Book Review

Digital Satellite Navigation and Geophysics: A Practical Guide with GNSS Signal Simulator and Receiver Laboratory by Ivan G. Petrovski and Toshiaki Tsujii, Cambridge University Press, 2012;
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Since its beginning, the GPS system has become an indispensable research tool in geosciences. It is used in studies of the atmosphere, the Earth, oceans, and even space. The system applications exceed the imagination of its creators and early users, and it is used today in areas that no one would have thought of yesterday [e.g., Global Navigation Satellite Systems (GNSS) reflectometry]. GPS was followed by the Russian GLONASS system, which is currently fully operational; it is being followed by European Galileo and Chinese BDS systems. Therefore, we use the term GNSS to cover this variety of satellite positioning systems. This book, however, focuses primarily on GPS and GLONASS signals, with the same information on QZSS.

Ivan Petrovski and Toshiaki Tsujii's book is preceded by an excellent foreword by Prof. Richard B. Langley that may serve as a review itself. It happened that both Professor Langley and me have research background in space geodesy; hence we share some common views on this book.

As a geodesist, I was raised on two excellent textbooks on GNSS, one by Alfred Leick, and the second by Bernard Hofmann-Wellenhof and co-authors. Therefore, I often unintentionally compare this book to these well established textbooks. In general, the well established high-quality textbooks on GNSS technology for geoscientists are more or less equally focused on all aspects of GNSS systems

and GNSS data processing, but they are lacking in-depth discussion on signals and in-receiver signal processing. They usually include detailed discussions on reference frames used in satellite positioning and geodetic/mathematical models of GNSS data processing and adjustment, since this knowledge is required by the most precise applications, e.g., geodesy. If you want to improve your knowledge on these topics, "Digital Satellite Navigation" is not for you, as it describes the reference frames and the adjustment methods in a very general way.

This book, however, provides a detailed explanation on GNSS signal generation in satellites and pseudolites, all aspects of in-receiver GNSS signal processing, signal simulations, software receivers, scintillation monitoring with a software receiver, and INS-aided satellite positioning. What is more, the book includes free academic versions of a real-time software receiver and signal simulator. The thorough discussion on the above-mentioned topics greatly exceeds what is found in other textbooks, and by this reason, it should be recommended. The authors use friendly and easy to understand language. This important feature definitely helps students and researchers without deeper knowledge of the GNSS technology follow the content of the book. Also, the book is worthy of recommending to all readers interested in GNSS signal processing; its appeal is not limited to geoscientists only.

Each chapter ends with a list of the references, and almost each chapter is concluded with a practical exercise project based on the included software. In addition, the book provides a number of case studies that help to understand its content and help with the

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provided exercises. The book website contains pre-recorded data, which a reader can process with the included software receiver while working with the example projects. Additionally, web resources at <http://www.cambridge.org/prteovski> provide book resources and erratum.

The book is organized into 13 chapters.

The first chapter of this book, “Methods of positioning with navigation satellites”, gives a general overview of principles and methods of satellite positioning, related reference coordinate and time systems, observational equations, definitions, etc. This general information is provided in an easy to understand way and is suitable for readers new to GNSS technology. Nevertheless, there is too little information on coordinate reference systems and frames.

Chapter 2, “Presentations and applications of GNSS orbits”, concerns Kelperian orbital parameters, forces affecting GNSS orbits, ephemerides of GPS and GLONASS satellites, and precise orbits in SP3 format from the IGS and CODE. However, the relation between the IGS and CODE is not clear through the whole book—CODE is one of several IGS Analysis Centers, and the final IGS orbital (and other) products are a combination of the products of these centers, ensuring their high accuracy and reliability.

Chapter 3, “GNSS signal generation in transmitters and simulators”, is devoted to spread-spectrum radio signals used for satellite navigation. It describes signal generation and provides very extended and valuable discussion on signal simulation with analogue and digital simulators, with special attention to differences between both methods. The construction and functional scheme of the simulator is discussed, too. Also, example applications are provided. In addition, in this chapter the authors explain the functionality of and technical issues related to pseudolites. The chapter ends with example exercises with the bundled ReGen simulator. I rate the content of this chapter very highly (although there is a glitch in the formula 3.23 result).

Chapter 4, “Signal propagation through the atmosphere”, pertains to radio wave propagation. The authors have limited the vertical range of the ionosphere to 300–500 km, while most scientists agree

that it spans at least from 100 to 1,000 km. Also, the discussion on violating the special theory of relativity by the phase advance in the ionosphere seems a bit shaky. Nevertheless, it is a good summary of radio signal propagation, shows signal phase and group velocity in the dispersive medium (ionosphere), and provides major GNSS signal propagation models in the ionosphere. This chapter ends with rather too little information on signal propagation in the troposphere, which, in my opinion, is an equally interesting problem in geophysical applications.

Chapter 5, “Receiver RF front end”, shows how a GNSS signal is converted by a GNSS receiver front end to a digital format for further processing. It describes front-end, antennas, rx clocks, down-conversion, digital-to-analogue conversion, etc. This is another example of a very interesting and valuable chapter bringing together information that is difficult to find in other texts. I rate the content of this chapter very highly.

Chapter 6, “Real-time baseband processor on a PC”, does a really outstanding job describing how the baseband processor processes digitized intermediate frequency (DIF) and outputs all information carried out by the GNSS signal: Doppler, pseudoranges and phase observations, signal-to-noise ratio, navigation data, etc. This is another very highly rated chapter.

Chapter 7, “Multipath”, deals with a multipath error. It is described in a short, separate chapter, since multipath directly affects a baseband processor. The chapter shows how to introduce a multipath error into a simulated signal using deterministic and stochastic models, and also discusses multipath effects on BPSK and BOC-modulated signals and relevant mitigation methods.

Chapter 8, “Optimization of GNSS observables”, concentrates on methods for error reduction in GNSS observables. It discusses carrier smoothing of pseudoranges, differencing of the observations (single, double, triple differences), and linear combinations of the signals. Additionally, this chapter deals with satellite and ground-based augmentation systems.

Chapter 9, “Using observables in navigation-related tasks”, evaluates carrier-phase ambiguity resolution methods for static and kinematic data and

cycle slip detection algorithms. It discusses several interesting case studies concerning GNSS applications in navigation.

Chapter 10, “Electromagnetic scintillation of GNSS signal”, includes a very interesting and good description of scintillation effects and their monitoring with GNSS, some example case studies, and scintillation models. This chapter should be of interest to those carrying out research on the ionosphere.

Chapter 11, “Geophysical measurements using GNSS signals”, in a concise and very interesting way, explains why GPS is an indispensable tool in a variety of geophysical research topics like studying the atmosphere, the Earth, and oceans. It brings several short examples and case studies that may interest the reader and points to the literature providing deeper discussion of these examples.

Chapter 12, “Aiding baseband and navigation processors using INS”, shows how external information from INS helps signal acquisition, tracking, and finally, navigation. The authors discuss different GNSS/INS integration levels, and also briefly address the PPP technique.

In conclusion, I have to admit that I have found this book very interesting, especially the middle

chapters presenting rare information on all aspects of GNSS signals acquisition, tracking, processing, and their simulation. I can only agree with the authors that the book, together with its web resources, may be a first step for many readers to building their own GNSS R&D lab. This actually happened to me (and many others, I am sure) years ago with another book, by Gilbert Strang and Kai Borre.

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