Benefits and Limitations of New GNSS Signal Designs

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My Opinions on New GNSS Signal Designs

- This briefing is loosely based upon Leadership Series article in INSIDE GNSS, March/April 2014
- It is also based upon my 46 years of working with GPS and involvement in GPS Modernizations and some of the other new signal designs
  - Just because they are new signal designs, it doesn’t mean that these signals are 100% better (or more desirable) than the existing GPS signals, although most are

Introduction

- As a person who has been around GPS since 1974 (40 years), I take it upon myself to critique the legacy GPS signals, the modernized GPS signals, legacy GLONASS signals, as well as proposed Galileo signals
  - GPS started with 3 navigation signals that were available to anyone and it was then relatively simple to design receivers that tracked available signals for a limited set of applications.
- A number of new GNSS signals have been proposed in the recent years with a variety of features not used in earlier signal designs
  - Longer codes, higher data rates, message error detection and control methods, use of pilot channels, multiplexing, etc.
- Do all of these new signals' features provide improvements, or are they simply a result of competition between the new GNSSs, or alternate signal designs imposed onto the GNSS users?
- "Is better the evil of good enough?"

The Legacy GPS C/A Code Signal has a Lot of Staying Power

- Why is that?
  - The main factor is that the C/A code is currently the only non-encrypted code available on most satellites
    - It has been around forever
  - It is also popular amongst manufacturers, cell-phone designers, etc., because it is simple and doesn't require much memory
    - Its cross-correlation properties are not the best, but we have learned to work around that problem

L5 is the 2nd GPS Civil Signal – Not the 3rd

- L2C is advertised as the 2nd GPS Civil signal
  - It is true that it was the 2nd one to be broadcast from the GPS satellites
  - It was the 3rd one to be designed
- The design of SBAS and L5 signals preceded L2C
  - Some of the L2C features were taken from the L5 signal, such as
    - The “so-called” CNAV data structure and content
    - The pilot channel
  - L5 and L2C borrowed data structure features from the SBAS data structure

The L5 Signal Structure

- More Power than Legacy C/A Code
  - To overcome losses due to pulse blanking and pre-LNA insertion loss due to filtering to reject adjacent DMEs
- Longer Codes
  - 10 times longer than the C/A codes
    - 10,230 chips in 1 ms instead of 1023 chips
  - The addition of a common 10 ms 10-bit overlay code for better synchronization
    - Increasing acquisition margin
    - Same code on all SVs
- Data-less component in quadrature
  - But, has 20 ms 20-bit overlay code
    - Same code on all SVs

Other L5 and L2C Features

- Neither L5 nor L2C incorporate higher data rates
  - In fact, L2C has one-half the data rate of the other GPS signals (25 bps) because it multiplexes the data and pilot signals, resulting 3 dB loss of received power
    1) Higher data rates reduce tracking margin; if not needed, it is better if not needed on GPS
- The pilot signal on L2C has a very long code
  - Each SV broadcasts a portion of an extremely long code, analogous to the P-code
    - (The P-code, if let to run to completion, is 37 weeks long)

Message Error Detection

- The GPS legacy codes have marginal data error detection, called message parity
  - Aviation receivers are required to collect the data twice (and be in agreement) before using the data
- L5 and L2C (and SBAS) use Forward Error Correction (FEC)
  - This only improves data collection margin, but does not improve tracking margin
  - Provides enough data collection margin so data need only be collected once in aviation receivers

L1C Signal Structure

- It is my opinion that the L1C signal structure should have been same as L5
  - But with 1/10 the chipping rate resulting in a 10 ms code, using the same codes
  - Much simpler implementation than L1C memory codes
    - This is an input from cell phone designers
  - Could still have adopted the L1C data structure (maybe)
- Nobody asked me, but many people agree with me

Galileo Data Rates

- Galileo data rate is 125 bps
  - Results in about 4 dB loss in data collection margin with respect to 50 bps
- This higher data rate was implemented so as to provide additional signal integrity messages
  - To my knowledge, these messages have not been defined or implemented
  - Even if they were, EUROCAE MOPS does not require their use
- Is it possible to still lower the Galileo data rate since the integrity messages are not being implemented?
  - And also increase the accuracy of some of the ephemeris and clock parameters to the level of the CNAV messages on GPS L5 and L2C using more bits?

BOC(6,1) L1 Component

- Added to Galileo and GPS L1C
  - Steals power from BOC(1,1) components
  - Purpose was to add some signal in GPS M-code spectral nulls
  - Implemented differently on Galileo and GPS
    - Same spectral density
    - Added signal on Galileo, multiplexed with BOC(1,1) on GPS L1C
- RTCA and EUROCAE MOPS do not require BOC(6,1) tracking
  - Because of implementation, more signal loss on Galileo than on GPS if not tracked
    - That signal loss is not much, so complexity of tracking implementation it is not always justified

New Features that Improve Receiver Performance in Presence of Multipath

- Higher chipping rates don’t necessary improve performance in presence of multipath unless associated with increase in transmitted (and received) bandwidth
  - Narrower spacingcorrelator designs could be implemented (in terms of seconds, not chips)
  - For example, first implementation was for the lower chipping rate C/A code
    - It was transmitted in about 30 MHz and receivers also had a wider bandwidth
- P-code or L5 code tracking will be similar with ½ chip spacing because of the transmitted bandwidth constraint

New Features that Improve Receiver Performance in Presence of Interference

- Here, code tracking performance will improve with a higher chipping rate in the presence of noise and interference
  - Multipath mitigation performance is based upon chip edge sharpness
  - Noise mitigation performance is based mor on chip width (more averaging)

New Signal Tracking Performance Summary

- In the end, the new signals do not improve performance much in the presence of multipath
- In the end, the new signals do improve performance in the presence of noise and interference
- It is not just the new signal features, but how the receiver takes advantage of the new signal features
  - For example, wider bandwidth is good if that bandwidth doesn't capture more interference

GLONASS

- In the current issue of Inside GNSS, an article mentions the testing of a new GLONASS CDMA Signal at 1202 MHz
  - In Aviation, that doesn't help much
  - Russians need to move their frequencies to GPS/Galileo/Beidou frequency bands to be interoperable – it is an antenna issue