

an American National Standard

ANSI/BICSI 006-2020

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



Documents

Document Sharing Hub

ANSI/BICSI 006-2020

Distributed Antenna System (DAS) Design and Implementation Best Practices

Committee Approval: November 9, 2019

ANSI Final Action: November 11, 2019

First Published: November 25, 2019



BICSI International Standards

BICSI international standards contain information deemed to be of technical value to the industry and are published at the request of the originating committee. The BICSI International Standards Program subjects all of its draft standards to a rigorous public review and comment resolution process, which is a part of the full development and approval process for any BICSI international standard.

The BICSI International Standards Program reviews its standards at regular intervals. By the end of the fifth year after a standard's publication, the standard will be reaffirmed, rescinded, or revised according to the submitted updates and comments from all interested parties.

Suggestions for revision should be directed to the BICSI International Standards Program, care of BICSI.

Copyright

This BICSI document is a standard and is copyright protected. Except as permitted under the applicable laws of the user's country, neither this BICSI standard nor any extract from it may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, photocopying, recording, or otherwise, without prior written permission from BICSI being secured.

Requests for permission to reproduce this document should be addressed to BICSI.

Reproduction may be subject to royalty payments or a licensing agreement.

Violators may be prosecuted.

Published by:



BICSI
8610 Hidden River Parkway
Tampa, FL 33637-1000 USA

Copyright © 2019 BICSI
All rights reserved
Printed in U.S.A.

Notice of Disclaimer and Limitation of Liability

BICSI standards and publications are designed to serve the public interest by offering information communication and technology systems design guidelines and best practices. Existence of such standards and publications shall not in any respect preclude any member or nonmember of BICSI from manufacturing or selling products not conforming to such standards and publications, nor shall the existence of such standards and publications preclude their voluntary use, whether the standard is to be used either domestically or internationally.

By publication of this standard, BICSI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Additionally, BICSI does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the standard or publication. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard does not purport to address all safety issues or applicable regulatory requirements associated with its use. It is the responsibility of the user of this standard to review any existing codes and other regulations recognized by the national, regional, local, and other recognized authorities having jurisdiction (AHJ) in conjunction with the use of this standard. Where differences occur, those items listed within the codes or regulations of the AHJ supersede any requirement or recommendation of this standard.

All warranties, express or implied, are disclaimed, including without limitation, any and all warranties concerning the accuracy of the contents, its fitness or appropriateness for a particular purpose or use, its merchantability and its non-infringement of any third party's intellectual property rights. BICSI expressly disclaims any and all responsibilities for the accuracy of the contents and makes no representations or warranties regarding the content's compliance with any applicable statute, rule, or regulation.

BICSI shall not be liable for any and all damages, direct or indirect, arising from or relating to any use of the contents contained herein, including without limitation any and all indirect, special, incidental, or consequential damages (including damages for loss of business, loss of profits, litigation, or the like), whether based upon breach of contract, breach of warranty, tort (including negligence), product liability or otherwise, even if advised of the possibility of such damages. The foregoing negation of damages is a fundamental element of the use of the contents hereof, and these contents would not be published by BICSI without such limitations.

TABLE OF CONTENTS

	PREFACE	ix
1	Introduction	1
1.1	Overview	1
1.2	Purpose.....	1
1.3	Categories of Criteria.....	2
2	Scope	2
2.1	Limitations	2
3	Required Standards and Documents	3
4	Definitions, Acronyms, Abbreviations, and Units of Measurement	5
4.1	Definitions	5
4.2	Acronyms and Abbreviations.....	9
4.3	Units of Measurement.....	9
5	Regulatory and Safety	11
5.1	Local Code Requirements.....	11
5.2	Local DAS Requirements	11
5.2.1	Emergency Communications.....	11
5.2.2	Public Safety Radio	11
5.3	Personnel Safety Requirements.....	11
6	Distributed Antenna Systems	13
6.1	Overview	13
6.2	Signal Sources.....	13
6.2.1	Introduction	13
6.2.2	Donor Antenna	13
6.2.3	Base Transceiver Station	13
6.2.4	Small Cell.....	13
6.3	Distribution Methods	14
6.3.1	Passive DAS	14
6.3.2	Active DAS	15
6.3.3	Hybrid DAS.....	16
6.3.4	Digital	17
6.4	DAS Specific Equipment.....	17
6.4.1	Headend and Backend Equipment.....	17
6.4.2	Passive Distribution Equipment	18
6.4.3	Active Distribution Equipment.....	20
6.5	Cabling Topology	21
6.6	Pathways and Spaces.....	22
6.6.1	Overview	22
6.6.2	Spaces	22
6.6.3	Pathways.....	25

6.7	Cabling	27
6.7.1	General Requirements.....	27
6.7.2	General Recommendations	27
6.7.3	Coaxial Cable.....	27
6.7.4	Radiating Coaxial Cable	29
6.7.5	Balanced Twisted-Pair	30
6.7.6	Optical Fiber	30
6.8	Antennas	31
6.8.1	Overview.....	31
6.8.2	Antenna Parameters	31
6.8.3	Antenna Characteristics	31
6.8.4	Antenna Types	32
6.8.5	Radiating Cable.....	35
6.8.6	Multiple Carrier Antennas	36
6.8.7	Recommendations.....	36
6.9	Electrical Power	36
6.9.1	Overview.....	36
6.9.2	Power Supply Units	36
6.9.3	Uninterruptible Power Supplies	36
6.9.4	Voltage Injectors	36
6.10	Bonding, Grounding, Surge Suppression and Lightning Protection.....	37
6.10.1	Grounding and Bonding.....	37
6.10.2	Lightning Protection	37
6.10.3	Surge Suppression.....	37
6.11	Administration and Documentation.....	38
6.11.1	Requirements	38
6.11.2	Recommendations.....	38
7	Design Considerations.....	39
7.1	Overview.....	39
7.2	Site Survey and Needs Analysis.....	39
7.2.1	Site Survey.....	39
7.2.2	Needs Analysis	40
7.2.3	Building/Structure Construction	42
7.3	Wireless Configuration	43
7.3.1	Signal Source and Site Orientation	43
7.3.2	Antenna.....	44
7.3.3	Power (Link) Budgets.....	45
7.3.4	RF Signal Conversion and Combining	45
7.4	Project Coordination Factors	46
7.4.1	Host/Donor	46
7.4.2	Cellular Service Providers	46
7.4.3	Antenna Coordination.....	46
7.4.4	Coordination with Site Owner(s).....	47
7.5	Security.....	47
7.6	Software and Management Systems	47
7.6.1	Overview.....	47
7.6.2	Requirements	47
7.6.3	Connections	47
7.6.4	Remote Access Configuration	48
7.7	Emergency Calls and Services Communications	48
7.7.1	General Requirements.....	48
7.7.2	Emergency Call Location	48

7.8	Passive Optical Networks	49
7.8.1	Overview	49
7.8.2	Requirements	49
8	Implementation.....	51
8.1	Overview	51
8.2	DAS Personnel.....	51
8.2.1	Overview	51
8.2.2	Division of Design and Installation Task Responsibilities	51
8.2.3	Designer Qualifications	51
8.2.4	Installer and Service Personnel Qualifications	52
8.3	Design and Implementation Coordination	53
8.3.1	Overview	53
8.3.2	Plan Documentation	53
8.4	Cabling Installation.....	55
8.4.1	Overview	55
8.4.2	Requirements	55
8.4.3	Recommendations	56
8.5	Antennas.....	56
8.5.1	Donor Antenna	56
8.5.2	Indoor Antennas	56
8.6	DAS Specific Equipment.....	56
8.6.1	Bidirectional Amplifier (BDA).....	56
8.6.2	Remote Amplifier Modules	57
8.6.3	Receivers	57
9	Management and Operations.....	59
9.1	Introduction	59
9.2	Managing and Operating DAS and Small Cell Systems	59
9.2.1	System Manager	59
9.2.2	Other Personnel	60
9.3	Administration.....	61
9.3.1	Documentation	61
9.4	System Testing and Inspection	61
9.4.1	General Requirements	61
9.4.2	Annual Testing	62
9.4.3	Five-Year Testing	62
9.4.4	Field Testing	63
9.5	System Revisions and Maintenance	64
9.5.1	System Upgrades, Revisions and Expansions	64
9.5.2	System Maintenance.....	64
10	Site and Functional Support Issues.....	65
10.1	Overview	65
10.2	Interior Trouble Spots	65
10.3	Office Buildings	65
10.3.1	Introduction	65
10.3.2	Building Ownership and Tenants	65
10.3.3	Office Building Core and Shell	66
10.3.4	Physical Construction	67
10.3.5	Coverage Areas	68
10.4	Multi-Tenant Residential Buildings.....	68

10.5	Industrial Facilities.....	68
10.5.1	Overview.....	68
10.5.2	Light vs. Heavy Industry.....	69
10.5.3	Chemical and Petrochemical Plants.....	69
10.5.4	Factories and Assembly Plants.....	72
10.5.5	DAS and Wireless LAN Antennas.....	72
10.5.6	Warehouses.....	72
10.6	Healthcare Facilities.....	73
10.6.1	Introduction.....	73
10.7	Schools and Colleges.....	73
10.7.1	Overview.....	73
10.7.2	Elementary and Secondary Schools.....	73
10.7.3	School Administration Entities.....	74
10.7.4	Colleges and Universities.....	74
10.8	Retail Locations.....	74
10.8.1	Description.....	74
10.8.2	DAS Challenges.....	75
10.9	Facilities for Vehicle Parking.....	76
10.9.1	Overview.....	76
10.9.2	Stand-Alone or Attached Parking Structure Construction.....	76
10.9.3	Parking Facilities Integrated into Structures.....	76
10.9.4	Parking Structure and Parking Facilities Construction Specifics.....	76
10.9.5	External Concerns.....	77
10.10	Hospitality and Entertainment.....	77
10.10.1	Overview.....	77
10.10.2	Hotels.....	77
10.10.3	Casinos.....	77
10.10.4	Stadiums.....	77
10.10.5	Convention Centers.....	77
Appendix A	Wireless Services and Signals (Informative).....	79
A.1	Introduction.....	79
A.2	Services and Systems.....	79
A.3	Common Signal Types.....	80
Appendix B	Legal Aspects of Wireless Design (Informative).....	83
B.1	Introduction.....	83
B.2	Setting the Legal Context.....	83
B.3	Legal Issues.....	85
B.4	Limiting the Design Professional's Liability.....	89
Appendix C	Terminating and Testing Coaxial Transmission Lines (Informative).....	91
C.1	Terminating Coaxial Cable.....	91
C.2	Testing Tools.....	92
Appendix D	Hazardous Environments and Locations (Informative).....	95
D.1	Definitions.....	95
D.2	Hazardous Atmosphere Classifications.....	97
Appendix E	Related Documents (Informative).....	99

INDEX OF FIGURES

Section 6	Distributed Antenna Systems	
Figure 6-1	Example of a Passive DAS.....	14
Figure 6-2	Example of an Active DAS.....	15
Figure 6-3	Example of a Hybrid DAS	16
Figure 6-4	Hierarchical Star Topology	21
Figure 6-5	Examples of Non-star Topologies.....	21
Figure 6-6	Example Floor Plan for MIMO Antenna Operations	24
Figure 6-7	Example Floor Plan for a Three Sector DAS	25
Section 10	Site and Functional Support Issues	
Figure 10-1	Outline for Coverage Model Provided by Two Directional Antennas Back to Back.....	75
Appendix B	Legal Aspects of Wireless Design (Informative)	
Figure B-1	International Telecommunication Union Regions.....	84

INDEX OF TABLES

Section 6	Distributed Antenna Systems	
Table 6-1	Example Wireless Service Provider Equipment Information.....	23
Table 6-2	Coaxial Construction Advantages and Disadvantages	28
Table 6-3	Types of Directional Antenna and Associated Applications.....	32
Table 6-4	Sector Antenna Types and Their Application.....	34
Section 7	Design Considerations	
Table 7-1	Availability as an Expression of Time	41
Appendix D	Hazardous Environments and Locations (Informative)	
Table D-1	Comparison of Terminology	97

This page intentionally left blank

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*

November 25, 2019 Revision of ANSI/BICSI 006-2015 published as ANSI/BICSI 006-2020, *Distributed Antenna System (DAS) Design and Implementation Best Practices*

Revisions include:

- Restructure of former Sections 6 - 10 with relevant content relocated into the new structure
- Expansion of materials related to emergency communication
- Expansion of signal source information
- Expansion of system and connector installation practices
- Addition of 5G cellular and multiple carrier support
- Addition of passive optical networks (PON)
- Other content updates and editorial corrections

Document Format (Usability Features)

This standard has the following usability features as aids to the user:

- Additions and changes, other than those for editorial purposes, are indicated with a vertical rule within the left page margin.
- Deletion of one or more paragraphs within unrevised content is indicated with a bullet (•) within the left page margin.

NOTE: The relocation of content within or between sections related to structure, readability, or content alignment is not indicated.

Translation Notice

This standard may have one or more translations available as a reference for the convenience of its readers. As that act of translation may contain inconsistencies with 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.

This page intentionally left blank

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 common services supported by 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, emergency medical service (EMS), and business band land mobile radio (LMR) (150-170 MHz, 450-512 MHz)

NOTE: 47 CFR 90.35 assigns 450-470 MHz to LMR; heavily used for businesses and government.

Other services which may be supported by a DAS include:

- Pocket pagers
- 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.

1.2 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 (802.11 protocol)
Although some vendors are beginning to include Wi-Fi capability in their DAS product lines, Wi-Fi networks are relatively mature, with requirements and recommendations provided in other standards, such as ANSI/BICSI 008.
- WiMAX
At the time of publication, WiMAX technology is not highly used within DAS deployments.

3 Required Standards and Documents

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BICSI

- ANSI/BICSI 003, *Building Information Modeling (BIM) Practices for Information Technology Systems*
- ANSI/BICSI N1, *Installation Practices for Telecommunications and ICT Cabling and Related Cabling Infrastructure*
- ANSI/BICSI N3, *Planning and Installation Methods for the Bonding and Grounding of Telecommunication and ICT Systems and Infrastructure*

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 11801-1, *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 Fire Protection Association (NFPA)

- NFPA 70®, *National Electrical Code®*
- NFPA 72, *National Fire Alarm and Signaling Code*
- NFPA 1221, *Installation, Maintenance, and Use of Emergency Services Communications Systems*

Telecommunications Industry Association (TIA)

- ANSI/TIA-568.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*
- ANSI/TIA-568.3, *Optical Fiber Cabling Components Standard*
- ANSI/TIA-569, *Telecommunications Pathways and Spaces*
- ANSI/TIA-606, *Administration Standard for Telecommunications Infrastructure*
- ANSI/TIA-607, *Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises*
- ANSI/TIA-5017, *Telecommunications Physical Network Security Standard*

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

4.1 Definitions

For the purposes of this standard, the following terms and definitions apply. Some terms and definitions may also be represented by an acronym as listed in Section 4.2.

absorption	A phenomenon causing attenuation of a radio signal passing through a medium that occurs when gaseous molecules or suspended water molecules in the atmosphere absorb the signal energy and convert it into heat due to molecular resonance.
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.
duplexer	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 that consists of two conductors of equal length and shape positioned opposite of each other. The end of each conductor is connected to a feedline to the receiver. Dipoles are frequently used within directional antenna designs.
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.
fading	The variation in path loss between the transmitter at one station and its normal receiver at the following station.
femtocell	A type of small cell typically used within small physical areas, such as a home or small business.
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 IP xy 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.
multi-path fading	On a wireless network, signal fading caused by the arrival of signals from different directions, each with a different path length.
N type (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.
small cell	A short-range base station used to complement wireless transmission from larger transmitters (e.g., cellular tower).
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 as follows:

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	SNMP	simple network management protocol
DC	direct current	TR	telecommunications room
EIRP	effective isotropic radiated power	UMTS	universal mobile telecommunications system
EMI	electromagnetic interference	UTP	unshielded twisted-pair
ER	equipment room	UHF	ultra high frequency
ERP	effective radiated power	VHF	very high frequency
ICT	information and communication technology	VSWR	voltage standing wave ratio
LMR	land mobile radio	WAN	wide area network
LTE	long term evolution	WLAN	wireless local area network
MCU	master control unit	WSP	wireless service provider

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. For example, 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)
dBi	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

This page intentionally left blank

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

5.2.1 Emergency Communications

The International Fire Code and standards such as NFPA 1221 provide requirements for the installation, performance, operations, and maintenance of systems used for emergency communications. Some of these requirements may directly affect design decisions, such as the selection of component, pathways, and placement of equipment and antennas.

5.2.2 Public Safety Radio

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.

This page intentionally left blank

6 Distributed Antenna Systems

6.1 Overview

In its simplest form, a DAS is a distribution method of RF signals that it receives from a source. For current DAS applications, sources include donor antennas, base cell transceivers, and small cell. Depending on the source, they may be connected to a passive, active, hybrid or digital distribution system to provide the source signal where needed.

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.

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.

6.2 Signal Sources

6.2.1 Introduction

The choice of signal source is often the most important factor in capacity and coverage area calculations. Much like structured cabling systems, the performance of a DAS will be limited by the lowest performing element, be it source, antenna, or connectivity media.

6.2.2 Donor Antenna

Donor antenna sources utilize roof mounted antennas to transmit and receive signals from the surrounding area, such as a cell tower. As donor antennas utilize the transmission infrastructure external to the building or site, they are the most common signal source used to supply a DAS.

When using a donor antenna as a source, they are subject to the effects of varying strengths of the signal being received at the site or "congestion" at the nearest towers, in the case of cellular signals. In many deployments, a donor antenna is used to extend the coverage of a network or signal into a location.

While donor antennas work with multiple carriers and sources, optimizing placement for antennas for all signals can be difficult, and in many jurisdictions, retransmission agreements may be required prior to deployment.

6.2.3 Base Transceiver Station

A base transceiver station (BTS) is the equipment used to provide a signal between the network and end user. When used in conjunction with a DAS, a BTS is the equipment typically located at the base of a cellular tower which provides the signal.

The use of a BTS as a signal source requires a connection between the BTS and the site, typically provided by an optical fiber cable. BTS source signals are often used in large scale deployments where high demand or capacity is needed, such as arenas, airports and transit centers. It is not uncommon for multiple BTSs to be connected to a site as part of a multi-carrier cellular solution.

As connection to a BTS is reliant on a carrier, deployment times may be increased awaiting on permissions, equipment, or connection between the BTS and the site. Depending on the project, a BTS can be built on-site, but may require meeting specific space, cooling, power, and operational requirements.

6.2.4 Small Cell

Small cells may be known by many names, such as femtocells, picocells, and metrocells, but all provide a signal source though the use of an Internet connection to a carrier or cellular network. While a small cell can be used to provide a coverage area of 460 – 1400 m² (5000 – 15,000 ft²), a small cell can also act as a signal source for a DAS.

While a small cell does not require a connection back to a BTS, small cells do require a reliable Internet connection that is capable of supporting the needs of a couple of hundred users. However, a small cell can only provide a signal for a single carrier and may have performance issues where multiple frequencies are in use.

To provide adequate bandwidth and coverage, a DAS may need to be supplemented by either small cell antenna or cloud radio access networks (C-RAN) solutions to distribute 5G signals in buildings with large number of users that wish to use 5G mobile phones within the building.

6.3 Distribution Methods

6.3.1 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.

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.

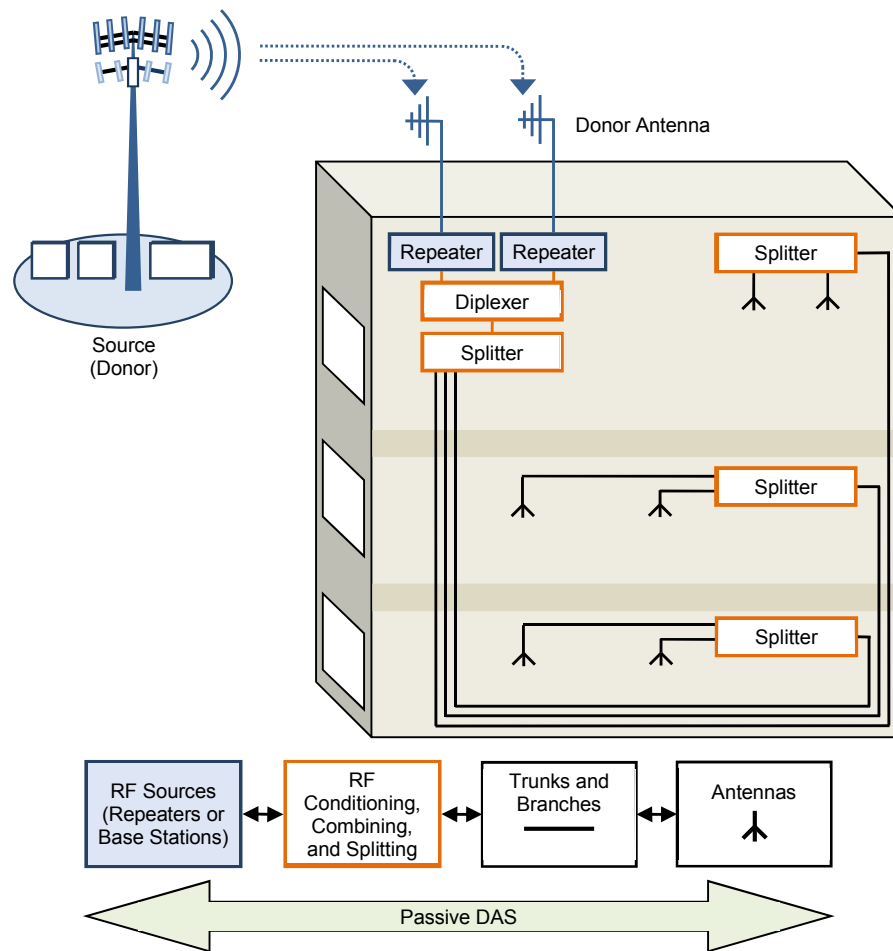


Figure 6-1
Example of a Passive DAS

6.3.2 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 (BTSS) 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.

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.

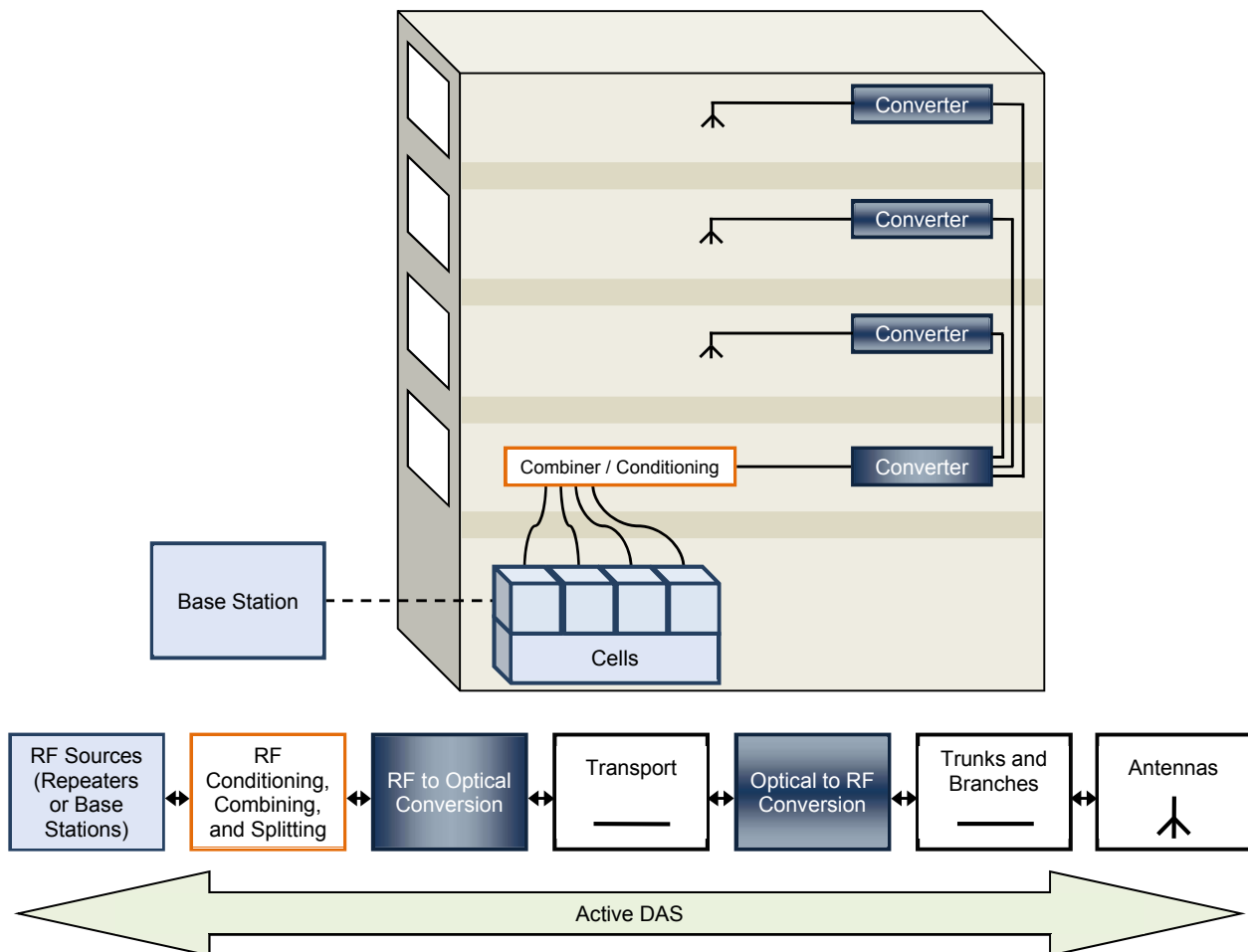


Figure 6-2
Example of an Active DAS

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.

6.3.3 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.

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)

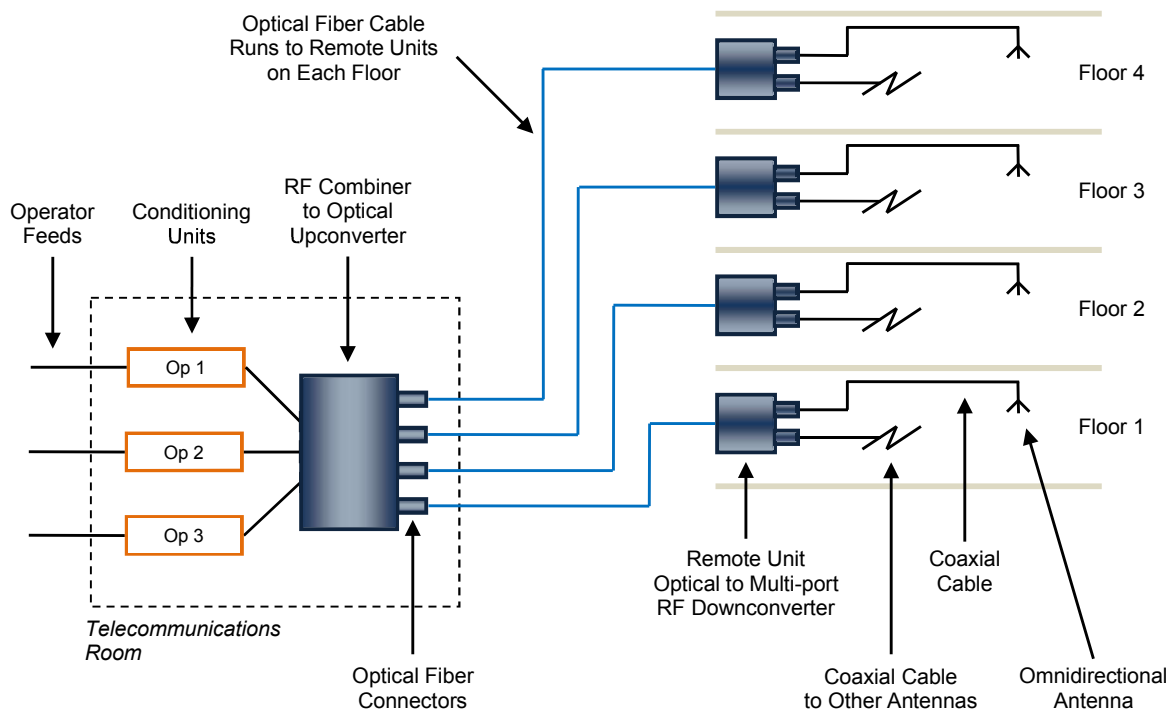


Figure 6-3
Example of a Hybrid DAS

6.3.4 Digital

The passive, active, and hybrid distribution methods all support analog signals. With the development of protocols such as Common Public Radio Interface (CPRI), it is possible for some types of signal sources to transmit through the entire DAS without need to convert to an analog signal. A digital DAS utilizes a base band unit, which is similar to the function of a BTS, to provide signal to a DAS master unit within a building's ER or TR. From the DAS master unit, communication cabling (e.g., balanced twisted-pair, optical fiber) is used to connect to antenna and other components.

As digital DASs are evolving, systems and equipment may not provide the same functionality or be interchangeable. Selecting the correct cabling media is also a factor in performance, a 1,000 Mbps transmission may be sufficient to carry one or two licensed bands, where as 10 Gbps should be sufficient for carrying all currently available licensed bands.

6.4 DAS Specific Equipment

6.4.1 Headend and Backend Equipment

6.4.1.1 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.

6.4.1.2 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.

6.4.1.3 Signal Booster (Bidirectional Amplifier)

There are two basic types of signal boosters: narrowband and broadband. A narrowband booster amplifies only those discrete channels intended to be retransmitted while a broadband booster amplifies all signals within the passband of the signal booster filter, usually many kilohertz or megahertz wide. The U.S. FCC refers to these types as "Class A" and "Class B," respectively.

Under U.S. FCC regulations, a Class A signal booster with output power that results in over 5 watts ERP per channel is NOT authorized under the signal booster rules. If the signal booster ERP exceeds 5 watts (+37 dBm), then the installation must be licensed as an individual base station site. Further, signal boosters must also comply with human RF exposure limits (e.g., FCC 47 CFR 1.1310). Accepted practice is to limit ERP of any single in-building antenna to 600 milliwatts (+28 dBm) maximum composite power. Example: For a 10 channel system, this is approximately +18 dBm maximum per channel.

High performance broadband signal boosters now have the capability to store and report excessive output excursions. These reports may also be used as alarms of oscillations. This data, combined with the option of remote controlled fixed gain adjustments, allow a system to easily be optimized for long term operation.

6.4.1.4 RF Source Equipment

A BTS (macro cell), small cell, fiber repeater, or an over-the-air repeater are all possible RF sources to a DAS headend. Base stations and small cells are connected to the radio access network (RAN) through a WSP's backhaul. Femto cells can also drive a DAS; however, their backhaul goes through a local Internet service provider's connectivity links to the RAN. Over-the-air repeaters use the WSP's licensed spectrum to bridge the gap between the venue being covered and the signal source.

Distributed base station architectures, where baseband processing can be separated from remote radio heads containing modulation, amplification, and filtering modules, are occasionally used to drive an active DAS. The link that carries the baseband data to the remote radio heads, which in turn may drive the DAS, is termed *fronthaul*.

6.4.1.5 Backend Equipment

Typical backend equipment consists of the following components:

- Slave processor(s)—signal processing for headend synchronization
- Power supplies—voltage supply and conditioning
- Host port(s) —communication interface between backend and host unit equipment
 - Backend equipment ports—communication interface between backend unit and other backend units farther down the system
 - Power ports—connectors for cables feeding power from backend unit to other backend units farther down the system
 - Signal converters and combiners—frequency conversion and consolidation
- Amplifiers and transceivers—signal regeneration and transmission
- Antenna port(s) —connector for coaxial cable to antennas
- Antennas—internal or external to discrete components

Backend equipment typically has a set number of devices or antennas it will serve. The number of devices is usually limited by the additive uplink noise contribution to the system by these devices.

6.4.1.6 Remote Monitoring and Network Management

Headend equipment may have provisions for Ethernet network management via a transmission control protocol/Internet protocol (TCP/IP) connection to remotely access the DAS, repeaters, or any other devices that are otherwise isolated from physical connectivity. Remote monitoring and maintenance systems can provide notification of equipment alarms while providing technicians the ability to problem-isolate, troubleshoot, and bring the appropriate replacement parts if a site visit becomes necessary. If the manufacturers' equipment does not provide direct network management, it is possible to include a modem to achieve remote monitoring of or access to some DASs.

6.4.2 Passive Distribution Equipment

6.4.2.1 Introduction

Passive distribution equipment in a DAS is defined as equipment not requiring external power input. Signals from an external source are coupled into a passive medium transporting RF signals. These components can be used in conjunction with active equipment in a hybrid DAS or as a completely passive system. Characterized by frequency response, power, and PIM ratings, the components selected need to be matched to the mission they are assigned. Further, performance of coupled passive devices is significantly dependent on proper installation.

6.4.2.2 Passive Intermodulation

6.4.2.2.1 Introduction

Passive intermodulation (PIM) distortion is created by either poor quality components or installation practices that cause non-linearities in the downlink RF path. These non-linearities leak (couple) modulated signal into the uplink band, affecting system performance.

6.4.2.2.2 Requirements

All passive materials in the RF signal path(s) of a DAS (e.g., cable, connectors, lightning protection devices) shall be designed and manufactured to have a passive intermodulation (PIM) rating of -150 dBc (decibels relative to the carrier) or better as given by the manufacturer. PIM requires that power level be specified as well as dBc rating. Commonly, two 20 watt modulated signals are specified with the -150 dBc specification.

6.4.2.3 Components

6.4.2.3.1 Directional Couplers

Directional couplers are linear devices that use induction, capacitive coupling, or another method to differentially split downlink power from an input connector to two or more output connectors. Unlike splitters, more downlink power is supplied to one output than the other. Uplink power is likewise combined with a bias toward one or the other connector. Cable taps can be used to achieve a similar effect without cutting the cable. These devices come in various coupling losses, starting with 6 dB and stepping up to 10 dB, 15 dB, and 20 dB.

6.4.2.3.2 Voltage Injectors (Bias Tees)

Voltage injectors combine direct current (DC) power with the alternating current (AC) RF signal on a coaxial cable and tap it off at the other end, thereby allowing remote powered devices to operate without a separate power source.

6.4.2.3.3 Hybrid Couplers

Often referred to as crossband couplers, hybrid couplers are designed to meet the special needs of the wireless market. They most commonly are used to combine two wireless bands to a single antenna feed or distribution cable. They are also called diplexers.

6.4.2.3.4 Signal Splitters

Signal splitters are used to connect more than one antenna to a single radio. It is sometimes necessary to attach multiple antennas to one radio interface to increase the area of coverage for that one transmitter/receiver. This does not provide antenna diversity or alleviate multi-path issues. Splitters only allow for multiple antennas to be connected to one interface for a larger coverage pattern around that one radio.

Signal splitters are also used to connect multiple radio receivers to a single antenna, which commonly are called receiver multicouplers. The multicoupler normally will be frequency selective and have an RF amplifier in front of it as a result of the loss incurred when the signal passes through the unit. The unit also is designed to keep the impedances at 50 ohms per port and limit the amount of signal allowed from the receiver to be radiated back to the other ports or the antenna.

6.4.2.3.5 Power Splitters

A power splitter is a passive device that accepts an input signal and delivers multiple output signals with specific phase and amplitude characteristics. Output signals theoretically possess the following characteristics:

- Equal amplitude
- Zero degree phase relationship between any two output signals
- High isolation between each output signal

6.4.2.3.6 Unequal Splitters

Unlike capacitive couplers, unequal splitters maintain DC continuity to both the main and coupled ports.

6.4.2.3.7 Power Combiners

Considered a reverse of a power splitter, a power combiner is used to combine two or more inputs into one output. A transmitter combiner allows several radios to use a single antenna. This could be used for different types of radios to combine transmit signals in the same frequency range but share the same antenna and provide separate functionality to separate applications using circulators and isolators.

NOTE: The power handling capability is not necessarily equal in both the splitter and combiner directions.

6.4.2.3.8 Duplexers

Duplexers are used to enable a repeater's receiver and transmitter to use a single antenna or to separate already combined transmit and receive signals. They may also minimize nearby RF interfering signals. Duplexers are three port combiners: transmit, receive, and antenna ports. The duplexers have filters that isolate the transmitter and receiver, ensuring each rejects the undesired frequencies while allowing the desired frequencies to be passed. A duplexer must be designed for operation in the frequency band used by the receiver and transmitter and must be capable of handling the output power of the transmitter. A duplexer must provide adequate rejection of transmitter noise occurring at the receive frequency and must be designed to operate at or less than the frequency separation between the transmitter and receiver. A duplexer must provide sufficient isolation to prevent receiver desensitization.

6.4.2.3.9 Filters

Filters are available as:

- Pass band filters
- Full band filters
- Notched filters (able to limit downlink out-of-band signal impedance)
- PCS cavity reject filters (when used with a repeater, these can provide out-of-band signal rejection)

6.4.2.3.10 Attenuator

Attenuators are designed to reduce the transmitter power, allowing RF signals to be reduced to the appropriate level. This can be useful when RF coverage is required inside a small office or business but is not to extend to the adjacent building or office. Even the lowest gain antenna (typically 2 dBi) and the lowest power setting on some transmitters will radiate farther than necessary or acceptable. In-line attenuators are also used to protect test equipment and to manage signal power levels interfacing to the DASs.

6.4.2.3.11 DAS Interface Unit/Tray

A DAS interface unit is an integrated passive or active component that simplifies the interconnection of repeaters and base stations to the DAS. These points of interface (POIs) are customizable to meet the headend technology, frequencies to be supported, test port requirements, connector type, and fixed or variable attenuation needs.

Active DAS interface units may also provide local and remote access via a LAN connection to make conditioning adjustments, use integrated test tools and for SNMP alarm monitoring to help diagnose potential issues.

6.4.3 Active Distribution Equipment

Active distribution equipment consists of the electronics associated with a DAS that require separate input power. Electrical power requirements for DAS active equipment vary for each manufacturer and should be identified and considered before conducting a site survey.

6.4.3.1 Transceivers

Transceivers transmit and receive RF signals. This dual function allows one device to function as two and thereby reduces the number of overall components within the DAS architecture. In duplex systems, the transmission and receiving frequencies must be different. In simplex systems, both links share a common frequency.

6.4.3.2 Amplifiers

Amplifiers can be used to boost the signal and increase the operational range of the RF transmitter. Amplifiers also can alleviate trouble areas where the signal strength is low, especially outdoors. It is important to calculate the antenna gain and transmitter power when designing any RF system to comply with the applicable regulatory agency rules.

NOTE: Use of RF amplifiers typically is subject to government regulations. The user is responsible for compliance with applicable laws and regulations. For example, at 2.4 GHz, the maximum transmitter power is 1 W or 30 dBm. In point-to-multipoint systems, the FCC limits the maximum effective isotropic radiated power (EIRP) to 36 dBm.

6.4.3.3 Bidirectional Amplifiers (BDA)

Bidirectional amplifiers (also called signal boosters) in RF communications systems operate in much the same way as transceiver elements. Bidirectional amplifiers receive RF in one port and transmit RF on another port. They contain two amplifiers oriented in opposite directions with inputs and outputs combined and steered by directional elements, generally either circulators or diplexer filters.

In the DAS environment, amplifiers are used to couple input signals of donor systems and amplify them in the host system for rebroadcast to antennas within the DAS. A WSP-grade amplifier is capable of providing 60–85 dB of gain and contains a filter and a digital signal processor (DSP) to determine a pass band for the specific system.

The amplifier will amplify noise as well as the desired signal. The downlink signal goes from the BDA to the DAS. The uplink signal goes from the user's device to the DAS back to the BDA. BDAs may have the ability to adjust the gain on the uplink and downlink and select specific channels or frequencies to support the DAS. BDAs can be remotely monitored for performance and may be remotely configurable and shut off if found to be causing problems with the macro environment.

The use of bidirectional amplifiers may also require compliance with the local AHJ. For examples of requirements, see regulations such as FCC 47 CFR 90.219.

6.4.3.4 Unidirectional Amplifiers

Unidirectional amplifiers receive RF in one port and transmit RF on another port but only amplify a single path of RF signal (either forward path or reverse path). They contain one amplifier and may use directional elements, such as circulators or diplexer filters, to separate and combine the different RF paths. An example of a unidirectional amplifier is a tower mount amplifier used to amplify the receive path prior to coaxial and line losses down to a base station receiver.

6.4.3.5 Repeaters

These devices are often referred to as bidirectional amplifiers although some repeaters may receive signals on one frequency and retransmit the signals on another frequency. Repeaters typically offer higher gain performance than bidirectional or unidirectional amplifiers. The filter band-pass characteristics are also more selective. Additional processing of the radio signals, such as down conversion, signal monitoring, and automatic gain control, and feedback control may occur within the unit.

6.4.3.6 Media Converters

Media converters typically receive power or data from one standard interface and output that power or data to a different standard interface. Most wireless equipment vendors provide power over Ethernet (PoE) capabilities to simplify installation.

Some vendors have implemented power injector media converters that receive data over the optical fiber cable through optical fiber connectors and then convert the optical fiber signals to Ethernet data signals, providing this data to the wireless bridge/access point through a balanced twisted-pair 8-position, 8-contact (8p8c) modular jack. Media converters can enhance the wireless design in instances where radios are to be installed beyond the 100 m (328 ft) horizontal cabling distance limit of a structured cabling distribution system.

6.4.3.7 Frequency Converters

These devices are designed to shift RF signals from one range to another. One example would be to migrate IEEE 802.11b wireless networks operating in the overloaded 2.4 GHz (2400–2483 MHz) unlicensed band into the 5.8 GHz (5725–5850 MHz) range.

6.4.3.8 Relays

Relay platforms have two bidirectional RF links. Those links may provide mesh connectivity between a serving node and gateway node or use separate RF protocols for serving the subscribers in its coverage objective and backhauling that service.

6.5 Cabling Topology

Active DASs and the active equipment (e.g., MCU, BDA) in passive DASs supported by the structured cabling infrastructure should use a star or hierarchical star topology, as shown in Figure 6-4, for required backbone and horizontal cabling. Non-star based topologies may be used to support a DAS in addition to a star topology. For example, a passive DAS may be configured in a tree topology. Examples of non-star topologies that are commonly used within a DAS are shown in Figure 6-5.

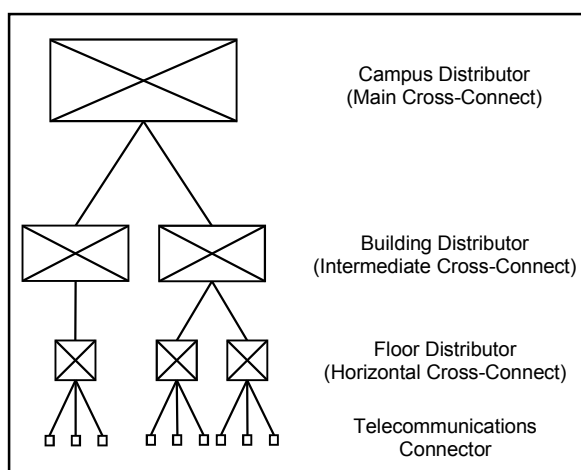


Figure 6-4
Hierarchical Star Topology

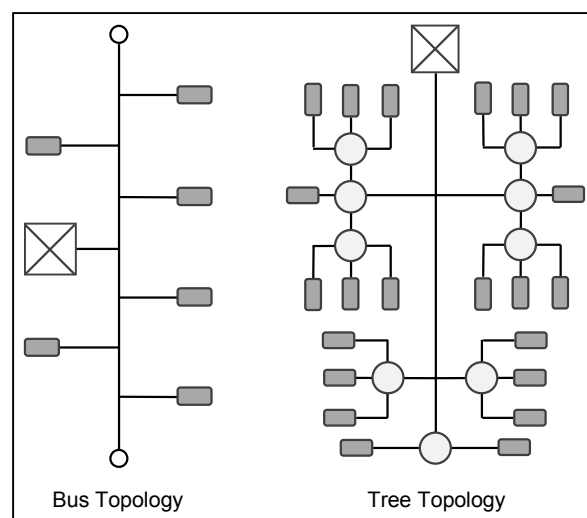


Figure 6-5
Examples of Non-star Topologies