



CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

GNSS Compatibility and Interoperability – Civil Transportation Perspectives

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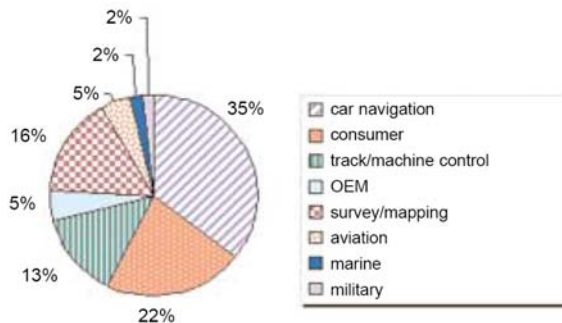
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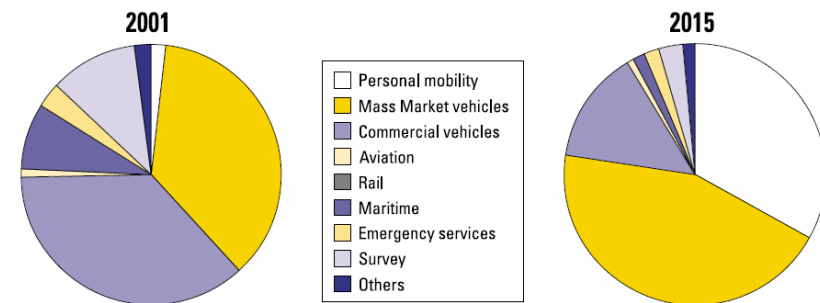


Civil Transportation

- **Worldwide fleet includes (not all GNSS-equipped):**
 - Over 20,000 passenger aircraft
 - Over 30,000 merchant ships of 1,000+ gross tons
 - Over 60,000 diesel locomotives
 - Over 300,000 general aviation aircraft
 - Over 600,000,000 land motor vehicles
- **Civil transportation represents a large segment of the satellite navigation market**



Source: U.S. Department of Commerce, *Trends in Space Commerce*, 2001.



Source: GJU, EC, and ESA, *Business in Satellite Navigation*, 2003.



Radio Frequency Compatibility (RFC)

- **Many transportation users rely on GNSS today**
- **The majority of these users employ receivers that either:**
 - **Process only GPS L1 C/A-code signals**
 - **Process GPS and satellite-based augmentation system (SBAS) L1 C/A-code signals**
- **Equipage for other satellite navigation systems anticipated to grow rapidly after constellations are fully populated**

Protection of existing user equipment against radio frequency interference for many years is a priority for transportation users.



User Equipment Standards- Aviation

- **International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs)**
 - **Current SARPs address only two core constellations and augmentations**
 - **GPS**
 - **GLONASS**
 - **ICAO Navigation Systems Panel (NSP) is responsible for updating GNSS SARPs**
 - **Updates to material on GPS, GLONASS and augmentations; new material on GALILEO**
- **Receiver standards developed by RTCA, Inc., and EUROCAE**



User Equipment Standards - Maritime

- **International Maritime Organization (IMO) Performance Standards**
- **Receiver and differential GNSS standards developed by:**
 - **International Electrotechnical Commission (IEC)**
 - **Radio Technical Commission for Maritime Services (RTCM)**



User Equipment Standards – Land Vehicles and Rail

- **No prevalent user equipment standards pertinent to RFC**
 - (Popular voluntary industry standards, e.g., National Marine Electronics Association [NMEA], primarily address receiver data input/output)



Observations on Radio Frequency Compatibility

- **Wide variety of GNSS user equipment in civil transportation**
- **Tolerance to interference, e.g., from other GNSS signals, is:**
 - **Well-understood for some applications, e.g., air navigation in instrument conditions**
 - **Not as well understood for other applications**
- **Recommended that classes of user equipment be considered in bi-/multi-lateral RFC discussions**
 - **Such as within International Telecommunication Union development of recommendations to protect GNSS**
- **Service Providers should establish compatible technical system characteristics to promote timely development of user equipment standards and recommended practices by ICAO, IMO, RTCA, etc**

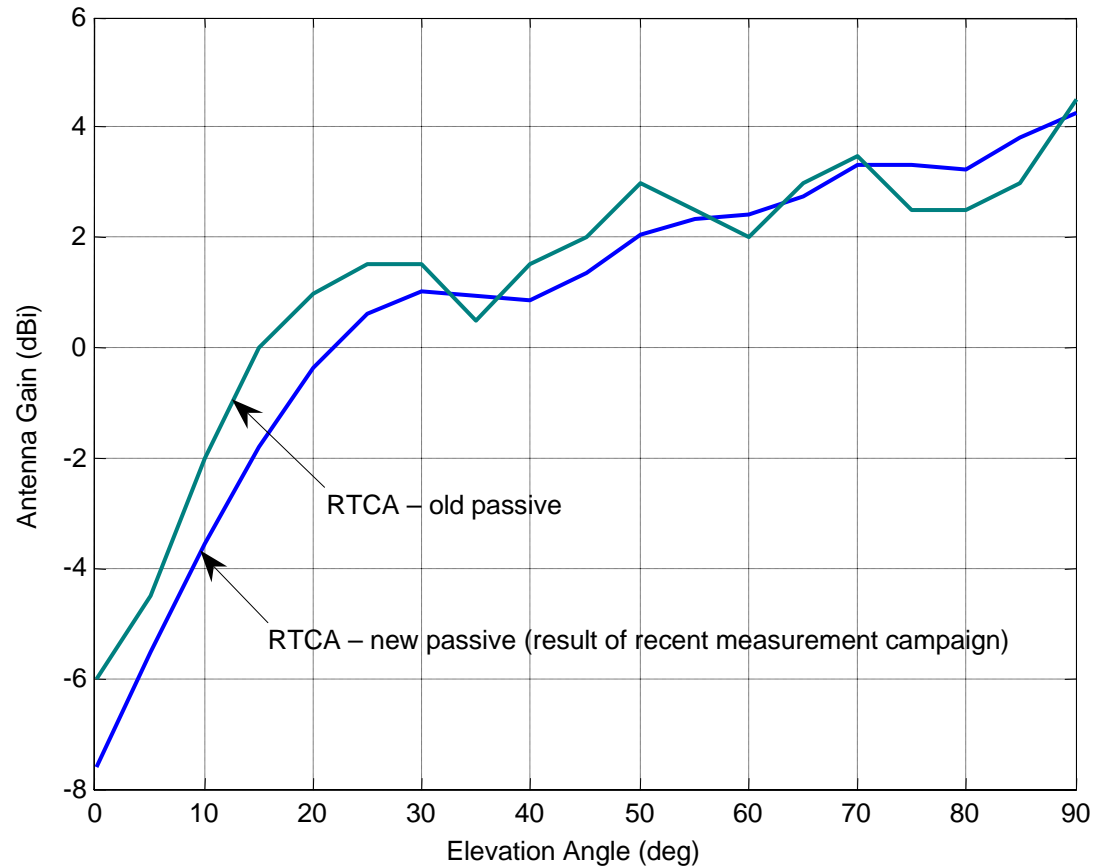


RFC Assessment Parameters that Vary Among Transportation Applications

- **Desired signals**
- **Mask angle**
- **Signal-to-noise thresholds**
- **User antenna gain patterns**
- **Receiver implementation and excess propagation losses**
 - **For desired and towards undesired signals**
- **Levels/types of external interference (e.g., consider L5/E5 band at 40,000 feet vs. mean sea level)**



Aviation User Antenna Gain Patterns



Even within aviation community with mature standards, understanding of user equipment characteristics is evolving.



Interoperability

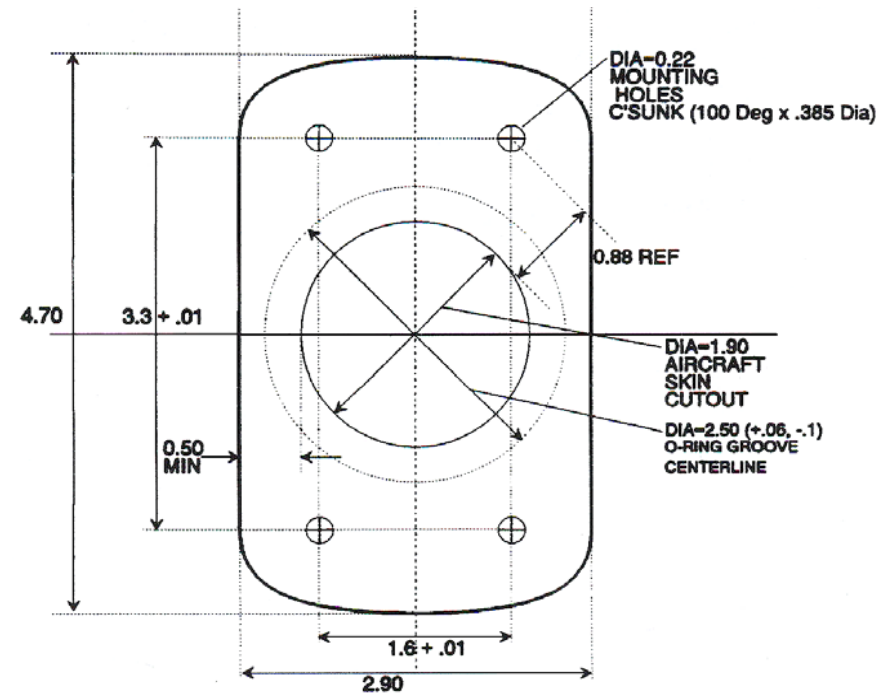
- **Most transportation applications would benefit from additional signals**
 - However many users will *not* immediately employ new GNSS signals/systems
 - Some may *never* be used for some applications
 - Incremental benefit/cost ratio must be sufficient to warrant retrofit or initial investment
 - Particularly in some transportation applications where installation/certification costs are very high
 - To simplify user equipment, it would be desirable for GNSS Service Providers to implement signals with:
 - Common carrier frequencies (e.g., L1 and L5/E5a)
 - Common/interoperable modulations
 - Common pseudorandom noise (PRN) code families
 - Common data elements
- **Common/consistent geodetic and time systems are also important**
 - E.g., ICAO's adoption of WGS-84





User Antennas – A Current Aviation GNSS Interoperability Topic

- Utilization of existing form factor and performance standards for aviation GNSS antennas with emergence of new signals/frequencies
 - L1-only to L1/L5 or L1/E5





Summary

- **Civil transportation is, and is expected to remain, a very large GNSS market segment**
- **As with most GNSS users, RFC is of tremendous importance to protect significant investments and preserve safety**
 - **Recognizing the diversity of user equipment, it is recommended that representative user classes be identified**
 - **Service Providers should establish compatible technical system characteristics to promote timely development of user equipment standards**
- **Transportation users look forward to additional interoperable GNSS components/signals**
 - **Common signal characteristics and consistent coordinate/time systems will encourage use**