ECC Report 183

Regulatory Framework for Outdoor GNSS Pseudolites

approved February 2013

0 EXECUTIVE SUMMARY

Pseudolites (Pseudo satellites, PL) are ground based radio transmitters, that transmit an “RNSS”-like navigation signal that can be received and processed by customised radio navigation receivers compatible to the signals published in the Signal-in-Space Interface Control Documents (SIS-ICD [1]) of the GPS and Galileo systems. They are intended to complement systems in the Radionavigation Satellite Service (RNSS) by transmitting on the same frequencies in the bands 1164-1215 MHz, 1215-1300 MHz, and 1559-1610 MHz. The present report may also apply to the GLONASS system as well.

Since other radio services could also be affected by uncontrolled use of PLs, CEPT conducted sharing studies between PLs and other services on the frequency bands.

The purpose of this Report is to describe guidelines for a regulatory framework under which outdoor PLs could be operated in CEPT countries. A separate ECC Report 168 [5] for indoor PLs is already available. Initial studies in ECC Report 128 [2] demonstrate that under certain conditions use of pseudolites is compatible with navigation in the radionavigation satellite service. The conclusions of this Report are based on ECC Report 128 [2] (Compatibility studies between pseudolites and services in the frequency bands 1164-1215 MHz, 1215-1300 MHz and 1559-1610 MHz).

It is recommended that PL be operated through individual authorisations so as to ensure that no PL will be installed in areas where restrictions apply (e.g. near airports or other areas for aeronautical operations).

On the basis of the conclusions of the technical studies, administrations wishing to implement outdoor PLs may apply the following recommendations related to technical and operational conditions for outdoor PLs:

- Outdoor GNSS PLs should be authorised by individual licensing;
- Outdoor GNSS PLs should not be allowed in airports or other areas for aeronautical operations;
- GNSS PL should only use dedicated codes (see section 3.1.2); this should be a license condition;
- PRN codes dedicated to PLs are provided by the respective RNSS system operator and should be locally administered by national authority and geographical separation of PL using the same PRN codes should be ensured;
- GNSS CW and pulsed-PLs should be authorised only in the 1559-1610 MHz band and not in the 1164-1215 MHz nor 1215-1300 MHz bands;
- Similar systems in non-GNSS bands offset from Radionavigation Satellite allocations are an alternative means of providing functionality without causing interference to GNSS receivers; Their accuracy and cost is currently unknown;
- GNSS PLs transmitting continuously should be limited to an e.i.r.p. of –50 dBm, but the e.i.r.p. should be reduced to the minimum value for the required coverage and quality of service;
- GNSS PLs transmitting pulsed signal, mean e.i.r.p. should be limited to –50 dBm, but the e.i.r.p. should be reduced to the minimum value for the required coverage and quality of service;
- In special environment (e.g. open-pit mine) where longer PL signal range is required, a higher mean e.i.r.p. could be allowed. In such a case, special attention shall be given to the protection of RNSS and ARNS, by using mitigation techniques, as appropriate;
- Installations of pulsed PLs (moderate to high power, mean e.i.r.p. higher than -50 dBm) should not be allowed without licensing and without case by case studies;
- Any authorisations for GNSS pseudolite installations could include guidance for reduction and reasonable checking of the potential to cause interference;
- Using directive PL antennas tilted toward the ground;
- Adjust the PL e.i.r.p. duty cycle to minimise the impact to non-participating receivers;
- GNSS PLs transmitting pulsed signal with mean on-axis e.i.r.p. higher than –50 dBm, mitigation techniques should be applied to limit the e.i.r.p. above 0 degrees elevation (e.g. by using the antenna patterns), accept locally (inside the intended coverage area) a different value for SNR loss (e.g. 3 dB);
- In addition, the following elements should be taken into account:
    - Transmit antenna patterns have to be adapted according to the site requirements and coverage areas. Antenna patterns should be designed to minimise impact on non-participating receivers and focus only on the operations area;

- Site installations should be conducted by professional installers only. This should include e.g. appropriate measures to avoid unauthorised insertion of additional RF power amplifiers between signal generator and antenna and others;

- Administrations should not allow the installation of GNSS pseudolite in freely moving mobiles. NRA's may on a case by case basis allow the use of PL in restricted areas on land vehicles not authorised for use in public environments;
- Military or other government authorities, including for meteorological, may require specific limitations at a deployment site to ensure adequate protection for their systems;
- Compatibility between pulsed PLs and the RAS is possible if there is an adequate separation distance between pseudolites and a Radio Astronomy Station and a PL out of band attenuation performance of 30 dB.

In addition, in order to support the authorisation of PL in areas where case by case studies are necessary (e.g. airports or other areas for aeronautical operations) relevant authorities (e.g. local aviation authorities) need to be involved.

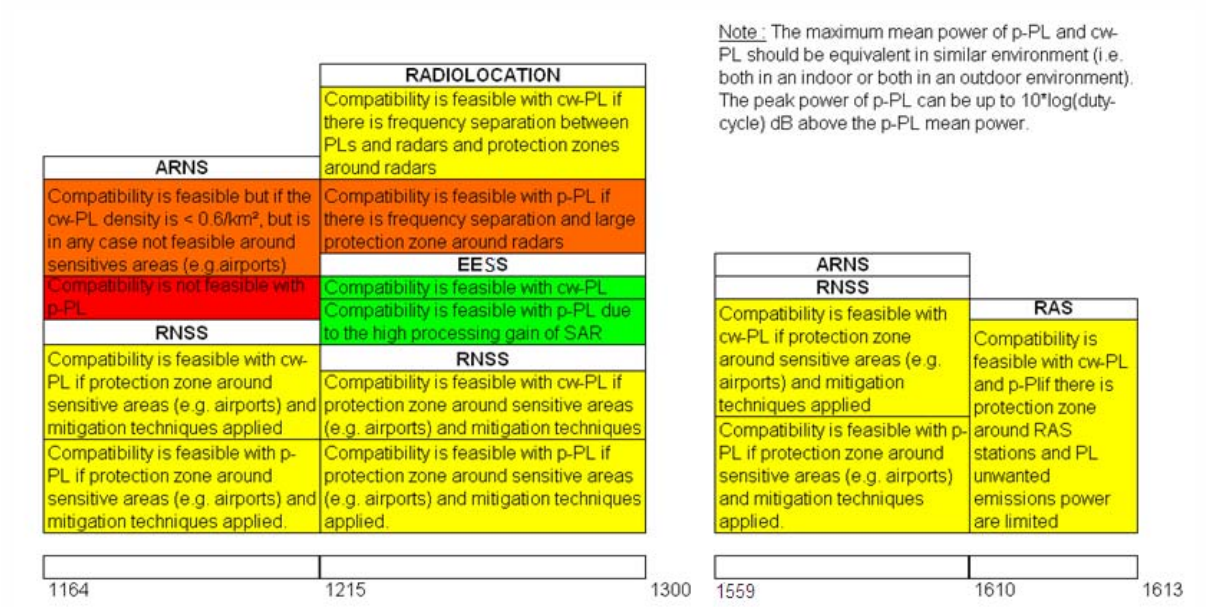

Figure 1: Result of compatibility studies

Note: In the Radio Regulations footnote 5.331 the band 1215-1300 MHz is also allocated to the radionavigation service on a primary basis in many CEPT countries.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
2D	Two-dimensional space
ARNS	Aeronautical Radio Navigation Service
A-RNSS	Assisted RNSS
CEPT	The European Conference of Postal and Telecommunications Administrations
CW	Continuous Wave
DME	Distance Measuring Equipment
EC	European Commission
ECC	European Commmunications Committee
EESS	Earth Exploration Satellite Service
e.i.r.p.	Equivalent isotropically radiated power
ESA	European Space Agency
ETSI	European Telecommunications Standardisation Institute
FDP	Fractional Degradation of Performance
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System operating within the RNSS
GPS	Global Positioning System of the United States, a GNSS system
GALILEO	Global Positioning System of the European Union, a GNSS system
ICAO	International Civil Aviation Organisation
ITU-R	International Telecommunications Union – Radio sector
PFD	Power Flux Density
PL	Pseudolites
PRN	Pseudo Random Number
RLS	RadioLocation Service
RNSS	Radionavigation Satellite Service
RAS	Radio Astronomy Service
SIS-ICD	Signal-in-Space Interface Control Documents
SNR	Signal-to-noise ratio

1 INTRODUCTION

Pseudolites (Pseudo satellites, PL) are defined as a sub-group of equipment that can support operation of GNSS receivers. They transmit GNSS equivalent signals on the same frequency bands allocated to the Radio Navigation Satellite Service. ECC Report 128 [2] provides detail of the Spectrum Engineering compatibility assessment of PL.

The technologies providing PL signals can help to address coverage and accuracy shortcomings, by providing additional ranging signals and by improving geometry. However, PLs are ground based radio transmitters that transmit a GNSS-like navigation signal. Currently it requires users to have modified GNSS-receivers to receive these signals. It is expected that these GNSS receivers have minor changes compared to today's receivers. PLs can be used as augmentation to GNSS or stand-alone in an environment where GNSS is not available. It is then possible to extend the service coverage of satellite navigation to difficult propagation environments maintaining high accuracy under attractive cost conditions (mass-market receiver hardware).

The purpose of this Report is to describe guidelines for a regulatory framework under which PLs could be operated in CEPT countries. The focus of the report is on PL implemented in outdoor environments. Outdoor PLs are not intended as a mass market product.

PLs have to be distinguished from GNSS repeaters which are ground based radio transmitters that receive, amplify and re-broadcast signals from existing GPS satellites without changing those signals in any way other than increasing their power. CEPT has adopted ECC Report 145 [3] on "Regulatory Framework for Global Navigation satellite system (GNSS) repeaters".

2 DESCRIPTION OF GNSS AND OUTDOOR GNSS PSEUDOLITES

2.1 RNSS/GNSS SYSTEMS

Systems using the Radio Navigation Satellite Service (RNSS) or Global Navigation Satellite Systems (GNSS) have developed into indispensable assets for navigation around the globe. Examples are GPS, GLONASS and the future Galileo system that provide data for navigation devices.

A GNSS receiver must lock to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude) and time. Once the user's position has been determined, the GNSS receiver can calculate other information, such as speed, bearing, track, trip distance, and distance to destination, sunrise and others. This information provides the basic information data for higher-level value-added location based services.

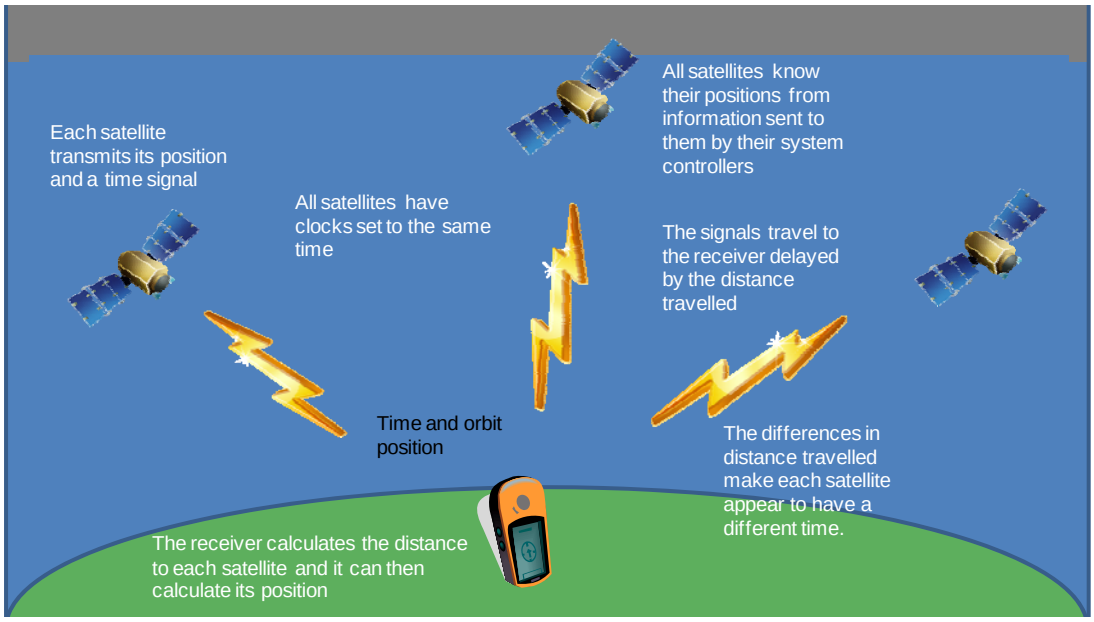

Figure 2: RNSS/GNSS functionality

2.2 OVERVIEW ON PSEUDOLITE USAGE

Pseudolites are intended to improve the availability of positioning service in areas of challenging radio propagation such as indoors and for example in urban canyons. RNSS satellites do not provide sufficient power flux density (PFD) to overcome major obstacles that attenuate the radio frequency wave front.

The protection of other radiocommunication services will have to be ensured by pseudolites, but the most critical performance issue with respect to PLs is their potential interference to other related RNSS applications.

A variety of applications where outdoor pseudolite transmitters have been used in augmenting the GPS constellation have been exploited. Such applications can be, for example:

- Machine control at open mining sites;
- Terrestrial deformation monitoring applications;
- Positioning of goods and vehicles;
- Improving signal coverage in cities with tall buildings;
- Maritime applications, e.g. harbours;

- Locating containers in large warehouse areas;
- Infrastructure protection.

In principle, outdoor pseudolites can improve the satellite coverage wherever the satellite signals are completely unavailable or have reduced visibility. A-RNSS, on the other hand, can be used in areas where there are weak satellite signals available, but cannot be used in areas where the level of satellite signals is too weak even for high sensitivity receivers.

Table 1: Pseudolite scenarios

Scenario	Description	Typical service area	e.i.r.p. (single PL device)	Remarks
A Scenario A for indoor pseudolites is covered in ECC Report 168 [5]				
B	Restricted propagation conditions	Urban canyon Several buildings	CW PLs (-59 dBm to -50dBm)	PL and Signal in Space (SIS)
	Restricted propagation conditions	Urban canyon Several buildings	*****Pulsed PLs (-50 dBm to 11 dBm)	PL and SIS
C	Combined reception over large Service Area	Harbor, open pit mine	CW PLs (-59 dBm to -50 dBm)	PL and SIS
	Combined reception over large Service Area	Harbor, open pit mine	*****Pulsed PLs (-50 dBm to 11 dBm	PL and SIS

***** Note: Power levels higher than -50 dBm may be required in some specific scenarios, and need to be determined on a case by case basis.

The classification in Table 1 is important in view of the definition of regulatory framework and interference issues between PL and Radio Navigation Satellite Services (RNSS) on the one hand, and PL and other services on the other hand. The main system parameters defining a pseudolite network are:

- Carrier frequencies - All the GNSS frequency bands were studied in order to cover all the existing and upcoming GNSS services. This includes at least GPS, and Galileo;
- Modulation & PRN codes: It is assumed that PL will only use dedicated PRN codes separately identifiable from those PRN used by GNSS satellites. PL with non-dedicated codes should not be authorised;
- Mean e.i.r.p.: the peak power of pulsed pseudolites can be up to 10 $\log_{10}$(1/duty cycle) above the mean power;
- Antenna characteristics: can be designed to reduce unwanted effects outside of coverage area.
- Applied duty cycle: Continuous or pulsed;
- Number of pseudolites: depends on area of coverage;
- Pseudolite Locations: Outdoor area/Restricted propagation conditions.

PL would usually transmit in the relevant GNSS frequency bands, though there are some similar systems today that transmit in other non-GNSS frequency bands, the prime example is the Industrial Scientific Medical (ISM) band where devices with proprietary signal specifications have been developed.

2.3 EXAMPLES OF DEPLOYMENT SCENARIOS

2.3.1 Container port logistics

The operation of a modern container port is dependent on positioning of moving machinery, containers and people. The driving forces for positioning are container tracking, auto steering and personnel safety.

Straddle carriers are used in container terminals to transport containers between port cranes and the container storage area. They are today driven manually but use GPS for positioning to give the operator driving instructions where to pick and release the container. A common problem is that the GPS position fix is lost under the port crane because the sky view is obstructed by the crane and the ship. When leaving the crane, the vehicle must be run 10 to 30 seconds without a GPS fix, wasting time and causing errors.

The accuracy requirement for container positioning corresponds to the size of the container slot, in the order of one meter. GPS based methods satisfy the accuracy requirement and are quite cost effective but suffer from patchy availability: there are gaps in the coverage in critical locations.

The gaps in satellite coverage can be filled by installing pseudolites to critical areas. For example, the area under each crane could be covered by 2 to 6 pseudolite signals to ensure near 100% coverage. Pseudolite antennas may be installed on the moving crane itself so that the signals always cover the critical area under the crane. The total number of pseudolites in the port area depends on the number of cranes and other satellite coverage gaps. However, the transmit powers for the pseudolite signals can be limited so that the coverage areas of each group of pseudolites do not overlap.

It should be noted that pseudolites are supporting satellite coverage and GPS receivers are receiving signal from both satellites and pseudolites.

2.3.2 Open pit mining

A large open pit mine has tens or sometimes more than a hundred haul trucks and 100 to 200 light vehicles operating in a confined area day and night. Because of the trucks' large dimensions (extreme case: 10x15x7 m, 600 tons loaded weight), collision avoidance systems are vital. Current systems are based on proximity detection using one or several of RFID, camera or radar technologies.

One possible solution is to use GPS equipment that is already fitted on the trucks and many of the lighter vehicles, and implement a situational awareness / collision avoidance system that keeps track of each vehicle's trajectory and predicts collisions. In deep mines or if high availability is required, GPS as only solution is not sufficient, because the GPS coverage is not enough. The coverage problem can be solved by installing 4-6 pseudolite transmitters around the rim of a single pit. The purpose of pseudolites is to complement satellite constellation inside the pit, the transmit antennas can be designed to minimise radiation outside the pit. The required pseudolite signal range to cover a large open pit mine can be several kilometres.

2.3.3 Other possible applications

Other possible application areas foreseen include nomadic pseudolite use e.g. temporary installation at construction sites and in agriculture.

2.4 POTENTIAL CANDIDATE FREQUENCY BANDS FOR SUPPORTING PSEUDOLITE IMPLEMENTATIONS IN RNSS FREQUENCY SPECTRUM

Frequency bands allocated to the radionavigation satellite service as listed in the ITU-R Radio Regulations Article 5 are shown in table 2. It is important to consider each of the bands as potential candidate bands for supporting pseudolite implementations. However, PLs as a terrestrial application are not within RNSS definitions and would operate under Radio Regulation Article **No. 4.4.**

The different sharing conditions for each band listed might necessitate particular licensing conditions for the operation of co-channel PL.

Table 2: RNSS frequency allocations

1 164-1 215	AERONAUTICAL RADIONAVIGATION 5.328 RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.328A
1 215-1 240	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A SPACE RESEARCH (active) 5.330 5.331 5.332
1 240-1 300	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A SPACE RESEARCH (active) Amateur 5.282 5.330 5.331 5.332 5.335 5.335A

1 559-1 610	AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.208B 5.328B 5.329A 5.341 5.362B 5.362C

3 TECHNICAL CONSIDERATION

3.1 THE NEAR FAR PROBLEM

Because the RNSS satellites are far away and their antenna broadcast beam is shaped, the received RNSS signal power varies only slightly over the Earth coverage (above 5° elevation angle). The PLs on the other hand are near-by and the PL received power varies with $20\log_{10}R$, where R is the range between the PL and the user's receiving antenna. Thus, if the average PL received signal power is made to match that of the satellite at one range, it will dominate at another range while being too weak at yet another. The effect of this is that, unless carefully designed, the PL signal will act as a jammer to the satellite signals at short range and the PL signal will be too weak to be useful at long range.

The near-far problem highlights two major problems related to the pseudolite usage. First, the problem must be solved so that pseudolites can be utilised in practical applications. Secondly, any pseudolite signals must be carefully controlled so that receivers that are not part of the PL constellation are not disturbed or jammed by pseudolite signals.

In order to solve the near-far problem, three signal diversity options described in the following sections provide partial solutions: frequency offsets, optimisation of the cross correlation between the codes, signal pulsing and waveform optimisation. The use of all three options is possible.

3.1.1 Frequency Offsets

Frequency offsets can either be in-band or out-of-band. In-band offsets have the advantage that the same receiver front-end can be used, which minimises inter-frequency biases when comparing PL measurements to satellite measurements. Out-of-band frequency offsets would usually require a different receiver front-end, which increases receiver cost and can create inter-frequency bias problems. However, this solution could eliminate interference to RNSS entirely and examples exist of bespoke similar systems already using the 2.4 GHz ISM band. Their accuracy and cost is currently unknown.

These off-set systems should be considered as similar applications since both GNSS PL and systems in non-GNSS bands are essentially bespoke systems. Systems in non-GNSS-bands are not considered further in this report.

3.1.2 Different PRN Codes

The association of Pseudo Random Numbers and the associated transmitted RNSS signals needs to be explained first to understand the issues associated with PRN codes. For example, the "C/A" code of GPS is a random set of bits, 1023 bits long. Each PRN code is associated with one specific arrangement of those 1023 bits. There are many possible arrangements of these bits. However, not all arrangements are good in terms of their cross correlation co-efficient, i.e. if one cross compares two codes to each other, what is the power ratio of that arrangement compared to one code itself correlated with the same code. Families of some codes with good cross correlation co-efficient (for example "Gold Codes") have been found, one of the PRN codes from such a family uniquely identifies it. For the RNSS constellations, each satellite operator assigns a different Gold Code family to each satellite.

Some RNSS operators have identified a limited number of PRN Codes in their code family specifically for ground based transmissions (e.g. for pseudolite (PL) functions).

In terms of this report, PRN codes associated with satellite transmissions are termed "Non-Dedicated PL codes". PRN codes that are specifically associated with pseudolite transmissions are termed "Dedicated PL codes".

The PL signal structure must be modified with respect to the SIS signal structure to minimise the interference to the RNSS signals. Using different PRN codes in a RNSS family of codes would minimise the impact on receiver design. For instance there are about 700 usable codes in the GPS C/A code family. There are also many usable wideband codes compatible with the GPS P-codes. Using a different code family should be

avoided to minimise receiver design modifications. Longer codes or ones with higher chipping rates are desirable.

Typical mass market RNSS receivers will not be capable of interpreting pseudolite signals, unless these receivers are modified. For example, current GPS receivers (non-participating in the use of PL signals) use PRN codes 1-32 and this is designed into the software or firmware engines embedded into the GPS receiver chip sets. Indeed, current mass market GPS receivers rely on the published and agreed Signal Interface Standards of GPS. Redesigned software and firmware would need to be implemented to cater for any PL signals and be published and agreed as a standard.

However, the near-far problem cannot be solved using different PRN codes alone. There is not enough cross correlation margin between codes. If codes from the RNSS code family are used, the modification must also include provisions to minimise cross-correlation with the RNSS-codes.

3.1.3 Signal Pulsing

Signal pulsing is the most effective interference solution, using low-duty cycle, higher power pulses. This is because RNSS receivers are naturally robust against low-duty cycle pulsed interference. The PL signal only interferes with the satellite signals when a pulse is present. The down side of low-duty cycle pulses is that PL signal reception is degraded by the square of the duty cycle, which dictates the PL peak power required for the desired radius of operation. Pulsing at low duty cycles is a necessity no matter what signal structure is chosen, unless larger frequency offsets are used.

However, because of the autocorrelation properties of the C/A code, very low-duty (less than 1%) cycles are not possible. The pulses must cover most of the code sequence during a reasonable receiver processing time interval. This becomes a problem when the number of PLs is increased: the aggregate duty cycle of pulsed signals grows and eventually causes harmful interference to non-participating receivers. Therefore the aggregate duty cycle of strong pulsed signals in a given area must be limited to protect non-participating receivers. Alternatively, it is possible to synchronise the pulses so that the aggregate duty cycle does not grow. The drawback of this solution is that the reception of the overlapping pulsed signals would be very difficult.

The aggregate duty cycle equals the sum of pulsed signals that are significantly stronger (peak power) than thermal noise level in the RNSS receiver. Only in this case the pulsed signals may saturate the receiver front-end. The interference caused by those pulsed signals that are weaker than this can be treated the same way as the interference caused by CW signals [7].

The interference caused by pseudolite signals below thermal noise level can be evaluated the same way as for CW signals (interference power level taken as the average power instead of peak power). In this case there are no saturation effects.

Where outdoor PLs are installed, case by case analysis against the expected type of GNSS receivers may be required to determine the robustness against pulsed interference.

3.2 INTERFERENCE DUE TO NOISE LEVEL ELEVATION

Even though PL signals are spread spectrum, the PL PSD increase the noise floor level, thus resulting in a degradation of the GNSS satellite C/N_0 equal to the noise floor elevation. If the PL signal is strong enough, the $C/(N_0+I_0)$ may be decreased below the acquisition and/or tracking threshold and navigation will be denied.

It is necessary to evaluate the impact of several CW (Continuous Waves) pseudolite or pulsed pseudolite transmitters on RNSS receivers. The aggregate effect is evaluated through an increase of the noise level for a 1 dB noise increase interference criteria.

The increase of noise level will affect the performance of the receiver depending on the level of signal received and its sensitivity.

4 TECHNICAL CONCLUSIONS

4.1 BAND 1164-1215 MHz, RNSS

Radio Navigation Satellite Systems are spread spectrum systems. Because of the similarities between RNSS and PL systems, the RNSS receiver tolerates more or less the PL wideband interference depending on the nature and characteristics of the PL signal.

The RNSS receiver tolerates also to some extent pulsed interference. The RNSS receiver saturates during the interfering pulse, but after short recovery time can receive the slightly degraded satellite signals. The 1 dB RNSS noise degradation due to wideband interference noise is an internationally accepted criteria.

Compatibility between continuously transmitting pseudolites and RNSS is feasible under the following conditions:

a) A specific attention should be given to the use of pseudolites operating in outdoor environment. In this case, in the absence of mitigation techniques and assuming an e.i.r.p. of -59 dBm, a separation distance of up to 190 m can be necessary to ensure the protection of non-participating receivers (these could be operating anywhere outside of closed areas (Note: closed area is an area where access is granted only to certain personnel and the area is mentioned in the radio license)and therefore local case by case analysis will need to be considered). In order to reduce the potential interference level for lower separation distances, the following measures could be taken:
   - Use of directive antenna and reduce the PL e.i.r.p. to -65 dBm above 0° elevation;
   - Optimisation of the pseudolite signal (e.g. by using longer code with better cross-correlation properties).

b) The impact of PLs on outdoors non-participating receivers differs depending on the type of PRN codes that is used by the PLs (i.e. dedicated or non-dedicated codes). In the case non-dedicated PRN codes are used, this area of potential performance degradation is much larger than with dedicated codes, and separation distances up to 1.5 km are necessary to guarantee the integrity of non-participating receivers (those used for safety applications). The impact in this area is an increase of the Time-To-First-Fix of non-participating receivers in cold start (see section 2, definitions of ECC Report 128 [2]).

   In order to reduce the potential interference level for lower separation distances, the following measures could be taken:

   - Use of directive antenna and reduce the PL e.i.r.p. to -65 dBm above 0° elevation.

   In addition, in order to avoid non-participating receivers using the RNSS code allocated to other systems (i.e. satellites), it is recommended to broadcast on the PLs a modified navigation message to ensure that the signal source validity is identified. PL transmissions and modified navigation messages should be analysed for their impact on non-participating receivers.

   Moreover, PL signals can monopolise some reception channels of non-participating receiver, even after the acquisition resolved. Therefore, non-participating receiver could have an insufficient number of available channels to receive satellite signals.

   It is recommended to develop associated PL receivers with an increased number of reception channels.

   Finally, it is necessary to ensure that a failure of the software management system used to allocate the satellite PRN codes to the PLs will never occur. For use in any area where safety is an issue, this software must be proven to be using well known safety case assessment procedures.

   Therefore, the use of non-dedicated code should only correspond to experimental purpose for a limited duration under specific regulation approval. The implementation of dedicated code for pseudolite is part of the modification of firmware expected from chipset manufacturer to meet mass market requirements.

In view of the unknown effect to all non-participating receiver designs associated with the use of non-visible satellite PRN codes by pseudolites, this method is not recommended for operational use.

c) Using dedicated code will avoid the type of impact described above in b) and is thus recommended as soon as possible (as soon as mass market chipsets are able to process such dedicated codes). Moreover, the use of longer codes will also improve the compatibility with non-participating receivers as well as the performance of participating receivers. The use of dedicated code is the solution to grant no interference described in b) with non-participating GPS receiver. Wideband dedicated PRN codes with cross correlation properties below acquisition and tracking thresholds of non-participating receivers should be considered.

d) It is not possible to determine a reasonable separation distance (i.e. less than the building dimensions) between an outdoor pseudolite and a non-participating GNSS receiver located in an adjacent building. Therefore, this kind of non-participating GNSS receiver cannot be protected.

e) The studies of the aggregate effect of PL on aeronautical RNSS receivers show that in average, the single PL transmitter density should be limited to 6 PL/km² if the e.i.r.p. is -59 dBm and 24 PL/km² if the e.i.r.p is limited to -65 dBm (or if equivalent mitigation techniques are applied). It should be noted that these values should not be taken as regulatory limitations since they correspond to average numbers, which may be exceeded locally.

In sensitive areas such as airports or other areas for aeronautical operations, the studies show that mitigation techniques should be applied. Moreover, since the aggregated effect really depends on the real deployment conditions, case by case studies may be necessary

Compatibility between pulse transmitting pseudolites and RNSS is feasible under the following conditions:

a) A specific attention should be given to the use of pseudolites operating in outdoor environment. In this case, in the absence of mitigation techniques and assuming a mean e.i.r.p. of -59 dBm and an SNR loss of 1 dB for any kind of “non-aeronautical receiver” / “for high precision receiver”, a separation distance of up to respectively “120 m” / “96 m” can be necessary to ensure the protection of non-participating non-aeronautical receivers. In order to protect aeronautical receivers the PL mean e.i.r.p. should be reduced to -65 dBm above 0°elevation. In order to reduce the potential interference level for lower separation distances or increase the mean on-axis e.i.r.p., the following measures could be taken:
   - Optimisation of the pseudolite signal;
   - To accept locally (inside the intended coverage area) a different value of SNR loss (e.g. 3 dB), but only after an analysis of this on non-participating receivers;
   - Use of directive antennas.

b) The peak power of pulsed pseudolites can be up to 10 $\log_{10}$(1/duty cycle) above the mean power, the duty cycle is not less than 1%.

c) The use of dedicated codes is highly recommended. Moreover, the use of longer codes will also improve the compatibility with non-participating receivers as well as the performance of participating receivers. Wideband dedicated PRN codes with cross correlation properties below acquisition and tracking thresholds of non-participating receivers should be considered. However, these longer codes do pose challenges to low-duty cycle PLs.

d) The studies of the aggregate effect of PL on aeronautical RNSS receivers show that in average, the PL density should be limited to 2 PL/km² if the mean e.i.r.p. is -59dBm and 6 PL/km² if the mean e.i.r.p. is limited to -65dBm (or if equivalent mitigation techniques are applied above 0 degree elevation angle). It should be noted that these values should not be taken as regulatory limitations since they correspond to average numbers, which may be exceeded locally.

e) In sensitive areas such as around airport or other areas for aeronautical operations, the studies show that mitigation techniques should be applied. Moreover, since the aggregated effect really depends on the real deployment conditions, case by case studies may be necessary.

4.2 BAND 1164-1215 MHz, ARNS

Aeronautical Radio Navigation Service (ARNS) is a safety related service and should be protected from interference. The protection criterion is I/N = -23 dB and does not include any relaxation for example as function of time (Fractional Degradation of Performance, FDP). The ARNS receivers are located on board aircraft on all altitudes up to 12 000 meters and the radio propagation environment is already rather difficult.

An aggregated PFD limit of -144.5 dB(W/m²/MHz) to protect ARNS from RNSS was assumed.

Compatibility between continuously transmitting pseudolites and ARNS would not be easily 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 operations are not feasible for RNSS operations in the band 1164-1215 MHz.

This report does not recommend to authorise the use of PLs in this band.

4.3 BAND 1215-1300 MHz, RNSS

Radio Navigation Satellite Systems are spread spectrum systems. Because of the similarities between RNSS and PL systems, the RNSS receiver tolerates more or less the PL wideband interference depending on the nature and characteristics of the PL signal.

The RNSS receiver tolerates also to some extent pulsed interference. The RNSS receiver saturates during the interfering pulse, but after short recovery, time can receive the slightly degraded satellite signals. The 1 dB RNSS noise degradation due to wideband interference noise is an internationally accepted criteria

Compatibility between continuously transmitting pseudolites and RNSS is feasible under the following conditions:

a) A specific attention should be given to the use of pseudolites operating in outdoor environment. In this case, in the absence of mitigation techniques, and assuming an e.i.r.p. of -59dBm, a separation distance of up to 185 m can be necessary to ensure the protection of non-participating receivers (these could be operating anywhere outside of closed areas (Note: closed area is an area where access is granted only to certain personnel and the area is mentioned in the radio license)and therefore local case by case analysis will need to be considered). In order to reduce the potential interference level for lower separation distances, the following measures could be taken:

   - Use of directive antenna and reduce the PL e.i.r.p. to -65 dBm above 0° elevation;
   - Optimisation of the pseudolite signal (e.g. by using longer code with better cross-correlation properties).

b) In the case non-dedicated PRN codes are used, this area of potential performance degradation is much larger than with dedicated codes, and separation distances up to 1.5 km are necessary to guarantee the integrity of non-participating receivers (those used for safety applications). The impact in this area is an increase of the Time-To-First-Fix of non-participating receivers in cold start.

   In order to reduce the potential interference level for lower separation distances, the following measures could be taken:

   - Use of directive antenna and reduce the PL e.i.r.p. to -65 dBm above 0° elevation;

   In addition, in order to avoid non-participating receivers using the RNSS code allocated to other systems (i.e. satellites), it is recommended to broadcast on the PLs a modified navigation message to ensure that the signal source validity is identified. PL transmissions and modified navigation messages should be analysed for their impact on non-participating receivers.

Moreover, PL signals can monopolize some reception channels of non-participating receiver, even after the acquisition resolved. Therefore, non-participating receiver could have an insufficient number of available channels to receive satellite signals.

It is recommended to develop associated PL receivers with an increased number of reception channels.

Finally, it is necessary to ensure that a failure of the software management system used to allocate the satellite PRN codes to the PLs will never occur. For use in any area where safety is an issue, this software must be proven to be using well known safety case assessment procedures.

Therefore, the use of non-dedicated code should only correspond to experimental purpose for a limited duration under specific regulation approval. The implementation of dedicated code for pseudolite is part of the modification of firmware expected from chipset manufacturer to meet mass market requirements.

In view of the unknown effect to all non-participating receiver designs associated with the use of non-visible satellite PRN codes by pseudolites, this method is not recommended for operational use.

c) Using dedicated code will avoid the type of impact described above in b) and is thus recommended as soon as possible (as soon as mass market chipsets are able to process such dedicated codes). Moreover, the use of longer codes will also improve the compatibility with non-participating receivers as well as the performance of participating receivers. In case of mass market deployment, the use of dedicated code is the solution to grant no interference described in b) with non-participating GPS receiver. Wideband dedicated PRN codes with cross correlation properties below acquisition and tracking thresholds of non-participating receivers should be considered.

d) The studies of the aggregate effect of PL on aeronautical RNSS receivers show that in average, the single PL transmitter density should be limited to 12 PL/km² if the e.i.r.p. is -59 dBm and 48 PL/km² if the e.i.r.p. is limited to -65 dBm (or if equivalent mitigation techniques are applied). It should be noted that these values should not be taken as regulatory limitations since they correspond to average numbers, which may be exceeded locally.

In sensitive areas such as airports and other areas for aeronautical operations, the studies show that mitigation techniques should be applied. Moreover, since the aggregated effect really depends on the real deployment conditions, case by case studies may be necessary.

Compatibility between pulse transmitting pseudolites and RNSS is feasible under the following conditions:

a) A specific attention should be given to the use of pseudolites operating in outdoor environment. In this case, in the absence of mitigation techniques and assuming a mean e.i.r.p. of -59 dBm and an SNR loss of 1 dB for any kind of “non-aeronautical receiver” / “for high precision receiver”, a separation distance of up to respectively “116 m”/ “92 m” can be necessary to ensure the protection of non-participating non-aeronautical receivers. In order to protect aeronautical receivers the PL mean of-axis e.i.r.p. should be reduced to -65 dBm above 0° elevation. In order to reduce the potential interference level for lower separation distances or increase the mean on-axis e.i.r.p., the following measures could be taken:

- Optimisation of the pseudolite signal;
- To accept locally (inside the intended coverage area) a different value of SNR loss (e.g. 3 dB). but only after an analysis of this on non-participating receivers;
- Use of directive antenna.

b) The peak power of pulsed pseudolites can be up to 10 log (1/duty cycle) above the mean power, the duty cycle is not less than 1%.

c) The use of dedicated codes is recommended. Moreover, the use of longer codes will also improve the compatibility with non-participating receivers as well as the performance of participating receivers. Wideband dedicated PRN codes with cross correlation properties below acquisition and tracking thresholds of non-participating receivers should be considered. However, these longer codes do pose challenges to low-duty cycle PLs.

d) The studies of the aggregate effect of PL on aeronautical RNSS receivers show that in average, the PL density should be limited to 2 PL/km² if the mean e.i.r.p. is -59 dBm and 10 PL/km² if the mean e.i.r.p. is limited to -65 dBm (or if equivalent mitigation techniques are applied above 0 degree elevation angle). It should be noted that these values should not be taken as regulatory limitations since they correspond to average numbers, which may be exceeded locally.

e) In sensitive areas such as around airports or other areas for aeronautical operations, the studies show that mitigation techniques should be applied. Moreover, since the aggregated effect really depends on the real deployment conditions, case by case studies may be necessary

4.4 BAND 1215-1300 MHz, RDS

The Radiodetermination Service (RDS) is a safety related service and should be carefully protected from interference. The protection criterion considered is I/N = -6 dB to be met 100% of the time.

Due to the high antenna gain and sensitivity of radars the separation distances are rather large already in the case of continuously transmitting pseudolites, becoming unacceptable in the case of pulse transmitting pseudolites.

Compatibility between pseudolites and the radio determination Service is possible if

a) There is a frequency separation between pseudolites and radars;
or,
b) There is a geographic separation distance between pseudolites and radars.

These separations should be computed on a case by case basis.

4.5 BAND 1215-1300 MHz, EESS

An EESS system scans the surface of the Earth with its antenna main beam. During scan the antenna footprint is about 20 km x 20 km area. One single pulse transmitting pseudolite in the antenna footprint cannot cause interference to EESS systems. If the number of pseudolites in the footprint increases aggregated average interference power level in the EESS receiver may be exceeded.

Compatibility between continuously transmitting pseudolites and EESS is feasible.

Compatibility between pulse transmitting pseudolites and EESS is feasible due to the high processing gain of the SAR system and that within any 20 km x 20 km area the likely hood of complete PL coverage is low.

4.6 BAND 1559-1610 MHz RNSS

Radio Navigation Satellite Systems are spread spectrum systems. Because of the similarities between RNSS and PL systems, the RNSS receiver tolerates more or less the PL wideband interference depending on the nature and characteristics of the PL signal.

The RNSS receiver tolerates also to some extent pulsed interference. The RNSS receiver saturates during the interfering pulse, but after short recovery time can receive the slightly degraded satellite signals. An RNSS 1 dB noise degradation due to wideband interference noise is an internationally accepted criteria. To keep below the 1 dB threshold of degradation for non-participating receivers, the combined aggregate duty cycle shall be less than 10% for a PL system (taking into account whether those PLs are synchronised to transmit at the same time and also having the potential to cause saturation to non-participating receiver.

Compatibility between continuously transmitting pseudolites and RNSS is feasible under the following conditions:

The increase of the PLs e.i.r.p. from -59 dBm to -50 dBm will create additional interference on outdoor non-participating receivers. In this case and in the absence of mitigation techniques, with a maximum PL e.i.r.p. of -50 dBm, a separation distance of up to 350 m can be necessary to ensure the protection of non-participating receivers (these could be operating anywhere outside of closed areas (note: closed area is an area where access is granted only to certain personnel and the area is mentioned in the radio license) and therefore local case by case analysis will need to be considered). In order to reduce the potential interference level for lower separation distances, the following measures could be taken:

- Use of directive antenna and reduce the maximum PL e.i.r.p. by 6dB above 0° elevation;
- Optimisation of the pseudolite signal (e.g. by using longer code with better cross-correlation properties).

Under these conditions, and with a typical RNSS receiver C/N_0 of 25 dBHz (in tracking mode not acquisition mode), a separation distance of between 18 m and 51 m (corresponding to PLs maximum e.i.r.p. of -59 dBm and -50 dBm respectively) will have to be maintained between any PL and outdoor non-participating receivers.

a) In the case non-dedicated PRN codes are used, this area of potential performance degradation is much larger than with dedicated codes, and separation distances of 1.1 km to 2 km are necessary to guarantee the integrity of non-participating receivers (those used for safety applications). The impact in this area is an increase of a receiver determining its first position fix. The Time-To-First-Fix of non-participating receivers in cold start will increase.

   In order to reduce the potential interference level for lower separation distances, the following measures could be taken:

   - Use of directive antenna and reduce the maximum PL e.i.r.p. by 6 dB above 0°elevation;
   - Reducing the PL maximum e.i.r.p..

   Under these conditions, and with a typical minimum receiver C/N_0 of 25 dBHz (tracking mode not acquisition mode), a separation distance of between 143 m and 403 m (corresponding to PLs maximum e.i.r.p. of -59 dBm and -50 dBm respectively) will have to be maintained between any PL and outdoor non-participating receivers. In some sensitive areas such as airports and other areas for aeronautical operations, a case-by-case interference analysis is recommended to evaluate the potential risk associated to a PL deployment proposal.

   In addition, in order to avoid non-participating receivers using the RNSS code allocated to other systems (i.e. satellites), it is recommended to broadcast on the PLs a modified navigation message to ensure that the signal source validity is identified. PL transmissions and modified navigation messages should be analysed for their impact on non-participating receivers.

   Moreover, PL signals can monopolise some reception channels of non-participating receiver, even after the acquisition resolved. Therefore, non-participating receiver could have an insufficient number of available channels to receive satellite signals.

   It is recommended to develop associated PL receivers with an increased number of reception channels.

   Finally, it is necessary to ensure that a failure of the software management system used to allocate the satellite PRN codes to the PLs will never occur. For use in any area where safety is an issue, this software must be proven to be using well known safety case assessment procedures.

   Therefore, the use of non-dedicated code should only correspond to experimental purpose for a limited duration under specific regulation approval. The implementation of dedicated code for pseudolite is part of the modification of firmware expected from chipset manufacturer to meet mass market requirements.

   In view of the unknown effect to all non-participating receiver designs associated with the use of non-visible satellite PRN codes by pseudolites, this method is not recommended for operational use.

b) Using dedicated code will avoid the type of impact described above in a) and is thus recommended as soon as possible (as soon as mass market chipsets are able to process such dedicated codes). Moreover, the use of longer codes will also improve the compatibility with non-participating receivers as

well as the performance of participating receivers. In case of mass market deployment, the use of dedicated code is the solution to grant no interference described in a) with non-participating GPS receiver. Wideband dedicated PRN codes with cross correlation properties below acquisition and tracking thresholds of non-participating receivers should be considered. However, these longer codes do pose challenges to low-duty cycle PLs.

c) The studies of the aggregate effect of PL on aeronautical RNSS receivers show that in average, the single PL transmitter density should be limited to 2.5 PL/km² if the e.i.r.p. is -50 dBm and 11.8 PL/km² if the e.i.r.p. is limited to -59 dBm (or if equivalent mitigation techniques are applied). It should be noted that these values should not be taken as regulatory limitations since they correspond to average numbers, which may be exceeded locally.

   In sensitive areas such as airports and other areas for aeronautical operations, the studies show that the e.i.r.p. should be limited to -59 dBm and mitigation techniques applied. Moreover, since the aggregated effect really depends on the real deployment conditions, case by case studies may be necessary.

Compatibility between pulse transmitting pseudolites and RNSS is feasible under the following conditions:

a) A specific attention should be given to the use of pseudolites operating in outdoor environment. In this case, in the absence of mitigation techniques and assuming a mean e.i.r.p. of -50 dBm and an SNR loss of 1 dB for any kind of “non-aeronautical receiver” / “for high precision receiver” / “for the measured non-aeronautical receivers”, a separation distance of up to respectively “255 m”/”200 m”/”77 m” can be necessary to ensure the protection of non-participating non-aeronautical receivers. In order to protect aeronautical receivers the PL mean e.i.r.p. should be reduced to -65 dBm above 0° elevation. In order to reduce the potential interference level for lower separation distances or increase the mean on-axis e.i.r.p., the following measures could be taken:
   - Use of directive antenna and optimisation of the pseudolite signal;
   - To accept locally (inside the intended coverage area) a different value of SNR loss (e.g. 3 dB). but only after an analysis of this on non-participating receivers.

b) The peak power of pulsed pseudolites can be up to 10 log (1/duty cycle) above the mean power. The duty cycle is not less than 1%.

c) The use of dedicated codes is recommended. Moreover, the use of longer codes will also improve the compatibility with non-participating receivers as well as the performance of participating receivers.

   The studies of the aggregate effect of PL on aeronautical receivers show that in average, the single PL transmitter density should be limited to 4 PL/km² if the mean e.i.r.p. is -59 dBm and to 18 PL/km² if the mean e.i.r.p. is limited to -65 dBm (or if equivalent mitigation techniques are applied above 0 degree elevation angle). It should be noted that these values should not be taken as regulatory limitations since they correspond to average numbers, which may be exceeded locally.

   In view of the unknown effect to all non-participating receiver designs associated with the use of non-visible satellite PRN codes by pseudolites, this method is not recommended for operational use.

d) In sensitive areas such as around airports and other areas for aeronautical operations, the studies show that mitigation techniques should be applied. Moreover, since the aggregated effect really depends on the real deployment conditions, case by case studies may be necessary

4.7 RAS IN THE ADJACENT BAND 1610.6-1613.8 MHz

Based the assumptions made in the ECC Report 128 [2] (in particular, an out-off band attenuation of 30 dB), it is concluded that:

For CW PLs:

- Compatibility between CW PLs and the RAS is possible.

For Pulsed PLs:

- Compatibility between pulsed PLs and the RAS is possible if there is an adequate separation distance between pseudolites and a Radio Astronomy Station. A co-ordination zone of 33 km (for a mean e.i.r.p. of 11 dBm per single PL device) should be adopted around observatories of the RAS and deployment of pulsed PLs within this zone should be assessed on a case by case basis for non-interference. Terrain effects between the PL and RAS observatory may facilitate deployment at reduced distances. This might be assessed using a path loss prediction tool with an appropriate terrain and clutter database. In addition, reduction in transmitter pulse power, careful choice of physical location, manipulation of the transmit antenna pattern in situ (additional shielding), reduction in duty cycle, etc. may also be used in combination to meet the requirements of Recommendation ITU RA.769 [6].

5 REGULATORY ASPECTS FOR OUTDOOR GNSS PSEUDOLITES

5.1 REGULATORY STATUS OF PSEUDOLITES IN RNSS FREQUENCY ALLOCATIONS

The operation of GNSS PLs is considered within the following RNSS allocations: 1164-1215 MHz, 1215-1300 MHz and 1559-1610 MHz – subject to the results of the studies within CEPT in each of these bands. Hence, GNSS PLs will operate according to national licensing conditions and this should be on a non-interference non-protected basis and in accordance with Article 4.4 of Radio Regulations.

5.2 PROPOSED REGULATORY REGIME

As a rule, the use of radio frequencies is subject to either a general authorisation, in particular if the risk of harmful interference is negligible, or an individual authorisation issued to each operator of PL, if there is potential cause of harmful interference. In particular, within the framework of a general authorisation, equipment may still have to comply with technical conditions included in such authorisation.

Those two options are considered as follows:

General authorisation option

Adopting general authorisation for the use by PLs of radio frequencies in RNSS bands would raise a number of issues:

- use of radio frequencies without individual authorisations would cause a potential increase in the risk of interference caused to GNSS receivers receiving direct satellite signals, as well as interferences between non-coordinated pseudolite systems themselves;
- a general authorisation regime will increase the likelihood that there is an unknown GNSS PL in the vicinity of other legitimate GNSS signals, which would result in potentially significant interference;
- Government users are also concerned that uncontrolled use of these devices might negate the trust in the use of GNSS and therefore undermine the regulatory basis of any location-based applications.
- Risk posed by “free” circulation of pseudolite devices, both to aviation and non-aviation sectors.

Considering these elements, this Report concludes that individual authorisation regimes for these devices are mandatory.

On a national level, if an administration makes the use of radio frequencies subject to a general authorisation, it is accepted that such an authorisation should be subject to approval by the national civil aviation administration.

Individual rights of use option

Due to the importance of ensuring compatibility with GNSS systems, the use by PLs of radio frequencies in RNSS bands should be subject to individual authorisations. Such individual authorisations should be granted to operators of PLs, and may be subject to technical and operational conditions necessary for the avoidance of harmful interference. Those conditions should define physical implementation of PLs, in order to properly assess the compatibility with GNSS systems for a given site, and to be able to determine if any local pseudolite is responsible for any harmful interference.

5.3 TECHNICAL AND OPERATIONAL CONDITIONS WHICH MAY BE ATTACHED TO RIGHTS OF USE FOR RADIO FREQUENCIES

On the basis of the conclusions of the technical studies, administrations wishing to implement outdoor PLs may apply the following recommendations related to technical and operational conditions for outdoor PLs:

- Outdoor GNSS PLs should be authorised by individual licensing;
- Outdoor GNSS PLs should not be allowed in airports or other areas for aeronautical operations;

- GNSS PL should only use dedicated codes (see section 3.1.2); this should be a license condition;
- PRN codes dedicated to PLs are provided by the respective RNSS system operator and should be locally administered by national authority, and geographical separation of PLs using the same PRN codes should be ensured;
- GNSS CW and pulsed-PLs should be authorised only in the 1559-1610 MHz band;
- GNSS PLs transmitting continuously should be limited to an e.i.r.p. of -50 dBm, but the e.i.r.p. should be reduced to the minimum value for the required coverage and quality of service;
- GNSS PLs transmitting pulsed signal, mean e.i.r.p. should be limited to -50 dBm, but the e.i.r.p. should be reduced to the minimum value for the required coverage and quality of service;
- To keep below the 1dB threshold of degradation for non-participating receivers, the combined aggregate duty cycle shall be less than 10% for a PL system (taking into account whether those PLs are synchronised to transmit at the same time and also having the potential to cause saturation to non-participating receiver;
- In special environment (e.g. open-pit mine) where longer PL signal range is required, a higher mean e.i.r.p. could be allowed. In such a case, special attention shall be given to the protection of RNSS and ARNS, by using mitigation techniques, as appropriate;
- Installations of pulsed PLs (moderate to high power, mean e.i.r.p. higher than -50 dBm) should not be allowed without licensing and without case by case studies
- Any authorisations for GNSS pseudolite installations could include guidance for reduction and reasonable regular checking of the potential to cause interference;
- Using directive PL antennas tilted toward the ground;
- Reducing the PL maximum e.i.r.p. to the minimum value for the required coverage and quality of service;
- Adjust the PL e.i.r.p. duty cycle to minimise the impact to non-participating receivers;
- GNSS PLs transmitting pulsed signal with mean on-axis e.i.r.p. higher than -50 dBm, mitigation techniques should be applied to limit the e.i.r.p. above 0 degrees elevation (e.g. by using the antenna patterns), and to accept locally (inside the intended coverage area) a different value of SNR loss (e.g. 3 dB);
- In addition, the following elements should be taken into account:
    - Transmit antenna patterns have to be adapted according to the site requirements and coverage areas. Antenna patterns should be designed to minimise impact on non-participating receivers and focus only on the operations area;
    - Site installations should be conducted by professional installers only. This should include e.g. appropriate measures to avoid unauthorised insertion of additional RF power amplifiers between signal generator and antenna and others.

5.4 PROTECTION OF NON PARTICIPATING GNSS RECEIVERS

Pseudo Random Number (PRN) codes are the identification code by which GNSS signals are associated with individual satellites and their different signals. Using different PRN codes in a RNSS family of codes will minimise the impact on receiver design. Using a different PRN code family should be avoided to minimise receiver design modifications.

Only PLs using dedicated codes should be used in deployed PL systems. The national administration must have a confirmation from the applicant that the PRN code requested is one of those that are dedicated to PLs (i.e. one that has been assessed for its cross-correlation compatibility within the RNSS system, by the RNSS system programme managers).

If the boundary edges of an installed PL network is within 10 km of an international border, national administrations shall inform and co-ordinate any installed PL system with their neighbour (the 10 km distance taken as five times the maximum potential distance outlined in this report, 2 km, a factor of 14 dB).

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 contacts to enable an efficient resolution of interference cases.

5.5 DEVELOPMENT OF A HARMONISED EUROPEAN STANDARD

As there are no standards for PLs, ETSI has been requested to develop in the near future a harmonised standard for outdoor PLs.

5.6 ENFORCEMENT

A malfunctioning or a badly installed GNSS pseudolite system could affect the performance of non-participating GNSS receivers operating in areas near to the devices coverage area.

A malfunctioning or an unprofessionally installed GNSS pseudolite could cause impact or inaccuracy in participating or non-participating GNSS receivers operating in areas near the coverage area.

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 if a GNSS interference case is detected in the vicinity of the pseudolite installation, the operator of the system can quickly be contacted to verify proper operations in line with the stipulated licence conditions.

For GPS, PRN codes for applications other than GNSS satellites are already allocated in SIS ICD IS-GPS-200F [1]. As some transport vehicles use GNSS receivers for accurate positioning, there is a need for rapid enforcement actions if interference is caused and reported to GNSS services. However, due to the low level of received GNSS signals, there might be a problem in locating any interference. Consequently, administrations are reliant on the reports of interference to begin to find these. Low-level signals may not be easily detected.

If an installation is found to cause harmful interference, this should be rectified by comparing the installed equipment against the technical and operational conditions attached to the authorisation and perhaps including measured results of the effect on other non-participating GNSS receivers in the local vicinity. If necessary, make suitable adjustments to any installation or methods of interference assessment.

5.7 ADDITIONAL GUIDANCE FOR A REGULATORY APPROACH FOR OUTDOOR PSEUDOLITE SYSTEMS IN RNSS BANDS

Unlike mobile telecommunication network operators such as GSM or 3G, GNSS operators such as GPS and Galileo have no coverage obligations to provide location services in every environment. It is assumed that most of the systems delivering outdoor location services will be operated as “location system operators” in closed geographical areas, which are not open for public. They may rely on various technologies, including PLs. Only location systems involving outdoor PLs (“pseudolite systems”) and their operators (“pseudolite system operators”) are addressed in this Report.

Pseudolite system operators wishing to operate pseudolite systems will have the obligation to get an authorisation from the national regulatory authority of the country where they are operating (see section 2), taking into account that pseudolite systems cannot guarantee absence of interference with non-participating GNSS receivers relying on satellite signals in outdoor operations.

6 CONSIDERATION OF MOBILE PSEUDOLITES

As the knowledge of the location of GNSS pseudolite installations through licensing is recommended, CEPT administrations should not allow the installation of GNSS pseudolite in freely moving mobiles. Administrations may on a case by case basis, allow the use of PL in restricted areas on land vehicles, but these shall not be authorised for use in public environments.

7 CONCLUSIONS AND GUIDELINES FOR AUTHORISATION

For those CEPT administrations wishing to implement outdoor PLs, it is recommended that these PLs be operated through individual authorisations so as to ensure that no PL will be installed in areas where restrictions apply (e.g. airports and other areas for aeronautical operations). It is recommended that PL be operated through individual authorisations so as to ensure that no PL will be installed in areas where case by case studies are necessary (i.e. airports and other areas for aeronautical operations).These studies have to be reviewed and approved by national administrations. No PLs should be installed before completion of those studies.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 contacts to enable an efficient resolution of interference cases.

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 if a GNSS interference case is detected in the vicinity of the pseudolite installation, the operator of the system can quickly be contacted to verify proper operations in line with the stipulated licence conditions.

On the basis of the conclusions of the technical studies, administrations wishing to implement outdoor PLs may apply the following recommendations related to technical and operational conditions for outdoor PLs:

- Outdoor GNSS PLs should be authorised by individual licensing;
- Outdoor GNSS PLs should not be allowed in airports and other areas for aeronautical operations;
- GNSS PLs should only use dedicated codes; this should be a license condition;
- PRN codes dedicated to PLs are provided by the respective RNSS system operator and should be locally administered by national authority and geographical separation of PL using the same PRN codes should be ensured, they shall be specified as part of any licence;
- GNSS CW and pulsed-PLs should only be authorised in the 1559-1610 MHz band;
- Similar system in non-GNSS bands offset from Radionavigation Satellite allocations are an alternative means of providing pseudolite functionality without causing interference to GNSS receivers. Their accuracy and cost is currently not known;
- GNSS PLs transmitting continuously should be limited to an e.i.r.p. of -50 dBm, but the e.i.r.p. should be reduced to the minimum value for the required coverage and quality of service;
- GNSS PLs transmitting pulsed signal, mean e.i.r.p. should be limited to -50 dBm, but the e.i.r.p. should be reduced to the minimum value for the required coverage and quality of service;
- In special environment (e.g. open-pit mine) where longer PL signal range is required, a higher mean e.i.r.p. could be allowed. In such a case, special attention shall be given to the protection of RNSS and ARNS, by using mitigation techniques, as appropriate;
- Installations of pulsed PLs (moderate to high power, mean e.i.r.p. higher than -50 dBm) should not be allowed without licensing and without case by case studies;
- Any authorisations for GNSS pseudolite installations could include guidance for reduction and reasonable checking of the potential to cause interference;
- Using directive PL antennas tilted toward the ground;
- Adjust the PL e.i.r.p. duty cycle to minimise the impact to non-participating receivers;
- GNSS PLs transmitting pulsed signal with mean on-axis e.i.r.p. higher than -50 dBm, mitigation techniques should be applied to limit the e.i.r.p. above 0° degrees elevation (e.g., by using the antenna patterns), and to accept locally (inside the intended coverage area) a different value of SNR loss (e.g. 3 dB);
- In addition, the following elements should be taken into account:
    - Transmit antenna patterns have to be adapted according to the site requirements and coverage areas. Antenna patterns should be designed to minimise impact on non-participating receivers and focus only on the operations area;
    - Site installations should be conducted by professional installers only. This should include e.g. appropriate measures to avoid unauthorised insertion of additional RF power amplifiers between signal generator and antenna and others;

- Administrations should not allow the installation of GNSS pseudolite in freely moving mobiles. NRA's may on a case by case basis, allow the use of PL in restricted areas on land vehicles not authorised for use in public environments;
- Any authorisations for GNSS pseudolite installations could include guidance for reduction and reasonable checking of the potential to cause interference and a requirement to conduct regular installation monitoring tests to avoid the generation of unwanted interference;
- Military or other government authorities, including for meteorological, may require specific limitations at a deployment site to ensure adequate protection for their systems;
- Compatibility between pulsed PLs and the RAS is possible if there is an adequate separation distance between pseudolites and a Radio Astronomy Station and a PL out of band attenuation performance of 30 dB;
- In addition, in order to support the authorisation of PL in areas where case by case studies are necessary (e.g. airports and other areas for aeronautical operations) relevant authorities (e.g. local aviation authorities) need to be involved.

ANNEX 1: LIST OF REFERENCES

[1] The GPS ICD 200D is now IS-GPS-200E, http://www.losangeles.af.mil/shared/media/document/AFD-100813-045.pdf and the Galileo ICD is http://ec.europa.eu/enterprise/policies/satnav/galileo/files/galileo-os-sis-icd-issue1-revision1_en.pdf.

[2] ECC Report 128 on Technical and Operational Provisions Required for the Use of GNSS Pseudolites.

[3] ECC Report 145 on Regulatory Framework for Global Navigation satellite system (GNSS) repeaters.

[4] ETSI TS 136 171 V9.1.0 (2010-07) Requirements for Support of Assisted Global Navigation Satellite System (A-GNSS) (3GPP TS 36.171 version 9.1.0 Release 9).

[5] ECC Report 168 on Regulatory framework for indoor GNSS pseudolites.

[6] Recommendation ITU RA. 769 Protection criteria used for radioastronomical measurements.

[7] JRC Scientific and Technical Reports: Impact of Pseudolite Signals on Non-Participating GPS Receivers - Compatibility analysis for Commercial Receivers.