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Agenda item: 9.7.1

Source: Apple Inc.

Title: Regulatory update for the 6GHz frequency range

WI/SI: FS\_6GHz\_LTE\_NR

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# 1 Introduction

Study on 6 GHz for LTE and NR in Licensed and Unlicensed Operations is the RAN level study item, which aims at capturing the latest information and status of the regulatory decisions for the 6GHz frequency range. In this discussion paper we present a text proposal for the corresponding TR 37.890 that captures the latest status in ITU region 1.

# 2 Text proposal

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# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-172804: “Feasibility Study on 6 GHz for LTE and NR”, Ericsson, Verizon Wireless, Qualcomm Incorporated.

[3] ITU-R Radio Regulations, Articles, Edition 2016;

[4] FCC ONLINE TABLE OF FREQUENCY ALLOCATIONS, 47 C.F.R. § 2.106, December 13, 2017;

[5] FCC 17-104, Notice of Inquiry, “Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz”;

[6] Comments of IEEE 802, in GN Docket No. 17-183;

[7] APPLE INC., BROADCOM LIMITED,,CISCO SYSTEMS, INC., FACEBOOK, INC., GOOGLE LLC, HEWLETT PACKARD ENTERPRISE, INTEL CORPORATION,MEDIATEK INC., MICROSOFT CORPORATION, and QUALCOMM INCORPORATED, in GN Docket No. 17-183;

[8] Reply Comments of the Wireless Internet Service Providers Association, in GN Docket No. 17-183;

[9] Comments of Ericsson, in GN Docket No. 17-183;

[10] Comments of T-Mobile USA, in GN Docket No. 17-183;

[11] Comments of Verizon, in GN Docket No. 17-183;

[12] Reply Comments of the Satellite Industry Association, in GN Docket No. 17-183;

[13] Reply Comments of the Fixed Wireless Communications Coalition, in GN Docket No. 17-183;

[14] Comments of Dynamic Spectrum Alliance, in GN Docket No. 17-183;

[15] Comments of the National Spectrum Management Association, in GN Docket No. 17-183;

[16] Comments of CTIA, in GN Docket No. 17-183;

[17] Reply Comments of Cisco Systems, Inc., in GN Docket No. 17-183;

[18] Reply Comments of WI-FI Alliance, in GN Docket No. 17-183;

[19] PART 15 - Radio Frequency Devices, Title 47 of electronic Code of Federal Regulations;

[20] The European Table of Frequency Allocations and applications in the frequency range 8.3 kHz and 3000 GHz (ECA Table), October 2017;

[21] RSCOM17-53rev1- Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for wireless access systems including radio local area networks in the band 5925-6425 MHz for the provision of wireless broadband services.

[22] Draft ETSI TR 103 524 V0.0.10 (2018-01) - ERM System Reference document (SRdoc), “Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) in the band 5 925 MHz to 6 725 MHz”;

[23] CEPT/ERC/REC 74-01: “Unwanted Emissions in the Spurious Domain”;

[24] Draft ECC Report, “Compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5 925 – 6 425 MHz”, December 2017.

[25] FCC Notice of Proposed Rulemaking. FCC 18-147. October 24, 2018

[26] ETSI TR 103 612, MFCN in the band 6425-7125 MHz

[27] ETSI TR 103 631, Characteristics of WAS/RLANs in 6 725 to 7 125 MHz

[28] ECC Report 302, “Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz”

[29] CCSA-TC5-WG8-2019-003 Project Proposal on the feasibility study of IMT system using 5925-7125MHz frequency band, [http://www.ccsa.org.cn/tc/meeting.php?meeting\_id=6243#](http://www.ccsa.org.cn/tc/meeting.php?meeting_id=6243)

[30] World Radiocommunication Conference 2019 (WRC-19) Provisional Final Acts, ITU-R <https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.13-2019-PDF-E.pdf>

[31] Report and order and further notice of proposed rulemaking, FCC 20-51

[32] ECC Report 306, “Sharing studies assessing short-term interference from Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) into Fixed Service in the frequency band 5925-6425 MHz”, 21 May 2020

[33] CEPT Report 075, “to study feasibility and identify harmonised technical conditions for Wireless Access Systems including Radio Local Area Networks in the 5925-6425 MHz band for the provision of wireless broadband services”; Report B: Harmonised technical parameters for WAS/RLANs operating on a coexistence basis with appropriate mitigation techniques and/or operational compatibility/coexistence conditions, operating on the basis of a general authorisation. Not yet published

[34] ECC Decision (20)01; “On the harmonised use of the frequency bands 5945 to 6425 MHz for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLAN)” Not yet published

[35] ETSI TR 103 524, "System Reference document (SRDoc); Wireless access systems including radio local area networks (WAS/RLANs) in the band 5925 MHz to 6725 MHz"

[36] EN 303 687, “"6 GHz RLAN Harmonised Standard for access to radio spectrum", Draft

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## 4.1 ITU Region 1

### 4.1.1 Europe

#### 4.1.1.1 Introduction

According to the European Common Allocations Table (ECA Table) [20] in ERC Report 25 and the ECO Frequency Information System (EFIS), only the 5.925-6.700 GHz frequency range is allocated on a primary basis to MS-Mobile Service, FS-Fixed Service and FSS-Fixed Satellite Service (earth to space), and on a secondary basis to Earth Exploration Satellite Service - EESS (passive). 6.700-7.075 GHz frequency range is allocated on a primary basis to FS and FSS (earth to space, space to earth), and on a secondary basis to EESS (passive); 7.075-7.145 GHz is allocated on a primary basis to FS and on a secondary basis to EESS (passive). In Russian federation, according to RR 5.459, 7.100-7.125 GHz is allocated to space operation service (Earth-to-space) on a primary basis. Generic SRD (UWB), LPR and TLPR also operate in 5.925-7.125 GHz frequency ranges on a no protection and no interference basis. More details are provided in Table 4.1.1.1-1 [20].

Table 4.1.1.1-1: European Allocation in 6 GHz

|  |  |  |
| --- | --- | --- |
| Frequency Range [MHz] | Allocation | Applications/Notes |
| 5 925 – 6 700 | MOBILEFIXEDFIXED-SATELLITE (EARTH TO SPACE)Earth Exploration Satellite (Passive)5.1495.4405.458 | ESV/Within 5925-6425 MHzFSS Earth stations/Priority for civil networksFixed/Point-to-pointPassive sensors (satellite)/For sea surface temperature, sea surface wind speed and soil moisture measurementsRadio astronomy/Spectral line observations, VLBIRadiodetermination applications/Within 4500-7000 MHz for TLRP application and 6000-8500 MHz for LPR applicationsUWB applications/Generic UWB as well as UWB on-board aircraft regulation within 6.0-8.5 GHz |
| 6 700 – 7 045 | FIXEDFIXED-SATELLITE (EARTH TO SPACE) (SPACE TO EARTH) 5.441Earth Exploration Satellite (Passive)5.4585.458A5.458B | FSS Earth stations/Within 6725-7025 MHz. Priority for civil networksFeeder linksFixed/ Point-to-point PMSE/ portable or mobile wireless video, cordless cameras, temporary P-t-P video links in 7-8.5 GHz tuning rangePassive sensors (satellite)/For sea surface temperature, sea surface wind speed and soil moisture measurementsRadiodetermination applications/Within 4500-7000 MHz for TLRP application and 6000-8500 MHz for LPR applicationsUWB applications/Generic UWN as well as UWB on-board aircraft regulation within 6.0-8.5 GHz |
| 7 045 – 7 145 | FIXEDEarth Exploration Satellite (Passive)5.458 | Fixed/ Point-to-pointPMSE/ portable or mobile wireless video, cordless cameras, temporary P-t-P video links in 7-8.5 GHz tuning rangePassive sensors (satellite) / For sea surface temperature, sea surface wind speed and soil moisture measurementsRadiodetermination applications/Within 6000-8500 MHz for LPR applicationsUWB applications/Generic UWB as well as UWB on-board aircraft regulation within 6.0-8.5 GHz |

Allocation for services (ITS, UWB, WIA, non-specific SRDs) in adjacent bands is shown in Table 4.1.1.1-2 and 4.1.1.1-3.

Table 4.1.1.1-2: Adjacent services below 5.925 GHz

|  |  |  |
| --- | --- | --- |
| Frequency Range [MHz] | Allocation | Applications/Notes |
| 5 850 – 5 925 | FIXEDFIXED-SATELLITE (EARTH TO SPACE)MOBILE5.150 | BFWA/Within 5725-5875 MHzDA2GC/Within 5855-5875 MHzFSS Earth stations/ priority for civil networksISM/Within 5725-5875 MHzMBR/Within 5852-5872 MHz and 5880-5900 MHzITS/ Within 5875-5925 MHz and 5855-5875 MHz. Traffic safety applications within 5875-5905 MHzNON-specific SRDs/Within 5725-5875 MHzRadiodetermination applications/ Within 4500-7000 MHz for TLPR applicationsWIA/Within 5725-5875 MHz |

Table 4.1.1.1-3: Adjacent services above 7.145 GHz

|  |  |  |
| --- | --- | --- |
| Frequency Range [MHz] | Allocation | Applications/Notes |
| 7 145 – 7 190 | FIXEDMOBILESPACE RESEARCH (DEEP SPACE) (EARTH TO SPACE)Space Operation (Earth-to-space)5.458 | Fixed/ Point-to-pointPMSE/ portable or mobile wireless video, cordless camera, temporary video links in 7-8.5 GHz tuning rangeRadiodetermination applications/ within 6.0-8.5 GHz for LPR applicationsUWB applications/Generic UWB. On-board aircraft regulations within 6.0-8.5 GHz |

#### 4.1.1.1a European standardisation

There are a number of ETSI deliverables that pertain to the 5925-7125 MHz frequency range. The relationship between these ETSI deliverables, System Reference Document (SRDoc), Technical Report (TR), the EC Mandate to CEPT, and Harmonized Standard (EN), is as shown in Figure 4.1.1.1a-1.



Figure 4.1.1.1a-1: Relationship between ETSI Deliverables and EC 6GHz Mandate.

The ETSI deliverables are as follows:

- ETSI TR 103 524 [35]: this document provides information on the intended applications, the technical parameters, mitigation techniques, the relation to the existing spectrum regulation and additional new radio spectrum requirements for Wireless access systems including radio local area networks (WAS/RLANs). The present document presents justification on the need for additional new license exempt spectrum for Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) in the 5 925 MHz to 6 725 MHz frequency range to support future growth, particularly of WAS/RLANs with greater utilization and efficiency of this spectrum. This document was also suggesting considering the additional 6 425-6 725 MHz frequency range and not only the 5 925-6 425 MHz frequency range, which was opposed by two Administrations.

- ETSI TR 103 631 [27]: this document provides information on the intended applications, the technical parameters, mitigation techniques, the relation to the existing spectrum regulation and additional new radio spectrum requirements for technology neutral wireless access systems including radio local area networks (WAS/RLANs) capable of operating in the 6 725 MHz to 7 125MHz range.

- ETSI TR 103 612 [26]: this document considers the possibility of sharing the frequency range 6 425 - 7 125 MHz between the incumbent services and MFCN (Mobile/Fixed Communication Network) services. It was concluded that the frequency range 6 425 – 7 125 MHz has the potential to support the growing demand for mobile broadband and other use cases. Further feasibility studies are required to assess the challenges around the co-existence and compatibility of 5G NR technology with the incumbent services in the same frequency range and neighbouring frequencies respectively.

- Draft ETSI EN 303 687 [36]: this Harmonised standard will specify technical characteristics and methods of measurements for Wireless access systems including radio local area networks (WAS/RLANs) operating in the band 5 925 MHz to 6 425 MHz

#### 4.1.1.2 Licensed operations

ETSI TFES has finalized a Technical Report [26] on the “possibility of sharing the band 6425-7125 MHz between the incumbent services and MFCN (Mobile/Fixed Communication Network) services.”. The summary of the document indicates that "*The present document does not include the co-existence studies to analyse the risk of interference between incumbent services and the 5G NR technology, which can be the next step in the process of feasibility study*". The conclusions, state that "*… further feasibility studies are required to assess the challenges around the co-existence and compatibility of 5G NR technology with the incumbent services in the same frequency range and neighbouring frequencies respectively. The present document can be considered as the base for such studies to determine the technical conditions to use the MFCN in this band*".

#### 4.1.1.3 Unlicensed operations

In December 2017, EC Radio Spectrum Committee finalized the Mandate to CEPT [21] to study and identify harmonised compatibility and sharing technical conditions for a sustainable and efficient use on a shared basis of the frequency range 5.925-6.425 GHz for Wireless Access Systems including Radio Local Area Networks (WAS/RLANs).

CEPT has created two new project teams, ECC SE 45 (coexistence) and ECC FM 57 (regulatory). ECC SE 45 has been tasked to undertake compatibility and sharing studies in the 5925-6425MHz GHz frequency range to support ECC FM 57, and the latter will define the regulatory rules for the band. The scope of the work items in these groups is the introduction of low power wireless access systems (including RLAN) in the frequency range 5.925-6.425 GHz under a non-protected and non-interference basis, ensuring certainty of continued operation, development and protection of existing services (Fixed Services (FS), Fixed Satellite Service (FSS)) considering RR 5.440 and 5.458. Currently, no WAS/RLAN coexistence studies have been undertaken within CEPT for the 6425-7125MHz range.

ETSI has published the draft TR 103 524 [22] providing information on the technical parameters for WAS/RLANs to support the CEPT Work Items activities covering the frequency range 5.925 GHz to 6.425 GHz. In addition, it contains a request for considering additional frequencies up to 6.725 GHz.

ETSI assumptions/proposals on technical RLAN parameters to be used for compatibility and sharing studies are reported in the following:

* BS maximum TX output power: 30 dBm EIRP;
* Band plan: 5.925-6.725 GHz (guard band towards ITS below 5.925 GHz may be accommodated at the lower edge);
* Channel BW: 20, 40, 80, 160 MHz for the IEEE802 standard; wider channel bandwidth can be supported by 3GPP standards via carrier aggregation, up to 32 carriers (including at least one anchor carrier in a licensed band) for eLAA. (Similar configurations for NR-U mentioned but without details on bandwidths and aggregated carriers).
* TX unwanted emissions in the 6 GHz bands: same transmitter spectrum mask as used in 5 GHz (since same modulation assumed) shown in Figure 4.1.1.3-1;



Figure 4.1.1.3-1: Transmit spectral power mask for RLAN equipment

* TX unwanted emissions outside the 6 GHz bands: as specified in ERC Recommendation 74.01 [23] and reported in Table 4.1.1.3-1.

Table 4.1.1.3-1: Out of band emissions limits

|  |  |  |
| --- | --- | --- |
| Frequency range | Limits | Reference Bandwidth |
| 30-47 MHz | -36 dBm | 100 kHz |
| 47-74 MHz | -54 dBm | 100 kHz |
| 74-87.5 MHz | -36 dBm | 100 kHz |
| 87.5-118 MHz | -54 dBm | 100 kHz |
| 118-174 MHz | -36 dBm | 100 kHz |
| 174-230 MHz | -54 dBm | 100 kHz |
| 230-470 MHz | -36 dBm | 100 kHz |
| 470-862 MHz | -54 dBm | 100 kHz |
| 0.862-1 GHz | -36 dBm | 100 kHz |
| 1-5.925 GHz | -30 dBm | 1 MHz |
| 6.725-26 GHz | -30 dBm | 1 MHz |

The Draft ECC Report on compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency range 5.925 – 6.425 GHz [24], developed by SE45, will use the technical characteristics specified in the ETSI TR 103 524 [22] for RLAN as starting point, and the technical parameters provided from SE19 and SE40 for FS and FSS respectively. It is to be noted that some of the technical parameters (for example max EIRP, TX unwanted emissions, etc.) for RLAN in the ETSI TR 103 524 may differ from the final rules for the band, depending on the results of the compatibility studies done by CEPT.

ETSI BRAN has initiated a Technical Report [27] to describe the technical parameters of unlicensed services in the 6.725 – 7.125 GHz frequency range. This TR (v1.1.1) was published in March 2019.

##### 4.1.1.3.1 Coexistence aspects

###### 4.1.1.3.1a ECC Report 302

ECC Report 302 [27] was approved during ECC WGSE#82 meeting (May 27th-29th). This report was triggered by EC Mandate on 6GHz and deals with sharing and compatibilities studies between WAS/RLAN and existing incumbent services or applications in the 5925-6425 MHz band and in the adjacent bands under a non-protected basis, ensuring certainty of continued operation, development and protection of existing incumbent services. The work is related to the EC Mandate to CEPT on WAS/RLAN in the 5925-6425 MHz band with the aim of exploring the availability of additional spectrum for the provision of internet-based services with increased data capacity and speed.

This Report lists the various coexistence studies that have been done in ECC SE45.Three different scenarios (Low, Mid and High) have been investigated considering busy hour and market adoption factors. The Report provides some preliminary conclusions on coexistence with:

* Fixed Service

Three types of studies have been done to evaluate interference from RLAN to FS networks.

The first study, based on MCL analysis, highlights two different types of areas where RLAN could possibly exceed the protection criteria (a circular area with small radius and a peak area largely down the boresight) and reveals critical scenarios without concluded about the likelihood of them.

The second study is a Monte Carlo study and analyses fixed links in UK and Netherlands. It shows that the long-term interference criterion is met (I/N value of -10dB not exceeded for more than 20% of time as advised by Recommendation ITU-R F.758). Another complementary protection criterion (FDP < 10%) was also studied and was exceeded for some of the link in the UK, some of those scenarios where exceedance occurred was considered as highly improbable. By restricting deployment to indoor only with a maximum EIRP of 200mW, almost all cases would be resolved. Based on these conditions, the conclusion is that sharing with FS is feasible.

The third study is based on three existing FS receivers in France and shows that outdoor RLAN operating with an EIRP of 1W would create interference from a large area around the FS link. But restricting the usage to indoor with an EIRP of 250mW would considerably reduce them. The statistically study based on Monte Carlo approach indicates that the long term protection criterion is not exceeded.

* Fixed Satellite Service

A representative set of FS satellites with coverage over Europe was used for those two studies.

The first study is based on Monte Carlo methodology and considers the Mid scenario. Results show feasibility on spectrum sharing based on the taken assumptions.

The second study is based on static analysis considering average values for the Low, Mid and High scenarios for RLAN deployment model in Europe by 2025. Results show the protection criterion is satisfied except for the High scenario, the calculated interference level was found out to be close to the FSS protection criterion used in the study.

Further investigation was done to investigate the sensitivity of increasing the proportion of outdoor WAS/RLAN usage above the agreed parameters – up to 5% outdoor use, The results highlight the risk of excess interference for the high scenario with the most sensitive satellite should higher power outdoor usage increase beyond the agreed parameters (3% outdoor) To compensate for this, the report is suggesting limiting RLAN usage to indoor with an EIRP limit.

* Road Intelligent Transportation Systems

A coexistence study, using the minimum coupling loss methodology, was done to assess the out-of-band emissions on Road-ITS service below 5925 MHz (adjacent band), considering a protection criterion of -6 dB I/N.

The results show that with appropriate WAS/RLAN Out-of-Band-Emissions limits road-ITS is protected plus with indoor usage obviously providing even better coexistence. Depending on the scenario, the RLAN out of band emissions should have a limit between -69 dBm/MHz and -36 dBm/MHz (main-lobe case) and between -59 dBm/MHz and -26 dBm/MHz (side-lobe case).

The most stringent requirement would be when the ITS antenna is integrated inside the vehicle (which might be an unlikely scenario).

The RLAN indoor usage scenario resulted in the least stringent Out of Band emissions below 5925 MHz.

* Communication-based Train Control systems

Two types of study were done to investigate CBTC protection: one with CBTC operating in the adjacent band, and the other one with CBTC operating in-band.

The study with CBTC in the adjacent band shows that RLAN out of band emission of -29 dBm/5 MHz would be sufficient to protect CBTC if RLAN is deployed indoor. If RLAN would operate indoor starting at 5940 MHz, an in-band EIRP of 21.5 dBm/20 MHz would comply with CBTC blocking requirements. Also, with RLAN portable devices (outdoor scenario), the study shows that RLAN out of band emission of -42dBm/5 MHz and an EIRP of 4.7 dBm/20 MHz would ensure CBTC operation.

The in-band study for the S-train in Copenhagen concludes that the distance between RLAN device and CBTC receiver should be in the range of 180 and 600m to avoid interference on the CBTC receiver. Such distance may not be guaranteed so dedicated mitigations techniques, to be applied locally (i.e. for Copenhagen) would need to be specified.

Note: During further discussions within CEPT there were some proposals to move the first WAS/RLAN channel for portable devices to 6025 MHz which would require the loss of one 160 MHz channel. There were also discussions on County Determination Capabilities and geolocation databases.

* Radio Astronomy

The number of Radio Astronomy sites in this frequency range is limited (around 19); compatibility would be then addressed on a case by case basis, at the national level. The Report suggests than an I/N threshold can be used to derive a zone around the RAS site following the applicable ITU-R Recommendations. The zone contours could be considered as coordination or exclusion zones, which would need to be managed by the Regulator.

* Ultra Wide Band

The introduction of WAS/RLANs could have an impact on the applications and users of UWB systems that can only operate over the frequency range under study in this Report. An MCL analysis studied a range of EIRP levels (0 dBm to 30 dBm) has shown that an individual RLAN would cause 3 dB sensitivity loss from between 30 m and 946 m away for location tacking systems and from 7 to 212m for UWB sensing applications. Aggregate interference studies using Monte Carlo simulations and RLAN activity factor shows that the probability exceeds 3 dB from 0.0024% to 3.3% depending on the scenario for location tracking devices. For UWB sensing applications the probability exceeds 0.042% to 1.7%.

Note: UWB operates under a non-interference regulatory regime and as such cannot claim protection from interference

###### 4.1.1.3.1b ECC Report 316

The ECC Report 316 [32], presented two studies expanding upon the studies in ECC Report 302 [27] by assessing the possible short-term interference impact of the WAS/RLANs into point-to-point Fixed Service (FS) links:

- Site-general Monte Carlo analysis;

- Site-specific sensitivity analysis on LPI deployment assumptions based on radio coverage.

A combination of low power indoor (LPI) WAS/RLANs operating at power levels up to 200 mW and outdoor Very Low Power (VLP) portable WAS/RLANs up to 25 mW is used in the studies

Results of the site-general Monte Carlo analysis show that the percentage of events for which the short- term threshold (I/N = 19 dB) is not exceeded for more than 4.5 ⋅ 10-4% (which was used as a proxy for short- term protection criterion) for the studied combinations of FS antenna heights, population densities, and WAS/RLAN deployment. Various VLP outdoor percentages of WAS/RLAN deployment show no effect on the overall interference impact.

Results of the site-specific sensitivity analysis on LPI deployment assumptions based on radio coverage have shown that the size of the area from where a WAS/RLAN may create interference to the FS receiver is sensitive among others to the clutter loss, building entry loss, WAS/RLAN height and position (relative to FS main beam). For the WAS/RLAN RF activity factor of 2%, it should be noted that for the combinations where some positions depict the exceedance of the short-term threshold I/N = 19 dB, this interference may be created for more than 4.5 ⋅ 10-4% of the time in any month (for errored seconds); the probability of this occurring has not been studied.

###### 4.1.1.3.1c CEPT Report 075

[Note: The CEPT Report 075 [33] is under Public Consultation and should be published by end of 2020].

###### 4.1.1.3.1d ECC Decision (20)01

[Note: The ECC Decision 20(01) [34] is under Public Consultation and should be published by end of 2020].

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