DESIGN SPECIFICATION FOR DISTRIBUTED ANTENNA SYSTEMS (DAS)

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DEFINITIONS

Approved Design means the 3rd party design produced by an entity engaged by a building owner, developer or interested party which has been reviewed and approved by a Carrier to proceed to construction.

ARPANSA RPS S-1 means the ARPANSA General Public power flux density ("Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz", Radiation Protection Series S-1, Australian Radiation Protection and Nuclear Safety Agency).

Carrier means a member of the Mobile Carriers Forum who is the owner and operator of a public mobile telecommunications network in Australia, currently Optus, Telstra and TPG Telecom/Vodafone and their related body corporates.

Category 1 IBC means an In Building Coverage or DAS system where none of the antennas exceed the ARPANSA Radiation Protection Series S-1 General Public reference levels at 20cm from the antenna.

Category 2 IBC means an In Building Coverage or DAS system where one or more of the antennas exceed the ARPANSA Radiation Protection Series – S1 General Public reference levels at 20cm from the antenna.

DAS Equipment means the approved equipment by the Lead Carrier which is used to distribute the mobile signal from the Carrier base stations over either an Active, Hybrid or Passive DAS.

Guiding Principles mean the principles set out in Section 1.00 (Guiding Principles) of this specification document.

Lead Carrier means a Carrier appointed by a building owner to validate compliance of the particular DAS for a building with these specifications. Such validation may then be shared with other Carriers to avoid duplication of effort regarding assessment of specification compliance. The appointment of a Lead Carrier is at the discretion of the building owner and is intended to reduce costs and increase efficiency, but is not mandatory. If a Lead Carrier is not appointed, then the words "Lead Carrier' should be interpreted as referring to all Carriers that are intended to use the particular DAS system.

Distributed Antenna System (DAS) means the distributed antenna system for mobile telecommunications coverage installed as per the Approved Design in the building comprising a constellation of antenna and interconnecting equipment which has been installed throughout the Building and can be a combination of Passive DAS, Active DAS or Hybrid DAS.

Exemption Zone(s) means areas within a building environment which have been approved by the Lead Carrier to be exempt from achieving the Coverage and/or Capacity KPIs as defined in this specification.

MCF means Mobile Carriers Forum.

Mobile Carrier(s) means see definition for Carrier.

Sharing Carrier or Collocating Carrier means a network operator connecting to a DAS that is not appointed as the Lead Carrier.

Target Coverage Area means the coverage area of a building or property which the Lead Carrier endorses as the zone which KPI thresholds should be met.

1. PURPOSE

1.0 GUIDING PRINCIPLES

Purpose:

Mobile Carriers are subject to numerous laws and regulations governing the supply of mobile services. These include obligations to maintain the integrity and security of networks, provide end-users with access to the emergency call service and to ensure radiated power limits (EME) are maintained at safe levels. There are also multiple technical codes, standards, guidelines and specifications relating to service delivery, quality and consumer protection.[1]

This document serves as general guidance to third parties interested in designing and installing Distributed Antenna Systems (DAS) that will support the supply of enhanced in-building mobile coverage by all Carriers. It sets out recommended design principles and installation methods and processes that a building owner or developer may choose to follow to enable multi-carrier access to an installed DAS. It also sets out a recommended process for the interested party and/or third-party designers to engage with a preferred Carrier (Lead Carrier) as a single point of contact for the review,

Distributed Antenna Systems (DAS) are used to provide enhanced mobile coverage and capacity management by using antennas strategically distributed within the proposed coverage area. The DAS consists of the cabling, splitting, distribution and radiating elements (antennas) as well as active elements required for such coverage solutions. These DAS are used for various applications, however, are ideally suited to provide an indoor coverage and capacity solution in situations where the external mobile network may not provide reliable penetration to all areas within a building.
When properly designed and installed, the installation of a DAS provides the ideal opportunity to ensure end-users receive an optimal quality experience. Conversely, a poorly designed or installed system will see end-users encounter unreliable user experiences such as dropped calls, clipped speech, slow data speed etc.

This specification applies only to DAS that are intended for multi-carrier use and is intended to avoid a situation where different Carriers could request different DAS requirements by setting out common standards that are known, in advance, to meet the requirements of all Carriers. A set of common standards is intended to reduce costs for building owners and increase the efficiency of DAS deployment in a multi-carrier environment. It remains open to building owners to engage individually with one or more Carriers and to negotiate or adopt different requirements or to cater for none, any or all Carriers.

The purpose of this specification is to streamline the installation of network equipment that is fit for purpose. The specification achieves this by recommending the minimum standards for multi-carrier access to a DAS, so that if a system is built according to this specification document, the DAS owner can be confident that each Mobile Carrier will be capable of connecting their equipment to it.

Individual DAS designs and installations may diverge from the specification, perhaps to reflect the physical characteristics of a site. While it is recommended that installing parties design DAS configurations that will future proof the in-building coverage for next generation mobile services, that option remains at the discretion of building owners and developers.

Each Carrier may decide not to connect or accept handover of an installed DAS. The specification helps ensure that an installed DAS will meet network performance criterion and/or comply with regulatory obligations and therefore be able to supply services over the DAS. Once a DAS is accepted, it may be used to supply services in accordance with the requirements of the Telecommunications Act.

[1] For a quick summary see for example the ACMA's Carrier licensing guide.pdf (acma.gov.au) and Communications Alliance - All Industry Publications (commsalliance.com.au)

<u>Application and interpretation:</u>

This specification document should be read and interpreted according to the following principles:

1. **Recommendations**
   a. Any use of peremptory language such as "must" or "shall" is to be interpreted as a recommendation to achieve the objectives of this specification (i.e., "should"), but is not mandatory. Whether or not a Carrier requires any aspect of this specification to be met is a matter for commercial negotiation between a building owner and that Carrier.
   b. Similarly, the design specifications and performance requirements set out in this document are not mandatory but are rather intended to be recommendations to reduce deployment costs in circumstances where all Carriers are likely to share access to a DAS system in a multi-carrier environment.
2. **Discretion regarding engagement of Lead Carrier and Carriers**
   a. Traditionally, a building owner has appointed a Lead Carrier to validate compliance with the specifications in the context of DAS instalment, thereby reducing time and cost for all Carriers by avoiding duplication of effort.
   b. However, there is no formal requirement for a building owner to appoint a Lead Carrier and a building owner may adopt alternative arrangements. Likewise, any Carrier may choose to seek its own independent validation.
   c. A 'Lead Carrier' could be appointed to operate and maintain the DAS, but such commercial arrangements are not a part of this specification.
   d. Any reference in this Specification to endorsement or approval by the Lead Carrier is intended as a reference to a certification that the requirements of this Specification have been met. Such certification can then be shared with other Carriers. The Lead Carrier is not acting with the authority of other Carriers. It is the responsibility of the building owner to confirm whether or not certification by the Lead Carrier is sufficient to meet the requirements of any Carrier.

1.2 PUBLICATION

This version replaces and supersedes previous versions of the Design Specification for DAS.Designs completed, submitted and approved prior to the publication of this specification can proceed to build, as approved.

For the latest version refer to the AMTA website:

https://amta.org.au/in-building-coverage-information-for-property-owners-managers/

1.3 SCOPE

This document details the design standards, performance and testing requirements for a DAS to which Mobile Carriers may agree to connect their radio communications equipment. The document outlines the process required for obtaining technical DAS design approval prior to commencement of DAS construction and the required compliance/acceptance documentation when the DAS construction is complete.

This document must be read and interpreted in accordance with the Guiding Principles.

This document details the technical standards for DAS designs intended for multi-Carrier use.

This document provides Carrier recommendations from a design, engineering and operational perspective. The document does not contemplate tenure or other commercial arrangements.

1.4 HEALTH, SAFETY AND WELFARE (HS&W) CONSIDERATIONS

This document provides information required to ensure a DAS can be designed and installed to meet the relevant workplace safety standards. However, this document should be considered subordinate to any general or project specific HS&W requirements.

In situations where there appears to be a conflict or contradiction between this document and any other workplace safety standards, the more conservative (i.e. the safer) solution should apply.

The DAS design process must address EME levels in line with mandatory ARPANSA standards. It should be noted that a significant modification of the EME guidelines has occurred in this revision around the antenna classification compliance categories and EME design methodologies.

1.5 LEAD CARRIER ENGAGEMENT

The building owner or developer may, at its sole discretion, seek the engagement of a Lead Carrier.

The Lead Carrier may be appointed by the building owner or developer to act as a single point of contact to reassess whether the design for the DAS is consistent with this specification document. To avoid doubt, the Lead Carrier is not acting for or on behalf of other Carriers, and has no liability to the other Carriers. Other Carriers remain free to determine whether the DAS meets their individual requirements.

In the event no Lead Carrier is nominated, then it is intended that each Carrier that may use the DAS system may independently validate whether the DAS meets their individual requirements. There is no obligation on any building owner to supply to all Carriers and there is no obligation on any Carrier to use a DAS, such matters being at the discretion of the parties and subject to any commercial arrangements.

2. DAS DESIGN

2.1 DAS PLANNING

Before beginning the detailed design of a DAS, the designer should follow these steps.

1. The design should evaluate the coverage levels (in consultation with the Lead Carrier) provided by the surrounding cells, considering any proposed network changes that are likely to cause an impact. Refer “Exemption Zones” later in document.

2. Obtain a list of any additional requirements and DAS objectives above and beyond what the DAS specification recommends from the building owner that the design should target to provide appropriate solutions for the requirement in the list. This list should be included in the design document.

3. The design should consider any technical, structural or architectural constraints.

4. The design must comply with any applicable regulatory conditions and standards (building codes, electrical safety etc.).

5. Future proofing of the DAS for all Carriers and all technologies should be considered where possible and where necessary. Future proofing can be achieved by a simple pathway to sectorisation to increase capacity capability of the DAS system as well as allowing for sufficient fibre and power to facilitate future upgrades.

2.2 DESIGN PRINCIPLES

The DAS should be designed with the following key principles in mind:

1. Provide enhanced coverage, and a consistent user experience within the Target Coverage Area.

2. Provide dominant coverage within the Target Coverage Area to avoid unnecessary hand-off and/or interference to/from the rest of the network.

3. Provide enough capacity for the size of the building and expected occupancy, with reasonable allowance for network traffic growth. DAS shall be designed so that it can be easily expanded and upgraded for capacity reasons by way of sectorisation or similar, without compromising the DAS performance.

4. Be sensitive to the building functions, structure properties and environments to reduce risk of DAS performance issues such as Passive Inter-modulation (PIM) and external interferers.

5. Be engineered to allow interference-free operation (including all necessary filtering requirements) between the Sharing Carriers.

6. Provide for inter-operability with each of the Sharing Carrier's macro networks. Each Carrier should be able to operate their network without adverse impact from the other Sharing Carriers.

7. Design should meet all the requirements from this MCF Design Specification for DAS to ensure the DAS is built with a Safety in Design approach and meet all regulatory requirements to safely allow the installation, operation and maintenance of the DAS by the Sharing Carriers.

8. Must be able to operate in accordance with each Mobile Carriers ACMA licence conditions.

9. The DAS type selection should consider the complexity, components, cost and the final performance KPI.

10. Designers need to be mindful of the population distributions between floors and service areas, such as car parks, lobbies, etc. within a building when calculating the number of sectors required for capacity in particular areas of a building.

11. The architecture of the DAS design should comply with the application as detailed in Section 3 and endorsed by the Lead Carrier as an approved product which has been solution on-boarded and compliant with Australian Federal Government advice around safety and security of network operations.

2.3 GENERAL DAS DESCRIPTION

Distributed Antenna System (DAS) are a shareable infrastructure which may be described as either:

1. Passive – where the base station signal is distributed to the antennas via a passive network of coaxial cables, splitters and couplers.
    a. A passive DAS is typically divided into the backbone feed system which forms the distribution to each floor area, and the floor/area cabling and antenna system. The backbone is generally comprised of cables, splitters and couplers.
    b. The floor/area equipment can be a combination cable, radiating cable, antennas and terminations.

2. Active – where the base station signal is connected to a central hub or interface unit, which then feeds a network of either optical fibre cables or dedicated structured cabling. Each of these cables in turn connects to a range of active antenna units for coverage distribution.

3. Hybrid – being a combination of Passive and active elements.

    a. For any single RF sector there should be no mixture of passive and other DAS architecture sectors.

4. Digital – where a digital signal is used to communicate directly with the DAS master unit through the remote units without any conversion to an analogue RF interface.

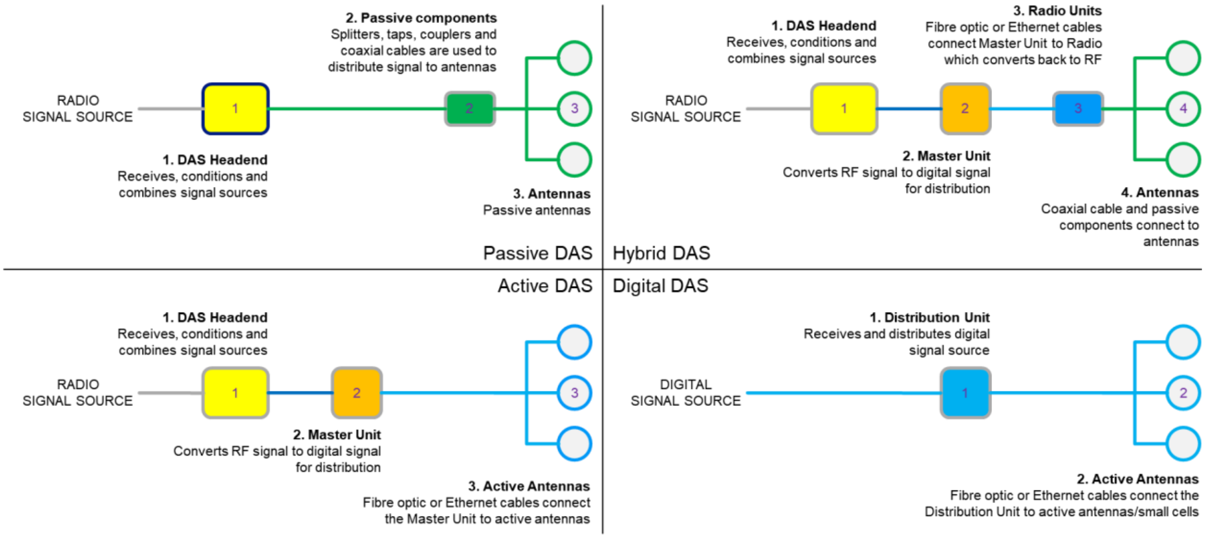

Figure 1 - Example DAS architectures

2.4 MIMO DESIGN CONSIDERATIONS

Multiple Input Multiple Output (MIMO) systems utilise multiple radio paths between Mobile Carrier's radio base stations and customer mobiles to enhance performance and capacity.

The MCF Design Specification for DAS is targeted to address the requirements of next generation 5G infrastructure.

The Lead Carrier will recommend the order of MIMO requirements when they assess the required performance attributes for a DAS. The Lead Carrier can present a business case for the DAS to the developer to support the technical requirements for MIMO. The end decision should be in consultation with the customer and the Lead Carrier.

Typical candidates for a higher order MIMO DAS configuration are locations which cater for large numbers of people congregating in relatively small and uncluttered areas such as stadiums, entertainment/exhibition/convention centres, auditoriums, function centres, transport/railway stations and tunnels, underground platforms, and airports.

2.5 OPERATING FREQUENCY BANDS

In Australia, the following bands are currently designated for use by the Mobile Carriers under both Spectrum and Apparatus Licences (PTS) which are administered by the ACMA.

Band	Frequency (MHz)
700 MHz	DL: 758 –803 UL: 703 –748
850 MHz	DL: 870 – 890 UL: 825 – 845
850E MHz	DL: 859 – 890 UL: 814 – 845
900 MHz	DL: 935 – 960 UL: 890 – 915
1800 MHz	DL: 1805 – 1880 UL: 1710 – 1785
2100 MHz	DL: 2110 – 2170 UL: 1920 – 1980
2300 MHz	2300 – 2400 (TDD)
2600 MHz	DL: 2620 – 2690 UL: 2500 – 2570
3500 MHz	3400 – 3800 (TDD)

Table 1 – Sub 6GHz Bands designated for use by mobile network operators

The band support in the DAS should be technology agnostic.

For maximum flexibility, the passive components of the DAS should be selected to allow operation on all available bands (703-3800 MHz).

Active systems should have the flexibility to operate on all the bands and be commercially available at the time of deployment. Exceptions to this requirement should be agreed by the Sharing Carriers.

2.6 OTHER FREQUENCY RANGES

Where provision is required for cellular bands not listed in Table 1, components that cover the required frequency range, technology and use-case should be specified. Non-cellular services such as public safety, land-mobile, paging and Wi-Fi should be deployed on separate infrastructure unless otherwise agreed and appropriately incorporated in the initial design. .

Unless otherwise agreed, the non-mobile services should be properly integrated and incorporated from the initial design phase, rather than being subsequently added to the DAS. Retrofit solutions for non-mobile services are not permitted as they may compromise overall DAS performance.

2.7 REFERENCE TECHNOLOGIES

DAS should be designed to operate with base station and repeater equipment that is compliant with the corresponding ACMA licence conditions, as well as the relevant 3GPP standards.

Reference Technology	*3GPP Series*
LTE	***TS 36 series***
NR	***TS 38 series***

Table 2 - Reference Technologies and 3GPP Standards

2.8 FUTURE TECHNOLOGIES & SPECTRUM

This release of this specification does not encapsulate DAS solutions using spectrum bands not covered in Section 2.5 Operating Frequency Bands (e.g. mmWave). Where mmWave or other solutions are required this will require independent consultation with the Carriers and likely independent antenna infrastructure for each Carrier.

3. DAS PERFORMANCE CAPABILITY

Since the completion of the 2018 specification, the deployment of 5G technologies has accelerated and with new spectrum and network equipment, Carriers are planning to shut down their 3G networks.

As a result, it is timely to now provide guidance on designing and installing DAS for 5G. This specification is intended to support the deployment of 5G capable network infrastructure,

Traditional DAS using passive, active or passive/active hybrid architecture may not support 5G. The DAS required to deliver the necessary network performance capability will depend on the specific areas and characteristics of the building (Target Coverage Area) – see section 3.3. Recommended minimum capacity types for each area within a building are set out at section 3.4.

A DAS should meet the required RF signal strength to ensure sufficient network performance capability within the Target Coverage Area. The efficient design and installation of DAS will be promoted where there is sufficient engagement between Carriers and an interested party. The Lead Carrier process is intended to facilitate early engagement on DAS design however design proposals remain at the discretion of the building developer or owner.

Carriers can accommodate reasonable flexibility in the design of a DAS to meet the different in-building connectivity needs of building developers and owners. However, a decision to not incorporate MIMO and/or sufficient capacity into a DAS may result in Carriers being unable to supply 5G within that building and potentially the need for upgrades to the DAS to enable supply of 5G services in the future.

3.1 PASSIVE DAS

All components and elements of a passive DAS should be designed to simultaneously distribute the range of frequencies and technologies identified in Section 2.5 and Table 1. It should be noted that passive components that have extended frequency operation from 703 - 3800 MHz bands should be used in the design.

Passive DAS should be designed and deployed for all technologies as outlined in section 2.5 and the Approved Design. The design should assume that all channels in every frequency band are in operation simultaneously at each MNC output port, noting that EME compliance must be achieved under these operational conditions.

3.2 ACTIVE DAS & HIGH POWER ACTIVE ELEMENTS

DAS Equipment should be operationally supported, refer to Section 3.20. Carrier approved component lists are available on the AMTA website. https://amta.org.au/in-building-coverage-information-for-property-owners-managers/

It should not be assumed that all products offered by vendors are acceptable for connection by the Carriers. Acceptability needs to be confirmed before finalisation of For Construction packages or procurement decisions are made.

DAS Equipment should be designed and deployed for bands as outlined in section 2.5, 3.3 and the Approved Design. The design shall assume that all channels in every frequency band applicable are in operation simultaneously at each output port of the Active remote head, noting that EME compliance must be achieved under these operational conditions.

3.3 TARGET COVERAGE AREA

The Target Coverage Area should be agreed prior to commencement of the DAS design and shall be documented and marked on copies of the site plan and floor plans. This is usually undertaken in consultation with the Lead Carrier prior to design and incorporating the owner/developer's coverage requirements.

In any situation where a reduction in the Target Coverage Area has not been agreed upfront and in writing, the Lead Carrier may propose that the Target Coverage Area encompasses the entire building or infrastructure in accordance with the performance levels detailed in Section 3.4 below before accepting handover of the DAS.

3.4 SOLUTION CATEGORIES

The Solution Categories in column 1 of Table 3 are recommended solution architecture designs that should be applied to Building Types in column 2 of Table 3 to achieve minimum acceptable performance in target coverage areas and there is flexibility to accommodate higher capacity types and denser sectorisation if required. Building owners should be aware that the network performance of a DAS will depend on a variety of factors, including, among other matters, the structure of the building or specific site, the capacity and location of the equipment installed and the number of users of the network at any given time.

Recommended Minimum Solution Category	Building types	Passive/Hybrid/Active Solution Type
Custom (large scale sites with high-capacity demands)	Shopping centres, Convention centres, Stadiums, Airports, Public Transport, Motorway Tunnels	Lead Carrier may be engaged to define the scope of this category. The final solution will be determined in consultation with all Carriers and coordinated by the Lead Carrier (if applicable). If a Lead Carrier is not engaged, the minimum outcomes below are recommended: 2x2 MIMO on 700, 850E, 900 MHz 2x2 MIMO on 1800, 2100, 2300, 2600 MHz 2x2 MIMO on 3500 MHz
Standard (areas within buildings with moderate capacity demands)	Hotels, Hospitals, Commercial Office and Residential/Serviced Apartments	2x2 MIMO on 1800 MHz 2x2 MIMO on 2100 MHz 2x2 MIMO on 3500 MHz
Limited (areas within buildings	Car Parks (freestanding or building levels), Commercial Office, Residential/Serviced	SISO on 700, 850E, 900, 1800, 2100, 2300, 2600, 3500 MHz

with lower capacity demands)	Apartments	

Table 3 - DAS capacity solution types

Notes on table 3:

While a limited solution is the recommended minimum solution category for Commercial Office, Residential/Serviced Apartments and carparks, SISO support remains dependent on RAN vendors support, technology and device support.

To minimise the potential for network congestion, Carriers recommend that DAS should be designed to provide capacity across max 5-10 levels per sector for limited and standard solutions and engage carriers for the other type of solutions.

While a standard solution is the recommended minimum solution category, the lack of low band in the solution may result in poor lift coverage. Therefore, Carriers recommend minimum coverage KPIs be met for mid bands 18/21 (e.g under section 3.4 – RF Levels).

The number and size of DAS segments necessary to cover the target area should be agreed by all Carriers that are intended to participate in sharing the DAS. These segments should be capable of being fed by a single sector or by multiple sectors as required by each Carrier.

The final solution for Custom Capacity Type segments may be determined in consultation with all Carriers and coordinated by the Lead Carrier. At minimum, the requirements of 3.3 TARGET COVERAGE AREA should be fulfilled.

The table specifies the DAS performance solution category for the various building types . The owner of the DAS is ultimately responsible for the DAS equipment.

3.5 RF LEVELS REQUIRED

The DAS should provide dominant coverage within the Target Coverage Area to avoid unnecessary hand-over and/or interference to/from the external mobile network and should also deliver high quality signal within the Target Coverage Area. The external mobile network is defined as any mobile network signal received/measured/identified within the Target Coverage Area which is not part of the DAS itself. This is undertaken in consultation with the Lead Carrier.

Table 4 specifies the required signal, quality and dominance levels for various technologies. These values need to be reliably achieved and available to >95% of the Target Coverage Area.

RF levels for the DAS design will vary according to the location within the building. For example, the influence of the external macro network is likely to be greatest in proximity to the perimeter walls and windows. The DAS design will need to particularly ensure performance from the DAS meets required criteria in these locations.

In situations where the end-state external mobile network signal levels cannot be reliably measured (e.g. a building not yet constructed or external façade has not been installed), the onus is on the DAS designer to measure the signals on the street for all Carriers and estimate building attenuation based on materials used in the building construction, the Lead Carrier may provide guidance and input into the process. Signal measurements should be collected for all Carriers on all bands.

	700 - 2600 MHz		3300 - 3800 MHz
		4G / 5G LTE / NR	5G NR
Reference Power (dBm) (RSCP, RSRP, SS-RSRP)		≥ -95	≥ -100
Quality (dB) (Ec/Io, SINR, SS-SINR @ Unloaded)		≥ 15	≥ 15
Dominance (dB) Greater than macro network		≥10	≥10

Table 4 - Signal, Dominance and Quality Performance Levels for DAS

Table 4 Notes:

1. KPI for 95% of Target Coverage Area.
2. 5G NR Reference Power based on 30KHz sub-carrier spacing.
3. 5G NR 3400-3800 MHz bandwidth 100MHz per operator.
4. Equal power spectral density (W/MHz)/Equal Coverage per operator across all bands, refer Section 3.10 Radio Power Sharing

Coverage at a distance 6m outside the building at 0.85m above ground level from the IBC should be low enough to ensure dominance by each Carrier's macro network and should be lower than the macro network by 10dB.

The dominance of external macros is extremely important to DAS performance. A Lead Carrier should be consulted in the determination of Exemption Zones, otherwise the coverage levels should exceed the minimum levels in Table 4 RF Signal, Dominance and Quality Performance Levels for DAS, by at least 10dB.

As per Section 7.1 any Target Coverage Area Exemption Zones need to be clearly shown with reasoning on all relevant floor plans.

3.5.1 BUILDING CORE AND LIFT WELL COVERAGE

Where there are lifts within the Target Coverage Area, it is recommended that antennas be placed in the lift foyer adjacent to the lift core (minimum one antenna per every three adjacent lifts). Placement of the antennas should be done in consultation with the Lead Carrier. RF power levels to each antenna should be the maximum allowable based on EME constraints and should be sufficient to provide "best effort" 4G and 5G coverage into lifts, and should factor the combined RF loss from the lift walls and lift shaft walls.

High speed lifts should incorporate dedicated in lift solutions to provide coverage and seamless network performance and handover. The solution to be implemented should be in consultation with the Lead Carrier.

In order to avoid triggering undue hand-offs, sector design for the DAS should consider the impact of lifts rapidly travelling through different sectors and the abrupt closure of lift doors.

3.6 HANDOVER ZONE

RF levels shall be designed to facilitate both-way handovers with the external mobile network at locations agreed on the Target Coverage Area.

The DAS design requires well-defined handover zones, preferably in areas of low-traffic inside the building. The aim is to minimise handover zones in large, open areas and DAS KPI Exemption Zones areas where it can be difficult to control the handover boundary. Designers should make use of natural isolation areas that are part of the building design.

Where floor separation can't be used as a handover boundary (e.g. large atriums), the handover zones are to be shown in the DAS design sectorisation plan.

As described in Section 2.2, the DAS should be designed so that it can be easily expanded in the future by way of sectorisation, without compromising the DAS performance. Handover borders for future sectorisation needs to be taken in to account with the DAS design.

The design should ensure that RF levels specified in Section 3.5 at 0.85m above ground level outside the building are met.

Handovers to/from external fast-moving mobiles need to be avoided except for DAS applications being installed specifically for transport infrastructure (tunnels, railway stations etc.). In those specific installations, coverage should be extended to ensure seamless handover to the macro network.

Satisfactory mitigation of signal leakage from the DAS out to the external mobile network should be demonstrated and approved by the Lead Carrier during DAS design in circumstances where buildings or DAS infrastructure are situated in close proximity to freeway overpasses, train lines or similar situations where inadvertent handover to external mobile network users passing the DAS at speed has the potential to impact performance.

3.7 DESIGN SOLUTIONS FOR VARIOUS DAS APPLICATIONS

The design solution which will be most appropriate for a specific DAS varies depending on the application. Specifically, a DAS for a mine or railway tunnel will not apply the same design approach as may be required for a stadium. Likewise, a residential apartment building DAS should address requirements differently to a commercial office environment.

To the extent it is possible to apply, the approaches to various DAS solutions discussed within this section should form the basis of a DAS design for the topics covered in this section.

3.8 TYPES OF IN BUILDING COVERAGE SOLUTIONS

3.8.1 INTRODUCTION

In situations where external mobile networks cannot supply reliable indoor coverage and it is necessary to provide RF coverage augmentation, the nature of the building and a variety of circumstances will determine the most appropriate coverage solution.

The particular DAS design considerations and objectives which will be considered by the Lead Carrier as part of assessing the most appropriate coverage solution for a given application type are outlined below.

The reduction in use of fixed line communication services for residential and business use means communication solutions for people’s everyday needs should be carefully considered by developers and builders. In areas where external Carrier macro network coverage will not be reliable for indoor residential apartments or business use, the possible solutions include: fixed lines (PSTN/NBN), VoWiFi, Small Cells, Carrier-approved repeater solutions or DAS solutions.

A DAS is designed to provide equivalent performance between all Carriers throughout the system..

3.8.2 RESIDENTIAL APARTMENTS

Wherever possible the DAS should be designed with antennas and infrastructure being placed outside the apartments (i.e. in common areas) to provide service to the Target Coverage Areas within the apartments.

Where the placement of antennas in building common areas will not provide sufficient performance to the Target Coverage Areas, it is important for all stakeholders to acknowledge that difficulty for the Lead Carrier to gain access to private residential apartments when required will inevitably lead to delays in rectifying faults on DAS in residential buildings. Consequently, the DAS should be configured so each apartment has a unique feed which can be physically isolated from the remainder of the DAS from outside the apartments – i.e. accessible from common areas of the building.

It is not appropriate for any branch of the DAS to service multiple apartments without the ability to inspect and isolate each individual apartment being serviced by that branch from common areas.

Reason: Supports DAS fault-finding without needing to access private residences and helps mitigate PIM contamination affecting other parts of the DAS.

All residential layouts are unique and the extent of Targeted Coverage Areas within apartments will depend on size, apartment layout, and even building exclusivity. For the best possible user experience, the generic approach to providing contiguous coverage within apartments should be prioritized as follows:

i) Communal living areas;

ii) Offices;

iii) Entries/hallways;

iv) Kitchens;

v) Bedrooms;

vi) Bathrooms/laundries.

With respect to antenna positioning, residential apartments typically have very confined false ceiling space due to the number of services being run inside ceiling cavities, such as plumbing, air- conditioning and electrical. The confinement and density of these services is regularly identified as a significant cause of PIM.

The currently available PIM-compliant DAS antennas mean that aesthetics may be an issue for some developers or architects.

On this issue, designers are specifically directed to Section 6.2. While proposals may be considered by the Lead Carrier, it should be noted that attempts to fully conceal antennas inside the ceiling space, or with the use of "low-profile" antennas which do not have a robust backplane to limit RF energy resonating within the false ceiling space are unlikely to operate without PIM problems in this environment.

Where concealed antenna solutions fail PIM, the Lead Carrier will not agree to commission the DAS. In such circumstances, stakeholders will need to consider whether compromised visual aesthetics, or poor mobile network coverage for residents are priority for the project.

In general terms, concealed antennas are not recommended and should not be utilised.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- Inside Apartments
- Building Core/Resident-accessible Common Areas, Storage etc.
- Inside Lift Cars
- Carparks
- Plant Rooms
- Fire Stairs (best effort)

3.8.3 SERVICED APARTMENTS

Depending on the size and configuration, the design principles will be similar to Residential or Hotels.

Serviced apartments are often individually owned through strata subdivisions – or readily capable of being changed to this configuration in the future – therefore DAS cabling to serviced apartments should be individually isolatable in the manner described in Section 3.8.2.

Performance Required:

Design RF coverage contours to achieve the performance levels contemplated in Section 3.5 to the following areas unless agreed otherwise:

- Inside Apartments
- Building Core/Occupant-Accessible Common Areas, Storage etc.
- Inside Lift Cars

- Carparks
- Plant Rooms
- Fire Stairs (best effort)

3.8.4 HOTELS

Where it is more cost-effective, branch cabling for antennas can be run through partition walls between hotel suites rather than through common areas as required for residential designs.

However, experience suggests that typically corridor mounted cabling and antennas will provide sufficient coverage to most hotel rooms.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- Inside Hotel Rooms
- Occupant-Accessible Areas (corridors, restrooms, hotel facilities, shops)
- Back-of-house areas (accessible to staff or authorised personnel)
- Building Core
- Lobbies, Restaurants, Function Areas (potential for large people volumes)
- Inside Lift Cars
- Carparks
- Plant Rooms
- Fire Stairs (best effort)

3.8.5 COMMERCIAL OFFICE

Unless the floors are already partitioned, the design should have spare RF power to allow for future changes to floor layouts – such as subdivision of floors, addition of meeting rooms, offices etc. When no fit out information is available a margin of 5dB should be factored.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- General Workplace Floor Areas
- Building Core (restrooms, kitchens, corridors, lift foyers, break areas)

- Inside Lift Cars
- Carparks
- Plant Rooms
- Fire Stairs (best effort)

3.8.6 SHOPPING CENTRES

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- General Public Accessible Areas (shops, food courts, walkways/promenades, entries etc.)
- Back-of-House Areas (storage, maintenance areas etc.)
- Building Core
- Inside Lift Cars (travelling non-stop the entire lift-run - best efforts required but does need to include RF design contours)
- Carparks
- Plant Rooms
- Fire Stairs (best effort)

3.8.7 CONVENTION CENTRES

To cater for sufficient performance and capacity requirements refer to Table 3. A safety in design approach should be undertaken to consider maintenance factors and ensure design seeks to simplify access. Avoid splitting devices in hard-to-access areas such as high ceilings etc. The likely numbers of people attending functions in the various parts of the building will need to be considered.

Performance Required:

Design RF coverage contours to achieve the performance levels specified in Section 3.5 to the following areas unless agreed otherwise:

- General Public Accessible Areas (convention halls, food courts, restrooms, entries etc.)
- Back-of-House Areas (offices, storage, maintenance areas etc.)
- Inside Lift Cars
- Carparks
- Plant Rooms
- Fire Stairs (best effort)

3.8.8 STADIUMS

It is strongly recommended prior to commencing any works that a Lead Carrier is engaged and approves the proposed design. Capacity, sectorisation and interaction with macro network are site specific and need to be treated carefully. MIMO will be considered mandatory for stadiums. Refer to Table 3 for guidance.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- Stadium criteria will be defined by dominance relative to external mobile networks and will be assessed by the Lead Carrier based on the information collected and presented by the
- designer, refer to Section 2.1.
- Seating Areas and Concourses
- Pitch/On-Field criteria will be defined by stadium manager's intended usage of the space and guided by the Lead Carrier
- Back-of-House Areas (offices, storage, maintenance areas etc.)
- Inside Lift Cars
- Back-of-House Areas (offices, storage, maintenance areas etc.)
- Basement Carparks
- Plant Rooms
- Fire Stairs (best efforts)

3.8.9 AIRPORTS

Refer to Table 3 for guidance around DAS architecture and sectorisation. Areas requiring varying orders of MIMO coverage should be targeted in consultation with the Lead Carrier. It will be important to determine with airport stakeholders what other areas should be addressed.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- General Public Accessible Areas
- Back-of-house areas (accessible to staff or authorised personnel)
- Inside Lift Cars
- Carparks

- Plant Rooms
- Fire Stairs (best effort)

For Airside and Stationary plane from (Clause 3.4 Table 3) dedicated external sectors, direct consultation is required with the Lead Carrier to provide direction and advice with respect to interaction characteristics with external macro networks and design input criteria from each Carrier which may differ from general specification requirements outlined in this document.

3.8.10 RAIL TUNNELS

MIMO is strongly recommended for all metropolitan rail tunnels. Handover between sectors should be carefully considered for continuity of service. The size of sectors will also be a particular area of interest to ensure the Carriers can provide adequate capacity.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- Contiguous performance through the length of the tunnel measured or simulated at the centre of a train carriage filled to capacity with commuters. Appropriate modelling should be undertaken to simulate expected RF characteristics to exceed the required performance KPIs in Table 4 and endorsed by the Lead Carrier.
- Underground Stations / Platforms
- Inside Lift Cars
- Emergency egress and back-of-house areas (accessible to staff or authorised personnel)
- Carparks
- Plant and Equipment Rooms/shelters

3.8.11 MOTORWAY TUNNELS

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.5 to the following areas unless agreed otherwise:

- Contiguous performance through the length of the tunnel (measured inside a typical motor vehicle)
- Emergency egress and back-of-house areas (accessible to staff or authorised personnel)
- Capacity should be designed to cater for network traffic peaks which arise due to delays caused by traffic incidents within the tunnels.

- Handover to and from external macro coverage areas immediately adjacent to the tunnel portals

- Plant and Equipment Rooms/shelters

3.8.12 HOSPITALS

Designers might also want to identify whether any particular machinery areas will be a problem for PIM due to noise.

Consideration should be given to installing the DAS infrastructure such that sterile areas can be isolated.

Performance Required:

Design RF coverage contours to achieve the performance levels outlined in Section 3.4 to the following areas unless agreed otherwise:

- All General Areas (consulting/treatment rooms, emergency, wards, operating theatres, shops, cafeterias, walkways, waiting areas, entries etc.)

- Back-of-house areas (accessible to staff or authorised personnel)

- Building Core

- Inside Lift Cars (travelling non-stop the entire lift-run - best efforts required but does need to include RF design contours)

- Carparks

- Plant Rooms

- Fire Stairs (best effort)

- Public stairs

Need for coverage to Radiology and X-Ray areas to be discussed and agreed with the hospital.

Care is also required to ensure that EMI limits in Section 3.14 are not exceeded in locations with sensitive medical equipment.

3.9 PASSIVE DAS INTERCONNECT PORTS

The accepted method for combining signals onto a common passive DAS is by way of a Multi-Network Combiner (MNC). These combiners are generally available with four input ports, and four output ports. Each of the four outputs carries a composite signal which is a composite of all the signals that appear at the input ports.

The MNC combines the signals from each of the Sharing Carriers, and then distributes these to the DAS segments. A single MNC port should be utilised per operator. The fourth or spare unused MNC port should be terminated with a suitable load and utilised for testing purposes.

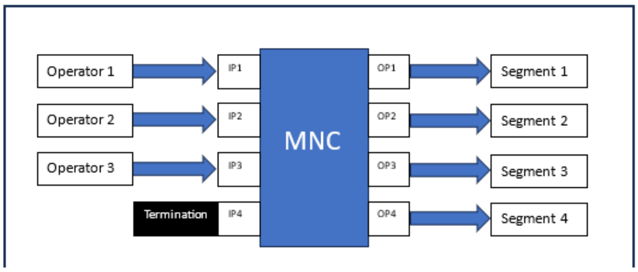

Figure 2 - MNC Configuration Diagram

In consideration of the potential for passive intermodulation (PIM) products to cause interference in a DAS, each input port of the MNC shall have input powers according to Table 5 Maximum Input Power.

Maximum composite input RF power per port	*Value*
Maximum composite RF power per MNC input port	*Within MNC manufacturer's specification*
Maximum RF power per individual channel (700/850E/900/1800/2100 MHz bands)	*10 watts (+40 dBm)*
Maximum RF power per individual channel (2300/2600/3500 MHz bands)	*20 watts (+43 dBm)*

Table 5 - Maximum Input Power

These levels should be used as the basis of the link power budget, maximum signal level limits and EME design requirements.

3.10 HYBRID & ACTIVE DAS INTERCONNECT PORTS

The design should provide a duplex input port for each Sharing Carrier for each frequency band which is being deployed. The combined RF power level at the point of interconnect should not exceed the Active DAS Equipment manufacturer's specification.

3.11 RADIO POWER SHARING

Most Hybrid and Active DAS solutions share common radios between all connecting Carriers to optimise the physical site footprint. Designers should consult with the Lead Carrier to implement a power sharing approach with the specific DAS technology used by the Lead Carrier.

With most technologies it will be optimal to share radio power with an equal power spectral density (PSD, measured in W/MHz) allocation per connected Carrier. A total composite power based on equal PSD will then be allocated per port, per spectrum band for each Sharing Carrier. The final power output of the radio is also adjusted to meet EME and KPI design constraints.

This approach facilitates the implementation of a single RF design per spectrum band for All Sharing Carriers and efficiently allocates radio hardware.

Spectrum bandwidth used in the power sharing calculations should be based on current ACMA licence holdings for the location. DAS designers should consult with the Sharing Carriers to confirm the bandwidth to allocated per band in the design.

The maximum radio power share per port, per spectrum band is calculated as:

$$MaxRadioPowerShare\ (W) = \frac{AvailableRadioPower\ (W) \times AllocatedBandwidth_{OperatorN}\ (MHz)}{\sum AllocatedBandwidth_{Operators}\ (MHz)}$$

See the table below for an example calculation for a single band.

Carrier	Allocated Bandwidth (MHz)	Maximum Power Share (%)	Available Radio Power (W)	Max Radio Power Share (W)
Operator 1	40	50%	20	10
Operator 2	20	25%		5
Operator 3	20	25%		5

Table 6 - Example power share calculation

3.12 EME DESIGN CONSTRAINTS

All DAS must be designed as per requirements in AMTA RF Safety Program Document **"EME Compliance for IBC and DAS Systems"** which is located in RFNSA document section as follows: "RF Safety Program\2020 IBC and DAS EME Compliance".

Where a DAS designer cannot access this information, they should request the Lead Carrier to provide it.

The onus remains with the 3rd party responsible for the design and build of the DAS to ensure the latest standards are taken into account.

3.13 EME DESIGN MARGIN FOR SHARING

The DAS must be designed in accordance with: “Recommended Maximum Input Power Levels for Category 1 IBC Antennas” which is located in the RFNSA Documents section as follows: “RF Safety Program\2020 IBC and DAS EME Compliance\Category 1 IBC Antennas”.

3.14 ELECTROMAGNETIC COMPATIBILITY (EMC) DESIGN CONSTRAINT

Designers should familiarise themselves with the environment in which the DAS will be installed, taking note of any potential EMC issues that may arise, or any local rules imposed on the use of radio transmitters.

Designers should be aware of the impact that Radiofrequency Interference may have on various types of equipment, particularly when designing IBC and DAS systems in hospitals. This issue is not limited to hospitals and there are two categories where Radio frequency Interference should be considered when designing IBC and DAS in hospitals or in locations where there may be explosive atmospheres or electronic explosive devices as follows:

Medical equipment

- Hospitals
- Emergency departments
- Helicopter landing pads
- Areas where patients connected to medical equipment can enter
- Not limited to the above list

Explosive Atmospheres and Electronic Explosive Devices (EEDs)

- Petrol stations
- Fuel storage and transfer depots
- Grain or other material storage silos
- Ammunition and explosives factories and storage facilities
- Not limited to the above list

AMTA has produced a guideline to help designers assess the impact of Radiofrequency Interference in the above situations titled, “7.11 Interference and ignition hazards from mobile base stations”.

This is available on the RFNSA Documents section under the RF Safety Program.

Where a DAS designer cannot access this information, they should request the Lead Carrier to provide it.

3.15 MAXIMUM SIGNAL RECEIVED BY USER EQUIPMENT (UE)

The maximum signal levels received by a UE (e.g. a mobile phone) situated as close as possible to any antenna while being 0.85m above floor level shall be in accordance with the table below.

Technology	*Maximum received power*	*3GPP Reference*
LTE	***-25 dBm/channel bandwidth***	TS36.101 Clause 7.4
NR	***-25 dBm/channel bandwidth***	TS38.101 Clause 7.4

Table 7 - Maximum Received Levels at MS/UE

Note that for a passive DAS the minimum path loss is typically determined by the maximum allowable levels at the BTS receiver inputs as in Section 3.16 below.

3.16 MINIMUM ALLOWABLE PATH LOSS

3.16.1 PASSIVE DAS

The DAS design should consider the circumstances where an uncoordinated UE (i.e. not being served by any of the RF carriers present on the DAS) is operating on an adjacent channel, or a controlled UE is operating on the wanted channel at maximum transmit power, may lead to the base station receiver being overloaded.

Table 8 shows the minimum allowable path loss – which in the case of a passive DAS refers to the coupling loss from a UE being operated at a nominal 1.5m above floor height, to the carrier base station input. (Note: this value includes the losses in the MNC and the antenna distribution network)

Technology	**UE Tx Power**	**Maximum Carrier Base Station Received Power**	**3GPP Reference**	**Minimum Path Loss**	
LTE	+23 dBm	-52 dBm/occ BW	TS36.104	75 dB	*Adj. - channel*
NR	+23 dBm	-52 dBm/1 MHz BW	TS38.104	75 dB	*Adj. - channel*

Table 8 - Minimum allowable path loss

3.16.2 HYBRID & ACTIVE DAS

The design should ensure that the Maximum BTS received power values of Table 9 are complied with.

Ensure that the maximum uplink input signal levels at the remote units do not exceed the manufacturer's ratings.

3.17 RF PROPAGATION MODEL

This document does not specify a propagation model as it is a responsibility of the DAS design vendor to select a suitable model for the DAS environment to ensure that the minimum signal levels specified in this document are delivered by the systems once it is in operation. The details of the propagation model used should be based in sound engineering principles and should be traceable via calculation to a solid empirical or theoretical base including sufficient design margins.

3.18 MEASURED PERFORMANCE OF INSTALLED DAS

In addition to the coverage, power and loss specifications above, a passive DAS shall meet the following performance requirements.

3.18.1 RETURN LOSS

The return loss of each passive DAS segment connecting to a multi-network combiner shall be ≥ 16 dB over the operating frequency bands. Where a DAS segment is comprised of multiple branches connecting to a DAS segment, the connection points to the branch should each also individually comply with the above performance requirement.

In the case of a Hybrid DAS system the return loss at the point of interconnect closest to the remote unit shall be greater than 16 dB.

3.18.2 PASSIVE INTERMODULATION (PIM)

The third-order passive intermodulation performance of each passive DAS segment connecting to a multi-network combiner shall be ≤ - 140 dBc with input power levels shown in Table 6 . The test should be performed with the antennas connected to the DAS segment under test and ensure EME precautions are followed.

The DAS should conform to above standards for frequencies in low band, mid band and high band. The corresponding bands are as follows:

- Low Band = 700/850/900 MHz
- Mid Band = 1800/2100/2300/2600 MHz
- High Band = 3500 MHz

PIM testing should be conducted with a device that is validly calibrated. The measurement should pass with a duration of 10 seconds or greater (e.g. PIM Vs Time for 10Sec). The DAS installer should provide the original PIM test result files as part of their handover documents.

For the purpose of PIM performance requirements on a Hybrid DAS each active remote unit will be viewed as if it is a “multi-network combiner” with the above passive DAS testing.

Where a DAS segment with a designed input power ≤ 5 watts, the passive intermodulation performance of each passive segment/interconnection point connecting to the remote shall be ≤ -140 dBc with 2 x 33 dBm carriers in both low band, mid band and high band as above.

In most cases a branch of the DAS system that passes the specification of -140dBc at 2600MHz is most likely to also meet the desired specification at 3500MHz. Testing PIM at 2600MHz while not testing PIM at 3500MHz is acceptable if the following conditions are satisfied:

- All the RF components comply to a minimum return loss of 16dB as per this specification. The PIM measurement should then remain consistent across frequencies with a +2.85dB / -5.5dB measurement uncertainty, for a return loss of 16dB and a lossless system.
- All the RF components complies to the PIM specification on all bands (from 703 to 3800MHz) defined in this specification.
- The 3500MHz system is part of the branch being tested at other frequencies, and there is no frequency selective component for the 3500MHz frequency band (e.g. a diplexer).
- PIM measurement to be performed swept measurement across the widest Receive frequency band possible to identify the peak PIM level.

Longer cable length acts in the favour of a lower PIM level at 3500MHz due to the higher cable insertion loss at 3500MHz. Therefore, the branches which are the most likely to be problematic at 3500MHz are the shortest branches.

For further details on PIM refer to Section 5.0.

3.18.3 PROPAGATION DELAY

DAS designs should incorporate appropriate architecture and components to address potential propagation delay issues that may impact performance by:

- Creating potential external RF propagation delay differentials that introduce inter-symbol interference;
- Impacting MIMO functionality with different losses/delays between MIMO streams;
- Introducing system delays that affect overall performance.

3.18.4 SYSTEM UPLINK NOISE PERFORMANCE

The uplink noise rise on any system should not exceed 3 dB as measured on the carrier base station receiver under no or low traffic conditions.

3.19 CABLE AND COMPONENT LABELLING

Labelling of DAS cable and components should be completed in accordance with the requirements of the Lead Carrier.

If the Lead Carrier is unknown during the physical installation, as a minimum, all installed cable and components should be labelled clearly with DAS identification as follows:

- *Horizontal* runs of cable should be labelled with a label at intervals of approximately 6 metres.
- *Vertical* runs of cable, such as in risers, labels should be placed at approximately 1.8 metres above floor level on every floor.

Labels should also be attached on or close to each component. Labelling stickers should not be placed on the radiating element of the antenna or on the component identification plate, however labelling stickers should also be placed on radiating cable in accordance with the spacing intervals indicated above.

All feeders should be identified at both feeder opening points with a label containing a concise identification code uniquely identifying each cable and cross-referenced to the system drawing. Identification labels should be provided by the contractor.

3.20 APPROVED MATERIAL LIST

An approved material list reflects regulatory requirements relating to network security and performance.

Material and equipment selection not only contribute to the long-term reliable performance of the DAS, but will enable a Carrier to provide the necessary ongoing management, maintenance and support.

It is strongly recommended that the DAS designer verify the suitability of all materials and equipment proposed to be used in the DAS.

Lead Carriers maintain (and can provide upon request) a list of approved equipment that is to be used for a DAS with the relevant Lead Carrier.

3.21 COMPONENT COMPLIANCE

Carriers refer DAS designers to the requirements of relevant building codes, fire authorities and building owners/managers in respect of fire retardant and/or low smoke zero halogen emission properties. Carriers maintain approved hardware lists for suitable cable.

If an existing DAS installation is to be modified or extended, equivalent cable in both environmental/mechanical properties (ie Fire Rating) and electrical/radio characteristics should be used. In all cases of an augmentation/extension then the latest standards should be followed (Building code, MCF, etc).

Emphasis should be made to ensure that appropriate RF signage to achieve EME compliance in accordance with industry standards.

3.22 DAS COMPONENT SPECIFICATIONS

Each individual component of the DAS should meet or exceed the performance characteristics detailed below for all operating frequency bands listed in Table 1 of Section 2.5.

3.22.1 CHARACTERISTIC IMPEDANCE

RF circuit impedance of all components should be 50 ohm unbalanced.

3.22.2 COMPONENT RETURN LOSS

All passive components should be rated by the manufacturer to have better than 16 dB return loss over the operating frequency bands listed in Table 1.

3.22.3 COMPONENT PIM PERFORMANCE

The third-order passive intermodulation (PIM) performance for each individual component in the DAS should be as indicated in Table 9 Passive Component PIM Specification.
The Test Condition detailed in this table requires performance specification conformance for frequencies in both a low band and a high band. The corresponding bands are as follows:

- Low Band = 700/850/900 MHz
- Mid Band = 1800/2100/2300/2600 MHz
- High Band = 3500 MHz

Component Description	**Third-order passive intermodulation performance**	***Test condition***
Splitters and Couplers	≤ -150 dBc	2 x 43 dBm carriers
Low power (<5 watt) **50 ohm terminations**	≤ -140 dBc	2 x 33 dBm carriers
High power (≥5 watt) ***50 ohm terminations***	*≤ -150 dBc*	2 x 43 dBm carriers

Table 9 - Passive Component PIM Specification

3.22.4 COAXIAL CONNECTOR TYPES

Table 10 indicates the types of coaxial connector which may be used on a DAS and where they can be deployed. All coaxial connectors should be checked for compliance with the relevant standards. All connectors should be installed and tightened in accordance with their applicable standards.

Connector Type	DAS Location
7-16	Subject to Lead Carrier direction
4.3-10	All Ports
N-Type	Not Allowed (except when connecting to relevant vendor equipment)
Inter-series coaxial adapters	Not Allowed
Other	Subject to Lead Carrier direction

Table 10 - Permitted Coaxial Connector Types

3.22.5 COAXIAL CABLES

Only coaxial cables with solid outer conductors may be used for multiband signal carriage.

Patch cables with solid outer should be used for interconnections between the base station equipment and any filters, splitters and combiners, unless specifically agreed by the Lead Carrier. The braided cables used should then only carry single band signals and be approved by the Lead Carrier. All cables, with either solid or braided outer conductors should meet the minimum performance parameters below.

Factory assembled feeder patch cables should be specified with the following minimum performance parameters:

- **Return Loss:** ≥ 26 dB over (or to the specification of the approved equipment capability) the operating frequency ranges listed in Table 1.
- **Intermodulation performance:** Any third order product should be ≤ -150 dBc with 2x 43 dBm carriers under both static and dynamic conditions for the operating frequency ranges listed in Table 1.
- **Connectors:** DIN 7-16 or 4.3-10, as required (refer Section 3.22.4)
- **Joiners and inter-series adapters** are not to be used in any circumstances.

3.22.6 CABLES WITH BRAID, FOIL OR FOIL/BRAID SCREENING

Cables of this type (for example LMR400, RG214 etc.) have been found to have poor intermodulation performance, regardless of the quality of the connector terminations, they should not be used.

3.22.7 ANTENNAS

Each of the mobile carriers has a published approved material list which should be adhered to.

3.22.8 GPS ANTENNAS

Carrier base station equipment now increasingly requires GPS synchronisation. It is becoming increasingly common that Carriers will be able to provide timing capability through the transmission network via phase Sync. The designer should consult with the Carriers to confirm the requirement for a physical GPS cable run.

This requires a direct cable path to be identified and reserved for the carriers from the equipment room to a viable GPS antenna position outside the building.

The DAS designer should identify an external location for carriers to install sky-facing GPS antennas with clear line-of-site above the horizon in order to receive signal from GPS constellations.

Ideally the GPS antenna should be in an open space with unobstructed 180° view of the sky as indicated in Figure 3. Where that is not possible, a location with visibility of no less than 90° of sky should be selected as indicated in Figure 4.

GPS cable route and GPS antenna locations should be clearly shown in a DAS design. The design should clearly articulate the length of the cable run and identify those which are >180m as this poses a risk for local GPS synchronisation issues.

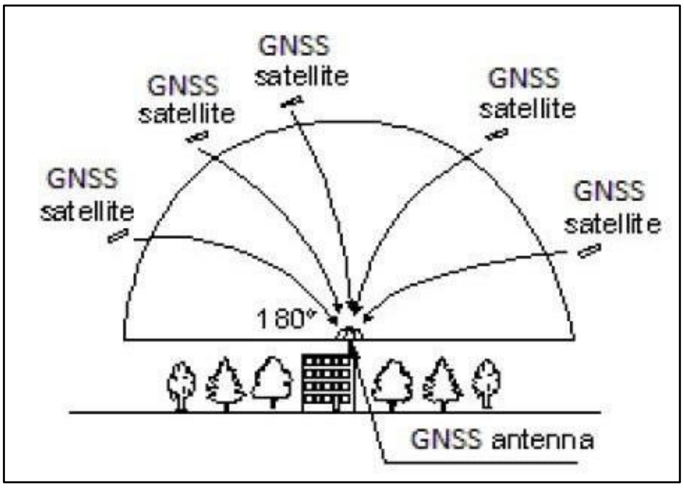

Figure 3 - Ideal GPS Antenna View of Sky

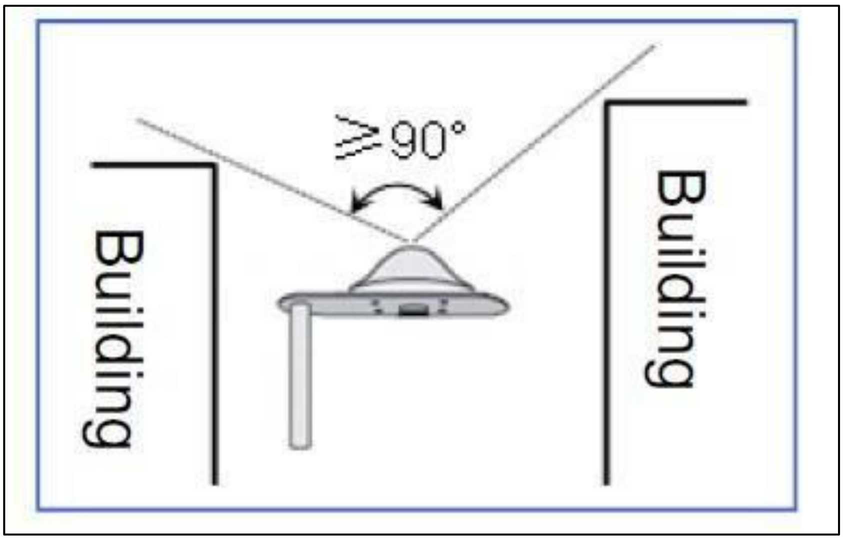

Figure 4 - Minimum GPS Antenna View of Sky

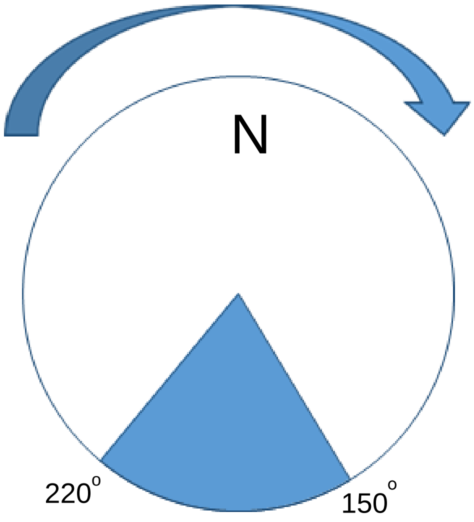

Figure 5 - GPS Line of Site - Horizontal Plane

The antenna location should not be obstructed in the horizontal plane (azimuth) between 220 degrees and 150 degrees looking clockwise through true north as per Figure 5.

In a DAS environment, multiple GPS antennas will be installed at the site and there should be allowance for at least 0.5m separation in the horizontal plane.

When allocating space, the GPS antenna:

- Should not be positioned close to high voltage power cables.
- Should not be positioned in the main lobe or exclusion field radiation areas of mobile RF panel antennas, microwave antennas or any other type of EME hazard.

A minimum 1 x GPS antenna is required per Carrier. The GPS cable is to be installed in consultation with the Sharing Carriers. The DAS installer should also identify a cable path from the carrier base station equipment to the GPS antennas. In some cases it may be more appropriate for the DAS contractor to install cables for GPS antennas during construction works to minimise disruption.

There should be a separate and dedicated GPS antenna for each Carrier and it is important to recognise that maximum feeder length can become a limiting factor for GPS antenna positioning. The Lead Carrier should be engaged to advise on GPS design criteria and requirements.

GPS antenna feeds cannot be combined because the GPS solution uses active antennas which are based on carrier hardware and capacity requirements.

3.22.9 CABLES THAT SUPPORT REMOTE OR ACTIVE EQUIPMENT

In an Active DAS or Hybrid DAS, fibre optic cable or twisted pair structured cabling is used to distribute the signals to different areas where long runs of RF Cable may not be practical.

If an Active system can support either optical fibre or structured cabling, optical fibre should be used unless the Lead Carrier agrees otherwise.

3.22.9.1 OPTICAL FIBRE CABLING

Optical fibre cabling to support active DAS Equipment should be supplied and installed to manufacturer specifications for the active DAS Equipment.

All fibres supporting active DAS Equipment should be physically separate and clearly distinguishable from any other fibre which may be installed within or throughout the premises. To avoid any risk of service disruption between different types of users (carriers for a DAS and building operators/occupants for other purposes), the use of base-building fibre to support active DAS Equipment is not permitted.

Optical fibre cabling comprises several components; the main fibre cables comprising multiple fibres in a sheath, pigtails spliced to the main fibres at each end and terminated into a patch panel and finally patch leads at each end. In some cases, there may also be intermediate splice points where smaller cables are spliced into larger cables.

On smaller installations, the use of individual prefabricated cables may be preferable to avoid the need for splicing onsite. Where splicing is used, all fibres should be spliced using a fusion splicing machine which is approved by the Lead Carrier. At joint locations, the average two way splice loss for jointed fibres should not exceed 0.10 dB at 1550 nm and 1625nm.

3.22.9.2 STRUCTURED CABLING

Where a DAS requires structured cabling, the cable quality standard of twisted pair structured cable should be equivalent or better than the manufacturer specifications required for the particular equipment which is being connected to that cabling. Shielded structured cabling is preferred.

The distances should not exceed the maximum cable length for the given standard of structured cable being used.

4. DELIVERABLES

4.1 DOCUMENTATION

4.1.1 SUMISSION OF DOCUMENTS

The DAS contractor should provide the Lead Carrier with all preliminary/detailed design documentation for review and approval. Turn-key as-built installation documentation should be provided to the Lead Carrier within 4 weeks of completion of the DAS.

Submission of DAS information to the Lead Carrier should be through soft copies of all drawings, documents and test results. Due to large file sizes, the most common method of submission is currently web-based file servers (e.g. Dropbox, OneDrive, Box etc.) which are accessible by the relevant Lead Carrier. The Lead Carrier will retrieve the information and permanently store the information onto the Lead Carrier's record keeping systems.

4.1.2 COPYRIGHT AND OWNERSHIP OF DAS DESIGN INFORMATION

Where the Lead Carrier assumes ownership and responsibility of the DAS, they should be granted unfettered title and copyright of any design material pertaining the DAS from the authors of that material.

4.1.3 FILE TYPES AND DOCUMENT SECURITY

All files should be submitted completely unlocked in their original software production form so they are editable by the Lead Carrier for future modifications to the DAS. For example, the power budget spreadsheets can be updated with the addition of extra technologies or channels in the future using the original MS Excel file. The Carriers should provide editable link budgets, but this does not include specific IP. Carriers may decide to share Power budgets.

Text or numeric documents should be provided using the latest suite of Microsoft Office (i.e. MS Word or MS Excel). Submission of any other file formats for these types of documents should be specifically agreed with the Lead Carrier.

All photos, digital images or screenshots are to be delivered in JPEG (*.jpg) or Bitmap (*.bmp) format to a minimum resolution of 1024 x 768 pixels (higher resolutions are preferred).

If a DAS has been designed in iBwave™ those format files should be provided.

Where CAD has been used for design, the drawings should also be supplied in AutoCAD format and be made available to the Lead Carrier. In cases where CAD files are not available, documentation should be provided in high resolution PDF.

Any other supplied documents – such as component specifications or scanned base-building drawings etc. should be provided in high resolution Portable Document Format (*.pdf).

4.2 PRELIMINARY DAS DESIGN DOCUMENTATION FOR LEAD CARRIER REVIEW

The DAS designer should submit preliminary DAS design documentation with any relevant related information to the Lead Carrier for confirmation of design acceptability prior to progression to detailed design. The preliminary documentation should address the following:

1. Location and physical size (sq. m) of the building.
2. Number of levels in the building and which levels are being serviced by the DAS (i.e. a clear indication of the Target Coverage Areas and Exemption Zones).
3. Forecast occupancy information
    a. Maximum number of people expected to be served by the DAS at peak time.
    b. Breakdown of tenants (if applicable and available).
    c. Any known high capacity service requirements (e.g. tenants want wireless offices).
4. Type of DAS proposed
    a. Passive, Active or Hybrid.
    b. Technologies proposed to be catered upfront (particularly for Active or Hybrid systems)
    c. Number of RF carriers the link budget has been designed for.
5. A general description of the proposed concept design based on Section 2.0;
6. Antenna layout floor plans (scaled);
7. A system schematic diagram;
8. A high-level sector design (visually identifiable with different colours for each sector).
9. Link power budget calculations for a single RF carrier in each of the frequency bands/technologies identified in Sections 2.5 and 2.6 of this document.
10. Calculation to show the composite power calculated at each antenna port to demonstrate compliance with Section 3.11, 3.12, 3.13 and 3.14.
11. Coverage predictions demonstrating that RF levels are in accordance with Section 3.4.
12. Bill of materials (excluding installation materials).

4.3 DETAILED DAS DESIGN DOCUMENTATION FOR LEAD CARRIER APPROVAL

After the preliminary design documentation has been reviewed and approved by the Lead Carrier, the DAS designer should provide further detailed design documentation expanding on the approved preliminary design.

The Lead Carrier will review the detailed documentation and provide an approval confirming the acceptability of the DAS design prior to any installation works commencing. The following information should be submitted for the Lead Carrier to provide approval of the detailed DAS design.

1. Design survey results:
   a. Existing coverage levels, conducted on street level to evaluate handover requirement.
   b. Existing coverage levels, conducted on a medium floor and a high floor to evaluate interference; these surveys should be conducted and plotted as a snail trail overlaid on floor plans. (RSCP and Ec/Io plots should both be collected for RSRP and SINR for LTE and SS-RSRP and SS-SINR for NR, for the bands the carriers are connecting to upfront).
   c. Best serving cell
   d. For construction sites where this may not be possible. Predictions based on floorplans and comparison to macro network will be required. Consultation with the Lead Carrier is critical to ensure endorsed assumptions are made to generate acceptable modelling.
2. Clearly demonstrate the DAS can achieve the performance criteria in Table 5 RF Signal, Dominance and Quality Performance Levels for DAS for all Target Coverage Areas to ensure satisfactory data throughput, capacity and performance.
3. Identify the proposed DAS coverage transition areas with the external mobile network.
4. System description.
5. System schematic diagram.
6. Backbone distribution description.
7. A high-level sector design (visually identifiable with different colours for each sector).
8. A high-level future sector design which allows doubling of the number of sectors without substantially modifying the DAS architecture.
9. Link Power Budget providing:
   a. Calculations to show the composite power calculated at each antenna port is within EME compliance (Section 3.12 and 3.13) when all channels in every frequency band are in operation simultaneously (Section 2.5 and 2.6).
   b. DAS Loss between MNC Input Port and Antenna Input port for every frequency band.
   c. Calculations to demonstrate that expected RF levels achieved are in accordance with Section 3.4
10. A RF Power allocation summary table. This table should propose the RF powers at MNC Input (or Active/Hybrid DAS Remote O/P) for all channels in every frequency band for all Carriers.

11. Fibre distribution schematic for Active/Hybrid DAS architectures which clearly articulates number of fibres available at each termination point and remaining available fibres for future use.

12. Equipment location and room details including access details, layout diagram/schematic showing BTS positions.

13. Actual photos of the proposed equipment room (if present).

14. Modelling of the expected performance KPIs (and associated prediction outputs) should be produced using an industry and/or commercial grade prediction tool. The model should be site specific and include site specific nuances which may affect performance outcomes of the system. The predictions created as a result of the model should also be provided in PDF format or post processed format easily reviewable and assessable by the Lead Carrier. A summary of key parameter settings used to define the model and produce the prediction should be summarised.

15. Manufacturer's specification for all relevant equipment and material (power splitters, directional couplers, antennas, standard feeder cables, radiating coaxial cables, etc.).

16. Identification of Category 2 antennas and Preliminary RF Hazard Drawings (PRD).

17. Bill of materials (excluding installation materials)

18. Authority from the Lead Carrier for any Category 1 antenna where the power inserted will exceed the maximum composite power as stipulated in Section 3.11. For Active DAS elements with integrated antennas the Lead Carrier will hold a product supplier's signed Declaration of Conformity to ARPANSA Radiation Protection Series – S1. The Lead Carrier can provide this to demonstrate as proof of compliance with EME requirements, consistent with the ACMA EME rules for equipment categorised as 'portable and mobile with integral antennas'.

19. For Active/Hybrid systems – information about the DAS alarming/remote module which the Lead Carrier will be connecting to. Any specific items that will be required from the Lead Carrier to facilitate connection to the DAS alarming/remote module.

20. As per Section 7.1 Any Target Coverage Area Exemption Zones need to be clearly shown with reasoning on all relevant floor plans.

21. A proposed GPS antenna installation location. Refer to Section 3.22.8 & 6.7

22. The GPS cable pathway from the equipment room to the proposed GPS antenna position. Refer to Section 3.22.8 & 6.7

23. Earthing requirements between future GPS antenna & future GPS feeder to existing building/Lightning protection earth" Refer to Section 3.22.8 & 6.7

24. Proposed earthing for any externally mounted antennas or their support structures.

25. DAS and EME Signage and Labelling specification, location and fixing requirements.

4.4 FOR CONSTRUCTION INSTALLATION DOCUMENTATION

These details are a combination of generic installation practice and fabrication drawings and will also include structural engineering and details for unique installation scenarios at a site. For construction drawings should provide installation related information, enough for actual installation works to proceed:

1. Instructions for installation of the design:

    a. antenna mounting instructions;
    b. floor cable mounting instructions;
    c. communications riser cabling instructions;
    d. equipment room cabling instructions;
    e. cable handling instructions;
    f. cable labelling instructions.

2. Drawing:

    a. DAS system schematic;
    b. floor layout for every floor;

3. Floor layout drawings:

    a. showing the cable runs and antenna placement on each floor,
    b. sufficient detail and landmarks so a person unfamiliar with the site can trace out the proposed cable run and show the proposed positions of antenna and other components (couplers, splitters, etc.) without needing to remove the ceiling tiles.
    c. Where applicable, the floor plan should also show preferred cable entry/exit points.

4. Drawings should be prepared to scale in accordance with Australia Standards and recommendations as follows:

    a. Drawing title, boundary, etc.
    b. Structural walls, lift cores, permanent brick or block partition walls, etc.
    c. Semi-permanent office partition walls (of plasterboard, glass, etc.) of full height to ceiling level. Other partitions, such as workstation partitions, may be omitted.
    d. Structural details and existing riser details, such as existing cable ladders, large pipes, etc., which are significant;
    e. proposed cable, component, and equipment design details
    f. proposed cable, component, and equipment label designation
    g. Installation details for non-standard cable and component installation.
    h. backbone distribution layout;

5. Bill of material (including installation materials).

6. All aspects of civil engineering design work (if required) including the following:

    a. the structural design of the antenna support structures; and
    b. any other structural calculations or designs.

7. Specifications and instructions relevant to cabling, wiring and termination work of the RF feeders, optical fibre cables, power wiring, and earth connections including: i) assembling of parts; ii) fitting of connectors; iii) Any other information that may fall within this category.

8. Specification of AC power outlets for all AC powered equipment specified in the DAS.

9. Security materials and installation specifications and details in accordance with requirements of Section 8.11.

10. Design and specification of the protective earth systems including lightning finials on the antenna support structures for all externally installed antennas.

11. DAS and EME Signage and Labelling specification, location and fixing requirements.

12. Testing and commissioning specification and procedure of the Distributed Antenna System, and data recording sheets (refer to Section 8.0 Carrier Equipment & Accommodation Requirements), including:

    a. RF sweeps;
    b. RF power measured at the designated test points;
    c. calculated line loss with regard to the reference point;
    d. passive intermodulation testing;
    e. all alarm indications of the supervisory system (if applicable) to demonstrate that they are operational to the manufacturer's specification.

4.5 HANDOVER DOCUMENTATION

The following information should be submitted in a final package to the Lead Carrier for acceptance and handover of the DAS to the Lead Carrier within 4 weeks of the completion of the DAS:

1. As-built versions of the information submitted in Section 4.3 above. (These drawings should not materially deviate from the proposal submitted to and approved by the Carrier in Section 4.3 above.)

2. Test results for all installed components as detailed in Section 7.1 below.

3. For Active/Hybrid DAS systems, all configuration information, including but not limited to:
    a. Active/Hybrid DAS parameter settings;
    b. Final DAS commissioning table summarising power allocation per operator per band;
    c. Low Power access point status/connectivity test report of all connected elements attached to the DAS system;
    d. Low Power access point commissioning report to show number of units and architecture, CAT cable and or fibre connection schematic.
    e. Fibre diagram for Active/Hybrid DASs including number of fibres terminated at each location clearly articulating number of fibres in use and remaining for future upgrade use.

4. Location of DAS equipment spares:

    a. Instructions how to access spares if they are held onsite
    b. Otherwise the Lead Carrier depot location where any spares were physically delivered to the Lead Carrier.

5. Any other relevant information reasonably obtainable and available by the developer/landlord/designer required for the Lead Carrier to assume responsibility to successfully operate and maintain the DAS.

6. IBC EME Guide prepared by an AMTA Approved RF Assessor (list available on the RFNSA.com.au home page).

5. PASSIVE INTERMODULATION (PIM)

5.1 WHAT IS PASSIVE INTERMODULATION (PIM)?

Passive Intermodulation (PIM) is a form of intermodulation distortion that occurs in components such as cables, connectors and antennas. However, when these non-linear, passive components are subjected to the RF power levels found in cellular systems, they behave like a mixer, generating new frequencies that are mathematical combinations of the downlink frequencies present at the site.

PIM signals that fall in a Carrier's uplink band can elevate the noise floor, resulting in higher dropped call rates, higher access failures and lower data transmission rates.

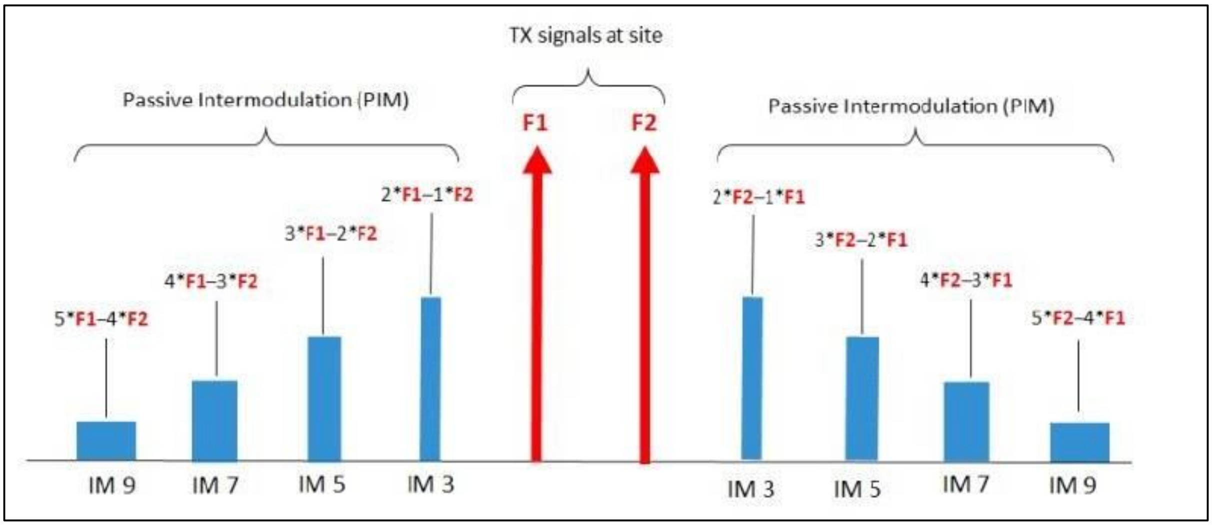

Figure 6 - Passive Intermodulation (PIM) Products Produced by Two Signals

When referring to PIM products, the sum of the multipliers (n + m) is called the product order, so if m is 2 and n is 1, the result is referred to as a third-order product. Generally, lower order intermodulation products (IM3, IM5) have higher magnitude than higher order intermodulation products (IM7, IM9, IM11, etc.). If the downlink frequencies in use at a site are able to combine in such a way that low order IM products fall in a Carrier's uplink band, PIM interference will be likely. This is not to say that higher order intermodulation products can be ignored. Depending on the degree of non-linearity and the RF power levels in use at a site, even high order IM products may be strong enough to impact site performance.

It is important to understand there is no relationship between Return Loss and PIM. It is possible to have good Return Loss and poor PIM, or, good PIM and poor Return Loss.

PIM is a bigger issue today than it used to be within DAS's because new generation systems introduce better Rx technology & higher capacity through improved radio sensitivity. These generational performance improvements come at the expense of much greater equipment sensitivity. Consequently, DAS systems which now support LTE require more stringent test levels, due to the lower resource block sensitivity level, compared to other air interfaces.

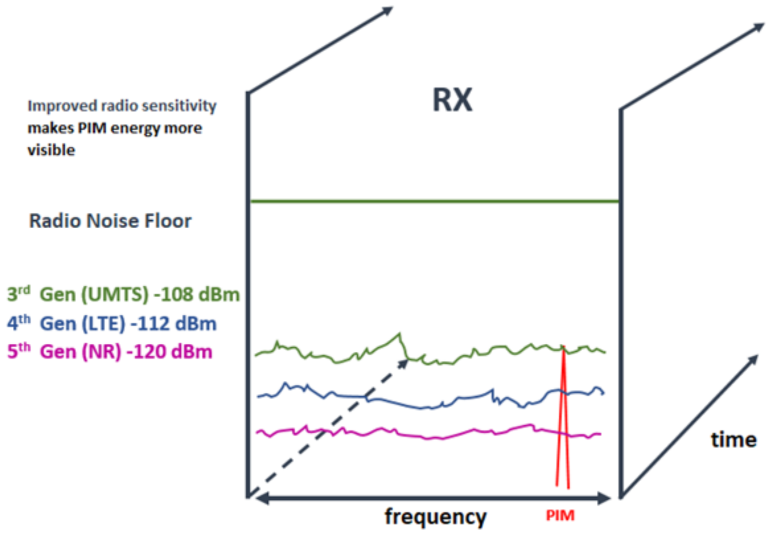

Figure 7 - Noise Floor Tolerances between Communications Generations

5.2 WHAT ISSUES DOES IT CAUSE TO A DAS?

Noise and interference on the network inhibit proper use of the system. Interference due to PIM presents as an elevated noise floor on a cellular base station. Whilst this noise cannot always be "heard" by end users, the sensitivity of the base station receiver is adversely impacted with the consequences of reduced coverage, increased call drops and decreased data throughput.

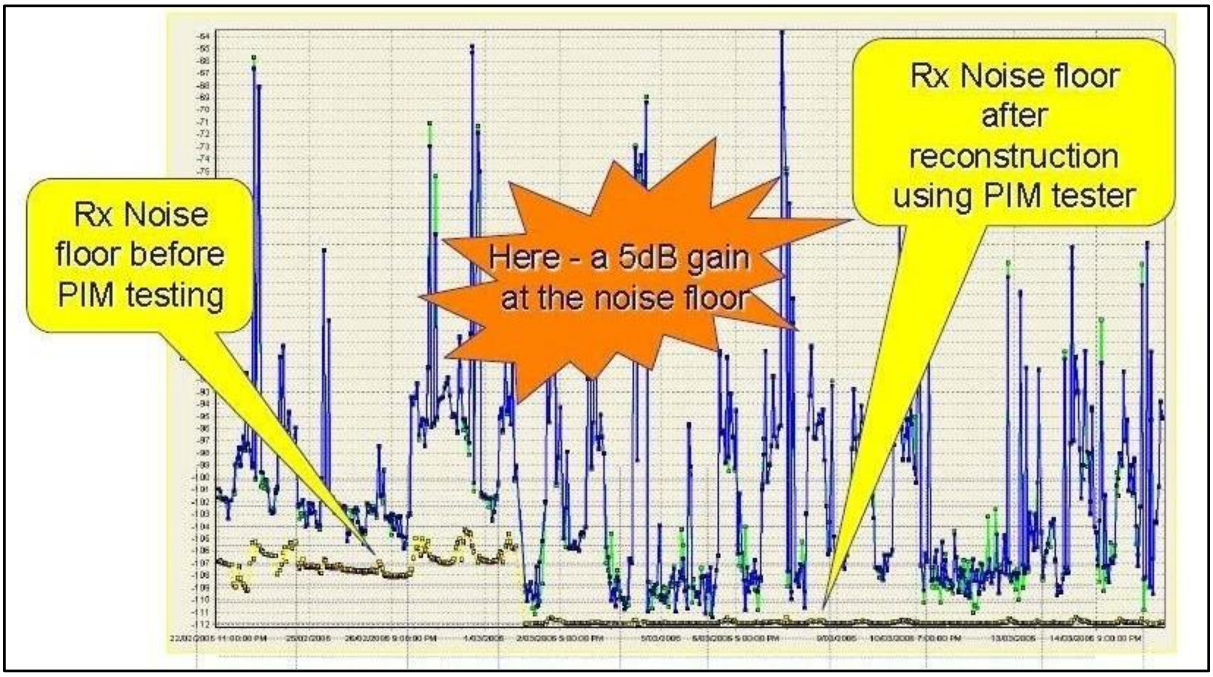

Figure 8 - Poor PIM Performance on Base Station Receiver

PIM interference causes poor quality of service experience for users on the network and also generates negative perceptions about carrier networks performance and coverage.

Fault-finding the source of PIM becomes much more complicated when a DAS is operational and supporting customer traffic since building works and fit-outs are completed by the time a DAS gets commissioned. The process of fault-finding and repair also takes much longer because there are physical access limitations to areas which have been sealed/closed upon completion of construction fit-outs and also simply to find suitable timeslots to undertake the repairs when a building/DAS may be quieter.

From a carrier perspective, once the DAS is accepted and treated as an active and operational network element, the internal procedures and stakeholder management processes (internal and also for other connected carriers) for any proposed works should be managed in accordance with standard national-level operational processes the carriers each use.

5.3 HOW DO PIM PROBLEMS TYPICALLY ARISE?

The main causes of PIM are:

I. poor quality components;

II. poor workmanship;

III. inappropriate placement of antennas;

IV. Environmental causes from reflective objects near the antennas (generally within the roof space, like AC ducting).

The subsections below outline some further information on these topics.

Since the amplitude the PIM products obeys a non-linear characteristic, PIM products become more prevalent as the power levels increase. These types of PIM issues typically arise when the DAS is commissioned and begins to take more traffic – after handover.

Consequently, the Carrier's require PIM testing to emulate the characteristics of a DAS which is operating at high power. These "stress tests" are conducted to confirm the DAS will be capable of supporting customers when the DAS is operating all potential carrier equipment in a high traffic operating environment.

5.3.1 POOR QUALITY COMPONENTS

Inevitably, efforts to reduce cost through sourcing of alternate components leads to problems as a consequence of the materials which are used in component manufacture. Thinner material coatings or alloys using greater ferromagnetic content are typically attributed to increased difficulties with PIM. Furthermore, these cheaper components are often more susceptible to degradation due to corrosion and oxidation (diode effect) and less able to tolerate the regular mechanical stresses associated with physical connection and disconnection over long periods of time.

5.3.2 POOR WORKMANSHIP

Poor workmanship often arises with the use of persons who are not appropriately trained in carrier-grade RF cabling and installation requirements. Although an electrician may know how to run and terminate a telephone line or LAN cable, and possibly even splice an optical fibre, the specific PIM sensitivities associated with properly installing and terminating RF cabling are often not fully appreciated until the system fails a PIM test.

5.3.3 INAPPROPRIATE PLACEMENT OF ANTENNAS

The small, low gain antennas normally used in DAS construction tend to illuminate external PIM sources near the antenna. These PIM sources are often behind the antenna, making them difficult to locate. Optimal antenna locations may be determined by PIM testing the antenna at its design location to evaluate external PIM sources. Moving the antenna within a few meters of the design location typically will have little impact on coverage, but may have a significant impact on PIM results. Small movements of the antenna away from the primary PIM source – usually within a 1m diameter circle – resolves most external PIM problems while maintaining desired coverage.

5.4 HOW DO PIM PROBLEMS TYPICALLY ARISE?

PIM can be generated anywhere in the RF path. The RF path includes not only the antenna feed system but also includes the antenna itself, as well as objects excited by the antenna. Since RF currents are strongest inside the coaxial cables and physically close to the antenna radiating aperture, non-linear junctions or materials in these locations are more likely to generate harmful PIM. As the RF currents decrease with distance from the RF path, the PIM levels will decrease according to a non-linear characteristic and will have less impact on the wider system.

The following list provides guidelines for minimising PIM in DAS installations:

- Antennas inside ceiling cavities or within cluttered environments will lead to reduced coverage and will be more prone to PIM.
- Avoid placing antennas near exit lights, door openers, LAN cables or other equipment which emits electrical interference.
- Use factory terminated and PIM certified RF jumper cables where possible
- Higher quality components made from high quality materials will not experience corrosion or oxidation (diode effect), whereas cheaper quality materials will.
- Use of compression fit connectors from the Carrier's approved hardware list opposed to manual fit connectors.
- Visually inspect RF connectors & RF cables before assembly to remove all metal flakes
- Verify that RF mating surfaces are clean and free of mechanical damage prior to assembly
- Wipe mating surfaces with a lint-free wipe, moistened with alcohol to remove dirt & oils
- Face coaxial cables downward while cutting so that any metal flakes produced fall out rather than into the coaxial cable
- Always use sharp cutting tools when preparing the ends of coaxial cables

- Use the correct cable preparation tools for the type and size coaxial cable you are working with
- Remove any metal burs from the cut edges of coaxial cables prior to connector attachment
- Prevent foam dielectric material from getting trapped between metal contacting surfaces
- Remove all adhesive residue from the mating region of the coaxial cable centre conductor
- Properly align RF connectors prior to assembly to prevent damage to mating surfaces
- Apply the manufacturer’s specified torque to all mated pairs of RF connectors.
- Do not over-torque RF connectors as this may cause damage to contacting surfaces
- Prevent excessive vibration and shock to RF components when transporting them to the site
- Leave protective caps on RF connectors until you are ready to attach the mating cable
- Position Antennas to avoid proximity to cable trays, vent pipes, air conditioning units, metal flashing, etc.
- Avoid loose metal objects (mounting hardware, metal chains, etc.) anywhere within 500mm of antennas

During construction, care should be taken to avoid mechanical stresses on RF connections so they do not create PIM sources over time. Proper mounting of components to a support structure and the use of stress relief in the cabling will assist in long term PIM performance.

Figure 9 indicates an initial and improved construction of a section of a MIMO RF path. The initial construction had components mounted by cable ties to plasterboard anchors, had no stress relieve and had poor tool access. Testing was difficult and the plasterboard anchors were not strong enough to properly secure the components and cables when assembly torque was applied. Consequently the anchors pulled out, leaving components hanging by the RF cables, introducing stresses to the RF connections. PIM became erratic over time.

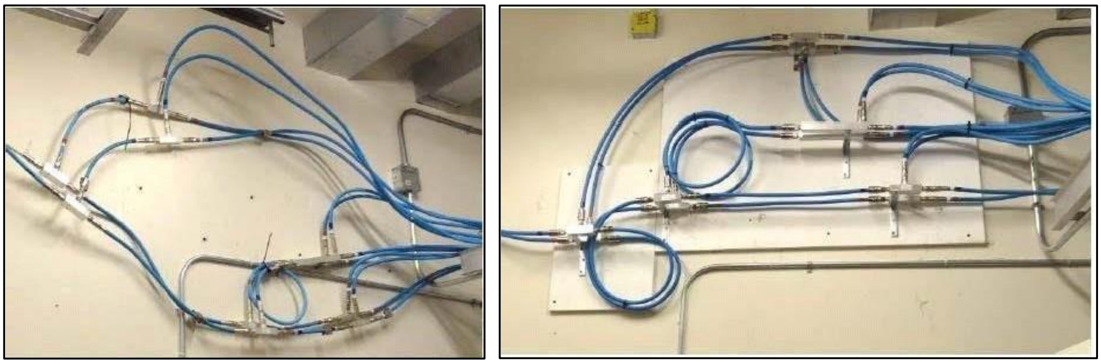

Figure 9 - Initial and Improved Installation to Reduce Stress on RF Connections and Improve Testability

In this case, by securing the components to a wooden surface, adding cable stress relief and providing for appropriate tool access, the PIM performance became much more stable. Secure mounting provided a means to isolate mechanical stresses introduced during test and allowed for easy access of torque wrenches.

5.5 WIDEBAND NOISE

One of the issues that we need to be careful of in the design of DAS's is the general noise floor of the DAS.

Issues such as PIM can cause a DAS to be ineffective, but so can wideband noise. The sources of wideband noise can be many and varied. In modern buildings the source is often a switched mode power supply or a digital signal that is not properly constrained.

LED lights need a low voltage power source, and compact switched mode power supplies are often used for this. Unfortunately, the quality of RFI suppression in these power supplies is often not very good. As a result, they generate a lot of wideband noise at quite high levels and the wiring to the LEDs and the AC power acts as radiators which can get into other systems such as cellular DAS's.

Cables with digital signals that are not well shielded can also act as wideband noise sources. These include video monitor cables, ethernet cables and similar digital signalling cables.

Other sources of wideband noise include large screen monitors, some light control circuits and similar digital devices.

Fortunately, levels of interference from most of these devices falls away with distance so it can often be simply managed using separation. In cases where it is not able to be managed it may be necessary to change the offending device. This may be a LED light incorporating a SMPS or a better quality of cable.

It is required that wideband noise sources be considered in the design and performance criteria of a DAS.

5.6 MINIMISING WIDEBAND NOISE

One way to minimise wideband noise is to identify possible wideband noise sources at design time. This will allow the DAS antennas to be located with enough distance from interference sources to ensure a low noise floor in the cellular bands. Distances greater than 1m from obstructing or interfering objects such as lighting and cabling can typically minimise signal noise.

If this is not possible because of the early stages of the design of the building it would then require checking the noise floor as antennas are installed to confirm they pass the wideband noise requirements.

5.7 MEASURING WIDEBAND NOISE

Measuring wideband noise in band on an active cellular frequency can be difficult due to the presence of active cellular signals. It will be possible to measure high level signals that dominate the cellular signal, but it will be difficult to measure signals that are at or below the level of the active cellular signals.

Given the wideband nature of these signals it may be possible to measure the wideband noise levels in the guard bands between cellular carriers. This will depend on several factors such as guard band IoT system usage and the actual bandwidth of the main carrier.

6. INSTALLATION GUIDELINES

All DAS components are specifically designed to transmit radio waves in a manner optimised to the radio frequency bands they are designed to support. All DAS components are exceptionally sensitive and may not operate properly if they are mishandled. For example, seemingly minor issues such as kinking or over-bending RF cable will disrupt its ability to properly transmit signal and will result in PIM difficulties or other defects – even after a damaged cable has been straightened. Similar performance problems will be encountered with optic fibre cables which are improperly handled.

The following processes will reduce the likelihood of installation defects which may lead to rejection of a DAS during the acceptance process by carriers.

Note that under no circumstances do the following instructions override Building Codes of Australia. Where there is any conflict with the building codes, installation contractor should follow Building Code of Australia.

It is not acceptable for conduits containing DAS Cable to be 'sunk' into the concrete during the slab pour.

6.1 CABLE HANDLING

Upon delivery of cable, each reel is to be inspected for damage. Reel numbers with cable lengths are to be logged at time of delivery.

Cable is to remain on the reels with lagging in place until delivered to the workplace for installation. Cable reels should always be transported or stored in the upright position.

Once delivered on site suitable reel stands, rated for the reel diameter and weight, should be used to unroll the cable for installation.

Cable should be unreeled carefully to avoid twisting. Care should be taken to ensure that the minimum- bending radius specified for repeated bends of each type of cable is not exceeded. Refer to Section 6.1.4 below for more details regarding bending radius.

If short cable pieces are cut off for installation from the reel, the cable ends should be protected again with caps to avoid water or dirt penetrating the cable.

Some fire rated cables are not UV resistant over a longer period of time and should, therefore, not be stored outdoors over a prolonged period of time, unprotected against UV radiation.

6.1.1 PASSIVE BACKBONE

All backbone feeder cables should run to the equipment room and be terminated with a DIN 7-16 or 4.3- 10 female connector that meets the approved equipment requirements of the Lead Carrier.

Wherever possible, cables are to be installed on the existing communication cable trays/ladders between the equipment room and the communications riser. It is the DAS contractor's responsibility to ensure sufficient space is available and where space is not available, additional cable trays/ladders should be supplied and installed.

If it is necessary to stack cables on top of each other, any cables that have connectors on the end should be installed in a manner that allows future access to the connectors.

The backbone cables should be secured to the cable tray at intervals not exceeding the manufacturer's maximum distance between supports.

The best method for attaching the cables to the trays is by use of nylon cable ties. If this is not possible any other approved fixing clamp may be substituted.

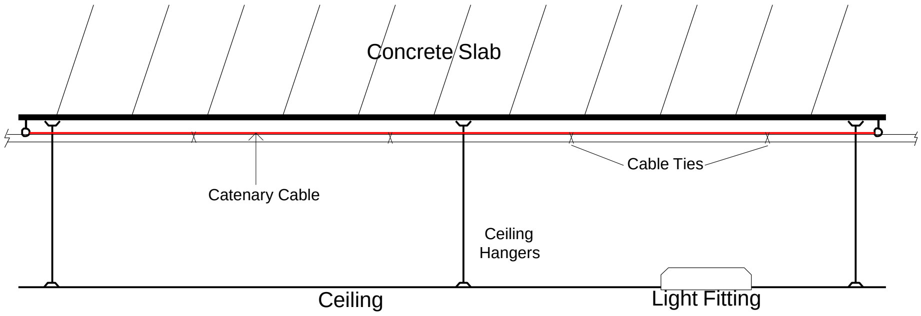

Figure 10 - Typical Cable Installation on catenary wire

Figure 11 shows the layout of the backbone cable in a typical installation. The coupler should be located in a position that is uncluttered and with a view to future maintenance. Both the coupler and cable should be secured to the riser wall or tray. Most couplers have holes to allow them to be screwed to the wall, but cable ties are also acceptable. Jumper cables may be omitted from one port if there is sufficient space to provide strain relief by putting a bend in a backbone cable.

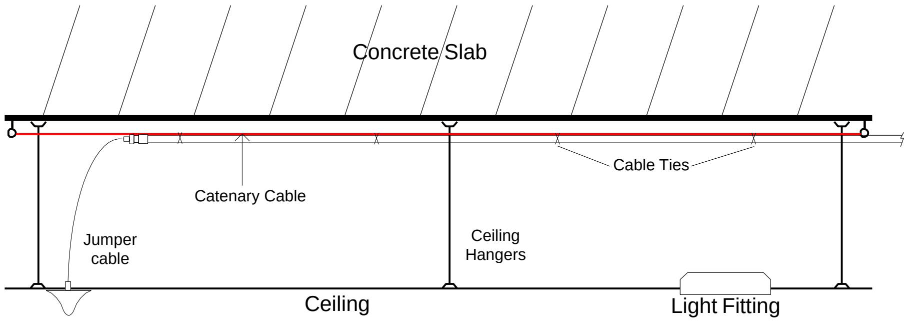

Figure 11 - Distribution from backbone cable

All cabling in the riser should be fixed neatly along the tray or to the wall with appropriate ties.

All cables should run straight with crossovers kept to a minimum. Multiple feeders are to be installed in bundles, wherever practicable.

When running feeders in existing or new cable trays, appropriate separation distances from existing services should be maintained to ensure avoidance of interference both physical or otherwise.

Fire-proof sealing should be applied at all penetrations where a cable crosses boundary from one fire control region to another, such as from a riser into a floor area. Watertight glands should also be installed where necessary.

6.1.2 ACTIVE BACKBONE

The requirements described in Section 6.1.1 above are still applicable, however Optical Fibre or Ethernet cabling may be used to feed remote units in place of RF cables. All hybrid and active DAS cables should be approved by the Lead Carrier and should run to the common equipment room.

The type of cabling required will be determined by the type/specification of approved active equipment solution utilised.

6.1.3 BRANCH (FLOOR) CABLING

Cables run in the roof space cable should installed on catenary (best practice) or cable trays unless explicitly permission given otherwise.

6.1.4 CABLE BENDING RADIUS

When installing any cables, they should not be bent more than the manufacturer specified minimum bending radius. There are two different specifications for most cables: i) Single bend; or ii) Multiple bends.

Generally, the single bend specification refers to the instance where a cable is bent in one direction only – for example, a right angle or in a loop. The multiple bend specification covers the instance where a cable is bent in one direction then back again as in an S bend. In cases where only a multiple bend radius is specified by the manufacturer, this should also apply to a single bend.

If cables are bent beyond the manufacturer's specification at any time, it is highly likely the outer conductor will be distorted. Although this may not be visible, it often severely impacts performance of the cable. Only testing will reveal this. The only remedy is replacement of the affected cable.

6.1.5 CABLE TENSILE STRENGTH

The maximum weight that can be applied longitudinally to any point of the cable is classified as its tensile strength. The tensile strength of RF and Fibre Optic cables is provided by manufacturers.

When hauling cables either horizontally across a cable tray or vertically up a riser, care should be taken not to exceed the tensile strength of the cable. If too long a length of cable is hauled, exceeding its tensile strength, the cable will be stretched damaging the cable and degrading its performance.

If a cable is hauled up a riser and only supported from its end point, the total weight of the cable should not exceed the tensile strength of that cable.

6.1.6 RF CONNECTORS

Good connector termination is paramount to good PIM performance. Great care and use of the correct cable preparation tools is essential. No cable should be prepared with the use of hand tools. Always use the manufacturer's recommended tools. Connector fitting to twisted pair cables is important and the appropriate shielded connectors are required. Poor Return Loss and frequency response of twisted pair can result in no communication between hub and remote small cell.

When cutting cable with a hollow centre conductor, ensure no fillings remain within the centre conductor otherwise poor PIM performance may develop over time – normally as the RF loads being carried through the DAS increase.

All manufacturers have instructions on connector termination which should be sourced for each different type of connector used and should be followed.

6.1.7 FEEDER CABLE MOUNTING (NON-RADIATING CABLE)

The cable should be neatly fixed, taking the shortest possible path, to the ceiling grid hangers by cable ties, allowing the maximum possible clearance above the ceiling tiles so as not to inhibit the lifting of ceiling tiles for maintenance purposes. Cable ties should be placed at intervals of not more than 2 metres. Note the requirements of Section 6.1.3 with respect to the use of ceiling hangers.

Cables under concrete slab needs to be attached at intervals of not more than 2 metres.

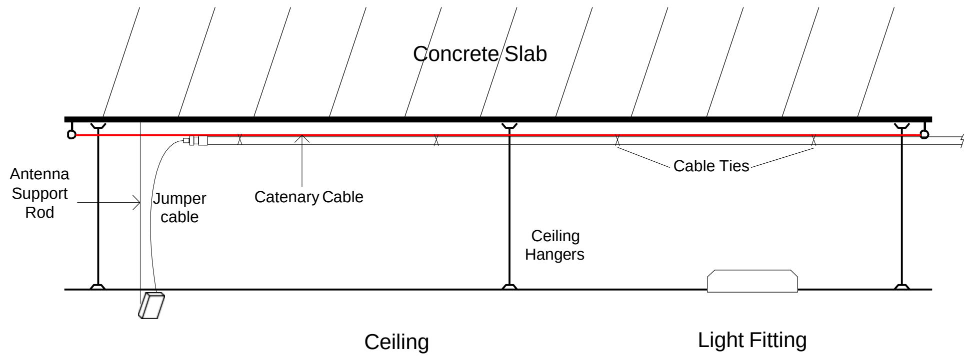

Figure 12 Floor Cable Mounting

6.1.8 RADIATING CABLE MOUNTING

In all situations involving deployment of radiating cable, the manufacturer's installation recommendations should be followed.

Radiating cables are not recommended for general use in applications where placement may lead to difficulties associated with PIM throughout the life of the DAS. The use of radiating cable should be specifically approved by the lead carrier in all proposed installations.

6.2 ANTENNA INSTALLATION

An antenna should be installed so that it is not normally accessible to the general public.

In its installed operating position, the antenna's EME compliance boundary should not extend or encroach into locations normally accessible to the general public.

Recommended installation practices are:

Category 1 antennas (20 cm compliance boundary) - should where possible be mounted on the ceiling or in locations that are not easily accessible to the general public.

Category 2 antennas (>20 cm compliance boundary) - installation will be dependent on the specific size of the compliance boundary and mounted with the same consideration as for macro site antenna.

For more details, refer to AMTA RF Safety Program Document, “EME Compliance for IBC and DAS Systems”.

Where a DAS designer cannot access this information, they should request the Lead Carrier to provide it.

Antennas should always be installed as far away as practical from metallic items that may affect their radiation pattern or cause PIM issues. They should also be mounted below any obstructions that will affect their radiation pattern.

When flexible tails are supplied as part of the antenna, patch leads should not be used to connect the antenna to the feeder. However, it is an acceptable installation technique to use a male connector on the end of a feeder where there is insufficient length in the manufacturer supplied antenna-tail for direct connection. Whilst it is not preferable an option to use tails is possible depending on construction constraints.

6.2.1 MOUNTING OF OMNIDIRECTIONAL ANTENNAS

The space around the antenna (including the ceiling space) should be as clear of metal objects as possible to minimise the generation of intermodulation products and prevent distortion of the radiation pattern.

Ideally, there should be no metal objects within 600mm of the antenna. In practice, locate antennas centrally in or on a ceiling tile to maximise the spacing from the supporting grid and place as far as from ductwork, cable trays, emergency lighting, door openers, etc.

Omnidirectional antennas should be installed on the underside of the ceiling. Alternate antenna locations which do not meet this requirement (e.g. for aesthetic reasons) should be specifically approved and installed subject to the conditions indicated by the Lead Carrier who will be responsible for the ongoing operation and performance of the DAS.

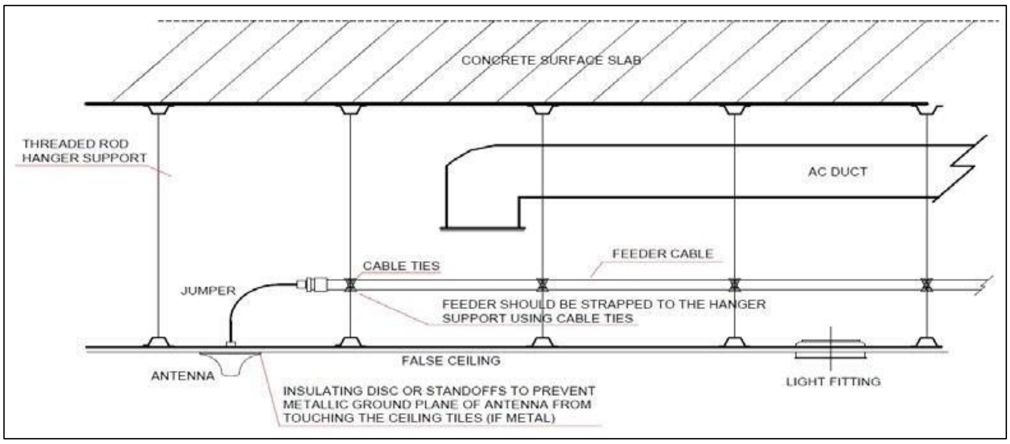

Figure 13 - Omnidirectional antenna Installation below false ceiling

Ensure that the metal ground plane of the antenna is insulated from the metal ceiling tiles, by using an insulating disc, insulated standoffs or in some cases the radome of the antenna may provide an effective stand-off if it wraps sufficiently over the edge of the ground plane.

Antennas which have a non-metallic securing nut are preferred in this situation. When screws are required to secure the antenna to the ceiling, use non-metallic screws, nuts and washers (nylon or similar).

When there are no false ceilings, the antenna should be supported on a bracket in such a way that the antenna is below the height of any obstructions. Where there are no obstructions, such as in a car park, the antenna can be fixed against the concrete slab.

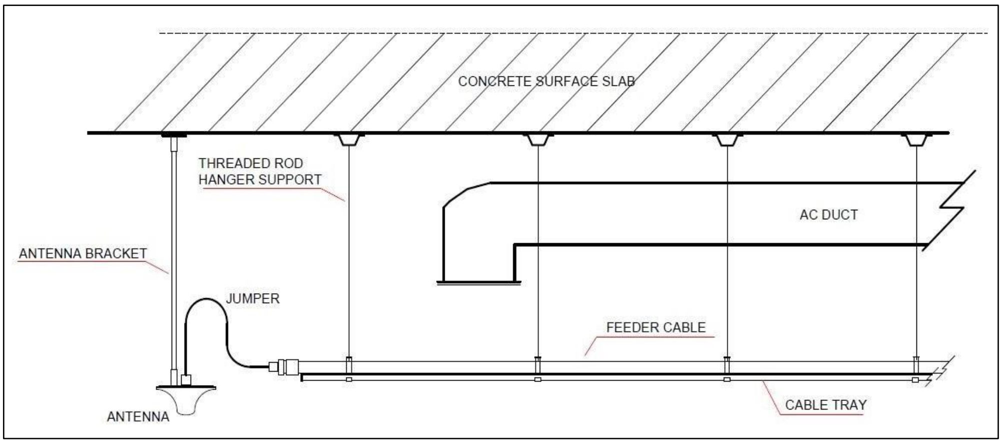

Figure 14 - Omnidirectional antenna mounted where no false ceiling exists

6.2.2 MOUNTING OF PANEL ANTENNAS

The panel antenna is a directional antenna. It needs to be mounted away from metal surfaces to minimise the generation of intermodulation products and prevent distortion of the radiation pattern. There cannot be metal objects within 1.2m of the coverage arc in front of the antenna.

Specify installation of panel antennas on a wall or the underside of the ceiling. Alternate antenna locations which do not meet this requirement (e.g. for aesthetic reasons) should be specifically approved and installed subject to the conditions indicated by the Lead Carrier who will be responsible for the ongoing operation and performance of the DAS.

The antenna should point in the same direction as specified in the design. If this cannot be achieved by flush mounting against a wall, then a bracket allowing rotation will be required.

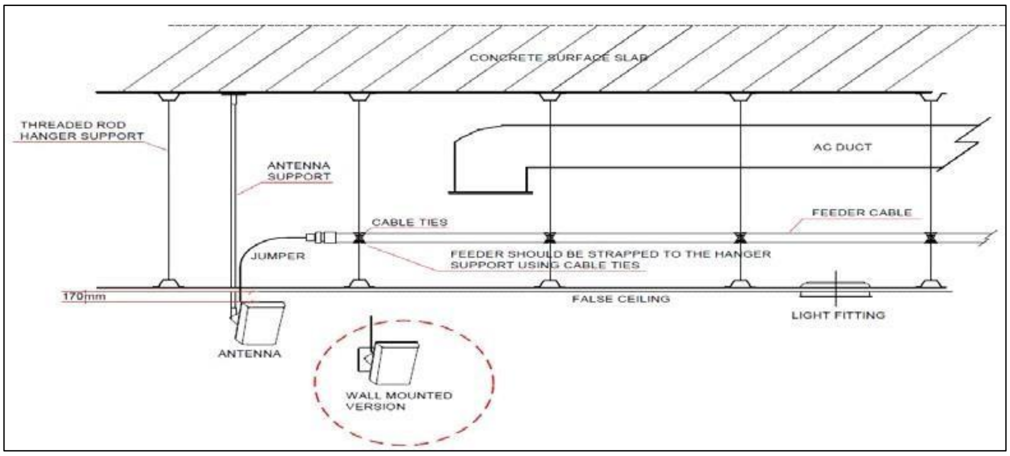

Figure 15 - Mounting of panel antennas

6.3 SPLITTER MOUNTING

The components should be located in a position that is uncluttered and which provides good access for future maintenance. Both the component and cable should be secured to the riser wall or tray.

Some splitters or couplers have holes to allow them to be screwed to the wall, these may be used if adequate clearance is available to remove cables when installed. Where adequate spacing is not available, tailor made support brackets and cable ties should be used to secure the component.

Adaptors should never be used to connect cables or components together.

Under no circumstance is a component to be installed so it is only supported by the cables attached to it.

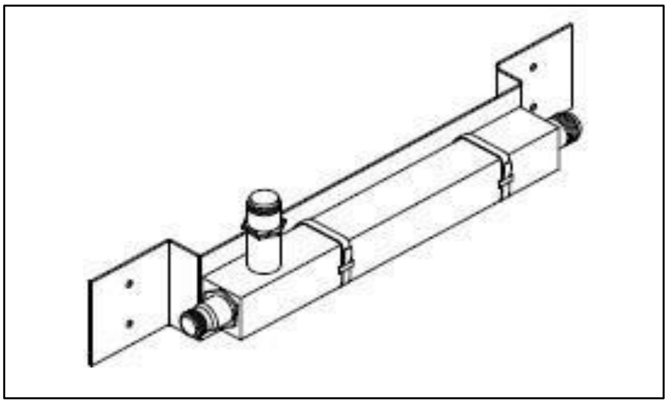

Figure 16 - Example of splitter / coupler mounting bracket

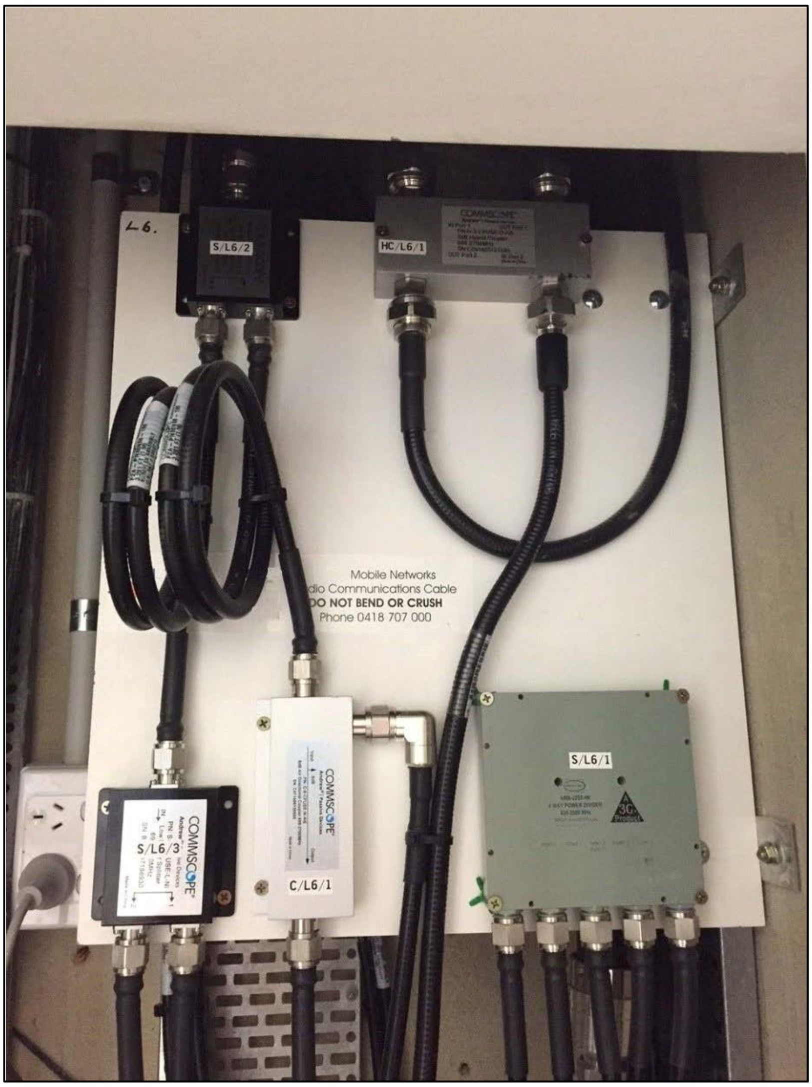

Figure 17 - Typical Installation

6.4 JUMPER CABLES

The use of jumper cables should be considered and factored at the design stage to avoid:

a. physical installation constraints – for example, it is not possible to install what has been designed in a manner that will physically fit, or be technician-serviceable; or

b. insertion loss impacts – for example, the only viable physical installation at site results in an under-powered system due to insertion losses resulting from using more jumper cables than anticipated.

All connectors should be torqued in accordance with the manufacturer's standards.

Jumper cables are required to connect:

1) All feeder cables to passive components (Splitters, couplers, MNC, etc)

2) All feeder cables to antennas (with or without fly leads)

3) One passive component to another

4) All feeder cables connecting to base station equipment and active DAS Equipment

The DAS designer should propose the jumper length and cable type suitable to ensure insertion loss has been considered at design stage as well as practicality of installation.

It is recommended to use jumper cables with 4.3-10 Male connectors at both ends that are from the Carriers approved hardware list. Where it has been determined that it is better to use jumper cables for all ports of a component, it is important to confirm the additional insertion losses remain consistent with the power levels from the original design, and arrange recalculation – particularly towards the far end of the distributed antenna system. Insertion loss problems may become more significant when the use of jumper cables is repeated many times in the backbone.

Normal practice is to put a loop in the jumper cable to further minimize any stress being placed on the connectors. Use of this installation technique also makes it much easier to disconnect components, which will be necessary in the later testing phases. Figure 17 shows a well organised installation utilising jumper cables.

IMPORTANT: If jumper cables have not been specified in the design but they are used during installation, the as-built configuration should be recalculated and reassessed by the designer as it may have an adverse impact on the original design due to extra insertion losses.

6.5 OPTICAL FIBRE INSTALLATION GUIDELINES

Optical cable is sensitive and will not perform correctly if it is has been incorrectly installed or the cable integrity has been compromised (over-bent etc.) during the installation process.

Where the DAS installer has provided optic fibre as part of the DAS, it should be installed and tested to meet the performance specifications indicated in Section 3.22.9.1 and 7.7.

6.5.1 OPTICAL FIBRE CABLING IN EQUIPMENT ROOMS

All cables should be terminated into a patch panel. Patch panels with inbuilt splicing trays should be used.

On smaller jobs a single RU unit that typically has 12 connectors can be used. For larger fibre count cables, larger tray units which have multiple rows of connectors should be used. These allow pigtails to be spliced onto the fibres and then terminated into the patch panel. These should be mounted into the same cabinet as the Active equipment. Cable management systems should be utilised to keep all cabling neat.

The connector type should be SC, SC-APC, LC as recommended by the equipment vendor.

Figure 18 - Optic Fibre Rack-mounted Splice Tray and Patch Panel

6.5.2 REMOTE UNIT CABLING

Cables to the remote units should be terminated into a small patch panel. These termination boxes are to be fixed to either the ceiling or another permanent structure that provides suitable support and protection. Pigtails are to be spliced onto the end of the fibre and terminated in the box.

Jumper cables should be used between the termination box and the remote unit. The patch ports are to be labelled as per the corresponding patch panel port in the main equipment room.

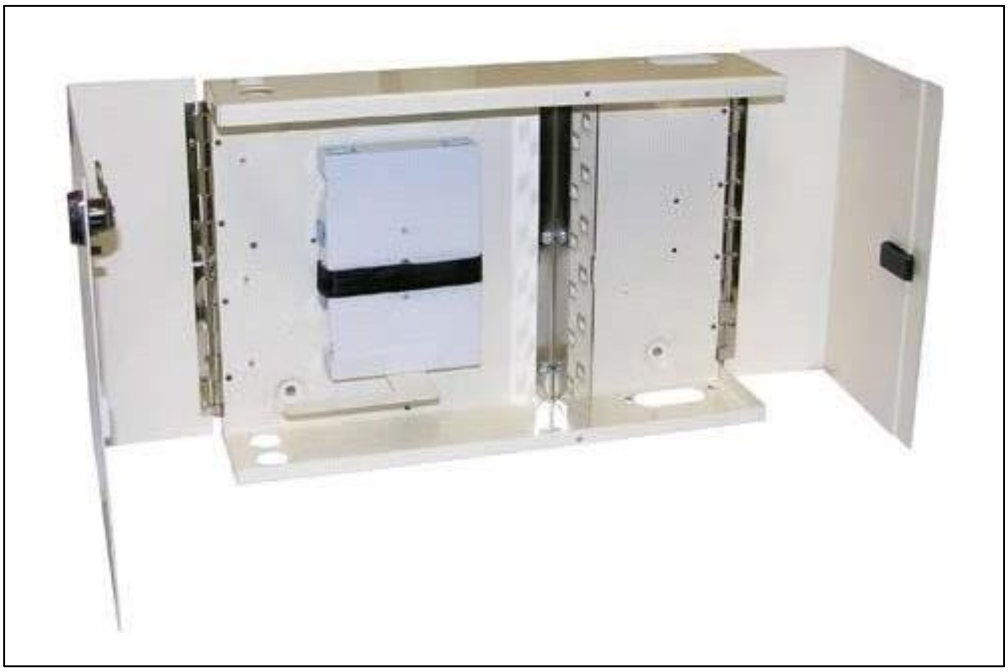

Figure 19 - Optic Fibre Splice Tray and Patch Panel

An acceptable alternative to using patch cables is to splice flexible cables directly onto the end of the fibre. Where this solution has been applied, the splices should be done in a splice box as per the illustration in Figure 20.

Figure 20 - Optic Fibre Splice Box

6.6 OPTICAL FIBRE CABLE INSTALLATION

All cabling should be supported on cable trays / ladders, catenary cables or in conduits. The cable should be neatly fixed, allowing the maximum possible clearance so cables do not get snagged or damaged during any building maintenance activities which may occur in vicinity of the cable (e.g. secure cables so they do not inhibit lifting of ceiling tiles etc.)

Velcro straps are the preferred attaching method to trays etc. When using cable ties to secure cables, they should be left a little loose around the cables to avoid possible damage to the fibre.

6.7 GPS ANTENNAS

Where GPS Antennas and feeders are required and they are expected to be installed by the DAS installer.

Cabling between the GPS antenna and the equipment room/s should be installed as per the guidelines in Section 6.1. Where different types of cables are provided, the cable manufacturer instructions should be followed. There should be particular attention given to the suitability of the maximum cable length and cable type for the amount of power required.

GPS antennas will also require the GPS feeder to be earthed (lightning protection earth).

Cables should be terminated into the GPS antenna and the tails left coiled with sufficient excess cable available to allow for termination into carrier base stations. (Note: It will always be better to leave too much cable for the carrier commissioning crew to shorten when terminating into the base station, rather than insufficient cable.)

7. TEST RESULTS

7.1 INSTALLATION / TEST REPORT

The final DAS commissioning report submitted pursuant to Section 4.5 above should provide all of the following:

Information Type	Reference Section	Test Reports
Any Target Coverage Area Exemption Zones with reasoning shown on floor plans	3.3	CW Test Report or Walk Test Report
Test Equipment Used	7.2	PIM test Sweep Test
As-built walk test results	7.6	CW Test Report or Walk Test Report
All sweep results (Return Loss – RL and Distance to Fault – DTF)	7.3	Certificate of Compliance that all sweeps Pass Return Loss and DTF Sweeps in original instrument format for all RF cables Converted Return Loss and DTF Sweeps in PDF or image format for all RF cables.
Insertion Loss	7.4	Sweep Test
PIM results tabulated and referenced to relevant section of DAS	7.5	PIM Test Report
Floor Plans showing all hardware locations	4.5	As-built Pack and design files Note: If iBwave™ is the design tool, iBwave .ibw files should be submitted.
Schematic diagram	4.5	
Composite power table	4.5	
Bill of Material (BOM) used	4.5	
Optic Fibre Testing/Commissioning	7.7	OTDR Test Report
Equipment room layout diagram	4.3	As-Built Pack and design files
Sectorisation plan	4.3	As-Built Pack and design files
Any configuration settings for Active systems	4.3	As-Built Pack and design files

Any site specific details that may be required to maintain the site e.g. circuit breaker number and location	4.3	As-Built Pack
Site Access details	4.3	As-Built Pack
Other DAS information reasonably required for operation and maintenance of the DAS. (May be requested by the Lead Carrier)	4.5	As-Built Pack and design files Note: If iBwaveTM is the design tool, iBwave .bw files should be submitted.

Table 11 - Installation/Test Report

7.2 TEST EQUIPMENT USED

List of all test equipment including:

- Type / Manufacturer / Model number
- Serial number
- Calibration date
- Purpose of test and configuration used for test.

7.3 RF SWEEPS

All RF cables used in the DAS should be swept / have a return loss measurement performed across all frequency bands indicated in Section 2.5.

If any cable is found to not meet specification as listed by the cable manufacturer, the problem should be found and rectified.

All RF sweeps are to be recorded in a similar format as per the diagram below and should include the cable number. The RF sweeps will be sent in electronic format to the Lead Carrier for validation and acceptance.

The majority of instruments can be configured for sweeps to display a Pass/Fail result. The data relating to feeder length should be updated in the As Built and Link Budget. Where a design tool model has not been utilised, the measurements should also be recorded in a spreadsheet summarising all measurements made and show pass/fail status with cross-referencing to the relevant cable number provided in the result.

The date (DD/MM/YYYY) of all measurements should be included in the supplied spreadsheet.

All cables should have a distance-to-fault test performed to validate the installed length of the cable and distance-to-fault value. The actual installation values should be utilised to update the design and recalculate in the as-built documentation to demonstrate it has not adversely impacted the design.

RF Cable sweeps should:

1. Be recorded in a similar format as per the diagram below and should include the cable number in the title.
2. Be performed on each individual feeder cable, without other passive devices, jumpers or antennas connected.
3. A suitable termination load be placed on the far end during test.
4. Display the date and time the test was performed and the calibration status of the instrument during the test.
5. Where the instrument permits (such as with Anritsu) the sweep should be configured to display PASS/FAIL status.
6. Return Loss and DTF limit line configured to represent the manufacturers specification for the equipment under test. This will clearly show PASS/FAIL.
7. Instrument be set to measure 2000 data points or higher for resolution.
8. Either cover all frequency bands indicated in Section 2.5 within one sweep, or multiple sweeps be supplied covering discrete bands (Low/High or Low/Mid/High). Measurement points of the instrument should be configured to provide sufficient resolution.

DAS installers should supply the following information to the Lead Carrier for validation and acceptance:

1. Certificate of Compliance confirming that all sweeps pass
2. Return Loss and DTF Sweeps in original instrument format for all RF cables
3. Converted Return Loss and DTF Sweeps in PDF or image format for all RF cables

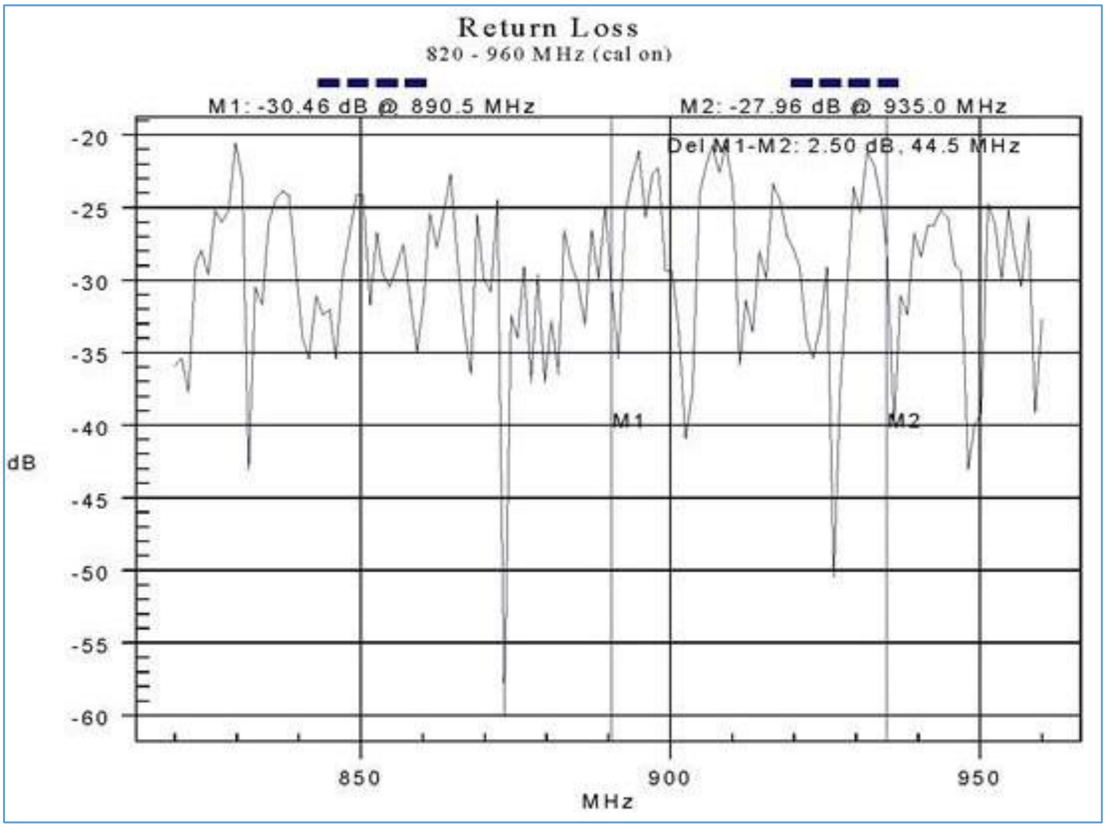

Figure 21 - Example of a Return Loss Sweep

7.4 INSERTION LOSS

The backbone distribution system should be checked and verified against design values for its insertion loss in both a low band, mid band and a high band. The tests should use a 3GPP low band, mid band and a high band selected from:

- Low Band = 700/850/900 MHz
- Mid Band = 1800/2100/2300/2600 MHz
- High Band = 3500 MHz

A signal should be fed in at the base station end and the level out should be measured at the final splitting or coupling point to each floor. Where a splitter feeds more than one floor or there is more than one output from the same splitter to a floor, only one output needs to be tested. The difference between the input level and the output level should be recorded as the insertion loss.

All measurements for insertion loss should be tabulated as per the example below and supplied in electronic format to the Lead Carrier for validation and acceptance:

Test Point	Frequency (3GPP Band)	Input Point	Input Power	Output Power	Measured Insertion Loss (a)	Original Design Insertion Loss (b)	Delta (b) – (a)
Splitter S/3/1	860 MHz	BC/B2/1	+20 dBm	-3 dBm	23.0 dB	22.0 dB	-1.0
Splitter S/3/1	2690 MHz	BC/B2/1	+20 dBm	-7 dBm	27.0 dB	25.0 dB	-2.0
Splitter S/3/1	3605 MHz	BC/B2/1	+20 dBm	-10 dBm	30.0 dB	28.0 dB	-2.0
Splitter S/11/1	860 MHz	BC/B2/1	+20 dBm	-7 dBm	27.5 dB	28.0 dB	0.5
Splitter S/11/1	2690 MHz	BC/B2/1	+20 dBm	-7 dBm	34.5 dB	27.9 dB	-6.6
Splitter S/11/1	3605 MHz	BC/B2/1	+20 dBm	-13 dBm	33.0 dB	30.2 dB	+2.8

Table 12 - Example of Insertion Loss Report

Note: insertion loss tests help quickly determine if any directional couplers have been installed incorrectly or there is a fault in the RF path.

7.5 PASSIVE INTERMODULATION TESTING

Passive intermodulation testing should be carried out in accordance with the document published and maintained by The International Wireless Industry Consortium (IWPC) titled *"TTER: Passive Intermodulation Testing Best Practices"* using the power levels shown in Table 6 to determine the PIM performance of the installed DAS.

Link to document: http://www.iwpc.org/WhitePaper.aspx?WhitePaperID=18
Link to IWPC: www.iwpc.org/

Testing should be done in at least three frequency bands comprising a low band test (one off 700/850/900 MHz), a mid band test (one off 1800/2100/2600 MHz) and a high band test (3500 MHz) where required as per Section 3.18.2 PASSIVE INTERMODULATION (PIM). Test results should be provided showing reflected third-order PIM measurements at the following points:

- Each input of the multi-network combiner with all output ports terminated with a precision 100W load. (MNC PIM test)
- One input on the multi-network combiner with each segment connected to multi-network combiner output individually with the other segments terminated into a precision load. (DAS Segment PIM tests)

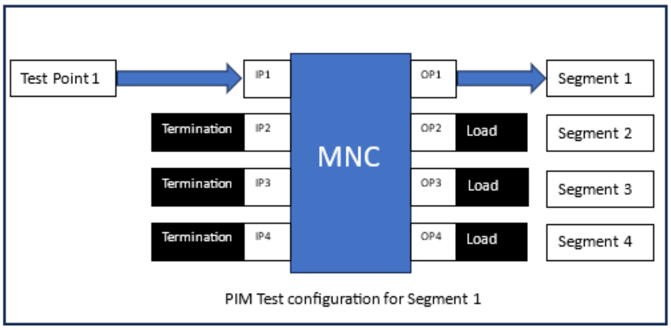

Figure 22 – PIM Test Configuration for Segment 1

Where a DAS segment has a composite input power ≤ 5 watts, the PIM testing should be undertaken with 2 x +33 dBm carriers into the POI. Where a DAS segment has a composite input power > 5 watts then should use the power levels shown in Table 6.

A table of the results, (in either PDF or excel format) of the PIM test results should be submitted, summarising all measurements made and all pass/fail statuses.

Photographs/screenshots showing correct date (DD/MM/YYYY) and time (HH:MM:SS) of PIM measurements should be supplied. At the time testing is undertaken, the PIM test equipment should show the correct time of day for the time zone in which the DAS operates.

PIM testing should be conducted with a device that validly calibrated. The measurement should pass with a duration of 10 seconds or greater (e.g. PIM Vs Time for 10Sec). The DAS installer should provide the original PIM test result files as part of their handover documents.

7.6 WALK TESTS

Post implementation walk surveys (aka coverage surveys) with survey readings should be plotted against final versions of building floor plans that have DAS antenna locations overlayed.

Separate plots are required for each frequency band (where installed) and technology which will be in operation from handover of the DAS.

,A scanner and test transmitters (CW signal generator) should be used at low, mid and high band frequencies:

- Signal levels (downlink (SS-RSRP/RSRP/RSCP) measurements)
- Quality
- Serving cell
- Rank indicator (applicable only for MIMO)
- Dominance over macro
- Handover zones
- Lift car vertical plots in elevation view of lift furthest from coverage antenna
- Demonstrating every installed antenna is operational
- Active call sessions for the designed band
- Demonstrate every antenna has been installed as per the Approved Design and is operational.

7.6.1 WALK TEST ROUTE

The walk test route should cover all trafficable areas of the building and meet or exceed the performance requirements for >95% of locations specified throughout this document.

The walk test route should pass under each antenna to highlight antenna transmitting required signal. It is a sign to demonstrate the antenna is connected.

The walk test route should specifically demonstrate DAS performance at the perimeter of each floor (to validate the DAS provides dominance over the macro apart from any agreed Exemption Zone) along with performance within the Target Coverage Areas as defined in Section 3.3.

The walk test route should also specifically test handover zones between DAS sectors and between Macro and DAS sectors at portals.

The walk test needs to ensure that the colour scheme used can clearly highlight where a DAS passes and fails the required KPI’s.

Walk test is to also include approved Exemption Zones.

All lifts are to be surveyed.

Frequency Band	Optus	Telstra	TPG	*Other*
700MHz				
850MHz				
900MHz				
1800MHz				
2100MHz				
2300MHz				
2600MHz				
3500MHz				

Table 13 - Walk tests to be conducted for all technologies and frequency bands which will operate from DAS handover

7.6.2 WALK TEST MEASUREMENTS

For NR technology, the signal strength measurement should be SS-RSRP in dBm for each PCI and the quality measurement should be CINR or SINR in dB for each PCI.

For LTE technology, the signal strength measurement should be RSRP in dBm for each PCI and the quality measurement should be CINR or SINR in dB for each PCI.

7.6.3 WALK TEST RESULTS

The results for walk tests are to be recorded using graduated- colour coded snail trail in a manner like Figure 23.

The log files for these tests should be supplied to the Lead Carrier as directed. This will typically be uploaded to a web-based file server which is accessible by the Lead Carrier.

Files should be in readable format without the need of any program processing, and they need to include a summary of the DAS performance and possible faulty points in the DAS (and plan for rectification).

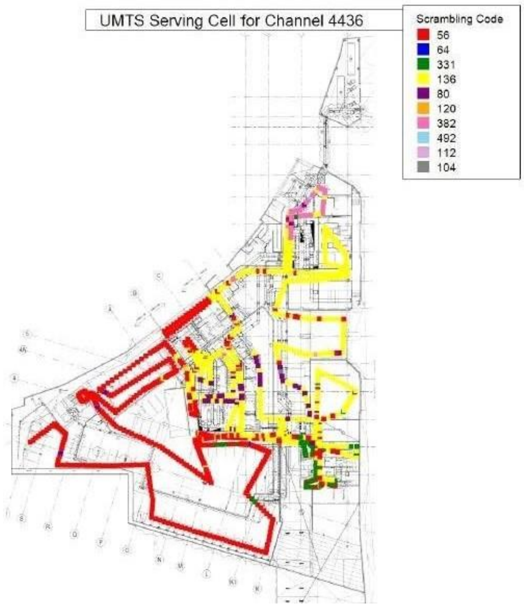

Figure 23 - Example of colour-coded coverage survey result

7.6.4 LIFT CAR VERTICAL PLOTS

The carriers will require to see a demonstration of RF penetration into each lift car installed at the premises and the behaviour at handoff between sectors within a lift – e.g. travelling through different sectors, or in the case of door closures leading to a sector handoff depending on the design architecture. Lifts which service high rises and by-pass lower levels (i.e. lifts which do not gain signal through lift doors in the lower levels of a building) will be a particular focus.

The two primary test scenarios which will demonstrate satisfactory in-lift performance are:

1) High speed travel through the entire lift run non-stop from end to end; and

2) Stop at each level, open doors and close doors.

The recording method to plot results will depend on the type of test being conducted – for example, a high-speed lift-travel run would likely use an established frequency of (say) 5 samples per second to plot performance as a user travels through the lift shaft from end to end (lowest level to highest level serviced by that particular lift). Whereas lift door-stop tests may use manual sampling at each floor.

High speed lifts, defined as a lift that travels 8m/s or two floors per second should incorporate dedicated in lift solutions (where possible) to provide coverage and seamless network performance and handover. The solution to be implemented should be in consultation with the Lead Carrier.

7.7 OPTIC FIBRE TESTING & COMMISSIONING

7.7.1 OPTICAL TIME DOMAIN REFLECTOMETER (OTDR)

Either “Mini” or “Full Featured” OTDR instruments, immune to polarisation noise and conforming to the Telcordia GR-196-CORE “Generic Requirements for Optical Time Domain Reflectometer (OTDR) – Type Equipment” are to be used for all OTDR measurements.

The OTDR should be capable of storing the traces on an electronic medium (e.g. USB stick) for transportation/submission; allow retrieval and reading of traces. All traces are to be stored and submitted – preferably in a format compatible with Telcordia standard SR4731- Issue 2 (SOR).

OTDR testing should be performed on all fibres in both directions (two-way) at 1310 and 1550

nm. Visual inspection of optic connector end faces to meet the IEC standard (IEC 61300-3-35).

Please reference AS/NZS ISO/IEC 14763.3:2012) and 2. TIA-568 C.3, as these will allow auto-population of parameters.

7.7.2 SECTION LINK LENGTH

The Section Link Length (L) or the optical OTDR Link Length is measured from the 1550nm OTDR trace. This is required for the theoretical calculation of OTDR Link loss (LL) and for calculation of Insertion Loss criteria.

7.7.3 OTDR LINK LOSS

OTDR Link Loss measurements should be completed on all fibres to confirm the integrity of the cable link without including the performance of the end connector/pigtails. These results can be achieved contingent on the use of core based splicing machines, and quality pigtails.

Two-way averaged OTDR Link Loss (LL) is measured at 1550nm and 1625nm from the bidirectional OTDR traces, as LL λ=1550nm and LL λ = 1625nm respectively. The measured OTDR Link Loss should conform to the following criteria:

- LL λ=1310nm ≤ 0.35L + 0.1N + 0.3;
- LL λ=1550nm ≤ 0.21L + 0.1N + 0.3; and
- LL λ=1625nm ≤ 0.25L + 0.1N + 0.3

L = the optical OTDR link Length in km (measured at 1550nm) N

= Number of splices excluding pigtail terminations.

Compliance with these parameters should be demonstrated at the time of DAS handover. The DAS Contractor will be required to resolve any anomalies and achieve this criteria.

8. CARRIER EQUIPMENT & ACCOMMODATION REQUIREMENTS

This Section outlines the typical accommodation and provisioning requirement for carriers which should be provided for a DAS. The specific nature of carrier requirements will vary depending on the capacity requirements for the site and the type of DAS solution which will be used. The Lead Carrier will advise specific requirements.

8.1 CARRIER ROOM SPECIFICATIONS

The equipment room contains base station equipment that will be installed and connected to the Distributed Antenna System (DAS). The floor space required to cater for 3 Carrier's is a minimum of 32m² (based on a 5.33m x 6m room size).

8.2 CARRIER EQUIPMENT RACK SPACE REQUIREMENTS

8.2.1 CARRIER RACK SPACE REQUIREMENTS FOR MAIN DAS ROOM

The minimum space requirement is 6 x racks per carrier = 18 racks total. The Lead Carrier should be consulted to determine whether more space may be required.

Allocation should also be considered for active DAS Equipment front end requirements as well as 2 x neutral equipment racks.

Rack allocations for all Carriers should be clearly shown in equipment room floor plan in the design documentation.

Equipment Rack Dimensions:–

- External Height – 2500mm
- External Width – 600mm
- External Depth (Including Door) – 1200mm

8.2.2 CARRIER SPACE REQUIREMENTS FOR PASSIVE REMOTE (RRU) LOCATION (RACK OR WALL)

DAS systems which have been designed to utilise Carrier remote radio unit (RRU) equipment locations throughout a property will require sufficient space to house several remote equipment units and associated ancillary requirements for each operator. Depending on the number of bands being deployed by each operator this will require a minimum of 3 x rack spaces per Carrier, The locations chosen should be easily accessible by each Carrier with appropriate consideration for access security, power availability per Carrier, fibre provisioning and environmental heat management to avoid overheating.

8.2.3 CARRIER SPACE REQUIREMENTS FOR ACTIVE REMOTE LOCATION

Active or Hybrid DAS systems which typically utilise remote equipment locations throughout a property will require sufficient space to house several remote equipment units and associated ancillary requirements. A minimum of 4 x rack spaces should be allowed for per remote location.

The locations chosen should be easily accessible by each Carrier with appropriate consideration for access security, power availability per Carrier, fibre provisioning and environmental heat management to avoid overheating.

8.3 POWER

8.3.1 AC POWER REQUIREMENTS

Following requirements are to be provided at the incomer of the DAS Room distribution board to reduce the impact of lightning strikes.

Distribution board requirements:

- One DB is required and should be wall-mounted within the room.
- 1 x 36-pole MCB chassis.
- The DB will have a 160A isolator, surge protection at the incomer only,
- Typically the DB will be 3-phase provided with a 100A per phase essential (generator-backed if possible) supply. Larger installations such as stadiums will need an electrical engineering solution. The circuit breakers within the DB for supply to the carrier's equipment are to be supplied and installed by the carriers.

Power should also be provisioned to all Active remote unit equipment or proposed carrier remote unit equipment and connected to house power.

8.3.2 AUXILIARY POWER AND REDUNDANCY

Essential Power is typically not required in the main DAS room as each Carrier will provide their own batteries within their own racks, however, it is preferred to underpin continuity of service.

In DAS deployments, Carriers usually deploy their equipment with up to 3 hours of battery backup power in case of power outages. This configuration will enable normal function of all components of Passive DAS which may be directly fed from the carrier radio equipment for up to 3 hours.

Any remote active DAS Equipment or Carrier remote radio unit equipment which is not connected to auxiliary power will not be available during power outages unless the requirement is factored into DAS design.

In cases where more robust communications service levels may be specified or required (such as tunnels, hospitals, or other critical infrastructure environments), the Lead Carriers should be engaged to co-ordinate auxiliary power solutions. These solutions may involve shared use of building generators or in some cases more battery strings (which will have floor loading implications).

As indicated above, special consideration for provision of backup power to remote active DAS Equipment or Carrier remote unit equipment should also be addressed where there may be an expectation of continued mobile communication during power interruptions.

Essential power, components and cables (both communications and power) should be connected to a compliant earthing system as per AS/NZS 3015.

Any essential power installation that includes batteries should provision the environmental requirements set out in AS/NZS 3015 (i.e. ventilation). This should be considered for all Carriers reserve technology choice.

For any installation the same reserve technology/chemistry (ie VRLA, Lithium) should be used for each carrier to ensure that the environmental requirements can be met by the facility. If differing technologies should be used, then the carrier initiating the change from the prescribed technology should ensure that their reserve technology is housed in a compliant environment.

8.3.3 POWER SUPPLY TO AIR CONDITIONING

Main DAS and remote unit equipment room air-conditioning should be kept on a separate power supply to the Carrier equipment and administered by the building owner/manager.

8.4 AIR CONDITIONING

The standard requirement is for minimum of 2 x 6KW split air conditioning systems in a 1+1 (hot standby) configuration. This requirement can change based on what or how many technologies are deployed by the Carrier's. The Lead Carrier will provide confirmation upon request. The average heat load per Carrier will also depend on the DAS configuration, as an active system will be hotter in a single room, whereas remote radio units will introduce heat in other locations.

Active DAS Equipment or Carrier remote radio unit equipment locations should also be provisioned with split unit air conditioning commensurate with the heat loading dissipation requirements also in a 1+1 (hot standby) configuration where existing cooling or building ventilation system is not sufficient to cater for the added heat loading requirements.

Carrier equipment generates heat. In certain environments and climatic conditions, the humidity and dew point differentials will lead to condensation. It is important to eliminate condensation / water drip risk to equipment from any vents, pipes or ducting which may be located directly above Carrier equipment or DAS equipment. Cassette-style air conditioner units are particularly prone to drip and should not be installed directly above carrier equipment or DAS equipment.

As stipulated in Section 8.3.3 above, air conditioning is to be provisioned on a separate power circuit.

8.5 FIRE PROTECTION

The Carrier equipment room should be 2-hour fire rated (inside and out) due to the probability that batteries installed in the room by the carriers will have a voltage exceeding 24V and capacity exceeding 10Ah.

Monitored fire alarming is preferable to sprinklers inside the equipment room; this is not compulsory but preferred by the carriers.

Fire retardant cabling should be specified and installed when required.

8.6 CABLE MANAGEMENT

As a minimum 600mm tray leading up to the communications room with a 600mm wide by 100mm high penetration into the communications room for COAX and Fibre access.

This tray infrastructure should be installed above each prescribed rack position at a minimum height of 2500mm and allow for interconnections between all racks. Exceptions to this minimum should be approved by the lead carrier.

All works should be mechanically treated to comply with building and environmental requirements and should utilise proper edging protection/caps.

Where cabling is required externally to the communications room a tray size should be agreed upon with the Lead Carrier.

8.7 REMOTE MULTI-NETWORK COMBINER (MNC) LOCATIONS

In all cases the DAS supplier should provide an MNC which supports the frequency bands listed in Section 2.5 and the performance requirements detailed throughout Section 3.0 as part of the DAS installation.

The Carriers will maintain their approved passive and active DAS materials lists and make them available on the AMTA website alongside the MCF Specification.

Each individual component of the DAS should meet or exceed the performance characteristics detailed for all operating frequency bands listed in Table 1 of Section 2.5 and appear in the approved component list of each of the Carrier's.

It is the responsibility of the Carrier's to each connect their base station equipment to the MNC.

It is strongly preferred and typically more practical for all parties to have a single common location for all the DAS equipment, including the MNC and Carrier base station equipment.

Difficulties may arise and additional connection charges may apply for Carrier connections to the DAS if the MNC is not located within the Carrier equipment room.

In situations where Carriers are attaching to a DAS through an MNC that is not located within the carrier equipment room, the methods used by Carriers to connect to the DAS will vary depending on the circumstances. The DAS supplier should ensure the following provisions are made:

Connection from a Carrier remote active base station unit requires:

- 240V power supply*
- 3 Rack space per Carrier (per dimensions in Section 8.2 above) – within 50m (cable length) of the MNC and a cable path for up to 7/8 inch feeder cable.

Direct RF feed from Carrier base stations require:

- Cable path from Carrier base station equipment to the MNC allowing space for at least 4 x 7/8 inch feeder cables per MNC including required cable containment systems.
- In cases where the MNC cannot be located within 50m of the Carrier base station equipment, consideration should be given to deploying an Active or Hybrid DAS solution. This should be done in consultation with the Lead Carrier.
- MNC should be located in an easily accessible location, with a nearby 240V GPO located within 3m of the remote end cabinet in order to plug in test equipment.

If there is insufficient space for all Carriers at a remote equipment location then an active solution should be deployed.

For any remote location (Carrier remote radio unit or active DAS Equipment remote units) where there is no air conditioning, there needs to be an engineering solution for environmental control.

* Carrier remote radio units do not have space for auxiliary batteries, so this arrangement may not be able to operate during power outages. Refer to Section 8.3.

8.8 TRANSMISSION

Building “lead-in” optical fibre conduit access should be provided from the carrier equipment to the nearest fibre access point (FAP) outside the premises in order for mobile carriers to connect their radio base station equipment from the equipment room to the carrier’s network.

The conduits should be sufficient to support independent fibre for each carrier.

It should be noted that the fibre access point for each Carrier may be from different locations surrounding a building precinct, Multiple lead in conduits may be required to ensure avoidance of isolating a carrier’s network.

8.9 LIGHTING

Luminaires should be selected in accordance with the facility owners requirements to ensure consistency in lighting technology, energy efficiency and maintainability. Lighting is administered by the building owner/manager and compliance is their responsibility.

The lighting should be provisioned as per AS/NZS 1680 with the following parameters:

Maintained Illuminance (lux)	Minimum Colour rendering index (Ra)	Maximum UGR	Work plane height
400	60	22	0.85m

Table 14 - Lighting Requirements

8.10 ROOM FINISH

Fully enclosed room, walls floor to ceiling.

Vinyl Floors are preferred; alternatively, the floor is to be painted with a non-slip anti-static paint up to a wall height of 300mm.

8.10.1 ROOM FINISH SUMMARY TABLE

Item	Specification	Comment
Floor Finish	Vinyl or non-slip anti-static paint	
Wall Finish	Painted	
Ceiling	Not specified by carrier	
Joinery	Not Required by Carriers	
Data Outlets	None required by carriers	
Cable Management	Comms tray/penetration into carrier room	*Refer 6.0, 8.6, 8.8*
GPO’s	Distribution Board Double GPOs GPO's required within 5m of proposed equipment racks for test instruments and tools. Multiple GPO's may required to ensure distance is not more than 5m from any rack.	*Refer 8.3*
Fire Protection	2-hour fire rated	*Refer 8.5*
Security Door	Key is preferred	*Refer 8.11*
Racks	Carrier supplied	*Refer 8.2*
UPS	Typically carrier supplied in Main DAS room	*Refer 8.3*
Surge protection	Yes	*Refer 8.3*
Air Conditioning	*DAS Main Room – 2 x 6KW 1+1 Hot standby configuration* *Remote Active/RRU Locations – X KW 1+1 Hot standby configuration*	*Refer 8.4*

Item	Specification	Comment
	Cooling capacity dependant on RRU architecture and location (standalone vs shared, however should be factored into delivery.)	

Table 15 - Room Finish Summary Table

8.11 DAS SECURITY

The Lead Carrier will require the carrier room and any remote equipment locations to be secure and allow them access for any ongoing maintenance or system issues. Access to the equipment locations should be restricted to authorised persons and be controlled with a key or card reader with clearly documented visitor logs.

DAS main rooms should provide enough infrastructure to allow for competent supervision and effective control over the DAS facility in accordance with Australian Government CIC TSSR requirements. The Carriers will share specific requirements as they may mature/develop throughout the engagement process.

Location of the main equipment room should mitigate the risk of tampering and not be accessible to the general public. Remote equipment locations should be allocated to mitigate the risk of tampering on a best effort basis.

8.11.1 SECURITY OF POWER AND TRANSMISSION TO REMOTE EQUIPMENT LOCATIONS

Active DAS Equipment is usually located remotely from the carrier equipment room. To preserve operational integrity of the DAS and mitigate risk due to deliberate tampering or inadvertent disconnection (e.g. cleaners unplugging equipment to use a GPO, fibres being cutover to another user etc.) it is important the remote equipment is adequately protected in the context of its installed environment.

The use of locked enclosures, captive GPO's or hard-wiring for remote equipment with a key operated power isolation switches held by the Lead Carrier may be appropriate solutions. The most appropriate solution will depend on the environment and the particular circumstance. Consult with the Lead Carrier for further direction on this subject.

Refer to Section 3.22.9 for discussion on the cables connecting remote active equipment to the DAS.

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