GPS Receiver Specification

• Garmin works closely with third party GPS chipset suppliers
  – Weekly or bi-weekly phone calls to discuss technical issues and drive supplier roadmap

• Specifications primarily market driven: what are the best price and performance possible to enable a wide variety of consumer products

• Other characteristics that must be considered in chipset specification:
  – Physical size of the chipset
  – Power consumption
  – Sensitivity
  – Interference / jammer rejection
  – Integration with complementary wireless technology (Bluetooth, WiFi, FM)
  – Multi-constellation
  – Integration with application processors
• Garmin works closely with component vendors to specify Low Noise Amplifiers (LNAs) and filters that meet the needs of each market segment.

• Specifications primarily driven by market segment: what performance is required to enable best-in-class consumer and aviation products

• Important characteristics of front end components:
  – Physical size of LNA and filters
  – Power consumption
  – Gain / noise figure
  – Linearity / compression
  – Adequate bandwidth for multi-constellation support while also rejecting interference within the known spectrum environment (e.g., cellular bands, Bluetooth/WiFi)
  – Phase / group delay across passband
GPS Receiver Specification

• The rate of innovation is very rapid in the consumer space

• A supplier typically delivers new chipsets every 12 to 18 months

• Some factors driving innovation:
  – CMOS process improvements: 90 nm -> 65 nm -> 45 nm. This reduces power and cost. Garmin is constantly moving to parts with lower CMOS feature size.
  – Integration of RF into CMOS -> full CMOS radios rather than bi-CMOS. This reduces cost.
  – Multi-GNSS: GPS + Glonass + Galileo + Compass + QZSS + ?
  – Modernized GPS Signals → L1C
  – Integration of GPS with other wireless technologies
  – Integration of GPS with application processors to create special purpose System on Chip (SoC) parts
  – Receiver performance improvements (better sensitivity, more correlators possible w/ shrinking die sizes, etc.)
GPS Has Unique Characteristics

- GPS is a radio navigation system and differs from radio communications systems
- The primary measurement in GPS is the timing of bit transitions in the navigation signal
  - Precise positioning requires sub-ns measurements of bit edge
  - Accurate measurement of bit edges requires wide receiver bandwidth
  - Effective multipath rejection also requires wideband signals
- Spread spectrum GPS signals are below the thermal noise floor when received
  - Cumulative effects of in-band interference can increase noise floor and degrade performance
The Product is Everything

- Success or failure in the consumer marketplace is driven primarily by customer acceptance of the product.
- Garmin’s success is evidenced by the fact that many customers, particularly in the aviation GPS sector, continue to use the products for a decade or more.
- Products that don’t work well simply don’t sell.
- Examples of poor performance of GPS:
  - Poor first fix performance
  - Poor accuracy
  - Poor urban canyon performance
  - Poor dynamic performance
  - Poor battery life
- Poor performance in any of these areas is addressed directly with the chipset supplier.
- Selection of chipsets in future designs is contingent upon satisfactory performance for the customer.
Certified Aviation Perspective

- FAA standards are the primary source of performance requirements for certified aviation products.
- Given safety concerns, detailed design requirements are appropriate.
- FAA standards for GPS receivers include detailed design requirements for:
  - Receiver sensitivity and dynamic range
  - Ranging and positioning accuracy
  - Differential group delay
  - Receiver bandwidth
  - Interference rejection
  - Correlator spacing (extremely design specific)
  - Environmental conditions (temperature, vibration, lightning, RF susceptibility)
  - Compatibility with other aircraft systems
- Garmin also designs/manufactures other aviation radio systems
  - VHF communications & navigation radios, satellite data link, transponders, weather radar
  - Mix of licensed and unlicensed products
  - There are distinct FAA design standards for each of these products
FAA GPS Interference Rejection Requirements

All new FAA certified GPS receivers are required to tolerate interference at these levels.

- Equipment certified to this standard first introduced in 2002
Certification Costs

• **Compliance with these standards requires time and expense**
  – Extensive documentation required throughout product development cycle to show compliance
  – Rigorous performance testing over a wide range of environmental conditions

• **The need for detailed design and verification data complicates the use of third party chipsets commonly used in the consumer space.**

• **Cost of non-compliance is high**
  – Aviation products have safety-of-life implications
  – Cannot ship aviation products that do not meet FAA Technical Standard Orders (TSO)
  – Safety issues require immediate customer notification and in some cases may result in grounded aircraft.
  – Grounded aircraft = no revenue and other significant impacts to business

• **Changes to existing products are similarly expensive**
  – Modifications require recertification

• **Expensive certification process translates into an expectation of a long service life for aviation products – more than 10 years.**
Standards vs. Innovation

- **Pace of innovation in certified aviation is slower than in the consumer marketplace.**

- **Aviation standards are developed by RTCA in consultation with government, industry, and users**

- **Standards updates** – 4 years on average

- **Equipment introductions** – 2-5 years within a product line

- **Typically 10-15 years to develop standards, design and certify products, and equip**

- **Compare to consumer – new products 12-18 months**