Satellite Radio Navigation Exam
Unauthorized documentation, authorized calculators
Duration: 1h45

General

The purpose of this exam is to assess your overall understanding of satellite navigation systems. As in your next coming engineer life, you will have to demonstrate your ability to apply acquired knowledge for answering concrete, open and complex industrial problems.
This exam is built on three parts, the raw acquired knowledge, your ability to use it to answer a concrete industrial problem and finally your creativity to answer the challenges of tomorrow.
During this exam, do not hesitate to illustrate your answers with examples from the course and annotated diagrams (a good image is often better than a long speech). In general, be specific, especially in your technical vocabulary, and develop your answers and analysis.

Good luck !

Course (~ 12 pts, ~ 1 h)

1. Recall in a table the main characteristics of GPS L1 C/A, GPS L2 P(Y), Galileo E1 BOC(1,1) signals. For each signal draw its time domain shape, frequency spectrum, autocorrelation function.

2. For a given C/N0 and considering equivalent receiver parameters, sort by ascending order the precision of the pseudo-range measurement for the following modulations : BPSK(1), BPSK(10), BOC(1,1). Justify your answer.

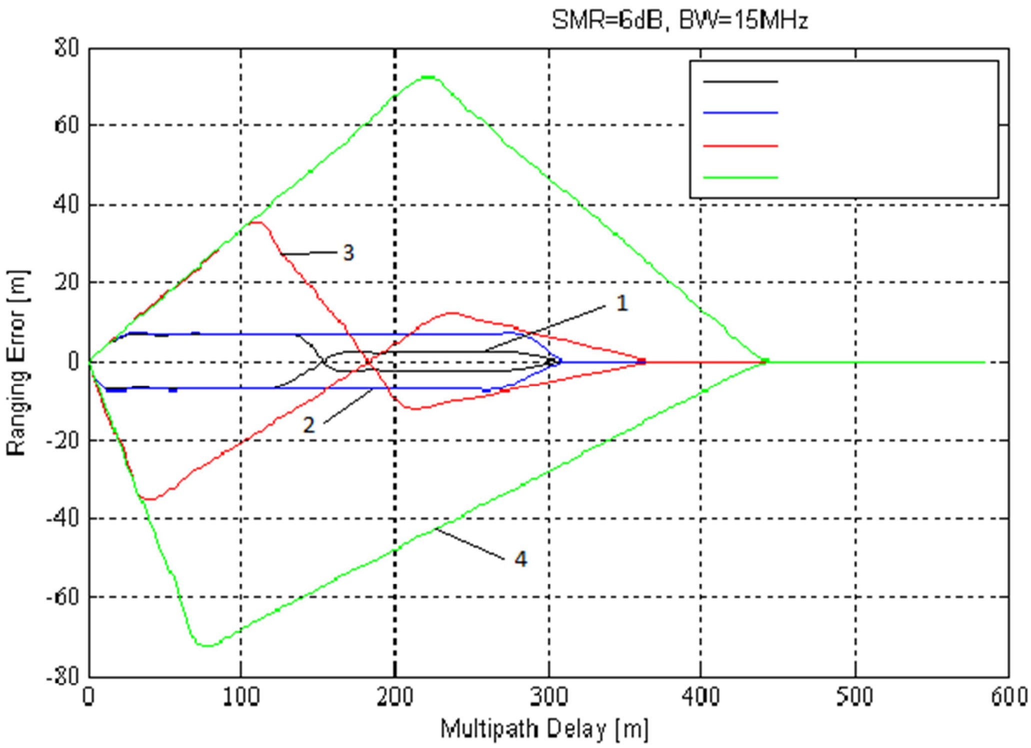
3. The acquisition is a process which tries to find energy in the time/frequency space. Give the 3 main sources of frequency uncertainty during this process and the order of magnitude for each of them. What is the search range for both time and frequency dimensions.
   Considering GPS L1 C/A signal, give recommendations on the maximum integration length during acquisition.

4. The tracking is a process which tries to keep a local signal replica aligned with received signals coming from space. Draw a block diagram representing the typical architecture of a tracking loop. Recall the name of the 2 tracking loops involves in every GNSS receiver.
   Considering GPS L1 C/A signal, give two recommendations on how to improve pseudo-range measurement errors.

5. Recall the 4 main sources of error affecting user position computation. What are the 2 mandatory information broadcasted by GNSS satellites to allow any receiver to compute its position.

6. Considering the following indications given by a receiver : HDOP=1.4142, VDOP=2, ranging error σ=2m. What is the associated PDOP ? What is the associated RMS position error ?

7. Comment the following diagram. What is the name of this diagram? What performances can be analyzed? What type of modulation is used on curve 3? What is the name of the technic used for curves 1, 2? Rebuild the missing legend.



Industrial problem (~ 8 pts, ~ 45 min)

A scientific article is attached to the present exam.

1. Who wrote this article ? Who published it?
   Cite this article in a proper manner using international bibliographic standards.

2. What is the main subject addressed in this article.
   In a few lines, summarize its content.

3. What is integrity for GNSS systems.
   What are the 3 other key performance indicators for all GNSS systems.
   How is integrity usually ensured nowadays ?

4. According to the article, what is the risk of EWF with respect to integrity ?
   How many EWF are here described ? For each of them draw : the time domain, frequency domain and autocorrelation correlation is presence of such failures.

5. Scientific literature now commonly considers a new threat model, called EWFC and which may be seen as a combination of EWFA and EWFB.
   Draw time domain and frequency domain signature of EWFC with respect to a fault free signal.

6. Considering that a 1m error on the pseudo-range measurement due to EWFA for a unique line of sight is acceptable, what is the maximum admissible lag of EWFA without triggering any integrity risk.

Bonus (5 pts)

1. IoT *(Internet of Things)* is a trendy domain where objects may connect, interact and exchange data with each other. IOT business is expected to double and reach a total of 520B$ by 2021. So far, one key limitation for a broader adoption is the ability of such objects to provide their location with the least amount of energy to preserve their power-autonomy.
   Knowing that typical GNSS processing requires intensive computations (acquisition, tracking, demodulation), propose a disruptive approach (based or not on GNSS) to allow low energy objects to communicate their location.

2. Autonomous transportation is getting closer and closer to reality. Continental wide services for civil aviation's are now offered thanks' to SBAS systems to provide more and more autonomy to aircrafts. Autonomous trains are the next challenge to be addressed by SBAS systems.
   Are the services offered to civil aviation sufficient to provide equivalent performances on rails ? How could they be improved?