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**Distributed Antenna System (DAS)
Design and Implementation
Best Practices**



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Distributed Antenna System (DAS) Design and Implementation Best Practices

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PREFACE

Revision History

May 13, 2015 First publication of this standard, titled ANSI/BICSI 006-2015, *Distributed Antenna System (DAS) Design and Implementation Best Practices*

Translation Notice

This standard may have one or more translations available for the convenience of its readers. As translated text may contain inconsistencies when compared to the original text, if differences between the translation and the published English version exist, the English text shall be used as the official and authoritative version.

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1 Introduction

1.1 Overview

A distributed antenna system (DAS) is a group of antennas spatially separated and distributed over a given geographic area to augment existing wireless (e.g., cellular, radio signal) service. Although useful in any circumstance where a single antenna is insufficient to provide the service levels expected, sophisticated commercial deployments typically take place in:

- Medical facilities
- Educational and industrial campuses
- Hotels
- Casinos
- Airports
- Tunnels
- Subways
- Office complexes
- Shopping malls
- Parking garages

A DAS may also be deployed to provide extra network capacity in venues that are infrequently used but are subject to high demand of wireless services such as stadiums, arenas, and auditoriums.

A DAS may be deployed either indoors or outdoors. It is a system of antennas typically deployed within isolated areas of a building or series of buildings, such as a campus, to increase the ubiquity of coverage within the objective. When a DAS is used to provide wireless service as part of an outdoor application, natural or manmade morphological or environmental factors are essential to consider during a full wireless signal distribution design. When a DAS is used to provide wireless service as part of an indoor application, architectural features, morphologies, and macro environmental impacts are essential to consider.

Some commonly retransmitted services of a DAS include:

- 700 MHz
- Cellular service (850 MHz)
- Global System for Mobile Communications (GSM) (900/1800 MHz)
- Personal communications service (PCS) (1900 MHz)
- Enhanced specialized mobile radio (ESMR) (800/900 MHz)
- Advanced Wireless Services (AWS) (1700-2150 MHz)
- Broadband Radio Services (BRS) (2600 MHz)
- Public safety and business band land mobile radio (LMR) (150-170 MHz, 450-512 MHz)

NOTE: 47CFR90.35 assigns 450-470 MHz to LMR; heavily used for businesses and government.

Uncommonly transmitted services of a DAS include:

- Pocket pagers
- Emergency medical service (EMS) radio
- Industrial, scientific, and medical (ISM) band equipment
- Wireless local loop
- Local unlicensed walkie-talkies

These lists are not intended to be comprehensive; they are used only to illustrate the variety of retransmitted services possible.

1.1.1 Trends Affecting DAS

1.1.1.1 Building Design and Construction

Since the 1990s, there has been an increasing focus of integrating sustainable practices into building design and construction. Defined within Leadership in Energy and Environmental Design (LEED), Energy Star[®], and other programs are requirements and recommendations that encourage the reuse of existing buildings, which will often block effective RF transmission penetrations through the outer shell, throughout a floor, or between floors within the interior space of a building. A DAS is one means to enable wireless services for new building tenants.

NOTE: Methods to reduce or eliminate thermal radiation through windows are effective at reducing or blocking most types of wireless transmission since microwave and other RF frequency bands fall under the broader spectrum of thermal radiation.

The macro network is becoming less and less able to deliver ubiquitous service as the number of buildings or the height of buildings in a given area increases. Both obstructions and elevated noise levels demand higher levels of signals than can be generated by conventional macro cellular base stations.

1.1.1.2 Public Safety and Services

Legislative developments have seen the creation of requirements for public safety wireless systems in the form of NFPA 1, *Fire Code*, NFPA 72, *National Fire Alarm and Signaling Code*, and the latest edition of the *International Building Code*. Adoption of these codes and their requirements is ongoing, and this is a trend that is expected to increase in the future.

As technology is increasingly integrated into safety and security services, additional capabilities and new functionalities become possible. With these advances in function, communication with a building's surveillance, fire detection/suppression, and access control systems by police, fire, and other personnel are now possible. Near-term objectives include allowing first responders access to information from the site's information systems, as well as allowing systems of differing responders to share information quickly and efficiently. Some authorities having jurisdiction (AHJs) are now creating requirements to ensure continued and effective wireless communication between responders, their equipment, and staff or equipment reporting about the incident on the site itself.

The public safety component for in-building solutions requires consideration of three capabilities. The first capability is being able to alert people in the building that there is danger (indoors or outdoors), and they should either shelter in place or evacuate as the situation dictates. The second is providing the capability for building occupants to both obtain and give "expected" information when an incident occurs in the facility. The third is providing the capability for responders to communicate clearly and effectively with each other, as well as to their dispatchers.

1.1.1.3 Underground Installations and Transit Corridors

As population densities increase within metropolitan areas, building underground has become a solution for providing additional space and transportation options, while minimizing the impact from construction and eventual use, as compared to its equivalent located above ground. However, the ground and the required infrastructure for underground structures are very effective at blocking wireless signals, making it necessary to implement a complete wireless transmission infrastructure for these spaces.

1.1.1.4 Data Traffic Explosion

In addition to the growth that is projected to continue, radio access (e.g., 4G Long-Term Evolution [4G-LTE]) is reaching the limits of spectrum availability. With this limit in sight, another solution must be found to increase overall mobile network capacity. One way to facilitate this objective is by deploying small cell and DAS technologies.

Now in their fifth generation, the most efficient way to use small cells is to position them in locations where significant amounts of data are being generated but where macro cell coverage is lacking or a DAS deployment is impractical for the size of the coverage hole being filled. In larger work places, university campuses, shopping malls, stadiums, public transportation hubs, and the like, one effective deployment method is to use an array of low power small cells to provide RF source signals to a well-engineered DAS.

1.2 Purpose

The purpose of this standard is to afford designers and installers an opportunity to enhance their knowledge of quality DASs, understand the requirements of superior performing systems, and provide requirements and recommendations for the design and installation of standards-compliant, vendor-neutral systems.

1.3 Categories of Criteria

Two categories of criteria are specified—mandatory and advisory:

- Mandatory criteria generally apply to protection, performance, administration and compatibility; they specify the absolute minimum acceptable requirements.
- Advisory or desirable criteria are presented when their attainment will enhance the general performance of the system in all its contemplated applications.

Mandatory requirements are designated by the word *shall*; advisory recommendations are designated by the words *should*, *may*, or *desirable*, which are used interchangeably in this standard. Where possible, requirements and recommendations are separated to aid in clarity.

Notes, cautions, and warnings found in the text, tables, or figures are used for emphasis or for offering informative suggestions.

2 Scope

This standard provides industry and service provider neutral requirements and acceptable best practices for the design and installation of DAS. For brevity, as used in this document, the terms *distributed antenna system* or *DAS* includes other in-building wireless and similar systems, such as radiating cable and small-cell networks, unless these systems are specifically described.

The document will address, at minimum, the following:

- A description of a typical DAS
- Components used within a DAS
- Types of host systems (2-way voice, cellular, LTE, public safety, business band, analog, digital, other)
- Compliance and integration with existing related codes and standards and other legal concerns
- Coordination with the host system owner(s)
- RF system design methods
- Telecommunication infrastructure design
- Installation and commissioning methods
- Electromagnetic compatibility (EMC) and radio frequency interference (RFI) mitigation
- Designer, installer and service personnel qualifications
- Administration, labeling and documentation
- Inspection, testing and maintenance

There are also sections devoted to trouble spot areas where RF coverage is often difficult, such as stairwells and elevators, and to special locations, such as hospitals, parking garages, schools and industrial plants.

While the specific requirements and recommendations of this standard were written for areas within North America, the general principles and recommendations are applicable throughout the world.

2.1 Limitations

Although the principles of this standard are applicable to all signal source technologies, this standard does not specifically address:

- Wi-Fi
Although some vendors are beginning to include Wi-Fi capability in their DAS product lines, Wi-Fi networks are relatively mature and can often be deployed just as effectively using standard structured cabling methods.
- WiMAX
At the time of publication, WiMAX technology is not highly used within DAS deployments.

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3 Required Standards and Documents

The following standards and documents contain provisions that constitute requirements listed within this standard. Unless otherwise indicated, all standards and documents listed are the latest published version prior to the initial publication of this standard. Parties to an agreement based on this standard are encouraged to investigate the possibility of applying a more recent version as applicable.

Where equivalent local codes and standards exist, requirements from these local specifications shall apply. Where reference is made to a requirement that exceeds minimum code requirements, the specification requirement shall take precedence over any apparent conflict with applicable codes.

BICSI

- ANSI/BICSI 003, *Building Information Modeling (BIM) Practices for Information Technology Systems*

European Committee for Electrotechnical Standardization (CENELEC)

- EN 50173-1, *Information technology – Generic cabling systems – Part 1: General requirements*
- EN 50174-2, *Information technology – Cabling installation – Installation planning and practices inside buildings*

Institute of Electrical and Electronics Engineers (IEEE)

- IEEE C2, *National Electrical Safety Code*
- IEEE 802.3, *Standard for Ethernet*

International Electrotechnical Commission (IEC)

- IEC 60364, *Electrical installations of buildings*
- IEC 62305-3, *Protection against lightning - Part 3: Physical damage to structures and life hazard*
- IEC 62305-4, *Protection against lightning - Part 4: Electrical and electronic systems within structures*

International Organization for Standardization (ISO)

- ISO/IEC 11801, *Information technology – Generic cabling for customer premises*
- ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*
- ISO/IEC 30129, *Application of equipotential bonding and earthing in buildings with information technology equipment*

National Electrical Contractors Association (NECA)

- ANSI/NECA/BICSI 607, *Standard for Telecommunications Bonding and Grounding Planning and Installation Methods for Commercial Buildings*

National Fire Protection Association (NFPA)

- NFPA 70[®], *National Electrical Code[®] (NEC[®])*
- NFPA 72, *National Fire Alarm and Signaling Code*

Telecommunications Industry Association (TIA)

- ANSI/TIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*
- ANSI/TIA-568-C.3, *Optical Fiber Cabling Components Standard*
- ANSI/TIA-569-D, *Telecommunications Pathways and Spaces*
- ANSI/TIA-606-B, *Administration Standard for Telecommunications Infrastructure*
- ANSI/TIA-607-B, *Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises*

United States Code of Federal Regulations (CFR)

- *Federal Communications Commission (FCC)*
 - 47 CFR 1.1310, *Radiofrequency Radiation Exposure Limits*
 - 47 CFR 17, *Construction, Marking, And Lighting Of Antenna Structures*
 - 47 CFR 90.219, *Use of Signal Boosters*

4 Definitions, Acronyms, Abbreviations, and Units of Measurement

For the purpose of this standard, the following definitions, acronyms, abbreviations, and units of measurement apply.

4.1 Definitions

antenna	A conductive structure which is specifically designed to couple or radiate electromagnetic energy. In radio frequency systems, the antenna may be used to both transmit and receive electromagnetic energy.
attenuation	The decrease in magnitude or the power loss of a signal that propagates between points, expressed in decibels (dB), as the ratio of received signal to transmitted signal level.
array (antenna)	An antenna made up of a number of elements, including an active or driven element, a reflector, and a director. Array antennas may be narrowband or broadband and are used in all frequency bands.
backend equipment	The equipment components of a distributed antenna system that are located in an area of coverage and receives and transmits signals to the headend.
backhaul (wireless)	The portion of a cellular wireless network that connects a cell tower to an Internet service provider.
bandwidth	A measure of the range of frequencies associated with a given signal or communication channel, typically expressed in hertz. It is used to denote the potential transmission capacity of the medium, device, or system.
base station	The fixed part of a mobile radio frequency network through which mobile and portable terminals (or stations) communicate and may be operated by local or remote means. A base station may also be known as a base transceiver station (BTS).
beamwidth (antenna)	The angular separation in which the gain of the antenna decreases by 3 dB (50% of the power) relative to that at the peak of the main beam. Also known as <i>half power beamwidth</i> .
bidirectional amplifier	See <i>signal booster</i> .
broadband	The transmission of signals through the simultaneous use of multiple communication channels or frequencies, allowing for more information or data to be transmitted in a given period of time. Contrast with <i>narrowband</i> . NOTE: <i>Broadband</i> is commonly used to describe a high speed digital signal associated with backbone or multiplexed transmissions.
cell	The fixed area in which a wireless base station or access point is configured to operate.
combiner	A device that merges two or more input signals into a single output signal.
coaxial cable	A cable consisting of a central metallic inner conductor separated from an enclosing outer conductor by a dielectric material. This material may be solid, foam, a suitable gas, or dry air. The outer conductor comprises a metallic braid, a foil layer, combination of braid and foil, or a solid metallic sleeve. The cable may be protected by an outer jacket of non-conducting material.
diplexer	A passive three-port frequency-dependent device that allows two transmitters operating at different frequencies (e.g., 150 megahertz [MHz] and 450 MHz) to share a single antenna system.

dipole	An antenna formed by splitting two wires of a two-wire transmission line and bending them back to form a single straight line. The antenna feed is in the middle of the dipole antenna where the split occurs. A dipole antenna is a resonant antenna. The optimal length of a dipole antenna is one half of the wavelength of the signal being received or transmitted by the antenna. A dipole antenna is a narrowband antenna, operating efficiently in only a narrow band of frequencies.
directional antenna	An antenna that radiates greater signal power in one or more specified directions, which yields increased transmission and reception performance with reduced interference from unwanted sources in those directions.
directional coupler	A device typically used in transmission line circuits to isolate the transmitter from the receiver while using a common antenna. Transmitted signals pass easily to the antenna while being blocked from reaching the receiver. Received signals pass to the receiver and are blocked from the transmitter. Unlike with a duplexer, transmission and reception cannot occur simultaneously.
distributed antenna system	A network of spatially separated antenna nodes, connected to transmission equipment by one or more types of transmission media, which provides wireless service(s) within a defined area.
donor signal	The signal from the originating source that is amplified and distributed throughout a facility by a distributed antenna system (DAS). The donor signal may be received by the DAS via either a donor antenna or by direct cable connection to the donor site.
downlink	Signals transmitted from the wireless service provider equipment to a wireless mobile device.
duplexer	A device that allows an antenna to be used to transmit and receive simultaneously by isolating the receiver from the transmitter.
effective isotropic radiated power	The power supplied to an antenna multiplied by the antenna gain in dBi in a given direction. Sometimes called equivalent isotropically radiated power.
effective radiated power	The power supplied to an antenna multiplied by the antenna gain in dBd in a given direction.
electromagnetic interference	Radiated or conducted electromagnetic energy that has an undesirable effect on electronic equipment or signal transmissions.
frequency	The number of cycles or sine waves occurring in a given time. If the unit of time is one second, then the frequency is stated in hertz (Hz); one Hz is equal to one cycle per second.
frequency band	A specified range of frequencies in the radio frequency (RF) spectrum for the operation of different radio communication classes.
frequency converter	An integrated component assembly required for converting signals into lower or higher frequency ranges for further processing.
gain	The increase in output current, voltage, or power relative to input current, voltage, or power, respectively. Gain is usually expressed in dB.
gain (antenna)	The ratio of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength at the same distance. Antenna gain is usually expressed in decibels relative to an isotropic radiator (dBi) (isotropic reference) or half wavelength dipole reference (dBd).
headend equipment	The main active equipment within a DAS that provides the interface between provider services (i.e., those to be retransmitted by the DAS) and the equipment and components distributing radio frequency signals to designated coverage areas.

ingress protection	The capability of an enclosure (e.g., outlet box, connector), equipment or other object to resist ingress of foreign objects and water. Ingress protection of an object is expressed in the form of IPxy where x represents the capability to resist penetration of foreign objects, and y represents resistance to water.
leaky coax	A colloquial term for <i>radiating cable</i> .
loss	The attenuation undergone by an electromagnetic wave in transit between a transmitter and a receiver. It may be caused by many effects such as free-space loss, refraction, reflection, aperture-medium coupling loss, and absorption.
morphology	The differences in the path loss decay between free space and the actual venue conditions. An RF signal's propagation is unique to each venue, being impacted by numerous factors, including the type of venue (arena, stadium, offices, cubicles, tunnel, outdoor open space, etc.); the venue structural materials (concrete, steel, wood, etc.); the signal's frequency and the modulation method. Therefore, a simple calculation, such as free space loss, cannot accurately predict actual RF signal coverage, especially indoors.
N type or N connector	A medium-size threaded coaxial connector, having a center pin that is installed over the cable's center conductor, typically used for radio frequencies up to 18 GHz.
narrowband	A limited (narrow) band of frequencies that carries voice information. Contrast with <i>broadband</i> . NOTE: Within the United States, it is a specific frequency range set aside for mobile or radio services, including paging systems, from 50 cycles per second (cps) to 64 kilobits per second (Kbps).
null	Area where signal strength has a non-detectable magnitude.
omnidirectional antenna	An antenna that radiates signal power equally in all directions along one plane with signal power decreasing as the angle between the radiated signal and the plane increases.
passive intermodulation	Undesirable mixing of signals by non-linear passive components.
radiating cable	A coaxial cable with a solid copper helical outer conductor and a solid copper inner conductor with a foam dielectric in between. The helical outer conductor has slots that allow ingress and egress of RF signals within a limited range, allowing the cable to function as an omnidirectional antenna. Radiating cable may also be called <i>leaky coax</i> .
radio frequency	An electromagnetic frequency typically between 3 kHz to 300 GHz used in wireless communication.
radio frequency interference	Electromagnetic interference that occurs at frequencies within the radio spectrum.
receiver	An electronic device that detects, demodulates, and amplifies transmitted signals.
repeater	A device (e.g., station, transceiver) that incorporates transmission and reception functions and is used to extend geographical range or coverage ability of wireless systems.
remote unit	Within a DAS, the term given to the distribution cable signal to RF signal converter that is connected to one or more antenna(s).
signal booster	A device at a fixed location that automatically receives, amplifies, and retransmits on a one-way or two-way basis, the signals received from base, fixed, mobile, and portable stations, with no change in frequency or authorized bandwidth. A signal booster may also be termed a <i>bidirectional amplifier</i> or <i>BDA</i> .
simulcast	An identical transmission in time, frequency, and phase between or among a set of emitters in a network.

site survey	A process used to identify the characteristics (e.g., physical, electromagnetic) within a defined area that will impact the installation and operation of a network within that area.
splitter	A device that divides an input signal into two or more output signals.
transceiver	A radio transmitter and receiver combined into a single unit.
wavelength	The length of a wave measured from any point on one wave to the corresponding point on the next wave (e.g., from crest to crest). Wavelength is inversely proportional to frequency.
wireless local area network	A local area network that functions wirelessly between the client and a wireless access point.
wireless service provider	A company or other entity that offers transmission services to users of wireless devices (handheld computers and telephones) through radio frequency (RF) signals. Signals from a wireless service provider are sometimes termed a <i>donor signal</i> .
Yagi antenna	A tree-shaped antenna that uses a reflector element and one of or more director elements to focus the radiated signal in one direction or plane.

4.2 Acronyms and Abbreviations

Abbreviations and acronyms, other than in common usage, are defined below.

AC	alternating current	MIMO	multiple input/multiple output (antenna)
AHJ	authority having jurisdiction	PoE	power over Ethernet
BIM	building information modeling	PIM	passive intermodulation
BDA	bidirectional amplifier	PTP	point-to-point
BTS	base transceiver station	RF	radio frequency
CW	continuous wave	RFI	radio frequency interference
DAS	distributed antenna system	TR	telecommunications room
DC	direct current	UMTS	universal mobile telecommunications system
EIRP	effective isotropic radiated power	UTP	unshielded twisted-pair
EMI	electromagnetic interference	UHF	ultra high frequency
ER	equipment room	VHF	very high frequency
ERP	effective radiated power	VSWR	voltage standing wave ratio
ICT	information and communication technology	WAN	wide area network
LMR	land mobile radio	WLAN	wireless local area network
LTE	long term evolution	WSP	wireless service provider
MCU	master control unit		

4.3 Units of Measurement

The units of measurement used in this standard are metric. Approximate conversions from metric to U.S. customary units are provided in parentheses; e.g., 100 millimeters (4 inches).

Units of measurement used in this standard are defined below:

Ω	ohm
BTU	British thermal unit
dB	decibel
dBd	dB (dipole)
dB _i	dB (isotropic)
ft	foot
ft ²	square foot
GHz	gigahertz
hr	hour
Hz	hertz
in	inch
kJ	kilojoule
kHz	kilohertz
m	meter
m ²	square meter
mm	millimeter
MHz	megahertz
V	volt
V _{AC}	volt alternating current
V _{DC}	volt direct current
W	watt

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5 Regulatory and Safety

5.1 Local Code Requirements

Local code requirements shall be followed. Always review the local code requirements with the local AHJ before proceeding with the installation. This includes reviewing what code and edition is adopted and what, if any, exceptions to the code are adopted by the governing authority. Most of the code requirements for the job should be included in the scope of work documents. The installer should never take this information for granted since the telecommunications contractor is fully responsible for all work done on the project.

If no code has been adopted locally, consult with the fire marshal's office to determine what agency is responsible for that geographic area and what codes are in effect. Do not depend on other installers, contractors, or even site owner personnel in making these determinations.

5.2 Local DAS Requirements

Within NFPA 72, there is inclusion of an annex recommending specific DAS or other in-building wireless system requirements for certain commercial buildings to provide coverage for public safety radio systems. The International Code Council (ICC) has developed a similar initiative.

A growing number of cities and states are adopting this or a similar code, making such coverage mandatory at least for new construction of a certain size. The specifics of these ordinances and codes vary, but most include:

- A minimum signal strength limit
- Application of the limit over a specified percentage of each floor
- A specific level of reliability or confidence in the signal level
- A specified frequency band or bands for public safety coverage
- Testing requirements and procedures
- Provisions for penalties
- Provisions for waivers of the requirements
- Pathway survivability

5.3 Personnel Safety Requirements

A number of jurisdictions have established personnel RF exposure standards for wireless transmission facilities, based on input from the public, academia, scientists, the telecommunications industry and government health and safety agencies. Follow local RF safety requirements. In the United States, the FCC has published OET Bulletin 65, to provide assistance in determining whether proposed or existing transmitting facilities, operations or devices comply with limits for human exposure to radiofrequency (RF) fields.

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6 Distributed Antenna Systems and Components

6.1 Types of DAS

6.1.1 Overview

There are three primary types of distributed antenna systems as explained in the following sections. While these types are shown in the context of a single building, all three may be deployed across multiple buildings, in an outdoor environment, or a combination thereof.

6.1.2 Passive DAS

Passive solutions distribute RF energy over coaxial cables and through signal combiners and filters to coverage antennas. Between the RF sources and the coverage antennas, there are only losses. There are no link budget gains. Although typically used to distribute small amounts of energy from RF sources less than 1 watt in power through distribution trunks and branches of less than 200 feet, high power systems of 20 or 40 watts can drive thousand-foot runs of radiating coaxial cables through train or pedestrian tunnels. Passive solutions are often desirable in small to medium buildings with less than 11,150 m² (120,000 ft²) of floor space when there is a good signal on the outside but assistance is needed to penetrate the building.

NOTE: A repeater or bidirectional amplifier, small cells, or macrocells can all be used as a source for a passive DAS.

A network of 50 ohm coaxial cabling, couplers, and splitters is used to carry the RF signal to and from the distributed antennas. Figure 6-1 shows a passive DAS with the three main stages indicated.

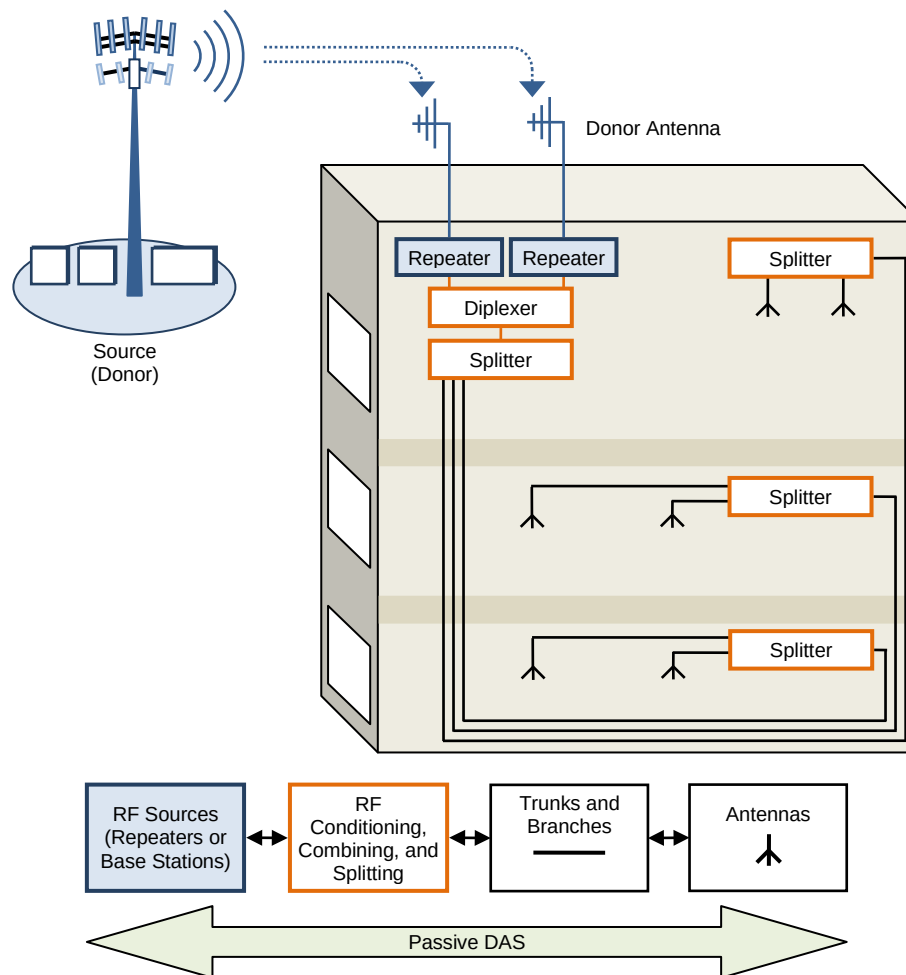


Figure 6-1
Example of a Passive DAS

While Figure 6-1 shows just one coaxial cable run per floor from the wideband splitter, further splitters can be used to distribute the RF signal via coaxial cable to multiple splitters.

In practice, a purely passive approach to distributing signals to each floor is limited. Each time a cable is split, the signal level is reduced, with potential additional losses from reflections and connections. Additionally, while attenuation of the cable can be lowered by the use of larger diameter coaxial cables, larger cabling typically has a higher cost per foot and an increased difficulty in installation as a result of its inherent stiffness. Thus, purely passive systems tend to be used only for small venues.

6.1.3 Active DAS

An active DAS is characterized by a main hub (located in a headend) that bidirectionally downlinks RF signals into media signals and uplinks media signals into RF signals. Remote media downlink to RF downlink and RF uplink to media uplink converter units tactically placed across the venue provides coverage to an array of zones or areas of interest. An active DAS is mostly deployed with dedicated base transceiver stations (BTS's) because of traffic demand.

Optical fiber cabling is the most common medium used by far in active DASs for the distribution of signals to the service zones even though other media, mainly unshielded twisted-pair (UTP), are recognized. This section discusses Active DASs in the context of optical fiber distribution, recognizing that other non-coaxial physical media are occasionally used as well. Figure 6-2 illustrates an active DAS, including an optical fiber distribution between floors.

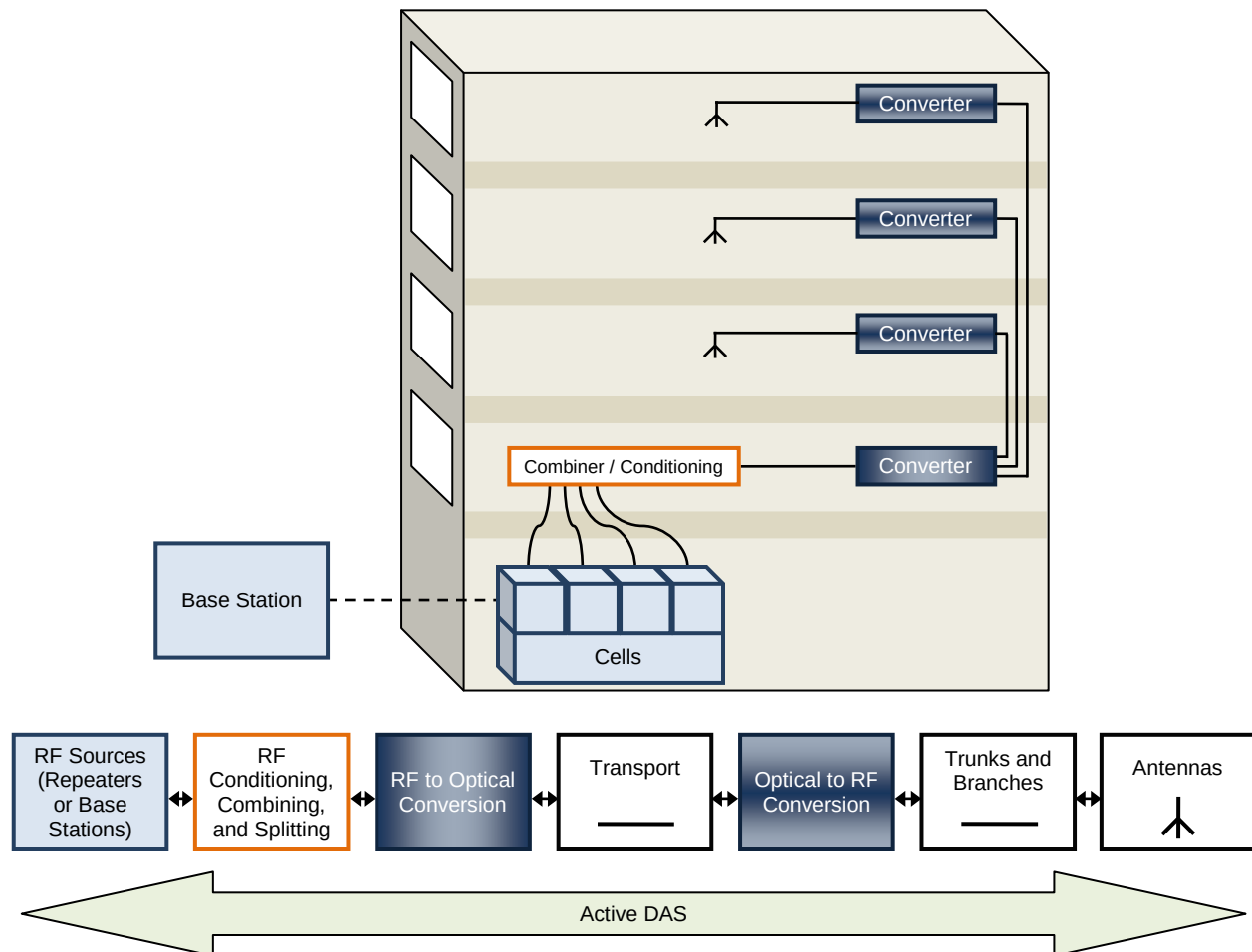


Figure 6-2
Example of an Active DAS

While Figure 6-2 shows a base station in place of the donor antennas shown in the passive system (Figure 6-1), both passive and active DASs use the same type of operator feeds and operator specific conditioning units. Multiple signals may be combined in both, however in an active DAS, the combined RF signal is fed to an RF-to-optical signal converter and then split off into multiple fiber ports supporting the combined signals. An optical fiber cable is then connected from each port to a remote active unit that serves to convert the optical fiber signals back into RF signals. After going through the remote unit's filtering and amplification stages, the RF signals are subsequently coupled to the antennas.

The choice of an active DAS versus a passive DAS is based on many site specific factors. In the past, purely active solutions were less likely to be seen in the building coverage application as there were several downsides to this purely optical approach. Although the installation of optical fiber cabling is typically more convenient than the installation of coaxial cable, optical fiber cabling requires the presence of active equipment at each antenna location. Today's systems are increasingly required to support more frequencies and technologies over larger areas. As a result, several manufacturers have developed solutions that deploy active antennas that greatly reduce the amount of loss between the headend and the antenna.

For large installations, the number of converters required can increase the complexity of designs as space and power needs to be allocated for each converter. This can be mitigated by using a hybrid cable that contains an optical fiber cable and an electrical conductor pair, for direct powering of the converter.

6.1.4 Hybrid DAS

A hybrid DAS combines the use of both active and passive components and system architectures. Various amounts of passive connectivity are required to couple the remote active units to its set of associated antennas. In order to overcome the limitations of the splitter and coaxial cable approach to distributing the wireless signals to multiple locations on each floor, alternative approaches to the fully active and fully passive DAS can be used.

While a hybrid DAS is configured primarily as an active DAS, passive DAS components are used between the optical-to-RF signal converter and the antennas.

An example of a hybrid DAS and its elements is shown in Figure 6-3.

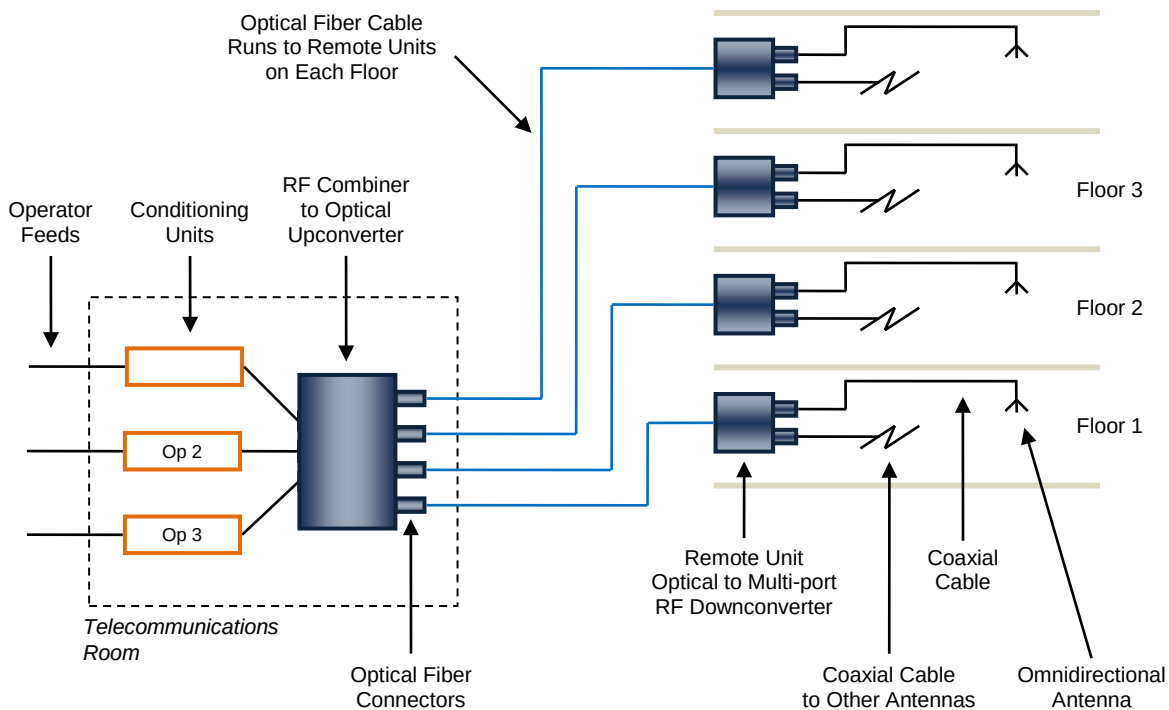


Figure 6-3
Example of an Hybrid DAS

The optical-to-RF converter in a hybrid DAS is connected to the DAS headend by optical fiber cable, but includes multiple coaxial cable ports to connect to the antennas being served. In addition to reducing issues because of coaxial cable length, other advantages include:

- Decreased numbers of active optical-to-RF converters
- Telecommunication spaces (e.g., TR) can be used to support active converters
- The use of telecommunications spaces for active equipment provides safe and secure accommodation of active equipment. (contrast with mounting active equipment near an antenna within a plenum space)

6.2 Signal Source Technology

6.2.1 Introduction

There are two methods for linking a DAS to a signal source. One is with a donor antenna installed on the roof of the building, directed toward the nearest wireless service provider's (WSP) tower. Since the tower's radio resources are used with this method, the DAS is not adding capacity; it is only improving coverage.

The second method is to install a dedicated cable (usually optical fiber) between the DAS and the donor network. This method allows for both coverage and capacity improvement, but it is more expensive.

The DAS designer's selection will depend on a number of factors, including, for example, the system's mission (improve coverage, improve capacity, or both), the WSP's preferences, obstructions to an antenna link between the DAS site and the signal source site, potential cable routes, and budget. Often, a combination will be used. For example, optical fiber cables may link to the cellular networks of the various WSPs while a roof-top antenna links to the local public safety LMR systems.

6.2.2 Common Signal Types

6.2.2.1 Global System for Mobile Communications (GSM)

GSM is a time-division multiple-access (TDMA) standard developed in the 1980s by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks. It became the de facto global standard for mobile communications with over 80% market share. Since its original development, several upgrades and enhancements have added frequency bands, data capability, and higher throughput speeds.

GSM phones have a Subscriber Identity Module (SIM) that holds the user's telephone number, personal information, and an authentication and encryption key to deter theft of service and illegal call monitoring. The SIM can be easily moved from phone to phone.

GSM is evolving into, and gradually being replaced by, third generation technologies, such as Universal Mobile Telecommunications System (UMTS) and High-Speed Packet Access (HSPA), and by fourth generation technologies such as Long Term Evolution (LTE). But, to date, GSM continues to have the majority of cellular phone users.

GSM, UMTS, and HSPA networks operate in over two dozen frequency bands, ranging from 380 MHz to over 3500 MHz. The DAS designer will need to consult with the local WSPs to determine which band(s) they use.

6.2.2.2 Code Division Multiple Access (CDMA)

CDMA is a channel access method protocol used in wireless communication. CDMA is a form of multiplexing, which allows several transmitters to send information simultaneously over a single communication channel, optimizing the use of the available bandwidth. By doing so, a band of frequencies can be shared by several users. CDMA uses spread-spectrum technology and a special coding scheme to prevent interference between the users. CDMA is used in cellular telephone systems in the 800 and 1900 MHz bands.

6.2.2.3 Wideband Code Division Multiple Access (W-CDMA)

W-CDMA is a third generation cellular standard developed in the late 1990s, and it was eventually accepted by the International Telecommunications Union as part of its IMT-2000 family of standards. W-CDMA uses direct sequence spread spectrum techniques, transmitting on a pair of 5 MHz-wide radio channels. Major advantages of this standard are its performance in the face of interference and its resistance to interception. As with the other protocols described here, W-CDMA networks operate over numerous frequency bands. The DAS designer will need to consult with the local WSPs to determine which band(s) they use.

6.2.2.4 Long Term Evolution (LTE)

LTE is a fourth generation standard for wireless communication of high-speed data for mobile phones and data terminals. Recent developments are adding voice and land mobile radio (LMR) to the standard's capabilities. The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s. It supports scalable carrier bandwidths from 1.4 MHz to 20 MHz and both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS, and CDMA2000. However, typical service has downlink speeds of 12 Mbits/s and uplink speeds of 5 Mbits/s or 5 times faster than 3G technology peak speeds.

LTE has become the primary upgrade path for both GSM-based and CDMA-based WSPs. As with the GSM and CDMA families of protocols, LTE can be used in a multitude of frequency bands, ranging within the current spectrum allocations between 700 MHz and 3800 MHz. The DAS designer will need to consult with the local WSPs to determine which band(s) they use.

6.2.2.5 Land Mobile Radio (LMR)

LMR systems use a fleet of vehicle-installed and handheld two-way radios to allow users to communicate among themselves and often with one or more base stations. LMR systems are used by emergency first responder organizations, public works organizations, companies with large vehicle fleets, campus or regional security staff, maintenance and operation crews, construction workers, and the military, among others.

The primary frequency bands used are the 150-172 MHz, 450-512 MHz, 800 MHz, and 900 MHz bands. The use of the 700 MHz band is growing as the result of congestion in the 800 MHz band. There are some LMR systems in the 30-50 MHz band, but the large equipment and long (up to 10 m [33 ft]) antennas required limits mobile and portable use.

Analog frequency modulation (FM) has been the primary modulation method for several decades. Although analog amplitude modulation (AM) exists, it is primarily in the broadcast and aeronautical bands and is generally not used for professional LMR systems. Although AM supports greater ranges, it is susceptible to interference from mechanical (e.g., vehicle engines) and natural (e.g., lightning) sources. Advances in technology in the last several years have allowed a migration to digital modulation methods to where analog LMR are now considered legacy systems for many applications.

LMR systems have a long life span, typically more than ten years, so it will be some time before analog LMR is no longer in service. This means that the DAS designer must be prepared to develop a system that can handle analog, digital or both modulation types.

There are numerous digital protocols that have been developed for use in the LMR bands. Some of these protocols also have applications that permit the use of analog radios, primarily to allow system owners to gracefully migrate their legacy analog system to digital in a cost effective manner. Further, whether analog or digital, LMR systems can also be categorized as either "conventional" or "trunked," depending on the overall system topology.

One version of conventional systems have mobile, portable, and base stations that link directly to each other, usually using a single frequency, referred to as simplex operation. This limits the range of the system because of power constraints of the portable and mobile units and to obstructions that block the signal. To overcome these limitations, the other version has one or more repeaters installed at elevated locations (on mountaintops or using tall towers), called half-duplex operation. The mobile, portable, and base stations transmit on one frequency to the repeater, which simultaneously re-transmits the signal on a second frequency. The higher power of the repeater and its higher elevation provides a much greater coverage area.

Trunked systems were developed when the available spectrum for conventional systems became heavily congested. Trunked systems use two or more repeaters along with a specially designed computer, called a controller, to allow a substantial increase in traffic capacity for a given set of channels. When a portable, mobile, or base station first transmits, it sends a "request to transmit" signal to the controller, which assigns an available repeater. The requesting unit and all other units in its group change to that repeater's channel and begin the conversation. When the communication is complete, the repeater is released and becomes available for other groups.

Amongst the protocols used for LMR are:

- Project 25 (P25)—The trunked protocol used by most public safety organizations in North America. Also used in several other nations.
- Terrestrial Trunked Radio (TETRA) —Used throughout Europe and most parts of the world. Some use is beginning in North America.
- Digital Mobile Radio (DMR) —A lower cost protocol used world-wide in both conventional and trunked topologies.
- Digital Private Mobile Radio (dPMR) —A digital protocol used mainly in Europe in both conventional and trunked topologies.

Detailed descriptions of these protocols and topologies are beyond the scope of this document, but the DAS designer should become at least somewhat familiar with them.

6.2.3 Common Services and Systems

6.2.3.1 Cellular 800 Mhz

The first commercial standard for mobile connection in the United States was the Advanced Mobile Phone System (AMPS), which was in the 800 MHz frequency band. The cellular frequencies are the sets of frequency ranges within the UHF band that have been allocated for cellular phone use by the FCC. The 800 MHz band includes the frequency bands of 824-849 MHz and 869-894 MHz. Because of the longer wavelength at 800 MHz, the 800 MHz cellular signals can travel farther and can penetrate common building materials better than higher frequencies used within the wireless industry.

The FCC has split the cellular band into two sets of frequencies, which means there can only be up to two carriers operating in the 800 MHz cellular band in the same region. The A channel frequency set includes 824-835 MHz, 845-846.5 MHz, 869-880 MHz and 890-891.5 MHz. The B channel frequency set includes 835-845 MHz, 846.5-849 MHz, 880-890 MHz and 891.5-894 MHz. Similarly the carriers operating these sets of frequencies are referred to as the "A" and "B" carriers for a specified area.

6.2.3.2 Personal Communications Service (PCS)

The personal communications system (PCS) evolved from mobile satellite technology. In February 1976, Communications Satellite (COMSAT) Corporation launched the Maritime Communications Satellite (MARISAT) System to provide mobile services to the U.S. Navy and other maritime customers. In the early 1980s, the Europeans launched the Maritime European Communications Satellite (MARECS) series to provide the same services.

PCS was introduced in 1998. In the fully developed PCS, a person can carry a wireless telephone anywhere to be used for voice or data. Several companies have committed themselves to providing a version of this system using satellites in low Earth orbit (LEO). Modern PCS is the result of the FCC's auctioning of frequencies in 1995. This provided a new generation of wireless telephone technology that introduced a range of features and services surpassing those available in analog and digital systems. Operating at 1.8 GHz for mobile telephony, PCS provides users with an all-in-one wireless telephone complete with paging, messaging, and data services with a greatly improved battery standby time. When the 900 MHz GSM cellular network was developed, provisions were made for a second network in the 1.8 GHz range. The higher frequency was expected to be used for low-cost, highly portable PCS.

The original cellular networks were developed for car telephones, and the progression to portables made a worldwide frequency standard desirable. The original cellular licenses were awarded in a lottery by using metropolitan statistical areas (MSA) and rural service areas (RSA), which were developed by Rand McNally for map census areas. For PCS, the FCC auctioned the frequencies in six blocks designated A to F. The PCS licenses were awarded using slightly different census areas (also from Rand McNally) called metropolitan trading areas (MTA) and basic trading areas (BTA). A major difference in the two schemes is that MTAs overlap BTAs like cities are to states or provinces (the New York BTA is part of the New York MTA).

6.2.3.3 Advanced Wireless Services (AWS)

AWS is a wireless telecommunication spectrum band used for mobile voice and data services, video, and messaging. AWS is used in the United States, Canada, Mexico, Chile and Peru. It replaces some of the spectrum formerly allocated to Multipoint Multichannel Distribution Service, sometimes referred to as Wireless Cable that existed from 2150 to 2162 MHz.

The AWS band uses microwave frequencies in two segments: from 1710 to 1755 MHz for uplink, and from 2110 to 2155 MHz for downlink. The service is intended to be used by mobile devices such as wireless phones for mobile data, video, and messaging services. Since for downlink AWS uses a subset of UMTS frequency band I (2100 MHz) some UMTS2100 capable handsets do detect AWS networks but cannot register on them because of the difference in uplink frequencies (1710–1755 MHz for AWS vs. 1920–1980 MHz for UMTS2100).

In the USA, the service is administered by the Federal Communications Commission. The licenses were broken up into 6 blocks (A–F). Block A consisted of 734 Cellular Market Areas (CMA). Blocks B and C were each divided into 176 Economic Areas (EA), sometimes referred to as BEA by the FCC. Blocks D, E, and F were each broken up into 12 Regional Economic Area Groupings (REAG), sometimes referred to as REA by the FCC.

6.2.3.4 Public Safety Services

In a growing number of jurisdictions, public safety radio systems (such as those used by police, firefighters and emergency medical technicians) operate in several portions of both the 700 MHz and 800 MHz bands. Commonly used frequency bands include 763-769 MHz, 793-799 MHz, 806-824 MHz and 851-869 MHz.

In some countries, such as the United States, additional wireless spectrum within the 700 MHz band has been added to existing public safety frequency bands as part of the transition to digital television transmission.

Specifically within the United States, the additional ranges for public safety are 758-763 MHz and 788-793 MHz, with the frequency bands of 769-775 MHz and 799-805 MHz being specifically reserved for public safety narrowband.

6.3 Headend and Backend Equipment

6.3.1 Overview

Headend equipment provides interfaces between signal sources (those to be retransmitted by the DAS) and the backend equipment that facilitates the distribution of RF signals to areas needing coverage, such as on different floors inside a building or to other buildings in a campus environment. Headend equipment is the core of the DAS. It is the point of interface where all RF sources and all distributed nodes meet and where resource couplings determine the geometry of simulcast zones.

Headend equipment conditions signals from WSPs and other sources to the DAS. Pre-conditioning often occurs between the base transceiver station (BTS) and the DAS headend components by using a DAS interface tray. The DAS tray typically reduces the BTS power to the DAS and aggregates several bands as required by the system design. The configuration of a DAS interface tray is unique to the coverage required at a particular venue.

DAS backend equipment typically consists of active components that transmit and receive signals from the headend equipment or other backend elements and radiate RF signals into antennas. Backend equipment can include signal repeaters, expansion modules, and remote units.

6.3.2 Master Control Unit (MCU)

The primary headend device is the master control unit (MCU). The MCU consists of several subsystems that have specialized functions within the DAS architecture.

Subsystems typically include inputs for signals that will be retransmitted through the DAS, amplifiers for signal balancing, output links to the backend devices, and power supplies for delivering power to the transmission equipment.