GPS Innovation Alliance

Proposed European (CEPT) Regulation Would Allow Harmful Interferers Into An ARNS & RNSS Radiofrequency Band Within Europe

A Presentation to the Position, Navigation, and Timing Advisory Board

Kurt R. Zimmerman, PhD and F. Michael Swiek
On Behalf of the GPS Innovation Alliance

June 3, 2014

Overview

- Proposed ECC regulation, based on European working group (CEPT SES SCN) studies and reports, would:
  - Authorize these precedents:
    - Unallocated ground radio transmitters in an ARNS/RNSS frequency band
    - Admitted harmful interferers and potential spoofers
    - GNSS availability exclusion zones and “no fly” zones
    - Admitted contravention of the international standard for protecting GNSS receiver performance
    - Unequal regulatory treatment of comm and nav
    - Apparent misstatement of GPS and Galileo Provider availability policy
- Contravene an international treaty and agreements
- Apparently disregard technical objections raised by the United Kingdom, ECC participant:
  - And GPS Industry technical review comments of a draft ECC Report submitted during a public consultation
- Admittedly fail to consider deployed, non-interfering pseudolite solutions transmitting outside of the ARNS/RNSS Bands as beyond the study scope
- Adopt a broader pseudolite definition acknowledging interference and recommend authorizing incompatible ground transmitters in GNSS bands to CEPT Administrations

An International Treaty Allocates ARNS And RNSS, As Co-Primary, At 1559-1610 MHz; Any Other Use Must Be On A Strictly Non-Harmful Interference Basis

International Telecommunication Union (ITU) Table of Frequency Allocations of the Radio Regulations allocates this band (emphasis added below):

- On a co-primary basis to:
  - Aeronautical Radionavigation Service (ARNS), a specialized terrestrial service restricted to safety-of-life use; and
  - Radionavigation Satellite Service (RNSS) for space-to-Earth use and space-to-space use.
- **Any other use of this spectrum is prohibited under the express terms of the ITU Radio Regulations from causing interference to, or claiming interference protection from, users of either of the co-primary allocations**
  - Ground transmitters (pseudolites) do not have an allocation in this band
  - Incompatible pseudolite operations – i.e., that cause any harmful interference to present or planned ARNS or RNSS uses – would be a violation of the ITU treaty
- Any Administration may make an ARNS safety-of-life assignment in this allocation at any time.
- *ITU Administrations have deployed RNSS operations, with an ITU safety-of-life designation, in the 1559-1610 MHz band for 30 years* (emphasis added).
- As authorized co-primary users of the 1559-1610 MHz band, all RNSS applications, safety-of-life or otherwise, must be protected from harmful interference.

The ITU International Radio Regulations Definition of Harmful Interference

"Interference which **endangers the functioning of a radionavigation service or of other safety services** or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with the Radio Regulations."

- *See* No. 1.169 of the ITU Radio Regulations (emphasis added).

GPS Innovation Alliance

The ITU International Radio Regulations Obligation for Stations Operating Without Allocations

"Administrations of the Member States **shall not assign** to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, **except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by**, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

- *See* No. 4.4 of the ITU Radio Regulations (emphasis added).

CEPT Working Group SES SCN

CEPT: Conference of European Postal & **Telecommunications Administrations** (48 Member Administrations), includes:

1. ECC: Electronic Communications Committee
   - Develops regulations for effective use of spectrum Europe-wide
   - WG FM: Working Group on Frequency Management (FM)
     - SES SCN: Satellite Earth Stations Satellite Communication and Navigation (formerly FM44), apparently includes:
       - European radiocommunications regulators and European private sector members
       - Primarily communications subject matter experts
2. ETSI: European Telecommunications Standards Institute
   - Develops standards for radiocommunications systems and equipment

Proposed ECC Regulation

Based on the following compatibility, scoping, and modelling study reports:

1. *ECC Report 128*, **Compatibility Studies Between Pseudolites and Services in the Frequency Bands 1164-1215; 1215-1300; and 1559-1610 MHz;** 01/09
2. *EC Joint Research Centre (JRC), EUR 24798 EN-2011*, **Scoping Study on Pseudolites**; C. O'Driscoll, D. Borio, J. Fortuny
3. *EC JRC*, *EUR 15014-2011,* **Non-Participating GNSS Receivers; Modelling Receiver Losses**; D. Borio; C. O'Driscoll, J. Fortuny
4. *ETSI Work Item Reference: 'DTR/SES-00321'*; GNSS pseudolite **product standard**; *Recent Draft 2013-02-04; Planned Publication 2014-06-11*

Proposed in the following regulatory framework reports and recommendation:

1. *ECC Report 168*, **Regulatory Framework for Indoor GNSS Pseudolites**, Miesbach, 05/11
2. *ECC Recommendation (11)08*, **Framework for Authorization Regime of Indoor Global Navigation Satellite System (GNSS) Pseudolites in the Band 1559-1610 MHz**; 10/11
3. *ECC Report 183*, **Regulatory Framework for Outdoor Pseudolites**; 02/13

An ECC Participant Comments On These ECC Reports

An ECC report (183) was adopted over the objections of the United Kingdom, an ECC participant, which included the following commentary on the ECC reports:

- "**No detailed work and analysis of *real proposed systems and operational concepts*** has occurred on the impact to actual GNSS signal reception, *beyond CEPT radio spectrum management overview studies* on these devices."
- "There is **no evidence from industry on conducted or analyzed details and specifications for real systems.** The interaction of the Galileo programme management office and GPS industry would be an integral part of such analysis."
  - The GPS industry submitted technical review comments to ECC on ECC Report 183 during a public consultation which were largely ignored.
- "The United Kingdom has no real evidence of a market demand for these devices and we do not support further CEPT work on outdoor GNSS pseudolites."
  - ➢ *See* United Kingdom comment. From the Document in Annex 7(Rev1) to FM44(12)051-Approved Minutes and Annex of 24th meeting FM44; 17/01/2013.

Proposed CEPT Regulation Would Allow Pseudolites To Operate In An ARNS & RNSS Frequency Band Within Europe

- A pseudolite is described in one European study as:
  - Ground-based transmitter of GNSS-like signals
  - Solution for navigation in environments where reception of GNSS is challenged
  - "Local Element" considered as part of Galileo System
  - Used by both GPS and Galileo systems to test signals prior to satellite launch
- A GNSS pseudolite definition is cited in this study:
  - ("Klein and Parkinson") characteristics, include: "4. Transmitting a signal which is **designed to prevent interference** with other GPS equipment"
- ***Then the European study rejects this GNSS pseudolite definition:***
  - "This definition is **highly restrictive**"
  - " it is recommended that a **much broader definition** be adopted for this study"

➢ *See* EC Joint Research Center (JRC) Scoping Study.

Proposed ECC Regulation Adopts A Broader Definition Of Pseudolite That Allows Interference To Authorized GNSS Signals

Using the proposed broader pseudolite definition, the European study raises the following "Issues:"

- "Legal: 1559-1610 MHz is reserved for aeronautical use
  - To use pseudolites transmitting in this band may require a change in legislation"
- "Interference with existing GNSS signals*:* **any signals broadcast in the navigation bands will interfere with existing GNSS signals**, the issue is to quantify and minimize this interference."
  - ➢ *See* EC JRC Scoping Study (emphasis added).

ECC Regulatory Recommendations Are Contradictory And Allow Unequal Treatment of ARNS & RNSS Bands Allocated To Safety-of-Life Uses

- Recommendation for the 1164-1215 MHz Band (**ARNS & RNSS**):
  - ECC Working Group FM 44 does not recommend to authorize use of the PLs in this band
    - "ARNS is a safety related service and should be protected from interference;
    - The ARNS receivers are located on board aircraft on all altitudes up to 12,000 meters and the radio propagation is already rather difficult;
    - ***Compatibility between continuously transmitting pseudolites and ARNS would not easily be feasible***, and in particular around airports and other areas for aeronautical operations;
    - ***Compatibility between Pulse transmitting pseudolites and ARNS is not feasible and therefore PL are not feasible for RNSS operations*** in the band 1164-1215 MHz."
  - ➢ *See* ECC Report 183, Regulatory Framework for Outdoor Pseudolites (emphasis added).
- Recommendation for the 1559-1610 MHz Band (**ARNS & RNSS**):
  - ECC Working Group FM 44 **asserts *"there is no ARNS use in this band"*** and recommends:
    - "**GNSS CW and pulsed-PLs should be authorized only in the 1559-1610 MHz band**" (emphasis added).
  - ➢ *See* ECC Report 183, Regulatory Framework for Outdoor Pseudolites (emphasis added).

ECC Regulation Would Establish No-Fly Zones

- Recommendation for the 1559-1610 MHz Band (**ARNS & RNSS**):
  - "It should be considered **to establish no-fly zones on the corresponding aeronautical charts** to ensure that pilots are aware of the potential impact on their navigation systems. This could be of particular relevance if an air ambulance service is required near outdoor pseudolite installations. **Aviation authorities should be informed of these installations and be provided with points of contact to enable an efficient resolution of interference cases."**
  - "If the boundary edges of an installed PL is within 10 km of an international border, national administrations shall inform and co-ordinate any installed PL system with their neighbor (the 10 km distance taken as five times the maximum potential distance outline in this report, 2 km, a factor of 14 dB)."

➢ *See* ECC Report 183, Regulatory Framework for Outdoor Pseudolite (emphasis added).

ECC Regulation Acknowledges In-band Pseudolite Potential To Transmit Misleading Information and Would Proceed Despite The Risk

- While ECC Report 183 does not directly acknowledge the potential for transmission of misleading information from in-band pseudolite networks:
  - It recommends establishing no fly zones for GNSS receivers that are not designed to utilize the pseudolite network (non-participating)
  - However, a participating receiver has increased susceptibility to spoofing or being mislead by erroneous data generated by the pseudolite network
- The JRC Scoping Study does acknowledge the potential for transmission of misleading information from in-band pseudolite networks:
  - "One issue that is rarely raised with pseudolites is that of monitoring:
    - Small errors in pseudolite positions can translated to large positioning errors, so great care must be taken with the installation of pseudolites;
    - **With distributed networks, the potential for spoofing or deliberate relocation of pseudolites is high;**
    - Over time, pseudolites will fail as components degrade; it is essential that some form of monitoring is in place." (emphasis added).

ECC Regulation Would Assign Responsibility To The PL Network Operator For Monitoring And Responding To Harmful Interference

The operator would be responsible for monitoring the potential for transmission of misleading information from the in-band pseudolite networks to authorized GNSS users:

- "Due to the potential threat posed by malfunctioning equipment, it should be the duty of the licence holder to monitor the correct functioning of the equipment and terminate transmission immediately if malfunctions occur (supervisory function)."
- "Similarly, for the case where such monitoring would fail to detect the malfunction, a registration system should be in place such **that a GNSS interference case is detected in the vicinity** of the pseudolite installation."

  ➢ *See* ECC Report 183, Regulatory Framework for Outdoor Pseudolites (emphasis added).

ECC Regulation Acknowledges The International Protection Standard for GNSS Receivers – And Proceeds To Contravene It

- ECC studies acknowledge that the internationally recognized standard for protecting GNSS receiver performance and noise floor is 1 dB from non-RNSS sources (e.g., ITU-R Recommendation M.1903):
  - The proposed ECC regulation would contravene this ITU standard by permitting a 3dB increase in the RNSS noise floor:

    "If a C/N0 loss of 3 dB is locally allowed (inside the defined area of coverage), the minimum distance for an effective transmit power of -50 dBm and the high-precision receiver decreases to less than 40 meters. For example, it was simulated for one system that a duty cycle of 6% could allow the non-participating receiver to be as close as possible without experiencing a loss greater than 3 dB."

    ➢ *See* ECC Report 128, Compatibility Studies Between Pseudolites and Services in the Frequency Bands 1164–1215, 1215–1300, 1559–1610 MHz, at Section 4.6, p.34.
- A GNSS receiver that cooperates with an in-band pseudolite network does not experience an improved mitigation effect:
  - The participating receiver experiences the 3dB increase, as well.

ECC Regulation Would Allow In-Band Pseudolite Networks Indoors, Admittedly Excluding Authorized Indoor GNSS Applications

Introduction of in-band pseudolite network operations admittedly would deny existing indoor GNSS availability:

- Asserted: "Usable RNSS coverage is typically close to 0% indoors"
  - ➢ *See* ECC Report 128 Compatibility Studies Between Pseudolites and Services in the Frequency Bands 1164-1215; 1215-1300; and 1559-1610 MHz; 01/09.
  - – The Federal Communications Commission (FCC) is conducting a rulemaking proceeding proposing measures in its **E911 rules to ensure accurate indoor location information**, and notes technologies that included reliance on GPS (specifically, assisted GPS) were valuable in providing indoor location information.
- "Considering:
  - – that **indoor GNSS pseudolites may have the potential to cause partial or total degradation of the accuracy** of other position location devices, in particular, of non-participating **GNSS receivers***;*
  - – that indoor GNSS pseudolites may have the potential to cause interference to GNSS receivers in airport areas, or in the vicinity of them*."*
  - ➢ *See* ECC Recommendation 11(08), Framework for Authorisation Regime Of Indoor GNSS Pseudolites In The Band 1559-1610 MHz (emphasis added).
- "It is not possible to determine a reasonable separation distance (i.e., much lower than the building dimensions) between the pseudolites and a non-participative GNSS receiver located in the same building. Therefore, **this kind of non-participative GNSS receiver cannot be protected**."
  - ➢ *See* ECC Report 168, Regulatory framework for Indoor GNSS Pseudolites, concludes that. (emphasis added).

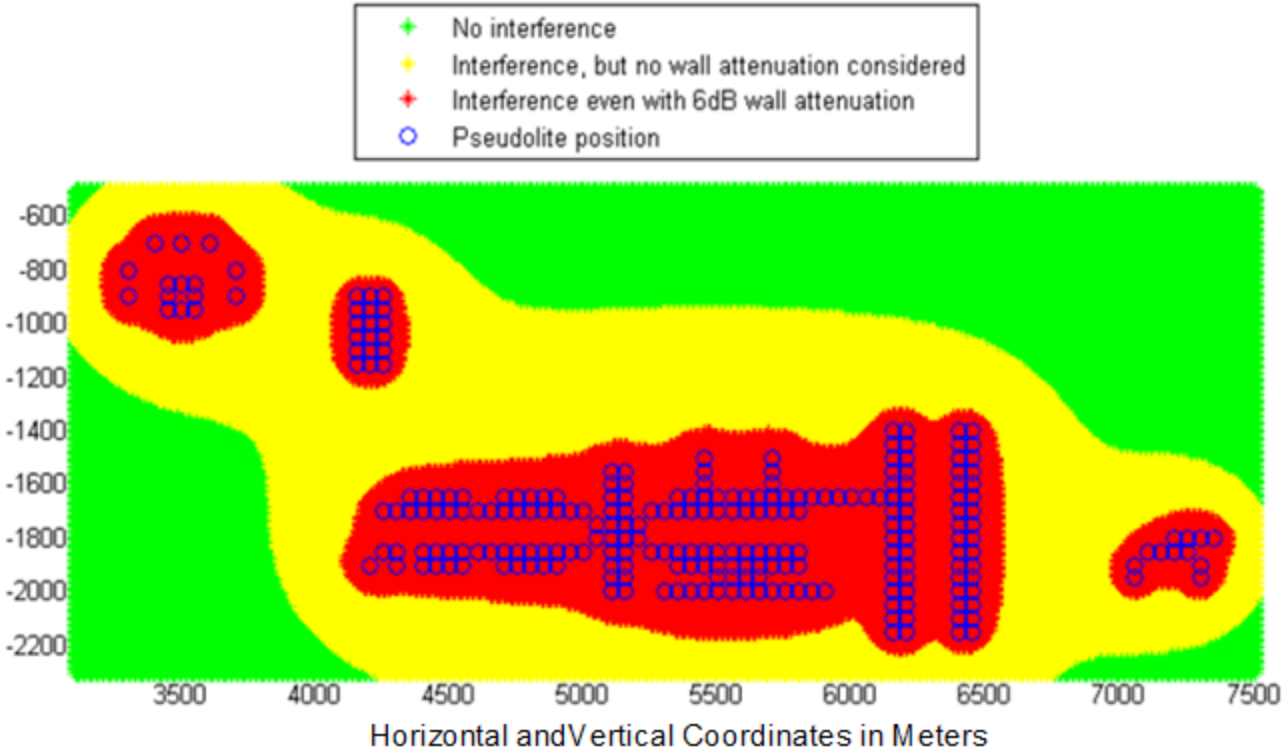
ECC Regulation Would Authorize Indoor Pseudolite Networks Potentially Causing Exclusion Zones Outdoors For Authorized GNSS Users

The potential for interference from in-band pseudolite network operations to extend outdoors is acknowledged:

- "The near-far effect is more significant. The required separation distance varies from 15 m to 128 m if the PL is limited to -59dBm, and 43 m to 359 m if the PL e.i.r.p is increased to -50dBm. A specific attention should be given to light indoor environment i.e., close to large apertures (doors, windows)."
- "it will be necessary to limit the maximum PL e.i.r.p. to -59 dBm in some sensitive areas (e.g. airport terminals). In these conditions, the near-far effect would be reduced to the values given below. A separation distance between 51 and 255 m (or equivalent attenuation) should be maintained with any aircraft or vehicles outside the building in airport areas."

➢ *See* ECC Report 128, Compatibility Studies.

ECC Considered the Effect On Outdoor GNSS Uses At Airports From In-Band Pseudolite Network Operations Inside the Airport



- "Indoor GNSS pseudolites should be installed in airport areas, or in the vicinity of them, **only after case by case studies** with the objective to avoid any potential interference to GNSS receivers in these areas"
  - ➢ *See* ECC Recommendation (11)08 Framework authorization regime of indoor pseudolites, Recommends 4 (emphasis added).
- ***"Outdoor GNSS PLs should not be allowed in airports or other areas for aeronautical operations"***
  - ➢ *See* ECC Report 183, Exec Summary, pg. 2 (emphasis added).

The International GNSS Community Examined – And Abandoned – In-band Pseudolite Installations Due To Interference

- The international GNSS community has examined pseudolites for over 30 years and **abandoned the in-band approach** because the resulting pseudolite interference negated any potential benefit.
  - "It is interesting to note that by 2005 all references to pseudolites (at least on L1) had been removed from the RTCA's LAAS in the U.S."
  - ➢ *See* JRC Scoping Study.
- Evolution of the International GNSS community experience with pseudolites in literature:
  - Out-of-RNSS-band pseudolite is the safe and viable solution for the introduction of GNSS pseudolite transmitters.

ECC Studies Admittedly Excluded Consideration of Deployed, Non-interfering, Out-of-Band Pseudolite Networks

- Out-of-RNSS-band pseudolite "solutions could eliminate interference to RNSS entirely and examples exist of bespoke similar systems already using the 2.4 GHz ISM band"

Minimal consideration:

- "Out of band frequency offsets would usually require a different receiver front-end, which increases receiver costs and can create inter-frequency bias problems"
- "[t]heir accuracy and cost is currently unknown"
- "[s]ystems in non-GNSS bands are not considered further in this report"
  - ➢ *See* ECC Report 183, Regulatory Framework for Outdoor Pseudolites.

Despite recognizing:

- "It is not unreasonable for GPS receivers built for pseudolite use to include a second RF tuner to receive out-of-band pseudolite signals.... Imposing the cost of an additional RF tuner on a small, specialized market seems *preferable to imposing the cost of degraded and sporadically unavailable navigation on the rest of the civil GPS user community*."
  - ➢ *See* JRC Scoping Study.

Proposed ECC Regulation Could Undermine GNSS Interoperability

- Galileo system integrity depends on the European Geostationary Navigation Overlay Service (EGNOS) Space-based Augmentation System (SBAS):
  - EGNOS uses the GPS L1 C/A code on the center frequency
- SBAS are required by the International Civil Aviation Organization to use the GPS L1 C/A code on the center frequency:
  - *See* ICAO Standards and Recommended Practices (SARPS), Annex 10 – Aeronautical Telecommunications, Volume I – Radio Navigation Aids, Section 3.7.3.4.
- The ECC and JRC reports do not acknowledge the dependency of the Galileo system on EGNOS for integrity.

ECC Regulation Appears To Undermine International Agreements To Cooperate on GNSS Interoperability

The ECC study reports propose different treatment among GNSS:

- "The impact of the spectral separation between the pseudolite signal and the local replica in the receiver was clearly demonstrated by the fact the Galileo signals suffered less SNR degradation then the GPS signals in the presence of a GPS pseudolite."
  - ➢ *See* ECC Report 128, Compatibility Studies Between Pseudolites and Services in the Frequency Bands 1164-1215; 1215-1300; and 1559-1610 MHz.
- This demonstration is based on authorizing an in-band pseudolite, which would require selecting a local pseudolite frequency in the RNSS band, that would cause different levels of potential interference to different GNSS.
- The proposed ECC regulation:
  - Appears to undermine the principles of interoperability agreed among the national GNSS operators in the International Committee on GNSS (ICG).
  - Includes an apparent misstatement of GPS & Galileo Provider policy on availability.
  - "Unlike mobile telecommunication network operators, such as GSM or 3G, GNSS operators, such as GPS and Galileo have no obligation to provide location services in every environment."
  - ➢ *See* ECC Report 183, section 5.7, page 23.

An ETSI Work Item May Introduce Another Incompatible Ground Transmitter in the1559-1610 MHz Band

- Work Item DTR/SES-00321 is developing a standard for in-band GNSS pseudolites.
- ETSI SES SCN may propose the introduction of another incompatible ground transmitter in 1559-1610 MHz:
  - Indoor Messaging System (IMES), was proposed by a Japanese company for indoor operations at low received power in Japan only.
    - No ranging capability, but transmits a terrestrial in-band positioning message with the potential to spoof nearby RNSS receivers;
    - Within the area of operation around the in-band IMES ground data transmitter, GNSS operations could experience harmful interference.

In-band IMES Networks Cause Potential Harmful Interference To Authorized GNSS Users

- IMES products include navigation bit decoding algorithms that decode a non-GNSS Pseudorandom Noise (PRN) code which present the potential for harmful interference in the network infrastructure.
- By design, IMES requires repetition of the limited set of non-GNSS PRN codes across grids of many transmitters, introducing risk of unintentional spoofing (and intentional spoofing through possible misuse) if the system is not precisely deployed and continuously monitored.
- Despite an 8.2 kHz offset from the GPS center frequency, IMES proponents acknowledge the potential for harmful interference to authorized GNSS users and that:

  "the [IMES] operators need knowledge of how to handle the PRN codes and their nature. The [IMES] **operators must avoid interference by arranging the assigned codes theoretically**. Installing in a disorderly manner by ignoring the management and maintenance after installation will not help IMES to become a reliable social [location] infrastructure. Firm installation rules, and the methods and regulations that are readily acceptable through the world must be established. Selling IMES transmitters irresponsibly and disorderly also **leads to the destruction of the social [location] infrastructure."**

  - *See* IMES: The invention originates from Japan. Development of Global Scale Application Services; GNSS Technologies, Inc.; Mr. H. Torimoto, President; January 17, 2013; article originally written for electronical Construction Engineering; Vol. No. 724 in 2013: website: http://www.gnss.co.jp/english/ (emphasis added).

ECC Recommends That CEPT And International Administrations Legislate In-band Ground-Based Transmitters

- "An alternative [to out-of-band] is to legislate for ground-based transmitters in the GNSS bands":
  - ➢ *See* JRC Scoping Study on Pseudolites, at Section 2.2.1, p. 3 "Legal Issues" (emphasis added); cites the legislative process by S. Martin, et al., below.
  - – "Consideration by the relevant regulatory working groups at regional and international level (ITU-R);
  - – Invite Administrations to consider new allocations for Pseudolites."
  - ➢ *See* S. Martin, H. Kuhlen, and T. Abt, "Interference and Regulatory Aspects of GNSS Pseudolites"; Journal of Global Positioning Systems, 6(2):98-107, at p.99 (2007).
- Does legislating ground radio transmitters in the GNSS bands potentially include various technologies other than pseudolites?
  - – Implementation and definition of in-band ground radio transmitters may be broader than a pseudolite transmitter.
  - – "[Location system operators] *may rely on various technologies,* including ***or not*** PL."
  - ➢ *See* ECC Report 168, Regulatory Framework for Indoor GNSS Pseudolites, Miesbach, section 4.6, page 18 (emphasis added).
  - – "[Location system operators] *may rely on various technologies* including PLs."
  - ➢ *See* ECC Report 183, Regulatory Framework for Outdoor GNSS Pseudolites, section 5.7, page 23. (emphasis added).

The Proposed CEPT ECC Regulation Is On A Path Towards Adoption Absent Direct Intervention

- To meet the objectives of the 2010 National Space Policy and the purposes of the 2004 US-EU Joint Agreement on GPS: Galileo Cooperation, GPSIA believes that it is vital that the responsible government agencies swiftly address these European developments, having global implications, with their international counterparts at the policy levels, as well as technical, to prevent harm to the global utility of GNSS.
- The CEPT ECC Recommendation on Indoor Pseudolites is out for adoption by CEPT Administrations:
  - It is unclear how this will be received.