Garmin Offers a Myriad of Devices in Five Markets

The applications span many design constraints, such as low power, small size, and form factor. Each has unique requirements to serve the required function.

AUTOMOTIVE

- Personal navigation devices for vehicles, including motorcycles, trucks and RVs
- OEM hardware, software and infotainment solutions
- Dashboard cameras, windshield navigation projection
- Mobile navigation applications

OUTDOOR

- Handheld and wrist-worn devices for:
  - Hunting
  - Hiking, Camping
  - Dog training
  - Geocaching
  - Golfing
- HD Action Camera
- Two-way radios
- BirdsEye satellite imagery

FITNESS

- Wrist-worn, mounted and pedal devices for wellness, running, cycling, swimming and multi-sport
- Heart rate monitoring, foot pods, speed/cadence sensors
- Track, store and share fitness activities on Garmin Connect

MARINE

- OEM, handheld and wrist-worn chartplotters, fishfinders and sounders for boating, sailing and fishing
- Charts, CHIRP sonar technology (high definition), satellite weather
- Radar, autopilot, cameras, sailing instruments, transducers

AVIATION

- Installed, OEM and portable flight decks and avionics for airplanes, helicopters and light aircraft
- Satellite weather, traffic and radio and terrain awareness
- Nav/Comm, transponders, indicators, audio panels, altimeters

Navigation vs. Communication Systems

- GPS is a 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 edges
  - 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 (the level of noise occurring naturally and apart from manmade sources) when received.
  - The cumulative effects of in-band interference can increase the noise floor and degrade performance.
- There are many differences between low-power satellite systems and high-power terrestrial broadband systems.
  - Space-to-Earth Satellite systems are designed to accommodate low-power signals received from distant satellites in space.
  - Mobile broadband networks, on the other hand, are designed to utilize high-power terrestrial signals broadcast from tens of thousands of towers around the nation.
  - If placed in adjacent bands, the high-power terrestrial signals from mobile broadband networks would overwhelm low power satellite signals. This overloading would impair the functioning of these systems.

GPS Receiver Specification

- Low Noise Amplifiers (LNAs) 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
  - Receiver front-end requirements vary by market segment (*e.g.*, high precision devices have wider bandwidth than consumer devices.)
- Recent empirical work has shown that GPS receivers have more robust interference rejection capabilities than other mass-market terrestrial receivers. *See* http://www.gps.gov/governance/advisory/meetings/2013-05/powell.pdf
- Receiver standards would stifle innovation and slow technological advancement.

Modernized GNSS

- The United States will begin to deploy an updated and modernized L1C code with Block III satellite launches beginning in 2016.
  - L1C, along with Galileo, GLONASS and other modern GNSS systems, requires wider receiver bandwidth than traditional L1 C/A code receivers.
  - This is due to the fact that the L1C signal will be transmitted in a wider bandwidth.
  - The longer codes used in this modern signal design provide increased performance to improve GPS reception in cities and other challenging environments.
- New GPS satellites also support new civilian signals on other frequencies
  - L2C (1227.60 MHz) and L5 (1176.45 MHz)
  - Dual frequency operations can improve accuracy and provide some redundancy against unintentional interference which will benefit public safety users needing high availability of service.
  - Galileo, GLONASS and other GNSS systems will also provide multiple civil signals
- Multi-constellation receivers will provide benefits to user
  - Increased number of visible satellites improves availability in challenging environments
  - Additional redundancy can protect against system failures, improving overall integrity with corresponding benefits to safety.
- The consumer space is moving towards modernized signals (L1C) and multi-constellation/multi-frequency to drive even better performance and new applications

Certified Aviation Perspective

- GPS has improved aviation safety
  - TAWS is a critical safety feature that relies on GPS and has dramatically reduced controlled flight into terrain “CFIT” accidents
  - ADS-B and NextGen are replacing conventional radar-based surveillance with more accurate GPS-based positioning. All aircraft in controlled airspace will be required to support ADS-B by 2020.
  - GPS position combined with real-time weather data allows pilots to avoid hazardous weather conditions
- FAA imposes standards for aviation GPS to ensure performance and safety
  - Requirements for sensitivity, dynamic range, accuracy, and interference rejection across a wide range of environmental conditions.
  - Detailed requirements for receiver bandwidth, correlator spacing, differential group delay, positioning and integrity algorithms constrain design space.
  - Performance standards are tailored for aviation use and not universally applicable.
- Compliance with these requirements is costly and time consuming
  - Need for detailed design and verification data complicates use of 3rd party chipsets.
  - Expensive certification process = expectation of service life of 10-20 years or more.
- FAA standards will evolve to incorporate modernized GNSS signals
  - New signals will increase availability and integrity of GPS/GNSS service for safety-critical airborne receivers.