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Franco-German Innovation Project on
5G for Resilient and Green Rail Communications

Work Package 2.2:
Coexistence of FRMCS & GSM-R

Report on Whitespace Concept *(public)*

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Contents

1 Executive Summary

This report summarizes the work and results of Work Package 2.2 (WP2.2) Task 2.21, which is a key element of the 5G-RACOM project activities on coexistence of FRMCS & GSM-R (in WP2.2). The target of Task 2.21 is to deliver in the first version of the deliverable D2.21 a concept description of the Whitespace approach which will allow a coexistence scheme between the 5G NR and the GSM-R within the 900 MHz RMR frequency band allocated to railways without impacting neither refarming the GSM-R deployed networks.

The second version of the deliverable D2.21 will deliver in addition the test plan definition for the coexistence of FRMCS & GSM-R.

2 Introduction

The whitespace approach consists in deploying a 5 MHz 5G-NR FDD system overlapping the current 4 MHz GSM-R FDD system as presented in the figure below.

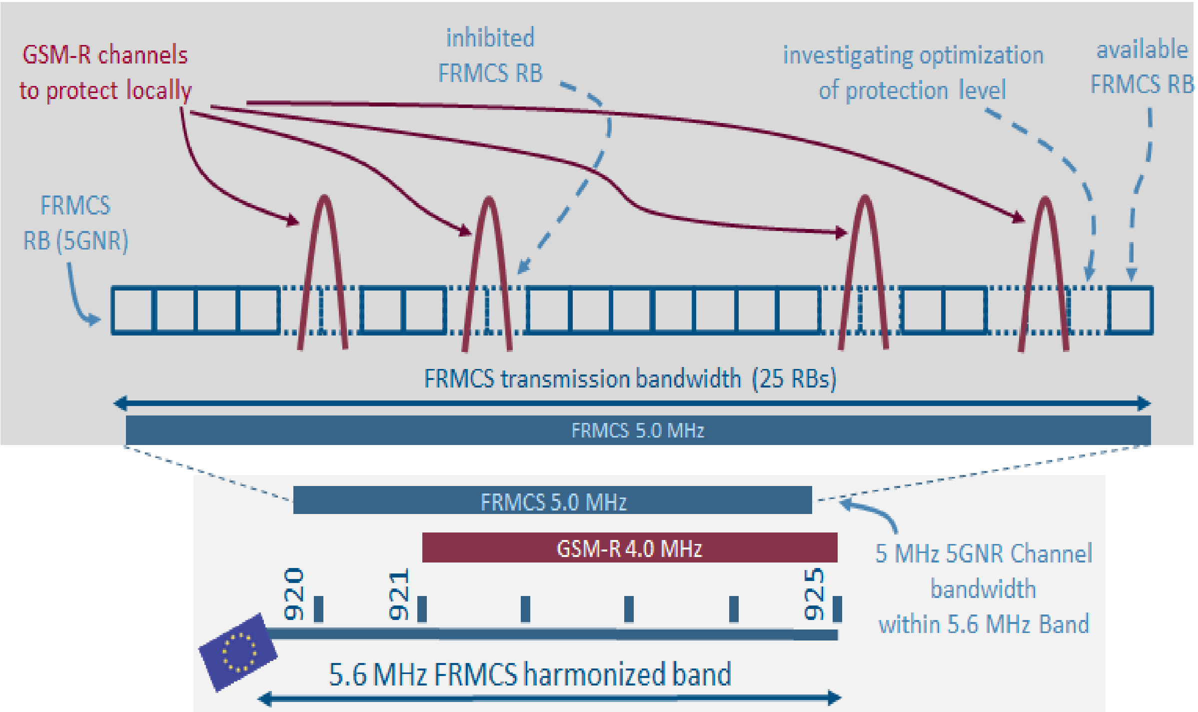

Figure 1 900MHz coexistence with White Space

Thanks to the flexible 5G OFDM structure, this 2G-5G coexistence is possible. Similarly, to what has been proposed in NB-IoT, especially for in-band mode, existing GSM-R carriers can coexist with a 5G system for which the mapping of the logical channels is done with consideration of the presence of the 2G carriers.

Considering the GSM channel bandwidth (271 kHz – Nyquist bandwidth), the RB size (180 kHz for 15 kHz sub carrier spacing) used in 5G and the capabilities to map flexibly the 5G logical channels at any time and frequency location, it becomes possible to separate the two technologies located in the same spectrum.

The first principle for this spectrum sharing is to preserve; as most as possible, the GSM-R for both UL and DL. To manage that separation, specific RB or subcarrier puncturing mechanisms are used, for both DL or UL, associated to appropriated radio scheduler taking into account the unused RB or subcarriers.

The second principle consists in accepting some form of GSM-R to 5G interference impacting the 5G performances, but reducing any form of 5G to GSM-R interference. 5G is strong enough in term of channel coding mechanisms (LDPC, HARQ, repetition strategies) to support this kind of additional interferers. 5G throughput will be impacted as well as the synchronization and initial access timing due the presence of such additional GSM-R carriers located into the 5G channel. Such performance degradations are depending on the number of punctured RB or subcarriers.

This concept entails deploying a 5G NR channel over the GSM-R spectrum on GSM-R sites and peacefully coexisting with the GSM-R system by minimizing inter-system interference. This is achieved through advanced scheduling techniques in the 5G NR base station to protect GSM-R carriers while remaining fully compatible with standard 5G NR FRMCS handsets and cab radios. With “Whitespace FRMCS”, railway infrastructure operators can efficiently introduce FRMCS and decide if, where and when to invest further in densification as digitalization takes off.

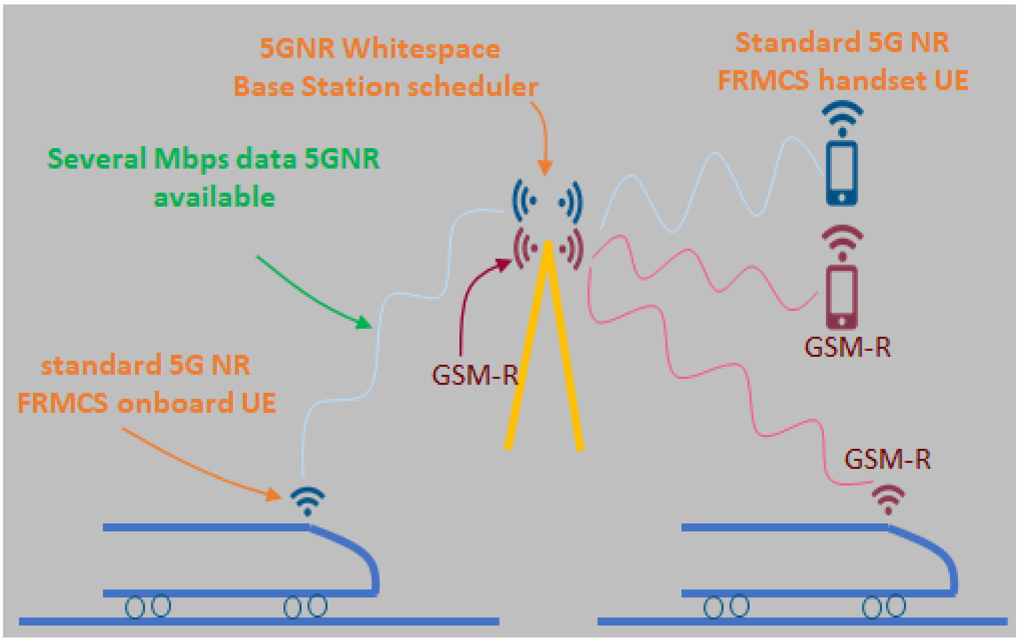

Figure 2: 900MHz White Space use cases

3 GSM-R and 5G FRMCS Radio Coexistence

The purpose of such coexistence is to locate GSM-R and 5G FRMCS system into a same radio channel.

The band n100 has a total bandwidth of 5.6 MHz and has been selected for railways on a non-exclusive basis in the 900 MHz spectrum.

3GPP band	Duplex mode	Frequency range
n100	FDD	UL: 874.4 – 880 MHz DL: 919.4 – 925 MHz

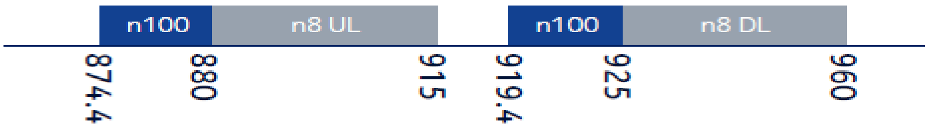

Figure 3: 900MHz - n100 Band for railway

The main goal of such scheme is to allow a smooth introduction of the 5G NR RMR 900 inside the GSM-R band without impacting GSM-R performances, nor requiring additional spectrum, nor introducing complex filtering solution to solve RF coexistence problems strongly impacting the legacy GSM-R system.

This is achieved through advanced 5G scheduling techniques in the 5G NR base station to protect GSM-R carriers while remaining fully compatible with existing 5G NR FRMCS handsets and cab radios (meaning no change on mobile devices required, standard 3GPP RMR 900 UE used).

Basically, it consists in reusing the inter GSM-R carriers frequency spaces to place the current 4 MHz GSM-R system and the future 5 MHz 5G FRMCS standard inside the UIC frequency band (UL: 874,4-880 and DL: 919,4-925) .

Both systems shall be precisely located on this same bandwidth for both DL and UL.

The below GSM-R´s radio receiver characteristics as per 3GPP TS 45.005 [3] should be considered :

- Blocking characteristics (MS and BS)
- Intermodulation characteristics (MS and BS)

For GSM-R, the reference interference level as 3GPP TS 45.005 [3] has to be considered to prevent a degradation of the GSM-R performance:

- for cochannel interference C/Ic = 9 dB
- for adjacent (200 kHz) interference C/Ia1 = -9 dB
- for adjacent (400 kHz) interference C/Ia2 = -41 dB
- for adjacent (600 kHz) interference C/Ia3 = -49 dB

and ETSI TS 102 933 [4] for the GSM-R MS should be considered as well.

3.1 GSM-R and 5G FRMCS Spectrum Sharing

The 5.6 MHz bandwidth of 3GPP band n100 will be occupied by the GSM and the 5G technologies considering this repartition:

- ✓ 5G located on the lower part of band n100: UL: [874,4 MHz, 879,4 MHz] and DL: [919,4 MHz, 924,4 MHz]
- ✓ GSM located on the upper part of band n100: UL: [876,0 MHz, 880,0 MHz] and DL: [921,0 MHz, 925,0 MHz]

Both radio technologies collide from 876 MHz to 879,4 MHz for UL and from 921 MHz to 924,4 MHz for DL. The other parts of the global common spectrum being not conflicting.

As most 19 GSM-R channels can be deployed in the 4 MHz bandwidth. The corresponding GSM-R central frequencies f_i, spaced from each other by 0.2 MHz and indexed from i = 0 to 18, are:

- ✓ UL: $f_i = 876 + 0.2(i+1)$
- ✓ DL: $f_i = 921 + 0,2(i+1)$

Considering today´s railway deployments, the GSM-R carriers deployed in a specific cell and in the 2 neighboring cells of such linear network, are spaced from each other by 0.6 MHz (typical GSM constraints to reduce inter GSM carrier interferences), at most 5 GSM-R carriers could collide with the 5G FRMCS technology. The worst case is obtained for the following index i {0, 3, 6, 9, 12, 15} over the 7 being deployed and visible from the cell on which the GSM-R system is present (the last GSM-R carriers being, in that case, indexed by i = 18).

3.2 Power Aspects

In DL, it is considered that the transmitted 5G energy is equally spread over the 25 resource blocks (RB's) of the 5MHz bandwidth channel. Consequently, the 5G energy transmitted in the 2G bandwidth (set to 270 kHz) becomes $P_{5G\ (dBm)} - 10\log_{10}(25x2/3) = P_{5G\ (dBm)}$ -12dB considering $P_{5G\ (dBm)}$ as the 5G power transmitted at each antenna port and one RB being 180 kHz large.

Considering MIMO (2x2) for DL, for which two 5G emissions at $P_{5G\ (dBm)}$ each are transmitted , the power difference between the 2G and 5G power in the GSM channel is at the end 9dB (when where $P_{2G} = P_{5G}$).

Other power adjustments than $P_{2G} = P_{5G}$ (per antenna) could be envisaged between the 2G and 5G systems in order to manage flexibly the mutual isolation Δ, having in mind that whitespace solution shall preserve the GSM-R performances and accept 5G performances degradations.

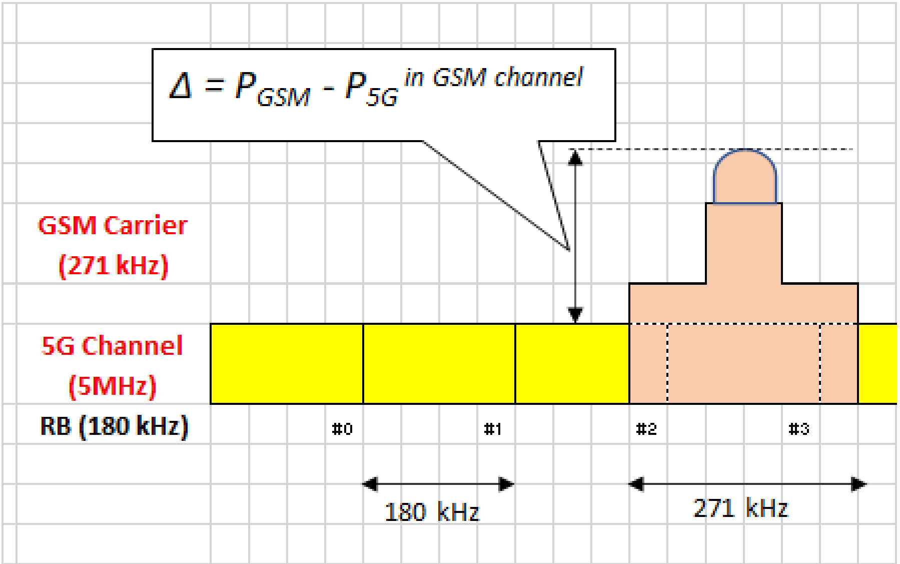

Figure 4: GSM-5G Power adjustment

In UL, it is considered a 23 dBm UE power class for 5G (Power class 3) and the GSM-R devices associated to different power classes (33 and 39 dBm). Of course, high power 5G UE (31 dBm, Power class 1), if introduced in the standard and available on the market, could also be considered. No MIMO schemes are considered for UL as it does not impact the Whitespace concept.

3.3 5G Channel Structure for GSM-R Coexistence

5G address multiple channels for both DL and UL to help the UE to discover the 5G technology, to connect to it for signalling and traffic purpose. Specific control and traffic channels are proposed being common or dedicated in both directions. Such channels are identical to those that have already been introduced in 4G, but their location on the time and frequency OFDM grid is much more flexible.

Thanks to this 5G flexibility, the different common and dedicated 5G channels could be locate on the OFDM channels in order to minimize the interference that could affect colliding GSM-R carriers.

The 5G FRMCS channel is operated with a subcarrier spacing (SCS) of 15 kHz for all kind of traffic and control channels.

3.3.1 Downlink (DL) Case

3.3.1.1 SSB: Synchronization Signal Block

For each 5G band, the SSB location can be discovered by 5G UE at specific frequencies. Those frequencies correspond to the center of the 20 RB SSB structure. SSB helps the UE to enter in the 5G cell. For the band n100, a reduced subset of frequency are possible each of them being associated to a unique GSCN (Global Synchronization Channel Number) indexed from 2303 to 2307. Such values give a subset of 5 possible location starting from the lowest center frequency of the SSB at 921.65 MHz (GSCN = 2303) to the highest center frequency at 922.95 MHz (GSCN = 2307).

It is proposed to select GSCN = 2303 for which the SSB structure is centered at 921.65 MHz.

With such choice, the lowest and highest boundary edge of the SSB composed of 20 RB are located at:

F_{SSB_low} = 921.65 - 10*0,180 = 919,85 MHz

F_{SSB_high} = 921.65 + 10*0,180 = 923,45 MHz

As indicated in the figure below, the SSB structure is composed of synchronization sequences (PSS/SSS) occupying 12 RB encapsulated in global structure of 20 RB spread over 4 OFDM symbols carrying the PBCH. The discovery of the 5G system is done thanks to the PSS/SSS while PBCH is used to receive specific (MIB: Master Information Block) information that give the opportunity to the UE to acquire more knowledge regarding the 5G channel structure in order to facilitate the initial UE access.

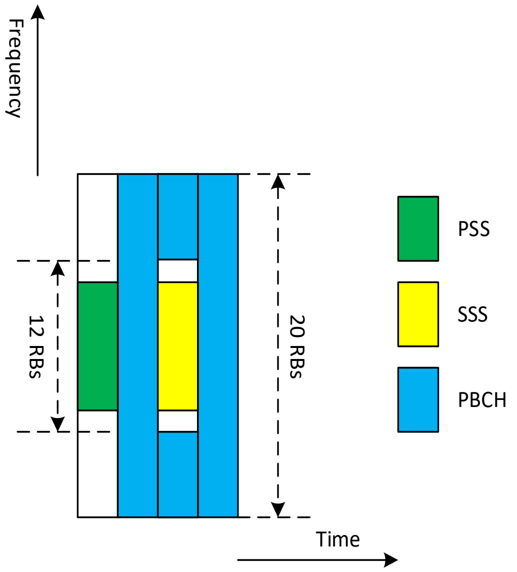

Figure 5: 5G SSB structure

For PSS/SSS, composed of only 12 RB, the lowest and highest boundary edge are located at:

F_{PSS/SSS_low} = 921.65 – 6*0,180 = 920,57 MHz

F_{PSS/SSS_high} = 921.65 + 6*0,180 = 922,73 MHz

With such SSB location choice, considering the presence of GSM-R carriers for the worst case highlighted before, the GSM-R carriers indexed by {0, 3, 6} collide with the PSS/SSS part while those indexed by the {0, 3, 6, 9} collide with the PBCH part.

3.3.1.2 CORESET 0

For a 5G UE, after the MIB, present in PBCH, is detected, the UE has enough information to establish CORESET#0 that is used to detect DCI messages inviting the UE to listen SIB1 For FR1, the size and starting location of CORESET#0 is also the size and starting location of the initial DL BWP. Specifically, for legacy Ues, the field *controlResourceSetZero* within the MIB is used as an index into an appropriate 16-row table in clause 13 of TS 38.213 [1] to establish the location of CORESET#0 relative to “the first RB of the corresponding SS/PBCH block”. The CORESET #0 is shift by a certain number of subcarriers from the first RB of the SSB. This shift is composed 2 different offset values added together: the ssb-subcarrierOffset (also called k_{SSS} expressed in number of subcarriers) and the RB Offset (expressed in number of RB) both indicated in the MIB. The next figure illustrates the relative location of SSB and CORESET#0.

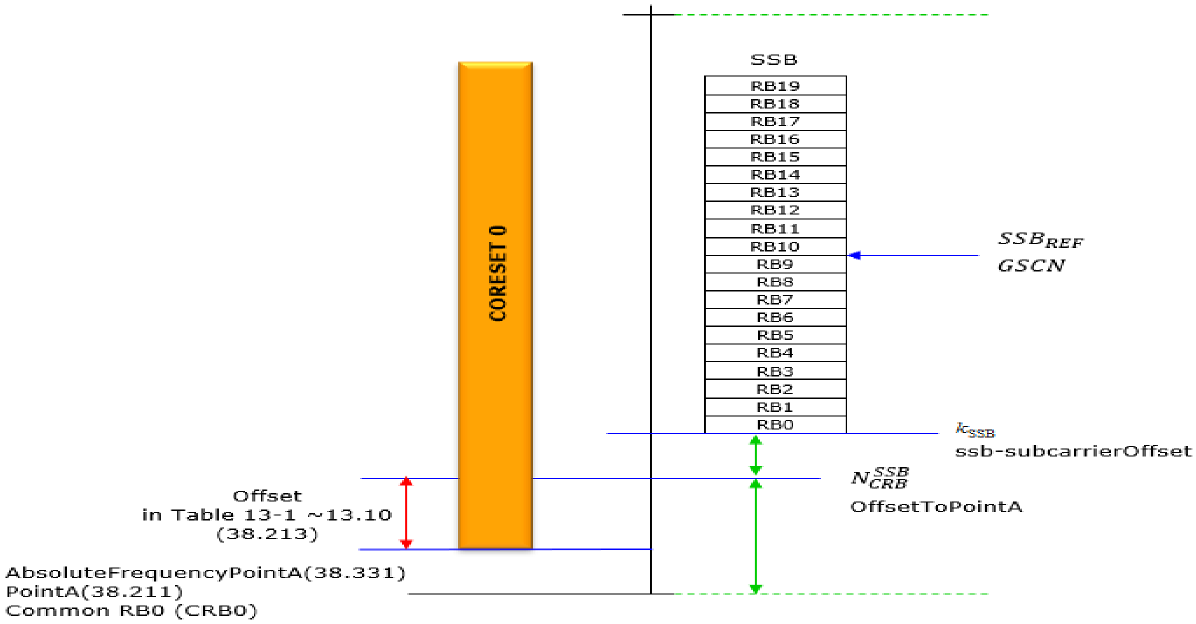

Figure 6: SSB & CORESET 0 Mapping

The UE reads the CORESET#0 configuration index from the MIB on the PBCH, which indicates time and frequency resource allocation parameters for the CORESET #0. Some of those parameters define the frequency domain offset between the first RB in which the SSB is located and the first RB of CORESET#0. This procedure is illustrated in Figure 7.

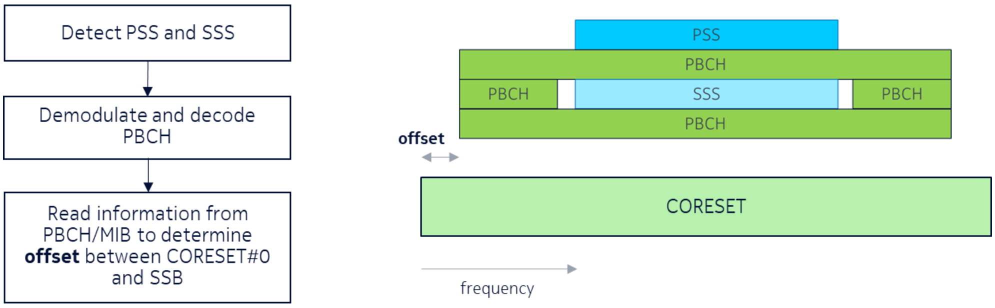

Figure 7: CORESET#0 frequency domain resource allocation signalling.

For a 15 kHz SCS SSB and CORESET#0, Table 13-1 of TS 38.213 [1] (see below Table 1) shall be used. Due to the **Erreur ! Source du renvoi introuvable.**5 MHz bandwidth of the 5G FRMCS channel the CORESET #0 is composed of 24 RB. Consequently, only index from 0 to 5 could be used.

TS 38.213 [1]

Table 13-1: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 15} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz

Index	*SS/PBCH block and CORESET multiplexing pattern*	*Number of RBs* $N_{RB}^{CORESET}$	*Number of Symbols* $N_{symb}^{CORESET}$	*Offset (RBs)*
0	*1*	*24*	*2*	*0*
1	*1*	*24*	*2*	*2*
2	*1*	*24*	*2*	*4*
3	*1*	*24*	*3*	*0*

4	*1*	*24*	*3*	*2*
5	*1*	*24*	*3*	*4*
6	*1*	*48*	*1*	*12*
7	*1*	*48*	*1*	*16*
8	*1*	*48*	*2*	*12*
9	*1*	*48*	*2*	*16*
10	*1*	*48*	*3*	*12*
11	*1*	*48*	*3*	*16*
12	*1*	*96*	*1*	*38*
13	*1*	*96*	*2*	*38*
14	*1*	*96*	*3*	*38*
15	*Reserved*			

Table 1 : Table 13-1 of TS 38.213.

Moreover, due to the SSB location, only index associated to RB Offset = 0 (centered around 921,65 MHz) is possible. All other offset values put the edge of the CORESET #0 outside from the 5G channel. Therefore, only index 0 or 3 can be selected.

In order to increase the robustness of 5G PDDCH associated to the CORESET #0 it is preferable to select index = 3 to spread the CORESET #0 on the higher number of symbols possible (3) to manage PDCCH transmission with the highest aggregation level (AL = 8)

By selecting RB Offset = 0 and ksss = 12 (1 RB) the CORESET #0 start at:

F_{SSB_low} – (12 x 0,015) = 919,85 MHz – (12 x 0,015) = 919,67 MHz

Consequently, a guard band of 919,67 – 919,40 = 270 kHz is present. This value complies to the 5G minimum guard band requirement being 242,5 kHz for 5 MHz 5G channels. Moreover, SSB OFDM grid and CORESET grid are RB aligned as ksss = 12 sub carriers = 1 RB.

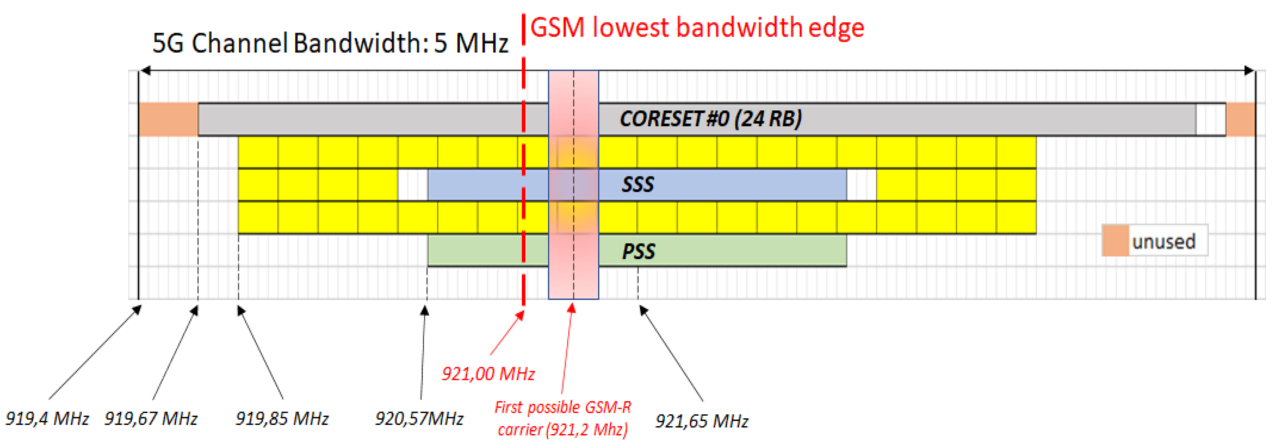

Figure 8: 5G FRMCS DL Channel Mapping

3.3.1.3 Non-Zero CORESET

The non-zero CORESET, on which other PDCCH than those devoted to SIB1, and Paging are mapped, can be configured with a maximum of 24 PRBs bandwidths in accordance with the PDCCH configuration rule of the multiple of 6 PRBs. Such channel shall be aligned with the CORESET#0. It is proposed to spread such CORESET on the first 3 OFDM symbols of each slot.

3.3.1.4 CSI-RS

No specific adaptations are required for such channel spread over the whole 5G FRMCS channel bandwidth. It is proposed to select the CSI-RS configurations indicated in TS 38.533 [2] (Table A.1.4.1-1) for CSI purpose and to switch off the RS called TRS for tracking (Tracking Reference Signal).

3.3.2 Uplink (UL) Case

The different 5G UL channels shall carefully be mapped on the 5G FRMCS UL channel. The figure below present the location of PUCCH, PRACH and PUSCH part. The 5G UL channel location is the in correspondence with has been done for DL.

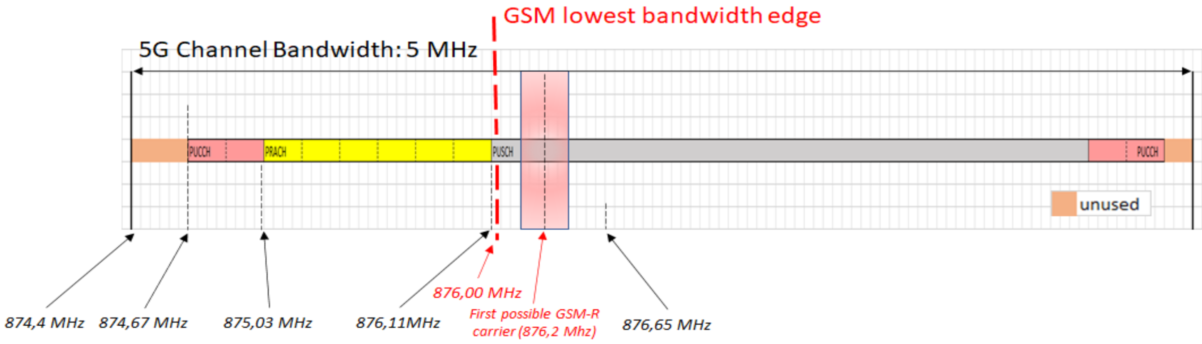

Figure 9: 5G FRMCS UL Channel Mapping

3.3.2.1 PRACH

Considering the 5 MHz channel bandwidth, only long PRACH with format 0/1/2 associated to SCS = 15 kHz and spread over 1.08MHz bandwidth (6 RB @ SCS = 15 kHz) are used. Periodicity shall be 10 or 20 ms. Considering the 25 RB of the UL channel numbered from RB#0 to RB#24, the location of PRACH shall be aligned from RB#2 to RB#7.

3.3.2.2 PUCCH

Two kind of PUCCH resources shall be discussed here: the cell-specific PUCCH resources that are used by the UE to manage ACK/NACK feedback during the initial access and the dedicated PUCCH resources that are indicated explicitly to the UE when the RRC connection is established.

It is proposed to use 5G long PUCCH format instead of short PUCCH. With long PUCCH UL located at the extremity of the UL channel can be configured with the possibility to manage them with frequency hopping mechanisms as illustrated in the next figure. For whitespace, at most 2 RB located at both boundaries of the UL 5G channel are introduced. Those RB are RB#0, RB#1, RB#23 and RB#24.

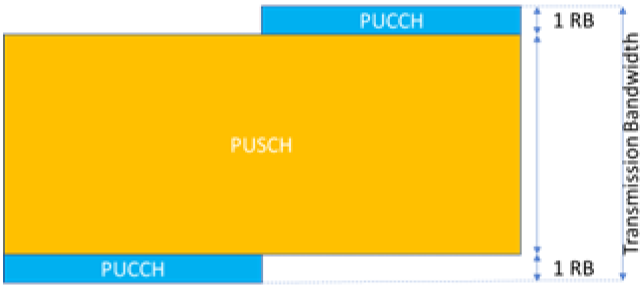

Figure 10: Long PUCCH

Cell specific PUCCH resources are indicated to the UE in SIB1 through an index associated to the Table 9.2.1-1 of TS 38.213 [1] (see below Table 2). Considering whitespace, it is proposed to use the index #12 associated to an offset of 0 and requiring 4 RB (2x (2 RB) located at both extremities of the UL channel).

Index	PUCCH format	First symbol	Number of symbols	PRB offset RB_{BWP}^{offset}	Set of initial CS indexes
0	0	12	2	0	{0, 3}
1	0	12	2	0	{0, 4, 8}
2	0	12	2	3	{0, 4, 8}
3	1	10	4	0	{0, 6}
4	1	10	4	0	{0, 3, 6, 9}
5	1	10	4	2	{0, 3, 6, 9}
6	1	10	4	4	{0, 3, 6, 9}
7	1	4	10	0	{0, 6}
8	1	4	10	0	{0, 3, 6, 9}
9	1	4	10	2	{0, 3, 6, 9}
10	1	4	10	4	{0, 3, 6, 9}
11	1	0	14	0	{0, 6}
12	1	0	14	0	{0, 3, 6, 9}
13	1	0	14	2	{0, 3, 6, 9}
14	1	0	14	4	{0, 3, 6, 9}
15	1	0	14	$\lfloor N_{BWP}^{size}/4 \rfloor$	{0, 3, 6, 9}

Table 1 : Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration

Frequency hopping mechanisms cannot be disabled for the cell-specific PUCCH. Therefore ACK/NACK transmission could coincide with GSM-R carriers located on the right part of the UL channel, as illustrated in the figure below. The 5G gNB will never receive them. The left part is not impacted by such collision.

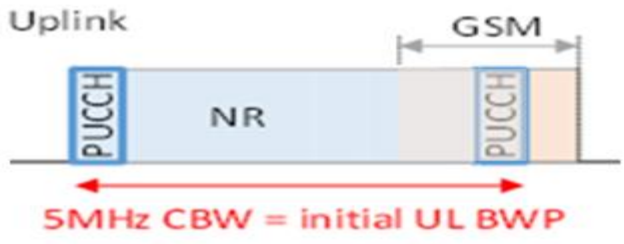

Figure 11: Cell Specific PUCCH

If the cell-specific PUCCH part, used during the initial access and located in GSM area, coincide with a GSM-R carrier, there is two possible options to avoid any issues:

- ✓ Option #A: force the PUCCH resource to be used by the different UE, to be located either on the couple of RB indexed by (#0, #24) or by those indexed by (#1, #23). Such indication can be provided in PDDCH message inviting UE to listen the DL through the PUCCH-Resource Indicator.

- ✓ Option #B: shift by 1RB the DL/UL channel position. By selecting k_{sss} = 0, the CORESET #0 becomes fully aligned with the SSB and the global channel is shift by 1 RB. Therefore, the conflicting GSM-R does not match the RB#24.

Frequency hopping (FH) can be freely configured on UE's dedicated PUCCH resource configuration. It is possible to disable such FH mechanisms. So, the proposal for whitespace is to select this option. In that case, only RB#0 and RB#1 are used, not colliding with GSM carriers.

Note that, the frequency hopping disabling for cell specific PUCCH resources has been proposed in the 5G standard in R17 for RedCap UEs and could be globally introduced in R18 according to the "*less than 5 MHz channel bandwidth*" work item.

3.3.2.3 SRS

It is proposed to not use SRS and to manage UL scheduling only considering the UL SINR monitoring. Depending on resulting 5G performances, SRS could be introduced. In that case, considering the possible SRS parameters indicated in the next figure two possible options are proposed:

- ✓ Option #A: N_{symb} = 1 located on the last symbol of a slot (l_{slot} = 0), reduced to m_{SRS} = 8 RB spread from RB#0 to RB#7

- ✓ Option #B: N_{symb} = 1 located on the last symbol of a slot (l_{slot} = 0), occupying the whole channel bandwidth but spaced from each other by K_{TC} = 4 subcarriers.

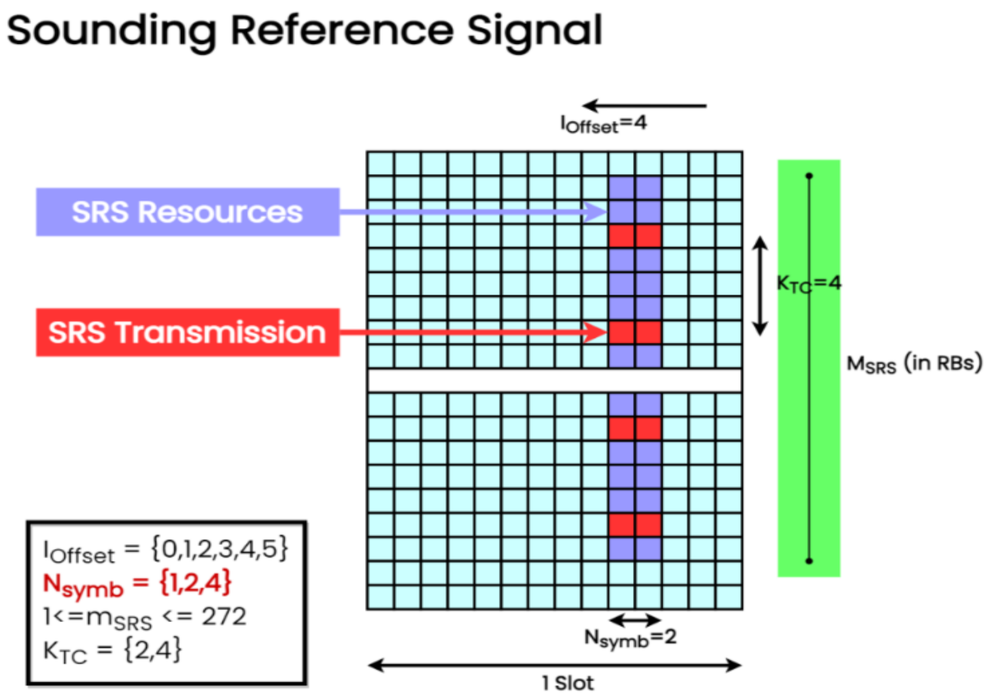

Figure 12: 5G SRS Configuration Parameters

3.3.3 Mutual Interference Management

To manage the mutual interference between both system sharing the same UL and DL channel with some conflicting part several mechanisms could be used. Some of them have been already indicated previously:

- ✓ For DL, a specific power adjustment between the GSM-R carriers and the 5G system in order to have the 5G power density located ∆ dB below the GSM power density.
- ✓ For both UL and DL, some specific 5G channel mapping minimizing the 5G – GSM conflicts.

Additional mechanisms are explained in the next chapters.

3.3.4 Specific Downlink (DL) RB and Subcarrier Puncturing Scheme

However, as a starting point, it can be seen from the figure here below, depicting the spectrum due to modulation and wideband noise for a normal 2G BTS, that most of the 2G energy is focused in +/-90KHz from either side of the center frequency.

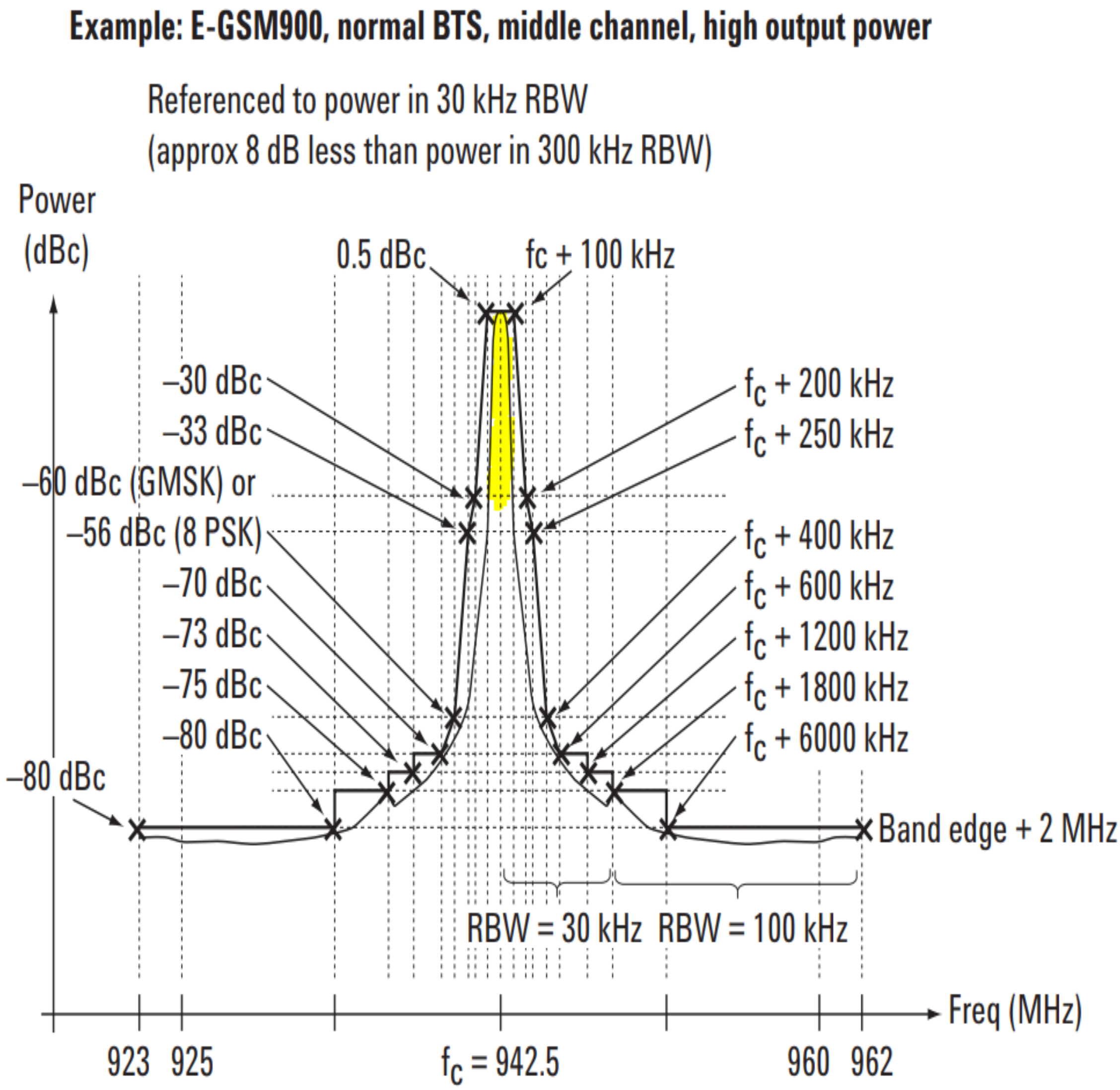

Figure 13 GSM Carrier Spectrum

To increase the isolation level between both systems the 5G subcarriers coinciding with GSM-R carriers shall be blanked. The blanking is done by replacing the modulated symbols of the 5G subcarriers colliding with the GSM carrier by a NULL value before the iFFT processing.

A priori, as most of the 2G energy is focused in +/-90KHz from either side of the GSM-R frequency removing twelve to fourteen 5G subcarriers around the GSM-R frequency (+/- 6 subcarriers or +/- 7 subcarriers) should be enough to guarantee a proper mutual isolation.

Moreover, it is proposed to differentiate such blanking for GSM-R carriers located in the cell or located in the adjacent cell:

- ✓ A full subcarrier blanking (12 or 14) shall be applied to GSM-R carrier collocated in the cell.
- ✓ A reduced subcarrier blanking (6 or 8) shall be applied to GSM-R carrier associated to adjacent cells.

3.3.5 Downlink (DL) Power Boosting

Some DL power boosting mechanisms could be applied to PSS, SSS, PBCH/DMRS and CORESET #0 in order to compensate loss of 5G performances due the puncturing proposed above.

3.3.6 PDCCH Optimization

PDCCH performances could be improved by deciding to systematically use high aggregation levels (AL) of 2, 4 and 8 even if CQI metrics indicate that AL 1, 2 or 4 could be selected.

Depending on where the GSM-R carriers are located, the RB selected to configure the CORESET managing the dedicated PDCCH, could be those not colliding with the GSM-R carriers present in the cell. By this way the number of CCE used for PDCCH decreases but are less impacted by the puncturing.

The RB used for CORESET are indicated through a bitmap, each bit represents a group of 6RB's. In a 5 MHz channel composed of 25 RB’s only 4 group of 6 RB’s each are present. In order to preserve a minimum of RB to operate PDCCH delivery a maximum of 1 group could be removed. In case of strong GSM-R carrier density, it could be interesting to remove the most impacted 6RB group.

3.3.7 DL/UL Scheduling Adaptation

The DL scheduler is not aware of the punctured part of the 5G channel. It manage its DL allocations considering all the RB.

It is proposed to use a DL scheduler being aware of the DL puncturing part, but to be efficient it have to introduce the Reserved Resource feature proposed in 5G for DSS (Dynamic Spectrum Sharing) purpose. Such feature is based on the presence of the RateMatchPattern parameter structure, used to configure Reserved Resources located on the time and frequency grid and indicated as a combination of Resource Blocks and symbols. The Reserved Resources indicated to the UE which part of the allocated PDSCH have not be used by the DL scheduler.

The UL scheduler shall be aware of the forbidden RB coinciding with GSM-R carriers in order to never force its UE to transmit on them.

4 Conclusions

This report introduces the concept related to the Whitespace approach supporting the coexistence of FRMCS and GSM-R in the 900 MHz band. This theoretical analysis is the essential input which will support the development of related prototypes for the study of the solution in both lab and field environments within the framework of WP2.2.

5 Abbreviations

2G	2nd Generation of mobile communications aka GSM/EDGE
3GPP	3rd Generation Partnership Project
5G	5th Generation of mobile communications
5G NR	5G New Radio
ACK	Acknowledgement
AL	Aggregation Level
BTS	Base Station Transmitter
BWP	BandWidth Part
CCE	Control Channel Element
CQI	Channel Quality Indicator
CSI-RS	Channel State Information – Reference Signal
DCI	Downlink Control Information
DL	Downlink
DMRS	DeModulation Reference Signal
DSS	Dynamic Spectrum Sharing
FDD	Frequency-Division Duplexing
FH	Frequency Hopping
FR1	Frequency Range 1
FRMCS	Future Railway Mobile Communication System
gNB	gNodeB i.e., BS in 5G
GSCN	Global Synchronization Channel Number
GSM	Global System for Mobile Communications
GSM-R	Global System for Mobile Communications – Rail
HARQ	Hybrid Automatic Repeat reQuest
iFFT	Inverse Fast Fourier Transform
LPDC	Low Density Parity Check
MIB	Master Information Block
MIMO	Multiple Input Multiple Output
NACK	Non Acknowledgment
NB-IoT	Narrow Band Internet of the Thing

NR	New Radio
N100/N101	3GPP 5G bands in 900/1900 MHz
OFDM	Orthogonal Frequency-Division Multiplexing
PBCH	Physical Broadcast CHannel
PDCCH	Physical Downlink Control CHannel
PDDCH	Physical Downlink Control CHannel
PDSCH	Physical Downlink Shared CHannel
PRACH	Physical Random Access CHannel
PRB	Physical Resource Block
PSS	Primary Synchronization Signal
PUCCH	Physical Uplink Control CHannel
PUSCH	Physical Uplink Shared CHannel
RACOM	Resilient and Green RAil COMmunications
RB	Resource Block
RF	Radio Frequency
RMR	Rail Mobile Radio
RRC	Radio Resource Channel
RS	Reference Signal
SCS	SubCarrier Spacing
SIB	Signalling Information Block
SINR	Signal Interference Noise Ratio
SRS	Sounding Reference Signal
SSB	Synchronisation Signal Block
SSS	Secondary Synchronization Signal
TRS	Tracking Reference Signal
UE	User Equipment
UL	Uplink
WP	Work-Package

6 References

[1] TS 38.213 : 3GPP 5G NR; Physical layer procedures for control specification

[2] TS 38.533 : 3GPP 5G NR User Equipment conformance specification

[3] TS 45.005 : Digital cellular telecommunications system (Phase 2+) (GSM); GSM/EDGE Radio transmission and reception

[4] TS 102.933 : Railway Telecommunications (RT) GSM-R improved receiver parameters