District of Columbia's Public Safety In-Building Radio Systems

Acceptance Test Requirements

Effective on October 15, 2019

Version 3.2

GOVERNMENT OF THE DISTRICT OF COLUMBIA
Office of Unified Communications, Washington, DC

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1 Introduction

Increasingly, public safety entities, commercial wireless service providers, and wireless users require reliable communications inside buildings and inside tunnels. For public safety, reliable two-way communications are essential throughout the whole geographical area of a jurisdiction including on-street, in tunnels and within buildings.

Effective January 2015, the District of Columbia has adopted a legislation mandating radio coverage for newly constructed buildings as recommended by the International Fire Code (see http://dcregs.dc.gov/Gateway/RuleHome.aspx?RuleNumber=12-H510). This legislation therefore results into the deployment of numerous in-building radio systems repeating signals from the District public safety radio network (host network) into the depth of the city's buildings. While the Bi-Directional Amplifiers (BDA) and Distributed Antennas Systems (DAS) that make up in-building radio systems do effectively enhance coverage, they also have the potential to negatively affect both in-building and overall radio network coverage if not properly designed, installed, and maintained. Furthermore, without proper BDA/DAS records management, locating in-building systems that interfere with the network can be very challenging.

The code specifies that "emergency responder radio coverage systems and related equipment shall comply with all additional requirements, specifications and criteria established by the District of Columbia Office of Unified Communications to satisfy the operational needs of emergency responders and to prevent adverse impact on the District of Columbia's public safety communications". The set of documents that constitutes the additional requirements, specifications and criteria established by the District of Columbia Office of Unified Communications is available at https://ouc.dc.gov/page/oucs-public-safety-building-radio-systems-requirements. It includes:

- A presentation giving an overview of the process
- A document describing in detail the process for the District validation of public safety in-building repeater systems.
- A document describing the OUC technical requirements for those systems
- A document describing the OUC systems acceptance testing process
- A document describing the annual testing requirements
- Various forms supporting the process

The purpose of this set of documents is to serve as a reference guide to outline how in-building BDA and DAS Systems shall be designed and deployed to provide emergency responders radio coverage in buildings throughout the District of Columbia. Those documents are provided to relevant organizations to facilitate the process of implementing and operating BDAs and DAS that will provide the required radio services and not adversely affect the mission critical radio network that the Office of Unified Communications (OUC) of the District of Columbia.

This specific document describes the Acceptance Test Process of the Public Safety In-building Radio Systems in the District of Columbia.

2 Procedure Overview

2.1 Tasks outline

This acceptance test is limited to radio functions and does not assess if the system installation complies with the Fire Code, that task being the Fire department's and DC Regulation Authority responsibility. The system shall stay "off" and not transmitting until the next steps are completed. The objective is to ensure that the first responders obtain the required quality of service while ensuring the public safety radio network is not degraded by the implementation of the in-building repeater system. The acceptance process includes the following steps:

1. PRE-REQUISITES
2. REVIEW DOCUMENTATION PROVIDED BY THE VENDOR
3. ACCEPTANCE TEST PREPARATION
4. REMOTE ACCESS CHECK:
5. SITE INSPECTION
6. BDA COMPLIANCE AND CONFIGURATION CHECK
7. UPLINK NOISE CONTRIBUTION EVALUATION
8. BDA GAIN ADJUSTMENT
9. UPLINK NOISE CONTRIBUTION EVALUATION
10. UPLINK SQUELCH ADJUSTMENT
11. ISOLATION TEST
12. FREQUENCIES AVAILABILITY VERIFICATION
13. AUDIO TEST
14. COVERAGE TEST AND DATA COLLECTION

2.2 Building Owner/Manager Responsibilities

The owner of the building is responsible for:

- Fund the testing and any troubleshooting and repairs costs if necessary
- Contract one of the OUC approved vendors to perform the testing
- Schedule with the approved vendor and the OUC the testing itself
- In case of deficiencies, investigating the cause of the issue(s)
- Fixing deficient equipment or configurations until meeting requirements.

A significantly number of buildings are built to be occupied by offices or for commercial use.

It might take a few months, sometimes years to rent all floors out. Meanwhile, some of the building interiors might not be completed when coming to perform a Public safety DAS test (floors without interior walls, no ceilings, etc.)

In that case the building is not complete i.e. the whole building still needs to be tested. The testing staff shall note which floors are not physically complete.

The transmission authorization letter sent by the OUC will specifically include which floors were complete when testing occurred and which floors were not. The letter will also explain that when significant modification will be made to the building affecting radio waves propagation and/or levels of interference, the building owner shall perform again a public safety BDA/DAS test at his cost using one of the OUC approved vendors. A non-exhaustive list of modifications affecting radio propagation includes:

- adding interior/exterior walls, ceiling, partitions,
- extending the Distributed Antennas System
- implementing additional wireless systems (internal systems or cellular systems for instance)

The extent of the test will depend on the modifications made to the building. It will be determined on a per case basis.

2.3 Deliverables

1. Updated OUC Uplink Budget spreadsheet:
    1. Design modifications need to be included in the “Designer ‘s Settings” tab
    2. Measurements need to be included in the “Objectives vs. Measurements” tab
2. Acceptance Test Checklist & results (see document 6.6 Acceptance testing checklist on this web page: https://ouc.dc.gov/page/oucs-public-safety-building-radio-systems-requirements)
    1. Information requested in the header tabs
    2. Checks and values included in the checklist tabs. Comment as necessary.
    3. Remote checks (at least one if copper DAS)
    4. Coverage baseline values
    5. Coverage plots (grid) & associated statistics
    6. Audio test results.

3 Acceptance Testing Prerequisites

Before scheduling a site acceptance test with the OUC or its approved vendor, the building owner technical representative will ensure that the following prerequisites are completed. The vendor shall provide the information below **ahead** of the scheduling of the testing.

1. Documentation

    a. Emergency contact information
    b. Building Manager contact information
    c. Plan describing what parts of the building:
        i. Are completed (including interior walls and ceilings)
        ii. What parts of the building the DAS has effectively been deployed
        iii. What parts of the building are targeted for immediate occupancy
        iv. IMPORTANT NOTE: All rooms of the building will be tested
    d. As built drawings including the following files:

i. antenna layout with identification (labeling) of antennas, splitters/couplers and remote units (if applicable) and their locations,
ii. coverage maps,
iii. link budgets,
iv. equipment specifications
v. floor plans

e. Antenna and cable sweep testing results
f. PIM Testing results (if applicable)
g. Written commitment from the building owner/manager that (s)he will provide an IP connection meeting the requirements of the OUC

That documentation shall be sent to das.ouc@dc.gov.

2. Site completion

a. Verification that the building completion actual status matches the description in section 1.c.i;
b. All spaces are clear for walking with a test cart.
c. Verification that all DAS infrastructure is installed in its permanent location (antennas, etc.) according to description in section 1.c.ii.

3. DAS Integrator's representative

a. Verification that the technician present has all necessary equipment to access BDA/DAS management system.
b. Verification that the technician is capable of changing antenna azimuth for donor antenna if alternate donor site is selected by OUC/OUC representative.
c. Ensure that the technician has assorted spare attenuation pad's (or variable pads) if adjustments are determined necessary.
d. Ensure the technician brings a spectrum analyzer and a signal generator.

4. Configuration.

a. Vendor has verified that P25 BDA is configured and bench tested with 1 filter per OUC Channel. (Deviations to be approved by OUC in advance)
b. Verification that the P25 BDA has been configured with adequate padding to protect it from OUC macro sites, and uplink has been padded/configured per OUC noise rise criteria.
c. Verification that the "Near Test" test has been completed and adequate protection provided. This test is described in section 4.6.2

4 Acceptance Test Process

4.1 Review documentation provided by the vendor.

The vendor MUST provide the information listed in the Acceptance Testing Prerequisites section above prior to the acceptance test. If the information provided is not complete, do NOT schedule the test.

4.2 Acceptance test preparation

Before heading to the building for testing, the OUC approved testing company shall make sure that:

1. It checked with the OUC System Manager the system is available for testing during the test time period.
2. It has scheduled the test with the building POC and the OUC system manager. The OUC system manager will take the necessary steps to make sure that measurements and read received levels at all potentially affected host sites can be collected.
3. It has the data collection equipment ready. Preferably a tool that allows you to plot on the floor plan RSSI and other parameters
4. It had defined a grid according to the following guidelines:
    a. Building drawings for each floor will be reviewed and test locations marked to determine these test locations as part of a test plan prior to actual testing. Grids must be created such that the long length of the grid is under 125% of the length of the short length of the grid. For example, a 40x50 grid is acceptable; a 20*26 grid is not acceptable.
    b. For floors less than 32,000 sq. ft., each floor of the building shall be divided into grids of 20ft x 20ft each.
    c. For floors between 32,000 sq. ft. and 128,000 sq. ft., each floor of the building shall be divided into 20 Grids.
    d. For floors over 128,000 sq. ft., each floor shall be subdivided into 40 grids.
5. You have two portable radios fully charged, calibrated, and programmed with in-building testing code plug.
6. You have another voice communication device like your mobile telephone in case radio communication is not possible.
7. The remote access to the BDA will be performed by the OUC

4.3 Site inspection

1. Check Head end room for any alarms or loose connection

    a. Enclosure: both BDAs, DAS head-ends and batteries active components are in NEMA-4 enclosures.

    b. Signage

    On a Red background with Yellow Lettering

    District of Columbia Fire Department Radio

    Contact OUC Radio Engineering

    (202) 373-3700

    c. Cables labeling (needs to match the as-built drawings)

    d. Check grounding of the BDA

e. Check that local system shutdown functions.

a. Roof Top Measurement and inspection:

a. Make sure physically the donor antenna is ok, there is no apparent rust or damage due to weather condition

b. Take measurement of received signal at host site transmitting with a portable and omni-antenna. Have the system manager read received levels at at least 3 possible sites. Make sure that your body is not masking the path loss (raise your arm with the portable). Make also sure you move a few feet left and right while the measurements are made such that you avoid fading holes. Multiple test locations might be necessary to ensure a view towards each Host Site.

c. Check Grounding: Check the antenna and mount are grounded as well as the coax outside and the equipment in the room it is located at. After many years of service, grounding system can deteriorate and so does its performance; make sure the connection to the ground is not corroded or disconnected. Make sure the grounding meets industry standard grounding guidelines (R56 or equivalent)

d. Check the surge arrestor shows no damage and is properly grounded.

e. Make sure all cables and antennas are clearly labeled to facilitate potential future troubleshooting.

f. Check that the labeling matches the as-built drawings

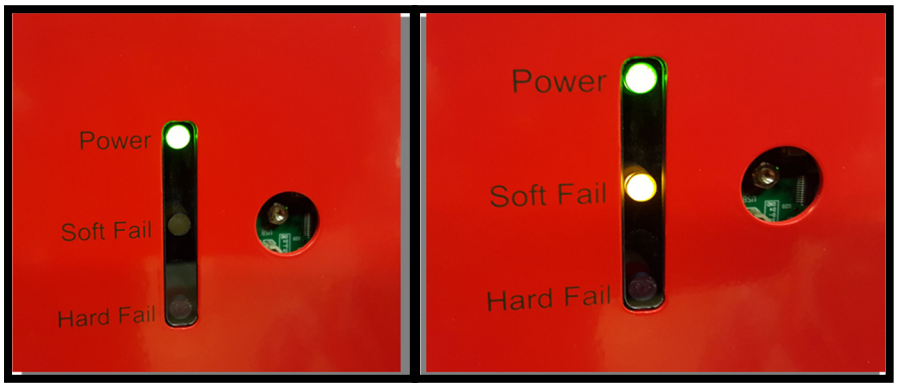
3. Battery backup needs to be tested:

a. Check the alarms display and make sure there are no existing alarms.

b. Unplug the AC cable and make sure the BDA power switches to battery backup

c. Check the alarm on the BDA/DAS are also visible (these may be at the fire annunciator panel)

d. Check that you can remotely login into the monitoring system and that the alarms were sent.

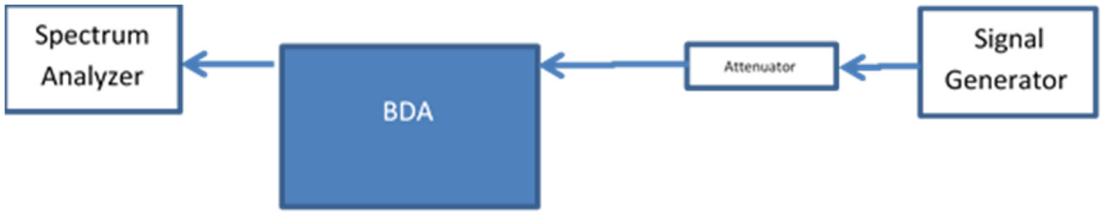


Before **After**

4.4 BDA compliance and configuration check

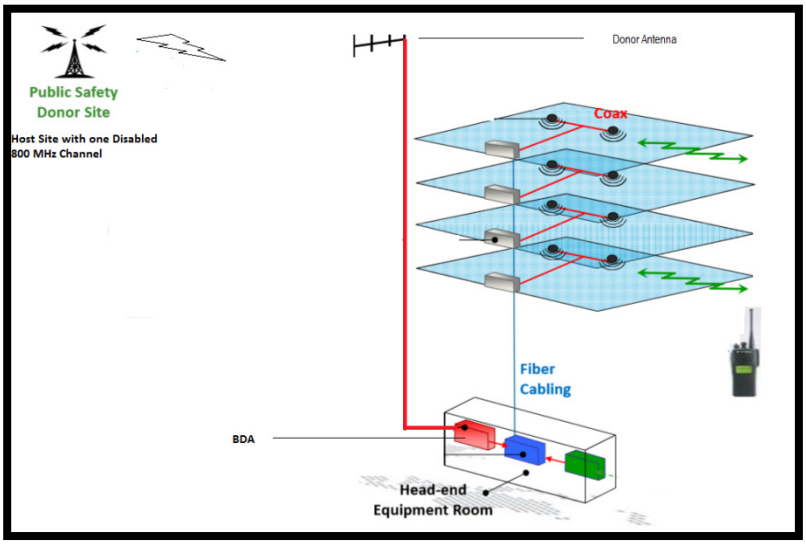
OUC BDA requirements call for Class A BDAs and one filter per channel. Depending on the BDA vendor and the model, that might require the combining of several BDAs. The channels' bandwidths are also generally configurable. The filter bandwidth for OUC BDAs needs to be set to 12.5 kHz.

1. Connect the signal generator, the attenuator and the spectrum analyzer as described above.
2. Generate the signal scanning through the whole spectrum of interest (may be split the 800 MHz and the 700 MHz spectrum)
   a. If equipment is unable to show single channel resolution on a sweep, per channel verification may be needed.
3. Check that the BDA passes all OUC channels
4. Check that the BDA filters are 12.5 kHz wide.
5. Check that the BDA is not passing any non OUC frequencies
   a. Here a band sweep is necessary to rule out other filters



Power level check: make sure the power level across the various channels is about the same.

4.5 BDA gain adjustment:

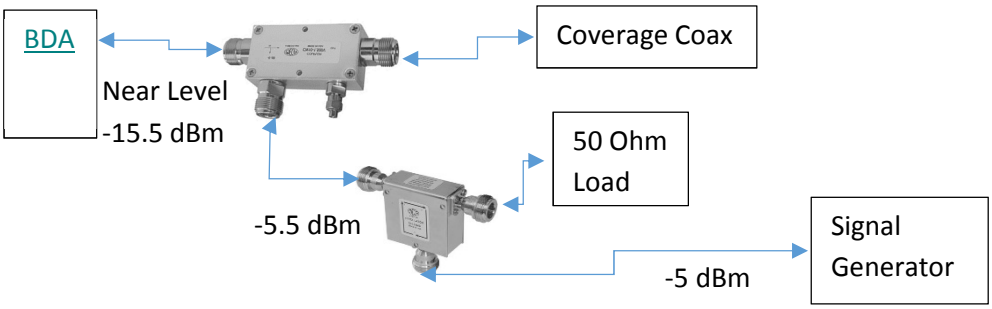


1. Host receiver noise floor measurement
    a. Check with the system manager that the testing frequency is clear for testing Example: "channel # 4".
    b. Make sure that the BDA is turned off and not transmitting.
    c. Make sure no radio is transmitting on the selected testing frequency.
    d. Ask the system manager to read the noise floor at the receiver for all the frequencies
    e. Have him check that all receiver noise levels are about the same.
    f. We obtained the receivers' noise reference (~ -115 dBm).
    g. Note the corresponding values: NoiseReference
2. Near signal test (Hot signal test).
    a. Attach spectrum analyzer to the Distribution Antenna System output right before the input to the BDA. Set the spectrum analyzer to be in peak hold mode.
    b. Key a radio near an antenna at head height, (or cruiser/ambulance height for mobile accessible antenna's) and walk a + pattern from directly under the antenna to 6 feet in each direction. (or to the antenna's primary lobe)
    c. Verify that the received signal at the spectrum analyzer is 5 dB below the max operating input power of the BDA, and 10 dB below the max damage number.
    d. Using a spectrum analyzer verify the BDA throws no spurious emissions with an input at this level.
    e. Check that the signal at the host site will be below -45 dBm based on path loss calculation. If not correction need to be made.
    f. This test needs to be done each active segment (each segment connected to the BDA or the fiber DAS remote units if a fiber DAS is deployed.

3. Gain adjustment

a. Power up the BDA making sure it is connected in normal operational conditions.
b. Make sure that only the test radio you are using is operating on that frequency.
c. Select a location where the coverage seems the weakest (check the coverage maps from the vendor or use common sense based on the layout of the building and of the DAS).
d. Use the radio portable to transmit. The portable radio needs to be set up on the channel matching the testing frequency.
e. Ask the system manager to read the receiver value at the selected target site(s)
f. Select Adjust the BDA output uplink transmit power to achieve a 18 dB SNR
g. Select a location near a donor antenna fully into AGC(near test location)
h. Use the radio portable to transmit. The portable radio needs to be set up on the channel matching the testing frequency.
i. Ask the system manager to read the receiver value at the selected target site(s)
j. Select Adjust the BDA output uplink transmit power to verify RSSI is below 45 dBm

4. Near-Far Signal Test



a. Attach the signal generator as shown above.
b. Select the transmit frequency to be 815.6125 MHz
c. Adjust transmit power so that the power at the input to the BDA matches the power recorded from the Near test.
d. Using a portable from the expected worst coverage area (from 3.c) transmit on any 800 MHz channel and verify that the received signal is still 18 dB above the noise floor.

4.6 Uplink Noise Contribution Evaluation

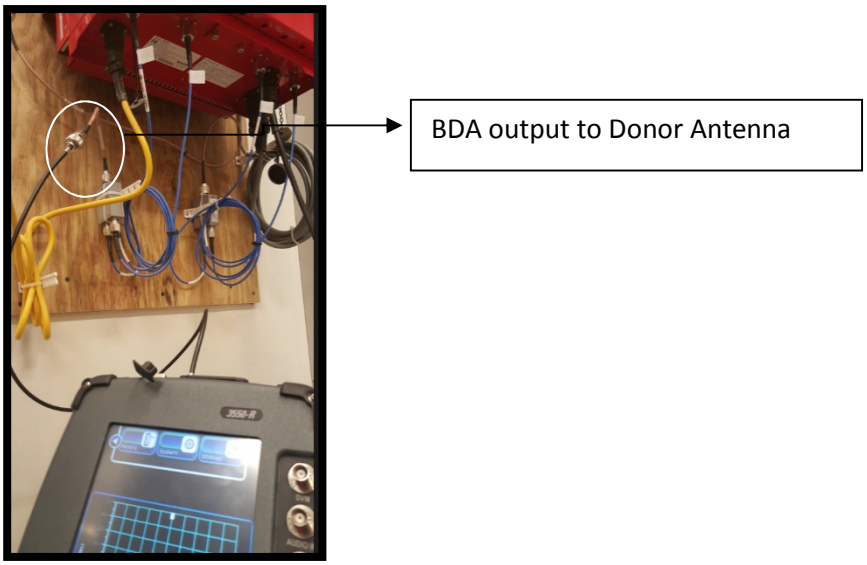
A- Evaluate Propagation loss

1- Setup a portable to transmit on channel locked talk-group at a known power level P.
2- Connect the portable to the donor antenna jumper and transmit on the uplink channel.
   a. If the donor site is close to the donor site, it is recommended to add an attenuator to avoid saturating the host receiver. In that case note the added attenuation value in the report.
3- Ask the system manager to read the received signal strength at all potentially affected OUC sites
4- Note the corresponding “RxLev” values.

5- Subtract those values from the transmitted P of the signal generator.

6- We obtained the propagation loss to each potentially affected site: Path Loss = P – RxLev

B- Evaluate Noise contribution



1- Connect the spectrum analyzer to the BDA output (the output that is transmitting the uplink towards the donor antenna).

2- Ensure that no radio is transmitting on the testing frequency and make the measurement on the testing frequency.

   a. This test should be performed with the squelch circuit turned off, or set low enough not to trigger.

3- Note the corresponding value that is the Noise generated by the BDA: N_BDA.

4- Calculate the contribution to noise received at each OUC site:

   Noise contribution = N_BDA – PL

5- Compare those values to the Noise References. They should be significantly lower (at least 15 dB).

4.7 Uplink squelch adjustment

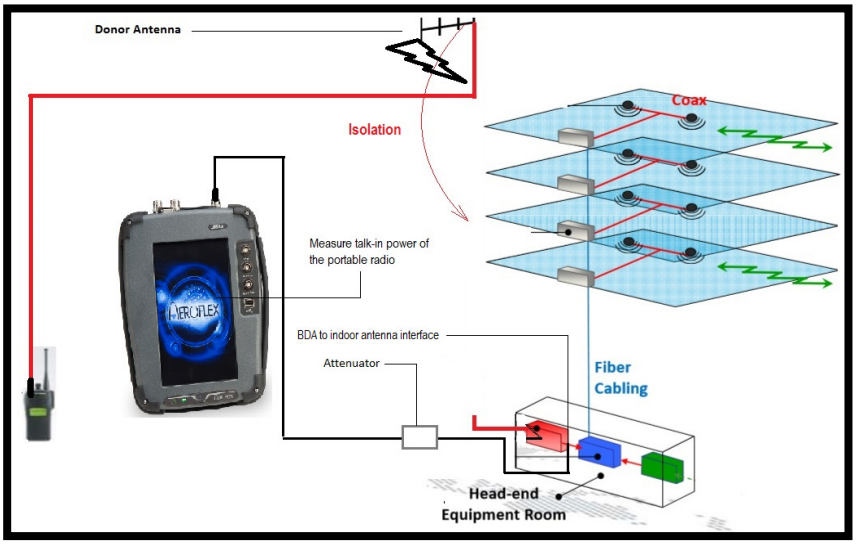
Here the technician shall check the level of the uplink squelch.

The uplink squelch threshold shall be set 5 dB above the noise on the uplink coming out of the DAS. It can be measured as the uplink input level to the BDA by the BDA itself. The measurement of the noise shall be done for a period of at least 5 minutes while making sure that no radio is transmitting.

4.8 Isolation test

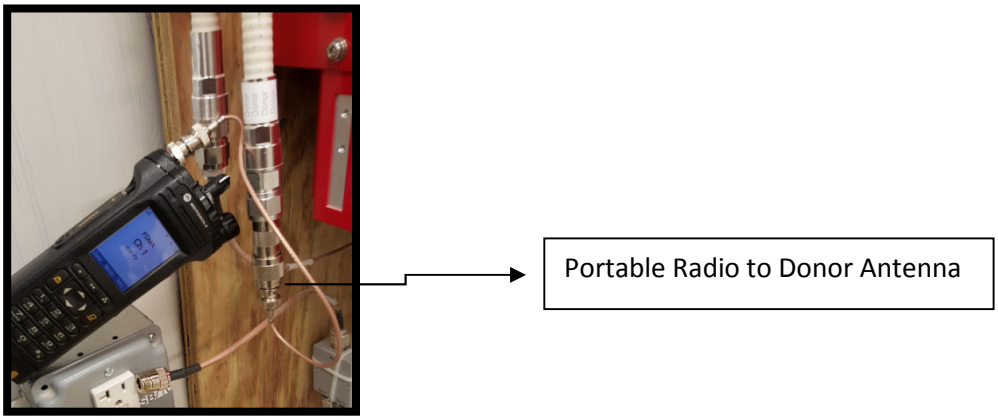
DAS System Isolation Measurement

The most frequent problem with an in-building installation is inadequate isolation (path loss) between the donor antenna and the DAS' antennas. When insufficient the system 'oscillates' and causes interference to itself and others. It is prohibited to operate a signal booster or BDA that oscillates.



Measure the DAS System Isolation as follows:

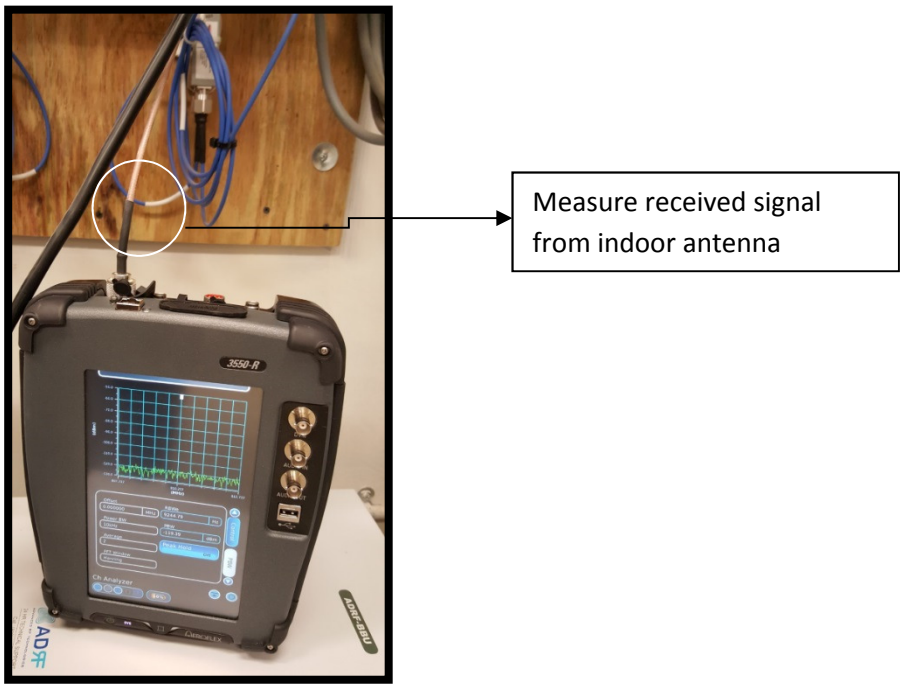
1. Disconnect the Donor Antenna coax cable from the off-air signal booster or BDA.
2. Use the "donor coax" and three foot jumper as shown below to connect a three (3) watt portable radio to the Donor Antenna coax cable through the radio antenna connection. This will allow the portable radio to transmit and receive using the Donor Antenna.



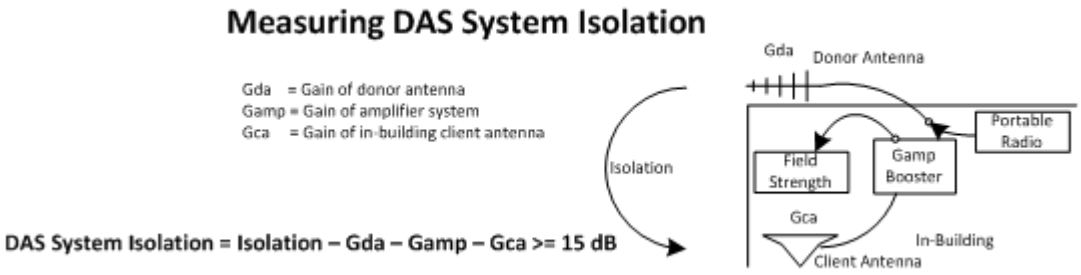
3. Set the radio to test OUC FDMA Channel "example FDMA Chan #26, 814.9875 MHz".

4. Connect the spectrum analyzer using a three (3) foot jumper to measure the power received by indoor antenna in the selected FDMA Channel. The spectrum analyzer will be

connected to the Uplink input of the BDA on DAS system **"Make sure there are no radios transmitting within the building during this test".**



5. Key-up the portable radio and hold: observe the selected channel on the spectrum analyzer. Average the power measurement of selected channel for at least 10 seconds.
6. Proceed to the calculation described in the drawing below. The DAS system isolation shall be greater than 15 dB.



4.9 Frequencies availability verification

To check that all channels are transmitted, you need to use radios that have a specific code plug. This code plug has every single frequency programmed as a conventional P25 channel. A spectrum analyzer can be used

to observe the frequency and received level when the radio is keyed up through the use of a directional coupler.

1. In area with no, or poor coverage when not augmented with a BDA, verify that the BDA passes all OUC frequencies.
2. If a fiber-DAS is deployed, repeat for any passive segment connected directly to the BDA, AND each active segment connected to a remote unit.

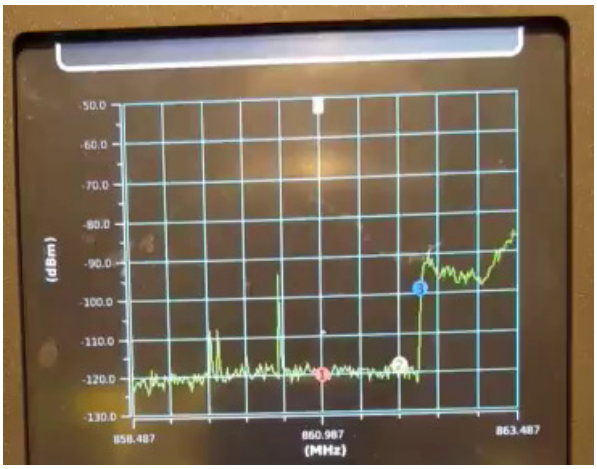
For more details on all frequencies in use by the District of Columbia refer to document 6.2 OUC public safety frequencies located here: https://ouc.dc.gov/page/oucs-public-safety-building-radio-systems-requirements.

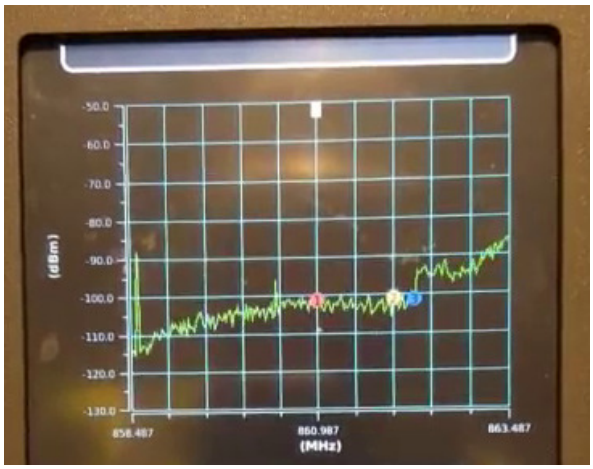
4.10 Commercial DAS Level of Interference Verification (if Applicable)

In some cases, commercial cellular systems deployed in a building can create interference with the public system repeater system. This is in particular true if the distributed antennas are not shared between the public safety frequencies and the cellular system. To check if such interference exists,

- Make sure the commercial DAS and its feed are on.
- Take a spectrum analyzer under the cellular DAS antenna the further apart from any public safety DAS antenna.
- Verify that the public safety band is free of interference, see pictures below. The first one is with the commercial BDA off. No interference shows in the public safety band (red marker). The second one shows that with the commercial BDA on the noise raises significantly.

Commercial BDA:





4.11 Audio Test

Even though signal strength and BER measurements are providing good evaluations of the quality of the coverage, the audio quality gives a sense of the ultimate quality of service perceived by the end-user.

To test the audio quality you need to:

1. Use radios with code plug installed where all 26 channels are programmed to be tested individually.

You can use the following phrase to test the uplink:

*"This is OUC doing in building test. Counting 1, 2,3,4,5 do you co*py?"

2. Evaluate the audio call quality using the following table:

DAQ Values	Subjective Performance Description
1	Unusable, speech present but unreadable.
2	Understandable with considerable effort. Frequent repetition due to noise / distortion.
3	Speech understandable with slight effort. Occasional repetition required due to noise / distortion.
3.4	Speech understandable with repetition only rarely required. Some noise / distortion.
4	Speech easily understood. Occasional noise / distortion.
4.5	Speech easily understood. Infrequent noise / distortion.

3. Test at each test location both talk-out and talk-in will for both 700 and 800 MHz talk-groups.

4. Repeat the same process throughout each floor of the building including stairways and elevator machine rooms

5. A maximum of 5% non-adjacent areas shall be allowed to fail the test for a given floor.

6. For talk-out tests, voice calls shall be made to a portable radio at hip level.

7. For talk in tests, voice calls shall be made from a portable radio at hip level (with a shoulder mike). At a given test location, rekeying will be allowed if an initial PTT does not receive a channel grant.

8. Note the locations where the test failed.

4.12 Coverage Test and Data Collection

To perform this test, you will make measurements on the control channel. Control channels are listed in Annex 1. Please check with the system manager which one is active (default is channel 2):

1. Then collect the RSSI data in dBm received with a spectrum analyzer or similar tool.
2. All floors, stairwells and areas of the building need to be measured
3. Critical areas include stairwells, headend room and emergency and standby power rooms
4. The measurements shall be grid based, the grid being developed as described in a previous section.
5. As per NFPA, the measurements within a grid will be recorded :
    a. while walking an “X” pattern with the center of the pattern located approximately in the center of each grid area
    b. The linear distance of each side of the “X” equal to at least 10% of the length of the grid side and a minimum length of 10 ft.
    c. Measurements sampled in an averaging mode to include a minimum of 1 sample per each 5 ft. travel recorded with no less than 10 samples per measurements per side of the ”X”
6. The results need include the following:
    a. A Map that color code the received levels (the map needs to demonstrate that all floors, stairwells elevators have been tested exhaustively).
    b. The map shall identify clearly the critical areas and the corresponding measured parameters
    c. Statistics that demonstrate that the criteria passed (95% per floor)
    d. An Excel table that shows the RSSI values measured directly under each antenna and indicates the floor and location of the measurement. This table will clearly identify the critical areas measurements. This table will serve as a baseline for annual testing.
    e. The location and identification of at least 2 fringe areas. Fringe areas are those areas where the coverage is the worst.

Appendix 1: Public Safety Sites Locations