# Distributed Antenna Systems (DAS)
## Competency requirements

This competency listing is an identification of individual topics in which **Distributed Antenna Systems (DAS)** technicians and installers are expected to obtain knowledge to prepare for the **DAS** certification examination. This includes basic knowledge concepts of distributed antenna systems and antenna installation including carrier (cellular, PTT) and public safety applications. This also includes service and skills applicable to all of the functions required to safely and completely install, maintain, troubleshoot and provide support of in-building distributed antenna systems, communications and electronic equipment.

Additionally, there are areas addressing Installation and Code Compliance for Public Safety DAS also known as Emergency Radio Communications Enhancement Systems (ERCES). (Known prior as Emergency Responder Radio Communications System (ERRCS) and BDA compliance.) For a full immersion into PUBLIC SAFETY DAS, please see the separate ETA P.S.DAS certifications

General Distributed Antenna Systems technicians must be knowledgeable in the following technical areas:

### 1.0 Distributed Antenna Systems Fundamentals

- 1.1. Define Distributed Antenna System (DAS)
  - 1.1.1. Types of DAS including:
    - 1.1.1.1. Active
      - 1.1.1.1.1. Hybrid fiber-coax
      - 1.1.1.1.2. Actives at the edge (fiber or category cable fed)
      - 1.1.1.1.3. Twisted pair (Cat 5e / 6 / $6_A$)
    - 1.1.1.2. BDA (bi-directional amplifiers) fed passive
    - 1.1.1.3. Fully passive
    - 1.1.1.4. In-building
    - 1.1.1.5. Outdoor
- 1.2. Describe DAS fundamentals
  - 1.2.1. Define wireless coverage
- 1.3. Define the DAS life cycle, differentiating between and complimenting:
  - 1.3.1. Public safety specifics
  - 1.3.2. Cellular carrier
- 1.4. Describe the In-building role of a DAS to include:
  - 1.4.1. Public Safety
    - 1.4.1.1. Radio Frequencies (Public Safety Spectrum – FCC)(47 CFR § 90.20 table)
      - 1.4.1.1.1. VHF Low Band (25-50 MHz = 6.3 MHz available)
      - 1.4.1.1.2. VHF High Band (150-174 MHz = 3.6 MHz available)
      - 1.4.1.1.3. 220 MHz Band (220-222 MHz = 0.1 MHz available)
      - 1.4.1.1.4. UHF Band (450-470 MHz = 3.7 MHz available)
      - 1.4.1.1.5. T-Band (470-512 MHz = 6-12 MHz blocks, see FCC new page)
      - 1.4.1.1.6. 700 Broadband (758-769/788-799 MHz = 22 MHz available), First Responder Network Authority (FirstNET)
      - 1.4.1.1.7. 700 Narrowband (768-775/798-805 MHz = 14 MHz available)
      - 1.4.1.1.8. NPSPAC Band (806-809/851-854 MHz = 6 MHz available), plans per 55 Reg. Planning Committees (RPCs)
      - 1.4.1.1.9. 800 MHz Band (809-815/854-860 MHz = 3.5 MHz available)
      - 1.4.1.1.10. 4.9 GHz Band (4940-4990 MHz = 50 MHz available)
      - 1.4.1.1.11. 5.9 GHz Band (5850-5925 MHz = 75 MHz available), Dedicated Short Range Comm. Service (DSRCS)
    - 1.4.1.2. Describe radio system fundamentals:
      - 1.4.1.2.1. Simplex
      - 1.4.1.2.2. Half-Duplex
      - 1.4.1.2.3. Trunked radio
      - 1.4.1.2.4. Balanced system's:
        - 1.4.1.2.4.1. Uplink
        - 1.4.1.2.4.2. Downlink
    - 1.4.1.3. P.S. DAS also known as Emergency Radio Communications Enhancement Systems (ERCES)

1.4.2. Cellular carrier
1.4.2.1. List frequency bands for 4G, LTE, LTE-A, FirstNet, 5G and 6G
1.4.2.2. Describe modulation technologies:
1.4.2.2.1. GSM including GPRS/EDGE (retired technology)
1.4.2.2.2. CDMA including UMTS
1.4.2.2.3. WCDMA including related HSPA protocols
1.4.2.2.4. LTE
1.4.2.2.5. 5G
1.4.2.3. Differentiate between SISO (single input-single output) and MIMO (multiple input-multiple output) antenna systems

1.5. List Federal Communications Commission (FCC) directives:
1.5.1. Rules and Regulations governing DAS / Signal Booster systems
1.5.1.1. Receive written permission from FCC licensee to legally rebroadcast their frequencies in building's DAS/BDA
1.5.1.2. Legal signal (and interference) responsibility (remains with the licensee, not with the DAS owner/designer)
1.5.2. Part 90 services for public safety and private mobile
1.5.3. Roll of U.S. CFR 47 § 90.219 (Use of signal boosters)
1.5.4. Rules concerning commercial versus consumer grade cellular signal boosters

## 2.0 Safety

2.1. List Occupational Safety and Health Administration (OSHA) requirements for In-building DAS:
2.1.1. Personal Protection Equipment (PPE)
2.1.2. earthquake (seismic) remediation
2.1.3. weather contingencies
2.1.4. Lockout / Tagout control of hazardous energy

2.2. List safety requirements of working with Radio Frequency (RF) energy:
2.2.1. maximum permissible exposure (MPE) to RF per OSHA; FCC OET Bulletin 65, sup.A-KDB; and IEEE/ANSI C-95 standard (C95.1-2019)

2.3. Explain how to safely handle and dispose of fiber optic cable and optical fiber debris
2.3.1. Identify optical fiber light source safety procedures

## 3.0 Building Codes and Standards

3.1. Describe the National Fire Protection Association (NFPA) safety guidelines related to DAS
3.1.1. List the National Electrical Codes (NEC®) as they apply to In-building DAS
3.1.2. Describe the role of NFPA in public safety DAS:
3.1.2.1. NFPA 72, Chapt.24 Emergency Communications Systems (ECS)
3.1.2.2. NFPA 1225-2022 in public safety DAS, which supersedes and consolidates the NFPA 1221 and NFPA 1061
3.1.3. Describe the International Code Council (ICC) guidelines on fire safety found in IFC-510 of an Emergency Responder Communication Enhancement Systems (ERCES) for public safety DAS
3.1.4. Explain the additional accordance of UL® 2524 Standard replacing UL/CSA 62368-1
3.1.5. IEEE® National Electrical Safety Code (NESC®) cabling requirements
3.1.6. Telecommunications Industry Association® (TIA®) 568- and 606B requirements

3.2. Describe DAS detail content from above codes for:
3.2.1. Enclosures (NEMA4, UL50E)
3.2.2. Alarms
3.2.2.1. BDA alarm to Fire Alarm system
3.2.3. Battery backup
3.2.4. Protected cable paths
3.2.5. Coverage requirements
3.2.6. Testing
3.2.6.1. Pre-Installation
3.2.6.2. Post-Installation
3.2.7. System/designer installation requirements (IFC minimum personnel requirements)

3.3. Describe where and how to find local municipality building (AHJ) codes
3.3.1. Differentiate versions of specific codes referenced and enforced by AHJs

3.4. Define codes that apply to cellular DAS installations

 

## 4.0 Radio Frequency (RF) Signal Characteristics and Requirements

- 4.1. Describe DAS coverage needs and measurement methods:
  - 4.1.1. Public Safety RSSI (received signal strength indicator)
  - 4.1.2. Public Safety DAQ (delivered audio quality)
  - 4.1.3. SINR (signal-to-interference-plus-noise ratio)
  - 4.1.4. BER (Bit Error Rate)
  - 4.1.5. Cellular RSSI
  - 4.1.6. Cellular RSCP (received signal code power)
  - 4.1.7. Cellular RSRP (reference signals received power)
- 4.2. Describe RF characteristics:
  - 4.2.1. Decibels (dB)
    - 4.2.1.1. dBm (in reference to milliwatt(s)
    - 4.2.1.2. dBd
    - 4.2.1.3. dBi
    - 4.2.1.4. dBc
    - 4.2.1.5. Rule of Three (3dB Rule) Power
  - 4.2.2. Wavelength
  - 4.2.3. Amplitude
  - 4.2.4. Free space path loss (FSPL)
  - 4.2.5. Fast Fading / Margins
  - 4.2.6. Multipath
  - 4.2.7. Reflection
  - 4.2.8. Absorption
  - 4.2.9. Diffraction
  - 4.2.10. Scattering
  - 4.2.11. Isolation
    - 4.2.11.1. Amplifier gain limitations
- 4.3. Describe Noise characteristics:
  - 4.3.1. Noise floor measurements
  - 4.3.2. Noise figure of amplifiers
  - 4.3.3. Noise rise at donor site due to BDAs

## 5.0 Site Surveys

- 5.1. Determine appropriate donor site(s) by the DAS owner/designer
  - 5.1.1. Distance(s)
  - 5.1.2. Azimuth(s)
- 5.2. Confirm bands of operation
- 5.3. Describe donor signal measurement methods and tools:
  - 5.3.1. Interference and mitigation best practices
  - 5.3.2. Maximum uplink ERP (effective radiated power)
- 5.4. Explain RF characterization of indoor environments
  - 5.4.1. Describe Public Safety indoor macro signal measurements
  - 5.4.2. Cellular
- 5.5. Explain equipment location best practices, clearances
- 5.6. Explain antenna locations best practices
  - 5.6.1. Donor
  - 5.6.2. Distribution
  - 5.6.3. Describe base location uplink/downlink best practices
- 5.7. Describe cable routing best practices by the DAS owner/designer and cable manufacturer
  - 5.7.1. Explain plenum space
  - 5.7.2. Define a riser space

## 6.0 Equipment

- 6.1. Discuss DAS signal source(s):
  - 6.1.1. Over-the air
  - 6.1.2. Fiber with light source
  - 6.1.3. off-air signal booster
  - 6.1.4. small cell
  - 6.1.5. eNodeB

 

- 6.2. Describe components in a passive DAS:
  - 6.2.1. Donor antenna system
  - 6.2.2. BDA(s)
  - 6.2.3. Distribution system
- 6.3. Describe components in an active DAS:
  - 6.3.1. Fiber
    - 6.3.1.1. Head-end
    - 6.3.1.2. Remote(s)
  - 6.3.2. Internet protocol (IP)
    - 6.3.2.1. Head-end
    - 6.3.2.2. Remote(s)
- 6.4. Describe the different choices of off-air signal boosting used in a DAS
  - 6.4.1. Repeaters / Signal Booster(s) / bi-directional amplifiers(BDAs) limited to 5 watts/channel
    - 6.4.1.1. Class A Signal Booster / Channelized BDAs
      - 6.4.1.1.1. Single channel amplification
    - 6.4.1.2. Class B Signal Booster / Non-channelized BDAs
      - 6.4.1.2.1. Broadband capable amplification

## 7.0 Antennas, Transmission Lines and Connectivity

- 7.1. Describe the different antennas used in DAS
  - 7.1.1. Donor system (antenna, protectors, cabling, connectors/combiners, polarity)
  - 7.1.2. Server / Distribution
- 7.2. Describe antenna gain
- 7.3. Describe the function and use of transmission lines
  - 7.3.1. Types
    - 7.3.1.1. Coaxial cables
    - 7.3.1.2. “Leaky” coax
    - 7.3.1.3. Optical fiber
    - 7.3.1.4. Twisted Pair (Cat 5e, 6, etc.)
  - 7.3.2. Explain Bend Radius for cabling types
  - 7.3.3. Explain Data grade testing
  - 7.3.4. Discuss Measurements
    - 7.3.4.1. Optical time-domain reflectometer (OTDR) for fiber
    - 7.3.4.2. Return Loss for coax (also reflection loss)
    - 7.3.4.3. Baseline recording
  - 7.3.5. Conformance testing
- 7.4. Describe the different DAS terminations/connectors for the 7.3.1 cabling types
  - 7.4.1. Explain how cable preparation, including labeling, for connectors is required
  - 7.4.2. Describe how fiber optic converters (transceivers) advance RF and Ethernet signals
- 7.5. Explain the use of splitters, couplers, tappers, and/or hybrid combiners
  - 7.5.1. Explain insertion loss (attenuation) testing for correct ratios
- 7.6. Describe how harnesses/hangers can and must be used for cabling
- 7.7. Explain how connectivity must be maintained
  - 7.7.1. Describe coaxial connectivity mechanics
  - 7.7.2. Describe installation procedures, including:
    - 7.7.2.1. Proofing line performance quality
      - 7.7.2.1.1. Tamper resistance and vermin protection
      - 7.7.2.1.2. Water protection
      - 7.7.2.1.3. Temperature variance protection
    - 7.7.2.2. Explain splicing procedures
    - 7.7.2.3. Describe correct usage of NEC® rated cable
    - 7.7.2.4. Fire-stopping best practices
- 7.8. Explain system maintenance inspection parameters and procedures

## 8.0 System Installation

- 8.1. Describe how to evaluate schematics, wiring and diagrams:
  - 8.1.1. Component access and locating
  - 8.1.2. Testing of wiring and circuits
  - 8.1.3. Common connection types
  - 8.1.4. Low current terminations (low voltage)

 

- 8.2. Describe tools used on DAS:
  - 8.2.1. Common
  - 8.2.2. Special Purpose
- 8.3. Installation best practices procedures:
  - 8.3.1. Motorola Solutions® R56 protocols
  - 8.3.2. Passive Intermodulation (PIM) versus Antenna placement procedures
- 8.4. Describe equipment mounting:
  - 8.4.1. Grounding and bonding (refer to the NEC®)
    - 8.4.1.1. Compression Lugs
  - 8.4.2. Accessibility (present and future)
    - 8.4.2.1. Wall-mounting best practices (treated backboard, hardware, connections)
  - 8.4.3. Repeaters / Signal Booster(s) / bi-directional amplifiers (BDAs) integration into system
  - 8.4.4. Donor Antenna installation details
  - 8.4.5. Other active devices
- 8.5. List installation test equipment:
  - 8.5.1. Digital Multimeter (DMM)
  - 8.5.2. Spectrum Analyzer
  - 8.5.3. FDR cable sweep, fault locator (sweep testing can cause interference)
  - 8.5.4. Continuous Wave (CW) signal generator
  - 8.5.5. Communications Service Monitor
  - 8.5.6. Test for Mobile Systems or other cellular survey equipment
  - 8.5.7. Optical Power Meters
  - 8.5.8. LAN Tester
- 8.6. Describe component installation of:
  - 8.6.1. Equipment
  - 8.6.2. Racks
  - 8.6.3. Bays
  - 8.6.4. Mounts
  - 8.6.5. Cables
    - 8.6.5.1. Coaxial
    - 8.6.5.2. Optical Fiber
    - 8.6.5.3. Twisted Pair (Cat 5e/Cat 6/Cat 6A/etc.)
    - 8.6.5.4. Other copper
  - 8.6.6. Connectors (combiners)
  - 8.6.7. Splitters (dividers)
  - 8.6.8. Couplers
  - 8.6.9. Filters and chassis per engineering drawings
  - 8.6.10. Bill of Material (BOM)
  - 8.6.11. Method of Procedure (MOP)
  - 8.6.12. Other additional components
- 8.7. Describe labeling per drawings requirements using TIA 606B standards
- 8.8. Explain commissioning of equipment factors:
  - 8.8.1. Power up / “Green Light” system(s)
  - 8.8.2. Baseline measurements
    - 8.8.2.1. Antenna isolation (including single frequency testing)
    - 8.8.2.2. Donor interference on distribution
  - 8.8.3. Gain settings (AGC = automatic gain control)
  - 8.8.4. Noise power

## 9.0 Testing and Troubleshooting

- 9.1. Explain Antenna Line Sweep Testing using an FDR:
  - 9.1.1. Return loss (RL)
  - 9.1.2. Insertion loss (IL) (attenuation)
  - 9.1.3. Distance-to-Fault (DTF)
- 9.2. Explain Passive Intermodulation (PIM) testing
  - 9.2.1. Describe other intermodulation testing
- 9.3. Describe the need for coverage surveys and link budget calculations:
  - 9.3.1. Shadowing / Fading
  - 9.3.2. Waveguide effects
  - 9.3.3. Grid testing confirmations for public safety (described in Site Survey)

 

9.3.3.1. "two-radio" test
9.3.4. KPI (key performance indicators described in 4.1) testing for cellular
9.3.4.1. Speeds (RSRP, RSCP, SINR, UL/DL {Uplink/Downlink})
9.4. Explain post installation quality assessment:
9.4.1. Reconnecting power
9.4.2. Resetting devices
9.5. Describe how to make received signal strength indicator (RSSI) calculations
9.5.1. Antenna versus actual
9.5.2. Each antenna (integrity testing) by:
9.5.2.1. Spectrum Analyzer
9.5.2.2. Power meter

**10.0 Documentation**

10.1. Define 'As Built' documentation
10.2. Explain "Walk-Test" documentation
10.3. Describe the 'Post install checklist'
10.3.1. System Inspection intervals
10.4. Explain Building Codes documentation
10.5. Describe permits and why they are required
10.6. Explain 'Proof labeling per drawings'

## End of overall Distributed Antenna Systems Competencies

**Find an ETA Test Site:** https://www.etai.org/test_sites.html

## Suggested Additional Study Material and Resources:

Useful DAS courses, white papers, discussion and videos can be found at the following web sites: https://www.waveform.com/pages/public-safety-das-and-bdas-for-nfpa; www.txrx.com; https://www.waveform.com/pages/das-distributed-antenna-systems; www.birdrf.com; www.iwatsi.com (IWA Technical Services); https://www.saferbuildings.org/; https://www.dhs.gov/publication/fog-documents, www.iccsafe.org/codes-tech-support/codes/the-i-codes/; www.nfpa.org/Codes-and-Standards; www.nfpa.org/nec; https://www.pctel.com/public-safety-testing-solution/; http://motodas.com/; https://daspedia.com/dasscell; https://harriscommunications.com/public-safety-das; https://alliancecorporation.ca/das-solutions/?vip=8DE50035-3D47-F8CA-A1C7-3D69963C0BE1&eid=26b70; http://danebrockmillerconsulting.com/ (dBc, LLC); https://www.dovertrainingsolutions.com; or by contacting ETA® International for other DAS resources: www.etai.org and 1-800-288-3824

**The Complete ERCES Handbook;** Chief Alan Perdue (ret), John Foley, with Mike Brownson, editor; ISBN 979-8-88955-863-7; Safer Buildings Coalition; 2023; also online https://erceshandbook.com/ or call 888-600-1011

**Distributed Antenna Systems Fundamentals, 2E;** Tom Dover, Dane Brockmiller, FOI, LAS, PIM, DAS CTT authors, Ken Law, illustrator and Jay Thompson, editor; ISBN 978-1940429-98-4; Dover Telecommunications, Inc; 2015; pp. 135; Kindle Ed on Amazon.com (2017);

**Wiring for Wireless Sites;** Ira Wiesenfeld, P.E.; ISBN 978-1401810375; Thompson Delmar Learning; 2002; pp. 260

**Practical Antenna Handbook, 5E;** Joseph Carr & George (Bud) W. Hippisley; ISBN 978-0071639583; McGraw-Hill/Tab Electronics; 2011; pp.784

**Modern Electronic Communication, 9E;** Jeff Beasley & Gary M. Miller; ISBN 978-0132251136; Prentice Hall; 2007; pp.992

**Handbook of Radio & Wireless Technology;** Sam Gibilisco; ISBN 978-0070230248; McGraw-Hill Professional; 1998; pp.640

**Basic Radio, Principles & Technology;** Ian Poole; ISBN 978-0750626323; Newnes; 1994; pp.224

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