Going places with SDR receivers

As Software Defined Radio (SDR) receivers find their way into many and varied applications, Etiido Uko and John Polak explore their benefits for satellite navigation and positioning

Image: Shutterstock

Receivers that process Global Navigation Satellite System (GNSS) signals for navigation and positioning purposes are usually configured as specialised hardware. However, it is a field undergoing continuous change in which such hardware can no longer be considered a viable and practical solution. The major satellite-based systems – GPS, GLONASS, Galileo and Beidou - are continually being improved with the addition of new technologies.

Likewise, regional, as well as augmentation satellite systems, undergo regular updates.

Furthermore, various new GNSS systems are currently being developed around the world. Hardware receivers lack the crucial flexibility required to keep up with all these changes and upgrades. This has led to the development and application of Software Defined Radio (SDR) technology in GNSS receivers.

Hugely flexible

SDR receivers offer numerous benefits in satellite navigation. Because of their configurable architecture, these highly flexible receivers can work across different GNSS systems without any hardware change. Only a simple software upgrade or reconfiguration is required. They can also be easily updated to implement changes in an existing GNSS, or to work with a new one.

Satellite navigation has thousands of commercial, civil, and defense applications where SDR receivers can be very easily integrated. They can also be combined with other location technologies to improve their functionality and accuracy. In comparison, entirely hardware-based receivers are usually constrained to particular applications. Even slight upgrades in a GNSS would require disproportional changes to implement in the receiver hardware.

Conventional hardware receivers exhibit high performance in signal reception and processing. However, they lack the flexibility and configurability that have become a priority in the field of GNSS. The use of ad-hoc hardware to create flexibility is considered impractical and inefficient. SDR receivers provide high versatility and configurability while providing equal or superior performance.

SDR architecture

These characteristics are a result of an SDR architecture that comprises an antenna, a front end (FE), an analog to digital converter (ADC), a Field-Programmable Gate Array (FPGA) + Digital Signal Processing (DSP) unit, and a host system such as a PC. This system can be seen in Fig.1.

The process of signal reception and processing in a GNSS SDR begins with identifying all probable satellites to be used, using user-provided or locally stored data. This process is followed by the acquisition stage in which the SDR uses software to emulate a multichannel receiver, by assigning the PRN (Pseudo Random Noise) codes of individual incoming signals to particular channels. Typically, most channels (about 12) are dedicated to master system signals, while a few (2-3) handle augmentation systems signals. The receiver channels switch to the tracking stage after signals have been received. This stage involves some critical operations such as tracking of synchronization parameters and frame detection.

The navigation stage is the final stage. The receiver calculates the user position by collecting all the data received from every channel, aligning it into a coherent set, and running the navigation routines to estimate positions. Signal processing in each channel is performed independently of the others, while final calculations of positioning equations require a combination of all received data. In entirely software SDR systems, the PC board performs all signal processing as well as navigation functions.

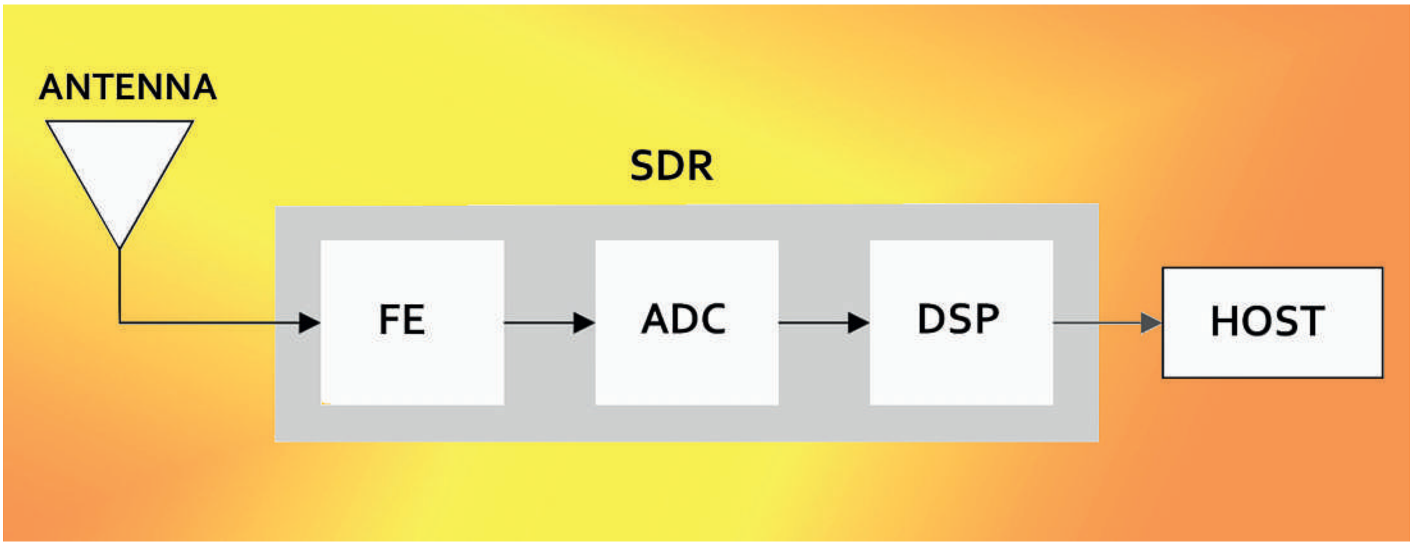

Fig.1: Block Diagram shows how SDR would fit into a GNSS. SDR is a one-block solution, taking care of the front end to the digital signal processing before sending the data to the host.

On the other hand, in hybrid software/hardware systems, the FPGA performs a portion of signal processing. The PC board performs the remaining part of signal processing, plus navigation functions and man-machine interfacing (output & input interface between PC and user). The DSP allows the functions of an SDR to be reconfigured to work with different systems, making them very flexible. The signal processing, planned time schedule, navigation, positioning, and man-machine interfacing differ from one GNSS to another. SDR receivers can be easily reconfigured to work with different satellite systems, e.g., An SDR configured to operate with GPS can be reprogrammed for GLONASS with simple software changes.

Varying processes and technologies

The various GNSS systems in existence all perform the same broadly-defined function of employing satellite constellations for geospatial positioning. However, the processes and technologies involved in performing this function vary, with differing multiple access techniques, code length, precision, and frequency range.

The two multiple access techniques employed by GNSS systems are CDMA (Code Division Multiple Access) and FDMA (Frequency Division Multiple Access). The former employs the same frequency and bandwidth to guarantee multiple access to satellites in a constellation. It is used in GPS, BeiDou, Galileo, QZSS, and NavIC. In FDMA, each satellite in a constellation possesses its frequency slot for transmitting the ranging signal. GLONASS employs FDMA for signal generation combined with CDMA signals to improve position accuracy.

The operational frequencies of current GNSS systems are as follows. GPS: L1 (1.563 - 1.587 GHz), L2 (1.215 - 1.2396 GHz), and L5 (1.164 - 1.189 GHz) bands. Galileo: E1 (1.559 - 1.592 GHz), E5a/b (1.164 - 1.215 GHz), and E6 (1.260 - 1.300 GHz). GLONASS: G1 (1.593 - 1.610 GHz), G2 (1.237 - 1.254 GHz), and G3 (1.189 - 1.214 GHz). BeiDou: B1 (1.561098 GHz), B2 (1.20174 GHz), and B3 (1.26852 GHz). Regional navigation satellite systems such as Japan's QZSS and India's NavIC also utilise frequencies in the L band. All these frequencies are available with SDR GNSS receivers. Provided that a high Radio Front End (RFE) and sufficient computational power are available, simple, compact, and robust SDR receivers are cable of receiving and processing signals at all the frequencies employed in GNSS.

Keeping up-to-date

GNSS systems are continuously being upgraded to increase their accuracy and reliability. Augmentation systems such as MSAS (Japan), EGNOS (Europe) and WAAS (USA) also undergo regular updates. Typical hardware receivers are at a disadvantage in this multifaceted, ever-changing context. Such receivers may require extensive hardware changes or even replacement to implement upgrades to a GNSS system. Furthermore, because GNSS systems employ different technologies, it is necessary to use specific hardware receivers for specific GNSS systems. This makes it impossible for a hardware receiver to switch between systems or work with more than one system simultaneously without additional hardware and extensive programming.

SDR receivers, on the other hand, are highly upgradeable. Through simple software updates, they can be augmented to work with multiple constellations using the same SDR platform. This capability makes them highly functional and accurate as they can simultaneously receive and process signals from various GNSS systems. They can also be upgraded via software to implement changes in current and future GNSS systems. Finally, SDR receivers provide the possibility of integrating satellite navigation with other positioning systems such as inertial or indoor navigation that use local sensors.

Etiido Uko and John Polak are both with Per Vices of Toronto, Canada (www.pervices.com) a leading RF and digital systems innovator, supplying multiple industries with wireless communication solutions.

Fig.2: Two of the most robust, versatile, and advanced commercially-available SDR transceivers are offered by Per Vices. These feature a hybrid architecture that combines high-performance with field programmability and full architectural and algorithmic reconfigurability. These products offer up to 16 independent radio chains with 1 GHz bandwidth configuration on each chain. They also come with extremely powerful processors.