



CEPT Report 74

Report from CEPT to the European Commission in response to the Mandate on spectrum for the future railway mobile communications system

Report A: Spectrum needs and feasibility (tasks 1 to 4)

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0 EXECUTIVE SUMMARY

The present CEPT Report answers tasks 1 to 4 of the Mandate from the European Commission to CEPT on spectrum for the future railway mobile communications system (FRMCS).

Only non-AAS FRMCS has been considered. Additional studies should be performed in case AAS are considered for FRMCS deployments.

Task 1: spectrum needs for mission critical operation of the future railway mobile communications system (successor system of GSM-R)

Ensuring railway interoperability throughout Europe must be considered when determining spectrum needs. Having the possibility to reuse as much as possible the current radio network infrastructure (BS sites) would save costs, time and reduce operational burden. Therefore, the spectrum in the whole 2x5.6 MHz in 874.4-880 MHz / 919.4-925 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond. Considering the FRMCS rollout timeframe, it may not make sense to invest in a 4G network compared to 5G. A migration using only the 900 MHz spectrum would require that the initial FRMCS deployment uses a deployment of a 1.4 MHz LTE carrier adjacent to GSM-R, or the realisation of overlapping NR wideband channels in a co-channel deployment with GSM-R.

The targeted 2x5.6 MHz of spectrum could be used by a 5.6 MHz FDD NR carrier during both migration and post-migration. Such a carrier would provide a higher traffic handling capacity than the current 3GPP defined 5 MHz carrier and thus would better support the anticipated growth of the FRMCS traffic volume. Although current indications are that such a 5.6 MHz carrier should be feasible within the 3GPP NR specifications, additional work is necessary in 3GPP to confirm feasibility and carry out the specification work.

In-band coexistence, based on an overlay of a 5 MHz FDD NR carrier or of a 5.6 MHz FDD NR carrier, co-channel with GSM-R carriers, would be an option for the migration using the 900 MHz spectrum while maintaining operation of GSM-R.

Alternatively, a 5 MHz FDD LTE/NR carrier could be implemented plus several NB-IoT carriers in the remaining 600 kHz. An NB-IoT carrier potentially supports a larger coverage area than a 5 MHz LTE/NR carrier. Certain critical railway applications like monitoring and control of critical infrastructure may benefit from the usage of NB-IoT.

As another alternative, a 1.4 MHz FDD LTE carrier may be used, adjacent to the 4 MHz for GSM-R during migration. This approach would have a lower traffic handling capacity and needs to be considered in terms of product lifecycle and longer-term migration to NR.

Furthermore, considering the throughput requirements, access to complementary spectrum, such as 1900-1910 MHz, is a prerequisite for many countries in order to fulfil the interoperability requirements, to enable parallel operation of GSM-R and its successor, to benefit from new railway critical applications (including ATO and critical sensing/video), and to deal with border and hotspot areas. Hence the spectrum 1900-1910 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond.

This does not preclude the use of public mobile networks, noting that the railway interoperability, coverage, availability and QoS requirements still needs to be fulfilled.

Task 2: technical feasibility for operating the successor system in the 874.4-880 MHz / 919.4-925 MHz frequency band while ensuring simultaneous operation of GSM-R and the successor system in these bands during a migration period

The 874.4-880 MHz / 919.4-925 MHz frequency band is feasible for RMR, provided that the following conditions are met.

1. RMR BS shall ensure coexistence with ECS BS receiving below 915 MHz. The statistical approach, as described in ECC Report 318, relying on existing GSM-R and ECS deployment data, was chosen to define the BEM which enables uncoordinated deployments, while ensuring an acceptably low occurrence probability of

residual interference cases to be addressed at national level when interference occurs. The BEM for FRMCS will include channels of 1.4 MHz, 5 MHz and 5.6 MHz.

National regulation may allow multiple carriers using wideband technologies¹ or higher e.i.r.p. for RMR BS than stated in the technical conditions, as long as no harmful interference on ECS BS can be ensured. As part of a national coordination procedure, the infrastructure manager could, for example, demonstrate that a coexistence criterion with respect to each ECS BS in the vicinity of the RMR radio site is fulfilled. The relevant national coordination procedure may differ from country to country, taking into account that coordination procedures with regard to ECS / GSM-R are already in force based on the guidance as described in ECC Report 229 [27].

2. FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 874.4-880 MHz provided that UL power control is activated, and that FRMCS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

3. RMR cab-radios shall be robust against adjacent emissions, including ECS BS above 925 MHz, aerial UE using ECS below 915 MHz and SRD below 919.4 MHz. For the latter case, the required level of robustness is driven by 4W RFID interrogators. ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR cab-radios.

Improved GSM-R cab-radios as per ETSI TS 102 933-1 are currently being deployed and are specified for the improved reception of GSM-R in the vicinity of intensive ECS emissions above 925 MHz, but the current GSM-R cab-radio receiver specification is less resilient against adjacent emissions from higher-power SRD below 919.4 MHz in some close proximity cases. Administrations may further consider the protection of GSM-R cab-radios² if the requirements in 916.1-918.9 MHz on the GSM-R cab-radio receiver in Table 2 of ECC Report 313 are not met.

FRMCS cab-radios need to fulfil the receiver characteristics determined in ECC Report 313.

4. RMR BS shall be robust against adjacent emissions, including SRD below 874.4 MHz. ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR BS.

5. When in close vicinity to rail tracks, ECS BS unwanted emissions may cause interference to FRMCS cab-radio. In practice, to solve these cases, technical and/or operational measures could be taken to ensure the coexistence of both ECS and FRMCS in parallel.

6. With respect to the use of a single NB-IoT carrier for FRMCS, the studies in ECC Report 318 can be applied to the in-band operation mode without power boost and to the standalone operation mode. If multiple carriers using wideband technologies¹ or power boost were to be used for in-band NB-IoT, the BEM would not directly be applicable.

Task3: technical feasibility for operating the successor system in part of the 1900-1920 MHz frequency band

The 1900-1910 MHz frequency band is feasible for FRMCS, provided that the following conditions are met.

1. FRMCS BS shall ensure coexistence with ECS BS receiving above 1920 MHz while ensuring an efficient use of spectrum. For uncoordinated deployment, the BEM for FRMCS BS will assume that ECS BS have enhanced selectivity compared to the current Harmonised European Standards. This would facilitate coexistence with FRMCS BS transmitting up to 65 dBm e.i.r.p. with the aim of having a future-proof regulation and allowing macro coverage. Current ECS BS located near an FRMCS radio site may need to be adapted, in such a way that they do not suffer interference from FRMCS. In such case, additional mitigation techniques would be needed, such as the upgrade of the ECS BS selectivity or on a case-by-case basis adjustment of antenna directivity, azimuth, tilt, etc. of the FRMCS and/or ECS BS³.

¹ including NB-IoT

² National coordination is allowed as per Note 7 relative to the table on the harmonised technical conditions for SRD in Decision (EU) 2018/1538.

³ Adjustments of antenna directivity, azimuth, tilt may not be sufficient to solve all interference cases. MFCN BS with improved selectivity would avoid the need for national coordination.

The improvement of the ECS selectivity for those ECS BS near the railway tracks can be achieved by either the usage of new radio units of ECS BS or by adding external filter to existing radio units operating with passive antenna systems. Enhanced selectivity should be included (potentially as a specific receiver class) in the relevant ECS BS Harmonised European Standards so that newly introduced products placed on the market based on this update natively fulfil this requirement.

The BEM for FRMCS BS will assume ECS BS with enhanced selectivity. In order to ensure that the ECS operators have enough time to adapt the concerned radio sites, they should have, sufficiently far in advance, information on the rollout of a new FRMCS BS in 1900-1910 MHz.

The BEM for FRMCS will include one channel of 10 MHz.

2. FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 1900-1910 MHz provided that UL power control is activated, and that FRMS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

3. FRMCS cab-radios shall be robust against adjacent emissions, including ECS BS below 1880 MHz and aerial UE using ECS above 1920 MHz. Depending on the possible introduction of governmental UAS in 1880-1920 MHz, ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR cab-radios.

4. FRMCS BS shall be robust against adjacent emissions, including ECS BS below 1880 MHz.

5. With regard to adjacent compatibility between DECT (1880-1900 MHz) and FRMCS, it is understood that FRMCS and DECT, adjacent to each other, will generally coexist. Where the DECT usage density is not high, the Dynamic Channel Selection (DCS) algorithm implemented in DECT would then allow the communication to use one of the DECT channels that do not experience interference. In some worst case scenarios, measures to enable coexistence between DECT in 1880-1900 MHz and RMR in 1900-1910 MHz might be needed, when information on DECT local deployment is made available.

Task 3bis: if necessary, technical feasibility for operating the successor system in another frequency band

The use of the 2290-2300 MHz frequency band for FRMCS raises several technical challenges to enable unsynchronised operation together with ECS TDD networks in the 2.3 GHz band. The required geographical protection distances between unsynchronised base stations are expected to be so large that this is not considered a realistic option for FRMCS deployment. The possible implications of a synchronised operation between FRMCS and ECS (which also includes sharing the same UL and DL frame structure) has not been studied. Considering that railways anticipate heavy UL traffic (see Table 5), it is unlikely that the required synchronisation of compatible TDD frame configurations between RMR and neighbouring ECS would be achieved.

The feasibility of FRMCS high-power cab-radios in terms of coexistence with ECS as well as of FRMCS coexistence with other applications in or adjacent to the band would require further study.

When considering ECC Report 172, coexistence of FRMCS with existing applications in and adjacent to the band 2290-2300 MHz as documented in the synthesis of the answers to the CEPT questionnaire on the 2290-2400 MHz range⁴, is challenging and would also require further studies.

The overall conclusion is that the 2290-2300 MHz frequency band is not a preferred option for identifying appropriate complementary spectrum for RMR.

Task 4: technical feasibility and scenarios of using commercial mobile networks

From a technical point of view, the use of commercial mobile networks for critical railway applications is possible under the condition that the relevant parts of the MNO's network fulfil the stringent interoperability, coverage, availability and QoS requirements of railways (including prioritisation and pre-emption). Use of a commercial mobile network would need to be specified and tested under real-life conditions to ensure those

⁴ See the synthesis in FM(20)056-Annex 11

railway requirements are met. To date, MNO processes do not cover railway safety-related and interoperability assurance, which currently requires extensive certification.

Some elements would require further exploration with respect to railway safety, certification and validation. Key issues are MNO's legal obligations, liabilities and risk assessment. In addition, the European railway regulatory framework must be fulfilled to guarantee interoperability.

MNO networks that do not fulfil railway requirements might be used for lines with different requirements and non-critical railway communications. Use of commercial mobile networks can also be envisaged to offer some flexibility in providing additional capacity to the spectrum harmonised for railway interoperability.

For the retention of the railway interoperability, the EIRENE SRS and CCS TSI should be amended to make the use of commercial mobile networks possible.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AAS	Active Antenna System
ACLR	Adjacent Channel Leakage power Ratio
ACS	Adjacent Channel Selectivity
ARPU	Average Revenue per User
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
BEM	Block Edge Mask
BS	Base Station
CCS	Control-Command and Signalling
CEPT	European Conference of Postal and Telecommunications Administrations
COTS	Commercial Off-The-Shelf
DECT	Digital Enhanced Cordless Telecommunications
DL	Downlink
EC	European Commission
ECC	Electronic Communications Committee
ECS	Electronic Communications Services
EDOR	ETCS Data Only Radio
EDP	European Deployment Plan
EIRENE	European Integrated Railway Radio Enhanced Network
e.i.r.p.	Equivalent Isotropic Radiated Power
ERA	European Union Agency for Railways
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
ETSI	European Telecommunications Standardisation Institute
EU	European Union
FDD	Frequency Division Duplex
FRMCS	Future Railway Mobile Communication System
FRS	Functional Requirements Specification
GBR	Guaranteed Bit Rate
GoA	Grade of Automation (4 levels)
GSM	Global System for Mobile communications
GSM-R	GSM for Railway
IAS	Internet Access Service

IC	Interoperability Constituent
IM	Infrastructure Manager
IMS	IP Multimedia Subsystem
KPI	Key Performance Indicator
LAS	Link Assurance Signal
LRTC	Least Restrictive Technical Conditions
LSA	Licensed Shared Access
MCL	Minimum Coupling Loss
MI	Mandatory for Interoperability
MNO	public Mobile Network Operator
MVNO	Mobile Virtual Network Operator
NB-IoT	Narrowband Internet of Things
QoS	Quality of Service
RB	Resource Block
RED	Radio Equipment Directive
R-GSM	Railways GSM (876-915 MHz / 921-960 MHz as defined by ETSI)
RFID	Radio Frequency Identification
RMR	Railway Mobile Radio
RU	Railway Undertaking
SpS	Specialised Service
SRD	Short Range Devices
SRS	System Requirements Specification
SSB	Synchronisation Signal Block
TC RT	Technical Committee for Rail Telecommunications (ETSI)
TSI	Technical Specification for Interoperability
UAS	Unmanned Aircraft System
UIC	Union Internationale des Chemins de fer
UL	Uplink
WAPECS	Wireless Access Policy for Electronic Communications Services

1 INTRODUCTION

This Report has been developed by the European Conference of Postal and Telecommunications Administrations (CEPT) in response to the Mandate from the European Commission to CEPT on spectrum for the future railway mobile communications system (FRMCS), in particular to tasks 1, 2, 3 and 4.

- Task 1 relates to the spectrum needs for mission critical operation of the future railway mobile communications system (successor system of GSM-R);
- Task 2 relates to the technical feasibility for operating the successor system in the 874.4-880 MHz / 919.4-925 MHz frequency band while ensuring simultaneous operation of GSM-R and the successor system in this band during a migration period;
- Task 3 relates to the technical feasibility for operating the successor system in part of the 1900-1920 MHz frequency band and, if necessary, the technical feasibility for operating the successor system in another frequency band;
- Task 4 relates to the technical feasibility and scenarios of using commercial mobile networks.

This Report gathers and complements the relevant elements from the following ECC Reports:

- ECC Report 294 on assessment of the spectrum needs for future railway mobile radio (RMR) communications;
- ECC Report 318 on compatibility between RMR and MFCN in the 900 MHz range, the 1900-1920 MHz band and the 2290-2300 MHz band;
- ECC Report 313 on coexistence between RMR in the 900 MHz frequency range and other applications in adjacent bands;
- ECC Report 314 on coexistence between FRMCS in the 1900-1920 MHz frequency range and other applications in adjacent bands;
- ECC Report 309 on use of MFCN for the command & control and payload links of UAs within the current MFCN harmonised regulatory framework.

In these studies, only non-AAS FRMCS and ECS have been considered. Additional studies should be performed in case AAS are considered for FRMCS deployments.

2 RAIL SPECIFICITIES

2.1 DEFINITIONS

Term	Definition
Aerial UE	The term “aerial UE” is equally applicable to unmanned aircraft (drone) and manned aircraft (see ECC Report 309)
ATO (Automatic Train Operation)	Functions otherwise assigned to the train driver
ATO degraded mode	Fallback mode in case of ATO failure, which allows the continued operation of a train at lower speed under continuous visual control by an on-board or remote train driver using video transmission
ATP (Automatic Train Protection)	System that ensures automatic compliance with railway signalling
Cab-radio	In this Report, the radio equipment on-board the train capable of supporting both voice and data applications (e.g. ETCS)
ERTMS (European Rail Traffic Management System)	European railway system, including trackside and on-board control-command and signalling subsystem as well as operation and traffic management, relying on a common radio access technology (today GSM-R) and ETCS
ETCS (European Train Control System)	Applicative protocol for railway signalling and train protection to enable railway interoperability at European level
GSM-R (GSM for Railway)	Current radiocommunication network for railways, which provides voice services (including emergency voice calls) and carries ETCS and other data services
Guard-band	The minimum channel edge to channel edge frequency separation
Infrastructure Manager	The entity who administrates the rail track network and the associated radio access network (today GSM-R)
M (Mandatory)	Designates mandatory requirements to allow that the technical characteristics of the network and fixed terminals are compatible with each other and with terminals on-board the trains or handheld
MI (Mandatory for Interoperability)	Designates mandatory requirements on lines under the scope of the Interoperability Directive [1] to ensure technical compatibility between Member States and safe integration between train and track
Movement authority	Information about where the train is allowed to safely move
Railway interoperability	Ability for trains and staff to operate uninterruptedly across borders and railway networks (requirement defined in the EU Directive 2016/797 [1], supplemented by Commission Delegated Decision (EU) 2017/1474 [18], formerly EC Directive 2008/57)
Railway Mobile Radio	Encompasses GSM-R and its successor(s), including the Future Railway Mobile Communication System (FRMCS)

Term	Definition
Railway signalling	Speed limits and movement authorities (provided by trackside signals, balises or wireless communications)
Railway Undertaking	A company which operates trains and thus uses the radio access network (today GSM-R) provided by the Infrastructure Manager

2.2 RAILWAY INTEROPERABILITY

Railway transport occupies a core position in Europe's overall transport sector, and the interoperability of the rail system within the European Union is the cornerstone of the establishment of a single European railway area. The concept of one single signalling system at EU level, to enhance interoperability, dates back to 1989, when the Commission launched an analysis of signalling issues across the EU Member States. The first legislative acts serving that objective were issued in 1996 with the so-called Interoperability Directive related to trans-European high-speed trains and in 2001 with another Interoperability Directive, this time related to trans-European conventional rail system. The Interoperability Directive currently in force dates from 2016 [1].

The interoperability of the European railway system is ensured today by the Railway Interoperability Directive [1] and the Technical Specifications for Interoperability (CCS TSI) [4] which provide the regulatory framework.

In the Directive 2016/797/EU [1] on the interoperability of the railway system within the Community, the definition of railway interoperability can be found in its Article 2:

'interoperability' means the ability of a rail system to allow the safe and uninterrupted movement of trains which accomplish the required levels of performance;

The technical details required for railway interoperability are included in the Technical Specifications for Interoperability (CCS TSI [4]). The definition, also in Article 2 of the Interoperability Directive 2016/797/EU, explains its content:

'technical specification for interoperability' (TSI) means a specification adopted in accordance with this Directive by which each subsystem or part of a subsystem is covered in order to meet the essential requirements and ensure the interoperability of the Union rail system;

Some of the requirements in the EIRENE specifications⁵ [5][6], related to interoperability, are legally binding in the European Union since they are part of the Control-Command and Signalling Technical Specification for Interoperability (CCS TSI), which is published in the Commission Regulation 2016/919/EU [4].

It is mandatory that each railway subsystem (train and infrastructure) in the European Union meets these requirements under the scope of the Railway Interoperability Directive [1], it is to ensure technical compatibility between Member States and safe integration between train and track. Radio related requirements on spectrum, coverage and signal strength are amongst these.

Railway transport will play a major role to support the delivery of European Green Deal objectives in the transport sector. Further growth of interoperable railway transport, including growth of its critical communication needs, can be expected. Interoperability must be considered when determining RMR spectrum needs.

⁵ The EIRENE specifications contain the requirements that are relevant to interoperability of the rail system within the European Union, according to the Directive 2016/797/EU.

2.3 MIGRATION FROM GSM-R TO ITS SUCCESSOR

2.3.1 GSM-R today

The radiocommunication system to be used is currently GSM-R. This is stated in the basic parameters included in the CCS TSI, section 4. The air interface is also characterised and it is specifically specified that the interfaces shall operate in the R-GSM band (see table 3-A in 3.5.1 of the EIRENE SRS [6]).

For the use of GSM-R, Commission Decision 1999/569/EC [8] and ECC Decision (02)05 [9] harmonise the frequency bands 876-880 MHz (train-to-ground) and 921-925 MHz (ground-to-train). The designation of a dedicated harmonised frequency band enabled the creation of a pan-European radiocommunication network for both passenger and freight trains to travel across EU borders without the need to install any other national radiocommunication system. This fulfils the requirement of the Interoperability Directive [1]. Furthermore, a dedicated frequency band is essential to ensure continuous reliable access to the network thus supporting critical, interoperable and safety-related applications.

Today, GSM-R and ETCS, as constituents of ERTMS, offer an interoperable railway communication and signalling system to all European railway networks. The ERTMS European Deployment Plan (EDP) sets deadlines (2020-2030) for the implementation of ERTMS and its aim is to ensure the progressive deployment of ERTMS along the main European rail routes. FRMCS will support as a minimum the same services as GSM-R today.

2.3.2 Need for parallel operation

The application of the Control-Command and Signalling Technical Specification (CCS TSI) for Interoperability does not have a retroactive effect. In general, new releases of the TSI are developed ensuring the compatibility with the existing authorised systems, to avoid the requirement of upgrading/replacing equipment, as per the "*Whereas (16)*" of the Interoperability Directive [1]. This discards in general actions such as a mandatory retrofit of cab-radios (unless specific rules are agreed).

Infrastructure Managers will still be rolling out or operating GSM-R networks⁶ while the successor to GSM-R is introduced. Thus, both technologies will have to be operated in parallel as Infrastructure Managers migrate from GSM-R to the new successor technology. Migration requires a long-term strategy as non-discriminating access to the rail network is legally required due to interoperability obligations.

For railways, it is an obligatory task to prove to the National Safety Authority (NSA) that the track-to-train performance complies with the performance requirements specified in the CCS TSI (which for GSM-R means compliance with the EIRENE specifications).

Therefore, several field tests must be performed using measurement trains before a railway line is put into operational service with GSM-R or its successor. These radio network tests are aimed at checking under real life conditions the coverage and quality performance, checking if availability requirements are met and ensuring that specific railway applications are running properly.

The procedure described above is one of the reasons why an overnight switchover from GSM-R to its successor in the same frequency band seems to be very unlikely. Even if a preceding upgrade of all on-board terminals would be performed, including their validation on an isolated railway line equipped with the successor system of GSM-R, an overnight switchover does not offer the possibility to perform the real life tests mentioned above. In addition to the items addressed above, an overnight switchover might cause an issue to the interoperability of railway networks.

From spectrum management point of view, the same interoperability issue applies here: it is necessary to have for a period of time sufficient spectrum available to operate both GSM-R and its successor in parallel. Because of the reasons described above, there is a strong need for additional spectrum during the migration period. This additional spectrum will also be required to cover railway's foreseen needs after the migration period in

⁶ On a national basis, the 873-876 / 918-921 MHz spectrum range or parts thereof will be operated with GSM-R prior to and during the migration period. The 874.4-876 MHz paired with 919.4-921 MHz are under consideration for railway usage on a harmonised basis in accordance with the EC mandate.

combination with the 2x4 MHz currently harmonised and used for GSM-R. Technical solutions that would enable GSM-R and FRMCS to operate together in parallel in the 900 MHz band can be considered.

2.3.3 Timeline perspective

The overall migration throughout Europe is expected to take place between 2024 and 2035. The migration scenarios will depend on the national plans of Transport Ministries and Infrastructure Managers to replace the current GSM-R infrastructure (e.g. reinvestment might be an option in certain countries), as also on agreements between Infrastructure Managers and Railway Undertakings on the timeline for deployment of both trackside and on-board equipment. A large variation between EU Member States in the deployment timelines for FRMCS is expected.

ERA investigates how to support IMs and RUs in the process of negotiating the migration towards the successor of GSM-R. The EU railway regulatory framework could potentially include provisions to allow IMs to signal to all RUs in a specific country: a notification of start and end dates for FRMCS rollout, and the switch-off date for GSM-R, in a way that a minimum duration for parallel operation of GSM-R and FRMCS is ensured. This could help to minimise the migration period while avoiding forcing Railway Undertakings to retrofit on-board equipment. In order to facilitate the migration, a national administration may consider setting up a financial incentive scheme.

3 SPECTRUM NEEDS FOR THE FUTURE RAILWAY MOBILE RADIO COMMUNICATIONS SYSTEM (TASK 1)

For the purpose of assessing the spectrum needs for FRMCS, *critical railway applications* have been considered. These critical railway applications are defined as “*applications that are essential for train movements and safety or a legal obligation, such as emergency communications, shunting, [human] presence [e.g. LAS], trackside maintenance, ATC, etc.*” [13] and are listed below.

The traffic requirement is compared to the estimated LTE/NR data throughput in a rail environment, taking into account the radio network design, the characteristics of the radio access technology used and the location of the frequency band within the radio spectrum.

Sources:

- for traffic analysis, see “FRMCS Traffic Analysis v2” [10];
- for throughput evaluation in railway environment, see ETSI TR 103 554-1 for LTE [11] and ETSI TR 103 554-2 for NR [12].

3.1 LIST OF CRITICAL RAILWAY APPLICATIONS

Spectrum needs are evaluated for two packages of applications:

- Package #1, which must be supported during the migration:
 - Roughly current GSM-R critical applications: Voice (including emergency calls), ETCS L2;
 - Train positioning⁷;
 - ATO up to GoA2;
 - Remote control of engine;
 - On-board intelligence and sensing (e.g. for ATO and object/person detection);
 - Critical video (e.g. for remote control in shunting yards and in degraded mode).
- Package #2, which must be supported after the migration:
 - Package #1;
 - ETCS L3;
 - ATO up to GoA4;
 - Virtual coupling;
 - Shunting voice;
 - and other applications as in [10]

The following table provides an overview of the critical applications that are required during the migration.

Table 1: List of the critical applications (based on [10])

Critical application	Applicable during the migration?
Operational voice ⁸	Yes
Shunting voice	No
Emergency call 112	Yes
Alert from the public	No
Alert to the public	No
ETCS	Yes

⁷ to replace the use of the Cell-ID

⁸ including Railway Emergency Call

Critical application	Applicable during the migration?
ATO	Yes
Remote control of engine	Yes
Train integrity	No
Advisory messaging	No
On-train telemetry & equipment control	No
Critical sensing/video Note 1 (e.g. object/person detection or video in degraded mode)	Yes
Note 1: H.264 and H.265 video codecs have been assumed.	

This table is a condensed version of the applications on which the traffic model [10] has been developed.

3.2 FRMCS THROUGHPUT REQUIRED BY CRITICAL APPLICATIONS DURING THE MIGRATION

Based on the subset of critical applications required during the migration period, as shown in Table 1, the following tables identify the traffic to be handled.

Table 2: Traffic during the migration for each area type, including critical video

	DL traffic per ref. train (Mb/s)	UL traffic per ref. train (Mb/s)	Nb. of trains per km	Cell size (km)	DL traffic per cell (Mb/s)	UL traffic per cell (Mb/s)
Low-density rail segment	3.5	3.49	0.33	8	9.24	9.22
High-density rail segment			0.67		18.77	18.73
High-speed rail segment			0.5		14.00	13.97
Note: The cell size reflected in this table is based on typical GSM-R networks currently in use. This assumes that FRMCS would be deployed on the same radio sites without further densification.						

Table 3: Traffic during the migration for each area type, excluding critical video

	DL traffic per ref. train (Mb/s)	UL traffic per ref. train (Mb/s)	Nb. of trains per km	Cell size (km)	DL traffic per cell (Mb/s)	UL traffic per cell (Mb/s)
Low-density rail segment	0.2	0.19	0.33	8	0.53	0.51
High-density rail segment			0.67		1.08	1.04
High-speed rail segment			0.5		0.80	0.77
Note: The cell size reflected in this table is based on typical GSM-R networks currently in use. This assumes that FRMCS would be deployed on the same radio sites without further densification.						

The reason for isolating a scenario without critical video is to see the conditions on one hand for the evolving continuity of the services today ensured through GSM-R, and on the other hand to reflect the progressive impact foreseen within the next 15 years caused by the introduction of autonomous trains and the related modernisation of applications. These are constitutive elements of the European railway strategy⁹, which is about to happen at very different pace in the various European countries.

3.3 FRMCS THROUGHPUT REQUIRED BY TARGET CRITICAL APPLICATIONS

The target critical applications include the current critical GSM-R functionality as well as the new critical applications foreseen for the successor, which are ETCS L3, relevant subset of Automatic Train Operation, Virtual Coupling, etc.

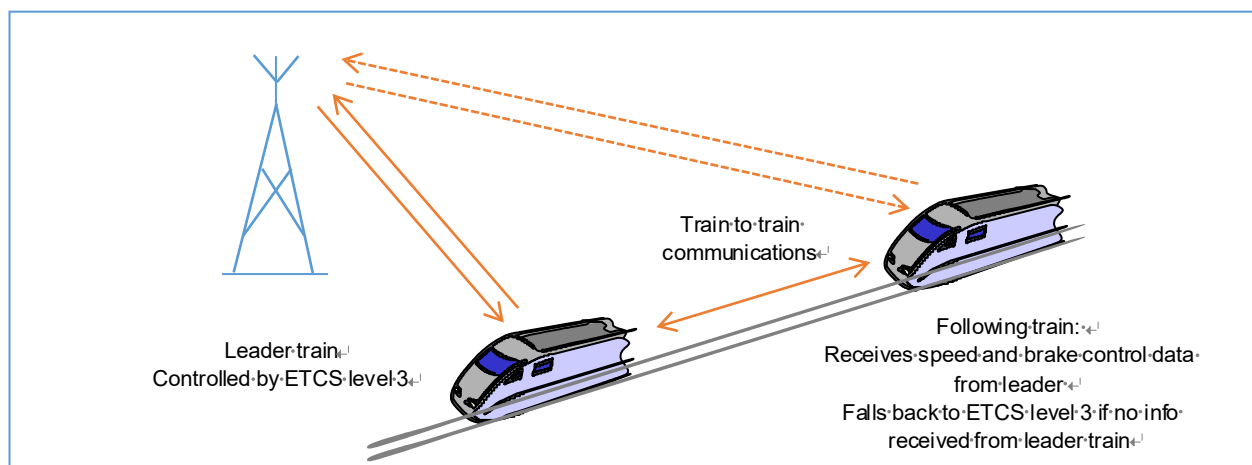


Figure 1: Principle of Virtual Coupling

Virtual Coupling: The following train receives speed and brake control data from the leading train (train-to-train communication). This system allows a reduction of the distance between trains and increases the capacity of transport.

The following tables show the traffic to be handled after the migration period, which includes additional applications (as presented in section 3.2).

Table 4: Target traffic for each area type, including critical video

	DL traffic per ref. train (Mb/s)	UL traffic per ref. train (Mb/s)	Nb. of trains per km	Cell size (km)	DL traffic per cell (Mb/s)	UL traffic per cell (Mb/s)
Low-density rail segment	4.38	7.42	0.33	8	11.55	19.60
High-density rail segment			0.67		23.45	39.79
High-speed rail segment			0.5		17.50	29.70

Note: The cell size reflected in this table is based on typical GSM-R networks currently in use. This assumes that FRMCS would be deployed on the same radio sites without further densification.

⁹ known under the name of “game changers”, see https://www.era.europa.eu/sites/default/files/library/docs/ex_post_evaluation/era_rep_150_ertms_longer_term_perspective_report_en.pdf

Table 5: Target traffic for each area type, excluding critical video

	DL traffic per ref. train (Mb/s)	UL traffic per ref. train (Mb/s)	Nb. of trains per km	Cell size (km)	DL traffic per cell (Mb/s)	UL traffic per cell (Mb/s)
Low-density rail segment	0.42	3.46	0.33	8	1.10	9.15
High-density rail segment			0.67		2.22	18.57
High-speed rail segment			0.5		1.66	13.86
Note: The cell size reflected in this table is based on typical GSM-R networks currently in use. This assumes that FRMCS would be deployed on the same radio sites without further densification						

3.4 THROUGHPUT OFFERED BY LTE/NR IN RAILWAY ENVIRONMENT

The data throughput assumptions for the future railway mobile radio communications depend very much on the assumptions for critical real-time video. This is expected to play an instrumental role in future rail operations, especially in the context of automated train operations (ATO). It should be noted that the term “video” in this context refers to “classical” video, but also the data obtained from other sensors, or pre-processed and/or combined forms of such data within sensor fusion platforms used in automated railway systems, mostly for the purpose to detect hazards and ensure safety. Assumptions for such critical video applications are at an early stage and the data throughput for a single train on the uplink can vary, with current estimates in the order of 1 Mb/s in normal train operation mode up to several Mb/s in degraded train operation mode. This is likely to be in excess of the 2x5.6 MHz of spectrum at 900 MHz, as depicted below.

ETSI TR 103 554-1 provides simulations of the throughput that can be offered at 900 MHz by a 2x1.4 MHz or a 2x5 MHz FDD LTE channel, and at 1900 MHz by a 10 MHz TDD LTE channel. Similarly, ETSI TR 103 554-2 provides simulations of the throughput that can be offered at 900 MHz by a 2x5 MHz FDD NR channel, and at 1900 MHz by a 10 MHz TDD NR channel. At 900 MHz, this does not preclude use of in-band and/or adjacent channel arrangement of GSM-R and FRMCS in the whole 2x5.6 MHz.

Noting that having the possibility to reuse as much as possible the current radio network infrastructure (BS sites) would save costs and reduce operational burden, the spectrum in 874.4-880 MHz / 919.4-925 MHz is one of the two identified spectrum bands for the successor of GSM-R for the migration and beyond.

As depicted in the two previous sections, the capacity offered by adding 2x1.6 MHz of spectrum is not enough to support the spectrum demand of GSM-R and FRMCS during the migration and beyond (including increased railway traffic, ATO and critical sensing/video). Access to complementary spectrum, such as 1900-1910 MHz, is thus a prerequisite for many countries in order to fulfil the interoperability requirements, to enable parallel operation of GSM-R and its successor and to benefit from new railway applications.

Hence, the spectrum 1900-1910 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond.

3.5 MIGRATION AT 900 MHZ

Considering the FRMCS rollout timeframe, it may not make sense to invest in a 4G network as by 2024 5G is expected to have become a mature and widely used technology in the commercial mobile networks.

FRMCS occupying 5 MHz bandwidth with no overlap with GSM-R in practice would rule out the 900 MHz as an option for a dual network operation during migration since a total available bandwidth of 2x5.6 MHz would only leave room for maximum three GSM-R channels, when assuming no guard-band.

In order to enable migration using the 900 MHz spectrum while maintaining interoperable and safe operation of GSM-R, two possible approaches have been identified:

- Adjacent deployment of a 1.4 MHz FDD LTE carrier, adjacent to the legacy 4 MHz for GSM-R:
 - This approach would have a lower traffic handling capacity and needs to be considered in terms of product lifecycle and longer-term migration to NR.
- In-band coexistence based on an overlay of a 5 MHz FDD LTE/NR carrier or of a 5.6 MHz FDD NR carrier (subject to 3GPP feasibility study), co-channel with GSM-R carriers:
 - This approach is based on a concept of advanced resource block scheduling that allows GSM-R channels to operate within the NR wideband channel. This is currently under study within ETSI TC-RT;
 - It would rely on the ability of GSM-R to withstand the interference resulting from the collision with the mandatory NR signalling sub-frames (SSB, Coreset 0) as well as on the ability of FRMCS to withstand the interference resulting from the presence of GSM-R channels within the channel bandwidth;
 - In particular, this approach would allow for a single step migration to NR with a gradual redistribution of traffic handling capacity between GSM-R and 5G usage as well as an increased efficiency in spectrum usage.

The current NR technical specifications only support channel bandwidths of 5 MHz or more. Adding smaller bandwidths in the NR specifications would require certain standardisation efforts with respect to the NR physical layer. Future standardisation in this direction should be monitored to evaluate its potential impact on FRMCS migration within the 900 MHz band.

3.6 HOTSPOTS AND BORDER AREAS

Some GSM-R radio network operators are currently facing the problem of insufficient radio resources in the harmonised GSM-R band to support their operational needs, especially in railway hubs / hotspots and border areas. In such areas, additional radio resources are required. However, a shortage of spectrum for GSM-R is not uniform across all European countries. For GSM-R, the band 873-876 MHz / 918-921 MHz may be used on a national basis and some countries solve the shortage of spectrum in this way¹⁰.

Examples of the most complex railway hubs / hotspots are:

- Mannheim area in Germany;
- Basel area in Switzerland, France and Germany;
- Brussels-Antwerp-Ghent area in Belgium.



Figure 2: Railway hub in Mannheim (Germany)

¹⁰ This band is not harmonised for railway use neither at EU level nor at CEPT level. Three CEPT countries, Germany, Switzerland and Liechtenstein, are currently using the band 873-876 MHz / 918-921 MHz for GSM-R. In Belgium, the infrastructure manager informed the administration they intend to obtain the rights to use the GSM-R channels 919.6 MHz to 921.0 MHz.

In border areas, the available spectrum for GSM-R is shared between two or more GSM-R operators, thus the radio frequency planning process must be supplemented by proper network coordination. This cross-border coordination becomes a major challenge for the radio network planning and rollout. Today, cross-border coordination agreements for railway radio communication are established and being used by default, giving GSM-R network operators some flexibility for their frequency planning.

For GSM-R network operators, the situation of the coordination between neighbouring countries varies considerably, depending on the number of parties.

Examples of the most complex border regions are:

- Germany / Switzerland / France (e.g. Basel area);
- Germany / Switzerland / Austria (e.g. Lake Constance);
- Germany / Belgium / The Netherlands (e.g. Aachen/Maastricht);
- Baltic Sea coastline;
- Switzerland / Germany / Liechtenstein / Austria (border area);
- Switzerland / Italy (e.g. Chiasso area);
- Switzerland / France (e.g. Geneva area);
- Switzerland / France (e.g. Lausanne area);
- Netherlands / Belgium / Luxembourg / France.

A similar situation is expected to occur with FRMCS, independently of the migration strategy. A complementary frequency band, such as 1900-1910 MHz, will be essential in the areas listed above and will offer more flexibility in sharing spectrum resources between railway users and in absorbing capacity demand in hotspots and border areas. Access to a commercial mobile network may alternatively be used provided that the railway interoperability requirement is fulfilled in cross-border scenarios.

With FRMCS, cross-border coordination as well as the effects of the single frequency network architecture and of TDD synchronisation are for further study.

3.7 CONCLUSION ON SPECTRUM NEEDS AND OPTIONS

Ensuring railway interoperability throughout Europe must be considered when determining spectrum needs. Having the possibility to reuse as much as possible the current radio network infrastructure (BS sites) would save costs, time and reduce operational burden. Therefore, the spectrum in the whole 2x5.6 MHz in 874.4-880 MHz / 919.4-925 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond. Considering the FRMCS rollout timeframe, it may not make sense to invest in a 4G network compared to 5G. A migration using only the 900 MHz spectrum would require that the initial FRMCS deployment uses a deployment of a 1.4 MHz LTE carrier adjacent to GSM-R, or the realisation of overlapping NR wideband channels in a co-channel deployment with GSM-R.

The targeted 2x5.6 MHz of spectrum could be used by a 5.6 MHz FDD NR carrier during both migration and post-migration. Such a carrier would provide a higher traffic handling capacity than the current 3GPP defined 5 MHz carrier and thus would better support the anticipated growth of the FRMCS traffic volume. Although current indications are that such a 5.6 MHz carrier should be feasible within the 3GPP NR specifications, additional work is necessary in 3GPP to confirm feasibility and carry out the specification work.

In-band coexistence, based on an overlay of a 5 MHz FDD NR carrier or of a 5.6 MHz FDD NR carrier, co-channel with GSM-R carriers, would be an option for the migration using the 900 MHz spectrum while maintaining operation of GSM-R.

Alternatively, a 5 MHz FDD LTE/NR carrier could be implemented plus several NB-IoT carriers in the remaining 600 kHz. An NB-IoT carrier potentially supports a larger coverage area than a 5 MHz LTE/NR carrier. Examples of critical railway applications that may benefit from the usage of NB-IoT are listed hereafter:

- Trackside maintenance warning system communication;
- Monitoring and control of critical infrastructure.

As another alternative, a 1.4 MHz FDD LTE carrier may be used, adjacent to the 4 MHz for GSM-R during migration. This approach would have a lower traffic handling capacity and needs to be considered in terms of product lifecycle and longer-term migration to NR.

Furthermore, considering the throughput requirements, access to complementary spectrum, such as 1900-1910 MHz, is a prerequisite for many countries in order to fulfil the interoperability requirements, to enable parallel operation of GSM-R and its successor, to benefit from new railway critical applications (including ATO and critical sensing/video), and to deal with border and hotspot areas. Hence the spectrum 1900-1910 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond.

This does not preclude the use of public mobile networks, noting that the railway interoperability, coverage, availability and QoS requirements still needs to be fulfilled.

4 TECHNICAL FEASIBILITY OF THE 874.4-880 MHz / 919.4-925 MHz FREQUENCY BAND (TASK 2)

4.1 COEXISTENCE BETWEEN GSM-R AND ITS SUCCESSOR

It is expected that GSM-R radio sites will mostly be used for FRMCS rollout (coordinated deployment with co-located base stations).

The critical case is interference from a GSM-R terminal to an FRMCS base station when uplink power control is not activated for GSM-R. There is confidence that a 200 kHz guard-band is sufficient between FRMCS and GSM-R, assuming co-location and similar e.i.r.p. for both systems.

The 200 kHz guard-band defined in the Commission Decision 2009/766/EC on 900/1800 MHz [19] as amended by the Commission Decision (EU) 2018/637 [20] corresponds to an uncoordinated deployment between two mobile network operators, one using UMTS/LTE and the other using GSM. It is related to blocking and out-of-band emissions phenomena.

For co-located/coordinated deployment, MNOs do operate without a guard-band (uplink power control activated). The MNO scenario is not directly applicable for RMR and whether a smaller or no guard-band can be implemented for railways, including the possibility for GSM-R to activate uplink power control, is out of the scope of the present Report.

With co-siting of GSM-R and FRMCS, no intermodulation phenomenon is expected in railway terminals, assuming similar or close values of e.i.r.p. for both systems.

4.2 COEXISTENCE WITH ECS

4.2.1 Impact of RMR BS on ECS BS receiving below 915 MHz

RMR BS operate within the duplex gap of the E-GSM band / 3GPP band #8, i.e. 915-925 MHz. They may interfere ECS BS receiving below 915 MHz.

4.2.1.1 BEM for RMR BS

As described in CEPT Report 19 Annex IV [21], the BEM is developed on the basis that detailed coordination and cooperation agreements would not be required to be in place prior to network deployment. The BEM for the transmitter emissions would not avoid all interference that might arise in certain deployment scenarios, including for some configurations at shared base station sites or between nearby base station sites. In these situations, mobile network operators and infrastructure managers may have to coordinate, and the use of additional interference mitigation techniques might be considered.

In order to derive a possible BEM for RMR BS, a reference MCL has to be defined. For this purpose, both a traditional 100m-based MCL calculation approach and a refinement based on statistics relying on existing GSM-R and ECS deployment data in France, Germany and Sweden have been considered. The statistical approach appears to be of particular relevance when the two systems under study exhibit significant differences in their deployment patterns, notably as a result of different coverage targets. In particular, railway coverage is largely focused along railway tracks and railway premises following curvilinear geometries whereas public networks focus on optimised area-based coverage of population concentrations.

The possible BEM based on the 100m-based MCL calculation¹¹ is expected to be unnecessarily stringent since the specificities of RMR deployments would make the 100m reference scenario occur in extremely rare cases. As a consequence, the statistical approach, as described in ECC Report 318, was chosen to define the

¹¹ Tables 14 and 16 in ECC Report 318

BEM¹² in order to enable uncoordinated deployments while ensuring an acceptably low occurrence probability of residual interference cases where the defined protection criterion is exceeded.

The statistical calculation leads to a reference MCL of 68 dB. This reference coupling loss predicts that less than 7% of RMR sectors might face an ECS neighbouring sector with less than 68 dB coupling loss. In practice, the number of RMR sectors is expected to be significantly lower, considering that simulations have only taken the EPM-73 propagation model into account, without any clutter, digital terrain model or building layer. Additionally, the statistical analysis shows that most occurrences of low coupling loss are located in urban areas where the real coupling loss is expected to be significantly higher in most cases due to building and clutter losses. Solving the interference issue for the remaining cases not covered by the BEM should be addressed at national level when interference occurs.

The BEM for FRMCS will include channels of 1.4 MHz, 5 MHz and 5.6 MHz.

CEPT noted that a 200 kHz frequency separation is required between networks adjacent in frequency in the following cases: GSM vs. WB (i.e. UMTS, LTE or NR), NB-IoT vs. WB and GSM vs. NB-IoT. This issue needs to be further addressed by regulatory measures at national level, consistently with the relevant RMR and MFCN harmonised technical conditions under development.

4.2.1.2 Coordination

National regulation may allow multiple carriers using wideband technologies¹³ or higher e.i.r.p. for RMR BS than stated in the technical conditions, as long as the absence of harmful interference on ECS BS can be ensured. It should be decided on national level how to coordinate between RMR and ECS. As part of a national coordination procedure, the infrastructure manager could, for example, demonstrate that the following formula with respect to each ECS BS in the vicinity of the RMR radio site is fulfilled:

$$TxI_{inblock} - CL \leq I_{IB} + S_{inblock} - \alpha$$

$$I_{IB} = -108.3 \text{ dBm}$$

$$CL = PL + D_{Rail} + D_{MFCN} - G_{MFCN}$$

$TxI_{inblock} - PL - D_{Rail} - D_{MFCN} + G_{MFCN} \leq -108.3 + S_{inblock} - \alpha$	(1)
--	-----

Where:

- $TxI_{inblock}$ is the sum of RMR BS in-block e.i.r.p. of each wideband carrier;
- I_{IB} is the total permitted interference at the antenna connector over 25 RB for an ECS BS noise figure of 5 dB;
- $S_{inblock}$ is the ECS BS selectivity dependent on the edge-to-edge frequency offset between the ECS and RMR carriers;
- α accounts for RMR BS out-of-band and spurious emissions;
 - $\alpha = 2$ dB for a baseline level of -49 dBm/5MHz below 915 MHz;
 - $\alpha = 1$ dB for a baseline level of -85 dBm/100kHz below 915 MHz (Table 6.6.1.2.1-1 for self-protection*);
- PL is the path loss specific to the propagation environment and ground occupancy;
- D_{Rail} is the RMR antenna discrimination, noting that having more directive antennas or adjusting tilt and azimuth may ease coexistence;
- D_{MFCN} is the ECS BS antenna discrimination;
- G_{MFCN} is the ECS BS antenna gain (including feeder loss).

* in 3GPP TS 37.104: -98 dBm/100kHz + 13 dBi antenna gain

¹² Tables 15 and 17 in ECC Report 318

¹³ including NB-IoT

The RMR BS in-block e.i.r.p. may be increased while fulfilling this coexistence criterion by means of adjustments of antenna directivity, azimuth, tilt, etc.

All the required elements related to the neighbouring ECS and RMR sites (coordinates, antenna height, azimuth, tilt, antenna reference, frequency carrier, etc.) could be made available to exchange between the ECS operator and the infrastructure manager as part of the national coordination procedure.

To enable a better coexistence between RMR and ECS, ECC Report 229 [28] proposes a systematic approach based on a coordination/cooperation process and guidelines for the dialogue between RMR and ECS licensees as well as with the spectrum administration.

4.2.2 Impact of FRMCS cab-radio on ECS BS receiving above 880 MHz

As of today, GSM-R cab-radios can already transmit up to 39 dBm (output power) without UL power control in 873-880 MHz. No harmful interference case has been reported so far on ECS BS receiving above 880 MHz, noting that 12 to 19 GSM-R carriers may fall within the ACS domain of adjacent ECS UMTS/LTE BS.

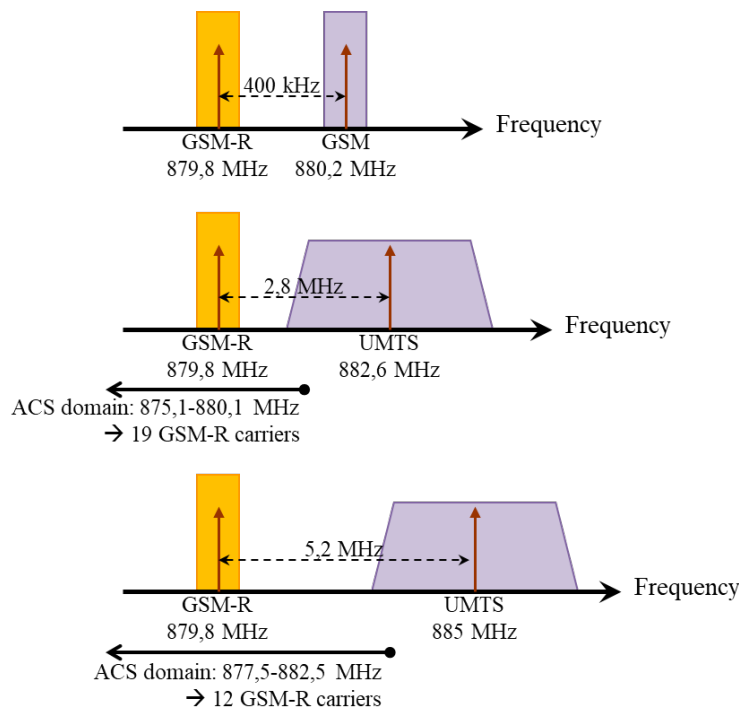


Figure 3: Scenarios where GSM-R falls within the ACS domain

According to ECC Report 318, FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 874.4-880 MHz provided that UL power control is activated, and that FRMCS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

4.2.3 Impact of ECS BS above 925 MHz on FRMCS cab-radio

ETSI TS 102 933-1 v1.3.1 [31] onwards has specified an enhanced blocking / intermodulation threshold for GSM-R cab-radios in a way that they are able to cope with ECS emissions above 925 MHz. This TS has been derived from UIC's report O-8736, which documents field measurements of emissions from UMTS BS and predicts a potential increase of ECS BS e.i.r.p. in the long term when moving to 10 MHz channels (as described in Report ITU-R M.2292-0, Table 3).

The requirements given in ETSI TS 102 933-1 are considered to be also applicable to FRMCS cab-radios, except the sensitivity level which needs to be specified by ETSI/3GPP, to ensure their robustness against emissions from ECS BS transmitting above 925 MHz. They should be considered by the relevant ETSI bodies.

ECC Report 313 shows that, when in close vicinity to rail tracks, ECS BS unwanted emissions may cause interference to FRMCS cab-radio. In practice, to solve these cases, technical and/or operational measures could be taken to ensure the coexistence of both ECS and FRMCS in parallel.

4.2.4 Impact of aerial UE in 880-915 MHz on RMR

This section assesses whether aerial UE in the uplink band 880-915 MHz may interfere RMR cab-radios receiving in 919.4-925 MHz through blocking effects and unwanted emissions.

ECC Report 313 determined the need to improve the receiver characteristics of the FRMCS cab-radio, compared to 3GPP specification for band #8, so that it can cope with aerial UE using ECS below 915 MHz. Reversely, the requirements calculated are already fulfilled by GSM-R cab-radios specified in ETSI TS 102 933-1.

According to ECC Report 309, aerial UE unwanted emissions will not cause harmful interference to RMR cab-radio, due to the additional filtering provided above 915 MHz by the duplexer of the aerial UE.

4.3 COEXISTENCE WITH SRD

4.3.1 Frequency use

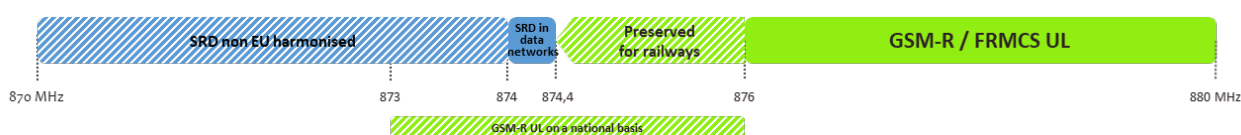


Figure 4: Band plan for 870-880 MHz

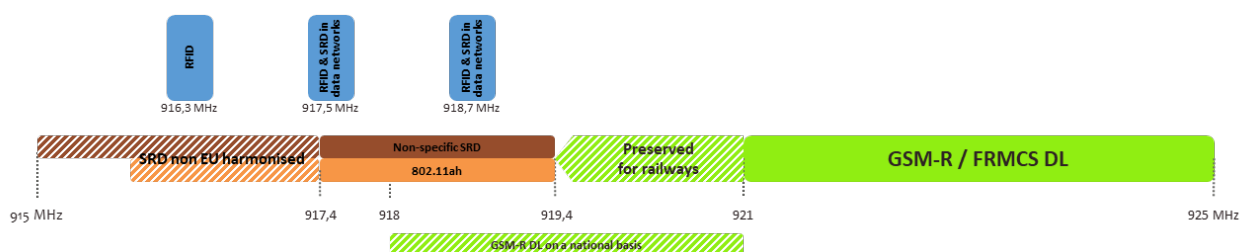


Figure 5: Band plan for 915-925 MHz

Notes:

- 500 mW SRD in data networks are harmonised in 874-874.4 MHz in the Decision (EU) 2018/1538, while the band 870-874.4 MHz is listed in ERC Recommendation 70-03 Annex 2;
- 25 mW non-specific SRD in data networks are harmonised in 917.4-919.4 MHz in the Decision (EU) 2018/1538, while the band 915-919.4 MHz is listed in ERC Recommendation 70-03 Annex 2.
- Wideband data transmission devices in data networks (802.11ah on the figure) are harmonised in 917.4-919.4 MHz in the Decision (EU) 2018/1538, while the band 915.8-919.4 MHz is listed in ERC Recommendation 70-03 Annex 3;
- The 874-874.4 MHz and 915-919.4 MHz frequency bands are harmonised at EU level for short-range devices under Decision (EU) 2018/1538;
- A few countries in Europe are using this frequency band 873-876 MHz / 918-921 MHz on a national basis for GSM-R. In some CEPT countries, these bands are used by other governmental/military systems.
- Some countries permit the use of SRD across the bands 870-876 MHz and 915-921 MHz, based on the ERC Recommendation 70-03 dated 7 February 2014. These entries have been subsequently modified in an update of ERC Recommendation 70-03 (June 2019) to align with Decision (EU) 2018/1538.

4.3.2 Coexistence of adjacent frequency 500mW networked SRD with RMR BS above 874.4 MHz

This section assesses whether 500mW networked SRD in 870-874.4 MHz may interfere with RMR BS receiving within 874.4-880 MHz through blocking effects and unwanted emissions.

ECC Report 313 determined the need to improve the receiver characteristics of the RMR BS, compared to 3GPP specification for band #8, so that it can cope with 500mW networked SRD below 874.4 MHz.

With respect to unwanted emissions, ECC Report 313 concluded that no specific requirement is needed on 500 mW SRD operating below 874.4 MHz and ERC Recommendation 74-01 should apply.

4.3.3 Coexistence of adjacent frequency SRD with RMR cab-radio above 919.4 MHz

This section assesses whether SRD in 915-919.4 MHz may interfere with RMR cab-radios receiving within 919.4-925 MHz through blocking effects and unwanted emissions.

ECC Report 313 determined the need to improve the receiver characteristics of the RMR cab-radio, compared to 3GPP specification for band #8, so that it can cope with SRD below 919.4 MHz. The level of robustness required is driven by 4W RFID interrogators, according to assumptions made in ECC Report 313. With other deployment scenarios, the RMR cab-radio also needs to be robust against 500 mW SRD.

Improved GSM-R cab-radios as per ETSI TS 102 933-1 [31] are currently being deployed and are specified for the improved reception of GSM-R in the vicinity of intensive ECS emissions above 925 MHz, but the current GSM-R cab-radio receiver specification is less resilient against adjacent emissions from higher-power SRD below 919.4 MHz in some close proximity cases. Administrations may further consider the protection of GSM-R cab-radios¹⁴ if the requirements in 916.1-918.9 MHz on the GSM-R cab-radio receiver in Table 2 of ECC Report 313 are not met.

FRMCS cab-radios need to fulfil the receiver characteristics determined in ECC Report 313.

4.4 USE OF NB-IOT WITH FRMCS

NB-IoT is a 3GPP radio technology for machine-to-machine communications. It supports half-duplex operation. The channel bandwidth is 200 kHz and the occupied bandwidth is 180 kHz, equivalent to one LTE/NR resource block. Three modes are defined:

- in-band operation mode where NB-IoT utilizes one or several resource blocks within an LTE/NR carrier;
- guard-band operation mode where NB-IoT utilizes the unused spectrum within an LTE carrier's guard-band;
- standalone operation mode where NB-IoT utilizes its own spectrum.

The studies in ECC Report 318 can be applied to the in-band operation mode without power boost¹⁵ (where the NB-IoT RB is one of the LTE/NR RB with the same power density) and to the standalone operation mode (where the NB-IoT channel can be compared to a GSM channel) for a single NB-IoT carrier. If power boost were to be used for in-band NB-IoT, the BEM would not be directly applicable. The conditions of use and the impact on ECS BS of multiple FRMCS carriers using wideband technologies (including NB-IoT) within 5.6 MHz spectrum is not yet technically assessed.

The guard-band operation mode would require further study if a need for this use case is confirmed.

¹⁴ National coordination is allowed as per Note 7 relative to the table on the harmonised technical conditions for SRD in Decision (EU) 2018/1538.

¹⁵ See section 6.3.3 of 3GPP TS 36.104

4.5 CONCLUSION ON FEASIBILITY

The 874.4-880 MHz / 919.4-925 MHz frequency band is feasible for RMR, provided that the following conditions are met.

1. RMR BS shall ensure coexistence with ECS BS receiving below 915 MHz. The statistical approach, as described in ECC Report 318, relying on existing GSM-R and ECS deployment data, was chosen to define the BEM which enables uncoordinated deployments, while ensuring an acceptably low occurrence probability of residual interference cases to be addressed at national level when interference occurs. The BEM for FRMCS will include channels of 1.4 MHz, 5 MHz and 5.6 MHz.

National regulation may allow multiple carriers using wideband technologies¹⁶ or higher e.i.r.p. for RMR BS than stated in the technical conditions, as long as no harmful interference on ECS BS can be ensured. As part of a national coordination procedure, the infrastructure manager could, for example, demonstrate that a coexistence criterion with respect to each ECS BS in the vicinity of the RMR radio site is fulfilled. The relevant national coordination procedure may differ from country to country, taking into account that coordination procedures with regard to ECS / GSM-R are already in force based on the guidance as described in ECC Report 229 [27].

2. FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 874.4-880 MHz provided that UL power control is activated, and that FRMCS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

3. RMR cab-radios shall be robust against adjacent emissions, including ECS BS above 925 MHz, aerial UE using ECS below 915 MHz and SRD below 919.4 MHz. For the latter case, the required level of robustness is driven by 4W RFID interrogators. ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR cab-radios.

Improved GSM-R cab-radios as per ETSI TS 102 933-1 are currently being deployed and are specified for the improved reception of GSM-R in the vicinity of intensive ECS emissions above 925 MHz, but the current GSM-R cab-radio receiver specification is less resilient against adjacent emissions from higher-power SRD below 919.4 MHz in some close proximity cases. Administrations may further consider the protection of GSM-R cab-radios¹⁷ if the requirements in 916.1-918.9 MHz on the GSM-R cab-radio receiver in Table 2 of ECC Report 313 are not met.

FRMCS cab-radios need to fulfil the receiver characteristics determined in ECC Report 313.

4. RMR BS shall be robust against adjacent emissions, including SRD below 874.4 MHz. ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR BS.

5. When in close vicinity to rail tracks, ECS BS unwanted emissions may cause interference to FRMCS cab-radio. In practice, to solve these cases, technical and/or operational measures could be taken to ensure the coexistence of both ECS and FRMCS in parallel.

6. With respect to the use of a single NB-IoT carrier for FRMCS, the studies in ECC Report 318 can be applied to the in-band operation mode without power boost and to the standalone operation mode. If multiple carriers using wideband technologies¹⁶ or power boost were to be used for in-band NB-IoT, the BEM would not directly be applicable.

¹⁶ including NB-IoT

¹⁷ National coordination is allowed as per Note 7 relative to the table on the harmonised technical conditions for SRD in Decision (EU) 2018/1538.

5 TECHNICAL FEASIBILITY OF THE 1900-1920 MHZ BAND (TASK 3)

5.1 COEXISTENCE WITH ECS

5.1.1 Impact of FRMCS on ECS BS receiving above 1920 MHz

5.1.1.1 FRMCS BS

FRMCS BS are expected to operate in 1900-1910 MHz, which is 10 MHz away from the lower edge of the 3GPP UL band #1. Thus, FRMCS BS may interfere ECS BS receiving above 1920 MHz.

For uncoordinated deployment, the BEM for FRMCS BS will assume that ECS BS have enhanced selectivity compared to the current Harmonised European Standards. This would facilitate coexistence with FRMCS BS transmitting up to 65 dBm e.i.r.p. with the aim of having a future-proof regulation and allowing macro coverage. Current ECS BS located near an FRMCS radio site may need to be adapted, in such a way that they do not suffer interference from FRMCS. In such case, additional mitigation techniques would be needed, such as the upgrade of the ECS BS selectivity or on a case-by-case basis adjustment of antenna directivity, azimuth, tilt, etc. of the FRMCS and/or ECS BS¹⁸.

The improvement of the ECS BS selectivity for those ECS BS near the railway tracks to enable a more efficient use of spectrum by FRMCS can be achieved either within new radio units of ECS BS or by adding external filter to existing radio units operating with passive antenna systems. Enhanced selectivity should be included (potentially as a specific receiver class) in the relevant ECS BS Harmonised European Standards so that newly introduced products placed on the market based on this update natively fulfil this requirement. It is assumed that, at the time of FRMCS rollout, there will be ECS BS equipment available that meets this improved selectivity.

The technical feasibility of improved receiver selectivity for ECS BS with AAS needs further study within the industry. An enhanced selectivity is assumed to be feasible for non-AAS ECS BS, although associated with some additional complexity and cost.

The BEM for FRMCS BS will assume ECS BS with enhanced selectivity. In order to ensure that the ECS operators have enough time to adapt the concerned radio sites, they should have, sufficiently far in advance, information on the rollout of a new FRMCS BS in 1900-1910 MHz.

The BEM for FRMCS will include one channel of 10 MHz.

5.1.1.2 FRMCS cab-radio

According to ECC Report 318, FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 1900-1910 MHz provided that UL power control is activated, and that FRMCS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

5.1.2 Impact of ECS BS below 1880 MHz on FRMCS

ECC Report 314 determined the need to improve the receiver characteristics of both FRMCS BS and cab-radios, compared to 3GPP specification for band #39, in a way that they can cope with ECS BS transmitting below 1880 MHz.

¹⁸ Adjustments of antenna directivity, azimuth, tilt may not be sufficient to solve all interference cases. MFCN BS with improved selectivity would avoid the need for national coordination.

5.1.3 Impact of aerial UE above 1920 MHz on FRMCS

This section assesses whether aerial UE in the uplink band 1920-1980 MHz may interfere FRMCS cab-radios receiving in 1900-1910 MHz through blocking effects and unwanted emissions.

ECC Report 314 determined the need to improve the receiver characteristics of the FRMCS cab-radio, compared to 3GPP specification for band #39, in a way that it can cope with aerial UE using ECS above 1920 MHz.

ECC Report 309 concluded that no specific measure is necessary to be applied to the aerial UE operating above 1920 MHz for the protection of FRMCS cab-radio receiver at 1900-1910 MHz.

5.2 COEXISTENCE WITH DECT BELOW 1900 MHz

5.2.1.1 Results of the studies

ECC Report 314 studied adjacent compatibility between DECT and FRMCS. Overall, it is understood that FRMCS and DECT, adjacent to each other, will generally coexist. Where the DECT usage density is not high, the Dynamic Channel Selection (DCS) algorithm implemented in DECT would then allow the communication to use one of the DECT channels that do not experience interference.

In some worst case scenarios, measures to enable coexistence between DECT in 1880-1900 MHz and RMR in 1900-1910 MHz might be needed, when information on DECT local deployment is made available. DECT is a licence-exempt system and there is generally no record of locations. Additionally, many PMSE type high-density activities will be of a temporary nature.

5.2.1.2 Comparison with current situation

As of today, DECT is harmonised in the 1880-1900 MHz frequency band and already coexist with ECS BS transmitting in 1805-1880 MHz, which is DL band #3. ECS BS may transmit up to 64 dBm e.i.r.p. and beyond. No harmful interference case has been reported so far on DECT.

Compared to ECS, the density of RMR radio sites is much lower and the RMR coverage is largely focused on railway track and railway areas following curvilinear geometries when public networks focus on optimized area-based coverage of population concentrations.

Hence, based on the current situation, a low probability of harmful interference on DECT is expected from FRMCS in 1900-1910 MHz.

5.3 COEXISTENCE WITH UAS

5.3.1 Coexistence with governmental UAS when adjacent in frequency

Spectrum for governmental UAS will be used for command-control and payload. ECC Report 314 studied coexistence between governmental UAS in 1880-1920 MHz and FRMCS in 1900-1910 MHz. Studies are still ongoing with respect to the possible introduction of governmental UAS in 1880-1920 MHz. Depending on the feasibility, FRMCS and governmental UAS may need to coexist.

Overall, UAS usage is very limited in time and space. Thus, the risk of causing harmful interference to an FRMCS cab-radio is expected to be rather low in practice.

To define the improvement of the receiver performance required on the FRMCS cab-radio, it is assumed that only 1 drone at a time may fly in the vicinity of rail tracks and that this drone operates below 1890 MHz in order to provide enough frequency space to reach the filtering level required. This is expected to be feasible in terms of operational rules set up by governmental UAS users.

It is up to ETSI to define the appropriate receiver characteristics of the FRMCS cab-radio so that it can cope with one drone operating below 1890 MHz.

These results would also be applicable if governmental UAS would operate in 1910-1920 MHz, but the required filtering would be more challenging due to lack of frequency separation between the two systems.

5.3.2 Adjacent channel compatibility with commercial UAS in 1900-1920 MHz

The dedicated spectrum for commercial UAS is targeted for command-control only. No study has been carried out on this topic since no need for such dedicated spectrum has been confirmed.

5.4 CONCLUSION ON FEASIBILITY

The 1900-1910 MHz frequency band is feasible for FRMCS, provided that the following conditions are met.

1. FRMCS BS shall ensure coexistence with ECS BS receiving above 1920 MHz while ensuring an efficient use of spectrum. For uncoordinated deployment, the BEM for FRMCS BS will assume that ECS BS have enhanced selectivity compared to the current Harmonised European Standards. This would facilitate coexistence with FRMCS BS transmitting up to 65 dBm e.i.r.p. with the aim of having a future-proof regulation and allowing macro coverage. Current ECS BS located near an FRMCS radio site may need to be adapted, in such a way that they do not suffer interference from FRMCS. In such case, additional mitigation techniques would be needed, such as the upgrade of the ECS BS selectivity or on a case-by-case basis adjustment of antenna directivity, azimuth, tilt, etc. of the FRMCS and/or ECS BS¹⁹.

The improvement of the ECS selectivity for those ECS BS near the railway tracks can be achieved by either the usage of new radio units of ECS BS or by adding external filter to existing radio units operating with passive antenna systems. Enhanced selectivity should be included (potentially as a specific receiver class) in the relevant ECS BS Harmonised European Standards so that newly introduced products placed on the market based on this update natively fulfil this requirement.

The BEM for FRMCS BS will assume ECS BS with enhanced selectivity. In order to ensure that the ECS operators have enough time to adapt the concerned radio sites, they should have, sufficiently far in advance, information on the rollout of a new FRMCS BS in 1900-1910 MHz.

The BEM for FRMCS will include one channel of 10 MHz.

2. FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 1900-1910 MHz provided that UL power control is activated, and that FRMCS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

3. FRMCS cab-radios shall be robust against adjacent emissions, including ECS BS below 1880 MHz and aerial UE using ECS above 1920 MHz. Depending on the possible introduction of governmental UAS in 1880-1920 MHz, ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR cab-radios.

4. FRMCS BS shall be robust against adjacent emissions, including ECS BS below 1880 MHz.

5. With regard to adjacent compatibility between DECT (1880-1900 MHz) and FRMCS, it is understood that FRMCS and DECT, adjacent to each other, will generally coexist. Where the DECT usage density is not high, the Dynamic Channel Selection (DCS) algorithm implemented in DECT would then allow the communication to use one of the DECT channels that do not experience interference. In some worst case scenarios, measures to enable coexistence between DECT in 1880-1900 MHz and RMR in 1900-1910 MHz might be needed, when information on DECT local deployment is made available.

¹⁹ Adjustments of antenna directivity, azimuth, tilt may not be sufficient to solve all interference cases. MFCN BS with improved selectivity would avoid the need for national coordination.

6 TECHNICAL FEASIBILITY OF THE 2290-2300 MHZ BAND (TASK 3)

6.1 COEXISTENCE WITH ECS

6.1.1 Suitability of existing BEM as per ECC/DEC/(14)02 for FRMCS BS

The LRTC specified in Annex 2 of ECC Decision (14)02 are considered valid in the case of FRMCS BS operating in 2290-2300 MHz. Reversely, LSA would not apply to FRMCS due to its permanent nature in terms of location, operation and availability requirements.

According to the answers to the CEPT questionnaire on the 2290-2400 MHz range²⁰, at least 15 CEPT countries out of 42 having a rail network have or plan to introduce ECS in the 2300-2400 MHz band. In these countries, the issue of TDD cross-network synchronisation arises.

In the case of FRMCS in the 2290-2300 MHz band, which falls within the in-block blocking domain of band #40, this raises specific concerns:

- From the FRMCS perspective, it is unclear whether specific latency constraints will be mandated.
- It is foreseen that the required frame for FRMCS would be more UL-centric contrary to ECS networks which are DL-centric. Synchronisation between ECS and FRMCS would imply a significant suboptimal loss of capacity either for ECS or for FRMCS (or both).
- Implementing synchronised operation between different technologies – when feasible – often implies suboptimal configurations. In the case of LTE/NR coexistence, the latency penalty is assessed in ECC Report 296.

In summary, the results on previous CEPT studies in the 2.3 GHz band as well as other 3GPP bands highlight several technical challenges to enable unsynchronised operation of FRMCS and ECS TDD networks within the 2.3 GHz band. The required geographical protection distances between unsynchronised base stations are expected to be that large that this is not considered a realistic option for FRMCS deployment. The possible implications of a synchronised operation between FRMCS and ECS (which also include sharing the same UL and DL frame structure) has not been studied.

6.1.2 Impact of FRMCS cab-radio on ECS BS above 2300 MHz

With respect to blocking, the feasibility of FRMCS high-power cab-radios (in terms of coexistence with ECS) depend on its density of usage, so that the ECS network adjacent in frequency face an acceptable throughput loss. This is for further study.

With regard to out-of-band emissions, a Power Class 1 UE (31 dBm output power) has a greater ACLR compared to a Power Class 3 UE (23 dBm output power)²¹, so that the spectrum emission mask remains the same.

The potential interference from FRMCS cab-radio out-of-band emissions to ECS BS above 2300 MHz has not been studied.

6.1.3 Impact of ECS BS above 2300 MHz on FRMCS cab-radio

This point has not been assessed.

6.2 COEXISTENCE WITH APPLICATIONS BELOW 2290 MHZ

This point has not been assessed.

²⁰ See the synthesis in FM(20)056-Annex 11

²¹ See 3GPP TS 36.101

6.3 COEXISTENCE WITH DEEP SPACE RESEARCH AND RADIOASTRONOMY IN 2290-2300 MHZ

This point has not been assessed.

6.4 COEXISTENCE WITH TELEMETRY, VIDEO PMSE AND FIXED LINKS IN 2290-2400 MHZ

This point, limited to adjacent compatibility study, has not been assessed.

6.5 CONCLUSION ON FEASIBILITY

The use of the 2290-2300 MHz frequency band for FRMCS raises several technical challenges to enable unsynchronised operation together with ECS TDD networks in the 2.3 GHz band. The required geographical protection distances between unsynchronised base stations are expected to be so large that this is not considered a realistic option for FRMCS deployment. The possible implications of a synchronised operation between FRMCS and ECS (which also includes sharing the same UL and DL frame structure) has not been studied. Considering that railways anticipate heavy UL traffic (see Table 5), it is unlikely that the required synchronisation of compatible TDD frame configurations between RMR and neighbouring ECS would be achieved.

The feasibility of FRMCS high-power cab-radios in terms of coexistence with ECS as well as of FRMCS coexistence with other applications in or adjacent to the band would require further study.

When considering ECC Report 172, coexistence of FRMCS with existing applications in and adjacent to the band 2290-2300 MHz as documented in the synthesis of the answers to the CEPT questionnaire on the 2290-2400 MHz range²², is challenging and would also require further studies.

The overall conclusion is that the 2290-2300 MHz frequency band is not a preferred option for identifying appropriate complementary spectrum for RMR.

²² See the synthesis in FM(20)056-Annex 11

7 FEASIBILITY AND SCENARIOS OF USING COMMERCIAL MOBILE NETWORKS (TASK 4)

This chapter investigates the feasibility of using commercial mobile networks to fulfil the communication needs of railways, when railways would either be users of the MNO's network or operate as an MVNO (with network slicing). This would be part of a contractual commitment between railways and the MNO. A national regulatory framework and/or Service Level Agreements may be needed to ensure railway requirements, when considering using an MNO network.

In its 5G Action Plan, the EU Commission emphasises that “*Public services may be an early adopter and a promoter of 5G connectivity-based solutions [relying on public commercial mobile networks], encouraging the emergence of innovative services, contributing to a critical mass of investment, and addressing issues of importance for society.*”²³ The use of public mobile networks may be considered as part of the FRMCS bearer-independent architecture. In addition, the economic implications of utilising public mobile networks need be considered.

7.1 TECHNICAL FEASIBILITY

Table 6: Comparison between current MNO offering and railway requirements

	MNO	Railways
Coverage target	Mainly designed to maximise consumer population coverage, at the expense of occasional not-spots In some countries, special design to provide in-train coverage from trackside	Designed for guaranteed performance on interoperable railway lines and railway-related premises (shunting yards, railway stations, etc.) Formal verification of coverage (KPI according to EIRENE)
Cellular model	Mostly hexagonal Possible specific radio design for in-train coverage from trackside Dedicated solutions for tunnels	Mostly linear/curvilinear Hexagonal in station areas and shunting yards
System/Service Availability Requirements	Mainly designed on a statistical approach, at the expense of occasional failures Frequent maintenance windows	Fault tolerant / high-availability requirements and performance guarantees, particularly for railway lines using train control signalling Limited maintenance windows (when no railway traffic) with mid to long term scheduling

²³ http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17131

	MNO	Railways
Resiliency to (cell) coverage outage	<p>Optimal geographical coverage having minimum overlap.</p> <p>Urban: currently high-density of cells to cover traffic requirements including some overlap of the cell coverage for capacity purposes.</p> <p>Rural: currently low density of cells having a limited overlap.</p> <p>In some countries, in-train coverage from trackside may lead to overlapping MNO outdoor coverage.</p>	<p>Resilience created for example in current GSM-R by usage of significant cell overlap or double coverage (urban, rural) for (high speed) ETCS lines.</p>
	<p>Coverage resiliency is expected to improve on high-traffic railway lines.</p>	<p>Backup via MNO possible at national level e.g. for voice communications.</p>
Orientation and specific features	<p>Massive broadband data services</p>	<p>Critical data communication for semi-automatic/automatic train operation (Emergency brake, Voice Group Calls, Emergency Calls, etc.)</p> <p>Reliant on priority and pre-emption</p> <p>Using Functional Addressing, Location-based Addressing</p>
	<p>System upgrades largely without interaction with customers</p>	<p>System upgrades only in close coordination with railway undertakings and National Safety Authorities, due to lengthy upgrade cycle on rolling stock</p>
	<p>Emphasis on bringing new features</p>	<p>Certification requirements prior to upgrades and introduction of new features</p>
Bandwidth	<p>Optimal statistical multiplexing of the users</p>	<p>Service throughput guarantee at the cell edge (e.g. at the handover points)</p>
Traffic QoS / Service Guarantee	<p>Best-effort for data communication</p> <p>Priority for VoLTE services</p>	<p>Critical applications having very strong QoS and service guarantee requirements (for GSM-R, refer to KPIs in EIRENE and Subset-093)</p>
	<p>QoS features and support (such as priority access and/or network slicing) may be implemented for a selected set of traffic profiles and subscriber contracts</p>	<p>Traffic handling based on priority and pre-emption mechanism</p>
Uplink versus downlink ratio	<p>Asymmetric, currently optimised for downlink capacity</p>	<p>For future applications, asymmetric with a higher traffic volume on the uplink than on the downlink</p>

Regarding the coverage of the railway lines by MNOs:

- In countries where licence conditions do not require specific coverage of the railway tracks, the coverage objective of MNOs is usually related to the percentage of the covered population, and not of the area.

There are also countries where MNOs have already committed to improve their coverage along railway lines. It is expected that the coverage of railway tracks by MNOs will be greatly improved in the upcoming years;

- Some countries have issued licence conditions with the aim to provide telecommunication services to train passengers and/or have introduced requirements to cover all or parts of railway tracks for passenger services.

In the above cases, where commercial mobile networks have not been designed and built for railway use, the suitability of MNO coverage needs to be assessed against railway requirements. There is currently no legal obligation to MNOs to offer hosting railway critical applications on their network.

Countries considering providing FRMCS services through commercial mobile networks could define an appropriate national regulatory framework complemented with a Service Level Agreement to meet the stringent technical (e.g. QoS and coverage) requirements expected by railways.

Coverage enhancement to meet the stringent railway requirements will require investments for e.g. additional radio sites.

Regarding the reliability, availability, maintainability and continuity of service of the commercial mobile network:

- Commercial mobile networks without obligations to provide communication services for railway use, can be envisaged to support non-critical railway applications, or to act as a backup, however assuming a lower quality if railway mobile communication facilities are unavailable;
- Countries considering providing FRMCS services through commercial mobile networks could define an appropriate national regulatory framework complemented with a Service Level Agreement (including risk management) to meet the level of Quality of Service for critical communications. Special attention in this approach should be given to alleviate concerns from railways on the ability of MNOs to ensure the safety-related services necessary for railway operation;
- Prioritisation and pre-emption are necessary to ensure the rail communication availability especially in emergencies.

From a technical point of view, the use of commercial mobile networks for critical railway applications is possible under the condition that the relevant parts of the MNO's network fulfil the stringent interoperability, coverage, availability and QoS requirements given by European railway regulations. Use of a commercial mobile network would need to be specified and tested under real-life conditions to ensure those railway requirements are met.

Use of commercial mobile networks is yet to be proven in the context of critical applications for railways. Coverage of railway properties by MNOs without railway oriented national regulatory framework remains identified in a 2018 joint report by BEREC and RSPG as a "challenge area" for mobile connectivity, see pages 11-14 in [14].

An MNO with obligation to support railway needs would deploy infrastructure in required locations including tunnels and thus improve signal strength along railway lines and other railway-related premises as needed. Such a network would also be designed to handle handover issues from cell to cell in a robust way without loss of the communication link. In addition to providing full coverage, the MNO would also need to satisfy other requirements, such as network resilience and availability which would entail specific engineering, long-term investments (additional radio sites, power backup, overall strengthening of the radio transmission, redesign of backhaul and core network).

7.2 OPERATIONAL AND LEGAL CONSIDERATIONS

Identified potential issues to be considered when using commercial mobile networks are:

- In case of railway accidents, the assignment of responsibility on legal and juridical matters, or related penalties, where malfunctioning of e.g. the radio network is involved;

- Management of MNO technology evolutions, including 3GPP releases and other regular software updates, which may need to be authorised by the Railway Safety Authorities before introduction on live network (this process could have a significant impact on MNO evolutions and operations);
- Congestion in case of major incidents or accidents;
- A long-term dependency and stable relationship between the railway infrastructure manager and the MNO;
- Long-term guarantee (possibly exceeding the equipment life cycle) for technology support related to available hardware, software and support services for the trackside infrastructure, as well as for railway terminal (cab-radio, handheld or data modem) backwards-compatibility.

In addition to satisfying technical requirements, the MNO would also need to satisfy other requirements, such as operational and field maintenance processes. The willingness of MNOs to take legal obligations and liabilities has to be taken into account. To date, MNO processes do not cover safety-related and interoperability assurance for railways, which currently requires extensive certification.

7.3 IMPACT OF RAILWAY INTEROPERABILITY REQUIREMENT

In case FRMCS make use of commercial mobile networks:

- Multiple-band support is to be realised through the availability of multiple-band on-board radio modules and antennas. The ECS network to be used will require the adoption of common technical standards (i.e. LTE/NR) and compatible network sharing mechanisms, and also will need to support standard conformance and interoperability specifications.
- Due to the potential implementation variations throughout the EU, trains will need to support both the dedicated RMR spectrum as well as the identified ECS spectrum parts.
- Several typical technical challenges need to be addressed: limited space for antennas on train roof; potential limitations on the total range of spectrum that can be covered at sufficient performance level; limiting the loss between the roof antenna and the RMR receiver input (6 dB according to EIRENE SRS for GSM-R); etc.

The CCS TSI and the EIRENE SRS would need to be amended to make the use of commercial mobile networks possible for railway critical applications. With respect to railway interoperability, a limited number of ECS frequency bands would need to be referenced in the CCS TSI. The national contract between the infrastructure manager and the MNO would mandate the provision of coverage with at least one of these frequency bands. It would also be necessary to integrate in the on-board radio equipment the entire set of frequency bands referenced in the CCS TSI to fulfil the railway interoperability requirement.

7.4 CONCLUSIONS ON USING COMMERCIAL MOBILE NETWORKS

From a technical point of view, the use of commercial mobile networks for critical railway applications is possible under the condition that the relevant parts of the MNO's network fulfil the stringent interoperability, coverage, availability and QoS requirements of railways (including prioritisation and pre-emption). Use of a commercial mobile network would need to be specified and tested under real-life conditions to ensure those railway requirements are met. To date, MNO processes do not cover railway safety-related and interoperability assurance, which currently requires extensive certification.

Some elements would require further exploration with respect to railway safety, certification and validation. Key issues are MNO's legal obligations, liabilities and risk assessment. In addition, the European railway regulatory framework must be fulfilled to guarantee interoperability.

MNO networks that do not fulfil railway requirements might be used for lines with different requirements and non-critical railway communications. Use of commercial mobile networks can also be envisaged to offer some flexibility in providing additional capacity to the spectrum harmonised for railway interoperability.

For the retention of the railway interoperability, the EIRENE SRS and CCS TSI should be amended to make the use of commercial mobile networks possible.

8 CONCLUSIONS

The present CEPT Report answers tasks 1 to 4 of the Mandate from the European Commission to CEPT on spectrum for the future railway mobile communications system (FRMCS).

Only non-AAS FRMCS has been considered. Additional studies should be performed in case AAS are considered for FRMCS deployments.

Task 1: spectrum needs for mission critical operation of the future railway mobile communications system (successor system of GSM-R)

Ensuring railway interoperability throughout Europe must be considered when determining spectrum needs. Having the possibility to reuse as much as possible the current radio network infrastructure (BS sites) would save costs, time and reduce operational burden. Therefore, the spectrum in the whole 2x5.6 MHz in 874.4-880 MHz / 919.4-925 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond. Considering the FRMCS rollout timeframe, it may not make sense to invest in a 4G network compared to 5G. A migration using only the 900 MHz spectrum would require that the initial FRMCS deployment uses a deployment of a 1.4 MHz LTE carrier adjacent to GSM-R, or the realisation of overlapping NR wideband channels in a co-channel deployment with GSM-R.

The targeted 2x5.6 MHz of spectrum could be used by a 5.6 MHz FDD NR carrier during both migration and post-migration. Such a carrier would provide a higher traffic handling capacity than the current 3GPP defined 5 MHz carrier and thus would better support the anticipated growth of the FRMCS traffic volume. Although current indications are that such a 5.6 MHz carrier should be feasible within the 3GPP NR specifications, additional work is necessary in 3GPP to confirm feasibility and carry out the specification work.

In-band coexistence, based on an overlay of a 5 MHz FDD NR carrier or of a 5.6 MHz FDD NR carrier, co-channel with GSM-R carriers, would be an option for the migration using the 900 MHz spectrum while maintaining operation of GSM-R.

Alternatively, a 5 MHz FDD LTE/NR carrier could be implemented plus several NB-IoT carriers in the remaining 600 kHz. An NB-IoT carrier potentially supports a larger coverage area than a 5 MHz LTE/NR carrier. Certain critical railway applications like monitoring and control of critical infrastructure may benefit from the usage of NB-IoT.

As another alternative, a 1.4 MHz FDD LTE carrier may be used, adjacent to the 4 MHz for GSM-R during migration. This approach would have a lower traffic handling capacity and needs to be considered in terms of product lifecycle and longer-term migration to NR.

Furthermore, considering the throughput requirements, access to complementary spectrum, such as 1900-1910 MHz, is a prerequisite for many countries in order to fulfil the interoperability requirements, to enable parallel operation of GSM-R and its successor, to benefit from new railway critical applications (including ATO and critical sensing/video), and to deal with border and hotspot areas. Hence the spectrum 1900-1910 MHz is one of the two identified spectrum bands for the successor to GSM-R for the migration and beyond.

This does not preclude the use of public mobile networks, noting that the railway interoperability, coverage, availability and QoS requirements still needs to be fulfilled.

Task 2: technical feasibility for operating the successor system in the 874.4-880 MHz / 919.4-925 MHz frequency band while ensuring simultaneous operation of GSM-R and the successor system in these bands during a migration period

The 874.4-880 MHz / 919.4-925 MHz frequency band is feasible for RMR, provided that the following conditions are met.

1. RMR BS shall ensure coexistence with ECS BS receiving below 915 MHz. The statistical approach, as described in ECC Report 318, relying on existing GSM-R and ECS deployment data, was chosen to define the BEM which enables uncoordinated deployments, while ensuring an acceptably low occurrence probability of

residual interference cases to be addressed at national level when interference occurs. The BEM for FRMCS will include channels of 1.4 MHz, 5 MHz and 5.6 MHz.

National regulation may allow multiple carriers using wideband technologies²⁴ or higher e.i.r.p. for RMR BS than stated in the technical conditions, as long as no harmful interference on ECS BS can be ensured. As part of a national coordination procedure, the infrastructure manager could, for example, demonstrate that a coexistence criterion with respect to each ECS BS in the vicinity of the RMR radio site is fulfilled. The relevant national coordination procedure may differ from country to country, taking into account that coordination procedures with regard to ECS / GSM-R are already in force based on the guidance as described in ECC Report 229 [27].

2. FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 874.4-880 MHz provided that UL power control is activated, and that FRMCS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

3. RMR cab-radios shall be robust against adjacent emissions, including ECS BS above 925 MHz, aerial UE using ECS below 915 MHz and SRD below 919.4 MHz. For the latter case, the required level of robustness is driven by 4W RFID interrogators. ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR cab-radios.

Improved GSM-R cab-radios as per ETSI TS 102 933-1 are currently being deployed and are specified for the improved reception of GSM-R in the vicinity of intensive ECS emissions above 925 MHz, but the current GSM-R cab-radio receiver specification is less resilient against adjacent emissions from higher-power SRD below 919.4 MHz in some close proximity cases. Administrations may further consider the protection of GSM-R cab-radios²⁵ if the requirements in 916.1-918.9 MHz on the GSM-R cab-radio receiver in Table 2 of ECC Report 313 are not met.

FRMCS cab-radios need to fulfil the receiver characteristics determined in ECC Report 313.

4. RMR BS shall be robust against adjacent emissions, including SRD below 874.4 MHz. ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR BS.

5. When in close vicinity to rail tracks, ECS BS unwanted emissions may cause interference to FRMCS cab-radio. In practice, to solve these cases, technical and/or operational measures could be taken to ensure the coexistence of both ECS and FRMCS in parallel.

6. With respect to the use of a single NB-IoT carrier for FRMCS, the studies in ECC Report 318 can be applied to the in-band operation mode without power boost and to the standalone operation mode. If multiple carriers using wideband technologies¹ or power boost were to be used for in-band NB-IoT, the BEM would not directly be applicable.

Task3: technical feasibility for operating the successor system in part of the 1900-1920 MHz frequency band

The 1900-1910 MHz frequency band is feasible for FRMCS, provided that the following conditions are met.

1. FRMCS BS shall ensure coexistence with ECS BS receiving above 1920 MHz while ensuring an efficient use of spectrum. For uncoordinated deployment, the BEM for FRMCS BS will assume that ECS BS have enhanced selectivity compared to the current Harmonised European Standards. This would facilitate coexistence with FRMCS BS transmitting up to 65 dBm e.i.r.p. with the aim of having a future-proof regulation and allowing macro coverage. Current ECS BS located near an FRMCS radio site may need to be adapted, in such a way that they do not suffer interference from FRMCS. In such case, additional mitigation techniques would be needed, such as the upgrade of the ECS BS selectivity or on a case-by-case basis adjustment of antenna directivity, azimuth, tilt, etc. of the FRMCS and/or ECS BS²⁶.

²⁴ including NB-IoT

²⁵ National coordination is allowed as per Note 7 relative to the table on the harmonised technical conditions for SRD in Decision (EU) 2018/1538.

²⁶ Adjustments of antenna directivity, azimuth, tilt may not be sufficient to solve all interference cases. MFCN BS with improved selectivity would avoid the need for national coordination.

The improvement of the ECS selectivity for those ECS BS near the railway tracks can be achieved by either the usage of new radio units of ECS BS or by adding external filter to existing radio units operating with passive antenna systems. Enhanced selectivity should be included (potentially as a specific receiver class) in the relevant ECS BS Harmonised European Standards so that newly introduced products placed on the market based on this update natively fulfil this requirement.

The BEM for FRMCS BS will assume ECS BS with enhanced selectivity. In order to ensure that the ECS operators have enough time to adapt the concerned radio sites, they should have, sufficiently far in advance, information on the rollout of a new FRMCS BS in 1900-1910 MHz.

The BEM for FRMCS will include one channel of 10 MHz.

2. FRMCS high-power cab-radios transmitting up to 31 dBm (output power) can be allowed in 1900-1910 MHz provided that UL power control is activated, and that FRMS cab-radios are compliant with an ACLR of 37 dB and 3GPP LTE/NR spectrum emission mask.

3. FRMCS cab-radios shall be robust against adjacent emissions, including ECS BS below 1880 MHz and aerial UE using ECS above 1920 MHz. Depending on the possible introduction of governmental UAS in 1880-1920 MHz, ETSI shall take the results of the studies into account when specifying the Harmonised European Standard for RMR cab-radios.

4. FRMCS BS shall be robust against adjacent emissions, including ECS BS below 1880 MHz.

5. With regard to adjacent compatibility between DECT (1880-1900 MHz) and FRMCS, it is understood that FRMCS and DECT, adjacent to each other, will generally coexist. Where the DECT usage density is not high, the Dynamic Channel Selection (DCS) algorithm implemented in DECT would then allow the communication to use one of the DECT channels that do not experience interference. In some worst case scenarios, measures to enable coexistence between DECT in 1880-1900 MHz and RMR in 1900-1910 MHz might be needed, when information on DECT local deployment is made available.

Task 3bis: if necessary, technical feasibility for operating the successor system in another frequency band

The use of the 2290-2300 MHz frequency band for FRMCS raises several technical challenges to enable unsynchronised operation together with ECS TDD networks in the 2.3 GHz band. The required geographical protection distances between unsynchronised base stations are expected to be so large that this is not considered a realistic option for FRMCS deployment. The possible implications of a synchronised operation between FRMCS and ECS (which also includes sharing the same UL and DL frame structure) has not been studied. Considering that railways anticipate heavy UL traffic (see Table 5), it is unlikely that the required synchronisation of compatible TDD frame configurations between RMR and neighbouring ECS would be achieved.

The feasibility of FRMCS high-power cab-radios in terms of coexistence with ECS as well as of FRMCS coexistence with other applications in or adjacent to the band would require further study.

When considering ECC Report 172, coexistence of FRMCS with existing applications in and adjacent to the band 2290-2300 MHz as documented in the synthesis of the answers to the CEPT questionnaire on the 2290-2400 MHz range²⁷, is challenging and would also require further studies.

The overall conclusion is that the 2290-2300 MHz frequency band is not a preferred option for identifying appropriate complementary spectrum for RMR.

Task 4: technical feasibility and scenarios of using commercial mobile networks

From a technical point of view, the use of commercial mobile networks for critical railway applications is possible under the condition that the relevant parts of the MNO's network fulfil the stringent interoperability, coverage, availability and QoS requirements of railways (including prioritisation and pre-emption). Use of a commercial mobile network would need to be specified and tested under real-life conditions to ensure those

²⁷ See the synthesis in FM(20)056-Annex 11

railway requirements are met. To date, MNO processes do not cover railway safety-related and interoperability assurance, which currently requires extensive certification.

Some elements would require further exploration with respect to railway safety, certification and validation. Key issues are MNO's legal obligations, liabilities and risk assessment. In addition, the European railway regulatory framework must be fulfilled to guarantee interoperability.

MNO networks that do not fulfil railway requirements might be used for lines with different requirements and non-critical railway communications. Use of commercial mobile networks can also be envisaged to offer some flexibility in providing additional capacity to the spectrum harmonised for railway interoperability.

For the retention of the railway interoperability, the EIRENE SRS and CCS TSI should be amended to make the use of commercial mobile networks possible.

ANNEX 1: CEPT MANDATE

Ref. Ares(2018)3947109 - 25/07/2018

**EUROPEAN COMMISSION**

Communications Networks Content & Technology Directorate-General

Electronic Communications Networks & Services
SpectrumBrussels, 12 July 2018
DG CONNECT/B4**INTERNAL DOCUMENT****RADIO SPECTRUM COMMITTEE****Working Document****Subject: Draft Mandate to CEPT on spectrum for the future railway mobile communications system.****Opinion of the RSC****pursuant to Advisory Procedure under Article 4 of Regulation 182/2011/EU and Article 4.2 of Radio Spectrum Decision 676/2002/EC**

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European Commission, DG Communications Networks Content & Technology, 200 Rue de la Loi, B-1049 Bruxelles
RSC Secretariat, Avenue de Beaulieu 33, B-1160 Brussels - Belgium - Office BU33 7/09Telephone: direct line (+32-2)295.6512, switchboard (+32-2)299.11.11. Fax: (+32-2) 296.38.95
E-mail : cnect-rsc@ec.europa.eu

1. PURPOSE

The objective of this Mandate is to consider the required amount of spectrum, identify appropriate spectrum bands, study technical feasibility and develop harmonised technical conditions for a sustainable and efficient use of such bands for the operation of the future railway mobile communications system (FRMCS), which is the successor of GSM-R.

This mandate specifically invites CEPT to study the following frequency bands for existing and future mission-critical¹ railway mobile communications

- 874.4-880 MHz and 919.4-925 MHz
- 1 900-1 920 MHz

Further spectrum bands, for example the band 2 290-2 400 MHz on a tuning range basis, and use of commercial mobile networks may also be studied. In this regard, the progressive phase-out of the existing GSM-R technology and the need for coexistence and simultaneous operation of the existing and the forthcoming system for up to several years should be considered, also in terms of spectrum needs.

2. EU POLICY CONTEXT

Railways are essential for the EU economy. The European railway network covers over 220 000 km of lines and carries 9 billion passengers and 1 700 million tonnes of freight per year². The frequency bands to be studied and commercial networks should be considered as a possibility to support railway digitalisation and innovation.

The radiocommunication system used for railway operation is currently GSM-R. Today over 100 000 km of railway lines are operated by GSM-R³ and this amount is still growing. It is defined through the basic parameters included in section 4 of the CCS TSI⁴. The air interface is specified to use the R-GSM⁵ band (see table 3-A in 3.5.1 of the EIRENE SRS). The so-called "UIC band" reserved for GSM-R operation is 876-880/921-925 MHz. These bands are harmonised EU-wide by Commission Decision 1999/569/EC of 28 July 1999⁶, which in its Article 2 provides that "*The*

¹ Mission Critical: applications that are essential for train movements and safety or a legal obligation, such as emergency communications, shunting, presence, trackside maintenance and Automatic Train Control (as described in UIC FRMCS User Requirement Specification v3.0.0. Art 4.1.3). <https://uic.org/IMG/pdf/fu-7100-3.0.0.pdf>

² Source: "The economic footprint of railway transport in Europe", CER 2014.

³ Source: UIC.

⁴ Control Command and Signalling Technical Specifications for Interoperability. <http://www.era.europa.eu/Core-Activities/ERTMS/Pages/Current-Legal-Reference.aspx>

⁵ GSM-R refers to the radio elements of ERTMS (network and equipment) while R GSM is a designation for the frequency band 876-915 & 921-960 MHz. This includes the public mobile GSM network.

⁶ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01999D0569-19990729&qid=1519396120758&from=EN>

frequency bands used for GSM-R radio links shall be 876-880 MHz for the train-to-ground link and 921/925 MHz for the ground-to-train link". These bands are used on a shared basis with others usages at national level (e.g. Defence) to ensure an efficient usage of the spectrum while ensuring an effective coexistence of these different usages.

As telecommunication standards are evolving and new railway applications are needed, GSM technology will become obsolete at some stage. The manufacturing industry is unlikely to support the GSM technology after 2030 and given the long time needed for selecting a technology and making it ready for operation, work has started at various levels (UIC, ERA, CEPT, ETSI...) on the definition of the most suitable radio technology and frequency bands for railway communications of the next generation. CEPT is preparing two ECC reports, respectively on spectrum requirements and on candidate bands for the implementation of the successor to GSM-R.

In its Opinion on ITS published in February 2017⁷, the RSPG highlighted that it will be important to ensure interoperability for FRMCS across Member States. A common approach to make spectrum available for the future railway mobile communications system across the EU would ease implementation.

Recent discussions in the Radio Spectrum Committee and CEPT have shown that the 874.4-880 MHz and 919.4-925 MHz bands as well as the 1 900-1 920 MHz band are the currently most prominent options under investigation for mission-critical operation purposes for the future rail mobile communication system. However, other frequency bands, for example 2 290-2 400 MHz on a tuning range basis are also still under investigation within CEPT as an alternative to the 1 900-1 920 MHz frequency band.

Concerning the 900 MHz range, CEPT is still investigating the total spectrum requirement needed after the GSM R switch off to handle all existing and new railway critical applications. Depending on the result of this CEPT investigation, the remaining spectrum could be considered for other applications such as SRD including RFID.

Within CEPT, the 1 900-1 920 MHz is also identified as a possible band to respond to future needs for professional drones/UAS. ETSI has proposed DECT evolution in 1 900-1 920 MHz⁸. Above 1 920 MHz, the spectrum band is widely and heavily used by WBB ECS.

⁷ https://circabc.europa.eu/sd/a/b30590d7-5190-480b-b1d1-def24719e061/RSPG17-008-Final_opinion_ITS.pdf

⁸ TR103 149 (2013).

3. JUSTIFICATION

Pursuant to Article 4(2) of the Radio Spectrum Decision⁹, the Commission may issue mandates to the CEPT for the development of technical implementing measures with a view to ensuring harmonised conditions for the availability and efficient use of radio spectrum necessary for the functioning of the internal market. Such mandates shall set the tasks to be performed and their timetable.

The Radio Spectrum Policy Programme¹⁰ (RSPP) requires that Member States, in cooperation with the Commission, ensure spectrum availability *"improving transport systems (...) and for intelligent transport safety and transport management systems"*¹¹.

Noting the work of CEPT, ERA, UIC, the evolving work of ETSI and the wider cooperation among stakeholders, the EU regulatory framework on the harmonised use of radio spectrum for railways should be updated in order to take into account the spectrum needs for the future railway mobile communications system taking into account the required migration phase.

4. TASK ORDER AND SCHEDULE

In order to support a common approach to spectrum for the future railway mobile communications system across the EU, CEPT is mandated to carry out the following technical tasks:

- Task 1** Assess the spectrum needs for mission critical operation of the future railway mobile radio communications system (successor system of GSM-R) in terms of required amount of spectrum and frequency ranges. Study solutions for the typical/average need and increased need at limited geographical areas (hotspots) separately.
- Task 2** Based on results of task 1, assess the technical feasibility for operating the successor system in the 874.4-880 MHz / 919.4-925 MHz frequency band while ensuring simultaneous operation of GSM-R and the successor system in these bands during a migration period. In this regard, take into account the spectrum needs, requirements and reliability needs of the railway system and ensure coexistence with services in adjacent bands (ECS below 915 MHz and above 925 MHz, SRD and Defence)¹².
- Task 3** Based on results of task 1, assess the technical feasibility for operating the successor system (FRMCS) in part of the 1 900-1 920 MHz frequency band

⁹ Decision 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community, OJ L108 of 24.4.2002.

¹⁰ Decision 243/2012/EU of 14 March 2012, OJ L81 of 21.3.2012.

¹¹ Article 8 (1) of the RSPP.

¹² Cfr. RSCOM17-50 and RSCOM17-60

in addition to the band mentioned in task 2 while taking into account the specific requirements of the railway system and ensuring coexistence with adjacent use. In this regard, study the impact of shared use between the railway system and other systems under study within this band, with the objective of safeguarding the railway system. In addition, and if necessary, assess the technical feasibility for operating the successor system (FRMCS) in another frequency band.

Task 4 Study and assess the technical feasibility and scenarios of using commercial mobile networks, taking into account wireless coverage and reliability needs of the railway system.

Task 5 Assess the best option for long term development of FRMCS and develop EU-harmonised technical conditions, possibly for shared spectrum use, for the future railway mobile radio communications system, which are suitable for both the migration period and after the GSM-R switch-off, taking into account the results of tasks 1, 2, 3 and 4.

In performing the tasks above, CEPT should take due consideration of the anticipated simultaneous operation between GSM-R and the future railway mobile communications system for several years, which may necessitate a solution for temporary supplementary spectrum allocation for the migration period. During the migration period, pan-European railway interoperability rules are assumed to continue relying on GSM-R carriers within 876-880 / 921-925 MHz frequency bands.

CEPT should work in cooperation with ETSI, as appropriate. CEPT should also ensure close cooperation with all concerned stakeholders when assessing scenarios and developing technical conditions for the shared use of spectrum. It is assumed that receiver characteristics of the future railway mobile communications system (for user terminals and possibly base stations) should fulfil the specific railway availability requirements and ensure appropriate co-existence with services in adjacent bands.

In the work carried out under the Mandate, the overall policy objectives of the Radio Spectrum Policy Programme (RSPP) such as effective and efficient spectrum use and the support for specific Union policies shall be given utmost consideration. When carrying out studies based on this Mandate, the CEPT shall, whenever relevant, take utmost account of the applicable EU law and support the principles of service and technological neutrality, non-discrimination and proportionality insofar as technically possible.

CEPT should provide deliverables under this Mandate according to the following schedule:

Delivery date	Deliverable	Subject
March 2020	Final draft CEPT Report A to the Commission	Draft results under tasks 1, 2, 3 and 4
July 2020	Final CEPT Report A to the Commission taking into account the outcome of the public consultation	Final results under tasks 1, 2, 3 and 4
July 2020	Final draft CEPT Report B to the	Draft results under task 5

	Commission	
November 2020	Final CEPT Report B to the Commission taking into account the outcome of the public consultation	Final results under task 5

CEPT is requested to report on the progress of its work pursuant to this Mandate to all meetings of the Radio Spectrum Committee taking place during the course of the Mandate.

The Commission, with the assistance of the Radio Spectrum Committee and pursuant to the Radio Spectrum Decision, may consider applying the results of this mandate in the Union, pursuant to Article 4 of the Radio Spectrum Decision and having taken into account any relevant guidance of the RSPG.

ANNEX 2: LIST OF REFERENCES

- [1] Directive (EU) 2016/797 of the European Parliament and of the Council of 11 May 2016 on the interoperability of the rail system within the European Union
- [2] Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community
- [3] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC
- [4] Commission Regulation (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union
- [5] EIRENE FRS v8.0.0: "Functional Requirements Specification"
- [6] EIRENE SRS v16.0.0: "System Requirements Specification"
- [7] Mandate to CEPT on spectrum for the future railway mobile communications system, RSCOM18-05 rev.3 Final
- [8] Commission Decision of 28 July 1999 on the basic parameters for the command-and-control and signalling subsystem relating to the trans-European high-speed rail system
- [9] ECC Decision (02)05: "The designation and availability of frequency bands for railway purposes in the 876-880 MHz and 921-925 MHz bands", approved March 2013
- [10] FW-ATwG 1903 v2.2.0 / FM56(18)065: "FRMCS Traffic Analysis"
- [11] ETSI TR 103 554-1: "LTE radio performance simulations and evaluations in rail environment"
- [12] ETSI TR 103 554-2: "NR radio performance simulations and evaluations in rail environment"
- [13] FRMCS User Requirement Specifications, UIC, v3.0
- [14] BEREC and RSPG joint report on Facilitating mobile connectivity in "challenge areas", BoR (17) 256 / RSPG18-001
- [15] Directive 2012/34/EU of the European Parliament and of the Council of 21 November 2012 establishing a single European railway area
- [16] Commission Implementing Decision (EU) 2018/1538 of 11 October 2018 on the harmonisation of radio spectrum for use by short range devices within the 874-876 and 915-921 MHz frequency bands (OJ L257, 15 Oct. 2018, p. 57)
- [17] Decision 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision)
- [18] Commission Delegated Decision (EU) 2017/1474 of 8 June 2017 supplementing Directive (EU) 2016/797 of the European Parliament and of the Council with regard to specific objectives for the drafting, adoption and review of technical specifications for interoperability
- [19] Commission Decision 2009/766/EC of 16 October 2009 on the harmonisation of the 900 MHz and 1800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community (OJ L274, 20 October 2009, p. 32)
- [20] Commission Implementing Decision (EU) 2018/637 of 20 April 2018 amending Decision 2009/766/EC on the harmonisation of the 900 MHz and 1800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community as regards relevant technical conditions for the Internet of Things (OJ L105, 25 April 2018, p. 27)
- [21] CEPT Report 19: "Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS", approved October 2008
- [22] ECC Report 294: "Assessment of the spectrum needs for future railway mobile radio (RMR) communications", approved February 2019
- [23] ECC Report 318: "Compatibility between RMR and MFCN in the 900 MHz range, the 1900-1920 MHz band and the 2290-2300 MHz band", approved July 2020
- [24] ECC Report 313: "Coexistence between RMR in the 900 MHz frequency range and other applications in adjacent bands", approved May 2020

- [25] ECC Report 314: "Coexistence between FRMCS in the 1900-1920 MHz frequency range and other applications in adjacent bands", approved May 2020
- [26] ECC Report 309: "Use of MFCN for the command & control and payload links of UAs within the current MFCN harmonised regulatory framework", approved July 2020
- [27] ECC Report 296: "National synchronisation regulatory framework options in 3400-3800 MHz: a toolbox for coexistence of MFCNs in synchronised, unsynchronised and semi-synchronised operation in 3400-3800 MHz", approved March 2019
- [28] ECC Report 229: "Guidance for improving coexistence between GSM-R and MFCN in the 900 MHz band", approved May 2015
- [29] ECC Report 172: "Broadband Wireless Systems Usage in 2300-2400 MHz", approved April 2012
- [30] UIC O-8736: "Assessment report on GSM-R current and future radio environment"
- [31] ETSI TS 102 933-1: "GSM-R improved receiver parameters; Part 1: Requirements for radio reception"
- [32] Commission Implementing Decision (EU) 2018/1538 of 11 October 2018 on the harmonisation of radio spectrum for use by short-range devices within the 874-876 and 915-921 MHz frequency bands
- [33] ERC Recommendation 70-03 relating to the use of Short Range Devices
- [34] ECC Decision (14)02: "Harmonised technical and regulatory conditions for the use of the band 2300-2400 MHz for MFCN", approved June 2014