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Distributed Antenna System (DAS) Design and Implementation Best Practices

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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 (e.g., Section 10, Mechanical Systems, Section 12, Security) 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.

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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 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 *half power beamwidth.*

bidirectional amplifier See *signal booster*.

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 *narrowband*.

NOTE: *Broadband* 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 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 *radiating cable.*

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 *broadband*.

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 *leaky coax*.

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

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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

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.