Investigation of new processing techniques for geostationary satellite positioning

Benjamin Chibout, Christophe Macabiau, Anne-Christine Escher, Lionel Ries, Jean-Luc Issler, Stéphane Corazza, Michel Bousquet

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B.Chibout, C.Macabiau, A-C.Escher, Ecole Nationale de l'Aviation Civile/Tesa
L.Ries, J-L.Issler, CNES
S.Corrazza, AlcatelAleniaSpace
M.Bousquet, Supaero

BIOGRAPHY

Benjamin Chibout is a Ph.D. student in the field of GPS space application in the signal processing lab of the Ecole Nationale de l'Aviation Civile (ENAC) in Toulouse, France. He graduated in 2004 as an electronics engineer from the ENAC, and received the same year his Master research degree in signal processing.

Christophe Macabiau graduated as an electronics engineer in 1992 from ENAC in Toulouse, France. Since 1994, he has been working on the application of satellite navigation techniques to civil aviation. He received his Ph.D. in 1997 and has been in charge of the signal processing lab of the ENAC since 2000.

Anne-Christine ESCHER graduated as an electronics engineer in 1999 from the ENAC in Toulouse, France. Since 2002, she has been working as an associated researcher in the signal processing lab of the ENAC. She received her Ph.D. in 2003.

Lionel Ries is a navigation engineer in the "Transmission Techniques and Signal Processing Department", at CNES since June 2000. He is responsible of research activities on GNSS2 signals, including BOC modulations and modernised GPS signals (L2C & L5). He graduated from the Ecole Polytechnique de Bruxelles, at Brussels Free University (Belgium) and then specialized in space telecommunications systems at Supaero (ENSAE), in Toulouse (France).

Jean-Luc Issler is head of the Transmission Techniques and signal processing department of CNES, whose main tasks are signal processing, air interfaces and equipments in Radionavigation, Telecommunication, TT&C, High Data Rate TeleMetry, propagation and spectrum survey. He is involved in the development of several spaceborne receivers in Europe, as well as in studies on the European RadioNavigation projects, like GALILEO and the Pseudolite Network. With DRAST and DGA, he represents France in the GALILEO Signal Task Force of the European Commission. With Lionel Ries and Laurent Lestarquit , he received the astronautic prize 2004 of the French Aeronautical and Astronautical Association (AAAF) for his work on Galileo signal definition.

Stéphane Corazza is a research and development engineer in Alcatel Alenia Space company. He has experience in GPS and Galileo receivers design, digital signal processing suited to radiocommunications and satellite navigation, ASIC and FPGA development for satellite digital payloads. He has received engineering degree in Electronics and Telecommunication in the National Institute of Applied Sciences (INSA - Lyon, France, 1994).

Michel Bousquet is a Professor at SUPAERO (French Aerospace Engineering Institute of Higher Education), in charge of graduate and post-graduate programs in aerospace electronics and communications. He has over twenty five years of teaching and research experience, related to many aspects of satellite systems (modulation and coding, access techniques, onboard processing, system studies...). He has authored or co-authored many papers in the areas of digital communications and satellite communications and navigation systems, and textbooks, such as “Satellite Communications Systems” published by Wiley.

ABSTRACT

In order to use GPS or Galileo receivers on board a geostationary satellite so as to compute its position, we need to determine the specific characteristics of the signals which reach a satellite in a geostationary environment. There are a lot of differences between the signal that an earth user can receive and the one that a geostationary satellite receives. The localisation of geostationary satellites thanks to the GPS or Galileo systems is harder than for an earth user because of the spatial configuration of the problem. Indeed, the geostationary orbit is ‘above’ the GPS/Galileo orbit.

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Consequently, the received signals have a low C/No. With this constraint, specific acquisition and tracking techniques are required for the geostationary satellites' positioning process.

The aim of this article is to describe the specific constraints of the geostationary environment.
In a first part, we interest in the link budget between the geostationary satellite and the GPS/Galileo satellite and in the number of GNSS satellites that we can use for the acquisition of the signal depending on the C/No.
The main factors which drive the C/No are the gain of the GPS/Galileo transmitting antenna, the gain of the receiver antenna and the free space losses. So we have studied different shape of the receiver antenna pattern in order to make it fit with the geometry of the problem: the spatial area which interests us is the area on each side of the earth.

Then, we interest in the impact on the link budget when we consider signals transmitted through the main lobe only or also through the side lobes of the transmitting antenna. In the first case, the link budget is >35dBHz. In that case, the number of visible GPS/Galileo satellites for a given position of the geostationary satellite is very low.
In order to get more satellites, we process the signals transmitted trough the side lobes of the GPS/Galileo antenna. The number of visible satellites will be increased. But, as the signals are transmitted through the side lobes, the global C/No is lower too. The results obtained in this part will show us that it will not be possible to use a classic acquisition technique but the performances obtained with typical high sensibility processing techniques will match our requirements.

Then, once the environment has been characterised, we interest in the reliability of the positioning for the geostationary satellites through the computation of the Dilution Of Precision (DOP). The area where the GPS/Galileo satellites are located is not wide from the GEO point of view and thus, their spatial configuration is not good for the DOP. In order to improve the DOP, we must take into account the signals transmitted through the main lobe and the side lobes, and so we will have to deal with low C/No signals. Again, high-sensibility processing techniques will show some major interests.

Finally, we study the range of the Doppler affecting the signal and investigate its effect on the acquisition time and processing techniques. The velocity of the geostationary satellites is such that the signal can undergo a Doppler as big as +/-15kHz.

INTRODUCTION

The geostationary context for GPS localization is particular. Indeed the geostationary orbit is 'above' the GPS/Galileo orbits. Consequently, there are numerous differences between the GPS/Galileo signal an earth user receives and the signal a GEO satellite receives. First, the transmitting GPS/Galileo antenna does not point toward the geostationary satellite for most of the time, whereas any earth user is close to the direction pointed by the GPS/Galileo antenna as they points toward the earth. Thus, the received signals in a geostationary context have a low C/No. Moreover, for most of the time, the distance between the GEO satellite and the GPS/Galileo satellite is much longer than the distance for a classic earth user. Lastly, the relative velocity of the satellites (GEO versus GPS/Galileo) is very high, and thus, the distance variation is high too. This implies important Doppler, far bigger than the classic Doppler range an earth user encounters.
In most of the previous studies concerning GEO satellites localisation, only the main beam of the GPS satellite antenna was considered. In this paper, an analysis of the advantage of using GPS/Galileo antenna side lobes is drawn. The link budget and the satellite visibility for the GPS constellation and for the Galileo constellation is studied and the interest in using GPS/Galileo satellite antenna side lobes is shown. Even if the C/No becomes very low with this method, current high sensitivity techniques should be efficient to acquire and to track the signals.
In a second section, we assess the accuracy of the position calculation for a GEO satellite. The accuracy depends on the quality of the Dilution Of Precision factors and the UERE. We only focus on the DOP factors and it is shown that once again, we have interest in using side lobes in order to improve DOP quality.
The Doppler range is a significant factor for the mean acquisition time due to the Doppler bins which must be explored. The last section provides results concerning the Doppler that can affect the signal in the GEO configuration.

LINK BUDGET AND SATELLITE VISIBILITY

- **Geometric presentation**

The use of GNSS for GEO positioning is possible under specific constraint. As described in the introduction, the GEO orbit is above the GPS/Galileo orbit. So the useful GNSS satellites for the GEO are not those which are close to the GEO, just 'under' him, but mainly those located at the opposite side toward the earth. Figure 1 illustrates the GEO configuration. For the GEO satellite, the earth hides a part of the space behind her. The GPS/Galileo satellites located in this space area are not visible for the GEO satellite. This is the S'' area in figure 1. An earth user

always receives a signal which is emitted through the main lobe of the GPS/Galileo antenna, but due to the configuration described before, it is not the case for a GEO satellite. It may receive signal emitted through side lobes. Indeed, due to the width of the main lobe of the GPS/Galileo antenna, the area where they emit a main lobe signal which can reach the GEO satellite is not wide. This area is represented by the S' area on figure1. GPS1 is the position where the GEO satellite receives a signal which is tangent to the earth. We have considered here that the earth radius encompasses the earth plus the ionosphere so as to get rid off the important ionospheric delay that could affect the signal **[1].** GPS2 corresponds to the extreme position where the GPS/Galileo satellite transmits signal through the main lobe to the GEO satellite. Beyond the second position, the GNSS satellites are in the S area and the signals which reach the GEO satellite are transmitted through side lobes. S' area is really narrow and the number of "visible" satellite will be low.
So as to get rid off this problem, we would like to extend the acceptable visibility region in order to acquire satellites which are in the S area. The gain of the emitting antenna decreases significantly after the main lobe (21.6° for the GPS L1 antenna, less than 20° for Galileo L1 antenna) so that, with a classical method, the signal can not be processed if it is emitted through a side lobe, i.e when the GPS/Galileo satellite is located in the S area. To achieve that, we must choose a lower threshold for the acceptable signal strength. Thus, it will be possible to process signal emitted through side lobes and the coverage area will be widely extended.
We first study the visibility and the link budget for main lobe signals, and then we will see the global link budget as well as the global satellite visibility. We will have to make assumptions, notably concerning the receiver and transmit antenna gain, to achieve this study.

- **Visibility and link budget with main lobe only**

As presented in **[2]** and **[3],** the number of visible satellites, when using only the main lobe of the GPS or Galileo antenna, is very low. For the GPS constellation, the GEO satellite can 'see':

- 1 satellite for 29% of the time,
- 2 satellites for 29% of the time,
- 3 satellites for 9% of the time,
- 4 or more satellites for 0% of the time,
- no satellite for 33% of the time.

For the Galileo constellation, if the width of the main lobe remains less than 15° according to the current characteristics, only one satellite is visible for less than 30% of time and two satellites for less than 5% of the time and it is not possible to see more than two satellites; the S' area is very small.

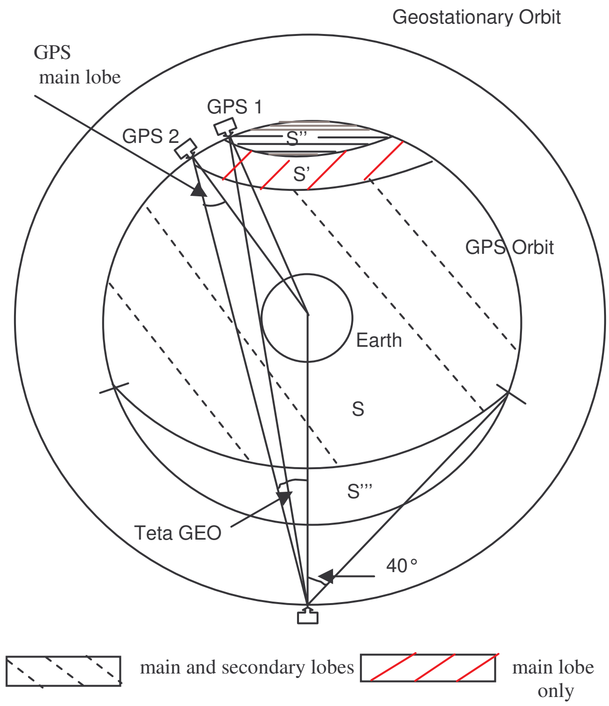


Figure 1: Geostationary Satellite Visibility

Let us interest in the link budget for the main lobe only.
The link budget is very good in this area. In order to be in a worst case link budget, the receiver noise power density No assumed to be -201 dBW/Hz. Indeed, according to the ambient space temperature and the direction the receiver antenna points, the noise power density is under –201dBW/Hz.
For the link budget computation, we have considered that the gain of the receiving antenna equals 9dB for the entire main lobe coverage area. The receiving antenna gain is constant for every signal emitted through the main lobe, in the S' area.
The antenna gain assumptions for the main lobe of the GPS and Galileo satellite is based on the results of **[4]**. The maximum antenna gain is taken higher than 14 dB while the minimum antenna gain value is 2dB. Thus, the gain difference between the two extreme positions of the S' area (which are represented by GPS1 and GPS2 on figure1) is important. We will assume that the antenna gain is quite similar for the L5-band signals.
Compared to an earth user, the free space losses are bigger, the distance between the receiver and the GNSS satellite is almost three times bigger here. Thus, the free space losses are around 10dB higher.
Under the previous assumptions, the link budget for the GPS L1 and Galileo L1 can be computed. The following values in table 1 are obtained assuming main beam only.

Link Budget Main Beam Only	GPS L1 (best case)	GPS L1 (worst case)	Galileo L1 OS (best case)	Galileo L1 OS (worst case)
Transmitted power (dBW)	*> 14*	*>14*	*>14*	*>14*
Typical Antenna Gain (dB)	*14*	*2*	*14*	*2*
Free Space Losses (dB)	-193	-192.7	-193.4	-193.1
GEO antenna gain (dB)	*9*	*9*	*9*	*9*
Noise Temperature (dBW/Hz)	*-201*	*-201*	*-201*	*-201*
Other losses (dB)	*2*	*2*	*2*	*2*
C/No (dBHZ)	*>43*	*>31.3*	*>42.6*	*>30.9*

Table1 – GPS and Galileo main lobe link budget

In table 1, we note that the received signals have very good C/No, above 32 dBHz, if we only use the main beam. Thus, these signals can be processed with classical acquisition and tracking techniques. The best case corresponds to GPS1 position (see figure 1) and the worst case corresponds to GPS2 position. GPS1 is the position where the GEO satellite receives a signal which is tangent to the earth. It is the best case because the GPS/Galileo antenna gain is maximum there. GPS2 corresponds to the extreme position where the GPS/Galileo satellite transmits signal through the main lobe to the GEO satellite. Beyond the second position, the GNSS satellites are in the S area and the signals which reach the GEO satellite are transmitted through side lobes.
Assuming that the transmitting antenna gains are similar on E5a/L5 and L1, comparable results were obtained with the E5a/L5 signals. The observed C/No are a bit higher because the free space losses are lowered by about 2.5 dB, compared to L1, and the transmitter power are also a bit higher **[4],**

However, the number of satellite is not sufficient to provide continuous positioning: there is no visible satellite for more than 1/3 of the time for GPS and it is even worst for Galileo. Moreover, the required number of four satellites to have an estimation of position and velocity of the receiver is not reached. In addition, the geometry of the processed satellite is rather poor, even with GPS and Galileo satellites processed simultaneously: the GDOP are usually above 100.

So, it may appear very beneficial to extend our analyse to the case where the GEO receiver gets signal from the side lobes of the GPS/Galileo antenna as it was already suggested in previous studies [1] and [5].

- **Link budget and visibility with side lobes**

The receiver can then use satellites located in both S' and S area and thus the number of satellite may be significantly increased as well as the DOP may be much more favourable.
On the contrary, the link budget becomes less favourable: while the GPS/Galileo satellites are located closer to the GEO orbit, although reducing free space losses, the overall C/No will decrease significantly. Indeed, in this case, the GNSS satellite antenna do not point towards the GEO satellite anymore and their gain may be significantly lower in the secondary lobes.

To evaluate the requirement for processing the signals incoming from the secondary lobes, it is necessary to recompute the link budget considering the transmitting antenna gain pattern for angles between 0 and 90°.
Little information is available on the GNSS satellite transmit antenna, the following analyses use the pattern provided in **[6],** for the GPS blocks I and II, and consider the same pattern for Galileo L1 antenna. To better manage differences in the gain pattern, a margin of 2 dB will be introduced in the gain for the secondary lobes. The GPS L1 antenna gain is shown on figure 2.

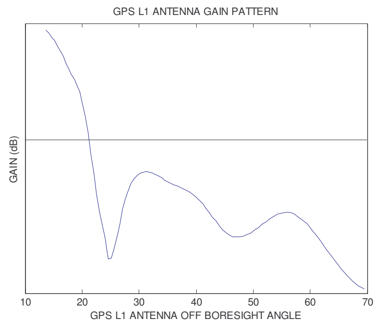


Figure 2: GPS L1 antenna gain pattern

Finally, the receiver's antenna gain pattern should be shaped such that the reception is optimised for elevation angle comprised between 8° and 40°, corresponding to area S in Figure 1. As the GPS/Galileo antenna gain decreases when they get closer and closer to the GEO (because the emission angle increases), the link budget for the satellite signal in this area decreases significantly despite the distance reduction. In order to moderate this problem, we would like to have a GEO antenna gain which compensates this effect in order to see more satellites with a good C/No. There is a big fall of the antenna gain between the main lobe and the secondary lobe. The side lobe antenna gain of the GPS/Galileo antenna is more than 10 dB lower than the gain in the main lobe area. So, we must try to maximise the GEO antenna in the area. Then, the loss of gain in the transmitting antenna is compensated by the GEO antenna. To sum up, the GEO antenna gain pattern must have a

high gain on a large range and its maximum must be around 15° off-boresight angle.
Reducing the gain in the region pointing the earth is also interesting because the earth contributes to the noise floor of the receiver. The overall optimisation of the antenna accounts for many other parameters such as weigh, volume, etc. In this study, a theoretical pattern rather than a real one is assumed: the same assumption is made as in the prior analyses (gain > 9 dB) for teta < 30° and a decreasing value above. The theoretical pattern we use here is the red curve on the figure 3: this is the minimum requirement for the GEO antenna pattern to obtain the following results. The blue diagram on the figure 3 gives an example of a shape which is well suited for a geostationary use and which matches the previous conditions.

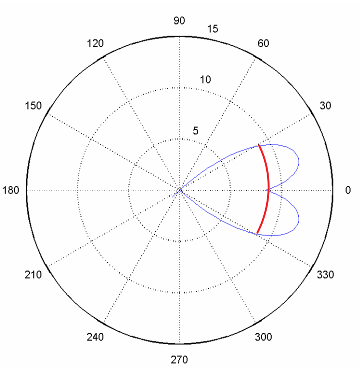


Figure 3: Receiver antenna diagram (main beam only) in polar representation

Figure 4 shows the C/No the GEO satellite is expected to receive for a given off bore-sight angle: TETA GEO. The area where the GPS and Galileo satellites are visible is inside a 40° half angle cone (it is a bit less than 40° for the GPS constellation and a bit more for the Galileo constellation due to their altitude difference). The received signal strength depicted in figure 4 is similar to the one obtained by J.Ruiz in **[1].**
We see that the main factor which drives the link budget is the GPS/Galileo antenna gain. Indeed, the general shape of the two following figures is highly correlated with the emitting antenna gain pattern. We remind that we have chosen similar antenna pattern for GPS and Galileo.
We see on figure 4 that the more the GPS/Galileo signal come from the side (which corresponds to a signal emitted through side lobes), the lower the C/No is.
By considering this enlarged area, the C/No of the signal can fall as low as 15 dBHz, with an important range of the total area which is between 20 and 25 dBHz.

Accounting the acquisition of the received signals, we have represented on figure 4 the two functioning zone of a receiver. The zone 1 corresponds to signal with C/No higher than 25 dBHz. The signals can be processed with classic acquisition techniques in this area. The zone 2 is for signals with a C/No lower than 25 dBHz that is for signals which have to be processed with high sensitivity techniques or code-only techniques **[5].**

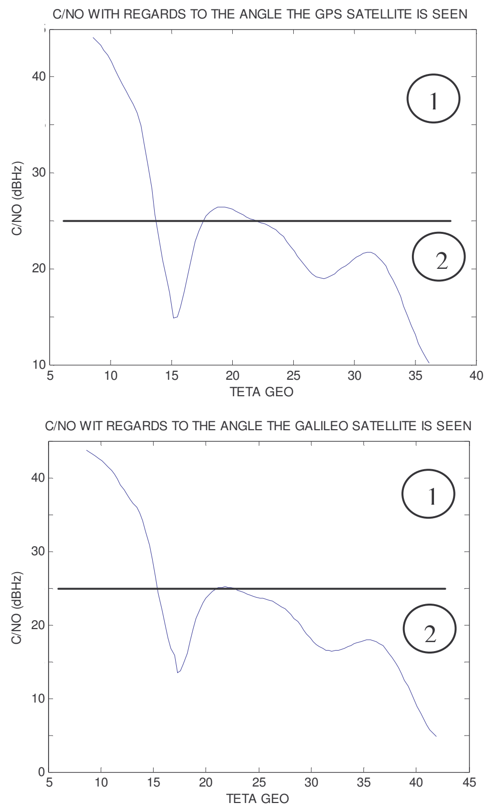


Figure 4: Global C/No from the receiver point of view with GPS (L1) satellites (up) and Galileo (L1)(down)

We note that most of the received signals are in the zone2. The current high sensitivity techniques are able to achieve acquisition and tracking for these low C/No values. Thus, it becomes really interesting to consider the side lobes, because of the higher visibility of the satellites.
The next part illustrates the contribution of side lobes signals in term of the number of visible satellites. The visibility is presented for three different C/No values: 20 dBHz, 25 dBHz and 28 dBHz.

- GPS satellite Visibility

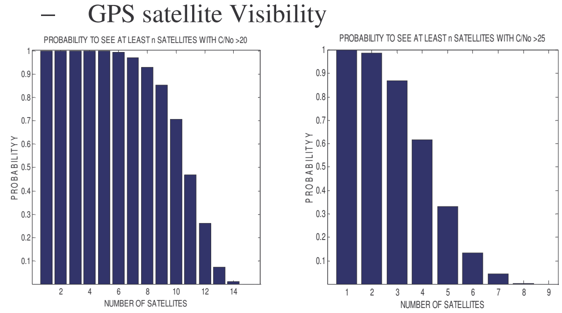


Figure 5:Probability to see at least N satellites with C/No>20 dBHz (left) and C/No>25dBHz (right)

We notice that in this configuration, we see more satellites then an earth user can see, if we are able to process signals with a low C/No. We have always 6 satellites in view with a C/No higher than 20 dBHz but this figure falls to two satellites for a C/No threshold put higher than 25dBHz.

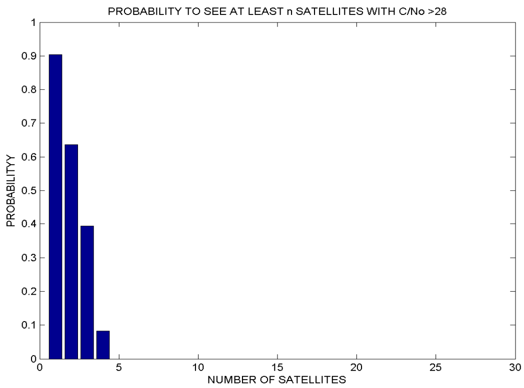


Figure 6: Probability to see at least N satellites with C/No>28 dBHz

The data demodulation threshold is set around 28 dBHz. For that threshold, we do not see one satellite all the time but only 90% of the time and four satellites are in sight less than 10% of the time. The periods when no satellite is visible do not exceed 70 minutes for this threshold as it is shown on figure7.

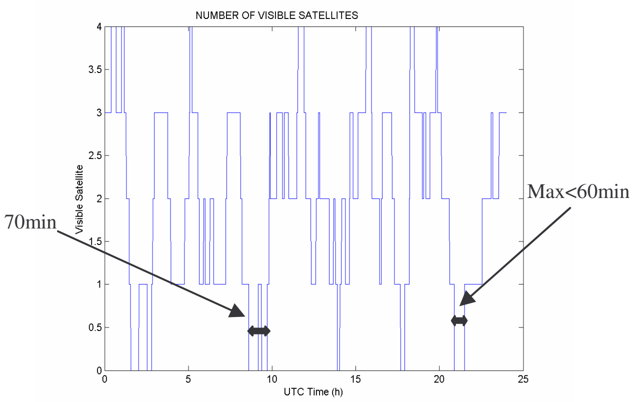


Figure 7: Number of visible satellites at C/No=28dBHz

Thus, it is possible to demodulate the data almost all along the time for at least one satellite. Useful data such as almanacs can be obtained and use in order to ease the acquisition and tracking process of lower C/No satellite signals.

– Galileo satellite Visibility

For the Galileo constellation which is higher than the GPS constellation, the results will be quite similar. The results are obtained with a constellation of 27 satellites.

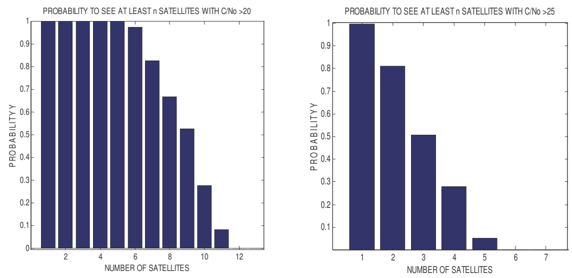


Figure 8: Probability to see at least N satellites with C/No>20 dBHz (left) and C/No>25dBHz (right)

As for the GPS constellation, the number of visible satellites decreases when the threshold satellite's C/No increases. However, for this constellation, there is not always two visible satellites with a threshold as low as 25 dBHz as the figure 8 shows. For a C/No threshold equal to 28dBHz, the probability to see at least one satellite is only 88%.

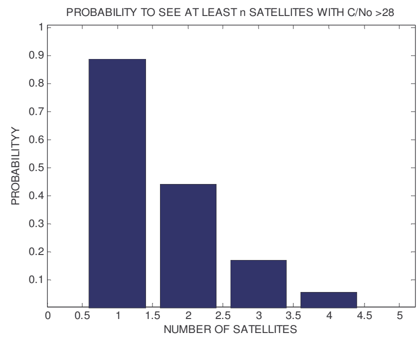


Figure 9: Probability to see at least N satellites with C/No>28 dBHz

Acquisition and tracking thanks to high sensitivity techniques will be achievable for the Galileo constellation too and the demodulation of the Galileo data will be easier.

– GPS and Galileo joint Visibility

The GEO receiver must be able to process signals incoming from GPS and Galileo. With both GPS and Galileo constellation signals, the satellites that we will try to acquire are even more numerous.

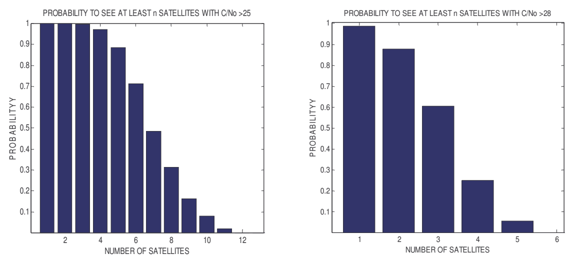


Figure 10:Probability to see at least N satellites with C/No>25dBHz (left) and C/No>28 dBHz with the two constellations

In particular, if we want to acquire satellites with C/No higher than 28 dBHz, the two constellations are very interesting because the number of visible satellites is well improved. We always see at least one satellite in this case: for 98% of the time, the data demodulation of at least one satellite is possible.

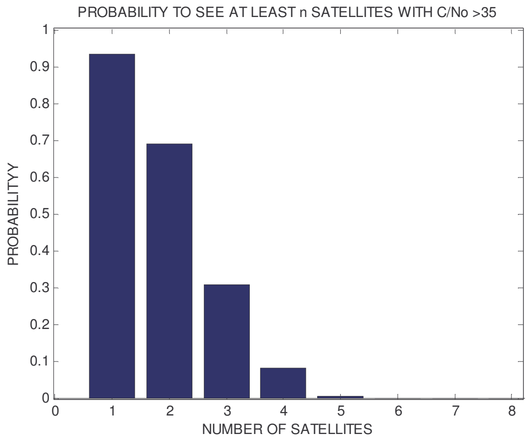


Figure 11:Probability to see at least N satellites with C/No>35Hz with the two constellations

With a receiver which computes acquisition with both GPS and Galileo signals, we will almost always have the possibility to acquire at least one satellite with a C/No threshold higher than 35dBHz (93% of time). Moreover, once the first satellite is acquired, the joint constellation is very interesting for lower C/No acquisition: Indeed, for more than 96% of time, we see at least four satellites simultaneously with C/No higher than 25 dBHz.

To conclude, the use of secondary lobes provides a real improvement in the number of visible satellites. With only the main lobe, we hardly see three satellites in the same time, so that a position calculation is not really achievable. Nevertheless, a receiver with high threshold sensitivity is able to process these signals with good C/No. If we chose to use a lower acquisition threshold such as 20 dBHz, we have seen that it is possible to process numerous signals coming from side lobes. High sensitivity and/or aided techniques are able to work with these weak signals, and thus, positioning may then be improved. Knowing the GEO positioning is achievable, another aspect of the specific constraint in a GEO context is tackle in the next part. We study the accuracy of this measurement.

DILUTION OF PRECISION

In this part, we focus on the Dilution of Precision in order to assess the accuracy that we should have for the GEO satellite positioning. The quality of the Dilution Of Precision (DOP) factor depends on two main factors:

- The number of visible satellites: the more visible satellites there is, the better the DOP factor are.
- The spatial distribution of the visible satellites: the satellites should have a uniform distribution to improve the DOP factor.

Let us analyse these two factors in a geostationary context.
For a geostationary satellite, the geometric repartition of the GPS/Galileo satellites is not good. Contrary to an earth user who can see satellites with low elevation as well as satellites at the zenith, the GEO satellite always see the GPS/Galileo satellites inside a confined area: Every satellite is inside a cone of around 40° half angle (there is a little difference between GPS and Galileo), see Figure 1. Thus, the spatial distribution of the satellites is not really uniform, and so the Dilution of Precision (DOP) factors will not be good.
Moreover, the DOP are better when the satellites in view are numerous. According to the previous section, the number of visible satellites decreases when the C/No threshold increases. Thus, the DOP should be even worse if we want to use satellites with a good link budget. If we want improved DOP factors, we have to use a high sensitivity receiver in order to receive signals with low C/No. We will then have more satellite in view and their spatial distribution will be better too: they are not confined in the S' area but in the S+S' area.

Besides, the DOP calculation requires to see at least 4 satellites if we want a reliable result. For satellites with C/No higher than 23dBHz (and even till 22dBHz for the Galileo constellation), we do not see more than 3 satellites all the time. So, the resulting DOP are not really measurable for satellites with C/No above 23dBHz.
The following DOP factors are obtained by fixing a sensibility threshold. The DOP are calculated from satellites whose received signals are above that threshold at a given time. This explains why the DOP factor increase when the C/No increases on the following figures. With a higher threshold, we have less visible (and usable) satellites. Thus, the number of processed signals decreases and the spatial distribution of the satellites become really bad and so, the combination of these two factors makes the DOP bad. The measurements are made over one day.
As it was expected, for the moment where we have less than four satellites in view, the DOP have very big peaks which largely exceed 100. These peaks are not representative of a true measure of the DOP. They are the consequence of the DOP calculation method.
For the lone GPS constellation or the lone Galileo constellation, the results are really bad, see figure 12 and 13. The level of the DOP never reaches a really low and interesting value. For a low C/No threshold as low as 15 dBHz, GDOP is around 5 but it often exceeds 10 as soon as the C/No threshold is 18-19 dBHz. These poor DOP

values will reduce the accuracy of the position measurement.

- GPS Dilution Of Precision

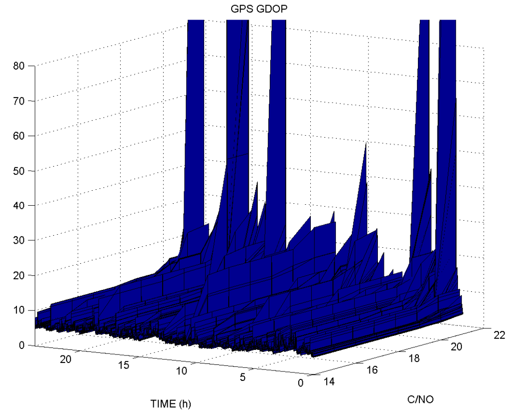


Figure 12: GDOP factor for the GPS constellation along one day

- Galileo Dilution Of Precision

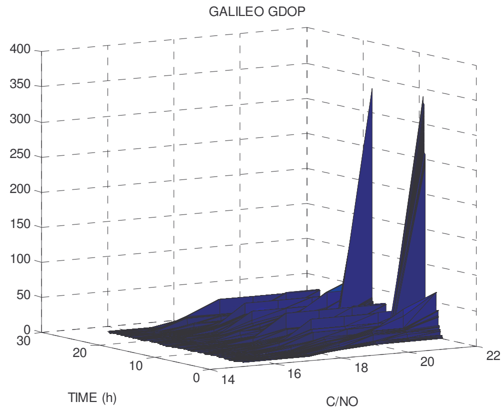


Figure 13: GDOP factor for the Galileo constellation along one day

- GPS + Galileo Dilution Of Precision

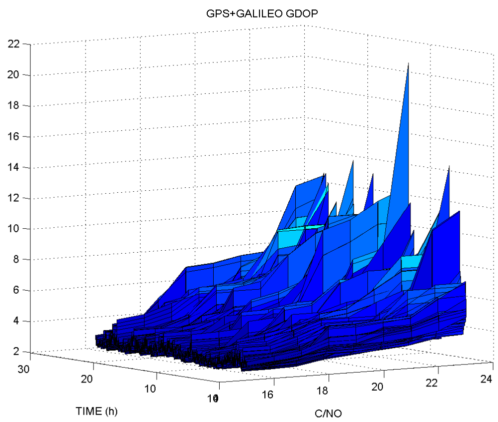


Figure 14: GDOP factor for the Galileo and GPS joint constellation along one day

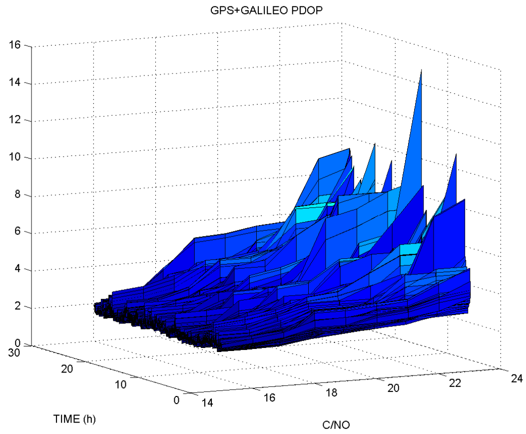


Figure 15: PDOP factor for the Galileo and GPS joint constellation along one day

There is an improvement when the two constellations are used in the same time. The number of visible satellites is increased and it is possible to compute the DOP factor for C/No up to 24dBHz without non relevant high peaks (as we had for the lone constellations). Here, GDOP values are under 14 for every C/No threshold from 14 to 24 dBHz and the PDOP values are under 10 (GDOP and PDOP exceed these value just once at a given time). These values are far better than for the lone constellations, and the positioning accuracy will be well improved with a receiver which computes signals from the two constellations.

So, the processing techniques will have to work for low C/No (between 14 and 24dBHz) in order to have a good accuracy.

DOPPLER RANGE

Another interesting characteristic of the signals is their Doppler. Indeed, the size of the Doppler range directly linked with mean acquisition time duration.

For most earth user, the usual Doppler range does not exceed +/- 5kHz. But the velocity of an earth user is very low compared to the velocity of a GEO satellite, and thus, the Doppler contribution of the earth user is reduced compared to the one of a GEO satellite.

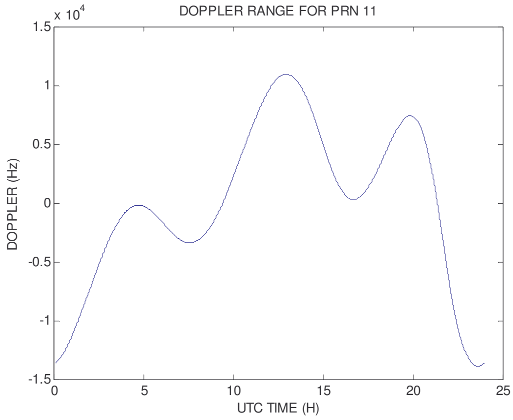
By definition, a GEO satellite makes one revolution in 24 hours; so its velocity is given by:

$$V_{GEO} = \frac{2\pi \cdot R_{GEO}}{T} \approx 3075\, m.s^{-1}$$

In comparison, the velocity of an earth user does usually not exceed 100m/s. The difference really is significant.

Let v_d be the Doppler velocity (i.e. the rate of change of the geometric distance), the Doppler effect on the signal is: $f_d(t) = -L_1 \frac{v_{LOS}(t)}{c}$

v_{LOS} is the projection of the GPS and GEO satellite velocity on the Line Of Sight. Figure 16 below illustrates the Doppler variation over one day for the PRN 11. The maximum value of the Doppler is -13.8 kHz. The Doppler range for the entire GPS constellation is also depicted. The Doppler variation for all the satellites remains between +/-15 kHz. This value is three times higher than the classic value for an earth user.



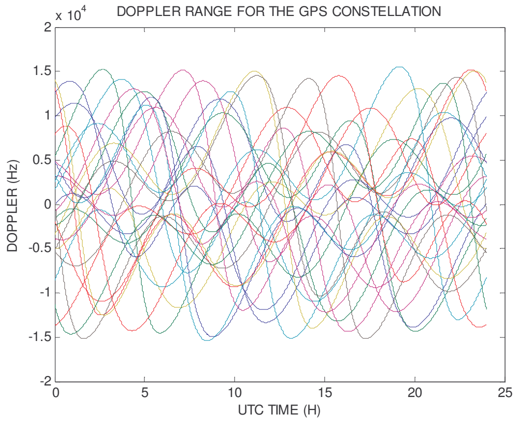


Figure 16: True Doppler for the PRN 11 (up) and for the entire GPS constellation (down)

During the acquisition, the size of the matrix of detection will be very large due to the number of Doppler bins if we have to explore such a wide range. The acquisition time will be high due to the number of operation that has to be made. The first two sections show that we have real interest in using signals with a weak C/No, but the required time to process them will already be long because time processing increase with weak signal level (more non coherent integration are needed). Thus, We must develop an specific acquisition strategy to reduce the width of the frequency range if we want to be able to process the signals within a reasonable acquisition time. With such a wide Doppler range, it is not possible. So techniques to reduce the Doppler range should be used, such as aided data (downloaded ephemeris, orbit), the use of demodulated almanacs or code-only processing (**[5]** and **[7]**), aided with an orbital filter.

CONCLUSION

In this paper, some characteristics of GPS/Galileo signals for a geostationary use have been studied. We have seen the advantage for the GEO receiver to be able to process signals with low C/No. In this case, the GEO satellite can receive signals coming from a wide area (almost the entire GPS/Galileo orbit envelope), so that the number of visible satellite increases drastically. The GEO satellite receives signals which are emitted from secondary lobes of their antenna so that these signals are weak. In order to achieve such a task, the acquisition threshold should be as low as 20 dBHz and we need a high sensitivity receiver to make it. Current high sensitivity or code-only techniques match this requirement. So it will be possible to use numerous satellites to compute the satellite position. The study of the DOP factor shows another advantage of using a high sensitivity receiver because the DOP are very bad in any case for a GEO satellite, but they are improved when the receiver can process signal with weak level. The accuracy of the position measurement will be improved too.

In counterpart, the use of weak signal increases the processing time for acquisition and signal tracking. The Doppler range for a GEO satellite is three times wider than for a classic earth user. Aided data or an efficient technique to reduce the Doppler range will be welcome if we want the receiver to provide a point position solution in a reasonable time.

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