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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

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GPS Receiver Specification

- **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

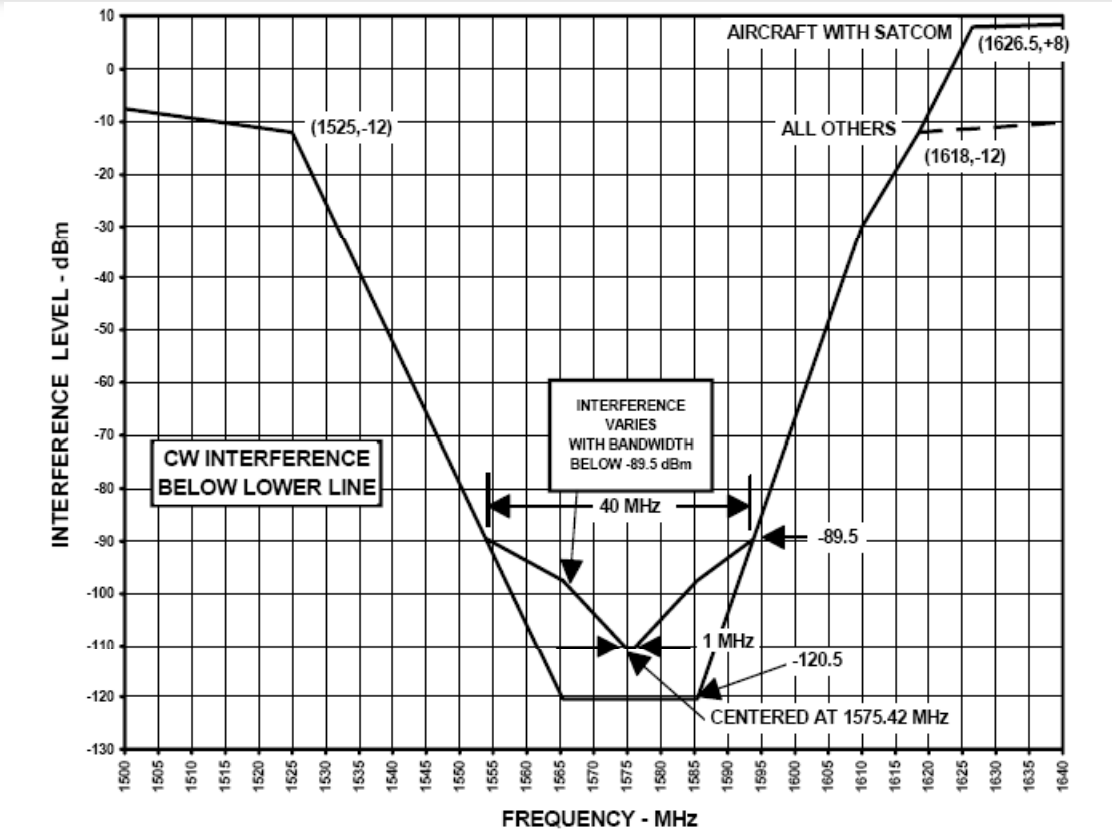

FIGURE C-1 INTERFERENCE LEVELS AT THE ANTENNA PORT

- All new FAA certified GPS receivers are required to tolerate interference at these levels.
- Standard published in 1996 in RTCA/DO-229, adopted internationally in 2001
- Equipment certified to this standard first introduced in 2002

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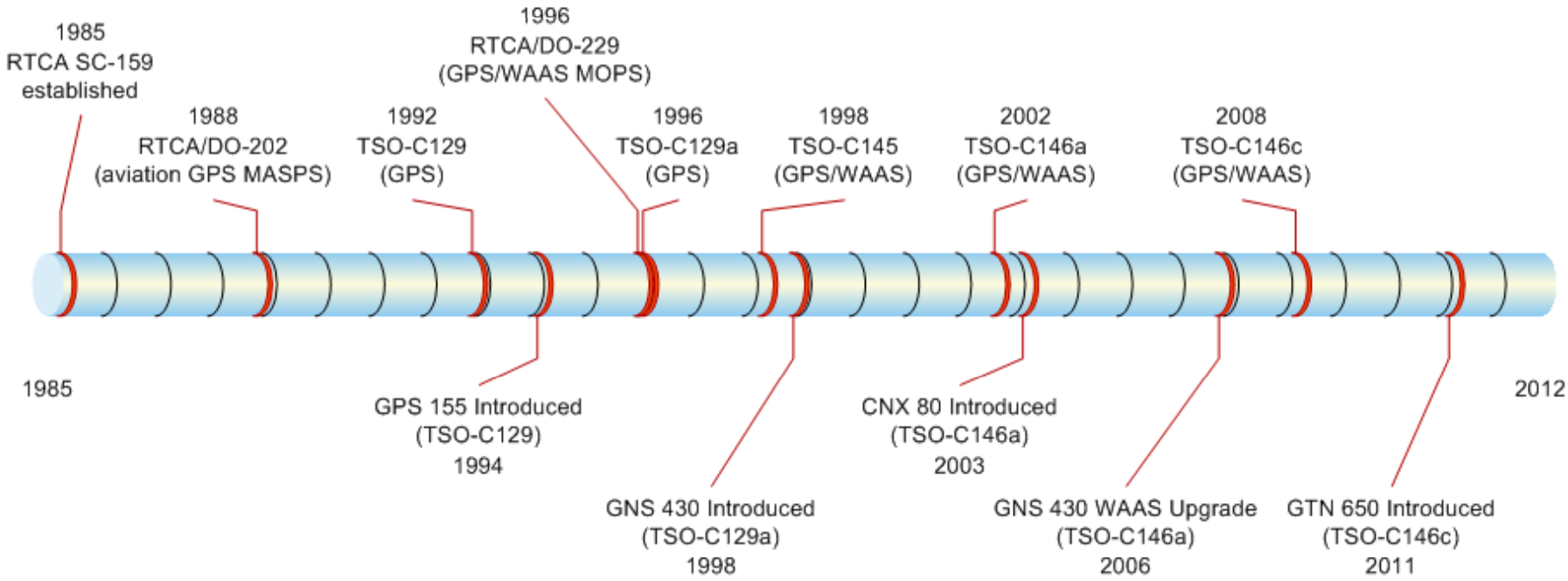
Certification Costs

- **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**

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