

[from the Guest Editors]

Advances in Signal Processing for Global Navigation Satellite Systems

Pau Closas, Marco Luise, José-Ángel Ávila-Rodríguez, Christopher Hegarty, and Jiyun Lee

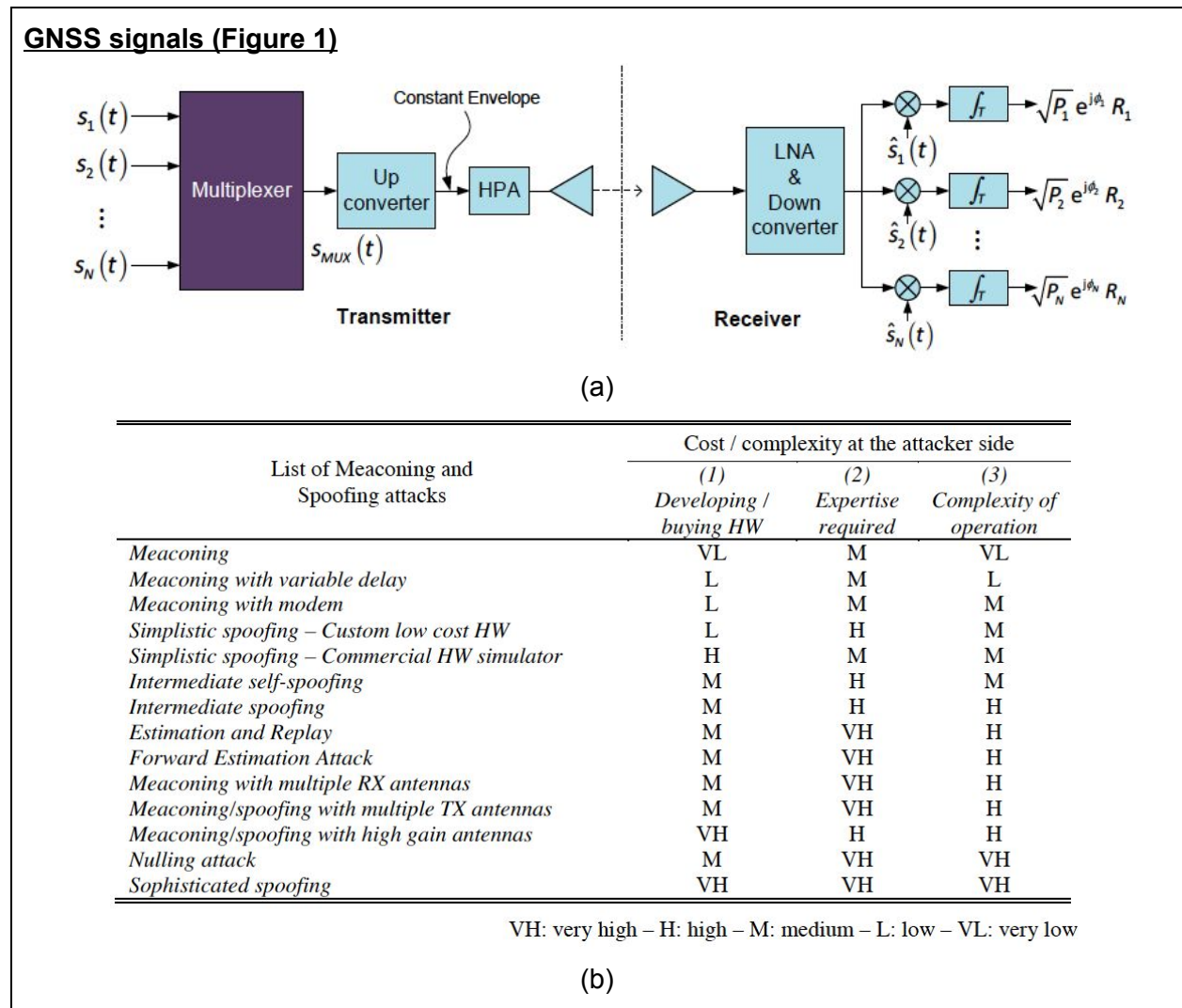
Where am I? What time is it? These are intimately related questions that have accompanied humanity for centuries. From past times when sailors were excitingly discovering recondite regions on Earth, to current outer space exploration. From the fascinating development of calendars by ancient civilizations all over the world - typically for agricultural purposes - to current developments of extremely accurate atomic clocks, reliable position and time measures have played an important role in human progress, and will continue to do so.

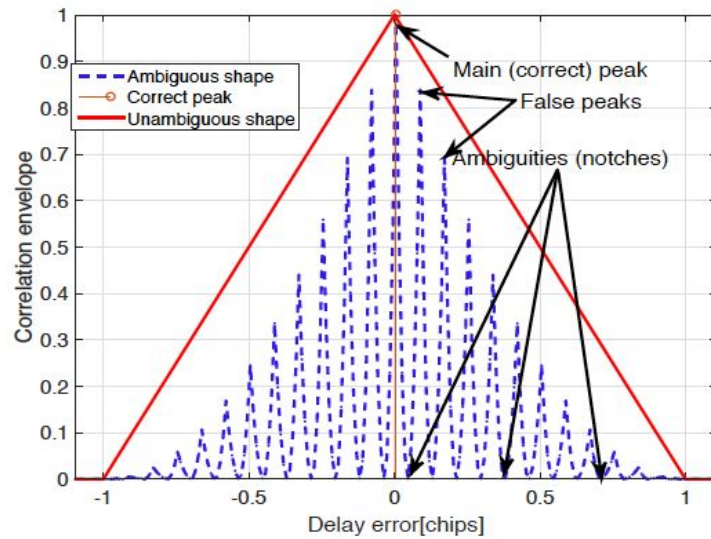
Nowadays, knowledge about one's own (or another's) position is used in countless applications, and represents an enabling piece of information. Mass-market location-based services (LBS), whose rise is tightly related to the advent of smartphone devices, call for it. Additionally, most critical infrastructures depend on accurate and secure access to position and timing references. Such infrastructures include ubiquitous road/rail/maritime/air transportation facilities, but also more applications a bit more detached from everyday life, like the synchronization of distant base stations in cellular communications, time synchronization in the power grid, or high-frequency trading and other banking operations.

In this context, it is fair to claim that use of Global Navigation Satellite Systems (GNSS) is the technology of choice whenever it is available. GNSS is the general term used to identify those systems and technologies pioneered by GPS, that enable positioning and timing based on a constellation of satellites and other augmentation systems. GNSS technology is nowadays ubiquitous in many transversal infrastructures and has become the backbone of all applications where precise position, navigation, and timing (PNT) of user equipment is required. Moreover, GNSS is *the* pervasive PNT technology in outdoor environments, where its performance, coverage, and reliability exceeds that of other technical solutions. However, in spite of all its virtues, challenges and vulnerabilities also exist in the use of this technology, particularly in challenging scenarios where signal propagation is either naturally impaired (for instance, due to multipath-rich channels, ionospheric scintillation, or urban canyons) or intentionally degraded (for instance, when jamming devices are in place or in case of spoofing attacks, where a malicious user tries to deceive the receiver by forging legitimate-like signals). In those situations, signal processing techniques appear extremely useful. In fact, signal processing has always played a key role in GNSS design, performance enhancement, and vulnerabilities mitigation.

The special issue that you have in your hands is the attempt of the editors to trigger discussion and shed some light into these fundamental topics. This said, we will go no further with a written

description of the exciting contributions you will find in this special issue. On the contrary, we prepared a *visual summary* for your perusal which contains the main topics addressed in this compendium: This special issue starts addressing the design of special GNSS signals, a topic of particular interest in the past and still of great relevance today; It continues with the discussion of effective techniques for receiver performance enhancement; and it finishes with the analysis of some vulnerabilities. Once you have had the time to read the issue, we hope you will agree with us that the included material is insightful and fresh. We also hope it will foster further discussion and application of the diverse techniques of signal processing to the ever-changing field of satellite-based navigation systems.

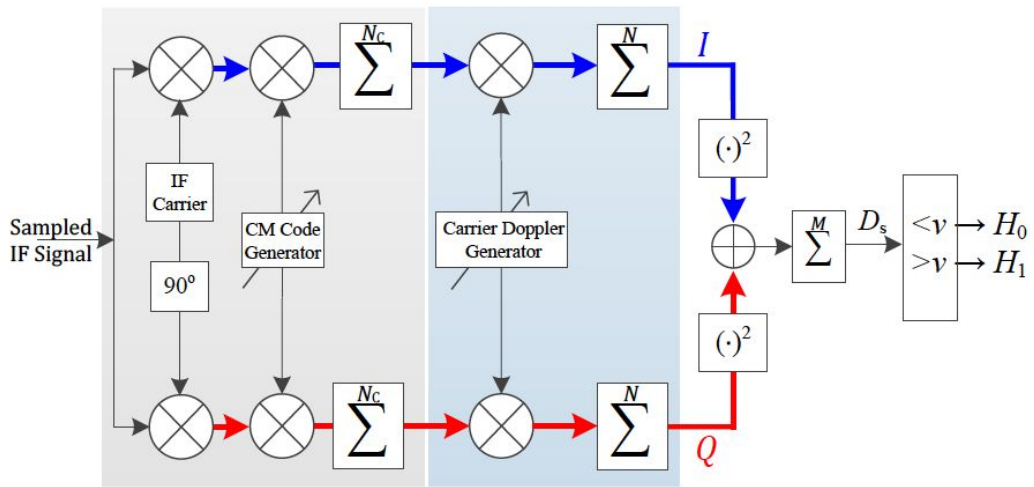




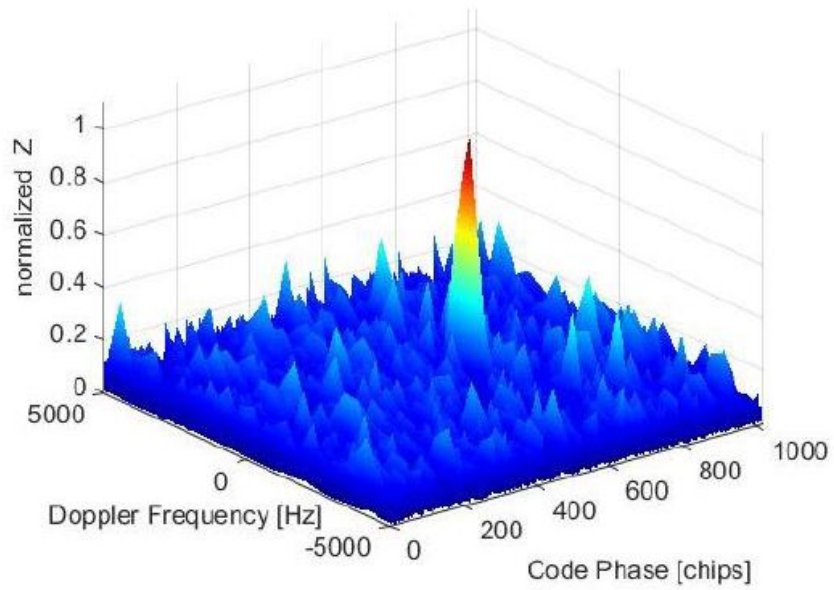
(c)

Figure 1. As the number of GNSS systems increases, so does the number of signals being emitted by the satellites. There is a wide variety of signal types, whose design and treatment is the subject of extensive research: (a) a generic GNSS signal generation, transmission, and reception diagram considering signal multiplexing (see the article “Signal Multiplexing Techniques for GNSS” by Yao and Lu), (b) a taxonomy of spoofing attacks, which could be compensated by signal authentication countermeasures (see the article “Signal Structure Based Authentication for Civil GNSS: Recent Solutions and Perspectives” by Margaria et al.), (c) most modernized signals suffer from ambiguities and false peaks in the correlation envelope (see the article “A Survey of Unambiguous Techniques in GNSS Modernized Signals” by Lohan et al.)

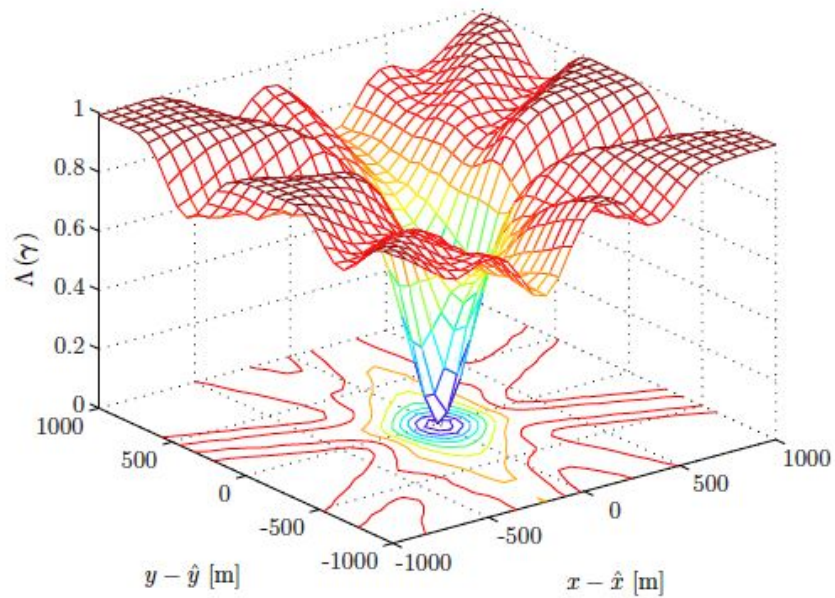
Receiver enhancement (Figure 2)



(a)



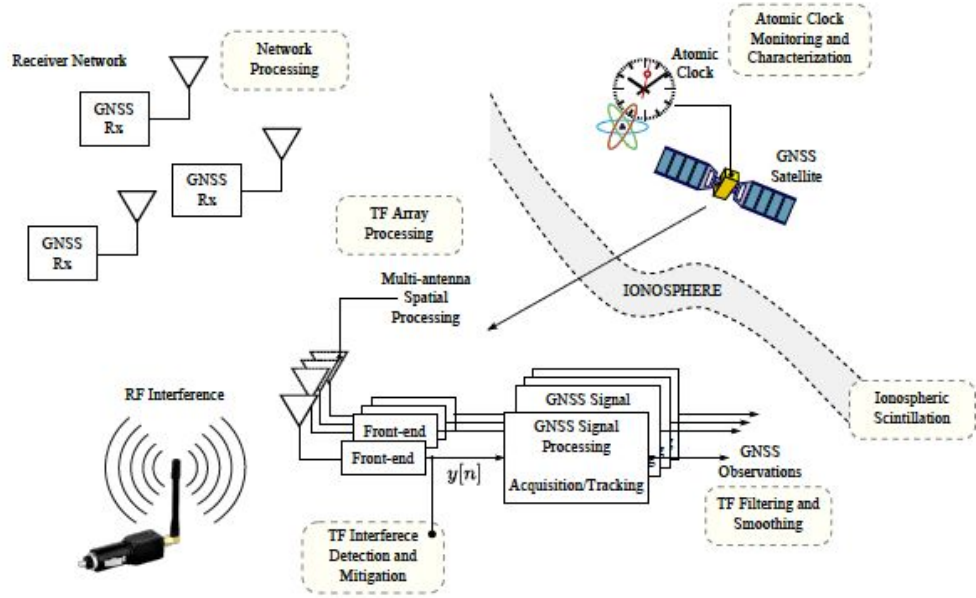
(b)



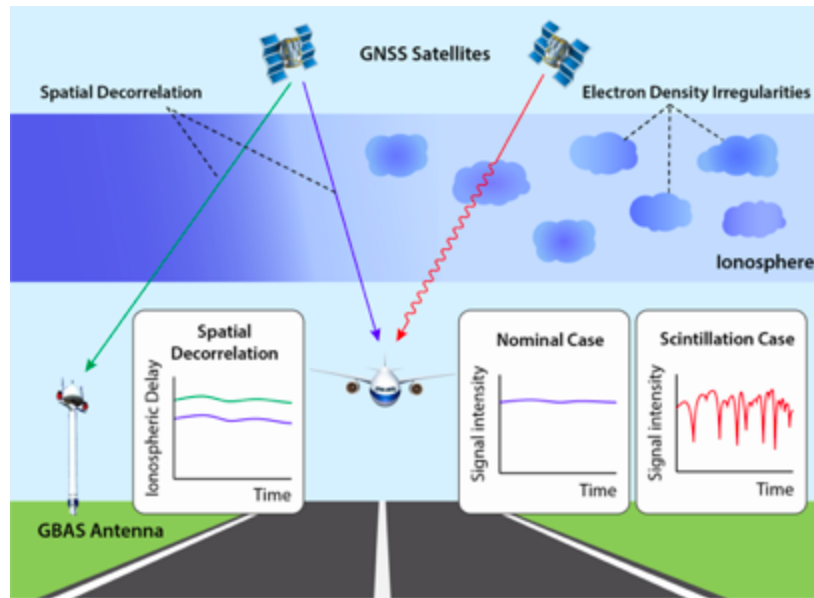
(c)

Figure 2. Receiver enhancement is a rich research area, for instance one of the most challenging environments is that where the reception of GNSS signals is very low: (a) acquisition is one of the most demanding operations in a GNSS receiver, some strategies exist to alleviate such computational burden (see article “Processing Cost of Doppler Search in GNSS Signal Acquisition” by Qaisar and Benson), (b) weak signals require high-sensitivity receivers, which often are challenged by slow acquisition times (see article “High Sensitivity and Fast Acquisition Signal Processing Techniques for GNSS Receivers” by Kong), (c) direct-positioning improves receiver sensitivity and robustness by exploiting the geometrical constraints among satellites (see article “Direct Position Estimation of GNSS Receivers” by Closas and Gusi-Amigó)

GNSS Vulnerabilities (Figure 3)



(a)



(b)

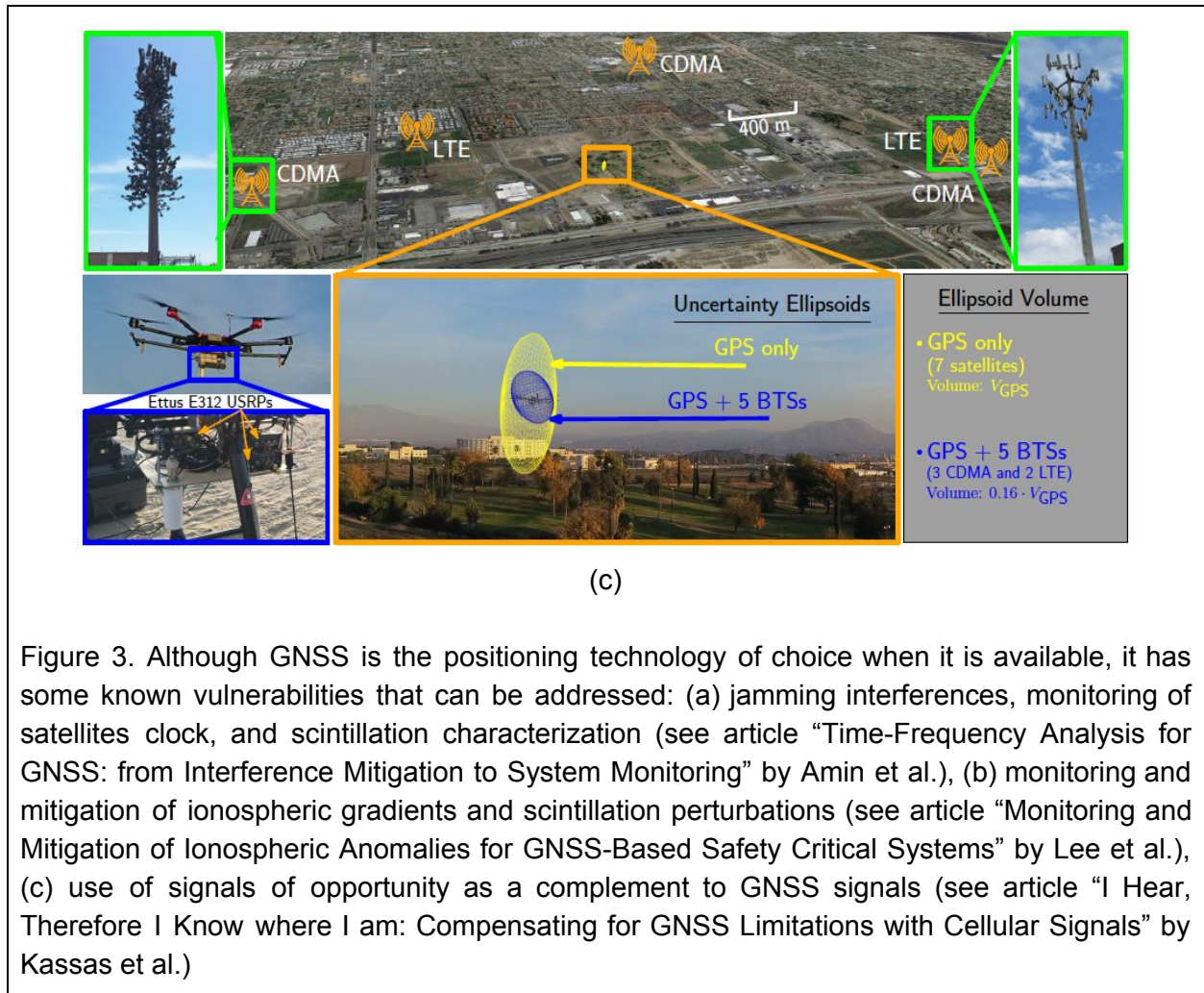


Figure 3. Although GNSS is the positioning technology of choice when it is available, it has some known vulnerabilities that can be addressed: (a) jamming interferences, monitoring of satellites clock, and scintillation characterization (see article “Time-Frequency Analysis for GNSS: from Interference Mitigation to System Monitoring” by Amin et al.), (b) monitoring and mitigation of ionospheric gradients and scintillation perturbations (see article “Monitoring and Mitigation of Ionospheric Anomalies for GNSS-Based Safety Critical Systems” by Lee et al.), (c) use of signals of opportunity as a complement to GNSS signals (see article “I Hear, Therefore I Know where I am: Compensating for GNSS Limitations with Cellular Signals” by Kassas et al.)

We wish to thank all the contributors for their outstanding articles which, individually and as a whole, addressed relevant and timely aspects in the art of navigation, highlighting the key role that signal processing takes. We are grateful to the SPM Editor-in-Chief Prof. Min Wu and the IEEE Signal Processing Society Publications Administration Rebecca Wollman for their continuous support and assistance. We very much enjoyed putting together this special issue, and we do believe that our readers will enjoy it twice as much – our energetic signal processing community will contribute for sure to the state of the art in the field with new and exciting original contributions.