high-rate GNSS · Satellite constellation · Noise · Kinematic

Introduction

GPS has been widely used for the measurement of deflections of bridges excited by various types of passing vehicles, including trains, or by pedestrian loading. Measurement is focusing on long-span cable-stayed bridges with deflections of several to tens of centimeters (Watson et al. 2007; Kogan et al. 2008), but recently, short-span bridges with openings of a few tens of meters and with deflections of up to 1 cm have also been covered (Meng et al. 2007; Moschas and Stiros 2011).

However, the potential of GPS to record oscillations induced by passing vehicles depends on the type of the bridge. For bridges with a frame section, GPS can be placed on the top of the structure with unlimited skyview (Fig. 1a) and results are excellent (Moschas and Stiros 2011). If a GPS antenna is placed on a level close to that of the bridge deck (Fig. 1b), recordings are seriously contaminated by noise which correlates with the passing vehicles and has been assigned to a vehicle-induced multipath. Two characteristic examples have been presented by Wieser and Brunner (2002) and by Moschas et al. (2013). The amplitude of this noise is of the order of 20–60 cm, which is much larger than the amplitudes of the typical noise of GPS measurements or bridge oscillations, preventing GPS measurements from being usable for most cases of structural monitoring.

Multipath and noise in GPS bridge monitoring differ from the conventional multipath which is due to slow changes in the geometry of satellites in the area of observations and is characterized by frequencies <0.05 Hz (Han