Satellite Navigation

P. F. Lammertsma
Institute of Information and Computing Sciences
Utrecht University

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Abstract

Satellites already play a significant role in our daily lives, aiding communication, exploration and research. In the future, we will undoubtedly see their influence grow. GPS is perhaps one of satellite's most successful applications, and for consumers, receivers are becoming ever more affordable and reliable. The recent signing of a cooperative agreement between the United States and the European Union will expand this system, laying the foundation for a compatible and interoperable Global Navigation Satellite System, the GNSS. With this relatively young technology, improved accuracy, better reception and altogether new applications lie in wait for us in the near future.

Contents

1 Introduction

> "I'm astounded by people who want to 'know' the universe when it's hard enough to find your way around Chinatown."
>
> \- Woody Allen

Using today's state of the art global navigation satellite systems (GNSS), you can pinpoint your location anywhere on earth with an accuracy of less than fifteen meters. Currently, the only system available to the general public is the American Global Positioning System, which has been fully functional since mid-1994.

The upcoming European competitor, Galileo, promises to improve accuracy. This would in fact make it possible to find your way through a city, solely based on the data gathered by your receiver from space. Perhaps someday GNSS will find extremely useful applications, such as replacing seeing-eye dogs and guiding motor vehicles.

This article discusses the historical significance of the TRANSIT and GPS systems, including their technical specifications and workings. Then it will briefly cover Galileo, a new satellite positioning system. The article will conclude by explaining the advantages of this system and why we need yet another satellite navigation system.

2 History

The history of satellite navigation goes back to the era of the 'space race'. With the launch of *Sputnik I* in 1957, the Russians had to keep the Doppler effect in mind [5]:

> *To maintain radio contact with a moving object, you have to keep changing your frequency.*

The Monitor Station would search over a certain frequency range until it could acquire a lock on *Sputnik*'s signal. By calculating the frequency shift, they could determine its velocity relative to the station. Consequently, they could determine its position in orbit.

In fact, they expressly chose a frequency which was audible on a normal transistor radio. Listening to it, you would clearly hear the Doppler effect, unmistakable proof that the Russians had launched the first man-made satellite into orbit.

This led to the development of the TRANSIT system, which was immediately followed by several other projects such as *Nova* and *Timation*. These were primarily experiments that eventually led to the research of GPS in 1969.

Russia has also played its part in satellite navigation, but constantly was one step behind. They followed the American's TRANSIT with the Russian Tsikada, and answered GPS with the exclusively military GLONASS system.[1]

[1] Russia no longer keeps GLONASS under maintenance, and now only 8 of the 10 satellites are still functional.

3 TRANSIT

In 1959, the American Navy discovered the benefits of inverting the Doppler shift concept, thereby starting the development of the TRANSIT system, initially known as the *Navy Navigation Satellite System* [3].

> *If you know the exact position of the satellite, you can determine your relative position to it.*

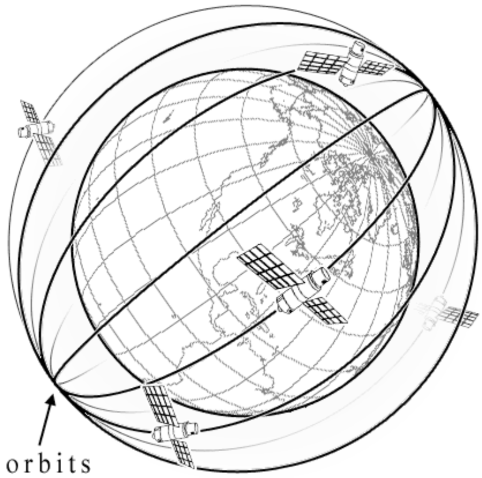


Figure 1: TRANSIT configuration

3.1 Configuration

The TRANSIT system is configured in such a way that the six satellites in orbit provide maximum coverage. To do so, scientists put the satellites in uniform orbital precession, in six separate polar orbits.

- Six satellites
- Six polar orbits
  Altitude: 960 km
  Period[2]: 106 minutes
  Inclination[3]: 90°
- Three ground-based Monitor Stations

3.2 Requirements

For a successful positioning measurement, the TRANSIT system specifications state that only one satellite is required. A position can be calculated as soon as the satellite passes overhead.

TRANSIT could guarantee a successful measurement within 110 minutes at the equator, as long as a satellite was in range of the receiver.[4] The greater the latitude, the more satellites become visible. For example, at 80° latitude, the average fix time was only 30 minutes.

Presently, as the system is no longer maintained, the satellites have lost their uniform orbital precession, this guarantee no longer applies.

3.3 Concept

The theory of the relationship between the satellite and receiver is described in the following five steps.

1. A satellite sends its exact position and time over frequency f_0.
2. A receiver, expecting to receive signals from the satellite on frequency f_0, searches for the signal over a certain frequency range above f_0.
3. If the signal can be found on a certain frequency f, the receiver will continue to track this frequency as it continues to drop.
4. When $f_0 = f$, then the satellite is somewhere overhead.

[2] The period of a satellite is the time it takes to complete one orbit.
[3] The inclination of an orbit is relative to the equator.
[4] This is directly related to the orbital period.

5. At this point, a calculation can be performed, and the receiver can stop listening.

3.4 Positioning

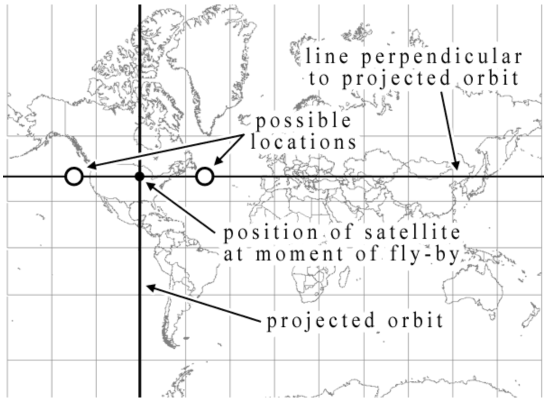


Figure 2: TRANSIT positioning

As mentioned, we know that the satellite is neither approaching nor departing (i.e. the satellite's relative velocity is zero) when $f_0 = f$. This can be proven with the Doppler frequency expression in equation 1, where f is the observed frequency, f_0 the source frequency, v_s the source velocity, and c the speed of light. [14]

$$f = \frac{f_0\sqrt{1 - \frac{v_s^2}{c^2}}}{1 - \frac{v_s}{c}} \quad (1)$$

When $v_s = 0$, the frequencies must evidently be equal.

$$f = f_0$$

With the information from the signal carried over the frequency, the receiver knows the exact position and time of the satellite at the moment that it passed overhead (figure 1). Therefore, the receiver must be located somewhere on a line perpendicular to the orbit of the satellite.

Although it may seem that we don't know the distance from the orbit, we *can* calculate this using a Doppler shift expression. However, this equation is rather complex and goes beyond the scope of this article.

What we don't know, is to which side of the orbit the receiver is located, because on the line perpendicular to the satellite's orbit, we only know the distance to the intersection. This means that still two possible locations remain, shown in figure 2.

3.5 Disadvantages

Not only do the calculations only narrow the receiver's position down to two possible locations, they're based on it being at sea level. For anything but maritime expeditions, this would render the system useless unless the altitude is known. Other disadvantages include bad coverage, poor accuracy and the requirement that the receiver physically has to wait until a satellite passes overhead.

The TRANSIT system was abandoned in 1996, due to the great success of GPS.

4 GPS

Before the first TRANSIT satellite even went into orbit, the US Department of Defense already had something much bigger in mind: the *Navigation Satellite Timing and Ranging Global Positioning System* (NAVSTAR GPS), known to most as GPS. Development, however, only started in 1973.

Just like TRANSIT, GPS satellites send the time and position in a signal carried over a given frequency. However, the similarity stops there. GPS receivers now only use the frequency as means of obtaining the signal that's carried over it. The Doppler shift is no longer relevant to the positioning, and the receiver simply transposes the observed frequency to the source frequency. This is done to ensure that the carried signal is decoded at the correct bitrate.[5]

Since 1994, GPS is fully functional with all 24 satellites in orbit. The United States had planned on reaching this stage by the late '80s, but due to several delays – amongst the Challenger Space Shuttle disaster in 1986, the deadline could not be met.

4.1 Configuration

Scientists developed a configuration for the GPS system that provided global coverage using at least 21 satellites in a medium earth orbit (MEO).

- 21 active satellites
  3 spare satellites
- Six orbital planes
  Altitude: 20,200 km
  Period: 11 hours 58 minutes
  Inclination: 53°
- Four satellites per plane
- Five Monitor Stations

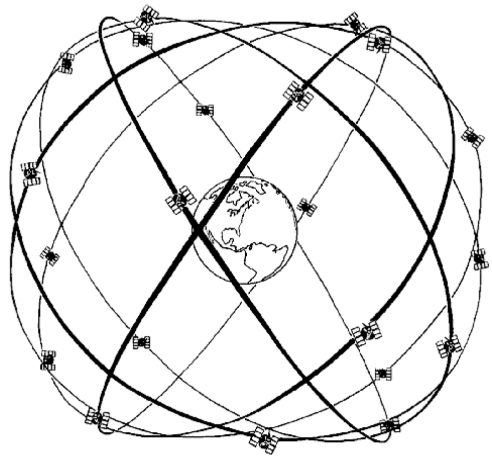


Figure 3: GPS configuration [9]

Initially, researchers contemplated a geostationary earth orbit (GEO) configuration at 36,000 km. This was discarded, however, because the satellites would require a stronger transmitter and a more powerful launch vehicle. More importantly, a GEO would provide poor coverage of polar regions.

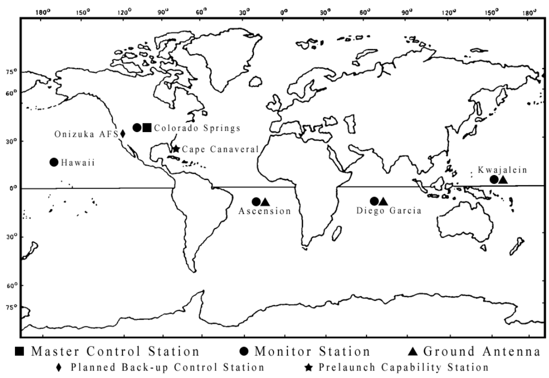


Figure 4: GPS Monitor Stations [7]

Instead, the preliminary test configuration – *Block I* – specified that the planes be inclined at 63°. Being the first generation of GPS satellites, the ten satellites successfully launched

[5] Explained in section 4.5 on page 8.

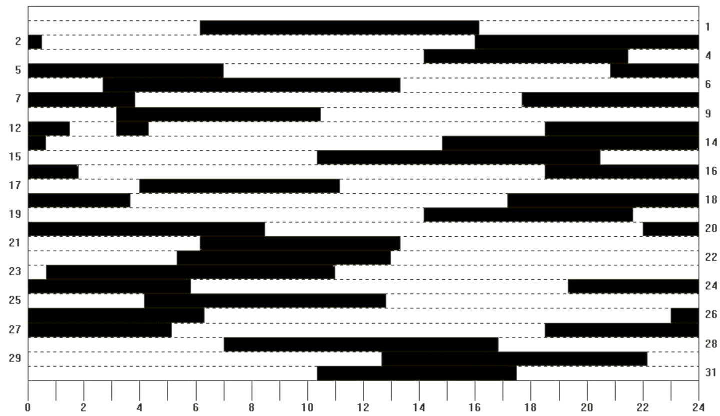


Figure 5: Coverage diagram of GPS satellites

into orbit from 1978 to 1985 are designated as the GPS/Block I satellites.

The 24 current GPS satellites are in the *Block II* configuration, and were launched between 1989 and 1994. This configuration specifies that the six planes are inclined at about 55°. Evenly spaced at 60° longitude, this inclination provides best global coverage, including the polar regions, as shown in figure 3.

These satellites are in fact divided into four generations: II, IIA, IIR and IIF. The primary differences have to do with accuracy and maximum number of days without contact from monitoring and control stations.

The Monitor Stations upload new, corrected data to each satellite every four hours. This data includes a corrections on the exact time and position of that and other GPS satellites in orbit. An update of the satellite's position can be determined by performing a GPS measurement to a ground antenna of which the exact location is known. The Monitor Stations are located near the equator to reduce the ionospheric effects (figure 4).

4.2 Requirements

The GPS system specifies that a measurement requires data from four different satellites. This means that at any point in time, at least four satellites must be in range of the receiver (figure 5).

If all four of these separate signals can be received, GPS guarantees a successful measurement within 36 seconds.[6]

Each GPS satellite must know the exact time, with an accuracy of at least 10 nanoseconds. Each satellite is therefore equipped with two rubidium and two cesium atomic clocks.

4.3 Concept

The basic relationship between the satellite and receiver is described in the following five steps, which will be explained in greater detail in sections 4.4 through 4.7.

1. A receiver receives a signal from a GPS satellite.
2. It determines the difference between the current time and the time submitted over the frequency.

[6]Explained in section 4.7.1 on page 10.

3. It calculates the distance of the satellite from the receiver, knowing that the signal was sent at the speed of light.

4. The receiver receives a signal from another two satellites, and again calculates the distance from them.

5. Knowing its distance from three known locations, the receiver triangulates its position.

4.4 Positioning

4.4.1 Ideal

In figure 6a you can see that by calculating the distance d_0 to satellite A, the receiver can place itself on a sphere with radius d_0 from A. We can then continue to determine the radius d_1 from satellite B. These two spheres *must* touch or intersect if the measurement was successful.

If the spheres merely touch, which is highly unlikely, we can already determine our position. However, if they intersect, we must be somewhere on a circle where any point of the circle is d_0 from A and d_1 from B, as shown in figure 6b.

Finally, figure 6c shows us how a third measurement will put the receiver d_2 from satellite C. This narrows our position on the circle down to one position (if the circle and sphere touch) or two (if they intersect).

One of these positions can be disqualified, because the location or velocity is virtually impossible. For example, it could put us at an altitude above the satellites.

4.4.2 Inaccuracy

Since a GPS completely relies on correct timing to make a successful measurement, both receiver and satellite must know the time very precisely. While the satellites are equipped with four atomic clocks that are updated every four hours, the receiver only has a simple clock, no better than a cheap digital watch.

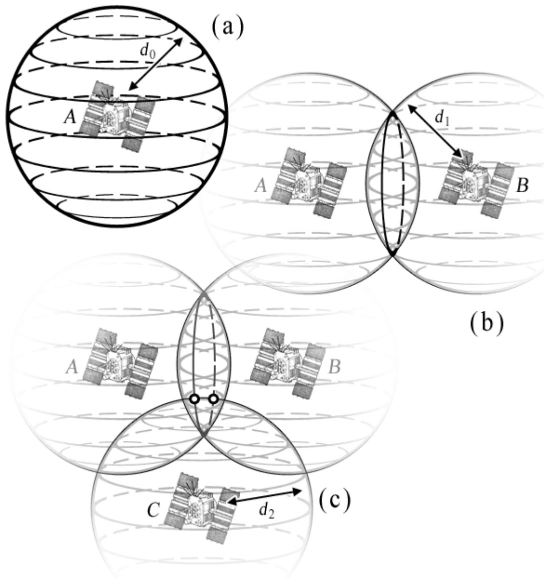


Figure 6: Ideal triangulation by GPS

To explain this, we'll simplify things to two dimensions. An ideal triangulation would then only need two satellites (assuming we can still disqualify one location). However, because we're using an inaccurate clock, we need an extra measurement. The ideal situation with three measurements is shown in figure 7.

In reality, these three circles don't align perfectly at all. The receiver cannot keep the exact time as precisely as the satellites, so we'll have to make the circles align by hand.

We can do this, because we know that the circles are supposed to align. If the circles are too large, we adjust our clock by moving it forward in time until the circles are small enough to intersect in one point (figure 8). If the circles are too small, we move our clock backwards.

In essence, the receiver's clock doesn't have to know the exact time; it only has to determine the travel time of each satellite's signal relative to each other. Since it only takes a sig-

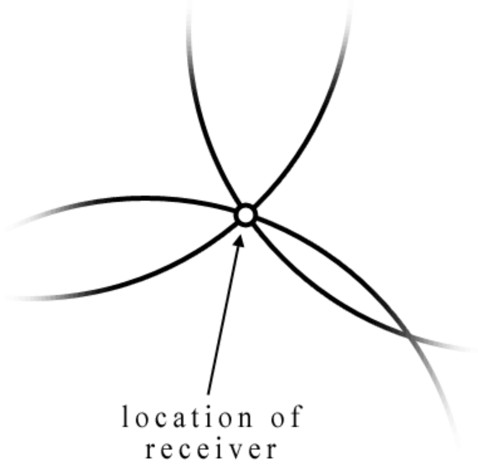


Figure 7: Ideal 2D positioning

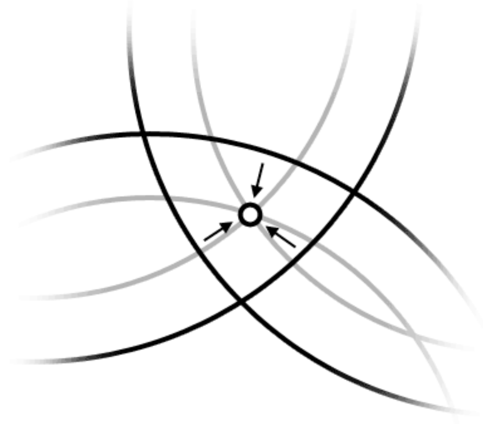


Figure 8: Pseudo-range reduction in 2D

nal 63 to 70 milliseconds to reach the receiver, it's still possible that the clock loses accuracy during the measurements, which results in that the four spheres still don't align properly.

This means that there's not a single exact position where the receiver can be. Instead, it is a certain area, called the *pseudo range*.

In some cases, it may be that only one sphere misaligns. Receivers are equipped with an algorithm that makes an educated guess within the pseudo range.

4.5 Broadcast

Now let's take a look at the actual broadcast. We already know that the actual frequency is not important; it is only used for carrying the signal. This signal contains all the vital information to the proper functioning of the GPS system.

There are actually two frequencies that are broadcasted. Both are in the microwave range (i.e. above 1,000 MHz), and are so identified by the prefix L.

The developers decided to use the rubidium atomic clock to set the frequencies. The clock has a nominal frequency f_0 of 10.23 MHz [6], which is used internally by the satellite as the fundamental frequency, and can simply be multiplied to reach the microwave range.

The first frequency, $L1$, is 1575.42 MHz, which is derived from the fundamental frequency f_0. It carries a signal for both civil and military receivers.

$$154 \cdot f_0 = 1575.42 \text{ MHz}$$

The second frequency, $L2$, is 1227.6 MHz, and is used only by the military.

$$120 \cdot f_0 = 1227.6 \text{ MHz}$$

Within the satellite, a data signal is created that contains the *Navigation Message*. This message contains all the information required by the receiver.[7] The signal is made at 50 bits per second (50 Hz).

The satellite must also be able to identify itself over the frequency. To do so, a *Pseudo Random Noise* code, or PRN-code is created. This is a signal that seems to be pure noise,

[7] Explained in section 4.7 on page 10

but in fact is a sequence of n bits that repeats after the n^{th} bit. Each satellite is assigned one of the 32 unique PRN-codes.

There are two different kinds of PRN-codes: one called the *coarse acquisition code*, or C/A-code, used for civil receivers, and another called the *precise code*, or P-code for military receivers.

The C/A-code is $10^n - 1$ bits long, where n is the number of digital shifting elements the device contains. In GPS satellites, this is 10, so the code is 1023 bits long. Subsequently, it is sent at a rate of 1.023 megabits per second, which is a tenth of the fundamental frequency:

$$\frac{f_0}{10} = 1.023 \text{ MHz}$$

At this frequency, it takes precisely 1 ms to send the 1023 bit C/A code.

The P-code is sent exactly at the fundamental frequency f_0. Because the frequency is 10 times as high, the data is 10 times as accurate. The P-codes are not publicly known, and therefore cannot be used by the general public.

For security reasons, the P-code is not as short as the C/A code. It repeats precisely once every seven days, therefore making it practically impossible to find, unless you know what you're looking for.

Finally, the PRN-code is combined with the Navigation Message by a modulo-2 adder, then mixed with the frequency, which will carry it to the receiver. This process is illustrated in figure 9.

4.6 Reception

For the receiver to revert the frequency to the Navigation Message, it replicates both the frequency on the L-band as the 32 PRN-codes for every possible satellite. Subtracting the pure frequency from the received signal, the PRN-code combined with the Navigation Message remains.

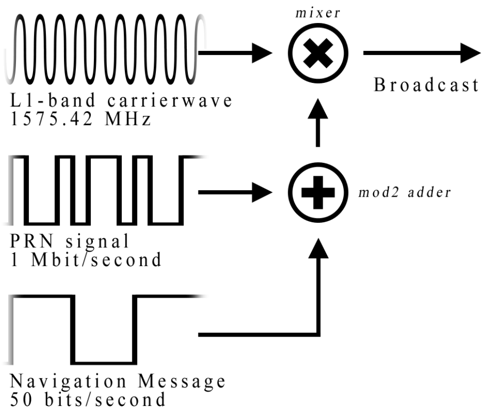


Figure 9: The PRN-code and Navigation Message are carried over the L-band [10]

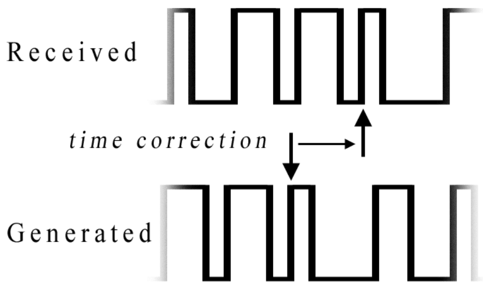


Figure 10: Acquiring full PRN correlation [10]

Once again, exact timing is essential to receive the message correctly. As the receiver generates the matching PRN-code, it doesn't align properly. The receiver tries to make the signals line up, acquiring full PRN correlation [8], correcting its clock to do so (figure 10). Once aligned, it will remove the PRN- code from the signal to recover the Navigation Message.

The chosen unique PRN-code used to decode the Navigation Message identifies which satellite sent the broadcast. The Navigation Mes-

[8] In this context, correlation is the so-called 'code-phase lock' on a signal. Only when two identical signals are aligned is the signal strength high enough to be detected (called the correlation peak).

sage, which contains the time, ephemeris[9] and other data, can now be analyzed.

4.7 Signal

The Navigation Message is a continuously repeating frame of 1500 bits, split up in 5 sub-frames. Each sub-frame, being 300 bits and sent at 50 Hz, takes precisely 6 seconds to send (see figure 11), and contains a 60 bit header and a 240 bit data block.

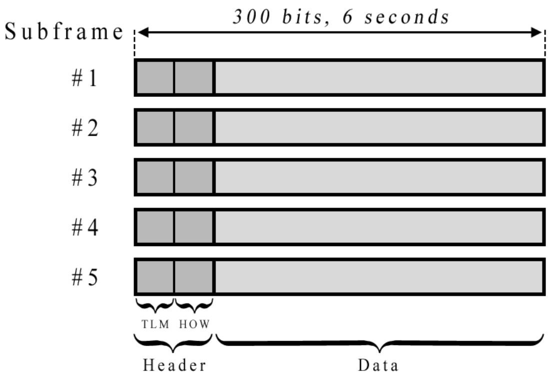


Figure 11: Removing correlation to line up the signals [13]

4.7.1 Header

The header is subsequently split up in two words[10].

The first is the *Telemetry Word* (TLM). Led by an 8 bit preamble, this is the first stage of recognition for the receiver. Followed by 16 bits of reserved data, which matches the ending 6 bit *checksum*, or parity.

A receiver would search for the preamble, which is defined as `10001011`. This marks the beginning of a new sub-frame. To confirm this, the receiver gathers the reserved data, creates a parity, and checks to see if this corresponds with the last 6 bits of the TLM. If this doesn't match, the receiver backtracks to look for the next preamble.

The second part of the header is the *Handover Word* (HOW). Spanning the first 17 bits of the HOW is the *time of week* (TOW). This is the first bit of significant data the receiver can use.

Although we have already synchronized our clock correctly, we have not discussed the difference between the way time is kept by satellites and how it is kept here on earth. The GPS systems do not take leap seconds into account, while this is a requirement. Therefore, the Navigation Message tells the receiver how to update its clock to 'correct' Coordinated Universal Time, UTC.

The next 7 bits contain general sub-frame data. This consists of the sub-frame ID (the number of the sub-frame, 1 through 5), a reserved alert flag and the *Anti-Spoofing* flag[11]. The alert flag notifies the receiver that the satellite may be giving an inaccurate measurement. [12]

Before the receiver can store any data, it has to double-check that it is actually reading the header, and not some series of bits that so happens to resemble it. It does this by making another parity, and checking it with the last 6 bits of the HOW. If this does not match, it backtracks to look for the next preamble, followed by the rest of the TLM, etc.

Each sub-frame has a separate header for the primary reason that a receiver can step into the middle of a broadcast, and not have to wait up

[9] An ephemeris is a table giving the coordinates of the satellite at a number of specific times during a given period. In the Navigation Message, only the current coordinates are sent.

[10] In GPS, words are 30 bits long.

[11] Anti-Spoofing is a special mode the GPS system can be put in, in which the P-code is replaced by a highly encrypted Y-code. This only affects the P-code military receivers, which then require a special cryptographic key to function at all.

[12] This can happen, for example, when the satellite's orbit or rotation is being adjusted.

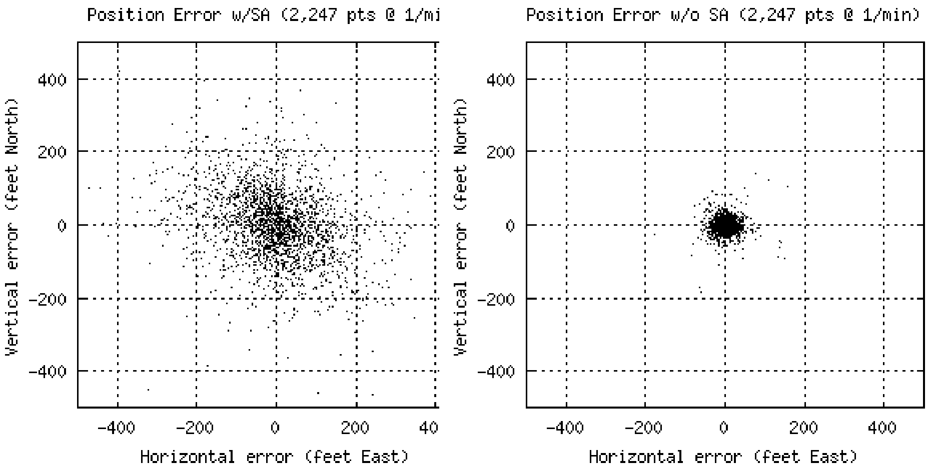


Figure 12: Deviation of GPS measurements with and without Selective Availability [2]

to 30 seconds for the next cycle. This way, a full data frame can be downloaded in less than 36 seconds, as long as the signal persists.

For example, if a receiver starts listening directly after the header of sub-frame 3 was sent, he will have to wait until sub-frame 4's header is sent to start downloading, which could take up to six seconds. It will take an additional thirty seconds to download the full frame, totaling 36 seconds in the worst-case scenario.

4.7.2 Data

While the two header word types are identical in each of the five sub-frames, the enclosed data is entirely different.

- Sub-frame 1 contains the exact time gathered from the four on-board atomic clocks.
- Sub-frame 2 and 3 are grouped, and contain satellite ephemeris data.
- Sub-frame 4 and 5 are grouped, and split up in 25 separate pages, which can be gathered over 12.5 minutes. This data is pretty much only of interest to the Monitoring Stations, and isn't covered in this article.[13]

Using the data from sub-frames 1 through 3, a receiver can pinpoint his relative position to a particular satellite, because he knows (1) the time elapsed to send the signal and (2) the position of the satellite at the time the broadcast was sent. As explained in section 4.4.2, repeating this process for three more satellites will put the receiver in a pseudo range.

4.8 Disadvantages

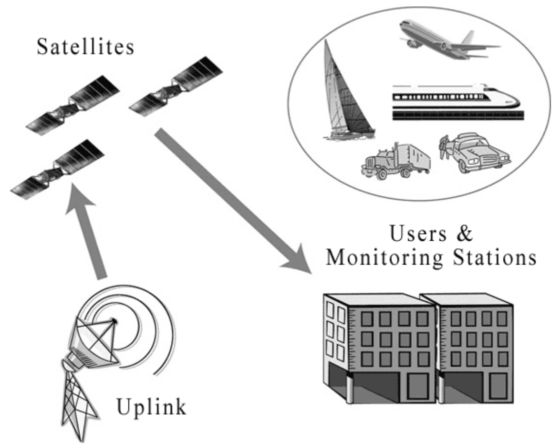
In reality, GPS coverage is relatively poor. This is especially the case in cities, in dense forests and other places where there are many large obstructions in the receiver's horizon. This is because the microwave frequencies that GPS broadcasts on is very sensitive. Signals may bounce, or be blocked entirely; both of these effects obviously have negative effects to a successful measurement.

[13] Some more expensive receivers make use of this data to update their ephemeris almanac of all satellites, as this data is enclosed in sub-frame 4 and 5.

When a signal bounces (off a building, for example) and is read by a receiver, a miscalculation occurs known as a *multipath error*. Since the signal didn't travel in a straight line from the satellite, the receiver will expect to be further away from it than it actually is.

From a civil point of view, another disadvantage of GPS is Selective Availability (SA), used by the military to reduce accuracy over a certain region. When enabled, SA increases the C/A code's inaccuracy by adding random noise.

As GPS becomes integrated in more and more systems, perhaps the most important disadvantage is reliability. Because GPS is run by the U.S. Department of Defense and is the only open service satellite navigation system, there is no guarantee that the service will always be available. The United States government could, for example, decide to block civil GPS altogether.



5 Galileo

A European global navigation satellite system was proposed in the early 1990s, an initiative to boost the economic advantages already proven by the GPS system. Disadvantages of GPS had come in to play, such as the long-lasting reduced accuracy over southern Italy resulting from Selective Availability during the Bosnia crisis.

Until the final agreement to start the Galileo project, the EU was not in a favorable position with respect to the current GNSS systems, being a consumer in the background instead of an active partner. From a civil point of view, accuracy was very limited and the whole system was in military hands. Therefore, civil aviation is still restricted to land-based navigation beacons.

In 2004, the first stage of development was completed and deployment started in 2005. Satellite contracts have been awarded amongst the Galileo Industries, a consortium of several European aerospace companies, therefore manufacturing the satellites will progress rapidly. The relatively lightweight 625 kg satellites will be able to be deployed in clusters of two to eight satellites per launch vehicle, thereby reducing expenses and deployment time.

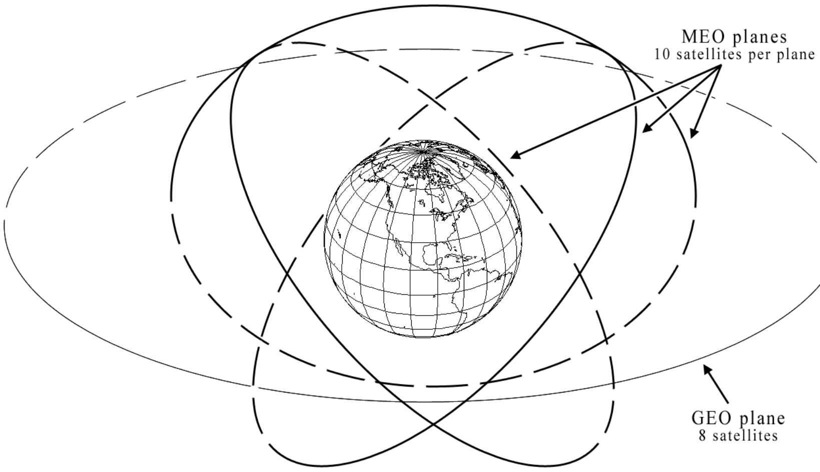


Figure 13: Galileo satellite configuration [12]

If Galileo continues to keep on schedule, the system should be fully functional by 2008.

5.1 Configuration

Galileo's configuration is slightly different than GPS, the leading difference being that it uses only three planes instead of six.[4]

- 27 active satellites
  3 spare satellites
- Three orbital planes
  Altitude: 23,616 km
  Period: 14 hours 4 minutes
  Inclination: 56°
- 10 satellites per plane

This configuration describes three planes in medium earth orbit. The satellites in MEO are at such a steep inclination to improve coverage at higher latitudes, unfortunately *reducing* coverage at the equator. The next step of development would allow the installation of eight geostationary navigation satellites. Although this doesn't have the highest priority at the moment, GEO satellites will certainly be included later, to compensate for this reduced accuracy. (See figure 13.)

Totalling 38 new satellites, this more than doubles the current 32 GNSS satellites in orbit.

5.2 Requirements

While GPS only provides two services – one public and one private – Galileo will provide five:

1. Open Service
   Free of user charge, this service is available to anybody with a GNSS receiver. It provides simple positioning and timing.
   Accuracy: 5 to 10 meters[14]
2. Safety of Life Service
   This addition to the Open Service provides authentication of the signal, improved integrity, and timely warnings of any problems.
   Accuracy: 5 to 10 meters
3. Commercial Service
   Subscribed users can decode two addi-

[14] If your receiver only supports single-frequencies, the accuracy is 15 to 20 meters.

tional signal to improve accuracy.
Accuracy: less than 1 meter

4. Public Regulated Service
For subscribed users requiring high continuity, an additional two signals can be decoded.[15]
Accuracy: 4 to 6 meters

5. Search and Rescue Service
The satellite listens for beacons broadcasting a distress signal, and globally broadcasts its position and message.

Galileo satellites broadcast over a wider spectrum of frequencies than GPS satellites, not only to improve reception, but also to incorporate the numerous services listed above. The system will send over the $L1$ and $L2$ discussed in section 4.5 on 8 and on another frequency, $L5$ (1176.45 MHz).

The Open Service is free of charge, so there is no liability on the part of the system operator when the service is disrupted. However, concession-holders will charge for other services that offer a guarantee of continuity of service. As stated in the anticipated *modus operandi*, Galileo will be liable for damages in the case of failure.[8] This legal jargon would, for example, finally allow civil aircraft to make full use of satellite navigation. This, in its turn, will lead to a new era in civil air transportation.

Equally important is the economical aspect. The estimated cost being between 3 and 3.5 billion euros, Galileo will cost no more than laying 150 kilometers of highway. Subscriptions alone will repay this in a matter of years, but the primary reward is the growth of the Gross National Product.

According to the CBA EC, Europe can expect a benefit of 62 billion euros in total from economic benefits and 12 billion euros in total from social benefits. Including approximately 2.5 billion euros in operation costs, the 74 billion euro profit significantly outweighs the 6 billion euro expenses within twenty years.[11]

Additionally, Galileo will be interoperable and compatible with GPS and GLONASS. Because more than twice as many satellites will be available from which to take a position, even in places that would normally obscure signals from GPS satellites low on the horizon will receive coverage.[1]

Although Galileo can be used in combination with the existing GNSS satellites, it will be self-sufficient and independent. This makes it not only a back-up to GPS, but also a *complete*, alternative system.

5.3 Concept

The relationship between receiver and satellite is identical to GPS, described in section 4.3 on page 6.

The European Space Agency put a lot of effort in designing a state of the art satellite for use in the Galileo system. Their design, which this year will go into production, has several advantages:

- Increased power output with Lithium-Ion batteries
- Lightweight and compact
- Laser retro-reflector allows 'pinging' from earth by laser
- Upgradeability with extra payloads
- Communication amongst satellites by Inter-Satellite Link (ISL)

[15]This service will also be integrated into the 112-network. For example, a user in distress calling 112 with his GNSS-receiver will submit his current location, and emergency response teams equipped with receivers with the Public Regulated Service will be able to track him in 'real-time'.

- Can be injected directly into the correct orbit by the launcher
- Launchers can accommodate two to eight satellite vehicles

5.4 Applications

The scientists and politicians moving Galileo forward are very enthusiastic about the new European civil GNSS. In 2008, we can expect our cell phones to have built-in GNSS receivers, allowing us to use them to find our exact position not only worldwide, but even inside a building. When making a 112 distress call, our telephones will automatically divulge our exact position to help emergency services find us.

Someday GNSS might be steering our cars or guiding the blind. Until then, we'll certainly see more reliable receivers in aircraft, shipping and road transportation for navigation and search and rescue.

6 Conclusion

GPS is perhaps one of satellite's most successful applications so far, and for consumers, receivers are becoming ever more affordable and reliable. Now over 10 years old, the system was revolutionary in its day and its popularity is still growing.

However, being under military control, there is no guarantee that the service will always be available. In 2008, the ESA's civil Galileo system will be fully functional and will grant consumers accuracy equal to that of the military. Anybody who owns a GNSS receiver will be able to make free use of Galileos open service. Commercial users will be allowed to purchase subscriptions to two additional services, which provide extra accuracy and continuity. Aircraft will be granted a special service that provides authentication of the signal, improved integrity and timely warnings of problems. Finally, a search and rescue service will help broadcast distress signals, wherever they may originate from.

In the 45 years of satellite navigation, GNSS has proven its economic, technological and practical value. Certainly new innovations will continue to show the benefits of this continuously expanding field.

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