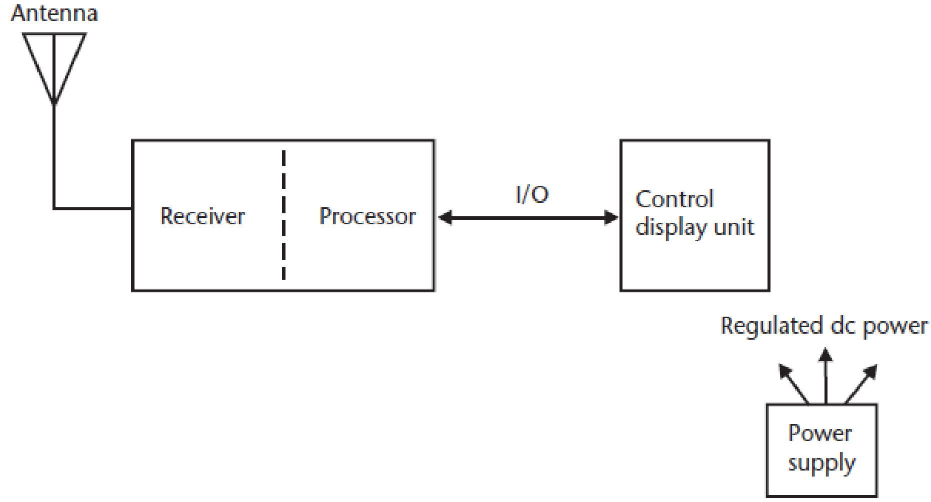
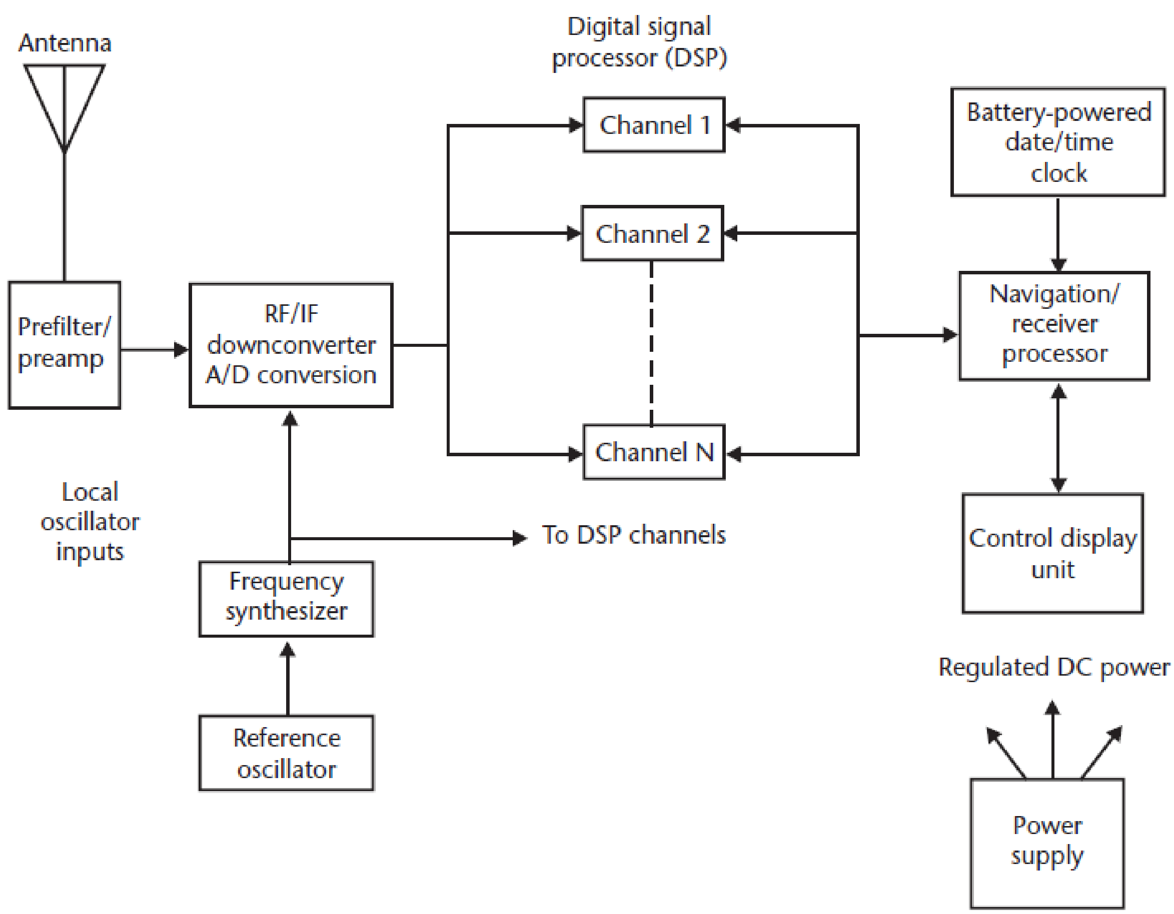
User Segment

A block diagram of a GPS receiving set is shown in Figure below. The GPS set consists of five principal components: antenna, receiver, processor, input/output (I/O) device such as a control display unit (CDU), and a power supply.

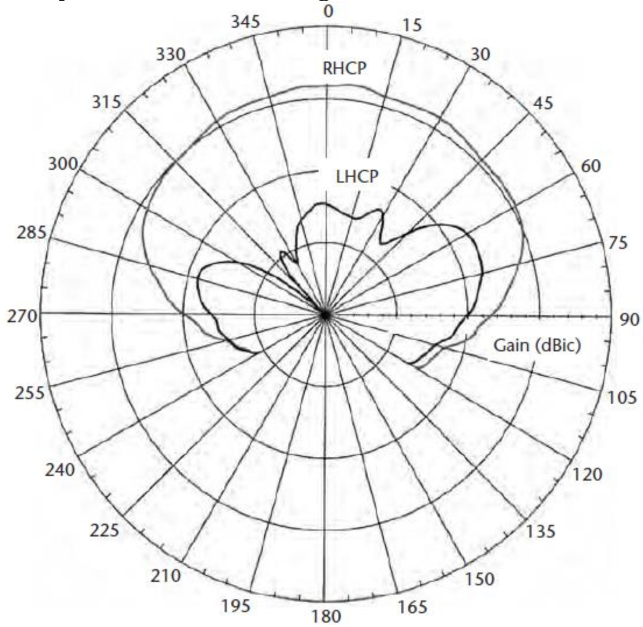


Principal GPS receiver components.



Generic SPS receiver.

Satellite signals are received via the antenna, which is right-hand circularly polarized (RHCP) and provides near hemispherical coverage. Typical coverage is 160° with gain variations from about 2.5 dBic at zenith to near unity at an elevation angle of 15°. (The RHCP antenna unity gain also can be expressed as 0 dBic = 0 dB with respect to an isotropic circularly polarized antenna.) Below 15°, the gain is usually negative. An example antenna pattern is shown in Figure below.



Example of RHCP hemispherical antenna pattern.

- In practice, a GPS receiver must first replicate the PRN code that is transmitted by the SV being acquired by the receiver; then it must shift the phase of the replica code until it correlates with the SV PRN code.
- When the phase of the GPS receiver replica code matches the phase of the incoming SV code, there is maximum correlation.
- Modern receivers use multiple (even massively multiple) correlators to speed up the search process and some use multiple correlators for robust code tracking.

GALILEO Satellite System

In 1998, the European Union (EU) decided to pursue a satellite navigation system independent of GPS designed specifically for civilian use worldwide. When completed, GALILEO will provide multiple levels of service to users throughout the world. Five services are planned:
1. An *open* service that will be free of direct user charges;
2. A *commercial* service that will combine value-added data to a high-accuracy positioning service;
3. *Safety-of-life* (SOL) service for safety critical users;
4. *Public regulated* service strictly for government-authorized users requiring a higher level of protection (e.g., increased robustness against interference or jamming);
5. Support for *search and rescue*.

A 30-satellite constellation and full worldwide ground control segment is planned. One key goal is to be fully compatible with the GPS system. Measures are being taken to ensure interoperability between the two systems. Primary interoperability factors being addressed are signal structure, geodetic coordinate reference frame, and time reference system. GALILEO is scheduled to be operational in 2008.
Satellite navigation, positioning, and timing have already found widespread applications in a large variety of fields. Recognizing the strategic importance of its applications, a European approach was developed in

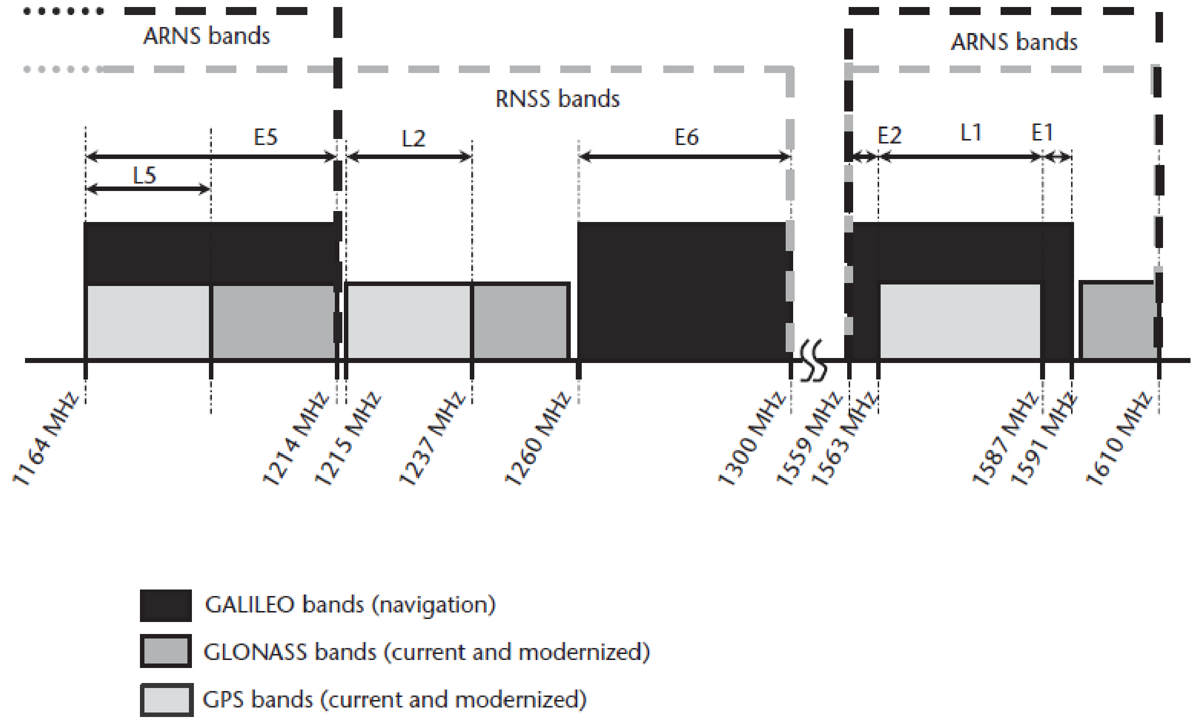
the early 1990s. It started with the European contribution to the first generation of Global Navigation Satellite Systems (GNSS-1).
The combined use of GALILEO, European Geostationary Navigation Overlay Service (EGNOS), and GPS/GLONASS will increase the overall performance, robustness, and the inherent safety of the services achieved from GNSS, and it will allow for worldwide acceptability of the exploitation and use of satellite navigation for the benefit of all potential users.

The orbit altitude above Earth of 23,222 km has been chosen so that the constellation has a repeat cycle of 10 orbits in 17 days. The GALILEO space segment will comprise 27 operational satellites in a Walker constellation with three orbital planes, equally spaced and with 56º nominal inclination. Each plane will contain nine satellites, nominally 40º apart.

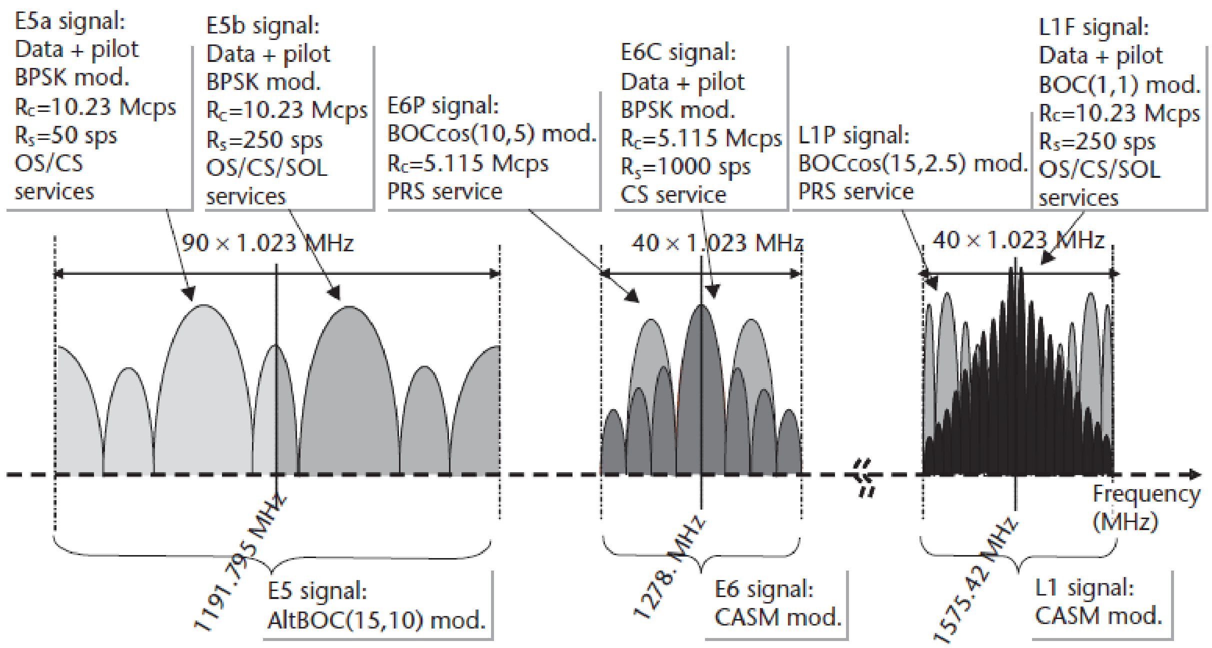
GALILEO will provide six navigation signals with RHCP in the frequency ranges 1,164–1,215 MHz (E5 band), 1,260–1,300 MHz (E6 band), and 1,559–1,592 MHz (E2-L1-E1 band), which are each internationally allocated for radionavigation satellite services (RNSS). (the frequency band E2-L1-E1 is sometimes denoted as L1 for convenience). All satellites will make use of the same carrier frequencies with different ranging codes through CDMA transmission.

The main considerations in the selection of the GALILEO signal characteristics were :

- Transmission of wide bandwidth signals in the L-band spectrum, enabling precise and robust tracking performance and multipath mitigation capability;
- Minimization of interference from and to existing satellite navigation systems (e.g., GPS, GLONASS) for the purpose of radio frequency compatibility;
- Selection of frequencies with good performance and small tracking errors in the upper L-band frequencies for the purpose of ionospheric compensation in dual-frequency receivers;
- Interoperability with GPS;
- Security aspects with respect to the military GPS M code and the GALILEO PRS (i.e., the separation of military and specially protected services from civil services).



GALILEO frequency plan.



GALILEO frequency spectrum.

The Russian GLONASS System

GLONASS is the Russian counterpart to the U.S. GPS. Like GPS, the Russians designed GLONASS to provide private information to suitably equipped civil and military users. Unlike GPS, the Russians have been unable to sustain the satellite constellation at full strength, and, therefore, users can only navigate with GLONASS part of the time. The Russians are currently developing several new generations of modernized GLONASS spacecraft to replenish the constellation. The Russians do not expect to fully replenish the GLONASS constellation up to 24 satellites until 2011–2012.

the Soviet military initiated the GLONASS program in the mid-1970s to support military requirements. Originally, GLONASS was funded to support naval demands for navigation and time dissemination.

The Soviets launched the first GLONASS satellite on October 12, 1982. An initial test constellation of four satellites was deployed by January 1984.
After the demise of the Soviet Union (SU), in 1990–1991, the Russians established a test constellation of 10 to 12 satellites. Extensive testing of the system followed this. As a result, in September 1993, Russian President Boris Yeltsin officially proclaimed GLONASS to be an operational system, part of the Russian Armory and the basis for the Russian Radionavigation Plan. In April 1994, the Russians initiated the first of seven launches to complete the constellation. In December 1995, the Russians successfully launched the last set of three satellites to complete the 24-satellite constellation. In February 1996, these satellites were declared operational, and the constellation was fully populated for the first and only time. However, a number of older satellites soon thereafter failed, and the constellation quickly degraded. From 1996 through 2001, the Russians only launched two sets of three satellites.

GLONASS satellite constellation.

Each GLONASS satellite is in a 19,100-km circular orbit referenced to the Earth's surface with an inclination of 64.8°. The orbital period is 11 hours and 15 minutes. The current orbital configuration and overall system design (including satellite nominal L-band antenna beamwidths of 35° to 40°) provide navigation service to users up to 2,000 km above the Earth's surface.

Unlike GPS, which transmits CDMA format, GLONASS employs frequency division multiple access (FDMA)

In 2003, the Russians began launching the new GLONASS-M spacecraft, where "M" stands for *Modified*. The GLONASS-M is a modernized version of the GLONASS spacecraft using more modern electronics and supporting a number of new features. These include:

1. ***Improved navigation performance****.* GLONASS-M carries a more accurate satellite clock, a better attitude control system, and intersatellite navigation links (incorporated after the second GLONASS-M satellite). These features will improve user private accuracy by reducing errors in measurements of time and ephemeris calculation.
2. ***Longer lifetime****.* GLONASS-M carries an increased propellant loading, improved onboard batteries, and modernized spacecraft electronics. These features support a longer design-lifetime of 7 years.
3. ***Improved navigation signals****.*
4. ***Improved navigation message****.*

The GLONASS operates in the following frequency bands:

G1 Band: 1589.0625 MHz to 1605.375 MHz
G2 Band: 1242.9375 MHz to 1248.625 MHz
G3 Band: 1201 MHz

Now a day:

GLONASS CONSTELLATION STATUS, 06.07.2021

Total satellites in constellation	27 SC
Operational	23 SC
In commissioning phase	-
In maintenance	1 SC
Under check by the Satellite Prime Contractor	-
Spares	1 SC
In flight tests phase	2 SC

The Chinese BeiDou Satellite Navigation System

BeiDou is the Chinese name for the multistage satellite navigation program designed to provide positioning, fleet-management, and precision-time dissemination to Chinese military and civil users.
The first BeiDou satellite was launched in October 2000, and the second in December 2000. The third BeiDou satellite was launched in May 2003.

GPS

- 6 Orbital Planes
- 24 satellites + spare
- 55 degree inclination angle
- altitude 20,200 km

Galileo

- 3 Orbital Planes
- 27 Satellites + 3 Spares
- 56 degree inclination angle
- altitude 23,616 km

GLONASS

- 6 Orbital Planes
- 35 satellites: 5 GEO, 27 MEO, 3 IGSO
- 64.8 degree inclination angle
- altitude 19,100 km

Beidou

- 3 Orbital Planes
- 21 satellites + 3 spares
- 55 degree inclination angle
- altitude 38,300 km 21,200km

Now a day:

BEIDOU CONSTELLATION STATUS 06.07.21

Total satellites in constellation	49
SV is included in operational orbital constellation	44
SV is not included in operational orbital constellation	5

GPS CONSTELLATION STATUS, 06.07.21

Total satellites in constellation	32 SC
Operational	30 SC
In commissioning phase	1 SC
In maintenance	1 SC
In decommissioning phase	-