The Egyptian Journal of Remote Sensing and Space Sciences (2016) **xxx**, xxx–xxx

HOSTED BY
ELSEVIER

National Authority for Remote Sensing and Space Sciences

The Egyptian Journal of Remote Sensing and Space Sciences

www.elsevier.com/locate/ejrs
www.sciencedirect.com

RESEARCH PAPER

GPS SNR prediction in urban environment

Shikhar Deep *, **Raghavendra S.**, **B.D. Bharath**

Indian Institute of Remote Sensing, Dehradun 248001, India

Received 23 May 2016; accepted 6 September 2016

KEYWORDS

GPS satellite availability;
SNR prediction model

Abstract The signal quality along with satellite availability & geometric dilution of precision plays a major role in GPS positional accuracy. In this study an attempt is made to develop a SNR prediction model for the urban environment. The height attribute value for 3D shapefile representing different urban environments is acquired from Cartosat-1 DEM and Total Station (which gave better accuracy in prediction). The best fit regression model correlating GPS signal SNR and satellite elevation angle in open environment for a GPS antenna was derived. The derived regression model between satellite elevation angle and signal SNR along with reflection and diffraction coefficients of surrounding urban environment was used to predict the GPS signal SNR at a given time.

1. Introduction

The motivation behind this research was to answer the following question: "How the accuracy of GPS is affected by the obstructions in urban environment?" These obstructions may lead to degradation of signal strength or complete signal blockage and multipath is one of its major cause. GPS multipath, where a signal arrives by more than one path, is a source of positioning error. It also influences other scientific products derived from GPS observables, which includes timing (Ray and Senior, 2005), water vapor products (Braun et al., 2001), and seismic waves (Larson et al., 2003). Therefore it is important to understand its cause and magnitude. In urban environment geometry of satellites and multipath affect GPS accuracy in a constant amount, so we need to deal with these two factors for SNR prediction in urban environment. Satirapod and Wang (2000) related SNR with RMS Phase noise residuals and concluded SNR to be an important quality indicator. To assess the GPS signal multipath error Byun et al. (2002 developed a ray tracing GPS signal multipath simulator incorporating the signal reflection and diffraction from the surroundings. Bilich et al. (2004) gave strong evidence of multipath from the observations of SNR data. When SNR was calculated from the prompt accumulations of the code tracking loop, the measured SNR was found directly related to carrier phase errors due to multipath Bilich and Larson (2007). They also presented a tool Power Spectral mapping which visually represented the multipath environment of a GPS site. The objective of this study is to predict the SNR values of all visible satellites using multipath prediction model. The model takes an urban environment (3D building model) as an input and incorporates the reflection and diffraction losses.

* Corresponding author.
E-mail address: iirs.deeps@gmail.com (S. Deep).

Peer review under responsibility of National Authority for Remote Sensing and Space Sciences.

http://dx.doi.org/10.1016/j.ejrs.2016.09.002

2. Study area and datasets

The ultrarapid products of ephemeris were used, with 48 h of orbits, accurate at 5–10 m level. The Cartosat1 DEM was taken from (Enkhtur (2010). The 3D building model of IIRS test site was also generated using Total Station (Leica TPS 1201) and had horizontal accuracy of 40 cm and vertical accuracy of 60 cm. A total of 1970 epochs for about 11 h were observed for Trimble R7 GNSS at IIRS, Dehradun. This data was used to relate elevation angle and SNR values.

The base receiver was kept at the roof of IIRS building while the rover receiver was in front of the buildings as shown in Fig. 1. The model was validated in differential mode, when the rover was taken to different urban geometries of IIRS campus, Raj-Plaza and Cross road Mall. A total of 634 observations were taken with an interval of 10 s on 3/01/13 at IIRS campus of which we had the 3D building model using Cartosat DEM & Total Station. At the different urban geometries 316 numbers of observations were taken so as to validate predictions using Cartosat 1 DEM.

3. Methodology

GPS ephemeris data (International GNSS Service), location, time and satellite mask angle were the inputs for the prediction of satellite elevation angle and the satellite availability. Satellites with an elevation angle below mask angle were removed. A regression model was derived to relate the elevation angle with SNR with the field data. This derived regression model predicted the available satellites in open environment. Since the multipath is affected by the electrical properties of the building surface materials which reflects the GPS signals and also by diffraction (Richter and Euler, 2001) therefore the reflection and diffraction coefficients were incorporated in the Multipath Prediction Model. The input for the model was the 3D building shapefile (building footprints with height attribute) which also contained the electrical properties (conductivity and relative permittivity) of the building materials. The different urban scenarios explained in Deep et al. (2013) incorporated the reflection coefficients. The diffraction losses were computed with the single knife-edge diffraction model. The derived multipath modes incorporated the LHCP R.R (rejection ratio) – a factor which accounts for antenna gain pattern for multipath signals (Hannah, 2001). The Trimble Zephyr geodetic model 2 antenna with LHCP value 20, validated the multipath prediction model.

4. Results and discussion

To predict SNR, a regression model was derived for Trimble R7 GPS receiver. The best fit regression model found was Polynomial of order 3 (Eq. (1)) with co-efficient of determination $R^2 = 0.969$ as shown Fig. 2.

$$SNR = 3.199 * 10^{-05} * \theta^3 - 0.0081 * \theta^2 + 0.6613 * \theta + 31.38 \quad (1)$$

All the satellites could be predicted completely in the open environment using the above regression model. Observing the GPS rover receiver data kept in the urban environment, it was found that few satellites getting observed could not be predicted using the derived regression model. The satellites with high SNR (> 50 dB) could be successfully predicted while the low SNR (< 35 dB) ones could not be predicted. Rest of them may or may not be observed. Incorporating the multipath prediction model, the satellite availability and SNR could be predicted in urban environment. The prediction accuracy of the model was found better when the height in the 3D building shapefile was taken from total station. However it can also be seen that the major differences were large at the places where the SNR was low. The maximum difference in Table 1

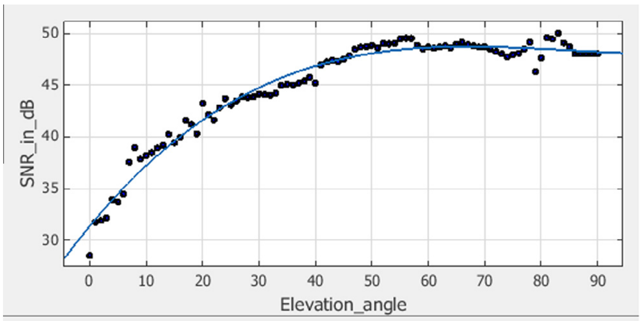

Figure 2 SNR vs. elevation curve.

Figure 1 GPS antennas (a) Base receiver on top of building (b) Rover at test site (Trimble R7 GNSS Base & Rover).

Table 1 Observed and predicted SNR values with 3D building model using Cartosat and Total Station (TPS) at an epoch.

Time-9.45.00	SNR			Difference (Observed-Predicted SNR)	
	Observed	Predicted			
PRN		TPS	Cartosat	TPS	Cartosat
G03	40.6	41.41	41.41	−0.81	−0.81
G06	37.1	38.1	38.1	−1	−1
G14	48.8	48.74	48.74	0.06	0.06
G18	49	48.3	43.28	0.7	5.72
G19	34.2	42.44	42.44	−8.24	−8.24
G21	48	47.5	44.47	0.5	3.53
G22	50.4	48.58	48.68	1.82	1.72
G24	44.6	43.77	39.21	0.83	5.39

is −8.24 for both Cartosat 1 DEM and TPS DEM. For PRN 24 we observe that with Cartosat 1 DEM difference of 5.39 dB and for the same, with the total station the difference is 0.83 dB only. This establishes that overall accuracy also depends on the accuracy of the height attribute field in 3D building shapefile.

The PRN 18, 21 22 & 24 were not visible without incorporating multipath model but after incorporating it they were predicted. The difference in all these cases is observed to be very minimum indicating performance of the model. Prediction accuracy of 82.60% was achieved when height was taken using Cartosat 1 DEM while using Total Station prediction accuracy of 89.13% was achieved.

5. Conclusions

The satellites in open environment could be predicted using the regression models. The multipath prediction model could efficiently predict the satellite availability and signal quality for different urban scenarios. The SNR predictions were validated successfully for the same. The height of the 3D shapefile taken from Total Station gave better prediction results than Cartosat DEM. It was seen that the major differences between SNR predicted and observed were at the places where the SNR is low (< 35 dB). At low elevation angles, the SNR is low and ground multipath dominates which effectively reduces the signal strength and sometimes the SNR reaches to a level below the threshold for the receiver and that satellite could not be observed.

Conflict of interest

The authors declare no conflict of interest.

References

Bilich, Andria, Larson, Kristine M., 2007. Mapping the GPS multipath environment using the signal-to-noise ratio (SNR). Radio Sci. 42 (6), RS6003.

Bilich, Andria, Larson, Kristine M., Axelrad, Penina, 2004. Observations of signal-to-noise ratios (SNR) at geodetic GPS site CASA: implications for phase multipath. Proc. Centre Eur. Geodyn. Seismolog. 23, 77–83.

Braun, John, Rocken, Christian, Ware, Randolph, 2001. Validation of line-of-sight water vapor measurements with GPS. Radio Sci. 36 (3), 459–472.

Byun, Sung H., Hajj, George A., Young, Lawrence E., 2002. Development and application of GPS signal multipath simulator. Radio Sci. 37 (6). 10–1–10–23.

Deep, Shikhar, Bharath, B.D., Raghvendra, S., 2013. GNSS Availability and Multipath Prediction in an Urban Environment. Andhra University. <http://www.iirs.gov.in/iirs/sites/default/files/StudentThesis/Thesis_final.pdf>.

Enkhtur, Bayarmaa, 2010. Topographic Database Extraction at 1:25000 Using CARTOSAT-1 Stereo Data. CSSTEAP14th RS&GIS Post Graduate Diploma Course., Indian Institute of Remote Sensing (NRSC). <http://www.cssteap.org/documents/s12.pdf>.

Hannah, Bruce M., 2001. Modelling and Simulation of GPS Multipath Propagation (Thesis). Queensland University of Technology. <http://eprints.qut.edu.au/15782/> (Accessed October 28, 2013).

Larson, Kristine M., Bodin, Paul, Gomberg, Joan, 2003. Using 1-Hz GPS data to measure deformations caused by the Denali fault Earthquake. Science 300 (5624), 1421–1424.

Ray, Jim, Senior, Ken, 2005. Geodetic techniques for time and frequency comparisons using GPS phase and code measurements. Metrologia 42 (4), 215.

Richter, B., Euler, H.J., 2001. Study of improved observation modeling for surveying type applications in multipath environment. In: Proc ION GPS-2001, Salt Lake City, UT, pp. 11–14.

Satirapod, Chalermchon, Wang, Jinling, 2000. Comparing the quality indicators of GPS carrier phase observations. Geomatics Res. Australas. 73, 75–92.

Please cite this article in press as: Deep, S. et al., GPS SNR prediction in urban environment, Egypt. J. Remote Sensing Space Sci. (2016), http://dx.doi.org/10.1016/j.ejrs.2016.09.002