JOINT OPERATORS TECHNICAL SPECIFICATION OF GSM, UMTS, LTE & 5G NR INDOOR CELLULAR SYSTEM

SCOPE

This document defines the requirements of indoor cellular system for GSM, UMTS, LTE and 5G NR operation. It covers the design and test requirements, and the characteristics of the elements used in the system where the network performance is affected.

It also defines the scope of work and the expected deliveries from the contractor during the different phases of a project.

It is expected that the contractor will be responsible for the maintenance of the indoor cellular system, therefore a high-level service level agreement is described.

PURPOSE

This document will be used by the neutral host contractor (NHC) for the design and implementation of indoor cellular systems for the GSM, UMTS, LTE and 5G NR operation.

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5.1	29/09/2022	Update the max single trip propagation delay requirement (73R) and the PIM requirement (158R)

DOCUMENT TABLE OF CONTENTS

ACKNOWLEDGEMENT

This document is created with inputs and contributions from the current UK 2G, 3G, 4G and 5G cellular mobile network operators BT/EE, Three, Virgin Media O_2 and Vodafone.

REFERENCES

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[2] 3GPP TS 25.101, Technical Specification Group Radio Access Network; User Equipment (UE) radio transmission and reception (FDD)

[3] 3GPP TS 45.005, Technical Specification Group GSM/EDGE Radio Access Network; Radio Transmission and Reception

[4] 3GPP TS 36.101, Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception

[5] 3GPP TS 36.104, Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception

[6] 3GPP TS 38.101-1,2,3,4, NR; User Equipment (UE) radio transmission and reception

[7] 3GPP TS 38.104, NR; Base Station (BS) radio transmission and reception

[8] 3GPP TS 25.106, Technical Specification Group Radio Access Network; UTRA repeater radio transmission and reception

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ABBREVIATIONS

3GPP	3rd Generation Partnership Project
ACI	Adjacent Channel Interference
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
ADC	Analog-to-digital converter
BBU	Baseband Unit of Base Station
BCCH	Broadcast Control Channel
BS	Base Station
CAPEX	Capital Expenditure
C/N	Carrier-to-Noise
CPICH	Common Pilot Channel
CPRI	Common Public Radio Interface
CU	Centralised Unit of Base Station for the layer three functions
CW	Continuous Wave (i.e. constant power and amplitude)
DAC	Digital-to-analog converter
DAS	Distributed Antenna System
dBi	Decibels relative to the gain of an isotropic antenna
dBm	Decibels relative to a milliwatt
DECT	Digital Enhanced Cordless Telecommunications
DIN	Deutsches Institute for Normung (Germans Standards Institute)
DL	Downlink
DSS	Dynamic Spectrum Sharing
DU	Distributed Unit of Base Station for baseband processing
Eb/Io	Energy per bit/total received signal
Ec/Io	Energy per chip/ total received signal
EIRP	Effective Isotropic Radiated Power
EMF	Electromagnetic Fields
eNodeB	E-UTRAN Node B (4G BS)
EPRE	Energy Per Resource Element
ER	Exposure Ratio
ESN	Emergency Services Network
ETSI	European Telecommunications Standards Institute
EVM	Error Vector Magnitude
FDD	Frequency Division Duplex
FR1	Frequency Range-1 (410MHz – 6GHz (7.125GHz (TBC))
GSM	Global System for Mobile Communication
GSM-R	GSM-Railway
gNodeB	3GPP-compliant 5G-NR base Station (5G BS)
GPS	Global Positioning System
HOT	Heads of Terms
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEE	Institution of Electrical Engineers
LOI	Location of Interest
LTE	Long Term Evolution
LTE-R	LTE for Railway-dedicated wireless communications network
LTE-U	LTE in unlicensed spectrum
M&E	Mechanical and Electrical
MBSFN	Multimedia Broadcast multicast service Single Frequency Network
MCL	Minimum Coupling Loss
MIMO	Multiple Input Multiple Output
MNO	Cellular Mobile Network Operator(s)
MT	Mobile Terminal
MuLTEFire	LTE in licence exempt (unlicensed or shared) spectrum
NB-IoT	Narrowband-Internet of Things
NDA	Non-Disclosure Agreement
NGR	National Grid Reference
NHC	Neutral Host Contractor

NMAS	National Measurement Accreditation Service
NR	New Radio
OPEX	Operating Expense
PCDE	Peak Code Domain Error
PMR	Private Mobile Radio
POI	Point of Interconnect/Interface
ppm	Parts per million
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
RBS	Radio Base Station
RE	Resource Element
RF	Radio Frequency
RFID	Radio-Frequency Identification
RI	Radiating Infrastructure
RS	Reference Signal of LTE
RSCP	Received Signal Code Power
RSRP	Reference Signal Received Power
RU	Radio Unit
SAR	Specific Absorption Rate
SAT	System Acceptance Test
SCS	Sub-Carrier Spacing in 5G New Radio (NR)
SIMO	Single Input Multiple Output
SLA	Service Level Agreement
SSB	Synchronization Signal Block
SS-RSRP	Synchronization Signal Reference Signal Received Power
SSS	Secondary Synchronisation Signal
TBC	To Be Confirmed
TDD	Time Division Duplex
TRX	Transceiver
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UWB	Ultra Wide Band
VSWR	Voltage Standing Wave Ratio
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network

1. INTRODUCTION

Riding on the success of the 2G (GSM), 3G (UMTS) and 4G (LTE) joint operator neutral host projects, the UK cellular network operators **EE**, **Three**, **Virgin Media O_2** and **Vodafone** agree to continue the scheme for the 5G NR networks. This document forms the baseline for the existing indoor system upgrade and the new deployment covering the requirements of both GSM, UMTS, LTE and 5G NR operations of sub-6GHz (FR1) bands given in Appendix A.

This document specifies the requirements of indoor cellular system for the 2G, 3G, 4G and 5G operations of which the Cellular Mobile Network Operators (MNOs) subscribe. The system will be designed, installed, and tested by a Neutral Host Contractor (NHC) who has the full turn-key responsibility for delivering such system meeting the requirements defined in this document. The NHC can be either an independent third party or one of the MNOs.

The indoor cellular system can take the form of a single radiating element or distributed radiating elements which can use omni antennas, sector antennas, radiating cables or a combination of both together with RF components and sub-systems. For convenience, such cellular system referred in this document is called distributed antenna system (DAS).

The technical requirements for both 2G, 3G, 4G and 5G operations are described in section 2 although it is expected that 3G may be phased out sooner than the other technologies. The coverage requirements, the system performance and the components characteristics are specified in detail.

Section 3 defines the scope of work with which the NHC will provide.

It is expected that the NHC will be responsible for the maintenance of the DAS. Section 4 describes a high-level Service Level Agreement (SLA) which will be negotiated under the commercial agreement with each individual MNO.

A DAS is only acceptable into operation when the NHC verifies and demonstrates to the MNO that the specifications defined in section 2 are met. Section 5 describes the system acceptance test requirements.

1.1 DOCUMENTATION STRUCTURE

The document is made up of sections dealing with different aspect of the 2G, 3G, 4G and 5G DAS. Each of the requirements is marked as **Q**, I, **R** or **M** defining the necessity. To qualify as a NHC, the Tender is required to answer the questions, requirements, and mandatory requirements.

For the purpose of this document, NHC is used in the document for the successful Tender.

Question **Q** is normally raised to get information from the supplier aiming for a better understanding of the issue.

Information I is supporting information for the NHC to design the DAS.

Requirement **R** is raised when the performance of the DAS is required to fulfil the mobile cellular operation. Full details of compliance will be useful in supporting our evaluation.

If the requirement cannot be fulfilled, the Tender should provide alternative solution and explain the effects of non-compliance.

Mandatory requirement **M** is a critical requirement for which Tender shall answer with a "Comply" or "Non-comply". Details shall be provided where possible to support the evaluation.

1.2 QUALIFYING PROCESS

The Tender shall submit a soft copy of response and any relevant information in MS Word, Power Point, Excel, Map Info, AutoCAD, etc. to each MNO for reviewing and making a decision on the suitability of the Tender to be a NHC. The Tender must response in full to the requirements. Where compliance is not possible, detailed explanation and alternatives shall be provided.

2. TECHNICAL SPECIFICATION OF THE DAS

2.1 GENERAL

1. R The NHC shall engage the MNO during each stage of a project.

2. M The DAS shall be capable of supporting radio signals of GSM, WCDMA, LTE and NR technologies. Where the DAS incorporates other users such as the emergency services, public and private WLAN, private NR, in particular the non-public area outside the common interest of MNO, the performance specification defined in this document and the design of the DAS shall not be compromised. However, such additional services leading to the extra DAS CAPEX and OPEX should be contributing to those costs.

3. M The DAS shall be with the provision of the capacity handling according to the expected traffic and footfall.

4. R The DAS shall be capable or cost-effectively upgradeable to cover the frequency bands given in Appendix A although it is not necessary all bands in Appendix A shall be delivered in each venue. Where only some of the bands in Appendix A are proposed and utilised, justification and upgrade path shall be provided and agreement between NHC and MNOs shall be established.

5. R Appendix A table A-1 summarises the spectrum currently licenced to the UK MNOs. Appendix A table A-2 specifically shows 3.4GHz–3.8GHz spectrum holdings due to 2019 and 2021 spectrum auctions in UK, and the the new spectrum arrangement at 3.4GHz-3.8GHz after a further spectrum trading agreement between Virgin Media O_2 and Vodafone in 2021. As a result, in terms of 3.4GHz-3.8GHz, there is a transition period that some indoor systems may need to support Virgin Media O_2 operating at 3.5-3.54GHz before the final configuration with reference to the spectrum arrangement shown in Appendix A table A-1. NHS shall directly consult Virgin Media O_2 and Vodafone regarding the specific requirements at 3.4GHz-3.8GHz during the design and implementation phases of the indoor solution.

6. M The proposed DAS must be the most cost-effective solution utilising the full capability of the MNO's equipment. Details of the equipment are provided in separate document.

7. R The requirements of the DAS defined in this document are only applied to the general public accessible area. If non-public area is required by the site owner and/or a third party or a specific individual MNO, it shall be covered separately between the site owner and the party of interest.

8. M Where a location already has a DAS installed for the 2G, 3G and/or 4G operation, the NHC must carry out an assessment of the impact of upgrading the existing system for supporting all GSM, UMTS, LTE and NR technologies. This is considered to be generally more cost effective. If this is not possible, a report on the shortcomings and a comparison of costs and performance between a new DAS, an upgrade to a sub-standard DAS or an overlap DAS shall be given in the design document.

9. M The DAS shall be of modular construction so that it can be easily expanded and upgraded for capacity reason by way of sectorisation into additional DAS zones, for example, without significantly compromising the existing performance, and offers options for individual operator mapping the capacity and base station sectors to the DAS zones.

10. M The upgrade shall minimise the disruption to the current operations.

11. M Although it is not essential that the 2G, 3G, 4G and 5G signals of a MNO shall be carried on the same sub-system, it is mandatory that the traffic of the same frequency band of the associated MNO shall be carried on the same sub-system.

12. I 3.4-3.6GHz and 3.6-3.8GHz may be considered as two separate bands and served by separate sub-systems if necessary.

13. R This document defines the technical specifications for a DAS supporting the operation of

- GSM at 900MHz & 1800MHz bands,
- UMTS at 900MHz, 1800MHz & 2100MHz bands,
- LTE and/or NR (including DSS) at 800MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz & 2600MHz bands and
- NR at 700MHz, 3.5GHz and 3.7GHz bands
- but excluding the GSM in the guard band.
- The actual technology/technologies to be deployed at a given band for a venue shall be agreed between the NHC and each individual MNO.
- However, all passive components must be wide band covering at least both GSM, UMTS, LTE and NR bands as given in Appendix-A except specific band selective units for the purpose of channelisation and filtering or specific radiating elements for specific band operation(s).

14. I In terms of LTE and NR, the baseline requirements are referred to the 2x2 and 4x4 MIMO DAS respectively. Where a SISO DAS for LTE and/or 2x2 MIMO for NR in a relatively low capacity venue is proposed, the NHC should provide

the justification and advise the upgrade path of the DAS for accommodating higher MIMO operation in future, and also provide the conceptual design and the indicative cost of the DAS with the MIMO capability. The requirements defined in here are not specifically dictated the indoor solution to the passive/active or SISO/2x2 MIMO/4x4 MIMO DAS. Each location of interest and the solution will be assessed according to the figure of merits and will be agreed between the NHC and MNO.

15. M The DAS shall be designed to operate with base station and mobile terminal meeting the 3GPP and ETSI standards [1]-[7]. Additionally, the DAS shall conform to all the current regulations, rules and the operation conditions imposed on MNOs by the UK Government and meet the 3GPP & ETSI Standards where appropriate i.e. [8]-[11].

16. M When either 2G, 3G, 4G or 5G is added to an existing system, it must be ensured that the systems and operations of both the 2G, 3G, 4G and 5G are compliant with the ETSI recommendations.

17. R The DAS shall be used in indoor and confined space environments such as, but not limited to, tunnel, shopping centres, conference, and exhibition halls etc.

2.2 DESIGN REQUIREMENT ASSUMPTIONS

18. R Where the DAS is used for in-building, road tunnel or non-high speed train tunnel, the propagation model and performance requirements specified in TS25.104 Case 1, Case 3 or Case 4 for a mobile terminal travelling at a speed up to 3km/hr, 120km/hr or 250km/hr respectively shall be used, or the highest mobile terminal travelling speed confined by the venue with an added 20% margin in the design for the purpose of call handover.

19. I Each of the MNOs shall provide the NHC with a specification pack detailing the mechanical, electrical and RF interface specifications of the base station equipment. This will be provided under separate cover and under the condition of Non-Disclosure Agreement (NDA) with the NHC in order to comply with the confidentiality agreement between the MNO and their equipment vendors.

20. R Where information is not given by the MNO, the NHC can assume

- the 2G, 3G, 4G and 5G base station receiver noise figure of 4dB,
- Mobile terminal maximum transmit power of 30dBm, 21dBm, 23dB and 23dBm for GSM, UMTS, LTE and NR respectively,
- Mobile terminal minimum transmit power of 5dBm, 0dBm, -50dBm, -40dBm and -40dBm, for GSM900, GSM1800, UMTS, LTE and NR respectively,
- the dedicated indoor system should provide at least a dominant coverage of 6dB over 95% of the coverage target area against the coverage provided by the external outdoor cell sites of any adjacent cellular networks,
- the dedicated indoor system delivers CPICH Ec/Io >= -8dB with reference to the UMTS cells of 20% loading (10% CPICH and 10% control signalling)
- a carrier-to-noise (C/N) ratio of 12dB for GSM voice calls in uplink and downlink, and
- 10% downlink RF composite power per UMTS operating channel assigned to Common Pilot Channel (CPICH)
- Reference Signal (RS) power of LTE may usually be with 3dB boosting as shown in table 1 but **not absolutely**. Although the RS may be with 3dB power booster, the average sub-carrier power of LTE will still remain as

  $$P_{FL} - 10 \times \mathrm{Log}_{10}(N_{sc}) ,$$

  where P_{FL} is referred to the full load channel carrier power and N_{sc} is the number of LTE sub-carriers in a given LTE channel bandwidth. There may be some cases that an individual MNO may implement a different power booster on RS i.e. between 0dB to 3dB and NHC will be specifically advised by the individual MNO. Irrespective of whether the power booster on RS is used, the composite channel carrier power is still referred to P_{FL}. For the design purpose in terms of the coverage, NHC may assume 0dB power booster.

- 5G NR channel carrier power is evenly assigned to all sub-carriers including **S**econdary **S**ynchronization **S**ignal **E**nergy **P**er **R**esource **E**lement (SSS

EPRE) of **S**ynchronization **S**ignal **B**lock (SSB) within the transmission channel.

carrier power [W]	carrier power [dBm]	LTE channel bandwidth [MHz]				LTE channel bandwidth [MHz]			
		5	10	15	20	5	10	15	20
		number of LTE sub-carriers within a given channel bandwidh				number of LTE sub-carriers within a given channel bandwidh			
		300	600	900	1200	300	600	900	1200
		Transmit Reference Signal power with *3dB power booster* [dBm]				average power of each sub-carrier [dBm]			
5	37.0	15.2	12.2	10.5	9.2	12.2	9.2	7.5	6.2
10	40.0	18.2	15.2	13.5	12.2	15.2	12.2	10.5	9.2
15	41.8	20.0	17.0	15.3	14.0	17.0	14.0	12.3	11.0
20	43.0	21.2	18.2	16.5	15.2	18.2	15.2	13.5	12.2
30	44.8	23.0	20.0	18.3	17.0	20.0	17.0	15.3	14.0
40	46.0	24.2	21.2	19.5	18.2	21.2	18.2	16.5	15.2

Table 1: Reference Signal & sub-carrier power of LTE.

21. R With reference to the typical macro base station, the following output level can be assumed, otherwise the lowest level and the highest level given in the MNO's standard pack shall be used for coverage design and power handling design respectively.

Base station type	Base station nominal output power per carrier per port	Power handling design per carrier per port (thermal consideration)
2G base station	40dBm/43dBm (TBC)	46dBm
3G base station	33dBm (CPICH), 43dBm (full load)	46dBm
4G base station (*) (non-MBSFN transmission)	43dBm per transmission channel	46dBm per transmission channel
base station (*)	43dBm	46dBm

Table 2: Base station output power.

There may be some specific cases that a different power class of base station, i.e. micro, pico, small cell, etc., may be used and NHC will be advised accordingly in the pre-feasibility/feasibility phase of the project.

Where an active DAS is proposed, the NHC shall provide a means to adjust the gains and losses of the active DAS per individual MNO per band for optimising the downlink and uplink of the DAS independently. Although it is the responsibility of the NHC to provide appropriate safe guard protecting the DAS from overloading, in particular the downlink, the NHC is required to provide the evidence to show the budget allocation between MNO in terms of the RF power, optical and/or digital bits on the active sub-systems of the DAS.

(*) For the system design, with reference to the downlink coverage requirements, it is referred to the linear average over the power contributions of the **R**esource **E**lements (the OFDM symbols) carrying reference symbols or

secondary synchronization signal only instead of the full load power, i.e. the downlink coverage is expressed as RSRP and SS-RSRP for LTE and 5G NR respectively.

22. R For the purpose of coverage overlapping design including the tunnel portals to and from the MNO macro networks, the handover time for mobile terminal travelling speed >3km/hr and <=3km/hr is 10 seconds and 4 seconds respectively.

23. I The following link budget assumptions can be used for the purpose of the system design:

- body loss: 5dB
- car penetration loss: 7dB
- train loss: case by case basis

2.3 THE DAS

24. R The DAS will comprise of a number of network sub-systems and interfaces as shown in figure 1.

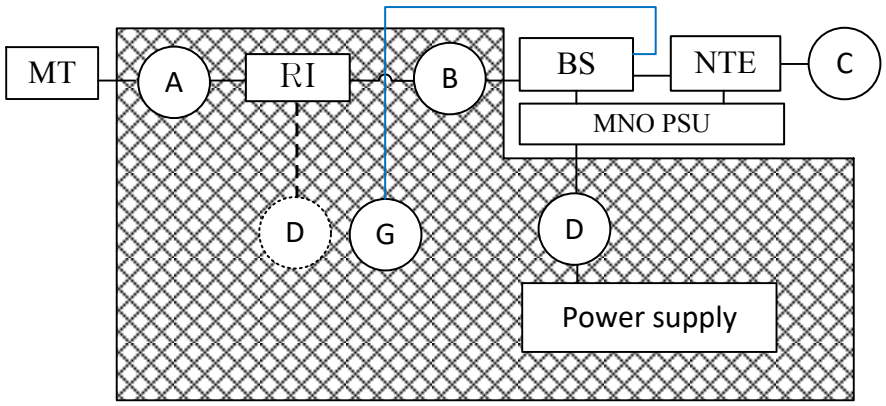

Figure 1: Schematic diagram of DAS system

Where MT is the mobile terminal,
RI is the Radiating Infrastructure,
BS is the Base Station,
NTE is the Network Transmission Equipment for connecting the traffic to core network,
MNO PSU is the MNO's power supplier unit(s) for BS and NTE,
A is the air-interface,
B is the Point of Interconnect (POI) with the MNO's equipment,
C is the interface with the external transmission connections,
D is the interface with the power supply, and
G is the GPS associated infrastructure & interface.

25. R All the components within the shaded enclosure of figure 1 including any cables connected to the MNO's equipment are the responsibility of the NHC.

26. R The DAS is made up of RI and the interfaces A and B.

27. R Irrespective of the B interface type, analog or digital, between MNO base station equipment and DAS, the coverage requirements, the system performance and the components characteristics specified in this document are applied.

28. R Depending on the size of the Location of Interest (LOI) and the complexity of the design for reason of technicality and practicality, the RI can be made up of:-

(a) passive elements such as filters, couplers, antennas, feeders and/or radiating cables
(b) active elements such as ADC, DAC, IP router/switch, radio over fibre sub-system and amplifier
(c) a mixture of (a) and/or (b) with or without in-line amplifier(s).

29. I For the DAS with active elements, two types are referred in this document:

- wideband active DAS: all downlink and uplink active elements covering the whole mobile cellular's downlink and uplink operating bands respectively per GSM and/or and/or UMTS and/or LTE and/or NR technology, and

- narrow band active DAS: some active elements only covering the sub-bands of the GSM, UMTS, LTE and NR operating bands with respect to the appropriate downlink and uplink directions.

30. R Where active DAS is proposed, the end-to-end system uplink loss shall be less than the end-to-end system downlink loss in general. Subject to the detailed analysis with justification approved by MNO, the end-to-end system uplink loss can be equal to or higher than the end-to-end system downlink loss.

31. M The NHC is responsible for the DAS, the Power Supply and a safe interface (D) so that the MNO can connect their equipment to the power supply. The NHC is also responsible for the provision of a proper accommodation for the installation of the MNO's equipment, provision of space for the installation of external transmission equipment (C) such as leased circuit or external microwave radio, and the delivery of GPS associated infrastructure & interface (G) for providing synchronisation signals to MNO's equipment.

32. R Where the RI requires power for its operation, the NHC is entirely responsible for the provision and installation of the required power supply.

2.4 COVERAGE

33. R The coverage requirements are referred to both downlink and uplink within the coverage target areas of the LOI and with mobile terminal at the height of 0.5m to 2m above the local ground.

34. R Unless specified in a separate agreement between the NHC and the individual MNO, the NHC shall ensure that the DAS delivers coverage to the standard defined in Table 3 below which is referred to the initial targets and has to be validated against the dominance requirements defined in section 2.2.

GSM			
Type of location/zone		Handheld MT (in-building)	Car roof mounted MT (road tunnel)
95% downlink BCCH Coverage Level (dBm)		≥ -95	≥ -85
95% uplink link loss (dB) (*)	GSM900	$\leq (133 - N_d)$	$\leq (123 - N_d)$
	GSM1800	$\leq (130 - N_d)$	$\leq (120 - N_d)$
UMTS (handheld MT – in-building)			
Type of zone	**A**: High Bit Rate Service	**B**: Medium Bit Rate Service	**C**: Portal area ONLY
95% downlink CPCIH coverage of the target zone (dB)	≥-77dBm (≤110dB link loss(**))	≥-87dBm (≤120dB link loss(**))	≥-97dBm (≤130dB link loss (**))
95% uplink link loss of the target zone (dB) (*)	$\leq (110 - N_d)$	$\leq (120 - N_d)$	$\leq (130 - N_d)$
UMTS (car roof mounted MT – road tunnel)			
95% downlink link loss (dB)		≥-87dBm (≤120dB link loss(**))	
95% uplink link loss (dB)		$\leq (120 - N_d)$	
LTE and NR (handheld MT – in-building)			
Type of zone	**A:** High data rate service	**B**: Medium data rate service	**C:** Portal area ONLY
95% downlink reference coverage (RSRP for LTE (***)) (SS-RSRP for NR (****))	>-95dBm	>-105dBm	>-110dBm
95% uplink loss (*)	$\leq (110 - N_d)$	$\leq (120 - N_d)$	$\leq (125 - N_d)$
Typical area	**Zone A**: low mobility **and** high-density mobile **Zone B**: medium/high mobility **and** low/medium density mobile **Zone C:** portal area ONLY		
Example (not exhaustive list. Each venue MUST be analysed and assessed on a case by case basis.)	**Zone A:** - Airport: lounge, restaurant/bar, shopping area, departure gate etc. - Shopping Centre: food court, restaurant/bar, seating area, etc. - sport venue: seating area, hospitality/concourse area - hotel/conference centre/exhibition centre: conference/meeting area, public break-out area, restaurant/bar **Zone B:**		

	- Airport: arrival gate, transit area etc. - Shopping Centre: back of the shop where public can access - sport venue: public transit area other than the concourse area mentioned in zone A - hotel: any other areas subject to a separate agreement between MNO and NHC **Zone C:** - any transition from the areas served by the dedicated indoor system to the adjacent cellular network which can be another indoor cell or the outdoor cellular network **Note:** - corporate coverage is likely to be designed as the requirements for zone A but it will be subject to a separate agreement between an individual MNO and NHC

Table 3: Coverage specification.

(*) where N_d in dB is the increase of receive noise floor at base station receiver due to the uplink noise of the DAS at the relevant band, and the base station noise floor is assumed to be -170dBm/Hz at the receive band.

Illustration example of the base station noise floor degradation calculation:
- Base station receive noise floor = -170dBm/Hz (or 10^{-17}mW/Hz, noise figure = 4dB)
- Uplink noise of DAS at base station interface = -165dBm/Hz (or $3.2x10^{-17}$mW/Hz)
- Composite uplink noise due to DAS and base station ≈ -163.8dBm/Hz (or $4.2x10^{-17}$mW/Hz)
- Increase of receive noise floor at base station, N_d, ≈ 6.2dB = (-163.8 – (-170))dB

(**) The downlink link loss of UMTS stated in table 3 is with reference to the typical CPICH transmit power of 33dBm for the case of the typical full load downlink carrier of 43dBm. Where a different power class of base station is used an appropriate offset shall be applied to the requirements.

(***) RSRP for each cell is the linear average over the power contributions of the **R**esource **E**lements that carry cell-specific **R**eference **S**ignals within the considered measurement frequency bandwidth. It can therefore only be referred to and measured in the OFDM symbols carrying **reference symbols**.

(****) SS-RSRP is the linear average of the secondary **S**ynchronization **S**ignal **R**eference **S**ignal **R**eceived **P**ower. The secondary synchronization signals on the **R**esource **E**lements are cell-specific to each NR cell.

35. R The NHC shall propose and define the zone types in each design for the MNO to comment and agree.

36. R The link loss defined in table 3 is the end-to-end loss between the mobile terminal (the interface A of figure 1) and the last connection of the individual MNO's base station (the interface B of figure 1).

37. R The NHC must make allowances for the floor variations, fading, clutter loss and environment etc. in the design in order to ensure the required percentage of the

agreed areas of the LOI covered. If the DAS is for train tunnel, the NHC shall make provision in the design of train carriage losses.

38. R For the 3G, 4G and 5G, busy traffic zones such as Zone A do not necessarily mean that more antennas will be required. The placement of the antennas (including radiating cable if appropriate) shall take into consideration that the demand of higher data rate is most likely at places where the 3G, 4G and/or 5G mobile terminal can be stationary or quasi-stationary such as lounges, restaurants and cafés etc.

2.5 COVERAGE OVERLAP BETWEEN RADIATING ELEMENTS OF DAS

39. R The NHC shall design the coverage delivered by each antenna of the DAS has adequate overlap without discontinuity of service in the coverage area.

40. R This requirement for coverage overlap also applies to boundaries where sectorisation is most likely to be employed when capacity expansion is required. Based on the local knowledge of the location, the NHC shall highlight these boundaries within the DAS.

41. R Where multiple cells are proposed, the cell boundary shall have adequate coverage overlap enabling a mobile terminal to complete a handover within the handover time defined above.

42. R Any sectorisation of the DAS shall avoid the high traffic area in order to minimise the handover between them. The design should provide an indication of the number of users per DAS zone.

43. I MNO considers a total of 2000 active users per DAS zone are reasonable assumption at this stage.

44. R The coverage overlapping areas provided by any two adjacent indoor cells of the DAS shall be less than 15% with reference to

- the coverage target area of that particular two indoor cells and also
- 3dB link loss window as shown in an example of figure 2 below.

45. R No area of the LOI shall be simultaneously served by more than 3 indoor cells.

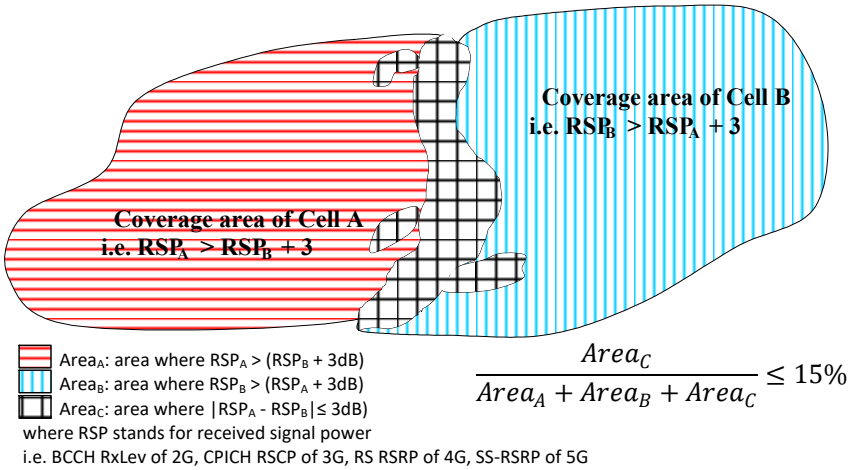

Figure 2: Coverage overlapping illustration of any two adjacent indoor cells.

2.6 COVERAGE OVERLAP BETWEEN THE INDOOR CELL AND OUTDOOR CELLS

46. R The NHC shall position some of the antennas of the DAS so that the portal shall be adequately covered without breaching the controlled leakage requirements defined in section 2.7. This shall ensure a proper handover in both directions between the indoor cell and the external cells which are defined as the cell(s) not under the responsibility of the NHC.

47. R The handover between the outdoor cells and the indoor cells may be of inter-frequency nature, i.e. hard handover which will take longer time to complete. Therefore, the coverage overlapping distance between the outdoor cell and the indoor cells at the portals shall ensure continuous voice call of a mobile terminal at the speed as defined in section 2.2

48. R For reason of avoiding uncertainty and conflict of responsibility, it is a preference where possible that all handover occur inside the LOI except the road tunnel and rail tunnel in where the handover may be taken place outside. The exceptional cases of tunnel are not the exhausted examples, and each LOI should be assessed accordingly.

2.7 CONTROLLED LEAKAGE AND HANDOVER

49. R The distance of the controlled leakage from the LOI is with reference to a mobile terminal at the speed as defined in section 2.2 and also takes the maximum and minimum handover time into account.

50. R As shown in figure 3, the distance of the signal overspill from any portals of the LOI shall be less than the double of the handover distance for the uplink link loss greater than 142dB. Where the DAS is designed for the non-high-speed rail or road tunnel, the controlled signal overspill shall be confined along the rail track or road route outside the tunnel for a proper handover between the tunnel cells and the MNO outdoor cells.

51. R With the exception of the portals of the LOI and as shown in figure 3, the distance of the signal overspill shall be less than the handover distance for the uplink link loss greater than 142dB.

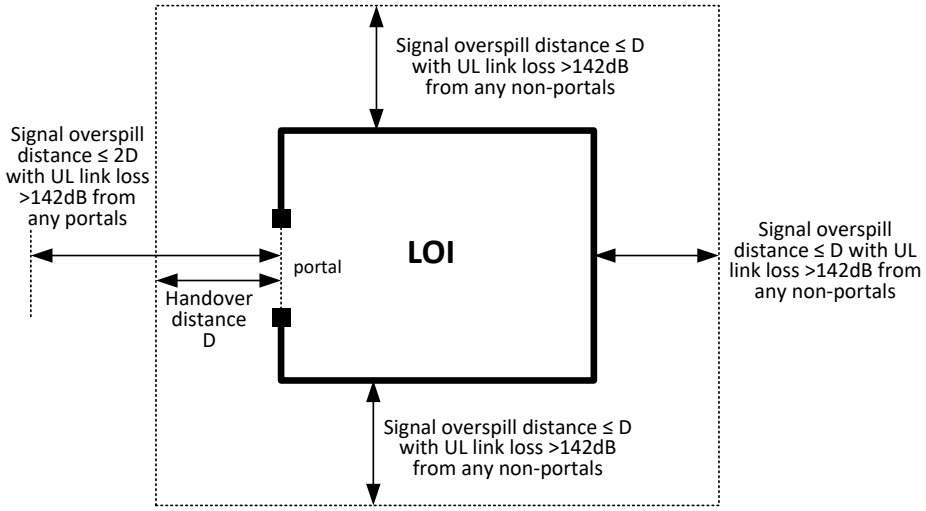

Figure 3: Illustration of the controlled leakage and handover distances.

2.8 OVERLOAD AND INTERMODULATION

52. R The selection and the placement of the radiating elements of the DAS shall not cause overloading, blocking and de-sensitisation to the mobile terminal in the downlink direction, and the MNO's base station and any active units of the DAS in the uplink direction due to the presence of a mobile terminal transmitting at full power within the coverage range of the radiating element, especially in close proximity to the radiating element concerned.

53. R The minimum coupling loss (MCL) is referred to the location at where the minimum path loss between the mobile terminal and the DAS will occur, and the mobile terminal will receive the maximum downlink signal and the MNO's base station will receive the maximum uplink signal.

54. R The NHC shall carry out an assessment for each design, state the MCL which will be achieved and ensure the downlink and uplink overload, blocking and de-sensitisation will not occur. The maximum downlink signals at a 2G, 3G, 4G and 5G mobile terminal shall be less than -40dBm, -25dBm, -25dBm and -25dBm per cellular channel respectively, and the maximum uplink signal level per cellular channel at the MNO's 2G, 3G, 4G and 5G base stations shall be less than -35dBm, -52dBm, -50dBm and -50dBm respectively. Consideration of alternative antenna types and/or the antenna locations and the overall system design may be necessary to achieve the requirements.

55. R The NHC shall endeavour to position the radiating element such that a far mobile terminal at the edge of an antenna coverage area will not be affected by

a near and uncoordinated mobile terminal at the MCL position of the same radiating element, transmitting 30dBm, 21dBm, 23dBm and 23dBm at the GSM, UMTS, LTE and NR frequency band respectively. The uncoordinated mobile terminal is due to the MNO who does not subscribe to the DAS.

56. R In the absence of 3GPP specification specifically for the DAS, the design of the DAS shall ensure that the total intermodulation and spurii generated by the DAS and the MNO's base station(s) under full load conditions shall still comply with the appropriate specifications recommended by the 3GPP Standards i.e. [1], [3], [5], [7], [8]-[10].

57. R When connected to all the base station equipment permitted by the design, the DAS must meet the same requirements as specified for a single GSM, UMTS LTE and NR base station.

2.9 CO-SITING

58. R The NHC shall ensure that the system is designed, either by suitable filtering or other means, to prevent any significant mutual interference between any 2G, 3G 4G and 5G channels of the MNO and other telecommunication installations in the premises at the time of design and installation. This includes but not limited to the presence of small cell, GSM-R, PMR, wireless local access network (WLAN), ultra-wide band (UWB) device, RFID, LTE-U, MuLTEFire, LTE-R, NR private network etc.

59. R The effective degradation to the UL and DL receive sensitivity due to the effect of co-siting shall not be more than 0.1dB over the additional RF branching loss essential for co-siting implementation. This is applied to where the GSM, UMTS, LTE and NR signals are distributed over different or same signal distribution layers with different or same radiating elements.

2.10 HEALTH AND SAFETY

60. R In terms of the DAS design related to human exposure to electromagnetic fields (EMF), appropriate exposure limits defined by ICNIRP standard [12] according to the implementation conditions shall be used as well as the EMF conditions required by Ofcom [13].

61. R The NHC shall take the full responsibility for the risk assessment in where the public or occupational EMF limit is applied to each radiating element. The EMF exposure limit for the general public shall be used in any public accessible locations.

62. R Maximum radiated power from any single radiating element shall not expose anyone to an EMF level which exceed the current guidelines in the ICNIRP standard. This shall take into account of the maximum number of carriers (2G, 3G, 4G and 5G as appropriate) to be carried by the DAS concerned.

- Where the radiating element will be installed at the general public accessible location and can be reached without any aids i.e. stand or

ladder, the Specific Absorption Rate (SAR) threshold, i.e. 2W/kg within 10g volume, for the general public is applied.

- Where the radiating element can only be reached with aids i.e. stand or ladder, the SAR threshold, i.e. 10W/kg within 10g volume, for the occupational can be used.

63. R The public and occupational ICNIRP thresholds shall be applied according to the radiating element locations:

- Any radiating elements at <2.5m above ground standing level shall be touch safe and meet the general public ICNIRP compliant limits.

- Any radiating elements out of reach of anywhere a general public may stand shall be touch safe and meet the occupational ICNIRP compliant limits. Where the radiating elements do not meet the occupational touch-safe limit of ICNIRP, specific access arrangement of those, i.e. managed outage, shall be defined and applied, and the occupational exclusion zone of those shall be clearly defined. It is also noted that some MNOs do not currently allow the deployment of indoor radiating elements that fail to meet ICNIRP occupational requirements for touch-safe compliance. This may require additional over-shrouds and/or limitation of RF power input to the radiating elements. The design of the DAS for individual MNOs should make sure the policy of that specific MNO is met.

64. R Any SAR thresholds such as the maximum input power to the radiating element established and used in the design shall be based upon the SAR based tests of the radiating elements according to the appropriate methodology as stated in [14] and [15].

65. R The total exposure ratio (TER), as defined in eq (1), of any radiating elements to be deployed at any public or occupationally accessible area shall be less than or equal to 1, and is given by

$$TER = \sum_{i}^{n} \frac{T_{x,i}}{P_{SAR,i}} \qquad \text{eq (1)}$$

where

- $T_{x,i}$ represents the composite RF power (stated in Watts) of a given band fed into a radiating element of the DAS. At present, the operating bands are referred to the mobile cellular band of 700MHz, 800MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz, 2600MHz and 3.4-3.8GHz. The other bands will need to be taken into account in the future.
- $P_{SAR,i}$, $P_{SAR,j}$, … and $P_{SAR,n}$ represent the maximum powers (stated in Watts) at MNO's bands that can be fed into a radiating element and whilst ensuring that the resulting exposure levels are less than the limits stated by ICNIRP. Again, the other bands will need to be taken into

account in the future. See [12] for further details on occupational and public exposure limits.

66. M The NHC shall issue a ICNIRP compliance statement for every design of the indoor cellular system and indicates which radiating elements are compliant with the public and occupational exposure limits.

67. M The equipment room/rooms and DAS shall be designed and built to meet all the relevant building and construction products regulations in particular in areas concerning health and safety.

68. M All the electrical installations shall follow the IET wiring guidelines [16].

69. M With the exception of the MNO equipment, the NHC is wholly responsible for the health and safety of the DAS which includes all of the components within the shaded enclosure of figure 1.

2.11 PEFORMANCE CHARACTERISTICS OF DAS ELEMENTS

70. M Where an active or a hybrid system is used for the DAS, all the active equipment must be type approved to the appropriate 3GPP recommendations.

71. M The spectral emission from the DAS together with the 2G, 3G, 4G and/or 5G base station(s) shall comply with the 3GPP standards offset according to the output power difference between a base station and the remote unit of an active DAS, i.e. the spectral mask in the specification shall be maintained. In addition, as specifically required by Ofcom for per carrier basis, irrespective of the number of radiating elements per antenna, any out-of-band emission spuii radiated by any radiating elements of the DAS,

- between 2500MHz-2615MHz and also 2700MHz-3100MHz, shall be <-45dBm/MHz (EIRP),
- below 3390MHz and also within 3410MHz-3800MHz but outside the permitted frequency blocks granted to MNOs, shall be <-52dBm/MHz (EIRP),
- between 3390-3410MHz and also 3800-3840MHz, shall be <-7dBm/MHz (EIRP),
- above 3840MHz, shall be <-21dBm/MHz (EIRP), and
- outside the permitted frequency blocks of 700MHz spectrum access, shall also be less than the limits defined in Ofcom licence requiremenets, [17], [18] & [19].

72. R The overall gain flatness of the DAS over the whole MNO's licensed bands per technology shall be less than 3dB. In addition, within MNO's 3G, 4G & 5G of each 5MHz block and 2G 200kHz channel, the gain flatness of the DAS shall be less than 1dB.

73. R The maximum single trip propagation delay caused by the DAS and air interface shall not be more than 45μs due to the cell range limitation and configuration of some vendor's base stations. The differential delays of 2G signals received by a mobile terminal from the same source shall be less than 16μs because of equalizer limitation of the mobile terminal. The group delay difference shall be no more than 30ns per 3G channel. The delay spread of 4G and 5G signals received by a mobile terminal from the same source shall be less than 5.2μs and 2.86μs respectively for the sub-carrier spacing of 15kHz and 30kHz respectively.

74. R The Error Vector Magnitude (EVM) introduced by the DAS shall be

- less than 6% for both 2G and 3G operation,
- less than 17.5%, 12.5%, 8% and 3.5% for all RE allocated for shared channels (PDSCH) with the modulation schemes of QPSK, 16QAM, 64QAM and 256QAM of 4G and 5G operations respectively, and
- less than 17.5% for all RE allocated for NB-PDSCH of NB-IoT (guard band and/or in-band) with QPSK.

75. R The DAS shall not degrade the phase noise performance of the UL and DL signals. If frequency conversion is involved in the DAS, the local oscillator shall use a single common reference with a frequency stability conforming to 3GPP recommendations. The frequency deviation of the output signal with respect to the input signal shall be no more than +/- 0.01ppm.

2.12 BASE STATION EQUIPMENT INTERFACE B

76. I The requirement is only referred to RF interface between MNO base stations and the DAS in this document.

77. I With the development of technologies, there may/will be the case that MNO Centralised Unit (CU) and/or Distributed Unit (DU) without Radio Unit(s) (RU(s)) can directly and digitally feed the DAS with a digital interface in the future, which will be subject to the MNO approval and the detailed compatibility and interoperability tests covering hardware, software, protocol and parametric testing between different MNO equipments and the DAS. These and the corresponding specification are out-of-scope in here.

78. R The DAS shall provide separate 2G, 3G, 4G and 5G interface ports for each MNO except the same band with different technology operations.

79. R The preferred operation mode is **duplex** unless specified differently by individual MNO.

80. R The interface impedance shall be 50 ohm with a VSWR of less than 1.4:1 over the whole 2G, 3G, 4G and 5G band detailed in Appendix A.

81. R In order to avoid any interference effect between the UL and DL of the mobile cellular operations based upon the same multiple access solution (frequency/time division), and also between different operators,

- the isolation between any transmits and any receives of the duplex point of interface B shall be more than 45dB,
- the isolation between any transmits of the duplex point of interface B shall be at least 30dB or higher, and
- the isolation between any receives of the duplex point of interface B shall be at least 30dB or higher.

82. R Where the DAS is for the 2G, 3G, 4G and 5G operations, the isolation between any 2G, 3G, 4G and 5G ports shall be more than 45dB except different mobile cellular technologies such as GSM, UMTS, LTE and/or NR of FDD dynamically sharing the same operating frequency band of the same network operator.

83. R In order to avoid any interference effect between FDD and TDD mobile cellular technologies, the isolation between any FDD and TDD duplex points of interface B shall be more than **75dB**.

84. R The DAS, in particular all the elements for interface (B), shall be rated to handle the total average power with an additional 3dB margin while all MNO equipment are under full load conditions.

85. R The interface connector shall be 4.3-10 of female type connector unless specified differently for the LOI by individual MNO.

86. R Regardless the SISO or 2x2 MIMO DAS is proposed, two interface ports per individual MNO per band are required.

87. R For 4x4 MIMO DAS is proposed, four interface ports per individual MNO per band are required.

2.13 SUPERVISORY

88. R For an active or hybrid DAS, the NHC shall provide a summary alarm per DAS zone and a summary alarm of the DAS for connection to the external alarm interfaces of the MNO's base stations. The alarm shall be of the dry-contact type. The connection terminals shall be labelled with the wiring details for easy access wiring.

89. I Where an active system is provided, it is the responsibility of the NHC for the provision of a full supervisory system with the capability of identifying faulty unit(s) to facilitate maintenance.

90. R The alarm shall remain on until specific remedy actions have been taken to clear the fault conditions.

91. R The supervisory system shall be able to suppress any transient to minimise incorrect alarms.

2.14 SYSTEM AVAILABILITY

92. R The availability of the whole DAS shall be better than 99.95% of the time measured over a sliding one-year period with reference to the last 12 months from the date when the current fault of the cellular system is fixed.

93. R Sum of partial failure of any active elements of the DAS will be permitted for 0.1% of the time measured over a sliding one-year period with reference to the last 12 months from the date when the current fault of any elements is rectified.

94. R Partial failure shall not require the shutdown of the whole DAS except in exceptional circumstances such as health and safety becomes an issue.

3. SCOPE OF WORK

95. M The NHC shall adopt quality processes starting from feasibility conception to the completion of the installation and integration of the DAS.

96. I This section describes the area of responsibilities and the processes that the NHC shall comply. Please note that each MNO may have a specific requirement on milestones for activating their own internal processes such as calling off of equipment.

97. I High level processes and responsibilities are outlined in the table below.

Step	Process	Initiator	Note
1	Feasibility Proposal	NHC	The NHC nominate a location on offer
2	Intention to participate	MNO	The MNO indicate their interest of participating in the project, or the MNO initiate a request to the NHC of a location requiring a DAS
3	Design with cost	NHC	A design is submitted to the MNO for comment. Project cost is also submitted to start the commercial discussion
4	Proposal acceptance	MNO	Indicating the acceptance of proposal and agree to participate in the scheme
5	Project review	NHC	Regular project review is held between the NHC and the individual MNO
6	Acquisition and Implementation	NHC	The NHC is wholly responsible for the acquisition of the site and the implementation of the DAS
7	Installation of the MNO equipment	MNO	The project needs to satisfy a certain prior-agreed conditions before the MNO can call off their equipment and start the installation.
8	Commissioning	NHC	Before the MNO's equipment is connected to the DAS, the NHC will carry out a system commissioning test
9	Integration	MNO	The MNO connect their equipment to the DAS and carry out functional tests ensuring the normal functioning of their equipment
10	System acceptance test	NHC	A fully functional system is tested for confirmation of the performance

Table 5: Processes and Responsibility Definition

3.1 RESPONSIBILITIES

98. I A successful completion of a DAS project relies on each party in the project fulfil their responsibilities in an effective and efficient manner.

3.1.1 NHC Responsibilities

99. R Entirely responsible for the acquisition of the site and delivering the best deal for the MNO.

100. R Carry out system design of both the DAS and the equipment room to accommodate the participating MNO's equipment

101. R Review and amend the design, if necessary, in response to MNO's comments on the design.

102. R Provide an equipment room drawing in a scale agreed with each individual MNO for detail positioning of the MNO's equipment

103. R Procure and supply the DAS equipment appropriate to the design meeting 3GPP Standards and Ofcom's requirements.

104. R Provide an accommodation for the DAS and the MNO's equipment. The equipment room must be appropriately designed to meet the environmental, health & safety and thermal management requirements. It must be suitably air-conditioned, if necessary, to accommodate all the equipment including all designed future expansion.

105. R Provide an easily accessible space for a third-party telecommunication provider for the installation of transmission interface (C) as shown in figure 1.

106. R Carry out installation of all the equipment for the DAS and those in the equipment room with the exception of the MNO's base station and transmission equipment.

107. R Provide and install the power supply equipment if necessary and provide the MNO with a main power supply connection point meeting the appropriate electrical regulations currently in force.

108. R Advise the participating MNO of technical difficulties in a timely fashion.

109. R Issuing a handover document including an electrical certificate confirming that the site is safe for the MNO to install their own equipment.

110. R Carry out commissioning test prior to the integration of the MNO's equipment, review and rectify non-conformance if any and highlight any non-conformance items with reference to "R"s of this specification.

111. R Invite the MNO's to witness the tests with an advance notice of at least 2 weeks.

112. R Improve the DAS where there is a performance short fall. If improvement is not possible, a formal concession application shall be submitted for MNO's approval. The project is not completed until the MNO have signed off the system acceptance certificate which will only be signed off if the system conforms to this specification, or concessions been approved.

113. R Carry out individual regular project review with the participating MNO.

114. R Provide project report to the participating MNO in an agreed format and frequency.

3.1.2 Participating MNO's Responsibilities

115. R Provide a standard pack of the mechanical, thermal, and electrical specification of their equipment to the NHC. Update the pack promptly when there is a revision of the specification.

116. R Agree with the NHC of the project review processes and the project report format and frequency of both.

117. R Carry out design review and feedback comments to the NHC in a timely fashion.

118. R Participate in technical review discussions with the NHC of complex project if necessary.

119. R Participating in the commissioning test and verification test if necessary.

120. R Review the verification test results and approve concession applications if acceptable.

3.2 DOCUMENTATIONS

121. R Over the course of the project, the following documentations will be provided by the NHC to the MNO.

(a) feasibility report
(b) Design document
(c) Test methodology document
(d) System commissioning and acceptance test report
(e) As built document
(f) Concession application
(g) Factory acceptance test data on new products

3.2.1 Feasibility Report

122. I This report is produced when a NHC identify a location of interest on their own initiatives.

123. R The report shall have the following information as a minimum to assist the MNO to make a decision of participation.

(a) An executive summary page stating DAS type (active/passive), number of sectors & DAS zones being proposed, footfall of venue, number of floors, expected number of antennas
(b) Location with the postcode and NGR,
(c) Local environment including the road access, and a comment of the nearby commercial activities and development,
(d) A map showing the position of the location of interest (LOI),
(e) Photographs showing the LOI from different angles if necessary,
(f) Size and footfall figures, and the site owner,
(g) Facilities and amenities, number of shops and the name of the major shops if the LOI is a shopping centre. These shall be shown on a floor plan,
(h) An indication of the construction method of the LOI, such as roof type,
(i) Current 2G, 3G, 4G and 5G network coverage where appropriate,
(j) A statement confirming landlord's consent,
(k) Access arrangements to site and the main equipment locations plus any special site features, and parking facilities
(l) Proposed DAS Zones (supported by polygon boundaries on site drawings,
(m) An indication of the chance of acquisition success and built within a period of 6 months.

3.2.2 Design Document

124. R Design documents will be issued over a different period of the design phase. The first document will be issued after the MNO confirm their interest of participation. The second design document will be issued confirming the final design after comments from the MNO.

125. R The design document shall be made up of two parts, namely the technical part and the commercial part.

126. R The technical part will have the following information as a minimum:-

(a) Project plan identifying the forecast dates of main milestones such as design approval, acquisition HOT, site access, start of installation, installation completion, commissioning test, verification test and the project completion. The project plan shall be presented in MS Project format.
(b) System schematic diagram with the component appropriately label, and the Point of Interface (POI) design details. Where necessary, the loss and power at each of the major DAS elements shall be given. Appropriate symbols shall be used for different type of antennas.
(c) The design methodology should be supported as appropriate by CW and/or prediction. Where the coverage prediction plots are provided, EIRP values such as the transmit pilot power of GSM BCCH, UMTS CPICH, LTE Reference Symbol and 5G NR secondary synchronization signal used in the prediction should be clearly noted.
(d) Link budget calculations which shall include the link loss and coverage for the near mobile and the far mobile at the edge of the coverage delivered by the antenna concerned.
(e) System budget calculations, in particular an active DAS, and the system budget summary as the template in Appendix E.

(f) Noise and intermodulation calculations if the proposed DAS is an active system. Each individual branch and the overall system noise calculations shall be provided. Degradation to the receiver sensitivity shall be provided.
(g) The area over which the DAS will deliver the coverage is shown by a polygon(s) drawn over a floor plan, also showing the potential sectorisation and DAS zone boundaries.
(h) An overall site plan showing the location of the antennas, its orientation and height information,
(i) Photograph showing the proposed locations of the antenna and its surroundings.
(j) Current 2G, 3G, 4G and 5G network coverage where appropriate
(k) An appendix of the technical specification of the equipment used for the DAS, in particular if the equipment is used for the first time
(l) ICNIRP compliance calculations and statement. A certificate confirming the compliance shall be included as part of the engrossment documentation.
(m) A large scale equipment room layout drawing for the M&E engineer of the participating MNO designing their equipment layout.
(n) Detail information about the power, lighting, cooling and containment of the proposed equipment room.
(o) A declaration of compliance to this specification.
(p) Proposed survey routes for the System Acceptance Test (SAT).
(q) The required structure and cable duct for supporting the transmission link for carrying traffic back to the MNO core network.
(r) Part list summary table in Excel format.
(s) Transmission termination and location.

127. R The commercial part may be different for each of the participating MNO, however, the NHC will provide the information as agreed.

128. M The NHC shall provide a complete final design document which will detail all the agreed amendments. This document will be used as the reference for the system build and acceptance verification. No change to the system design is permitted without the agreement from the participating MNO's.

3.2.3 As Build Document

129. R This document shall reflect the actual build of the system covering the following areas:-

(a) Actual installation in the equipment room.
(b) Certification of the electrical installation.
(c) A statement of conformance to all the health and safety regulations.
(d) Confirmation of the ICNIRP compliance and verification work carried out.
(e) Drawing showing the routing of cables.
(f) Drawings showing the location of the actual antenna positions
(g) As-built system diagram and set-up.
(h) A summary table to confirm the antenna type, position, orientation, height and EIRP, and justification for any change from the design document.
(i) As-built part list summary table.
(j) A photograph showing the location of the antenna and its surroundings.
(k) A table summarising deviations from the design.

3.2.4 Commissioning and System Acceptance Test Report

130. R This report is part of the handover document providing details of the tests carried out on the DAS and records all the measurements results.

131. R Where the results indicate that the design target is not met, the NHC shall carry out an internal review to rectify the deficiency.

132. R This report provides the test results of the final version of DAS. Copies of this report shall be provided to the participating MNO.

133. I The test items are described in section 5.

3.2.6 Concession Applications

134. R The NHC should advise MNO about concessions of this specification during any stages of the project.

135. R Where the NHC has not been able to deliver as promised in the design, a concession application shall be submitted at the time of providing the system acceptance test report. It is noted in here that concessions on matters relating to health and safety shall not be granted under any circumstance.

136. R The concession application must be submitted on a concession template for which a sample is given in Appendix D.

137. R The concession application shall provide the reason for the non-compliance, action plan and estimated time by which the non-compliance will be rectified, a drawing showing the area of non-compliance and the coverage/performance statistics as appropriate.

3.2.7 Factory Acceptance Test Report

138. R Where a new product is deployed, the NHC shall provide a complete set of factory acceptance test results before/with the design. The factory acceptance tests are the responsibility of the NHC and are carried out in order to support the DAS design, support the acceptance of the design by MNO and confirm the sub-systems to be used in the DAS meeting the design requirements of this specification and also the 3GPP's specifications & Ofcom's requirements, in particular the active elements and sub-systems of the DAS.

139. R The test methodology for the factory acceptance test shall be provided in the same report.

3.2.8 Test Methodology Report

140. R This report is a general description of the method the NHC employed for the system commissioning and acceptance tests.

141. R It shall outline the quality processes adopted, and define the method by which the test routes are defined.

4. SERVICE LEVEL AGREEMENT

142. R With the exception of the participating MNO's equipment, it is expected that the NHC will be responsible for the maintenance of all the equipment used in the DAS and the equipment room and its accessories.

143. R The maintenance regime and a service level agreement shall be agreed with the individual participating MNO reflecting the system reliability specified in section 2.1.4.

144. R The NHC shall make arrangement with the site owner permitting the MNO unlimited access to the equipment room for the maintenance of the MNO's equipment and checking the functioning of the DAS for network quality assurance purposes.

145. I Contractual details shall be covered in the commercial part of the specification. Therefore it will be handled separately.

5. DAS TESTINGS

146. R Commissioning and system acceptance tests for verifying the design and installation of the system shall be conducted by the NHC who will provide the participating MNO with the test results.

147. R These tests are carried out and completed by the NHC before the MNO's equipment is integrated to the DAS.

5.1 TEST EQUIPMENT

148. R All the test equipment must be fully calibrated by nationally recognised establishment such as National Measurement Accreditation Service (NMAS).

149. R All the test equipment used shall have a next calibration date that is at least one month away.

150. R The test report shall have a chapter listing all the equipment used in the tests with the specific details on the type, model, calibration date and the next calibration.

151. R Calibration certificate shall be made available for inspection if required.

152. R All test equipment used shall be fit for purpose i.e. the test equipment is sensitive enough to distinguish the DAS system noise and the test equipment noise. The sensitivity of the test system shall be at least 6dB better than the DAS's.

5.2 COMMISSIONING AND SYSTEM ACCEPTANCE TESTS

153. R The commissioning and system acceptance tests shall be carried out by the NHC after the installation of the DAS. The main objectives are to verify the performance of the DAS under a controlled environment. Therefore majority of

the tests will be carried out with CW signals at the applicable bands of the DAS.

154. R The test results and calculations of each test shall be included in the report which shall form part of the handover document. Since the CW test signals injected to the DAS may be different from the base station carrier or pilot power, in particular the downlink coverage verification, appropriate offsets shall be applied to the measured CW results in order to translate into the equivalent levels, i.e. RxLev of GSM, RSCP of UMTS, RSRP of LTE and SS-RSRP of NR, and presented accordingly. See section 5.2.2 and Appendix F for the guidance. Where a high gain antenna, instead of a 0dBi antenna, is used in a CW test receiver/scanner for the downlink coverage measurements, an appropriate offset of the measured results including the effects of high gain downlink coverage antenna and the associated cable loss between the antenna and the test receiver/scanner shall be taken into account.

155. R Where an existing and operational DAS is upgraded to cater for new technology, some of the tests may not be required unless the upgrade affects the current services. Where appropriate, the NHC shall submit the concession and partial test detail against each requirement defined in this section for the MNO's approval prior to the commissioning tests or even the design phase of the project.

156. R For any new DAS designed and built for providing the 2G, 3G, 4G and/or 5G services, all tests defined in this section are required

5.2.1 VSWR, Noise Level and System Gain/Loss

157. R The VSWR of each interface port shall be measured and recorded. The results shall be better than 1.4.

158. R The passive inter-modulation (PIM) at the POI of the DAS and the radiating infrastructure where the multi-band signals are combined shall be measured and the PIM shall be <-155dBc.

159. R With reference to the downlink path of the active or hybrid system, the insertion loss from each interface port (B) to the downlink input interface of each FIRST active sub-system or module of the DAS shall be measured and reported.

160. R With reference to the uplink path of the active or hybrid system, the insertion loss from the uplink output interface of each LAST active sub-system or module of the DAS to the interface port (B) shall be measured and reported.

161. R The uplink noise level at the interface point (B) due to the active or hybrid system shall be measured with all the radiating element ports terminated with appropriate loads unless the NHC is confident that the radiating elements (antennas) are not picking up signals which cannot be separated from the noise due to DAS itself, or with the input port of the last active elements in each of the DAS branches terminated with appropriate loads. The alternative is to measure the uplink noise level at an appropriate access point of the system and the insertion loss from the selected access point to the interface point (B).

162. R The downlink levelling measurements are only applied to the active or hybrid system. A CW signal of appropriate level is injected at the interface point B and the output level at each RF stage of any cascaded active sub-systems or modules shall be measured. Where the wideband active DAS is deployed, the CW signal shall be at the downlink centre frequency of 700MHz, 800MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz, 2600MHz, 3.5GHz and 3.7GHz mobile cellular bands. Where the narrow band active DAS and multiple RI layers are deployed, the CW signal shall be at the centre frequency of each designated layer.

163. R The uplink levelling measurements are only applied to the active or hybrid system. A CW signal of appropriate level is injected at each remote unit and the output level at each RF stage of any cascaded active sub-systems or modules shall be measured. Where the wideband active DAS is deployed, the CW signal shall be at the uplink centre frequency of 700MHz, 800MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz, 2600MHz, 3.5GHz and 3.7GHz mobile cellular bands. Where the narrow band active DAS and multiple RI layers are deployed, the CW signal shall be at the centre frequency of each designated layer.

164. R The results shall be presented in a structured table for easy tracking and review.

165. R Where the active DAS is deployed, the NHC shall confirm that the end-to-end system uplink loss plus the base station noise floor degradation is not greater than that of the downlink according to the system insertion gain/loss measurement results.

5.2.2 Coverage

166. R For reason of convenience, the measurement can be conducted over the downlink direction. However, with the measurement results of the downlink coverage and the uplink system performance (gain, loss and noise), analysis shall be provided to confirm the coverage level, coverage quality and system link loss meeting the requirements given in this specification, in particular the DAS with active sub-systems.

167. R A CW test signal injected at the interface point B or an appropriate access point of the RI agreed by the MNO shall be set to the level according to the system design budget. For the passive and the wideband active DAS, the test frequency shall be at the downlink centre frequency of 700MHz, 800MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz, 2600MHz, 3.5GHz and 3.7GHz mobile cellular bands. For the narrow band active DAS, the test frequency shall be at the downlink centre frequency of each layer of the RI. The signal levels measured at a height of 1.5m above floor level are collected over the agreed test routes within the coverage area. The measurements shall be carried out under the normal operation conditions within the LOI.

168. R Where the DAS is designed for rail tunnel, the coverage tests shall be carried out in the train carriages of all types for that particular rail route. Where the DAS is designed for road tunnel, the coverage tests shall be carried out with a 0dBi roof mounted antenna attached to a typical family saloon vehicle (not a

tall vehicle van) under normal usage conditions unless there is a restriction imposed by the appropriate authority.

169. R Where the coverage or link loss fails to meet the requirements of this document, the NHC shall carry out an investigation to identify the cause(s) of the shortfall. Where the shortfall is due to the design, the NHC shall seek for the resolution. Where the rectification is not possible, a concession has to be submitted to the MNO for an approval. Where the shortfall of the system is due to the installation, no concession will be accepted, and the NHC shall get the system fixed prior to the MNO base station integration.

170. R The statistics of the results shall be provided to demonstrate that the requirements of the coverage and the link loss are met.

171. R For the confirmation of the downlink coverage met, 95% of the measured downlink signals, $R_{x95\%}$ (the level at 95% of the cumulative distribution function of the measured downlink coverage signals), in the coverage target area shall be greater than or equal to the requirements given in section 2.4.

172. R For demonstrating the downlink link loss meeting the requirements given in section 2.4, the downlink link loss, $L_{DL95\%}$, at 95% coverage of the target area shall be calculated with:

- $L_{DL95\%} = T_{xDLB} - R_{x95\%}$ eq (2) ,

where T_{xDLB} representing the transmit pilot power of GSM BCCH, UMTS CPICH, LTE Reference Symbol associated with the corresponding LTE RSRP at the receive side or 5G NR with reference to SSS EPRE, as noted in section 2.2, is the equivalent level of the CW test signal applied to the last connection of the DAS (the interface point B of figure 1) at the MNO's base station,

173. R Without taking the radio propagation difference at the downlink and associated uplink bands into account, for the confirmation of the uplink link loss met as the requirements given in section 2.4, based upon the downlink coverage measurement results, the uplink link loss, $L_{UL95\%}$, at 95% coverage of the target area shall be calculated with:

- $L_{UL95\%} = T_{xDLB} - R_{x95\%}$ eq (3), for the passive DAS and
- $L_{UL95\%} = T_{xDLB} - R_{x95\%} - S_{ddL}$ eq (4), for the active DAS,

where

- $S_{ddL} = \frac{1}{M}\sum_{i=1}^{M}(S_{D,i} - S_{U,i})$ eq (5)

is the average system loss difference between the downlink and uplink sub-system loss, M is the total number of the remote active units feeding N distributed antennas and/or radiating cable branches (see figure 4 below), $S_{D,i}$ is the downlink system loss from the interface B to the remote active unit "i", and $S_{U,i}$ is the uplink sub-system loss from the

remote active unit "i" to the interface B. i.e. if $S_{D,i}$=30dB (base station power at interface B = 40dBm and remote unit = 10dBm) and $S_{U,i}$=10dB (UL active gain = 30dB and passive loss = 40dB), then S_{ddL} of the branch "i" will be equal to 20dB.

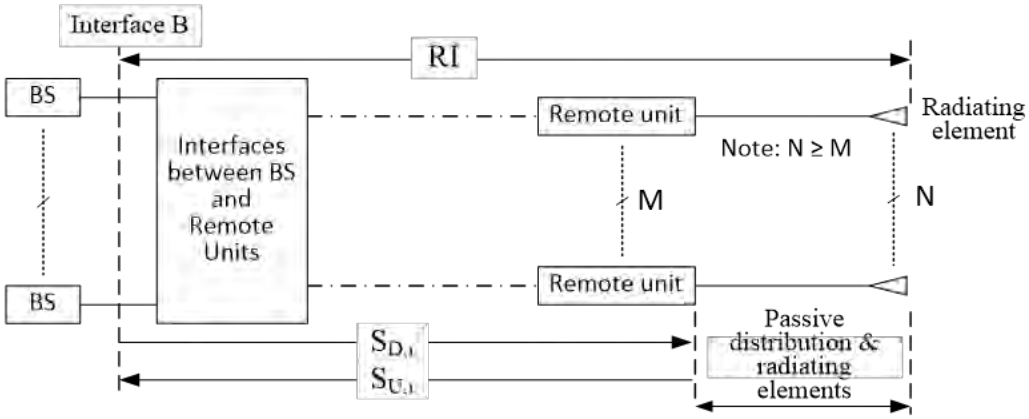

Figure 4: Illustration of the link loss calculation reference points.

174. R As stated, the RF power of the CW test signal, T_{xlev_cw}, injected to the DAS for the downlink coverage tests may be different from the pilot power of the actual base stations. With reference to figure 5, according to the CW measurement results, rxlev_cw, and the test set-up, the downlink coverage levels and the corresponding uplink link losses of a given mobile cellular technology shall be calculated with:

$$CW\_downlink\_link\_loss = T_{xlev\_cw} - rxlev\_cw \quad \text{eq (6)}$$

$$T_{x\_delta} = T_{xlev\_cw} - T_{xDLB} \quad \text{eq (7)}$$

$$\text{Equivalent downlink coverage} = rxlev\_cw - T_{x\_delta} \quad \text{eq (8a), or}$$

$$= T_{xDLB} - CW\_downlink\_loss \quad \text{eq (8b)}$$

$$\text{Equivalent uplink link loss} = T_{xlev\_cw} - rxlev\_cw - (S_D - S_U) \quad \text{eq (9)}$$

Where S_D represents the downlink end-to-end active sub-system loss including the active downlink gain and the passive loss of the sub-system of the DAS, and S_U is referred to the uplink end-to-end active sub-system loss including the active uplink gain and the passive loss of the sub-system of the DAS.

Where T_{xDLB} is based upon the technology type, with reference to a full load carrier of 43dBm provided by a typical macro base station as stated in section 2.2,

- For 2G: the pilot (BCCH) carrier power: T_{xDLB} = 43dBm eq (10)
- For 3G: the pilot CPICH carrier power: T_{xDLB} = 33dBm eq (11)

  if 10% full load carrier power is assigned to the CPICH as stated in section 2.2

- For 4G: for the case of 20MHz transmission channel bandwidth, the OFDM Reference Signal power with 3dB power booster (if power booster is applicable):

  T_{xDLB} = 43dBm - 10*Log_{10}(1200) + 3dB = 15.5dBm eq (12)

  referring to the Resource Elements carrying reference symbols only (see table 1 for the cases of different LTE transmission channel bandwidths and carrier power levels).

- For 5G: for the example of 40MHz transmission channel bandwidth of 30kHz SCS, the secondary synchronisation signal for SS-RSRP:

  T_{xDLB} = 43dBm - 10*Log_{10}(106*12) = 11.96dBm eq (13)

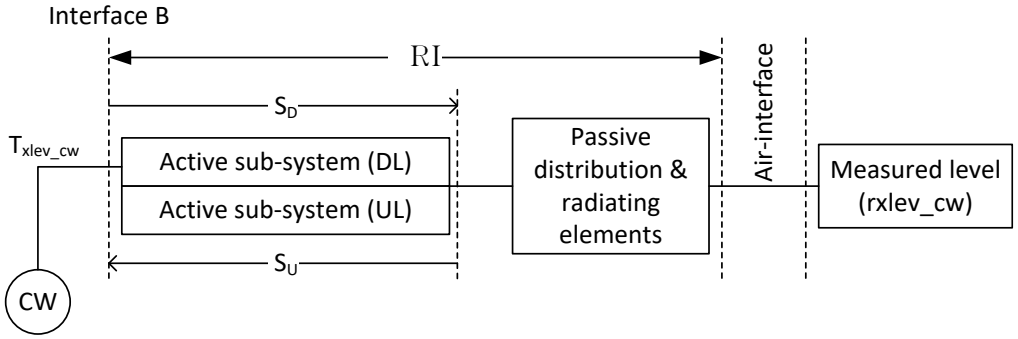

Figure 5: Illustration of the reference points for the calculations of the downlink coverage and the uplink link loss according to the CW measurement results.

175. R The measured coverage results are plotted on the floor plan layouts for the GSM, UMTS, LTE and 5G NR technologies. The threshold levels in dBm and dB used in the coverage and link loss plots respectively shall be

- Equivalent GSM BCCH RxLev coverage plot: ≥-55, (-55,-65], (-65,-75], (-75,-85], (-85,-***95***], (-95,-98], (-98,-101], (-101,-103], (-103, -106] and <-106

- Equivalent UMTS CPICH RSCP coverage plot: ≥-55, (-55,-65], (-65,-77], (-77,-87], (-87,-***97***], (-97,-100], (-100,-106], (-106, -109], (-109, -112) and <-112

- Equivalent LTE RSRP and 5G NR SS-RSRP coverage plot: ≥-65, (-65,-80], (-80,-95], (-95,-105], (-105,-***110***], (-110,-113], (-113,-116], (-116,-118], (-118, -121] and <-121

- Uplink link loss plot per technology: ≤60, (60,80], (80,110], (110,120], (120,125], (125,130], (130,133], (133,136] and >136

with the legends as defined in Appendix F, where (x, y] is referred to any values within the range from x to y and including y but excludes x. In addition, a summary table summarising the corresponding downlink coverage

levels and the corresponding uplink link loss levels of 5%, 50% and 95% percentile for each coverage target zone is required.

176. R The NHC shall propose the survey routes for each of the LOI. A guide on the generation of survey routes is given in Appendix C.

177. R Where LOI has a very large footprint, the coverage area shall be divided into multiple survey zones and the coverage statistics of each zone shall be produced. Each of the zones shall meet the agreed coverage requirement. The NHC shall propose the zones for MNO agreement.

5.2.3 Coverage Overlap Between Antennas Of The Same DAS

178. R This test is not required for every antenna serving the same cell because it is the NHC's responsibility ensuring contiguous coverage within the LOI, however this test is required at the expected coverage boundaries where the DAS is or will be divided for serving different cells for capacity expansion reason, and also at the coverage boundaries of different live cells serving the same LOI. Within the coverage overlap area, the signal level shall not be less than that derived from the permitted link loss by 3dB for both 2G, 3G, 4G and 5G.

179. R For reason of convenience, the measurement can be conducted over the downlink.

180. R Two CW signals of appropriate level at different downlink frequencies of each technology are simultaneously injected at the appropriate access points of any two adjacent indoor cells; one CW for each cell. The coverage levels of these two CW signals are simultaneously measured within the coverage target areas of these two cells. The measured signal level difference in the coverage target areas shall be plotted on the layout map. The test results shall be analysed to confirm the coverage overlapping requirement met, and the coverage overlapping region(s) are adequate for call handover according to the handover time required and the speed of the mobile terminal defined.

5.2.4 Coverage Overlap Between Indoor and Outdoor Cells

181. R This test shall be carried out at each of the portals of the LOI.

182. R A CW signal of appropriate level at the centre frequency of 700MHz, 800MHz, 900MHz, 1800MHz, 2100MHz, 2300MHz, 2600MHz, 3.5GHz and 3.7GHz mobile cellular bands is injected to the antennas of the DAS from which the handover coverage will be delivered to the portals of the LOI, or an appropriate access point of the RI. The downlink coverage overlapping distance between the indoor and outdoor cells shall be measured from the portals to the external of the LOI at where the equivalent uplink link losses as defined in section 2.6 are delivered.

5.2.5 Controlled Leakage and Handover

183. R To assess the impact of the interference to the existing cellular network due to the DAS, the NHC shall carry out measurements of the RF leakage immediately and at a distance of 20m (wherever possible) around the building external wall of the LOI, 600m from the portals of the road tunnel, or 1.2km from the portal of the high speed train tunnel. Where the leakage measurement cannot be taken at 20m around the building external wall of the LOI, the distances from the LOI and the corresponding signal levels shall be noted and reported.

5.2.6 RF Exposure

184. R The NHC shall confirm that the DAS installed is compliant to the ICNIRP recommendation according to the SAR thresholds established for the associated radiating elements of the DAS. Based upon the downlink end-to-end system gain/loss test results, the NHC shall calculate the composite RF power to be delivered at the connector of each radiating element under full load condition.

185. R The analysis results shall be presented in a table format confirming the compliance of each radiating element.

5.2.7 Supervisory

186. R Where an active or hybrid DAS is used, the NHC shall carry out a test on the supervisory system by simulating all the appropriate faulty conditions. An alarm and the corresponding indicator shall turn on and a summary alarm shall be created.

187. R The alarm shall remain on until a remedy action has been specifically taken.

188. R Test conditions shall also be created simulating faults for the triggering of a summary alarm in the MNO's network management centre. This test will require the co-operation of the participating MNO after the MNO's base station integration.

5.3 BASE STATION INTEGRATION AND LIVE COVERAGE VALIDATION

189. R The NHC shall provide logistical support to the MNO carrying out the base station integration.

190. I It is the MNO's responsibility to make to the last interface connections from the DAS to the base stations with the cables properly labelled and provided by the NHC at the top of the base station racks.

191. R Due to different cabling from each MNO base station to the DAS interface, if the DAS is an active one, the NHC shall be responsible for carrying out the system gain/loss levelling of the DAS to the appropriate and optimum settings after the MNO base station integration according to the system equipment specification.

192. R If the DAS is an active one, the NHC shall assist the MNO to establish and test the summary alarm connections in the MNO's network management centre via the external alarm ports of the base stations.

193. R The NHC shall assist the site access for the MNO to carry out post-integration coverage and service surveys where necessary.

194. R The NHC shall carry out the post-integration coverage and service surveys after the MNO's base station integration onto the DAS.

APPENDIX A: LICENCED SPECTRUM OF THE UK MOBILE CELLULAR OPERATORS

Table A-1 summarises the spectrum curretly licenced to the UK MNOs. Table A-2 shows 3.4GHz–3.8GHz spectrum holdings due to 2019 and 2021 spectrum auctions in UK, and the the new spectrum arrangement at 3.4-3.8GHz after a further spectrum trading agreement between Virgin Media O_2 and Vodafone 2021. As a result, in terms of 3.4-3.8GHz, there is a transition period that some indoor systems may need to support Virgin Media O_2 operating at 3.5-3.54GHz before the final configuration with reference to the spectrum arrangement shown in table A-1.

			Mobile transmit (MHz)		Base transmit (MHz)	
			UPLINK		DOWNLINK	
Operator	**designation band**	**technology**	**lower limit**	**upper limit**	**lower limit**	**upper limit**
EE/BT	1800MHz - FDD	GSM, LTE, NR	1736.7	1781.7	1831.7	1876.7
	2100MHz – TDD	LTE, NR	1899.9	1909.9	1899.9	1909.9
	2100MHz – FDD	UMTS, LTE, NR	1959.7	1979.7	2149.7	2169.7
	800MHz - FDD	LTE, NR	837	842	796	801
	2600MHz - FDD	LTE, NR	2520	2570	2640	2690
	700MHz - FDD	5G NR	723	733	778	788
	700MHz - TDD	5G NR	738	758	738	758
	3500MHz - TDD	5G NR	3540	3580	3540	3580
	3600MHz - TDD	5G NR	3680	3720	3680	3720
Virgin Media O_2	900MHz - FDD	GSM, UMTS, LTE, NR	885.1	890.1	930.1	935.1
		GSM, UMTS, LTE, NR	902.5	914.9	947.5	959.9
	1800MHz - FDD	LTE, NR	1710.1	1715.9	1805.1	1810.9
	2100MHz – TDD	LTE, NR	1909.9	1914.9	1909.9	1914.9
	2100MHz – FDD	UMTS, LTE, NR	1934.9	1944.9	2124.9	2134.9
	800MHz - FDD	LTE, NR	852	862	811	821
	2300MHz - TDD	LTE, NR	2350	2390	2350	2390
	2600MHz - TDD	LTE, NR	2595	2620	2595	2620
	700MHz - FDD	5G NR	703	713	758	768
	3700MHz - TDD	5G NR	3720	3800	3720	3800
Three	1800MHz - FDD	LTE, NR	1721.7	1736.7	1816.7	1831.7
	2100MHz – TDD	UMTS, LTE, NR	1914.9	1920	1914.9	1920
	2100MHz – FDD	UMTS, LTE, NR	1920	1934.9	2110.3	2124.9
	800MHz - FDD	LTE, NR	832	837	791	796
	1400MHz	LTE, NR			1472	1492
	700MHz - FDD	5G NR	713	723	768	778
	3400MHz - TDD	5G NR	3460	3500	3460	3500
	3600MHz - TDD	5G NR	3580	3680	3580	3680
	4000MHz - TDD	5G NR (TBC)	3925	4009	3925	4009
Vodafone	900MHz - FDD	GSM, UMTS, LTE, NR	880.1	885.1	925.1	930.1
		GSM, UMTS, LTE, NR	890.1	902.5	935.1	947.5
	1800MHz - FDD	LTE, NR	1715.9	1721.7	1810.9	1816.7
	2100MHz – FDD	UMTS, LTE, NR	1944.9	1959.7	2134.9	2149.7
	800MHz - FDD	LTE, NR	842	852	801	811
	2600MHz - FDD	LTE, NR	2500	2520	2620	2640
	2600MHz - TDD	LTE, NR	2570	2595	2570	2595
	1400MHz	LTE, NR			1452	1472
	3400MHz - TDD	5G NR	3410	3460	3410	3460
	3500MHz - TDD	5G NR	3500	3540	3500	3540

Table A-1: Licenced spectrum.

3.4 - 3.8GHz (Pre-Swap)				3.4 - 3.8GHz (Post-Swap)			
5G	start [MHz]	stop [MHz]	BW_{config} [MHz]	5G	start [MHz]	stop [MHz]	BW_{config} [MHz]
Vodafone	3410	3460	50	Vodafone	3410	3460	50
3UK	3460	3500	40	3UK	3460	3500	40
Virgin Media O_2	3500	3540	40	Vodafone	3500	3540	40
EE	3540	3580	40	EE	3540	3580	40
3UK	3580	3680	100	3UK	3580	3680	100
EE	3680	3720	40	EE	3680	3720	40
Vodafone	3720	3760	40	Virgin Media O_2	3720	3800	80
Virgin Media O_2	3760	3800	40				

Table A-2: 3.4GHz – 3.8GHz spectrum auction results and the outcome of the spectrum swap between Vodafone and Virgin Media O_2.

APPENDIX B: FACTORY TESTS: SUB-SYSTEMS AND SYSTEMS

B.1 I Although there is no specific factory acceptance test requirements defined in here, for the NHC's own benefit, the NHC should verify the performance of any new sub-systems or modules to be used in the DAS, in particular the active elements of the DAS. The MNO would not be responsible for the cost of carrying out the factory tests.

B.2 R The test items covering 3GPP Standards and Ofcom's requirements may include but may not be limited to:

(a) Operating frequency band,
(b) Input and output levels at each stage of the system,
(c) Frequency response and gain flatness,
(d) Noise performance including the noise figure,
(e) Output power, 1dB compressed point and the 3rd order intercept point IP3,
(f) Intermodulation performance under normal and overloading conditions,
(g) In band and out of band spurii,
(h) Out-of-band emission levels defined in Section 2
(i) Phase noise performance,
(j) Spectral mask conformance,
(k) Adjacent channel leakage power,
(l) Error vector magnitude (EVM) and Peak Code Domain Error (PCDE),
(m) Power handling capability,
(n) Delay and group delay,
(o) PIM of RF components/sub-systems

APPENDIX C: GUIDELINES ON THE GENERATION OF SURVEY ROUTES

Below is guidance on the generation of survey routes which shall be agreed with the participating MNO. The NHC shall use common sense bearing in mind the main objective of the testing is to verify that the DAS will deliver the required signal level to mobiles used by the general public. Where the guideline is not possible, the NHC should use common sense proposing alternatives.

C.1 Passages $\leq$ 7 metres wide

Passages not more than 7m wide shall be surveyed along a route defined by the centre-line of the passage with a tolerance of +/- 1m.

C.2 Passages >7 metres wide

Passages wider than 7m shall be surveyed along routes on both sides of the passage at a distance of 2±1 m from the passage walls.

C.3 rooms $\leq$ 5 metres wide

Rooms with an average width of not more than 5m shall be surveyed on routes around the internal perimeters, at a distance of 1±1m from the perimeter wall. Where this route is not accessible then the nearest public accessible route shall be taken.

C.4 5m < Room width $\leq$ 10m

Rooms with an average width of between 5 and 10m shall be surveyed on routes around the internal perimeters, at a distance of 1±1m from the perimeter wall and along a centre-line parallel to the longest wall of the room. Where this route is not accessible then the nearest public accessible route shall be taken.

C.5 Room width >10m

Rooms with an average width greater than 10m shall be surveyed on routes around the internal perimeters, at a distance of 2±1m from the perimeter wall and along zigzag route sweeping the floor area. The pitch of the zip-zap route shall be not more than 4m. Where this route is not accessible then the nearest public accessible route shall be taken.

C.6 stairs and escalators

Stars and escalators shall be surveyed along the centre line of the stair or escalator. Where multiple stairs or escalators are located within the same passage way or bore, then the survey routes shall be along the stair or escalator located nearest to the centre-line of the passage way or bore. Where stairs and escalators are contained within separate passage ways or bores, they shall be treated as separate stairs and escalators.

C.7 port of entry (entrances and exits)

Entrances and exits shall be surveyed along a centre-line route normal to the entry or exit doorway, or as near as is practically possible by the general public. The route shall be extended to at least 20m on either side of the port of entry.

C.8 building perimeter

The perimeter of the building shall be surveyed along the nearest publicly accessible route. Surveying is not required if the nearest publicly accessible route is over 50m from the building perimeter. All section of road highway which falls within 100m of the building perimeter should be surveyed for leakage assessment purpose.

In all the above cases, where obstacles prevent or impede public access, then the nearest publicly accessible route shall be taken to get back onto the defined survey route.

C.9 Road tunnels

The road tunnel shall be surveyed using a saloon style vehicle in each direction/carriage way in the slow lane, i.e. the lane furthest from the tunnel centre line.

C.10 railway carriage

Railway carriage shall be surveyed with a walk along the centre line of the carriage and at sitting position on every five aisle seat inside the carriage.

C.11 car park

Car parks shall be surveyed using a typical saloon vehicle along all designated entrance, throughway and exit routes.

APPENDIX D: CONCESSION TEMPLATE

Site Details			
Cell ID	Cell ID as appropriate to the individual MNO	Date of issue	
Site Name		Issue version	
Site Address			

Concession Approval			
NHC : name	Prepared by	Name in block	Signature
	Telephone		date
	Checked by	Name in block	Signature
	Position		date
MNO	Approved by	Name in block	Signature
	Position		date

Concession Details		
Concession		
Affected Area		
Supporting Doc.	Performance statistics ☐ Plots/Drawings ☐	Ref: Ref:
Remedy Proposal		
Est. Completion Date		

APPENDIX E: SYSTEM LINK BUDGET SUMMARY TEMPLATE EXAMPLE

Frequency band [MHz]: 800

DAS zone	antenna label	active DAS sub-system				total RF component loss (end-to-end) [dB]	total cable loss (end-to-end) [dB]							antenna gain [dBi]
		$S_{D,i}$		$S_{U,i}$										
		active downlink gain [dB]	passive downlink loss [dB]	active uplink gain [dB]	passive uplink loss [dB]	couplers, splitters, filters etc	jumper-0.5m	jumper-1m	jumper-2m	jumper-3m	LDF2-50 (or equivalent)	LDF4-50 (or equivalent)	LDF5-50 (or equivalent)	
1	A1-1													
1	A1-2													
1	A1-3													
.														
.														
.														
1	A1-m													
1	A1-n													
2	A2-1													
2	A2-2													
2	A2-3													
.														
.														
.														
.														
2	A2-p													
etc														

… etc.

Where the radiating element is referred to the case of radiating cable instead of antenna, the radiating cable coupling loss of 95% should be defined and included under the column for the antenna gain.

With reference to the template example above, as shown in figure E-1, $S_{D,i}$ is referred to the downlink system loss from the interface B to the remote active unit "i", and $S_{U,i}$ is referred to the uplink sub-system loss from the remote active unit "i" to the interface B.

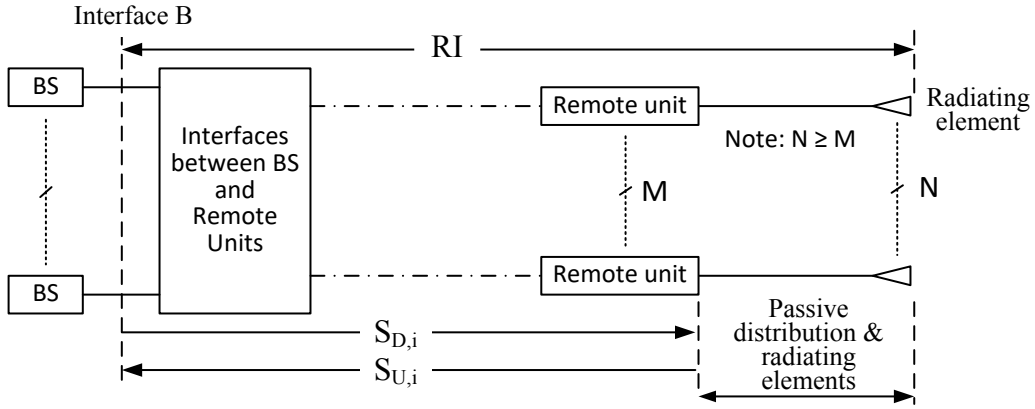

Figure E-1: Illustration of the link budget reference points.

APPENDIX F: CONVERTING CW TEST RSSI RESULTS INTO GSM RXLEV, UMTS CPICH RSCP, LTE RSRP AND 5G NR SS-RSRP

For the purpose of the downlink coverage tests as required and defined in section 5.2, if a narrow-band CW signal at an appropriate frequency is injected into the DAS at a power level different from the pilot power of the base station carrier, a normalisation factor has to be included for normalising the CW signal level into the equivalent top of rack carrier power (pilot) for each band and technology accordingly. The equivalent levels of GSM RxLev, UMTS CPICH RSCP, LTE RSRP and 5G NR SS-RSRP should be presented accordingly.

GSM, e.g.

- CW input to the POI "B" of DAS, T_{xlev_cw} = 40dBm at the GSM band.
- GSM BTS carrier power to the POI "B" of DAS, T_{xDLB} = 43dBm.
- Normalisation factor, *X:*
  - $X = T_{xlev_cw} - T_{xDLB} = 40 - 43 = -3$dB,
- To get the equivalent GSM RxLEV for a BCCH carrier from the measured narrow-band CW RSSI, rxlev_cw, the normalisation factor have to be included
- Equivalent BCCH RxLev = rxlev_cw – *X* , i.e. if rxlev_cw = -83dBm, the equivalent BCCH RxLev will be -80dBm

UMTS, e.g.

- CW input to the POI "B" of DAS, T_{xlev_cw} = 40dBm at the UMTS band.
- UMTS Node-B carrier power to the POI "B" of DAS = 43dBm
- CPICH transmit power, T_{xDLB} = 33dBm if 10% of 43dBm carrier is assigned to the CPICH: 43dBm + 10 Log_{10} (10%) = 33dBm
- Normalisation factor, *X*:
  - $X = T_{xlev_cw} - T_{xDLB} = 40 - 33 = +7$dB
- To get the equivalent CPICH RSCP from the measured narrow-band CW RSSI, rxlev_cw, the normalisation factor have to be included
- Equivalent CPCIH RSCP = rxlev_cw – *X* , i.e. if rxlev_cw = -83dBm, the equivalent CPICH RSRP will be -90dBm

LTE, e.g.

- Reference Symbol power of Reference Signal, T_{xDLB}, is related to
  - the number of LTE OFDM sub-carriers within a given LTE channel bandwidth, as noted in the table below, and

LTE channel bandwidth, BW_{LTE} [MHz]	1.4	3	5	10	15	20
number of sub-carriers	72	180	300	600	900	1200
a LTE sub-carrier power as a fraction of a full load carrier power	1/72	1/180	1/300	1/600	1/900	1/1200
a LTE sub-carrier power as a fraction of a full load carrier power, $F_{sub\text{-}carrier}$, [dB]	-18.6	-22.6	-24.8	-27.8	-29.5	-30.8

  - the power booster, $P_{RS\_booster}$, assigned to the Reference Signal (see section 2.2.)
  - $T_{xDLB} = P_{eNB} + F_{sub\text{-}carrier} + P_{RS\_booster}$, where P_{eNB} is a carrier power of eNode-B to the POI "B" of DAS
  - For the case of BW_{LTE} = 20MHz leading to $F_{sub\text{-}carrier}$ = -30.8dB, $P_{RS\_booster}$ =3dB and P_{eNB} = 43dBm,

    T_{xDLB} = 43dBm – 30.8dB + 3dB = 15.2dBm to the POI "B" of DAS

- Thus, if a CW input to the POI "B" of DAS, T_{xlev_cw} = 40dBm at the LTE band, the normalisation factor, *X*:
  - $X = T_{xlev_cw} - T_{xDLB} = 40 - 15.2 = +24.8$dB
- To get the equivalent LTE RSRP from the measured narrow-band CW RSSI, rxlev_cw, the normalisation factor has to be included
- Equivalent LTE RSRP = rxlev_cw - *X* , i.e.
  - if rxlev_cw = -83dBm and Reference Symbol with 3dB power booster, the equivalent LTE RSRP will be -107.8dBm

As aforementioned, converting the measured narrow-band CW RSSI to the equivalent LTE RSRP is depended upon the LTE channel bandwidth, the full load carrier power and the Reference Symbol power booster regardless the received signal being referred to the SISO or MIMO transmission. The LTE RSRP is the linear average over the power contributions of the **R**esource **E**lements that carry cell-specific **R**eference **S**ignals within the considered measurement frequency bandwidth. It can therefore only be referred to and measured in the OFDM symbols carrying **reference symbols**

5G NR, e.g.

- SSS EPRE, T_{xDLB}, is related to
  - the sub-carrier spacing and the number of resource blocks within a given 5G NR channel bandwidth, as noted in the table below,
  -

Transmission bandwidth configuration N_{RB} for FR1													
SCS [kHz]	**5MHz**	**10MHz**	**15MHz**	**20 MHz**	**25 MHz**	**30MHz**	**40 MHz**	**50 MHz**	**60 MHz**	**70MHz**	**80 MHz**	**90MHz**	**100**
15	25	52	79	106	133	[160]	216	270	N.A	N.A	N.A	N.A	N.A
30	11	24	38	51	65	[78]	106	133	162	[189]	217	[245]	273
60	N.A	11	18	24	31	[38]	51	65	79	[93]	107	[121]	135

  - $T_{xDLB} = P_{gNB} + F_{sub\text{-}carrier}$, where P_{gNB} is a carrier power of gNode-B to the POI "B" of DAS and $F_{sub\text{-}carrier}$ is a fraction of the full-load carrier power according to the transmission bandwidth configuration,
  - For the case of P_{gNB} = 43dBm, BW_{NR} = 40MHz and SCS=30kHz leading to $F_{sub\text{-}carrier}$ = -31.045dB,

    T_{xDLB} = 43dBm – 31.045dB = 11.96dBm to the POI "B" of DAS and the corresponding SSB transmit power of 32.99dBm.
- Thus, if a CW input to the POI "B" of DAS, T_{xlev_cw} = 40dBm at the 5G NR band, the normalisation factor, *X*:
  - $X = T_{xlev_cw} - T_{xDLB} = 40 - 11.96 = +28.045$dB
- To get the equivalent 5G NR SS-RSRP from the measured narrow-band CW RSSI, rxlev_cw, the normalisation factor has to be included
- Equivalent SS-RSRP = rxlev_cw - *X* , i.e.
  - if rxlev_cw = -83dBm, the equivalent SS-RSRP will be -111.045dBm.

It is also emphasised in here that all of the examples above are based upon the assumption of the CW coverage tests with a 0dBi antenna at the test receiver/scanner as a typical mobile handset receive antenna gain. If a higher gain antenna is used for the CW RSSI measurements, an appropriate offset should be included to establish the equivalent GSM BCCH RxLev, UMTS CPICH RSCP, LTE RSRP and 5G NR SS-RSRP.

In terms of the presentation of the equivalent GSM BCCH RxLev, UMTS CPICH RSCP, LTE RSRP and 5G NR SS-RSRP, the bin sizes as defined in section 5.2.2 and the

corresponding legends as below should be followed. For a completeness, the bin sizes and legends for GSM RxQual, UMTS E_c/I_o, LTE SNR and NR SNR are included.

R G B	legend	GSM RxLev [dBm]	UMTS CPICH RSCP [dBm]	LTE RSRP [dBm]	5G SS-RSRP [dBm]	legend	Uplink link loss [dB]
176 255 255		≥-55	≥-55	≥-65	≥-65		≤60
0 255 255		(-55,-65]	(-55,-65]	(-65,-80]	(-65,-80]		(60,80]
0 75 224		(-65,-75]	(-65,-77]	(-80,-95]	(-80,-95]		(80,110]
0 255 0		(-75,-85]	(-77,-87]	(-95,-105]	(-95,-105]		(110,120]
0 153 0		(-85,-***95***]	(-87,-***97***]	(-105,-***110***]	(-105,-***110***]		(120,125]
255 255 0		(-95,-98]	(-97,-100]	(-110,-113]	(-110,-113]		(125,130]
255 153 0		(-98,-101]	(-100,-106]	(-113,-116]	(-113,-116]		(130,133]
255 0 255		(-101,-103]	(-106,-109]	(-116,-118]	(-116,-118]		(133,136]
255 0 0		(-103, -106]	(-109, -112]	(-118, -121]	(-118, -121]		>136
48 48 48		<-106	<-112	<-121	<-121		

R G B	legend	GSM RxQual (sub/full)	UMTS E_c/I_o [dB]	LTE SNR [dB]	5G SS-SINR [dB]
0 255 255		[1,3]	>-4	>20	>20
0 255 0		4	(-4,-8]	(14,20]	(14,20]
255 255 0		5	(-8,-10]	(6,14]	(6,14]
255 153 0		6	(-10,-13]	(0,6]	(0,6]
255 0 0		7	<-13	< 0	< 0