Australian Mobile Telecommunications Association

DESIGN GUIDELINES FOR DISTRIBUTED ANTENNA SYSTEMS (DAS)

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This document replaces and supersedes any previous versions of the 'Design Specification for Distributed Antenna Systems (DAS)' and applies to DAS designs that commence after the publication date.

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1 DEFINITIONS

ARPANSA RPS S-1 means the ARPANSA General Public power flux density ("Standard for Limiting Exposure to Radio Frequency 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 and their related body corporates.

Category 1 IBC means an In Building Coverage or DAS 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 where one or more of the antennas exceed the ARPANSA Radiation Protection Series – S1 General Public reference levels at 20cm from the antenna.

DAS Contractor means an organisation that designs, installs and implements a DAS.

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

DAS Infrastructure Operator means a third party that can perform the functions of a 'Lead Carrier'. The DAS Infrastructure Operator may, or not, provide a turnkey service to a building owner providing a service facilitating inbuilding coverage from some, or all, mobile network providers. A DAS Infrastructure Operator would need to satisfy regulatory requirements to operate and maintain infrastructure used to provide carriage services.

Distributed Antenna System (DAS) means the distributed antenna system for mobile telecommunications coverage installed in the building comprising a constellation of antenna and interconnecting equipment which has been installed throughout the building.

Exemption Zone(s) means areas within a building environment which have been agreed by the Lead Carrier/DAS infrastructure Operator and Building Owner to be exempt from achieving the Coverage and/or Capacity KPIs as defined in this guideline.

Lead Carrier means a Carrier engaged contractually by a Building Owner to provide Carrier base station connection and ongoing maintenance/fault management. If for any project or building, a Lead Carrier is not appointed, then in this guideline the words "Lead Carrier' are to be interpreted as referring to all Carriers that are intended to use the DAS which may include a third-party DAS Infrastructure Operator.

MCF means Mobile Carriers Forum.

Mobile Carrier(s) - see definition for Carrier.

OTDR - Optical Time-Domain Reflectometer.

Sharing Carrier or Collocating Carrier means a mobile 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.

2 COMMON ACRONYMS AND ABBREVIATIONS

ACMA – Australian Communications and Media Authority

DAS – Distributed Antenna System

EMC – Electromagnetic Compatibility

EME – Electromagnetic Energy

IBC - In Building Coverage

MCF - Mobile Carriers Forum

MIMO – Multiple Input Multiple Output

MNC – Multi-network Combiner

MNO – Mobile Network Operator

PIM - Passive Intermodulation

RAN – Radio Access Network

RF – Radiofrequency

SISO – Single Input Single Output

UE – User Equipment

3 PURPOSE

3.1 CONTEXT

A Distributed Antenna System (DAS), when connected to Carrier networks, provides mobile coverage and capacity solutions in situations where the external mobile network may not provide reliable services to all areas within a building or structure.

When a DAS is properly designed and installed it can provide the mobile user with an optimal quality experience. Conversely, a poorly designed or installed system will see users encounter unreliable experiences such as dropped calls, clipped speech, slow data speed, etc.

The purpose of these DAS Design Guidelines is to provide guidance for the installation of network equipment in buildings and other infrastructure so that by compliance with these DAS Design Guidelines, the building owners and occupiers can be confident that mobile carriers will be capable of connecting their equipment and providing high quality coverage within the facility. These DAS Design Guidelines provide a series of recommended technical standards and procedures to facilitate multi-carrier access to a DAS.

3.2 SCOPE

These DAS Design Guidelines outline the recommended design, engineering, operational aspects and performance criteria for a DAS that in most circumstances will be considered to be sufficient to ensure that end-users receive a carrier-grade service in locations where terrestrial mobile network coverage may be affected by the built environment or may otherwise be insufficient to meet capacity demands. These DAS Design Guidelines should be read and interpreted within the framework of the Scope set out in this section 3.2.

These DAS Design Guidelines provide a source of information for stakeholders (including building owners and developers) interested in installing a DAS that meets the regulatory and network requirements of each Carrier. These DAS Design Guidelines include guidance on designing and installing DAS to accommodate new spectrum and technology changes, and specifically to support the deployment of 5G capable network infrastructure.

This document includes recommendations in relation to the:

- technical aspects and typical processes associated with the design and delivery of a DAS;
- design standards, performance, and testing requirements for a DAS;
- processes for technical DAS design review prior to construction; and
- documentation required when the DAS construction is complete.

The design, specification, and performance guidelines set out in this document are recommendations to assist with meeting regulatory requirements and to reduce deployment costs in circumstances where all Carriers are likely to share access to a DAS in a multi-carrier environment. These recommendations suggest standards for a properly designed DAS which, if adopted, are intended to:

- assist in ensuring that the DAS is fit for purpose for the building type and user experience;
- meet performance quality criteria to ensure end-users receive a carrier-grade service;
- minimise deployment costs and provide for multi-carrier access;
- streamline the engagement process and installation of network equipment;
- minimise costs associated with future upgrades; and
- minimise costs associated with faults, rectification, and maintenance.

This DAS Design Guideline is intended to provide guidance to stakeholders to achieve a benchmark for best practice. It is recognised that in particular circumstances, a carrier and a stakeholder may agree to deviate from these DAS Design Guidelines when designing or constructing a DAS. A carrier will continue to make its own independent decisions about whether to connect to any particular DAS.

These DAS Design Guidelines do not address nor cover any commercial arrangements (including tenure) that may be negotiated or agreed between Carriers and stakeholders.

3.3 KEY STAKEHOLDERS

The building of a DAS involves three key stakeholders who will typically have the following responsibilities and interactions with one another (note reference to Lead Carrier also refers to a DAS Infrastructure Operator):

3.3.1 THE BUILDING OWNER

The building owner may, in its discretion:

- initiate the DAS requirement and engage the DAS Contractor to provide a solution;
- provide equipment room/s to house DAS and Carrier equipment (e.g. Floor Space, Secure Rooms, Wall Space);
- provide power supply for the DAS and Carrier equipment (e.g. AC lead in and outlets);
- provide environmental management for DAS and Carrier equipment (e.g. Airconditioning);
- provide cable path access and amenities (e.g. risers, cable trays, conduit, floor penetrations);
- engage a Lead Carrier to provide Carrier connection and maintenance (e.g. Carrier base station and ancillary equipment) through commercial agreements that typically specify service level agreements on repair and maintenance timing, fault monitoring, and managing DAS adjustments resulting from fit-outs and refurbishments; and
- may engage a third party to provide and own the DAS.

3.3.2 THE DAS CONTRACTOR

The DAS Contractor may, in its discretion:

- produce a DAS design to meet the Building Owner's requirements and budget;
- consult with Carrier/s for design recommendations;
- install the DAS, tests and seeks compliance validation from DAS Lead Carrier; and/or
- produce documentation and test reports.

3.3.3 LEAD CARRIER/ SHARING CARRIERS/ DAS INFRASTRUCTURE OPERATOR

Typically, a building owner appoints a Lead Carrier who will provide a compliance assessment of designs and installations to ensure that the DAS installation meets all regulatory, operational, security, and health and safety standard requirements. Engagement of a Lead Carrier is usually on terms that its assessment may then be shared with other Carriers to avoid duplication of effort regarding assessment of 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. There is no formal requirement for a building owner to appoint a Lead Carrier and a building owner may adopt alternative arrangements.

A Lead Carrier may in its discretion:

- provide an opinion on the effectiveness of designs and installations;
- publish lists of approved components based on testing and certification to applicable operational, security and health and safety standards;
- engage contractually with Building Owners to provide Carrier base station connection and ongoing maintenance/fault management through commercial agreements; and/or
- facilitate connection of other carriers.

3.3.4 STAKEHOLDER INTERACTIONS AND RELATIONSHIPS

This Guideline anticipates that the key stakeholders will each be responsible for discrete elements in the solution delivery and interact with one another in various stages and manners.

Figure 1 depicts a typical division of these responsibilities and interactions.

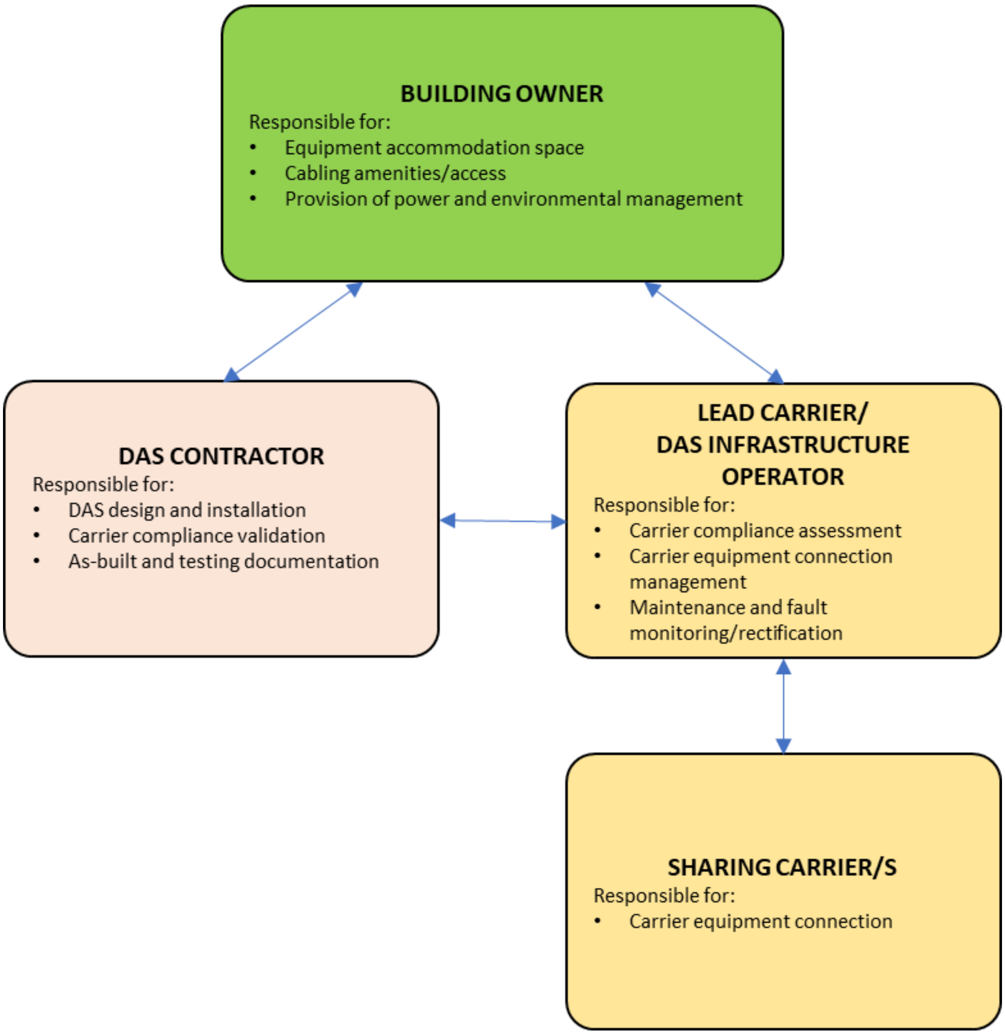

Figure 1 Stakeholder Responsibilities and Relationships

3.3.5 TYPICAL DESIGN AND CONSTRUCTION PROCESS

Figure 2 depicts the typical process flow and interactions of the key stakeholders from DAS inception to completion of a DAS ready for Carrier connection.

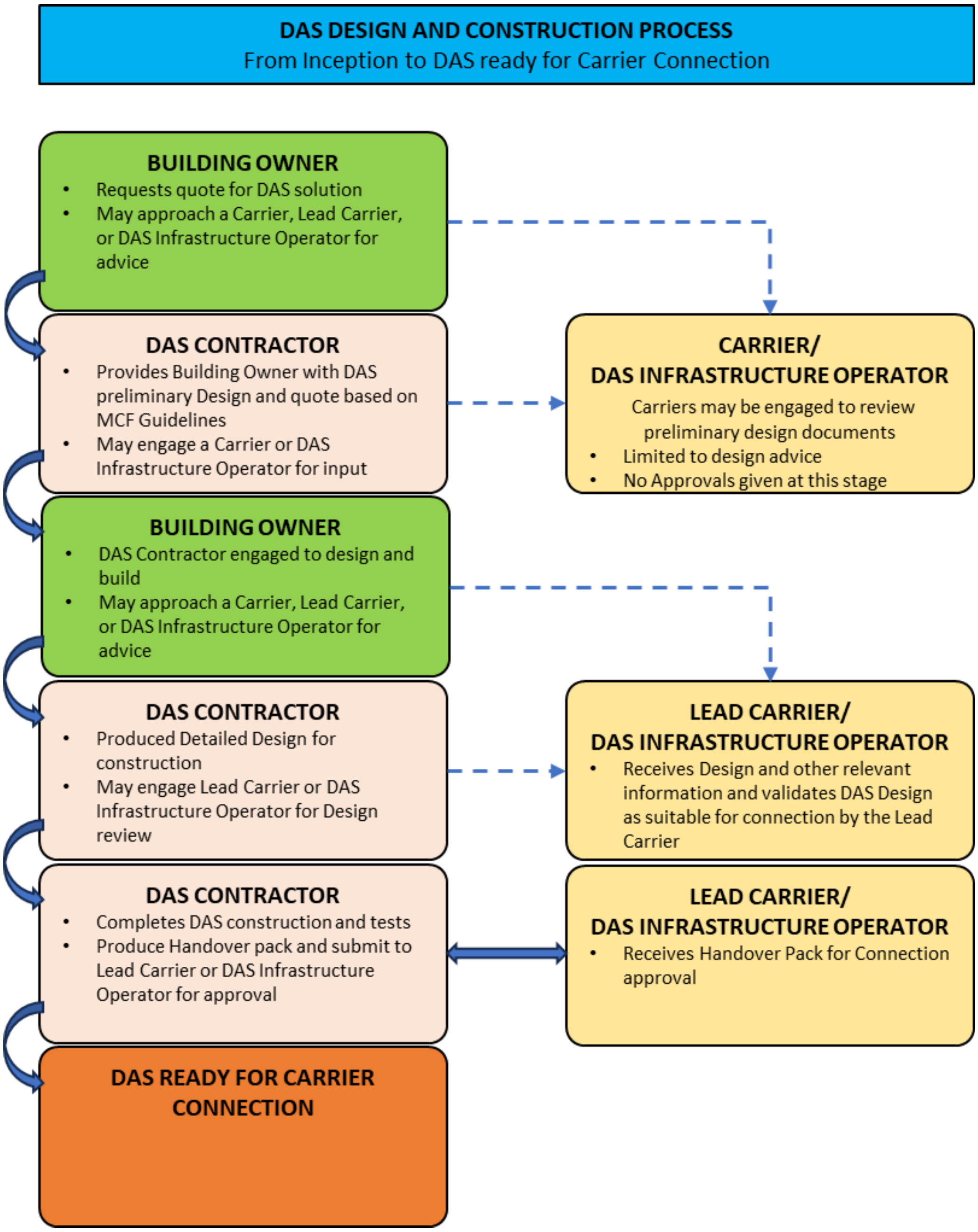

Figure 2 DAS Design and Construction Process

3.4 CARRIER ENGAGEMENT

To complete an in-building coverage solution, a DAS requires connection to Carrier network infrastructure. While Carrier connection of base station equipment can only occur when the DAS installation has been completed and assessed to meet all regulatory, operational, security, and health and safety standard requirements, the Building Owner may pursue engagement of a Lead Carrier or DAS Infrastructure Operator in parallel with the DAS development and ideally commence the two simultaneously.

By law, the combined DAS and Carrier equipment solution can only be operated by an entity that is registered with the ACMA as a licenced carrier.

A Carrier chosen by the building owner to licence or own the DAS is typically considered a Lead Carrier. Early engagement of a Lead Carrier by the Building Owner will generally facilitate effective collaboration between the DAS Contractor and all Carriers which can optimise the DAS design, delivery, and Carrier connection process.

Where a Building Owner chooses to engage a Lead Carrier or DAS Infrastructure Operator, that entity is generally able to provide the following design advice:

- Evaluation of coverage levels;
- Recommendation of DAS architecture and antenna systems;
- Target Coverage Area assessment and determination of exemption zones;
- Defining the scope of custom builds;
- Providing guidance on RF Levels and handover zones;
- Recommending lift antenna placement;
- Assessing equipment accommodation and environmental management requirements; and/or
- Design assessment for compliance with this standard and suitability for connection by the Lead Carrier.

Appointment of a Lead Carrier assessing DAS compliance does not constitute or imply that the Lead Carrier acts for, or on behalf of, other Carriers in connection with the appointment. Appointment of a Lead Carrier assessing DAS compliance does not of itself signify or imply that the Lead Carrier has any liability to the other Carriers in relation to the appointment. Other Carriers remain free to determine whether the DAS meets their individual requirements.

A DAS constructed to comply with this design guidance will enable connection by all Carriers.

There is no obligation on a building owner to allow all Carriers to connect. Conversely there is no obligation on any Carrier to use a DAS.

As a guide *Figure 3* depicts the typical process steps that relate to the Carrier connection process and is included for information only. The specific testing and documentation requirements that relate to this process are included in commercial agreements between the Building Owner and the Lead Carrier/DAS Infrastructure Operator and as such are not part of this guideline.

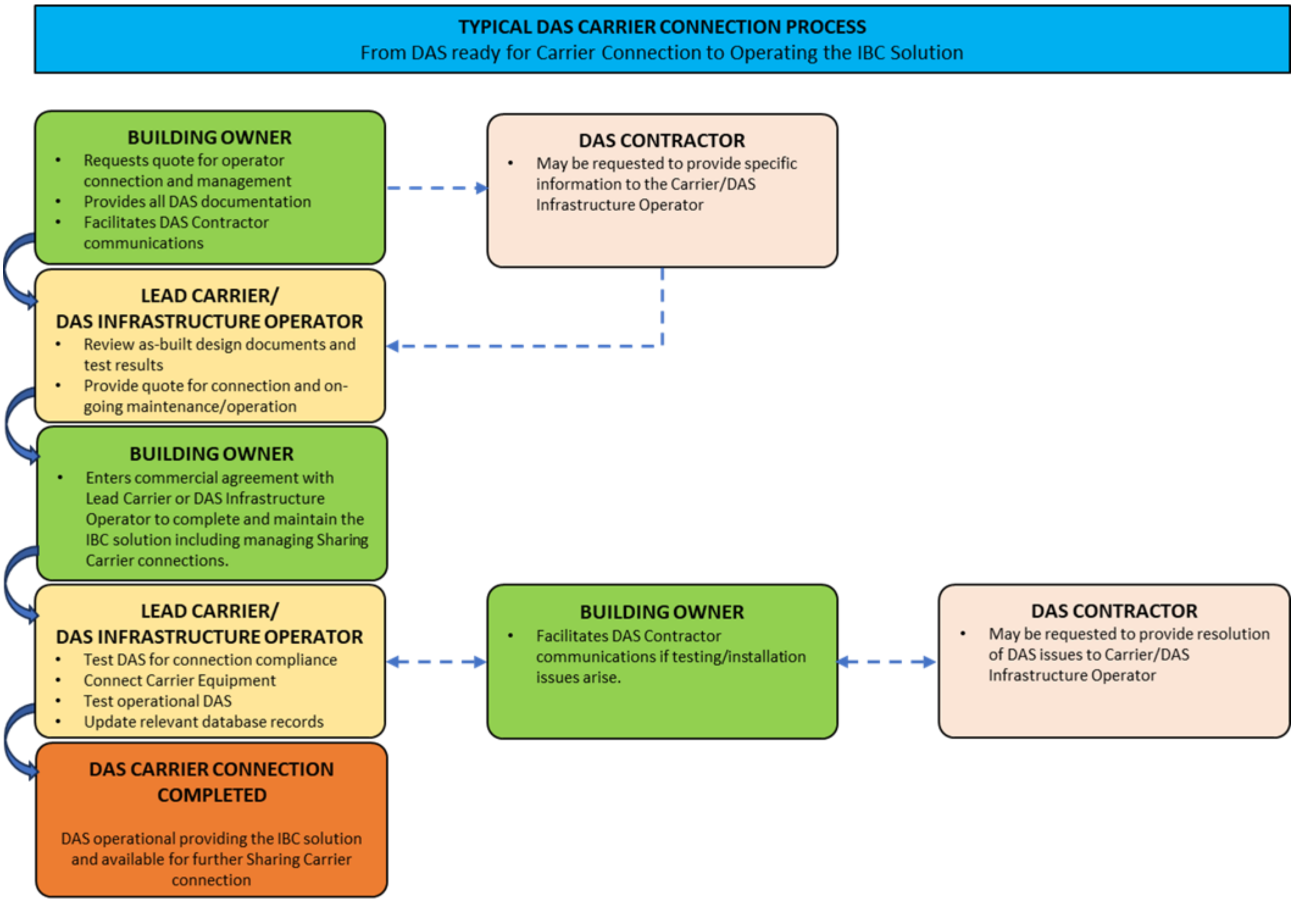

Figure 3 Typical DAS Carrier Connection Process

Where significant changes are required to an existing operational DAS (i.e. commercial building floor fit-out), the Lead Carrier or DAS Infrastructure Operator may be engaged to provide advice and assistance. *Figure 4* depicts the typical process steps that relate to upgrade activities. As is the case for the Carrier connection process, the specific testing and documentation requirements that relate to this process are included in commercial agreements between the Building Owner and the Lead Carrier/DAS Infrastructure Operator and as such are not part of this guideline.

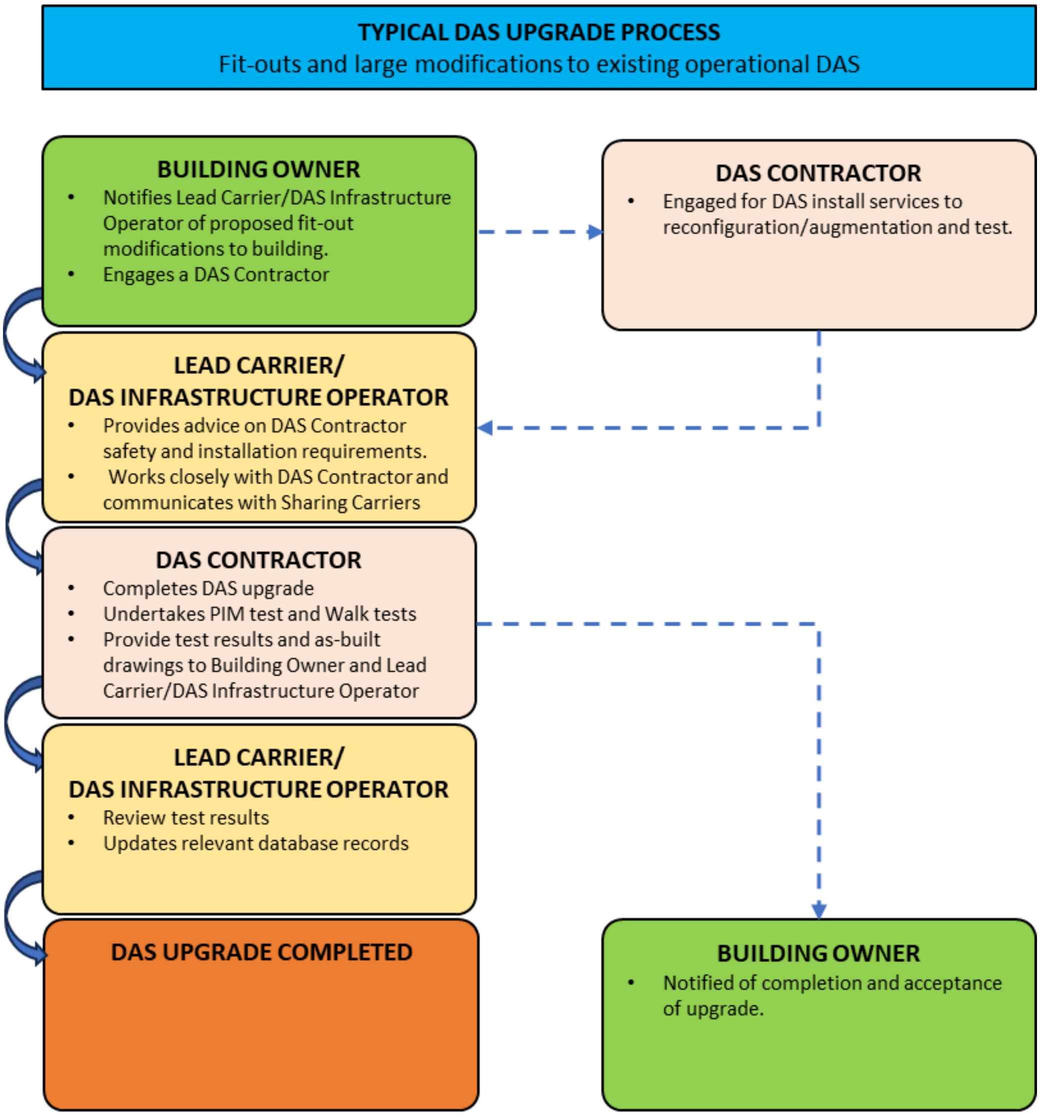

Figure 4 Typical DAS Upgrade Process

3.5 PUBLICATION

This document replaces and supersedes any previous versions of the ‘Design Specification for Distributed Antenna Systems (DAS)’ and applies to DAS designs that commence after the publication date.

Refer to the AMTA website for the latest version:

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3.6 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, laws or regulations.

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.

4 PLANNING

4.1 PRINCIPLES

In the development of a DAS solution, it is recommended that the designer consider the following solution principles and aspects.

4.1.1 COVERAGE ASPECTS

- Incorporate any additional requirements and DAS objectives from the building owner that the design target to provide above and beyond what the DAS guideline recommends.
- Provide enhanced coverage, and a consistent user experience within the Target Coverage Area.
- Provide dominant coverage within the Target Coverage Area to avoid unnecessary hand-off and/or interference to/from the rest of the network. The design should ideally 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 to HANDOVER ZONE AND CONTROLLED LEAKAGE.

4.1.2 INSTALLATION ASPECTS

- The design should ideally consider any technical, structural, and/or architectural constraints.
- To avoid any risk of service disruption between different types of users all fibre optic and electrical cables associated with a DAS are ideally physically separate and clearly distinguishable from any other cable which may be installed within or throughout the premises.
- To meet best practice, it is not appropriate for conduits containing DAS Coax Cable to be 'sunk' into the concrete during the slab pour. Ideally all DAS Coax Cable should be installed surface mounted to allow for ease of fault finding and maintenance.
- When a chosen DAS topology requires fibre connectivity, Carriers may agree to the use of existing in-building optical dark fibre where access and identification is possible however dedicated fibre connectivity is preferred.

4.1.3 REGULATORY ASPECTS

The design must:

- comply with any applicable regulatory conditions and standards (building codes, electrical safety, etc.);
- ensure that appropriate RF signage is used to achieve EME compliance in accordance with industry standards; and/or
- be able to operate in accordance with each Carrier's ACMA licence conditions and be and compliant with Australian Federal Government advice around security of network operations (e.g. CISC TSSR).

4.1.4 TECHNICAL ASPECTS

To meet best practice, DAS Equipment should:

- be designed and deployed for bands as outlined in Section 4.3. The design should assume that all channels in every frequency band applicable are in operation simultaneously;
- provide enough capacity for the size of the building and expected occupancy, with reasonable allowance for network traffic growth. It is recommended that the DAS is designed so that it can be easily expanded and upgraded for capacity reasons by way of sectorisation or similar, without compromising the DAS performance;
- 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; and/or
- include filtering requirements to resolve uplink/downlink channel interference issues to be addressed with Carrier advice.

The DAS designer is typically responsible for selecting a suitable propagation model for the DAS environment to ensure that the minimum signal levels recommended 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.

4.2 ARCHITECTURE

The DAS architecture type selection should consider the complexity, components, cost (total DAS infrastructure and Building Owner expenses), and the final performance KPI. When determining the most appropriate architecture, the DAS designer should consider the complete solution including the carrier equipment requirements and building owner equipment housing and environmental conditioning requirements.

A DAS design may consist of a combination of DAS architectures however, for any single RF sector it is recommended that there should be no mixture of passive and other DAS architecture segments. See Figure 5 for a simplified schematic of example DAS architectures.

Distributed Antenna System (DAS) solutions can be provided using architecture that may be described as:

4.2.1 PASSIVE DAS DEFINITION

Where the base station RF signal is distributed to antennas via a passive network of coaxial cables, splitters, and couplers. 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.
- The equipment can be a combination of cable, radiating cable, antennas, and terminations.

4.2.2 HYBRID DAS DEFINITION

Where the base station RF signal is converted to digital and distributed via a digital network to remote radio units that then feeds an RF passive network of coaxial cables, splitters, and couplers.

- A hybrid DAS typically has a backbone feed system of digital equipment which provides the distribution to each floor area via optical fibre cables or electrical cabling.
- The floor/area equipment can be a combination of passive equipment including cable, radiating cable, antennas, and terminations fed from remote radio equipment.

4.2.3 ACTIVE DAS DEFINITION

Where the base station RF signal is converted to digital and distributed to active antenna units.

- An Active DAS typically has a backbone network of Master/Slave Units feeding floor area antenna systems via a network of either optical fibre cables or electrical cabling.
- The floor/area antenna systems can convert digital inputs to RF and are typically referred to as Access Points.

4.2.4 DIGITAL DAS DEFINITION

Where the base station digital signal is distributed to active antenna units.

- A Digital DAS typically has a backbone network of Master/Slave Units feeding floor area antenna systems via a network of either optical fibre cables or electrical cabling.
- The floor/area antenna systems can convert digital inputs to RF and are typically referred to as Access Points.

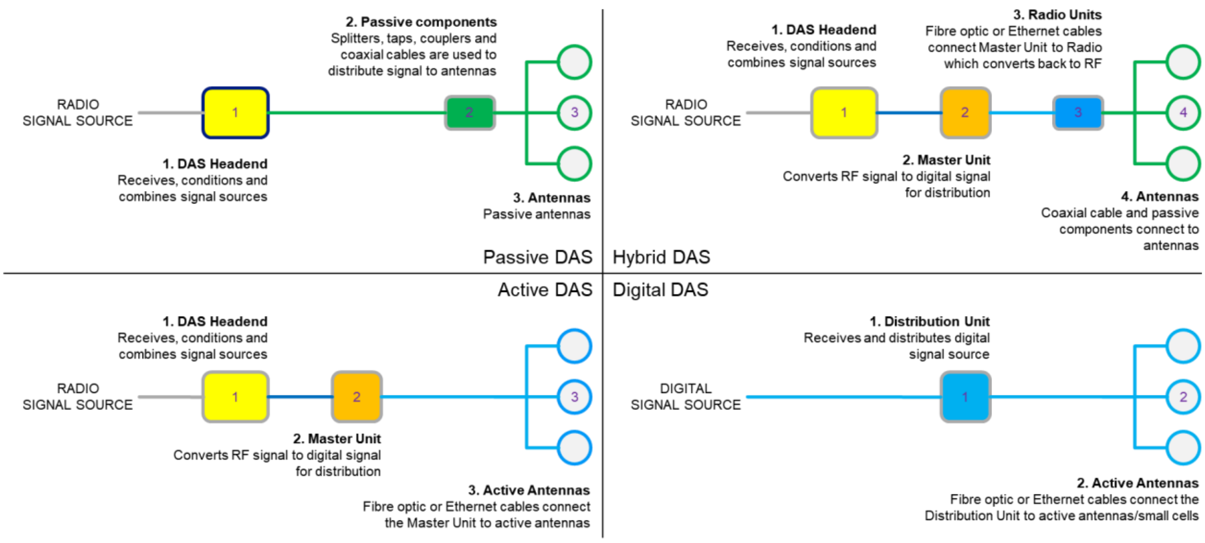

Figure 5 Example DAS architectures

4.3 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)	3GPPP Band
700 MHz	DL: 758 –803 UL: 703 –748	Band 28
850/850E MHz	DL: 859 – 890 UL: 814 – 845	Band 5/Band 26
900 MHz	DL: 935 – 960 UL: 890 – 915	Band 8
1800 MHz	DL: 1805 – 1880 UL: 1710 – 1785	Band 3
2100 MHz	DL: 2110 – 2170 UL: 1920 – 1980	Band 1
2300 MHz	2300 – 2400 (TDD)	Band 40
2600 MHz	DL: 2620 – 2690 UL: 2500 – 2570	Band 7
3500 MHz	3300 – 3800 (TDD)	Band n78

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

It is recommended that 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).

4.4 REFERENCE TECHNOLOGIES

Best practice is that 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

4.5 APPROVED MATERIAL LIST

Carriers will regularly undertake testing and compliance certification of materials and equipment prior to inclusion into network infrastructure to ensure compliance with network security, performance, and regulatory requirements.

Certified materials and equipment may be listed in an approved material list that DAS Contractors can access when designing a DAS. Refer to the AMTA website for the latest version:

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

Approved material and equipment selection also contributes to the long-term reliable performance of the DAS and enables a Carrier to provide the necessary ongoing management, maintenance, and support.

A DAS that is designed and constructed with only approved materials and equipment will ensure Carriers will be capable of connecting their equipment to a compliant system.

5 DESIGN

5.1 RF DESIGN - COVERAGE, CAPACITY, AND PERFORMANCE

The DAS required to deliver the necessary network performance capability will depend on the specific areas and characteristics of the building and Target Coverage Area.

A DAS should be designed to provide appropriate network performance capability within the Target Coverage Area. Carriers can accommodate reasonable flexibility in a DAS design to meet the different in-building connectivity needs of building developers and owners. However, while some designs may initially provide sufficient network performance, they may limit the system capabilities. For example, a decision to not incorporate MIMO and/or sufficient capacity into a DAS may result in Carriers being unable to supply 5G features and performance within that building and potentially the need for upgrades in the future.

Early Lead Carrier engagement is an option available to Building Owners and DAS Contractors to assist in design considerations.

5.1.1 TARGET COVERAGE AREA

Best practice is that the Target Coverage Area should encompass the entire building floor area to provide continuous connectivity.

Target coverage areas typically include the following:

- Inside Rooms (Apartments, Hotel Rooms, Offices, etc.);
- General Public Accessible Areas (convention halls, food courts, restrooms, entries, corridors, restrooms, hotel facilities, shops, etc.);
- Hospital 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;
- Lobbies, Restaurants, Function Areas;
- Inside Lift Cars;
- Carparks;
- Plant Rooms;
- Fire Stairs and Emergency egress areas;
- Through the length of a Rail or Motorway tunnel; and/or
- Underground Stations / Platforms.

Exemption zones that are incorporated into the Target Coverage Area need to be agreed between stakeholders.

5.1.2 SOLUTION CATEGORIES

Network performance of a DAS may depend on a variety of factors, including the structure of the building or specific site, and the number of users of the network at any given time. The design should ideally take into consideration these factors when selecting the appropriate solution architecture to achieve an acceptable performance in Target Coverage Areas.

Carriers may be engaged to assist with determining appropriate DAS solution architecture for a site or alternatively the Solution Categories in *Table 3* can be used to assist Building Owners and DAS designers with this architectural determination, by associating typical building types with recommended solution types.

Building Types	Solution Description	Recommended Minimum Solution
Hotels Hospitals Commercial Office Residential Apartments Serviced Apartments Small Shopping centres Carparks	Standard Solutions Typically small scale sites with low to medium capacity demands	**Option 1** **Architecture** – SISO **Bands (MHz)** – All Bands 700, 850/850E, 900,1800, 2100, 2300, 2600, 3500 **Option 2** **Architecture** – 2x2 MIMO **Bands (MHz)** – 1800, 2100, 3500
Large Shopping centres Convention centres Stadiums Airports Public Transport Motorway Tunnels	Custom Solutions Typically large to very large scale sites with high capacity demands	The final solution may be determined in consultation with a Lead Carrier or all Carriers (coordinated by the Lead Carrier) if applicable. If a Lead Carrier is not engaged, the minimum outcomes below are recommended: **Architecture** – 2x2 MIMO **Bands (MHz)** – All Bands 700, 850/850E, 900, 1800, 2100, 2300, 2600, 3500

Table 3 DAS site type Minimum Solution Recommendations

5.1.3 RAN DESIGN ARCHITECTURE CONSIDERATIONS: MIMO & SISO

5G was designed to provide improved data speeds and to many customers simultaneously. To realise these benefits, known as throughput and capacity respectively, Multiple Input Multiple Output (MIMO) technology is preferred.

Single Input Single Output (SISO) solutions, in contrast, are potentially more cost effective to deploy due to complexity reduction and equipment and installation costs. In terms of customer experience a SISO IBC will typically deliver reduced speed and capacity to customers as that of a MIMO solution.

Furthermore, MIMO typically provides increased signal quality, coverage, interference resistance, both spectral and energy efficiency, resulting in better service to more customers than a comparable SISO solution.

Typical candidates for a higher order MIMO DAS configuration are locations which cater for large numbers of users e.g. stadiums, entertainment/exhibition/convention centres, auditoriums, transport/railway stations and tunnels, underground platforms, and airports.

Carriers can assist DAS designers and Building Owners with determining the order of MIMO best suited to the required performance attributes for a DAS.

5.1.4 HANDOVER ZONE AND CONTROLLED LEAKAGE

The DAS design should ideally include well-defined handover zones to minimise unwanted handovers to maximise customer experience. This is applicable for both internal sectors of the DAS and handovers to and from the external mobile network at entry/egress points.

DAS sector boundaries should avoid high traffic, KPI exemption zones or dwell areas, and make use of natural separation areas of the building design e.g. horizontal floor levels where possible.

Where defined separation cannot be used as a handover boundary (e.g. large open atriums), the expected handover zones should be annotated in the DAS design sectorisation plan.

As described in Section 0, it is recommended that the DAS be designed so that it can be easily expanded in the future by way of sectorisation without compromising the DAS performance. Handover boundaries for future sectorisation should be considered as part of the DAS design.

As best practice, 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.

In circumstances where buildings or DAS infrastructure are situated near 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, it is recommended that satisfactory mitigation of signal leakage from the DAS to the external mobile network should be demonstrated and assessed by the Lead Carrier during DAS design appraisal.

5.2 SPECIFIC BUILDING TYPE DESIGN ASPECTS

In addition to the general design requirements for all DAS solutions, it is best practice that there are additional design aspects that relate to specific building types and applications.

The design solution considered 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 the design for a stadium. Likewise, a residential apartment building DAS should address requirements differently to a commercial office environment.

This section identifies specific design considerations for typical building type categories.

5.2.1 RESIDENTIAL AND SERVICED APARTMENTS

All residential layouts are unique and the extent of Targeted Coverage Areas within apartments will depend on size, apartment layout, and even building exclusivity.

In small apartments the Target Coverage Area requirement inside an apartment may possibly be met with antennas and infrastructure placed outside the apartments (i.e. in corridors and common areas). Larger apartments will typically require antennas inside to meet the KPIs for performance and quality – particularly at the higher frequency bands.

Where antennas are required inside apartments, ideally it is important for all stakeholders to acknowledge that access to private residential apartments for maintenance and fault finding may be difficult and will inevitably lead to delays in rectifying faults. To mitigate this risk, it is best practice that the DAS should be configured so each apartment has a unique feed accessible from common areas of the building which can be physically isolated from the remainder of the DAS to assist with fault finding and help mitigate PIM contamination affecting other parts of the DAS. It is not recommended that any branch of the DAS service multiple apartments without the ability to inspect and isolate each individual apartment being serviced by that branch from common areas.

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 and therefore careful consideration of this is recommended at the design stage and during installation.

5.2.2 HOTELS

With respect to addressing coverage requirements inside Hotel rooms the design considerations for residential and serviced Apartments can be applied. However, experience suggests that typically corridor mounted cabling and antennas should provide sufficient coverage to most hotel rooms. Where antennas in Hotel rooms are required, ideally the DAS should be configured so each room has a unique feed accessible from common areas of the building which can be physically isolated from the remainder of the DAS. However, as access to Hotel rooms do not have the same restrictions as residential apartments, branch cabling design has more flexibility and where it is more cost-effective, branch cabling for antennas can be run through partition walls between hotel suites rather than through common areas.

5.2.3 COMMERCIAL OFFICE

Typically, the changing nature of fit-out configurations in Commercial Office buildings introduces a design challenge for satisfying existing and future coverage objectives. It also highlights the importance of good installation practices to minimise faults and maintain system integrity.

A commercial building that is not tenanted will usually require the DAS designer to use appropriate prediction modelling that will represent the expected RF environment. Where possible the design should include the capability for adding spare RF for future changes to floor layouts – such as subdivision of floors, addition of meeting rooms, offices.

5.2.4 CONVENTION CENTRES

Due to the complexity of convention centre DAS design, it is recommended a Lead Carrier is engaged to facilitate Carrier consultation and design guidance.

5.2.5 STADIUMS

Due to the complexity of stadium DAS design, it is recommended a Lead Carrier is engaged to facilitate Carrier consultation and design guidance. Capacity, sectorisation, and interaction with macro network are site specific and need to be treated carefully. MIMO is strongly recommended for stadiums. Pitch/On-Field criteria will usually be defined by stadium owner's intended usage of the space and guided by the Lead Carrier.

5.2.6 AIRPORTS

Design input criteria from each Carrier may differ from general specification requirements outlined in this document and direct consultation with a Lead Carrier is recommended to provide direction and advice with respect to the DAS design and interaction characteristics with external macro networks.

5.2.7 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. Contiguous performance is typically required through the length of a tunnel measured or simulated at the centre of a train carriage filled with commuters. Appropriate modelling should be undertaken to simulate expected RF characteristics to exceed the required performance KPIs.

5.2.8 MOTORWAY TUNNELS

It is recommended that capacity should be designed to cater for network traffic peaks which arise due to delays caused by traffic congestion within the tunnels.

It is important to consider external macro coverage areas immediately adjacent to the tunnel portals and the impact on handovers.

5.2.9 HOSPITALS

All hospital layouts are unique and the extent of Targeted Coverage Areas within rooms may depend on size, layout, and construction. Access to some Hospital rooms for fault finding and maintenance (i.e. theatres, radiology rooms, etc.) may be restricted and as such, wherever possible, the DAS should ideally be designed to meet the Target Coverage Area requirements inside these rooms with antennas and infrastructure placed outside (i.e. in common areas).

Certain medical equipment may generate RF noise that impacts DAS performance and the DAS installer may be required to relocate antennas to minimise the impact.

5.2.10 COLD SHELL INSTALLATIONS

Providing a DAS for a building that is completed as a cold shell presents design and installation challenges. An RF design completed without considering losses presented when partitions, ceilings, and furnishings are later constructed may well fail Target Coverage Area performance and quality KPIs after fit-out. To mitigate this risk the DAS designer should use appropriate prediction modelling that will represent the expected RF environment.

5.3 GENERIC BUILDING COMPONENT DESIGN ASPECTS

5.3.1 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 (with a recommended minimum of one antenna per every three adjacent lifts). Placement of the antennas may be designed in consultation with a Lead Carrier. RF power levels to each antenna should ideally:

- be the maximum possible based on EME constraints;
- be sufficient to provide “best effort” 4G and 5G coverage into lifts; and
- factor the combined RF loss from the lift walls and lift shaft walls.

High speed lifts (typically defined as a lift that travels 8m/s or two floors per second) may require dedicated inside lift solutions to provide coverage and seamless network performance and handover. The solution to be implemented may be designed with Lead Carrier input. It is important for stakeholders to acknowledge that difficulty in accessing lifts and lift infrastructure when required for maintenance may well lead to delays in rectifying faults of dedicated inside lift solutions.

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.

5.3.2 FIRE STAIRS

Where there are fire stairs in the Target Coverage Area and antennas cannot be located inside the stair area it is recommended that an antenna be placed within 5m and with an unobstructed line of sight of a fire stair door for best effort coverage. Placement of the antennas may be designed in consultation with a Lead Carrier. RF power levels to each antenna should ideally:

- be the maximum possible based on EME constraints;
- be sufficient to provide “best effort” 4G and 5G coverage into fire stairs; and
- should factor the combined RF loss from the walls and doors.

5.4 EQUIPMENT & ACCOMMODATION DESIGN

This section outlines the typical accommodation and provisioning requirements for carrier equipment which should be provided by the Building Owner and DAS Contractor as part of the design proposal.

The equipment room will usually contain the carrier’s base station and peripheral equipment racks that will be installed and connected to the DAS. The equipment footprint per carrier will vary based on the DAS architecture and capacity requirements of the site.

5.4.1 MAIN CARRIER EQUIPMENT ROOM REQUIREMENTS

Dimensioning of the room should be undertaken in conjunction with the Lead Carrier to ensure that sufficient space requirements have been factored into the design. Rack allocation should also be considered for any active DAS equipment based on the design.

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

For planning purposes, it is recommended that $32m^2$ of floor area be considered a typical requirement to cater for all carriers based on 4 Racks per carrier and 2 additional racks for shared requirements. Carrier racks may be installed rear to wall. Standard carrier equipment rack dimensions are as follows:

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

As best practice, a minimum a 300mm cable tray is required leading up to the communications room with a 300mm wide by 100mm high penetration for COAX and Fibre access into the communications room and continue inside the equipment room across all racks to provide access to from above. 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.

Main Carrier accommodation will usually house sensitive telecommunications equipment and will require suitable security measures allowing carrier access for any preventive and reactive maintenance.

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.

5.4.2 ACTIVE OR HYBRID EQUIPMENT HOUSING REQUIREMENTS

Active or Hybrid DAS, which typically utilise remote equipment locations throughout a property, typically require sufficient space to house several remote equipment units and associated ancillary equipment.

Locations should be easily accessible by each Carrier with appropriate consideration for access security, power availability per Carrier, fibre provisioning, environmental heat management and should be undertaken in conjunction with the Lead Carrier advice.

For planning purposes, it is recommended that $3m^2$ of wall space be considered a typical requirement for a single sector of remote equipment.

Hybrid and Active DAS architecture 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 (unplugging equipment to use a GPO, fibres being cutover to another user etc.). It is best practice that the remote equipment is adequately protected in the context of its installed environment.

The use of locked enclosures, captive GPO, 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 circumstance and Lead Carrier consultation can assist with this determination.

5.4.3 AIR CONDITIONING

Where existing cooling or building ventilation systems are not sufficient to cater for the added heat loading requirements of DAS and Carrier equipment, additional air-conditioning systems may need to be provided. Where required, Active DAS Equipment and/or Carrier radio unit equipment locations should be provisioned with air-conditioning that meets heat loading dissipation requirements.

Heat load may vary depend on both the DAS configuration and the equipment deployed by the Carriers and as such advice should be sought from Carriers on the anticipated loads. For planning purposes, 12kW of cooling can be considered a typical requirement in a main/secondary equipment room.

5.4.4 AC POWER REQUIREMENTS

MAIN AND SECONDARY EQUIPMENT ROOMS

AC power requirements for a DAS and associated Carrier equipment will typically depend on the type and location of equipment. As a guideline, for an installation that has all DAS and

Carrier equipment in a single equipment room the following requirements are typical:

- 3-phase provided with a 100A per phase supply (generator-backed if possible).
- One AC Distribution Board is required and should be wall-mounted within the room with a 160A isolator and surge protection at the incomer only.
- 1 x 36-pole MCB chassis with 1 x 3pole 32A circuit breaker per carrier.
- 1 x 32A 3 phase 5 pin outlet per carrier.
- 1 x 35mm² Earth cable feeding a lug type earth bar.

REMOTE DAS AREAS

Where DAS equipment (Hybrid and Active architecture components) and Carrier equipment are housed in remote locations, each location will typically require individual assessment for AC Power requirements. One Single phase captive outlet per remote unit is typically required.

Essential Power is typically not required in the main DAS equipment room or any remote location however, it is preferred to underpin continuity of service.

Any remote active DAS Equipment or Carrier 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 radio 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.

Electrical engineering designed solutions may be required for larger installations such as stadiums.

5.4.5 TRANSMISSION LEAD IN

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

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 and therefore multiple lead in conduits may be required.

5.4.6 GPS REQUIREMENTS

The designer ideally should consult with the Carriers to confirm the requirement for a standalone GPS installation.

Where required, the DAS design should incorporate a direct cable path from the equipment room to a viable, unobstructed, GPS antenna position outside the building. 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.

In some cases, it may be more appropriate for the DAS Contractor to install cables for GPS antennas and in those circumstances the DAS Contractor should identify the specific cabling requirements of the Carrier/Carriers. GPS antennas will typically also require the GPS feeder to be earthed (lightning protection earth).

Cables should be left coiled and protected at both ends with sufficient excess cable available to allow for termination into carrier base stations and the GPS antenna.

5.5 CARRIER CONNECTION DESIGN

5.5.1 PASSIVE DAS INTERCONNECT PORTS

Best practice and 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. Output ports connect to DAS segments and each output port carries a composite signal that is a combination of all the connected Carrier signals at the input ports.

It is recommended that a single MNC input port should be utilised per operator. The fourth or spare unused MNC input port should be terminated with a suitable load and utilised for testing purposes. Unused output ports require termination with an appropriate load.

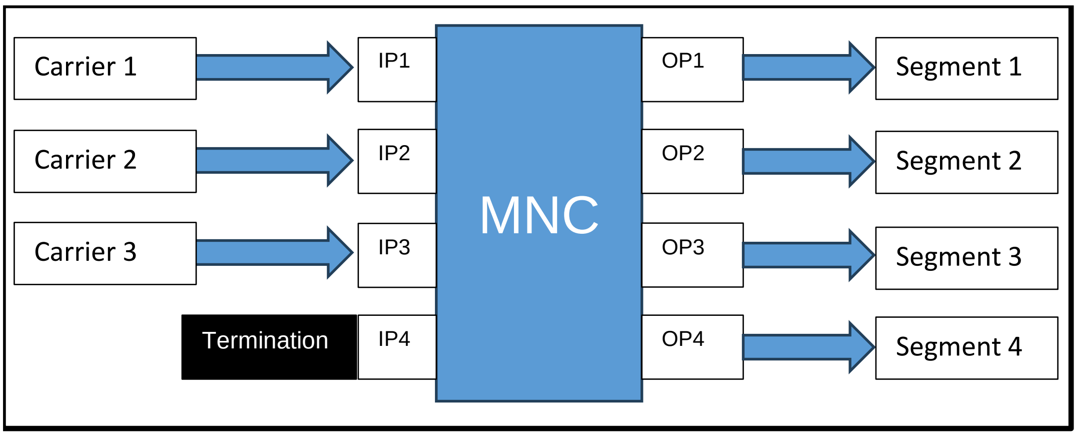

Figure 6 MNC Configuration Diagram

It is recommended that each input port of the MNC should have input powers according to *Table 4*.

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 (700/850/850E/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 4 Maximum Input Power

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

5.5.2 MULTI-NETWORK COMBINER (MNC) LOCATIONS

It is typically the responsibility of the Carrier's to connect their base station equipment to the MNC and the DAS design should incorporate the accommodation requirements as per Section MAIN CARRIER EQUIPMENT ROOM REQUIREMENTS 5.4.1.

The MNC and all Carrier base station equipment should be co-located in a main equipment room that will require appropriate dimensioning to provide a single common location for all the DAS equipment.

In circumstances where building constraints result in a main equipment room dimension that cannot accommodate all Carrier equipment, then some of the Sharing Carrier equipment may be accommodated in a separate room with coaxial tie cables provided (supplied and installed by the DAS Contractor - typically 7/8inch feeder) between the MNC and the separate Sharing Carrier equipment location for connectivity. Due to cable loss, the separation between the MNC and Sharing Carrier equipment is limited to 15m. Secondary equipment rooms will have the same requirements as the main equipment room as per Section MAIN CARRIER EQUIPMENT ROOM REQUIREMENTS 5.4.1.

In circumstances where a Passive DAS design incorporates additional equipment rooms accommodating Carrier Equipment and MNC, the additional room/s will require a fibre link to the main equipment room to connect Carrier radio equipment to Base band equipment. The DAS Contractor will typically be responsible for provision and testing of this fibre connection and the specific fibre pair requirements can be provided by the Lead Carrier.

A Lead Carrier can provide recommendations on all Tie Cable/Fibre connection requirements and advice on alternate solutions if necessary.

5.5.3 HYBRID & ACTIVE DAS INTERCONNECT PORTS

It is best practice that 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 DAS Equipment manufacturer's specification.

5.5.4 RADIO POWER SHARING

Most Hybrid and Active DAS solutions share common radios between all connecting Carriers to minimise the physical site footprint. It is recommended designers consult with the Lead Carrier to implement a power sharing approach appropriate for the specific DAS technology used.

With most technologies it will be optimal to share radio power with an equal power spectral density (Power Spectral Density, 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 should also be adjusted to meet EME and KPI design constraints.

This ideal 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.

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

$$MaxRadioPowerShare\ (W) = \ AvailableRadioPower\ (W) \times AllocatedBandwidthOperatorN\ (MHz)$$

$$\Sigma\ AllocatedBandwidthOperators\ \ (MHz)$$

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

<table>
<tr><th>Carrier</th><th>Allocated Bandwidth (MHz)</th><th>Maximum Power Share (%)</th><th>Available Radio Power (W)</th><th>Max Radio Power Share (W)</th></tr>
<tr><td>Operator 1</td><td>40</td><td>50%</td><td rowspan="3">20</td><td>10</td></tr>
<tr><td>Operator 2</td><td>20</td><td>25%</td><td>5</td></tr>
<tr><td>Operator 3</td><td>20</td><td>25%</td><td>5</td></tr>
</table>

Table 5 Example power share calculation

5.6 EME DESIGN CONSTRAINTS

All DAS must be designed as per requirements in AMTA RF Safety Program Document “EME Compliance for IBC and DAS” which is located in RFNSA document section as follows:

“RF Safety Program\Documentation – RF Safety Compliance \2024 IBC EME Compliance”.

The onus remains with the DAS Contractor responsible for the design and build of the DAS to ensure compliance with the latest standards.

5.6.1 EME DESIGN MARGIN FOR SHARING

It is recommended that the DAS is to 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\Documentation – RF Safety Compliance\2024 IBC EME Compliance”.

5.6.2 ELECTROMAGNETIC COMPATIBILITY (EMC) DESIGN CONSTRAINT

It is recommended that designers 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 are recommended to be aware of the impact that Radio Frequency Interference may have on various types of equipment, particularly when designing a DAS in hospitals or in locations where there may be explosive atmospheres or devices.

AMTA has produced a guideline to help designers assess the impact of Radio Frequency 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.

“System Documents\RF Safety Program\Documentation RF Safety Compliance(Guidelines. Processes. Procedures)\A. RF Safety Program Manuals CURRENT\RFSP Supporting Documents”.

5.7 PERFORMANCE DESIGN CRITERIA

5.7.1 RF LEVELS

It is recommended that 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 typically defined as any mobile network signal received/measured/identified within the Target Coverage Area which is not part of the DAS itself.

Table 6 Signal, Dominance, and Quality Performance Levels for DAS, specifies the required signal, quality, and dominance levels for various technologies. These values should be reliably achieved and available to >95% of the Target Coverage Area.

RF levels for the DAS design will typically 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 should 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 typically on the DAS designer to measure the signals on the street for all Carriers and estimate propagation and building attenuation. The Lead Carrier may provide guidance and input into the process. Where possible, signal measurements should be collected for all Carriers on all bands.

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

Table 6 Signal, Dominance, and Quality Performance Levels for DAS

Table 6 Notes:

KPI for 95% of Target Coverage Area.
5G NR Reference Power based on 30KHz sub-carrier spacing.
Equal power spectral density (W/MHz)/Equal Coverage per operator across all bands, refer Section 5.5.4.

DAS signal levels at a distance 6m outside the building at 1.5m above ground level from the IBC should be low enough to ensure dominance by each Carrier's macro network.

The dominance of external macros is extremely important to DAS performance. A Lead Carrier may be consulted in the determination of any Exemption Zones, otherwise it is recommended that the performance levels exceed the minimum levels in Table 6.

As per Section 7.5.1 any Target Coverage Area Exemption Zones should be clearly documented by the DAS Contractor with reasoning on all relevant floor plans.

5.7.2 RETURN LOSS

It is best practice that the return loss of each Passive DAS segment connecting to a multi-network combiner should 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 the return loss at the point of interconnect closest to the remote unit should be greater than ≥ 16 dB over the operating frequency bands.

5.7.3 PROPAGATION DELAY

It is recommended that DAS designs 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; and
- introducing system delays that affect overall performance.

6 INSTALLATION GUIDELINES

6.1 ANTENNA INSTALLATION

In its installed operating position, it is recommended that 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" in Section 5.6 of this document.

It is recommended that 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 as far away as practical from items 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.

It is recommended that concealing antennas for aesthetic reasons inside a ceiling space should be avoided as the resulting reduction in RF performance will increase antenna quantity requirements and therefore increase cost and will impact maintenance/fault finding.

6.1.1 MOUNTING OF OMNIDIRECTIONAL ANTENNAS

Ideally, there should be no 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.

It is recommended that the metal ground plane of the antenna is insulated from any 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.

When mounting Access Points for Active DAS systems the structural integrity of the mounting surface needs to be considered in relation to the load bearing capabilities.

6.1.2 MOUNTING OF PANEL ANTENNAS

The panel antenna is a directional antenna. It is recommended that it should 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.

It is recommended that installation of panel antennas be specified on a wall or the underside of the ceiling. Preferably, 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.

6.1.3 LOCATING ANTENNAS TO MINIMISE WIDEBAND NOISE

To minimise wideband noise, best practice is to identify possible wideband noise sources at design and during installation and 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. The sources of wideband noise can be many and varied.

Typical interfering objects to avoid include:

- Switch mode power supplies;
- LED lights;
- Cables with digital signals that are not well shielded including video monitor cables, ethernet cables and similar digital signalling cables;
- Large screen monitors; and/or
- 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.

6.2 SPLITTER MOUNTING

The components should be installed a position that is accessible 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.

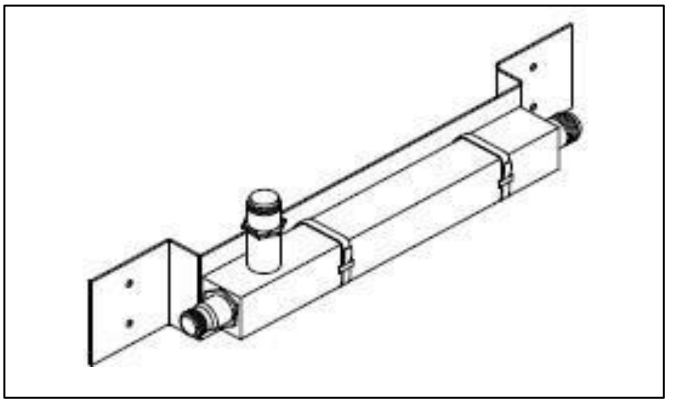

Figure 7 Example of splitter / coupler mounting bracket

Components should not be installed with support only by the attached cables.
It is best practice that adaptors should never be used to connect cables or components together.

6.3 JUMPER CABLES

Jumper cables are typically required to connect:

- All feeder cables to passive components (Splitters, couplers, MNC, etc);
- All feeder cables to antennas (without fly leads);
- One passive component to another;
- All feeder cables connecting to base station equipment and active DAS Equipment.

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

Normal practice is to put a loop in the jumper cable to minimise stress being placed on the connectors and to make it easier to disconnect components.

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.

6.4 CABLE INSTALLATION

6.4.1 COAX FEEDERS

It is recommended that all backbone feeder cables should run to the equipment room and be terminated with connectors that meet the approved equipment requirements.

Wherever possible, cables are to be installed on the existing communication cable trays/ladders between the equipment room and the communications riser. It is typically 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 and preferably using nylon cable ties.

When running feeders in cable trays, appropriate separation distances from existing services should be maintained to avoid interference - both physical or otherwise.

Fire-proof sealing should be applied at all penetrations where a cable crosses a 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.

Branch floor feeder cables run in the roof space should be installed in a manner that minimises the potential for damage if fit-out changes are made. The preference is for coax cables to be supported on a catenary, secured in cable trays, or mechanically fixed to the concrete slab.

6.4.2 RADIATING CABLE

Where radiating cable is deployed 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. A Lead Carrier can advise on the use of radiating cable.

6.4.3 NETWORK CABLING - FIBRE OPTIC AND ELECTRICAL

Fibre optic and electrical network cabling is not as resilient as coaxial cables and therefore support and management is critical to ensuring functional longevity.

As best practice, fibre optic cables (including hybrid power plus fibre cables) need to be physically secured and protected, and ideally separated from other cabling. Fibre optic and hybrid cables should be supported and affixed to cable trays/ladders, or in conduit that is suitable affixed to building components. Catenary wires do not provide sufficient stability for fibre cable support and should not be used.

All network cables should be terminated into a patch panel and cable management systems should be utilised. Patch panels with inbuilt splicing trays should be used for fibre optic terminations. On a small DAS 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 using connector types recommended by the equipment vendor.

Cables to remote units should be terminated into a small patch panel housed in a termination box fixed to either the ceiling or another permanent structure that provides suitable support and protection. Pigtails should 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 should be labelled as per the corresponding patch panel port in the main equipment room.

An acceptable alternative to using fibre 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.

6.4.4 CABLE AND COMPONENT LABELLING

It is best practice that 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. Labelling stickers should be placed on radiating cable in accordance with the spacing intervals indicated above.

All feeders should be identified at both feeder entry/exit 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.

6.5 INHIBITING PIM

Typically, interference due to PIM presents as an elevated noise floor on a cellular base station which can inhibit proper use of the system. 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.

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.

The main causes of PIM are:

POOR QUALITY COMPONENTS
Carriers undertake tests on DAS components that includes PIM compliance and recommend the use of only approved components.

POOR WORKMANSHIP
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.

INAPPROPRIATE PLACEMENT OF ANTENNAS
The small, low gain antennas normally used in DAS construction tend to illuminate external PIM sources near the antenna.

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

- Only use approved components.
- Use factory terminated and PIM certified RF jumper cables where possible.
- 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.
- 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.
- Antennas inside ceiling cavities or within cluttered environments will lead to reduced coverage and will be more prone to PIM.
- Avoid loose metal objects (mounting hardware, metal chains, etc.) anywhere within

500mm of antennas.

- Avoid placing antennas near exit lights, door openers, LAN cables, TVs, Large displays, or other equipment which emits electrical interference or close to cable trays, vent pipes, air conditioning units, metal flashing, etc.

7 DELIVERABLES

7.1 DOCUMENT MANAGEMENT

7.1.1 SUBMISSION OF DOCUMENTS

For efficiency, the DAS Contractor should ideally provide the Lead Carrier with all preliminary/detailed design documentation for review.

Submission of DAS information to the Lead Carrier should be through soft copies of all drawings, documents, and test results.

7.1.2 FILE TYPES AND DOCUMENT SECURITY

It is best practice that 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 file. The Carriers should provide editable link budgets, but this does not include specific IP. Carriers may decide to share power budgets.

If a DAS has been designed in specific software (e.g. iBwave™ or equivalent planning tools) those format files should ideally 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.

7.2 PRELIMINARY DAS DESIGN DOCUMENTATION FOR LEAD CARRIER REVIEW

The DAS designer may submit preliminary DAS design documentation to the Lead Carrier for confirmation of design acceptability prior to progression to detailed design. For efficiency, the preliminary documentation should ideally contain all relevant related information to 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 proposed Exemption Zones).
3. Forecast occupancy information that includes the maximum number of people expected to be served by the DAS at peak time and any specific user requirements.
4. Breakdown of tenants (if applicable and available).
5. Any known high-capacity service requirements (e.g. tenants want wireless offices).

6. Type of DAS architecture proposed.
7. Technologies proposed to be catered upfront (particularly for Active or Hybrid systems).
8. Number of RF carriers the link budget has been designed for.
9. A general description of the proposed concept design.
10. Antenna layout floor plans (scaled).
11. A system schematic diagram.
12. A high-level sector design (visually identifiable with different colours for each sector).
13. Link power budget calculations for a single RF carrier in each of the frequency bands/technologies proposed.
14. Calculation to show the composite power calculated at each antenna port.
15. Coverage predictions showing RF levels.
16. Bill of materials (excluding installation materials).

7.3 DETAILED DAS DESIGN DOCUMENTATION

The DAS designer may engage a Lead Carrier to review a detailed design prior to any installation works commencing. In order to facilitate the efficiency of the review, it is recommended that the following information be submitted to the Lead Carrier. The industry expectation is that this design will be “for construction” and will not deviate substantially from final as-built design.

7.3.1 DESIGN COMPONENTS

1. Design survey results:
   a. Existing coverage levels should be conducted on street level to evaluate handover requirement.
   b. Where possible 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. (Plots should 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 are recommended. Consultation with the Lead Carrier may assist in generating acceptable modelling.
2. Target Coverage Area on all relevant floor plans.
3. Exemption Zones should be clearly shown with reasoning on all relevant floor plans.
4. System description.
5. System schematic diagram.
6. DAS architecture.
7. Backbone distribution description.
8. Performance predictions of RF Signal.
9. Identify the proposed DAS coverage transition areas with the external mobile network.
10. A high-level sector design (visually identifiable, ideally with different colours for each sector).
11. A high-level future sector design which ideally allows doubling of the number of sectors without substantially modifying the DAS architecture.
12. Link power budget ideally providing:
   a. Calculations to show the composite power calculated at each antenna port is within

EME compliance levels when all channels in every frequency band are in operation simultaneously.

b. DAS Loss between MNC Input Port and Antenna Input port for every frequency band. Or between tie cable input and Antenna Input Port where a tie cable is included at the input of the MNC.
c. Calculations to demonstrate that expected RF levels achieved are in accordance with Section 5.7.1.
d. An RF Power allocation summary table showing the proposed RF powers at MNC Input (or Active/Hybrid DAS Remote O/P) for all channels in every frequency band for all Carriers.

13. Fibre distribution schematic for Active/Hybrid DAS architectures should also clearly articulate number of fibres available at each termination point and remaining available fibres for future use.
14. Equipment location and room details including access details, layout diagram/schematic showing BTS positions.
15. Photos of the proposed equipment room (if present).
16. 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 from 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/propagation models used to define the model and produce the prediction should be summarised.
17. Identification of Category 2 antennas and Preliminary RF Hazard Drawings (PRD).
18. Bill of materials (excluding installation materials).
19. Authority from the Lead Carrier for any Category 1 antenna where the power inserted will exceed the maximum composite power as stipulated in Table 4. For Active DAS elements with integrated antennas the Lead Carrier will typically 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.
20. 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.
21. A proposed GPS antenna installation location.
22. The GPS cable pathway from the equipment room to the proposed GPS antenna position.
23. Earthing requirements between future GPS antenna & GPS feeder to existing building/Lightning protection earth.
24. Proposed earthing for any externally mounted antennas or their support structures.
25. DAS and EME Signage and Labelling specification, location, and fixing requirements.

7.3.2 INSTALLATION COMPONENTS

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

Drawings should be prepared to scale in accordance with Australia Standards and recommendations and include the following:

- Physical Cable runs – complete path via penetrations/risers, etc.;
- Structural details and existing riser details, such as existing cable ladders, large pipes, etc., which are significant to the design;
- Backbone distribution layout;
- Proposed positions of antenna and other components (couplers, splitters, etc.);
- Preferred cable entry/exit points;
- Location of AC power outlets; and/or
- Equipment accommodation – main and remote.

Where required include all aspects of civil engineering design work including the following:

- Structural design of the antenna support structures; and/or
- Other structural calculations or designs.

Installation documentation should also include:

- Specification of AC power outlets for all AC powered equipment specified in the DAS;
- Security materials and installation specifications and details in accordance with requirements of Section 5.4;
- Design and specification of the protective earth systems including lightning finials on the antenna support structures for all externally installed antennas; and/or
- DAS and EME Signage and Labelling specification, location, and fixing requirements.

7.4 HANDOVER DOCUMENTATION

It is recommended that the following information be submitted in a final package to the Lead Carrier to achieve acceptance and handover of the DAS.

- Design documentation should be provided as revised/As-built versions of the information submitted in Section 7.3 above. These designs should not materially deviate from the proposal submitted to and reviewed by the Carrier;
- Test results for all installed components as detailed in Section 7.5 below;
- For Active/Hybrid DAS, all configuration information;
- Final DAS commissioning table summarising power allocation per operator per band;
- Low Power access point status/connectivity test report of all connected elements attached to the DAS;
- Low Power access point commissioning report to show number of units and architecture, CAT cable and or fibre connection schematic;
- Fibre diagram for Active/Hybrid DAS including number of fibres terminated at each location clearly articulating number of fibres in use and remaining for future upgrade use; and
- 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.

7.5 TEST RESULTS

7.5.1 INSTALLATION / TEST REPORT

It is recommended that the final DAS commissioning report submitted pursuant to Section 7.4 above should provide the following:

Information	Associated Test Reports
Any Target Coverage Area Exemption Zones with reasoning shown on floor plans	CW Walk Test Report
Test Equipment Used	PIM test Sweep Test Fibre Test
As-built walk test results	CW Walk Test Report
All sweep results (Return Loss – RL and Distance to Fault – DTF)	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.
PIM results tabulated	PIM Test Report
Floor Plans showing all hardware locations	As-built Pack and design files Note: If iBwave^{tm} is the design tool/ iBwave .ibw files
Schematic diagram	
Composite power table	
Bill of Material (BOM) used	
Optic Fibre Testing/Commissioning	Test Report
Equipment room layout diagram	As-Built Pack and design files
Sectorisation plan	As-Built Pack and design files
Any configuration settings for Active systems	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	As-Built Pack
Site Access details	As-Built Pack
Other DAS information reasonably required for operation and maintenance of the DAS e.g Type, Model, Serial Numbers and Locations of all Active DAS components. Photos of all Active DAS components installed. (May be requested by the Lead Carrier)	As-Built Pack and design files/iBwave .ibw files

Table 7 Installation/Test Report

7.5.2 TEST EQUIPMENT USED

It is recommended that a list of all test equipment be provided including:

1. Type / Manufacturer / Model number;
2. Serial number;
3. Calibration date; and
4. Purpose of test and configuration used for test.

7.5.3 RF SWEEPS

It is recommended that all RF cables used in the DAS should be swept / have a return loss measurement performed across all frequency bands indicated in Section 4.3.

Where a design tool model has not been utilised, the measurements should also be recorded in a spreadsheet summarising all measurements made with cross-referencing to the relevant cable number provided in the result.

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

It is recommended that all cables should have a distance-to-fault test performed to validate the installed length of the cable using the 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. The data relating to feeder length should be updated in the As Built and Link Budget.

RF Cable sweeps should:

- Be recorded in a similar format as per the diagram below and should include the cable number in the title.
- Be performed on each individual feeder cable, without other passive devices, jumpers or antennas connected.
- Have a suitable termination load placed on the far end during test.
- Display the date and time the test was performed and the calibration status of the instrument during the test.
- Return Loss limit line configured to represent the manufacturers specification for the component under test.
- Instrument be set to measure 2000 data points or higher for resolution.

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

- Certificate of Compliance confirming 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.

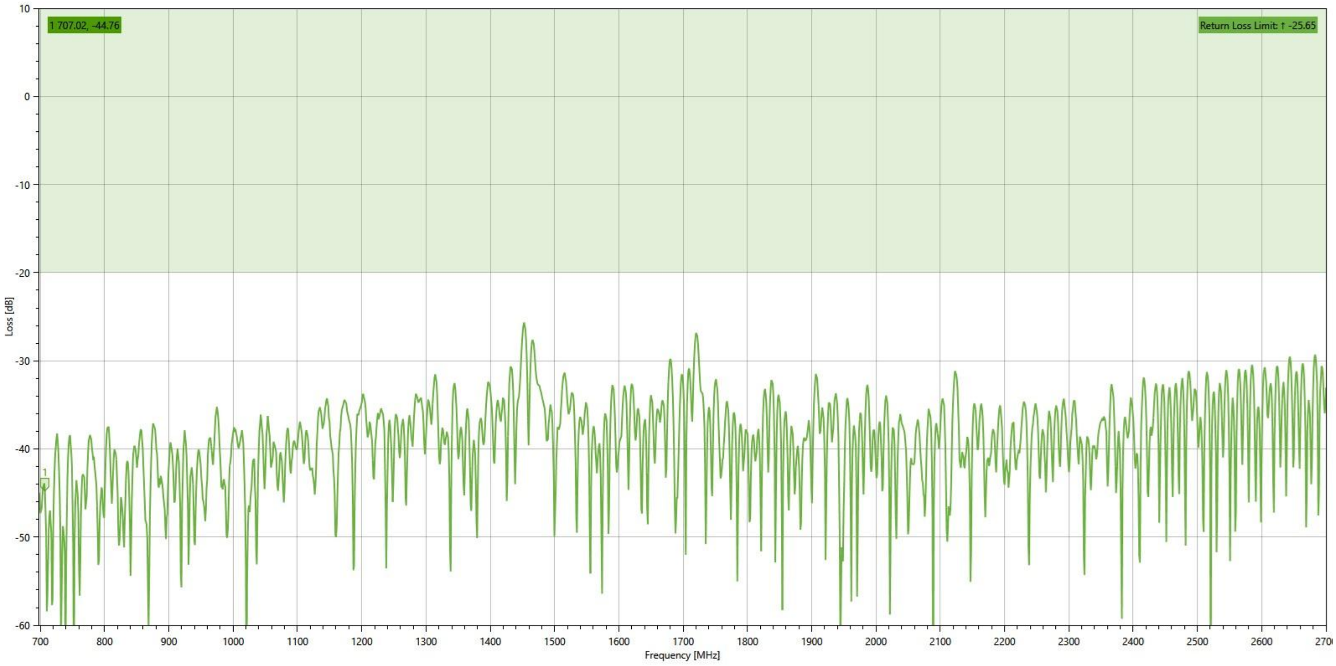

Figure 8 Example of a Return Loss Sweep

7.5.4 PASSIVE INTERMODULATION TESTING

It is recommended that 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” 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 a Passive DAS should commence with a PIM test of the MNC as an integrity test only and no results typically need to be provided as part of the test report deliverables.

PIM tests should be provided as part of the handover documentation are conducted on all the inputs of the multi-network combiner with all segments connected. Unused output ports will require termination into a precision load. Figure 9 shows the test configuration for Input 1 and Table 8 shows the PIM test parameters that apply. The test should be performed with the antennas connected to the DAS segment under test and ensure EME precautions are followed.

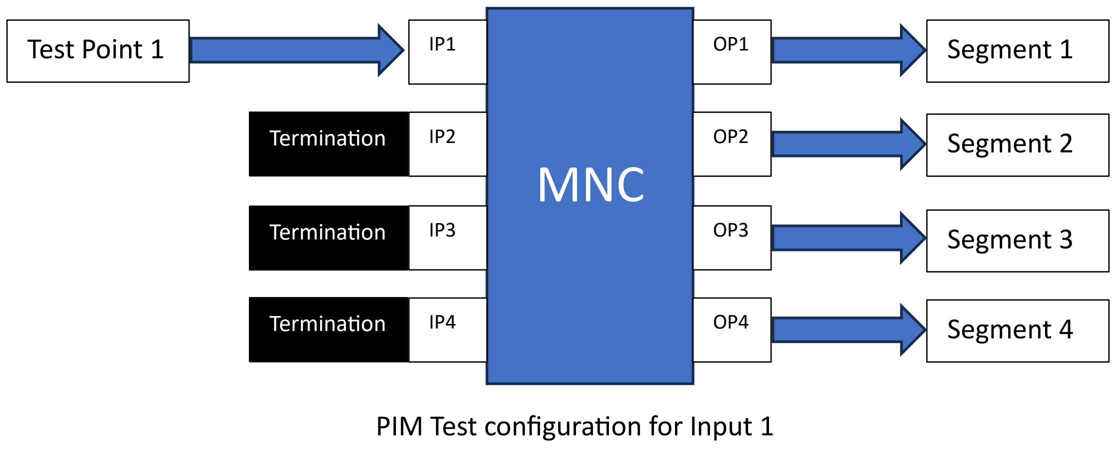

Figure 9 PIM Test Configuration for testing Segment 1

PIM TEST ON IP1	TEST TONE POWER	TARGET PASS
Low band test (one of 700/850/850E/900 MHz)	+40dBm	≤ - 140dBc
Mid band test (one of 1800/2100/2600 MHz)	+43dBm	≤ - 140dBc
High band test (3500 MHz) *where possible*	+43dBm	≤ - 140dBc

Table 8 MNC Input PIM Test Parameters

For a Hybrid DAS, test results should be provided showing reflected third-order PIM measurements taken from the input of each Passive Segment of the DAS connected to a remote unit (at the most forward location from the remote unit and after any filtering/band-specific componentry). Table 9 shows the PIM test parameter that apply and are based on per channel power levels.

PIM TEST ON	TEST TONE POWER	TARGET PASS
Low band test (one of 700/850/850E/900 MHz)	+34dBm	≤ - 140dBc
Mid band test (one of 1800/2100/2600 MHz)	+37dBm	≤ - 140dBc
High band test (3500 MHz) *where possible*	+37dBm	≤ - 140dBc

Table 9 Passive Branch PIM Test Parameters

Where PIM tests are conducted on points in the DAS other than the MNC input these tests should be conducted at power levels that consider the applicable losses at that point. For example, if a PIM test is undertaken for trouble shooting purposes into a DAS segment on the output side of the MNC, then the ~6dB loss through the MNC needs to be accounted for and the test tone power levels will be as per Table 9.
Equally, where a DAS segment has a lower proposed composite input power the PIM test tone power should be reduced accordingly and a target ≤ - 140dBc pass achieved.

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.

Testing PIM at high band is optimal if possible, however testing at 2600MHz while not testing PIM at 3500MHz is acceptable.

7.6 WALK TESTS

It is recommended that walk survey readings be plotted against final versions of building floor plans that have DAS antenna locations overlayed.

A scanner and test transmitter (CW signal generator) should be used at the highest frequency band proposed in the DAS system and using proposed operational power levels.

The results should indicate:

- Installed antennas are operational; and
- Signal levels achieved.

Walk survey tests of MIMO DAS system elements requires a different methodology to SISO DAS system tests to ensure validation of both MIMO streams. Typically, this can be achieved by either using two different test frequency inputs and providing a walk test scans that captures both, or by testing each MIMO stream in two separate walk tests.

7.6.1 WALK TEST ROUTE

It is recommended that the walk test route cover all trafficable areas of the building and pass under each antenna to capture antenna transmitting signal levels.

The walk test route should specifically demonstrate DAS performance meets or exceeds the performance requirements for >95% of the Target Coverage Area (apart from in any agreed Exemption Zone).

It is best practice for the walk test to ensure that the colour scheme used can clearly highlight where a DAS passes and fails the required KPI’s.

7.6.2 WALK TEST RESULTS

It is best practice for the results for walk tests to be recorded using a graduated and colour coded snail trail – as per the example shown in *Figure 10*.

For efficiency, the log files for these tests should be supplied to the Lead Carrier. 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.

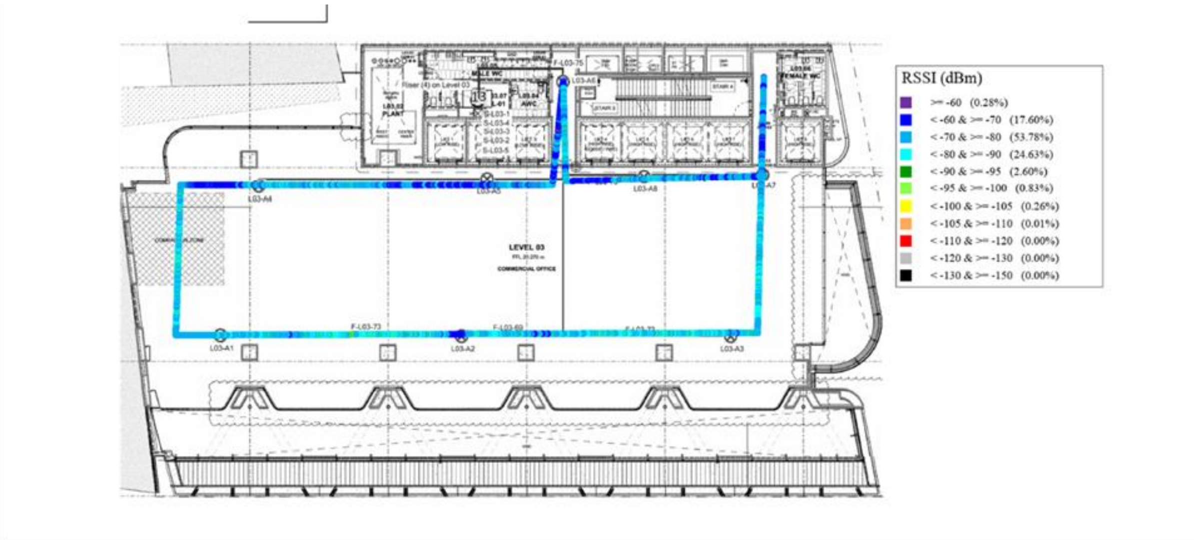

Figure 10 Example colour-coded coverage survey result

7.7 OPTIC FIBRE TESTING & COMMISSIONING

7.7.1 OTDR/LINK LOSS

It is recommended that OTDR/Link Loss measurements be completed on all fibres (used and spare) to confirm the integrity of the cable link without including the performance of the end connector/pigtails.

Link Loss (LL) is measured at 1550nm and/or 1310nm and the measured link insertion loss should be less than or equal to theoretical calculated maximum insertion losses as per manufacturer's specifications. Test results for all fibres are to be documented showing theoretical and achieved levels along with the current calibration date/status of all used.

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