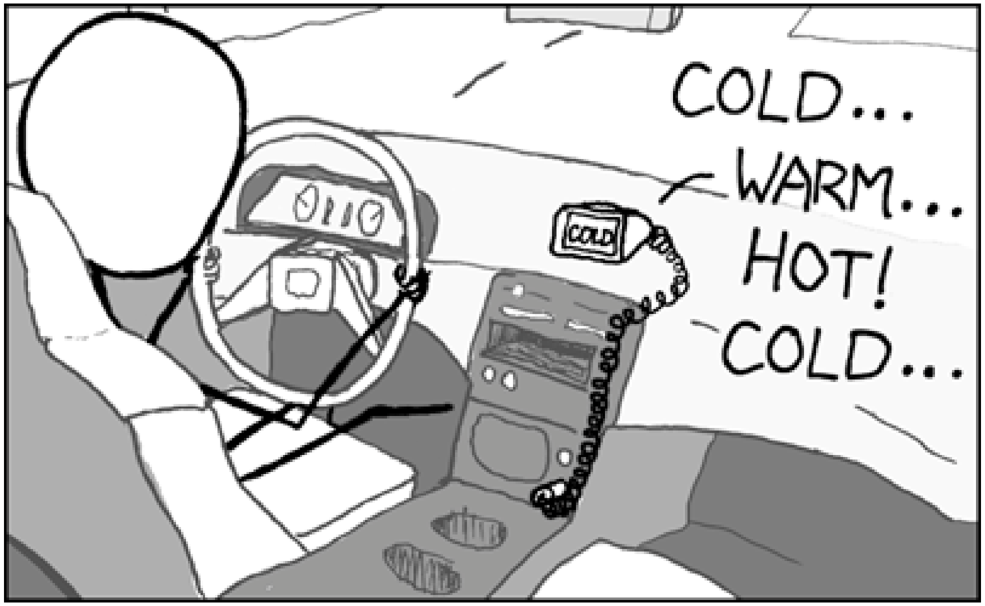
Hemisphere GPS Inputs to Improve GNSS Interoperability

About Hemisphere GNSS and UniStrong

- January 31, 2012: Beijing UniStrong acquires the Precision Products and CORE GNSS receiver development business from Hemisphere GPS.
- *Founded in 1994, UniStrong has maintained a leading position for 18 consecutive years in Chinese GNSS market.*
- *2007 CSI changes name to Hemisphere GPS*
- *1999 CSI Acquires Satloc*
- *1990 CSI Founded*

Low Precision Navigation Aids



Predecessor to the SATLOC light-bar

NASCAR Navigation

turn left, turn left, turn left, ...

Medium and High Precision GNSS

Applications: Marine, GIS, Survey, Construction

- *GPS and DGPS receivers* - single and dual frequency, GLONASS, BeiDou, Galileo
- Smart Antennas: DGPS and antenna - single and dual frequency
- XF-series of Smart Antennas for handheld mapping
- GPS Compasses – Vector family - two antennas for positioning and heading
- OEM receiver boards – single (Crescent) and dual (Eclipse) frequency
- GPS and DGPS Antennas
- Excavator and dozer products

Heading Applications

Professional

Segments:

- Hydrographic Survey
- Bathymetric Survey
    - Heave
    - Pitch
    - Roll
- Dredging
- Marine Construction

Commercial

Segments:

- Commercial Navigation (w/Autopilot)
- IMO Certified
    - Positioning
    - Heading
- Custom applications
    - -Fishing Vessels

General Nav

Segments:

- Yachting
- Small commercial
- NMEA2000 Certified
- Accessory Integration
    - Echo Sounders
    - Fish Finder
    - -TV Ant Pointing

OEM

Applications:

- Marine Private label
- Machine control
- Robotics
- Antenna pointing
    - Coms dishes
    - Cellular
    - Sniper detection

New Signals and Future Signals

- The Past
  - GSP L1CA, L1P(Y), L2P(Y)
- The Future is Now, but maybe we can influence the next future?
  - GSP L1CA, L1C, L1P(Y), L2P(Y), L2C, L5
  - BeiDou B1, B2, B3
  - Galileo E1, E5, E6
  - Glonass FDMA G1, G2, CDMA
  - QZSS L1CA, L1C, L1P(Y), L2P(Y), L2C, L5, L1-SAIF, LEX

New Signals and Future Signals (cont)

- Timely releases of ICDs from the signal providers would certainly help level the playing field.
- Elimination of signal usage royalty fees
- Will there be a BeiDou Phase III?
  - How long will we have to maintain backwards compatibility with Phase II?
- When will we have Glonass CDMA ICD?

Increase in Noise Floor

- Do you see a threat to GNSS receivers due to many more GNSS signals centered at 1575.42 MHz?
- We are not concerned about a little additional noise, especially given the large number of new signals that will soon be available allowing us to drop weak L1CA signals

Increase in Noise Floor

- Whether you see a threat or not, do you prefer all new CDMA signals at "L1" to be centered at 1575.42 MHz or have some of them elsewhere, e.g., at 1602 MHz?
- There are pros and cons to having a common L1 (or LX) frequency. The pros are simplicity, lower cost and lower power utilization of the receiver. The con is the loss of jamming immunity gained by multiple frequencies.
- We believe the pros far outweigh the cons.
- Increased noise floor obviously increases code and carrier jitter, but with more signals you can de-weight the lower C/N0 signals.

Increase in Noise Floor

- Given that most GNSS providers plan to transmit a “modernized” signal at 1575.42 MHz, what is your long term perspective on whether you will continue to use C/A? Why and How?
- We will continue to use L1CA until L1C is fully operational. Due to backwards compatibility (differential reference stations, inter channel biases) we will likely support L1CA for 10 years after L1C FOC

CDMA and FDMA

- Once there are a large number of good CDMA signals, will there be continuing commercial interest in FDMA signals?
- Only for the Russian market and for Heading products. (Maybe abandon when Russia has fully implemented CDMA)
- The biases associated with FDMA add unnecessary complications to firmware, and partially reduce the usefulness of the FDMA signals. FDMA induced biases change across manufacturers and even across product lines.
  - One manufacturer (Septentrio) wrote a nice paper about this.
- With enough CDMA signals, there will be little incentive to use FDMA for positioning, but they will remain viable for heading.

Compatibility

- Do you prefer signals in different “L1” frequency bands for interference mitigation rather than at one center frequency for interoperability?
- A single band enables simplicity and cost reduction in the receiver.
- Commonality of carrier frequencies makes it easier to develop lower power solutions.
- Commonality of carrier frequencies makes it easier to implement a filtering scheme that allows a GNSS receiver to be a friendly player in the global spectrum market.
- We believe this outweighs the benefits that multiple bands offer towards interference mitigation.

What to do About Misbehaving Signals

- **If a satellite's signals do not meet quality standards …?**
- They should be set unhealthy. (Ideally, multiple unhealthy bits would distinguish between issues that cause a constant offset that can be corrected with differential, or a non-correctable problem.)
- Differential systems can still use unhealthy satellites if they do their own integrity monitoring.

What to do About Misbehaving Signals

- **To assure only “good” signals, should GNSS providers agree on minimum international signal quality standards and agree to provide only signals meeting the standard?**
- Yes, that would be nice.

E5a and E5b

- Given that L5/E5a will be transmitted by most GNSS providers, do you intend to use the E5b signal?
- Yes, the E5b frequency lines up with Beidou B2, so a receiver can gain access to both signals with one RF path. This makes the use of E5b with B2 compelling.
- We will use the combined E5a and E5b spectrum to obtain higher accuracy code phase. This will allow quicker receiver convergence, better accuracy, and perhaps interesting combinations of code and carrier phase.
- A nice inexpensive receiver would be L1/L5, E1/E5a.

Frequency Steps

- For your applications, are small satellite “frequency steps” (Δf) a problem?
- Yes, this is a huge problem, especially for precise positioning. Allowed differential latency is reduced in RTK applications and problems arise in all applications that assume stable satellite clocks (which virtually all do).
- The heart of GNSS is the clocks, these need to be as good as possible.
- We are much more concerned about short term effects (on the order of seconds to minutes) than longer term stability of the GNSS clocks.

Frequency Steps

- If so, what interval between “frequency steps” and what Δf magnitude would be excessive?
- Anything that causes more than a centimeter of clock change in less than 30 seconds.
  - 30 seconds is our preferred maximum for age of differential.
- We know this may not be possible, but we certainly are in favor of sacrificing some of the long term stability to gain better short term stability.

Interoperable Use

- Assuming signal quality is acceptable from every provider, would you limit the number signals used by provider or by other criteria? What criteria?
- We are more likely to use the signals that share common spectra with other GNSS systems.
- One criteria will be receiver complexity (number of RF channels required).
- High-end receivers will likely use more signals. We have no plans to limit signal use, but cost will go up as more frequency bands are covered.
- At some point, it is better to add satellites than signals.
- May start limiting based on SNR, elevation, rising or setting, code noise.

Interoperable Use

- Is having more signals inherently better or do you think there should be a limit?
- More satellites are more important than more signals. Three bands seems like an adequate number (common to all GNSS). There should be data and data-less signals on each band, with the data-less signals having longer spreading codes for weak signal tracking. Simplicity is good. Why complex BOC? (better multi-path mitigation)
- Probably asymptotically reach a point of diminishing returns.
- Will the marketplace "force" you to make use of every available signal?
- Yes, that is one of the ways we are measured

Interoperable Use

- For best interoperability, how important is a common center frequency? How important is a common signal spectrum?
- A common center frequency is very important since is allows simpler and lower power receiver design.
- Common spectrum is only marginally important (a common spectrum allows the receiver's bandwidth to be optimized).
- A common modulation format would reduce hardware complexity. Of course the BOC signals require the most hardware, so if they were all BOC then commonality would increase hardware complexity.

Another Common Open Service Signal

- Will you provide “tri-lane” capability in the future?
- Yes
- If so, do you prefer a common middle frequency or the combined use of L2 (1227.6), B3 (1268.52), and E6 (1278.75) if B3 and E6 open access is available E6 (1278.75) if B3 and E6 open access is available
- We would like to see a common middle frequency that minimizes the noise in the iono-free combination. Of the above signals, E6 appears to be closest to the ideal frequency, so it would be nice to see E6 become open and other GNSS systems plan a signal in this band. B3 is 10MHz offset from E6 which is not very convenient.

Another Common Open Service Signal

- Would you prefer a common open signal in S Band? In C Band? Why?
- C Band is interesting
  - Cons:
    - Higher frequency means increased path loss given by $20*\log10(f_L/f_C)$. So for 5GHz as has been proposed we have about 10dB more path loss. Maybe you offset this with higher gain steerable antennas and aiding from L1?
  - Pros:
    - First order iono-free combination code range has less error amplification.

Precision Code Measurements

- Does a wider satellite transmitter bandwidth help with multipath mitigation?
- What minimum transmitter bandwidth would you recommend for future GNSS signals in order to achieve optimum code precision measurements?
- Wide bandwidth is crucial to code accuracy, especially when multipath is present. The edges of the signal are the most important part for tracking accuracy.
- We would like to see a minimum of 20 MHz Bandwidth.
- Wide BW at transmitter leaves it up to receiver to decide its own BW and hence correlation lags.
- Of course the sharpness of an edge is related to ratio of signal BW to transmitter BW not just transmitter BW itself.

Added GNSS or SBAS Messages

- Would you recommend GNSS or SBAS services provide interoperability parameters
  - System clock offsets, Geodesy offsets, ARAIM parameters, Others?
- Clock offsets are not too important since we must estimate these regardless. Geodesy offsets are important. GNSS systems should strive for a common geodetic frame (ITRF) to simplify the logic when processing multiple GNSS systems. (without the need for differential corrections or offset parameters).
- Putting parameters in GNSS or SBAS messages is not necessary if the offsets remain constant over long periods of time.

Added GNSS or SBAS Messages

- Should they be provided by other means so as not to compromise TTFF or other navigation capabilities.
- No opinion here. It would be fine to obtain these from the internet.

Signal Coherence

- For your applications and for each signal, what amount of drift between code and carrier over what time frame would be excessive?.
- No worse than what we have today with GPS. We know this works.
- We are trying to get cm level precision.

Signal Coherence

- For your applications and for two or more signals in different frequency bands, e.g., L1 and L5 (when scaled properly), what amount of relative drift in code and carrier between the signals would be excessive?
- No worse than what we have today with GPS. We know this works.
- Already, we must deal with code-carrier drift:
  - Ionosphere code-carrier divergence
  - Carrier Phase wind up
- Carrier vs carrier does not seem to work currently for satellites with L5. They seem to have systematic drifts of up to 1 wavelength.

Hemisphere GPS

Spectrum Protection

- Should the international community strive to protect all GNSS signal bands from terrestrial signal interference?
  - Yes, we are all global players, we need to protect each other's spectrum. This is particularly important to high-precision products where wide bandwidth front-ends are required. That being said, we also think that some sort of receiver standards might be useful in helping improve spectrum allocation.

System Geodesy

- Do the current differences (~10 cm) in Geodesy pose a problem for your users? Why or why not?
- If geodesy differences are a problem, what is the preferred method of compensation:
  - Published values (e.g., on websites)
  - Satellite message?
- The differences become a problem as you drive autonomous accuracy down. It is better to have all GNSS systems move as close as possible to a common Geodetic frame.
- If the offsets remain fairly constant over time, then placing these on the web is fine.

System Time

- Do you want each system to cross reference the other's time (e.g., with a GGTO type of message) or compare itself to a common international GNSS ensemble time? To what precision?
- A simple message with a bias to a common reference time would be nice, particularly to enable simpler low-precision applications. The broadcast bias only needs to be accurate to the decimeter level. (decimeter is OK for low precision) So for low precision GGTO is preferred because it improves solution availability.
- High accuracy applications must estimate time-differences regardless, and our receivers do estimate these time differences. Of course this uses up one satellite in the solution
- It would be nice to have the GGTO and use it in a low SV visibility environment and solve for it if you do have the SVs.