ECC Report 336

Compatibility study between wideband Mobile Communication services operating 5G NR non-AAS system in 1800 MHz and 2.6 GHz bands on board Vessels (MCV) and land-based MFCN networks

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0 EXECUTIVE SUMMARY

The initial version of the regulatory framework for Mobile Communications on board Vessels (MCV) allowed use of GSM technology in the 900 MHz and 1800 MHz bands. The framework in ECC Decision (08)08 [1]), published on 31 October 2008 was based on ECC Report 122 [2] “The compatibility between GSM use on board vessels and land-based networks”.

ECC Decision (08)08 was updated in 2017 to introduce UMTS in the frequency band 2100 MHz and LTE in the 1800 MHz and 2600 MHz band. This update is based on the ECC Report 237 [3] which examined the necessary compatibility between systems operating on board vessels and land-based networks.

ECC Decision (08)08 includes technical operational requirements for 2G, 3G and 4G on board vessels (OBV) systems to ensure operational compliance with land-based networks operating in the same frequency bands.

The mobile technology is evolving, and 5G NR systems have been introduced. The evolution to 5G has also been requested in the maritime market, triggering the need to update the ECC Decision (08)08 with the technical requirements for 5G NR non-AAS systems operation OBV.

This Report at first provides the comparison between LTE and 5G NR system parameters and on board vessels deployment parameters. Based on the comparisons, it is concluded that similar regulatory technical conditions for MCV LTE systems apply also to MCV 5G NR non-AAS.

By considering that ECC Report 237 covers the sharing and compatibility study results from MCV LTE system to land LTE system with non-AAS antenna and that results of ECC Report 237 could also be used in regard of interference from MCV 5G NR non-AAS system to land LTE due to the identical characteristics of MCV LTE and MCV 5G NR, the second part of this report (section 3 and 4) describes the analysis only for interference from MCV 5G NR non-AAS system to land MFCN (5G NR) with AAS.

The analysis has been made by simulating the interference from MCV 5G NR non-AAS to the land MFCN networks (5G NR) with AAS using the same simulation scenarios as described in ECC Report 237.

The compatibility study for LTE in the 1800 and 2600 MHz band carried out in ECC Report 237 shows that the probability for interference/capacity loss in the 2600 MHz band is lower than in the 1800 MHz band, therefore a separate simulation scenario for 5G NR with AAS in the 2600 MHz band is considered not needed.

The comparison of simulation results of land MFCN 5G NR AAS network capacity loss caused by MCV 5G NR non-AAS system with the land MFCN LTE non-AAS network capacity loss caused by MCV LTE non-AAS system show that with the regulatory technical and operational conditions described in ECC Report 237 is below the required protection threshold of 1%.

The simulation result and the comparison with results in ECC Report 237 show that a 5G non-AAS on board a vessel may be compatible with 5G NR non-ASS and AAS land networks in the 1800 and 2600 MHz band without additional measures. The technical and operational conditions given in ECC Decision (08)08 [1] are sufficient to ensure the protection of LTE and 5G NR land networks.

Sharing and compatibility study requirements expressed in this Report based on the capacity loss < 1% in terrestrial 4G, 5G NR (with and without AAS) can be met without additional required measures, and therefore the technical conditions from ECC Report 237 remain valid for MCV 5G NR non-AAS system.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
5G NR	5G New Radio
AAS	Active Antenna Systems
ACCMIN	Minimum received signal level for accessing the network
BCCH	Broadcast Control Channel
BP	Break Point
BS	Base Station
CPICH	Common Pilot Channel
DAS	Distributed Antenna System
DTX	Discontinuous Transmission
ECC	Electronic Communications Committee
EEZ	Exclusive Economic Zone
e.i.r.p.	equivalent isotropically radiated power
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
GSM	Global System for Mobile communications
GSMOBV	GSM on board vessels
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
LTE	Long Term Evolution
MCV	Mobile Communications on-board Vessels
MFCN	Mobile/Fixed Communications Networks
MSL	Mean Sea Level
NM	Nautical Mile
NS	Not Simulated
non-AAS	non-Active Antenna Systems
OBV	On-Board Vessels
OFDMA	Orthogonal Frequency Division Multiple Access
OMC	Operational Maintenance Centre
PCI	Physical layer Cell Identity
PLMN	Public Land Mobile Network
RR	Radio Regulations
RRC	Radio Resource Control
RS	Reference Signal
RSRP	Reference Symbol Received Power

Abbreviation	Explanation
RXLEV	Received Signal Level
SDCCH	Standalone Dedicated Control Channel
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SINR	Signal to Interference Noise Ratio
SSB	Synchronisation Signal Block
TCH	Transport Channel
TDD	Time Division Duplex
TS	Technical Specification
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UNCLOS	United Nations Convention on the Law of the Sea

1 INTRODUCTION

According to the current regulatory framework (ECC Decision (08)08 [1]), Mobile Communications on board Vessels systems are allowed using the GSM technology in the 900 MHz and 1800 MHz bands, using UMTS technology in the 2 GHz band and using LTE technology in the 1800 MHz and 2.6 GHz bands.

The ECC Decision (08)08 “on harmonised use of GSM systems in the 900 MHz and 1800 MHz bands, UMTS systems in the 2 GHz band and LTE systems in the 1800 MHz and 2.6 GHz bands on board vessels, published on 31 October 2008 is based on ECC Report 122 “The compatibility between GSM use on board vessels and land-based networks” [2]. The update from 30 June 2017 to introduce UMTS and LTE systems OBV is based on ECC Report 237 [3].

Since 5G NR technology has been made available to the Mobile/Fixed Communications Networks (MCFN), the Report aims at studying the use of new technology/band combinations on board vessels while ensuring the compatibility with land-based networks. The new technology/band combinations envisaged for the MCV systems is 5G NR non-AAS in the 1800 MHz and 2600 MHz bands. Since 5G NR in the 1800 MHz and 2.6 GHz bands benefits from harmonisation at EU level [4] and since this technology was not part of ECC Report 237, the present Report studies the compatibility between 5G NR non-AAS on board with land-based network using 5G NR in the 1800 MHz and 2.6 GHz bands.

The specific parameters needed for AAS in the studies are given in section 2. The other land-based networks and the MCV networks scenarios and parameter remain the same as in ECC Report 237. The possible interferences from MCV networks on to land-based network are studied since MCV networks shall not cause harmful interference to, or claim protection from, any other authorised system. A total of 5 sub-scenarios, have been addressed to cover all the technology/band/network topology combinations. The simulation results are presented in Annex 1 to Annex 4. The conclusions are given in section 4.

2 COMPARISON BETWEEN LTE AND 5G NR NON-AAS FOR MCV

2.1 COMPARISON BETWEEN LTE AND 5G NR SYSTEM PARAMETERS

There is some difference between LTE and 5G NR systems due to different channel occupancy rate for some channel bandwidths, as shown in Table 1.

Table 1: LTE and 5G NR channel bandwidth and occupied channel bandwidth

Technology	LTE (ETSI TS 136.101 [5])/ TS 136.104 [6])	5G NR (ETSI TS 138.101 [7]/ TS 138.104 [8])
Channel bandwidth (MHz)	5, 10, 15, 20	5, 10, 15, 20, 25, 30
Occupied channel bandwidth (MHz)	4.5, 9, 13.5, 18	4.5, 9.36, 14.22, 19.08, 23.94, 28.8

The commonality between LTE UE and 5G NR UE transmitter characteristics is summarised in Table 2 where it could be observed that:

- LTE UE and 5G NR UE have the same maximum transmit power;
- LTE UE and 5G NR UE have the transmit power dynamic range;
- LTE UE and 5G NR UE have the same ACLR (Adjacent Channel Leakage Power Ratio).

Table 2: Commonality between LTE UE and 5G NR UE

Technology	LTE UE (ETSI TS 136.101 [5])	5G NR UE (ETSI TS 138.101 [7])
Maximum transmit power (dBm/Channel) (Class 3)	23	23
UE transmit power dynamic range for 5, 10, 15, 20 MHz channel	63 dB (from 23 dBm to -40 dBm)	63 dB (from 23 dBm to -40 dBm)
ACLR (For Tx Power Class 3) (dB)	30	30

Both LTE and 5G NR BSs have the same ACLR of 45 dB. Both LTE and 5G NR UE maximum power are specified in 3GPP and ETSI technical specifications. LTE and 5G NR Base Station maximum transmit powers are not specified in 3GPP/ETSI technical specifications, they are subject to conformity with the national licence defined based on CEPT regulations. The same regulatory limit applies to both LTE and 5G NR non-AAS BS.

Even though there is a slight difference of channel occupancy rate between LTE UE and 5G NR UE, they have the same in-band and adjacent band transmitter characteristics. MCV LTE and 5G NR non-AAS systems use 5 MHz channels. For 5 MHz channels LTE and 5G NR have the same channel occupancy.

The LTE broadcast signal CRS (CELL Specific reference signal)channel bandwidth is 15 kHz only, while the 5G NR SSB channel bandwidth can be 15, 30 or 60 kHz for data channel bandwidths from 5 MHz to 100 MHz.

2.2 COMPARISON BETWEEN MCV LTE AND 5G NR NON-AAS DEPLOYMENT PARAMETERS

The 5G NR non-AAS system MCV configuration is equal to the MCV configuration used for LTE in ECC Report 237 [3], as summarised in Table 3.

Table 3: MCV base station parameters

MCV base station parameter	Unit	LTE/5G NR 1800	LTE/5G NR 2600
Channel bandwidth	MHz	5 MHz	5 MHz
Indoor antenna transmit power (per antenna)	dBm/channel	-5	
Typical number of antennas		50	
Indoor antenna gain	dBi	2	4
Outdoor antenna transmit power (considering four antennas of -5 dBm/antenna facing the land modelled as a single omni antenna for MCV)	dBm/channel	1	
Outdoor antenna (modelled as a single omni antenna for MCV) gain	dBi	2	4
Antenna pattern		Omni	
Antenna height above ground	m	3	
Typical terrain height above sea	m	12 (for ferry) / 27 (for cruise vessel)	
Minimum coupling loss (UE-BS)	dB	50	
Typical noise figure	dB	8	
Receiver thermal noise level	dBm/channel	-99.4 dBm/(4.5 MHz)	
Receiver sensitivity	dBm/channel	-96.5 dBm/(4.5 MHz) (LTE) -96.7 dBm/(4.5 MHz) (5G NR, 15 kHz SCS)	
Cell radius	km	0.05	
Number of transmitting UE per cell (for LTE simulations)		5 indoor / 1 outdoor	

Based on the comparisons between LTE and 5G NR system parameters and MCV deployment parameters, it can be concluded that the similar technical and regulatory conditions applied to MCV LTE system can be applied to MCV 5G NR non-AAS system.

3 CO-EXISTENCE STUDY BETWEEN 5G NR NON-AAS MCV SYSTEM AND 5G NR AAS SYSTEMS OPERATING ON LAND

3.1 ASSUMPTIONS AND PARAMETERS

As both 4G and 5G use OFDMA modulation, methods and simulation scenarios defined and used in ECC Report 237 [3] are reused for 5G.

The compatibility study for LTE in the 1800 and 2600 MHz band carried out in ECC Report 237 shows that the probability for interference/capacity loss in the 2600 MHz band is lower than in the 1800 MHz band, therefore a separate simulation scenario for 5G with AASs in 2600 MHz band is considered not needed.

The parameters defined for LTE 1800 in ECC Report 237, section 2.2 are reused for the AAS simulations. The cell range and antenna parameters had to be adjusted to correspond to Recommendation ITU-R M.2101 [9] for 8x8 AAS antenna.

3.1.1 AAS antenna SSB gain calculation

As SEAMCAT 5.4.2[1] only supports the Recommendation ITU-R M.2101 antenna pattern [9], the simulations are done using 8x8 antenna configuration, using 3 degrees down-tilt as specified for rural macro [10].

Figure 1 shows the AAS antenna horizontal gain, and Figure 2 shows the vertical gain plot.

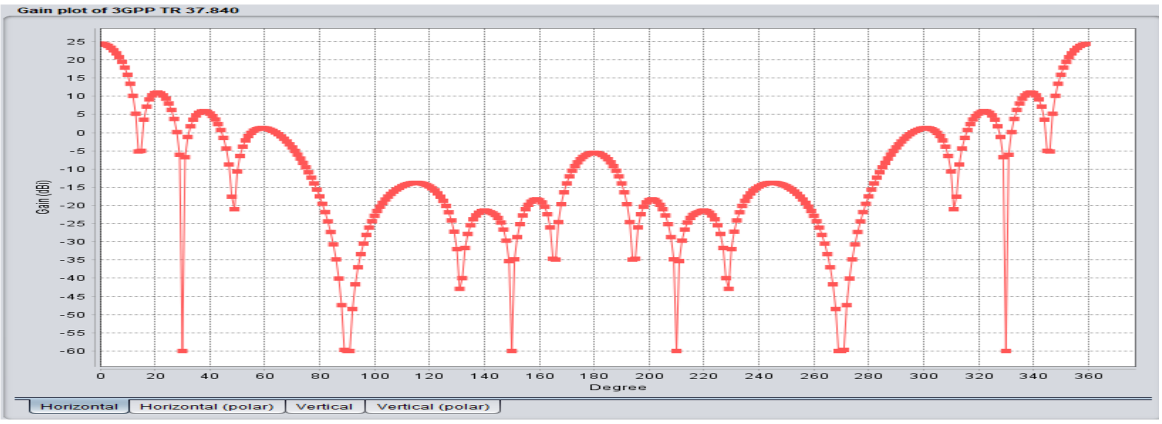

Figure 1: AAS antenna horizontal gain

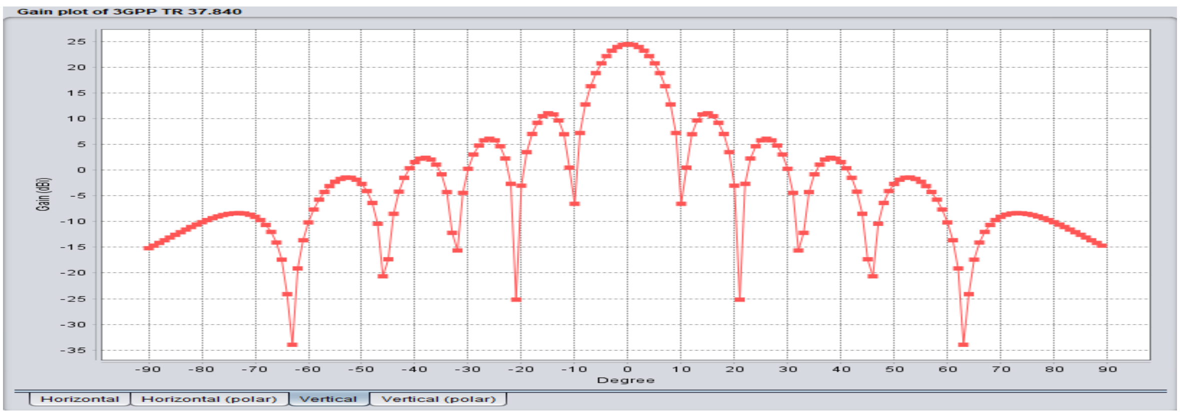

Figure 2: AAS antenna vertical gain

1 https://www.seamcat.org/

The composite antenna gain is: 10 × $\log_{10}(64)$ + 6.4 = 24.5 dBi at 0 degrees horizontal offset. The antenna gain at 3 degrees vertical offset is 23.2 dBi. The antenna gain at 7.5 degrees horizontal offset is 20.1 dBi.

With the down-tilt of 3 degrees the antenna gain in horizontal direction (0 degrees elevation) will be a maximum of 23.2 dBi for long distances. In a setup with 8 multi-beam SSB, each beam must cover +/-7.5 degrees offset. The composite beam antenna gain in this range will then vary from 18.8 dBi to 23.2 dBi at 0 degrees elevation. The average gain over the +/- 7.5 degrees range is 21.0 dBi at 0 degrees elevation.

The average gain (21.0 dBi) is used as SSB antenna gain in the path loss and cell range calculation. A fixed beam SSB would result in lower SSB antenna gain and thus lower cell range for the land network and reduced the potential interference impact from MCV system. Multi-beam SSB is used for cell range calculation.

3.1.2 Cell range

Link budget of land cell using AAS antenna is provided in Table 4.

Table 4: Link budget of land cell using AAS antenna

5G NR AAS link budget	1800 MHz			2600 MHz		
	UL data	DL data	DL SSB	UL data	DL data	DL SSB
UE Tx power (dBm)	23			23		
5 UE users gain	7			7		
UE sensitivity (dBm) 10 MHz cell		-93.8			-94.8	
Minimum SSB signal strength (15 kHz) criteria			-115			-115
UE antenna gain (dBi)	-3	-3	-3	-3	-3	-3
UE body loss (dB)	1	1	1	1	1	1
BS Tx power (dBm)		46			46	
BS SSB Tx power per 15 kHz			17.8			17.8
BS sensitivity (dBm) 10 MHz cell	-101.7			-101.7		
BS antenna gain, data (dBi)	24.5	24.5		24.5	24.5	
BS antenna gain, SSB (dBi)			21.0			21.0
Margin (dB)	5	5	5	5	5	5
Maximum air path loss (dB)	147.2	148.3	144.8	147.2	149.3	144.8

The BS AAS antenna gain includes the ohmic loss.

UE and BE reference sensitivity is from ETSI TS 138 101 [7] and ETSI TS 138 104 [8]. BS antenna gain is the average in phase gain as calculated above. The other parameters are the same as used in ECC Report 237 [3].

SSB -115 dBm/(15 kHz) downlink is used as criteria for cell access since this has the lowest maximum path loss. The land cell range using free space model is 230 km on 1800 MHz and 160 km on 2600 MHz for a maximum path loss of 144.8 dB.

When using Recommendation ITU-R P.452-16 model [11] for land network the cell range will be:

- 59 km on 1800 MHz and 59 km on 2600 MHz for 330 m land base station height;
- 30 km on 1800 MHz and 29 km on 2600 MHz for 70 m land base station height.

The free space model was used for land scenarios in ECC Report 237 [3] and the JTG 5-6 sea model for all interferer path losses. The JTG5-6 model was a SEAMCAT plugin and modified to include the sea path. Unfortunately this plugin is not available in the SEAMCAT v5.4.2, and therefore the Recommendation ITU-R P.452-16 has been used instead for the interferer path loss.

The below figures show air loss for free space model and Recommendation ITU-R P.452-16 [11] model on 1800 MHz used in the simulations for scenarios 8.1-8.5.

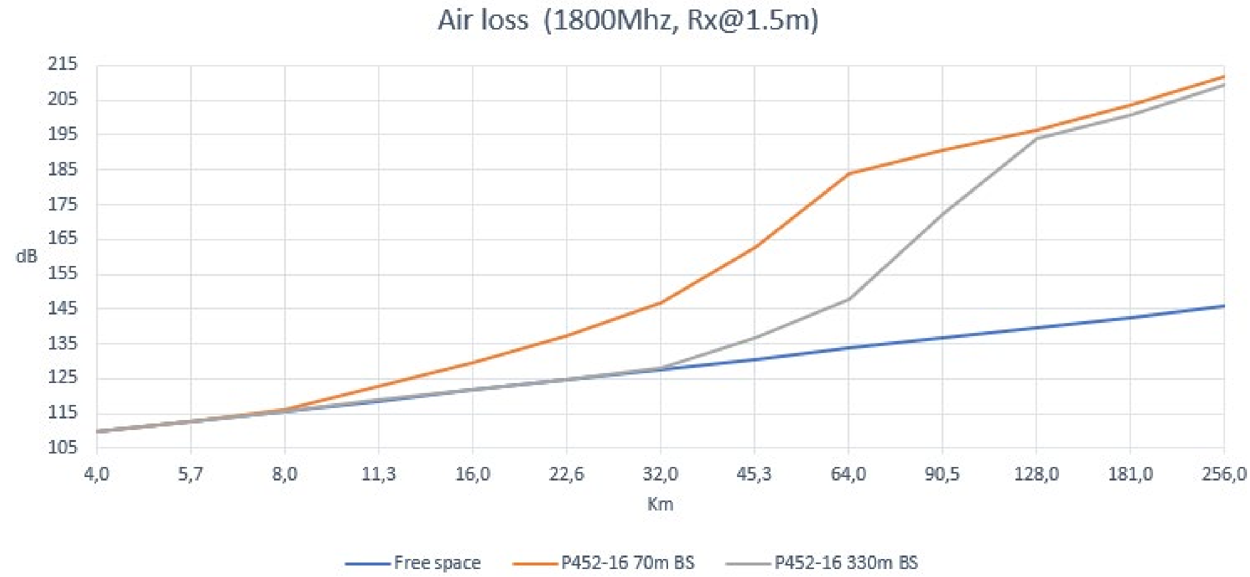

Figure 3: Air loss - 256 km

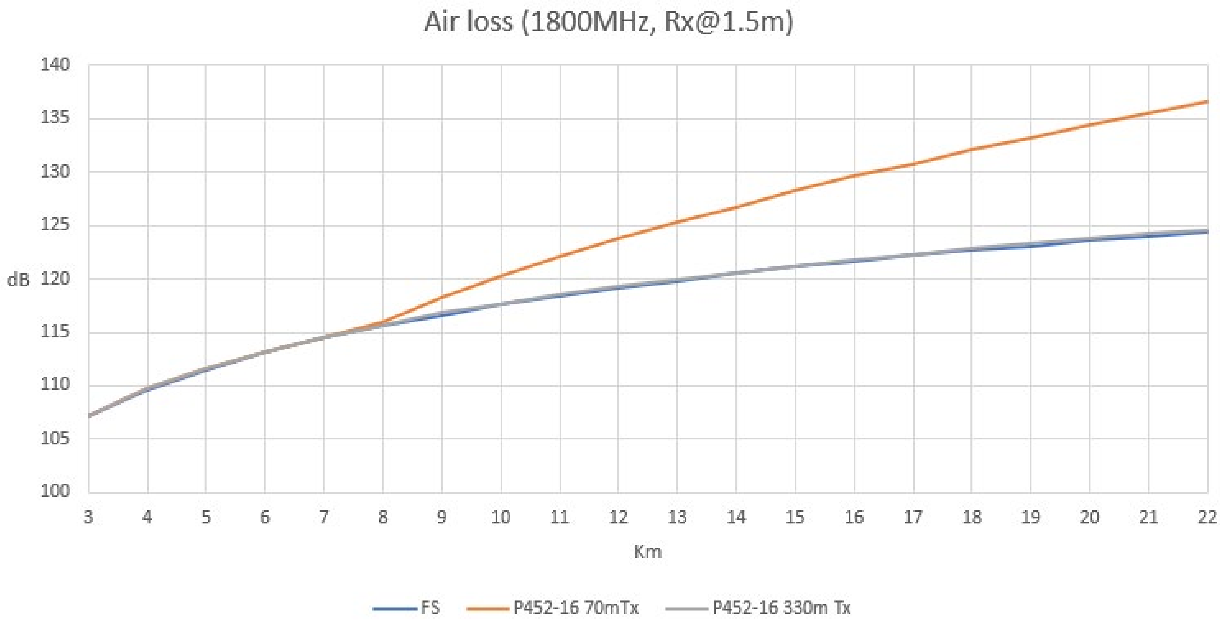

Table 5 below shows the path loss and corresponding cell ranges for the land network using free space model and Recommendation ITU-R P.452-16 models for the interferer scenarios with BS height of 70 m and 330 m.

Table 5: Scenarios, path loss and cell range for scenario 8 and 9

Cell range - Scenario	Path Loss (dB)	Free Space	P.452-16 70 m BS antenna height	P.452-16 330 m BS antenna height)
8. MCV 5G NR non-AAS - Land 5G NR AAS 1800	144.8	230 km	30 km	59 km
9. MCV 5G NR non-AAS - Land 5G NR AAS 2600	144.8	160 km	29 km	59 km

3.1.3 Parameters for simulations

Parameters used in the simulations:

- Cell range of 230 km for 1800 MHz and 160 km for 2600 MHz;
- 1 interfering user on deck is used in the simulation (scenario 8.2, 8.3, 9.2 and 9.3);
- 5 interfering users inside ship is used in the simulation (scenario 8.5 and 9.5);
- Standard deviation of 3.3 dB for free space land network model used in all simulations;
- Maximum power as agreed + simulation with power proposed as mitigation factor 10 MHz and 15 kHz SCS on 5G NR land cell;
- 11 dB hull loss + 1 dB fence loss is used for interfering MCV indoor mobile simulation (scenario 8.5 and 9.5);
- 30 dB hull loss is used for interfering MVC indoor BS simulation (scenario 8.4 and 9.4);
- 1 dB fence loss (outdoor mobile on land-facing side of ship);
- 1 dB handheld body loss used in the simulations, 4 dB body loss is not used;
- 30 dB loss through ship (outdoor mobile on sea-facing side of ship).

3.2 SCENARIOS AND PROPAGATION MODELS

3.2.1 Scenarios

The simulation scenario for 5G NR AAS on land is scenario 8 for the 1800 MHz band and scenario 9 for the 2600 MHz band. For comparison, the corresponding non-AAS scenarios are scenario 4 and scenario 7 in ECC Report 237 [3].

The simulations in the AAS scenario are divided into the same 5 sub-scenarios as defined in ECC Report 237.

Table 6: Scenarios studied

Band	MCV Techno	Land Techno	Interferer	Victim	Scenario #
1800	5G NR non-AAS	5G NR AAS	Outdoor v-BS	I-UE	8.1
			Outdoor v-UE (connected to indoor v-BS antenna)	I-BS	8.2
			Outdoor v-UE (connected to outdoor v-BS antenna)	I-BS	8.3
			Indoor v-BS	I-UE	8.4
			Indoor v-UE	I-BS	8.5
2600	5G NR non-AAS	5G NR AAS	Outdoor v-BS	I-UE	9.1
			Outdoor v-UE (connected to indoor v-BS antenna)	I-BS	9.2
			Outdoor v-UE (connected to outdoor v-BS antenna)	I-BS	9.3
			Indoor v-BS	I-UE	9.4
			Indoor v-UE	I-BS	9.5

3.2.2 Propagation models

In order to examine possible interferences, the following propagation paths were defined and used in this Report:

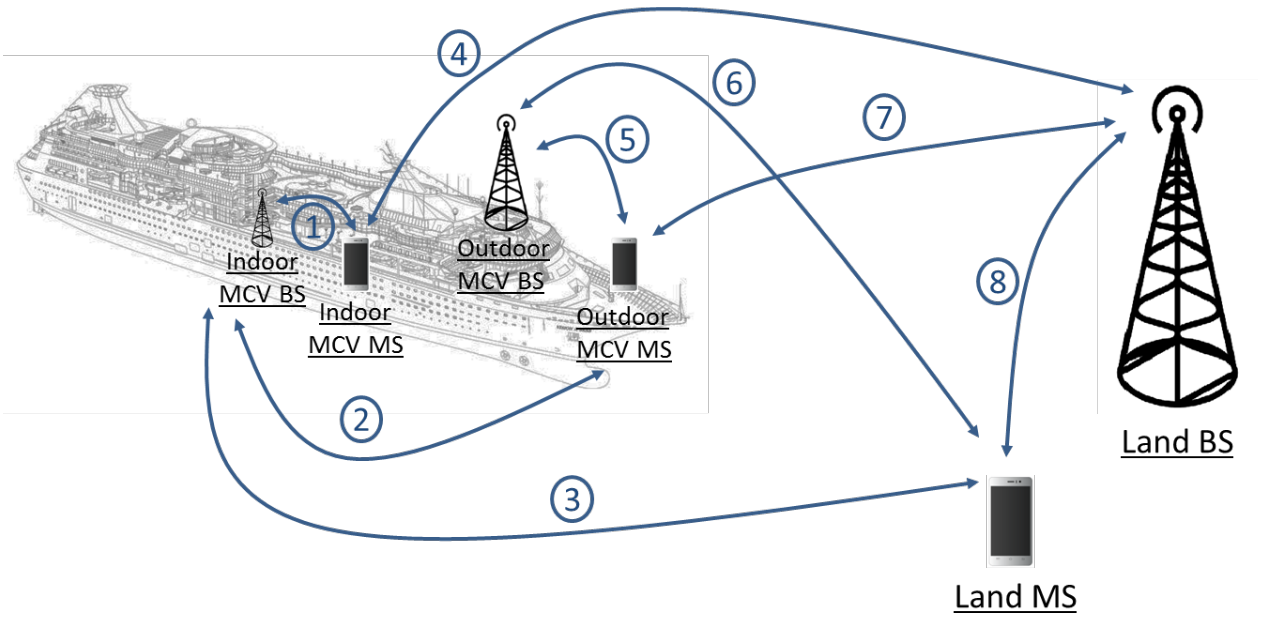

Figure 5: Propagation paths considered in the studies

In ECC Report 237 [3], the ITU-R JTG 5-6 Sea model propagation was used for all interferer pathloss. The JTG 5-6 sea model was implemented as a SEAMCAT plugin and unfortunately not available in the current version of SEAMCAT. Hence for the 5G NR AAS simulations it was replaced by the Recommendation ITU-R P.452-16 propagation model [11].

Table 7: Propagation models per path

Path number	Path description	Propagation Model
1	Indoor MCV BS - Indoor MCV MS	IEEE C-model (Break Point = 15 m)
2	Indoor MCV BS - Outdoor MCV MS	Baseline: IEEE C-model (BP = 15 m) + 11 dB (σ = 6 dB) Sensitivity analysis: IEEE C-model (BP = 15 m) + 20 dB
3	Indoor MCV BS - Land MS	Baseline: ITU-R P452-16 + 30 dB (σ = 6 dB) [11]
4	Indoor MCV MS - Land BS	Baseline: ITU-R P.452-16 + 11 dB (σ = 6 dB) + 1 dB Sensitivity analysis: ITU-R P.452-16 + 20 dB
5	Outdoor MCV BS - Outdoor MCV MS	IEEE C-model (Break Point = 15 m)
6	Outdoor MCV BS - Land MS	ITU-R P.452-16 + 1 dB
7	Outdoor MCV MS - Land BS	Baseline: ITU-R P.452-16 + 1 dB (UE land side of ship) ITU-R P.452-16 + 30 dB (UE sea-facing side of ship)
8	Land BS - Land MS	Free space with a 3.3 dB standard deviation P.452-16 model used for some additional simulations (8.5 and 9.5 scenarios)

For paths 2, 3, 4 and 7, several values for the additional attenuation factor are taken, accounting for all the attenuations of the body structures of the vessel (hull, walls, doors, windows, fences, etc).

To consider the specificity of the indoor environment inside vessels (presence of people across the propagation link in the corridors), the IEEE C-model is used with a breakpoint at 15 m.

3.3 SIMULATION RESULTS

The LTE and 5G systems are technically similar and uses OFDMA modulation. However, ECC Report 237 [3] did not include compatibility with 5G NR AAS systems in the land network. AAS gives higher cell range, capacity and quality. This analysis intends to verify if MCV 5G NR non-AAS is compatible with 5G NR AAS land network. The analysis in this Report is based on the same set of MFCN and MCV input parameters, and the operational and mitigation requirements defined in ECC Decision 08(08) [1]. The new scenarios 8 and 9 are for the 1800 MHz and 2600 MHz bands respectively.

As defined and used in ECC Report 237 the acceptance criteria is 1% or less capacity loss. The simulation carried out for the new scenario 8 (Annex 3) and scenario 9 (Annex 4) is based on the same simulation and path scenarios as used in ECC Report 237 with one exception: The ITU-R JTG 5-6 Sea model used has been available as a SEAMCAT plugin but unfortunately not in the current SEAMCAT version and was replaced with the ITU-R P.452-16 model for the interferer scenarios. The equivalent non-AAS scenarios for the 1800 MHz and 2600 MHz band is attached as Annex 3 and Annex 4.

The propagation model for simulating interference on 5G NR AAS land network is the Recommendation ITU-R P.452-16 propagation model. The Recommendation ITU-R P.452-16 propagation model result in an insignificant higher capacity loss than the ITU-R JTG 5-6 sea model. The non-AAS and AAS simulation results are comparable.

The simulation results for scenario 8, which is the co-existence scenario between 5G NR non-AAS on board Vessel in 1800 MHz and land 5G NR AAS network in 1800 MHz, are described in the Annex 1. The simulation results show the worst case is the outdoor MCV UE (scenario 8.2) connected to indoor MCV BS, even at restricted MCV UE maximum Tx power at 0 dBm. The land MFCN BS data throughput loss is 3.5% at a separation distance of 7.4 km (4 NM) from the Vessel to the land MFCN BS (Annex 1 Table 11).

The simulation results for scenario 9, which is the co-existence scenario between 5G NR non-AAS on Board Vessel in 2600 MHz and land 5G NR AAS network in 2600 MHz, are described in the Annex 2. The simulation results in Annex 2 show that globally the land MFCN 5G NR network in 2600 MHz band capacity loss is smaller compared to that in the case of MFCN 5G NR network in 1800 MHz band described in Annex 1.

It should be noted that the simulation presented in Annex 3 and Annex 4 are copied from ECC Report 237 for the purpose of comparison with the simulation results presented in Annex 1 and Annex 2 (for scenario 4 and 7).

The scenario 4, which is the co-existence scenario between LTE1800 non-AAS on Board Vessel and land LTE1800 non-AAS network, is described in the Annex 3 and scenario 7, which is the co-existence scenario between LTE2600 non-AAS on Board Vessel and land LTE2600 non-AAS network, is described in Annex 4. The simulation results for scenario 4 and scenario 7 in Annex 3 and Annex 4 for LTE1800 and LTE2600 show that the land MFCN LTE1800 and LTE2600 network capacity losses are in the same order as for 5G NR networks in 1800 MHz and 2600 MHz.

The comparison of the simulation results is given in Annex 5.

Summary of results for scenario 8 and scenario 9:

- Scenario 8.1 and 9.1 “Outdoor v-BS interference on Land UE”. The outdoor antenna is switched off in the territorial water and the capacity loss impact from the v-BS beyond the territorial border is close to 0;
- Scenario 8.2 and 9.2 “Outdoor v-UE interference on Land BS”. A v-UE out on deck will not attach to and use the indoor BS. The outdoor v-BS antenna is switched off in the territorial water, the use of QrxLevMin and maximum allowed emission to deck will effectively prevent UEs on deck to attach to and use the onboard MCV network;
- Scenario 8.3 and 9.3 “Outdoor v-MS (connected to outdoor antenna) to land BS”. The simulation shows a potential risk for interference from v-UEs on deck when the vessel is beyond the territorial border. The MCV operator shall operate internationally according to the ITU Constitution [12] and reduce the max UE Tx power accordingly to reduce/eliminate the potential harmful interference on the land network;
- Scenario 8.4 and 9.4 “Indoor v-UE to land UE. The hull loss and “max UE Tx Power =0” are effectively eliminate the risk for interference from “indoor” UE’s;
- Scenario 8.5 and 9.5 “Indoor v-UE to land BS”. The “max UE Tx Power to 0 dBm” will effectively reduce the potential capacity loss below 1% in the area between 4 NM and 12 NM.

4 CONCLUSIONS

Based on the comparisons between LTE and 5G NR system parameters and MCV deployment parameters, it can be concluded that the similar technical and regulatory conditions applied to MCV LTE system can be applied to MCV 5G NR non-AAS system for protecting both LTE non-AAS and 5G NR non-AAS land networks.

The new simulation results presented in this report and the comparison with results in ECC Report 237 [3] show that a 5G NR non-AAS onboard a vessel is compatible with 5G NR AAS land networks in the 1800 MHz and 2600 MHz bands without additional measures. The technical and operational conditions given in ECC Report 237 can apply to MCV 5G NR non-AAS system for ensuring the protection of both LTE and 5G NR AAS land networks.

The system requirements for protection of land based MFCN systems are summarised in Table 8.

Table 8: MCV system specific values to protect land networks systems in the 1800 MHz and 2600 MHz band

System	On/off border (from baseline)	Outdoor antennas on/off (from baseline)	On board UE max tx power	Quality criteria QrxLevMin	Indoor on-board BS emission on deck	RRC inactivity release timer	Cell range for the DAS (note 1)
5G NR non-AAS (1800 MHz and 2600 MHz)	4 NM	12 NM	0 dBm (PcMax)	SSB channel: >= -105 dBm/ (15 kHz) (note 2) Data channel: (>= -83 dBm/ (5 MHz)) between 4 and 12 NM from the baseline	SSB channel: -120 dBm/(15 kHz) (note 2) Data channel: (-98 dBm/ (5 MHz))	2 seconds	400 m
Note 1: The timing advance parameter has to be set according to the corresponding cell range Note 2: for SSB channel bandwidth other than 15 kHz, a conversion factor of 10*log10(SSB BW/15 kHz) should be added.							

ANNEX 1: RESULTS FOR SCENARIO 8, 5G NR NON-AAS 1800 ON BOARD VESSEL AND 5G NR 1800 AAS ON LAND

Table 9: Overview of scenario 8

Band	MCV Tech.	Land Tech.	Interferer	Victim	Scenario #
1800	5G NR non-AAS	5G NR AAS	Outdoor v-BS	I-UE	8.1
			Outdoor v-UE (connected to indoor v-BS antenna)	I-BS	8.2
			Outdoor v-UE (connected to outdoor v-BS antenna)	I-BS	8.3
			Indoor v-BS	I-UE	8.4
			Indoor v-UE	I-BS	8.5

As a general assumption, the same parameters as defined in ECC Report 237 are also used to simulate interference, except that cell range and antenna parameters has to be adjusted to correspond to standard ITU 8x8 AAS antenna.

In addition: 20 dB and 12 dB hull loss is used for indoor mobile simulation and 30 dB hull loss is used for indoor BS simulation

UL: 1740 MHz, DL: 1840 MHz

In the tables below, the cases for which no simulation has been run are marked as “NS” (not simulated).

Cases where calculated values were very low are indicated with a value of "0.0".

Scenario 8.1: Outdoor v-BS to land UE

The simulations have been performed only for distances greater than 12 NM, as outdoor antennas are not allowed between 2 and 12 NM. Composite power is 1 dBm, 4 antennas, -5 dBm input on each.

Table 10: Capacity loss for Scenario 8.1: Outdoor v-BS to land UE

MCV 5G NR non-AAS 1800 MHz Outdoor MCV-BS => Land UE 30 m MCV BS antenna height	Capacity loss (%) depending on the distance km (NM) from the baseline				
	22 (12)	30	50	100	150
330 m antenna height	0.0	0.0	0.0	0.0	0.0
70 m antenna height	0.0	0.0	0.0	0.0	0.0

Scenario 8.2: Outdoor v-UE (connected to indoor antenna) to land BS

Assumption: The simulations are made with the outdoor antennas OFF as the worst case. When the v-UE is located on the sea-facing side of the vessel, an additional 30 dB attenuation is used for the path between the outdoor-UE and the land BS accounting for the loss through the vessel. When nothing is mentioned, the UE is on the land-facing side of the vessel. For the path between the outdoor UE and the indoor MCV BS, using either 12 dB or 20 dB attenuation (accounting for the losses due to the vessel structure) does not have an impact on the simulation results.

Table 11: Capacity loss for Scenario 8.2: Outdoor v-UE (connected to indoor antenna) to land BS

MCV 5G NR non-AAS 1800 MHz Outdoor MCV-UE => Land BS 30 m MCV BS height and the outdoor antenna OFF	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	70	80	100
330 m antenna height and the outdoor v-UE on the land-facing side of vessel maxTxPowerUl = 23 dBm	52.58	40.95	27.49	19.66	15.16	5.56	5.06	0.1
70 m antenna height and the outdoor v-UE on the land-facing side of the vessel maxTxPowerUl = 23 dBm	59.65	42.03	26.94	19.00	NS	NS	NS	NS
70 m antenna height and the outdoor v-UE on the sea-facing side of the vessel maxTxPowerUl = 23 dBm	3.44	1.18	0.35	0.16	NS	NS	NS	NS
With maxTxPowerUl restriction								
70 m antenna height, land-facing side maxTxPowerUl = 0 dBm	8.91	3.56	1.11	(10) 0.85	NS	NS	NS	NS
70 m antenna height, land-facing side maxTxPowerUl -2 dBm	6.93	2.53	0.71	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl -3 dBm	NS	NS	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl -4 dBm	4.90	1.83	(6) 0.82	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl -5 dBm	NS	NS	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl -8 dBm	2.56	0.84	NS	NS	NS	NS	NS	NS

Scenario 8.3: Outdoor v-UE (connected on outdoor antenna) to land BS

This scenario is not applicable inside 12 NM, as the outdoor antennas are currently switched off on MCV inside 12 NM. Simulations are therefore for the area outside 12 NM.

Table 12: Capacity loss for Scenario 8.3: Outdoor v-UE (connected on outdoor antenna) to land BS

MCV 5G NR non-AAS 1800 MHz Outdoor MCV-UE => Land BS 30 m MCV BS height and the outdoor antenna ON	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means “not simulated”)								
	3.7 (2)	22.2 (12)	30	50	60	70	80	90	100
70 m antenna height, UE on land-facing side 23 dBm maxTxPowerUI	NS	20.0	13.95	2.15	NS	0.02	0.00	NS	NS
330 m antenna height, UE on sea-facing side	NS	0.16	0.08	0.03	NS	0.01	0.01	0.0	0.0
330 m antenna height, UE on land-facing side 23 dBm maxTxPowerUI	NS	19.77	14.85	8.89	NS	5.98	4.61	NS	0.1
With UE Tx Power restriction and UE on land-facing side									
330 m antenna height, UE on land-facing side, UE Tx Power Max 20 dBm	NS	14.74	10.31	5.62	NS	3.65	2.8	NS	0.05
330 m antenna height, UE on land-facing side, UE Tx Power Max 15 dBm	NS	7.53	5.52	2.55	NS	1.47	1.11	NS	0.02
330 m antenna height, UE on land-facing side, UE Tx Power Max 10 dBm	NS	3.73	2.39	0.86	NS	NS	NS	NS	NS
330 m antenna height, UE on land-facing side, UE Tx Power Max 5 dBm	NS	1.69	1.03	NS	NS	NS	NS	NS	NS
330 m antenna height, UE on land-facing side, UE Tx Power Max 2 dBm	NS	0.84	NS	NS	NS	NS	NS	NS	NS

Scenario 8.4: Indoor v-BS to land UE

For indoor BS interference towards land MS, 30 dB wall loss is used. Composite power is 12 dB (50 antennas with -5 dBm input).

Table 13: Capacity loss for Scenario 8.4: Indoor v-BS to land UE

MCV 5G NR non-AAS 1800 MHz Indoor MCV-BS => Land UE 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline							
	2 (3.7)	3 (5.55)	4 (7.4)	5 (9.25)	6 (11.1)	8 (14.8)	10 (18.5)	12 (22.2)
330 m antenna height	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70 m antenna height	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Scenario 8.5: Indoor v-UE to land BS

Simulations using a 20 dB loss for the attenuation between indoor v-UE and land BS are shown below. Results in brackets are with the Recommendation ITU-R P.452-16 [11] model for the land network

Table 14: Capacity loss for Scenario 8.5: Indoor v-UE to land BS

MCV 5G NR non-AAS 1800 MHz Indoor MCV-UE => Land BS 30 m MCV BS height and 20 dB Hull loss	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	40	60	80
330 m antenna height, maxTxPowerUl = 23 dBm	23.42 (16.93)	15.13 (9.59)	7.78 (4.10)	4.19 (2.39)	NS	1.63	0.73	NS
70 m antenna height, maxTxPowerUl = 23 dBm	29.97 (21.73)	16.64 (10.92)	8.00 (4.42)	4.25 (2.59)	NS	1.49	0.01	NS
With maxTxPowerUl restriction								
70 m antenna height, maxTxPowerUl = 20 dBm	22.59	11.44	4.55	2.36	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 15 dBm	13.33	5.66	1.84	0.91	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 10 dBm	6.26 (4.15)	2.32 (1.30)	0.63	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 5 dBm	2.80 (1.74)	0.82 (0.47)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	1.08 (0.52)	NS (0.14)	NS	NS	NS	NS	NS	NS

Simulations using a 12 dB propagation loss (accounting for the vessel attenuation) for the attenuation between indoor v-UE and land BS are shown in Table 15 (5 MCV UEs). Results in brackets are with the Recommendation ITU-R P.452-16 model for the land network.

Table 15: Capacity loss for Scenario 8.5: Indoor v-UE to land BS (12 dB propagation loss)

MCV 5G NR non-AAS 1800 MHz Indoor MCV-UE => Land BS 30 m MCV BS height and 12 dB Hull loss	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	40	60	80	100
300m antenna height, maxTxPowerUl = 23 dBm	46.70 (35.93)	33.90 (23.35)	20.20 (12.95)	12.91 (8.24)	6.22	3.68	2.17	0.04
330 m antenna height, maxTxPowerUl = 20 dBm	NS	26.37	NS	NS	NS	NS	NS	NS
330 m antenna height, maxTxPowerUl = 15 dBm	NS	16.18	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 23 dBm	53.17 (44.19)	34.83 (25.59)	20.45 (13.85)	13.78 (9.95)	6.40	0.08	NS	NS
70 m antenna height, maxTxPowerUl = 20 dBm	43.49	26.37	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 15 dBm	NS	16.80	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 10 dBm	NS	8.89 (5.83)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 5 Bm	NS	3.77 (2.64)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	NS	1.40 (0.73)	1.01	NS	NS	NS	NS	NS

ANNEX 2: RESULTS FOR SCENARIO 9, 5G NR NON-AAS 2600 ON BOARD VESSEL AND 5G NR AAS ON LAND

Table 16: Overview of scenario 9

Band	MCV Tech.	Land Tech.	Interferer	Victim	Scenario #
2.6 GHz FDD	5G NR non-AAS	5G AAS	Outdoor v-BS	I-UE	9.1
			Outdoor v-UE (connected to indoor v-BS antenna)	I-BS	9.2
			Outdoor v-UE (connected to outdoor v-BS antenna)	I-BS	9.3
			Indoor v-BS	I-UE	9.4
			Indoor v-UE	I-BS	9.5

In the tables below, the cases for which no simulation has been run are marked as “NS” (not simulated).

Cases where calculated values were very low are indicated with a value of "0.0".

Scenario 9.1: Outdoor v-BS to land UE

Assumptions: The simulations have been performed only for distances greater than 12 NM, assuming the outdoor antennas are not to be allowed between 2 and 12 NM.

Table 17: Capacity loss for Scenario 7.1: Outdoor v-BS to land UE

Outdoor MCV-BS => Land UE 30 m MCV BS antenna height	Capacity loss (%) depending on the distance km (NM) from the baseline				
	22 (12)	30	50	100	150
330 m antenna height	0.0	0.0	0.0	0.0	0.0
70 m antenna height	0.0	0.0	0.0	0.0	0.0

Scenario 9.2: Outdoor v-UE (connected to indoor antenna) to land BS

Table 18: Capacity loss for Scenario 9.2: Outdoor v-UE (connected to indoor antenna) to land BS

Outdoor MCV-UE => Land BS 30 m MCV BS height and Outdoor antennas OFF	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	50	80	100
330 m antenna height, UE on land-facing side and maxTxPowerUl = 23 dBm	44.00	32.94	NS	13.37	NS	NS	NS	NS
70 m antenna height, UE on land-facing side and maxTxPowerUl = 23 dBm	50.39	33.43	NS	14.31	NS	NS	NS	NS
70m BS, sea-facing side UE	1.95	0.63	NS	0.08	NS	NS	NS	NS

Scenario 9.3: Outdoor v-UE (connected on outdoor antenna) to land BS

When the v-UE is located on the sea-facing side of the vessel, an additional 30 dB attenuation is used accounting for the loss through the vessel.

Table 19: Capacity loss for Scenario 9.3: Outdoor v-UE (connected on outdoor antenna) to land BS

LTE 2600 Outdoor MCV-UE => Land BS 30 m MCV BS height maxTxPowerUl = 23 (vessel) Outdoor antenna ON	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")						
	3.7 (2)	22	30	50	70	80	100
330 m antenna height, UE on land-facing side	NS	13.92	NS	5.30	NS	NS	0.04
70 m antenna height, UE on land-facing side	NS	13.71	NS	1.62	NS	NS	0.00
330 m antenna height, UE on sea-facing side	NS	0.08	NS	NS	NS	NS	NS

Scenario 9.4: Indoor v-BS to land UE

Assumptions: A 30 dB wall loss is used between the indoor MCV BS and the land MS. The composite power is 12 dBm (50 antennas with -5 dBm input).

Table 20: Capacity loss for Scenario 9.4: Indoor v-BS to land UE

LTE 2600 Indoor MCV-BS => Land UE 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline			
	2 (3.7)	4 (7.4)	8 (14.8)	12 (22.2)
330 m antenna height	0.0	0.0	0.0	0.0
70 m antenna height	0.0	0.0	0.0	0.0

Scenario 9.5: Indoor v-UE to land BS

With a 20 dB wall loss the results are as follows. Results in brackets indicate that the Recommendation ITU-R P.452-16 model is used for the land network.

Table 21: Capacity loss for Scenario 9.5: Indoor v-UE to land BS

LTE 2600 Indoor MCV-UE => Land BS 30 m MCV BS height and 20 dB wall loss	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	70	80	100
330 m antenna height, maxTxPowerUl = 23 dBm	17.22	10.68	NS	2.11	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 23 dBm	21.67 (14.69)	11.20 (6.62)	NS	2.37 (1.27)	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 10 dBm	NS	1.12 (0.61)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 5 dBm	NS	0.39 (0.17)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	NS	0.12 (0.06)	NS	NS	NS	NS	NS	NS

With a 12 dB hull loss accounting for the vessel attenuation, the results are as follows. Results in brackets indicate that the Recommendation ITU-R P.452-16 model is used for land network.

Table 22: Capacity loss for Scenario 9.5: Indoor v-UE to land BS (12 dB propagation loss)

LTE 2600 Indoor MCV-UE => Land BS 30 m MCV BS height and HL = 12 dB	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means “not simulated”)							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	70	80	100
330 m antenna height, maxTxPowerUl = 23 dBm	36.72	24.90	NS	9.18	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 23 dBm	44.35 (31.88)	26.10 (18.24)	NS	8.78 (5.02)	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 10 dBm	NS	5.40 (2.86)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 5 dBm	NS	1.91 (1.26)	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	NS	0.77 (0.4)	NS	NS	NS	NS	NS	NS

ANNEX 3: RESULTS FOR SCENARIO 4, LTE 1800 NON-AAS ON BOARD VESSEL AND LTE 1800 NON-AAS ON LAND

Table 23: Overview of scenario 4

Band	MCV Tech.	Land Tech.	Interferer	Victim	Scenario #
1800 MHz	LTE	LTE	Outdoor v-BS	l-UE	4.1
			Outdoor v-UE (connected to indoor v-BS antenna)	l-BS	4.2
			Outdoor v-UE (connected to outdoor v-BS antenna)	l-BS	4.3
			Indoor v-BS	l-UE	4.4
			Indoor v-UE	l-BS	4.5

General assumption: The cell range is calculated to 55 km based on the free space model. The LTE channel bandwidth is set to 10 MHz for both land and on-board vessels systems.

In the tables below, the cases for which no simulation has been run are marked as "NS" (not simulated).

Scenario 4.1: Outdoor v-BS to land UE

Assumptions: The simulations have been performed only for distances greater than 12 NM, assuming the outdoor antennas are not to be allowed between 2 and 12 NM.

Table 24: Capacity loss for Scenario 4.1: Outdoor v-BS to land UE

LTE 1800 to LTE 1800 (land) Outdoor MCV-BS => Land UE 30 m MCV BS antenna height	Capacity loss (%) depending on the distance km (NM) from the baseline				
	22 (12)	30	50	100	150
330 m antenna height	0.00	0.00	0.01	0.0	0.0
70 m antenna height	0.00	0.00	0.00	0.0	0.0

Scenario 4.2: Outdoor v-UE (connected to indoor antenna) to land BS

Assumption: The simulations are made with the outdoor antennas OFF as the worst case. When the v-UE is located on the sea-facing side of the vessel, an additional 30 dB attenuation is used for the path between the outdoor-UE and the land BS accounting for the loss through the vessel. When nothing is mentioned, the UE is on the land-facing side of the vessel. For the path between the outdoor UE and the indoor MCV BS, using either 12 dB or 20 dB attenuation (accounting for the losses due to the vessel structure) does not have an impact on the simulation results.

Table 25: Capacity loss for Scenario 4.2: Outdoor v-UE (connected to indoor antenna) to land BS

LTE 1800 Outdoor MCV-UE => Land BS, 30 m MCV BS height outdoor ant OFF	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means “not simulated”)							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	70	80	100
330 m antenna height and the outdoor v-UE on the land-facing side maxTxPowerUl = 23 dBm	87.29	82.57	62.45	47.71	36.22	2.26	0.56	0.06
70 m antenna height and the outdoor v-UE on the land-facing side of the vessel maxTxPowerUl = 23 dBm	95.06	83.80	63.22	48.50	36.55	0.06	0.01	0.00
70 m antenna height and the outdoor v-UE on the sea-facing side of the vessel maxTxPowerUl = 23 dBm	5.94	1.47	0.35	0.17	0.09	0.0	0.0	0.0
70 m antenna height, maxTxPowerUl = 0 dBm	18.94	5.88	1.50	0.65	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 2 dBm	13.31	3.77	0.94	0.41	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 3 dBm	10.85	2.98	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 4 dBm	8.90	2.33	0.58	0.26	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 5 dBm	7.63	1.85	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 8 dBm	3.77	0.95	0.23	0.1	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 10 dBm	2.40	0.58	0.15	0.07	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 13 dBm	1.17	NS	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl - 14 dBm	0.93	NS	NS	NS	NS	NS	NS	NS

Scenario 4.3: Outdoor v-UE (connected on outdoor antenna) to land BS

Table 26: Capacity loss for Scenario 4.3: Outdoor v-UE (connected on outdoor antenna) to land BS

LTE 1800 Outdoor MCV-UE => Land BS 30 m MCV BS height 23 dBm maxTxPowerUl and the outdoor antenna ON	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")								
	3.7 (2)	22.2 (12)	30	50	60	70	80	90	100
330 m antenna height, UE on land-facing side	87.26	47.97	36.39	19.88	8.23	2.14	0.53	NS	NS
70 m antenna height, UE on land-facing side	NS	48.48	36.78	2.53	NS	0.06	0.01	NS	NS
630 m antenna height, UE on land-facing side	56.87	46.13	NS	NS	14.91	NS	2.12	0.69	NS
70 m antenna height, UE on land-facing side, UE Tx Power Max 23 dBm	94.96	48.26	NS	NS	0.36	NS	NS	NS	NS
70 m antenna height, UE on land-facing side, UE Tx Power Max 0 dBm	18.56	0.66	NS	NS	NS	NS	NS	NS	NS
70 m antenna height, UE on land-facing side, UE Tx Power Max -10 dBm	2.34	NS	NS	NS	NS	NS	NS	NS	NS
70 m antenna height, UE on land-facing side, UE Tx Power Max -14 dBm	0.92	NS	NS	NS	NS	NS	NS	NS	NS

Scenario 4.4: Indoor v-BS to land UE

Assumptions: For indoor BS interference towards land, a wall loss of 30 dB is used (simulations with a wall loss of 11 dB show similar results). The composite power is 12 dBm (50 antennas with -5 dBm input).

Table 27: Capacity loss for Scenario 4.4: Indoor v-BS to land UE

LTE 1800 Indoor MCV-BS => Land UE 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline							
	2 (3.7)	3 (5.55)	4 (7.4)	5 (9.25)	6 (11.1)	8 (14.8)	10 (18.5)	12 (22.2)
330 m antenna height	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70 m antenna height	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Scenario 4.5: Indoor v-UE to land BS

Simulations using a 20 dB loss for the attenuation between indoor v-UE and land BS are shown below.

Table 28: Capacity loss for Scenario 4.5: Indoor v-UE to land BS

LTE 1800 Indoor MCV-UE => Land BS 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	50	70	80
330 m antenna height, maxTxPowerUl = 23 dBm	23.11	16.85	5.53	2.56	1.39	0.50	0.04	0.01
70 m antenna height, maxTxPowerUl = 23 dBm	41.20	18.25	5.70	2.60	1.41	0.05	0.00	0.0
70 m antenna height, maxTxPowerUl = 9 dBm	3.75	0.9	0.23	0.1	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 5 dBm	1.37	0.37	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 3 dBm	0.89	0.23	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	0.46	0.11	0.03	0.01	NS	NS	NS	NS

Simulations using a 12 dB propagation loss (accounting for the vessel attenuation) for the attenuation between indoor v-UE and land BS are shown below (5 MCV UEs).

Table 29: Capacity loss for Scenario 4.5: Indoor v-UE to land BS using a 12 dB propagation loss

LTE 1800 Indoor MCV-UE => Land BS 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	40	60	70	80
300m antenna height, maxTxPowerUl = 23 dBm	57.03	NS	NS	14.09	4.99	1.13	0.27	NS
70 m antenna height, maxTxPowerUl = 23 dBm	75.23	NS	NS	14.21	2.52	0.04	NS	NS
630 m antenna height, maxTxPowerUl = 23 dBm	19.99	NS	NS	13.43	4.9	2.2	0.8	0.26
330 m antenna height, maxTxPowerUl = 0 dBm	1.03	NS	NS	0.08	NS	NS	NS	NS
330 m antenna height, maxTxPowerUl = -5 dBm	0.32	NS	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 7 dBm	12.94	3.63	0.91	0.40	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 3 dBm	5.56	1.44	0.38	0.16	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 1 dBm	3.63	0.91	0.22	0.10	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	2.88	0.7	0.18	0.08	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = -5 dBm	0.91	0.22	0.06	0.03	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = -14 dBm	0.11	0.03	0.01	0.00	NS	NS	NS	NS

ANNEX 4: RESULTS FOR SCENARIO 7, LTE 2600 NON-AAS ON BOARD VESSEL AND LTE 2600 NON-AAS ON LAND

Table 30: Overview of scenario 7

Band	MCV Tech.	Land Tech.	Interferer	Victim	Scenario #
2.6 GHz FDD	LTE	LTE	Outdoor v-BS	l-UE	7.1
			Outdoor v-UE (connected to indoor v-BS antenna)	l-BS	7.2
			Outdoor v-UE (connected to outdoor v-BS antenna)	l-BS	7.3
			Indoor v-BS	l-UE	7.4
			Indoor v-UE	l-BS	7.5

In the tables below, the cases for which no simulation has been run are marked as “NS” (not simulated).

Scenario 7.1: Outdoor v-BS to land UE

Assumptions: The simulations have been performed only for distances greater than 12 NM, assuming the outdoor antennas are not to be allowed between 2 and 12 NM.

Table 31: Capacity loss for Scenario 7.1: Outdoor v-BS to land UE

LTE 2600 to LTE 2600 (land) Outdoor MCV-BS => Land UE 30 m MCV BS antenna height	Capacity loss (%) depending on the distance km (NM) from the baseline				
	22 (12)	30	50	100	150
330 m antenna height	0.00	0.00	0.0	0.0	0.0
70 m antenna height	0.00	0.00	0.0	0.0	0.0

Scenario 7.2: Outdoor v-UE (connected to indoor antenna) to land BS

Table 32: Capacity loss for Scenario 7.2: Outdoor v-UE (connected to indoor antenna) to land BS

LTE 2600 Outdoor MCV-UE => Land BS 30 m MCV BS height and Outdoor antennas OFF	Capacity loss (%) depending on the distance km (NM) from the baseline							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	50	80	100
330 m antenna height, UE on land-facing side and maxTxPowerUl = 23 dBm	81.49	75.28	52.51	37.45	27.10	13.48	0.23	0.03
70 m antenna height, UE on land-facing side and maxTxPowerUl = 23 dBm	91.49	77.40	53.57	38.00	27.42	1.31	0.01	0.00

Table 33: Capacity loss for Scenario 7.2 (with reduced maxTxPowerUl)

LTE 2600 Same assumptions as above with reduced maxTxPowerUl	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")		
	2 (3.7)	4 (7.4)	12 (22.2)
330 m antenna height, UE on land-facing side and maxTxPowerUl = 0 dBm	5.02	NS	0.46
330 m antenna height, UE on land-facing side and maxTxPowerUl = -5 dBm	1.67	NS	NS
330 m antenna height, UE on land-facing side and maxTxPowerUl = -10 dBm	0.54	NS	NS

Table 34: Capacity loss for Scenario 7.2 (maxTxPowerUl restriction)

LTE 2600 Outdoor MCV-UE => Land BS maxTxPowerUl restriction 30 m MCV BS height Outdoor ant off	Capacity loss (%) depending on the distance km (NM) from the baseline				
	2 (3.7)	4 (7.4)	6 (11.1)	8 (14.8)	12 (22.2)
land-facing side, 70 m 0 dBm	12.64	3.76	1.68	0.94	0.43
land-facing side, 70 m -3 dBm	6.99	1.94	0.85	0.49	0.22
land-facing side, 70 m -5 dBm	4.59	1.22	0.54	0.30	0.14
land-facing side, 70 m -6dBm	3.74	0.96	0.43	0.24	0.11
land-facing side, 70 m -10 dBm	1.50	0.38	0.17	0.10	0.04
land-facing side, 70 m -12 dBm	0.96	0.25	0.11	0.06	0.03

For the indoor-outdoor propagation loss accounting for the vessel structure attenuation, using 11 dB or 20 dB gives similar simulation results.

Scenario 7.3: Outdoor v-UE (connected on outdoor antenna) to land BS

When the v-UE is located on the sea-facing side of the vessel, an additional 30 dB attenuation is used accounting for the loss through the vessel.

Table 35: Capacity loss for Scenario 7.3: Outdoor v-UE (connected on outdoor antenna) to land BS

LTE 2600 Outdoor MCV-UE => Land BS 30 m MCV BS height maxTxPowerUl = 23 (vessel) Outdoor antenna ON	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means "not simulated")						
	3.7 (2)	22	30	50	70	80	100
630 m antenna height, UE on land-facing side	NS	35.86	NS	NS	NS	0.97	NS
330 m antenna height, UE on land-facing side	81.7	37.30	27.03	13.29	1.03	0.23	0.02
70 m antenna height, UE on land-facing side	NS	37.97	27.54	1.39	0.03	0.01	0.00
70 m antenna height, UE on sea-facing side	NS	0.10	0.06	0.02	0.00	0.0	0.0
70 m antenna height, UE on sea land-facing side	91.49	38.07	NS	NS	NS	NS	NS

Table 36: Capacity loss for Scenario 7.3 (with reduced maxTxPowerUl)

LTE 2600 Outdoor MCV-UE => Land BS Same assumptions as above with reduced maxTxPowerUl	Capacity loss (%) depending on the distance km (NM) from the baseline	
	3.7 (2)	22
330 m antenna height, UE on land-facing side maxTxPowerUl = 0 dBm	5.13	0.42
70 m antenna height, UE on land-facing side maxTxPowerUl = 0 dBm	12.65	0.42
70 m antenna height, UE on land-facing side maxTxPowerUl = -5 dBm	4.59	NS
70 m antenna height, UE on land-facing side maxTxPowerUl = -10 dBm	1.51	NS
70 m antenna height, UE on land-facing side maxTxPowerUl = -12 dBm	0.96	NS

Scenario 7.4: Indoor v-BS to land UE

Assumptions: A 30 dB wall loss is used between the indoor MCV BS and the land MS. The composite power is 12 dBm (50 antennas with -5 dBm input).

Table 37: Capacity loss for Scenario 7.4: Indoor v-BS to land UE

LTE 2600 Indoor MCV-BS => Land UE 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline			
	2 (3.7)	4 (7.4)	8 (14.8)	12 (22.2)
330 m antenna height	0.0	0.0	0.0	0.0
70 m antenna height	0.0	0.0	0.0	0.0

Scenario 7.5: Indoor v-UE to land BS

With a 20 dB wall loss, the results are in Table 38.

Table 38: Capacity loss for Scenario 7.5: Indoor v-UE to land BS

LTE 2600 Indoor MCV-UE => Land BS maxTxPowerUl = 23 dBm 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means “not simulated”)							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	30	70	80	100
330 m antenna height	15.94	11.30	3.49	1.62	0.90	0.02	0.01	0.0
70 m antenna height	31.29	12.40	3.66	1.66	0.91	0.00	0.0	0.0
70 m antenna height, maxTxPowerUl = 5 dBm	0.93	0.23	NS	NS	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 11 dBm	3.598	0.933	0.235	0.104	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 10 dBm	2.950	0.729	0.187	0.083	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 5 dBm	0.931	0.231	0.059	0.027	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 3 dBm	0.579	0.150	0.037	0.017	NS	NS	NS	NS
70 m antenna height, maxTxPowerUl = 0 dBm	0.305	0.072	0.019	0.008	NS	NS	NS	NS

With a 12 dB propagation loss accounting for the vessel attenuation, the results are in Table 39.

Table 39: Capacity loss for Scenario 7.5: Indoor v-UE to land BS (12 dB propagation loss)

LTE 2600 Indoor MCV-UE => Land BS maxTxPowerUl = 23 dBm 30 m MCV BS height	Capacity loss (%) depending on the distance km (NM) from the baseline (NS means “not simulated”)							
	3.7 (2)	7.4 (4)	14.8 (8)	22.2 (12)	40	50	60	70
330 m antenna height	46.6	NS	NS	9.14	3.35	2.04	0.63	NS
70 m antenna height	66.62	NS	NS	9.35	1.63	0.17	0.02	NS
630 m antenna height	13.23	NS	NS	8.57	3.05	1.99	1.35	0.46
330 m antenna height, maxTxPowerUl = 0 dBm	0.67	NS	NS	0.05	NS	NS	NS	NS
70 m, 11+1 dBm hull loss, 9 dBm	12.41	3.625	0.932	0.418	NS	NS	NS	NS
70 m, 11+1 dBm hull loss, 6 dBm	6.816	1.857	0.472	0.211	NS	NS	NS	NS
70 m, 11+1 dBm hull loss, 3 dBm	3.692	0.923	0.235	0.106	NS	NS	NS	NS
70 m, 11+1 dBm hull loss, 0 dBm	1.891	0.463	0.120	0.052	NS	NS	NS	NS
70 m, 11+1 dBm hull loss, -3 dBm	0.938	0.237	0.059	0.026	NS	NS	NS	NS
70 m, 11+1 dBm hull loss, -5 dBm	0.587	0.148	0.037	0.017	NS	NS	NS	NS

ANNEX 5: COMPARISON OF SIMULATION RESULTS

It should be noted that the simulation results for land network LTE non-AAS are copied from ECC Report 237 [3].

Table 40: Interference caused by an outdoor antenna on a mobile terminal in the land network

Capacity loss for Scenario: Outdoor v-BS to land UE					
Outdoor MCV-BS => Land UE		70 m antenna height Distance from baseline		330 m antenna height Distance from baseline	
		22 km	100 km	22 km	100 km
1800 MHz	Land network LTE non-AAS (scenario 4.1)	0.0	0.0	0.0	0.0
	Land network 5G NR AAS (scenario 8.1)	0.0	0.0	0.0	0.0
2600 MHz	Land network LTE non-AAS (scenario 7.1)	0.0	0.0	0.0	0.0
	Land network 5G NR AAS (scenario 9.1)	0.0	0.0	0.0	0.0

When the vessel is in the area between 4 NM and 12 NM from the baseline the outdoor antennas are switched off. The simulation shows that the potential capacity loss impact is eliminated.

Table 41: Interference caused on land base stations by mobile terminals out on deck on the vessel and connected to an indoor antenna on board the vessel

Capacity loss for Scenario: Outdoor v-MS (connected to indoor antenna) to land BS (NS means “not simulated”)					
Outdoor MCV-UE => Land BS		70 m antenna height 0 dBm		330 m antenna height 23 dBm	
		7.4 km	22.2 km	7.4 km	22.2 km
1800 MHz	Land network LTE non-AAS (Scenario 4.2)	5.88	0.65	82.57	47.71
	Land network 5G NR AAS (Scenario 8.2)	3.56	<0.85	40.95	19.66
2600 MHz	Land network LTE non-AAS (Scenario 7.2)	3.76	0.43	75.28	37.45
	Land network 5G NR AAS (Scenario 9.2)	NS	NS	32.94	13.37

To prevent capacity loss caused by this scenario the max allowed emitted power on deck from indoor antennas is limited and the QrxLevMin criteria set so that a mobile on deck should not attach to and use the signal from the indoor antenna. The max allowed MS power is 0 dBm.

The simulation shows a potential capacity loss slightly above 1% at 4 NM and less than 1% at 12 NM, measured at the land-facing side of the vessel.

Table 42: Interference caused by a mobile terminal (connected to the outdoor antenna) to land base station/network

Capacity loss for Scenario: Outdoor v-MS (connected to outdoor antenna) to land BS					
Outdoor MCV-UE => Land BS		70 m antenna height and distance from baseline (23 dBm)		330 m antenna height and distance from baseline (23 dBm)	
		22 km	70 km	22 km	70 km
1800 MHz	Land network LTE non-AAS (Scenario 4.3)	48.4	0.06	47.97	2.14
	Land network 5G NR AAS (Scenario 8.3)	20.0	0.02	19.7	5.98
2600 MHz	Land network LTE non-AAS (Scenario 7.3)	>12.65	0.42	37.30	1.03
	Land network 5G NR AAS (Scenario 9.3)	13.72	0.04 at 100 km	13.92	0.0 at 100 km

The simulation shows no potential interference as the outdoor antenna is switched off.

Table 43: Interference caused by an indoor antenna on a mobile terminal on land

Capacity loss for Scenario: Indoor v-BS to land MS					
Indoor MCV BS => Land UE 10 MHz land network and 30 m MCV BS height		70 m antenna heigh and distance from baseline		330 m antenna height and distance from baseline	
		7.4 km	22 km	7.4 km	22 km
1800 MHz	Land network LTE non-AAS (Scenario 4.4)	0.0	0.0	0.0	0.0
	Land network 5G NR AAS (Scenario (8.4)	0.0	0.0	0.0	0.0
2600 MHz	Land network LTE non-AAS (Scenario 7.4)	0.0	0.0	0.0	0.0
	Land network 5G NR AAS (Scenario 9.4)	0.0	0.0	0.0	0.0

The simulation shows no capacity loss when the vessel is inside 12 NM.

Table 44: Mobile terminals indoor connected to an indoor antenna impact on base stations in the land network

Capacity loss for Scenario: Indoor v-MS to land BS (NS means “not simulated”)					
Indoor MCV UE => Land BS MCV BS antenna height = 30 m. 20 dB hull loss. 10 MHz land network		70 m antenna height and distance from baseline. UE Tx = 0 dBm		330 m antenna height and distance from baseline (23 dBm)	
		7.4 km	22 km	7.4 km	22 km
1800 MHz	Land network LTE non-AAS (Scenario 4.5)	0.11	0.01	16.85	2.56
	Land network 5G NR AAS (Scenario (8.5)	<1 (NS)	NS	15.13	4.19
2600 MHz	Land network LTE non-AAS (Scenario 7.5)	0.072	0.008	11.3	1.62
	Land network 5G NR AAS (Scenario 9.5)	0.112	NS	10.68	2.11

Max UE Tx power is 0 dBm and the potential capacity loss is below 1% in the land network.

ANNEX 6: AAS ANTENNA DATA

Table 45: Beamforming antenna characteristics for IMT in 1710-4990 MHz (document 5D/716, Chapter 4, Annex 4.4, Table 9 [10])

Reference	Parameter	Rural macro	Suburban macro	Urban macro	Urban small cell (outdoor)/Micro cell	Indoor (small cell)
1	**Base station antenna characteristics**					
1.1	Antenna pattern	Refer to the extended AAS model in Table A of Annex 3			Refer to section 5 of Recommendation ITU-R M.2101 [9]	N/A
1.2	Element gain (dBi) **(Note 1)**	6.4	6.4	6.4	6.4	N/A
1.3	Horizontal/vertical 3 dB beam width of single element (degree)	90° for H 65° for V	90° for H 65° for V	90° for H 65° for V	90° for H 65° for V	N/A
1.4	Horizontal/vertical front-to-back ratio (dB)	30 for both H/V	30 for both H/V	30 for both H/V	30 for both H/V	N/A
1.5	Antenna polarization	Linear ±45°	Linear ±45°	Linear ±45°	Linear ±45°	N/A
1.6	Antenna array configuration (Row × Column) **(Note 2)**	4 × 8 elements	4 × 8 elements	4 × 8 elements	8 × 8 elements	N/A
1.7	Horizontal/Vertical radiating element/sub-array spacing, d_h /d_v	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 0.7 of wavelength for V	N/A
1.7a	Number of element rows in sub-array, M_{sub}	3	3	3	N/A	N/A
1.7b	Vertical radiating element spacing in sub-array, $d_{v,sub}$	0.7 of wavelength of V	0.7 of wavelength of V	0.7 of wavelength of V	N/A	N/A
1.7c	Pre-set sub-array down-tilt, $\theta_{subtilt}$ (degrees)	3	3	3	N/A	N/A
1.8	Array Ohmic loss (dB) **(Note 1)**	2	2	2	2	N/A
1.9	Conducted power (before Ohmic loss) per antenna element/sub-array (dBm) **(Note 5, 6)**	28	28	28	16	N/A

Reference	Parameter	Rural macro	Suburban macro	Urban macro	Urban small cell (outdoor)/Micro cell	Indoor (small cell)
1.10	Base station horizontal coverage range (degrees)	±60	±60	±60	±60	N/A
1.11	Base station vertical coverage range (degrees) **(Notes 3, 4, 7)**	90-100	90-100	90-100	90-120	N/A
1.12	Mechanical down tilt (degrees) **(Note 4)**	3	6	6	10	N/A
1.13	Maximum base station output power/sector (e.i.r.p.) (dBm)	72.28	72.28	72.28	61.53	N/A

Note 1: The element gain in row 1.2 includes the loss given in row 1.8 and is per polarisation. This means that this parameter in row 1.8 is not needed for the calculation of the BS composite antenna gain and e.i.r.p.
Note 2: For the small/micro cell case, 8 × 8 means there are 8 vertical and 8 horizontal radiating elements. For the extended AAS model case, 4 × 8 means there are 4 vertical and 8 horizontal radiating sub-arrays.
Note 3: The vertical coverage range is given in global coordinate system, i.e. 90° being at the horizon.
Note 4: The vertical coverage range in row 1.11 includes the mechanical down tilt given in row 1.12.
Note 5: The conducted power per element assumes 8 × 8 × 2 elements for the micro/small cell case, and 4 x 8 x 2 sub-arrays for the macro case (i.e. power per H/V polarised element).
Note 6: In sharing studies, the transmit power calculated using row 1.9 is applied to the typical channel bandwidth given in Table 5-1 and 6-1 of Doc. 5D/716 respectively for the corresponding frequency bands.
Note 7: In sharing studies, the UEs that are below the base station vertical coverage range can be considered to be served by the “lower” bound of the electrical beam, i.e. beam steered towards the max. coverage angle. A minimum BS-UE distance along the ground of 35 m should be used for urban/suburban and rural macro environments, 5 m for micro/outdoor small cell, and 2 m for indoor small cell/urban scenarios

ANNEX 7: LIST OF REFERENCES

[1] ECC Decision (08)08: "The harmonised use of GSM systems in the 900 MHz and 1800 MHz bands, UMTS systems in the 2 GHz band and LTE systems in the 1800 MHz and 2.6 GHz bands on board vessels", approved October 2008, amended March 2016 and updated June 2017

[2] ECC Report 122: "The compatibility between GSM use on board vessels and land-based networks", approved September 2008

[3] ECC Report 237: "Compatibility study between wideband Mobile Communication services on board Vessels (MCV) and land-based MFCN networks", approved July 2015

[4] EC Decision 2011/251/EU: 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

[5] ETSI TS 136.101: "Technical specification, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA);User Equipment (UE) radio transmission and reception"

[6] ETSI TS 136.104: "Technical specification, LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception"

[7] ETSI TS 138.101: "5G; NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[8] ETSI TS 138.104: "5G; NR; Base Station (BS) radio transmission and reception"

[9] Recommendation ITU-R M.2101: "Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies"

[10] Document ITU-R 5D/716 (chapter 4 - annex 4.4): "Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23"

[11] Recommendation ITU-R P.452-16: "Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz"

[12] Constitution of the International Telecommunication Union