

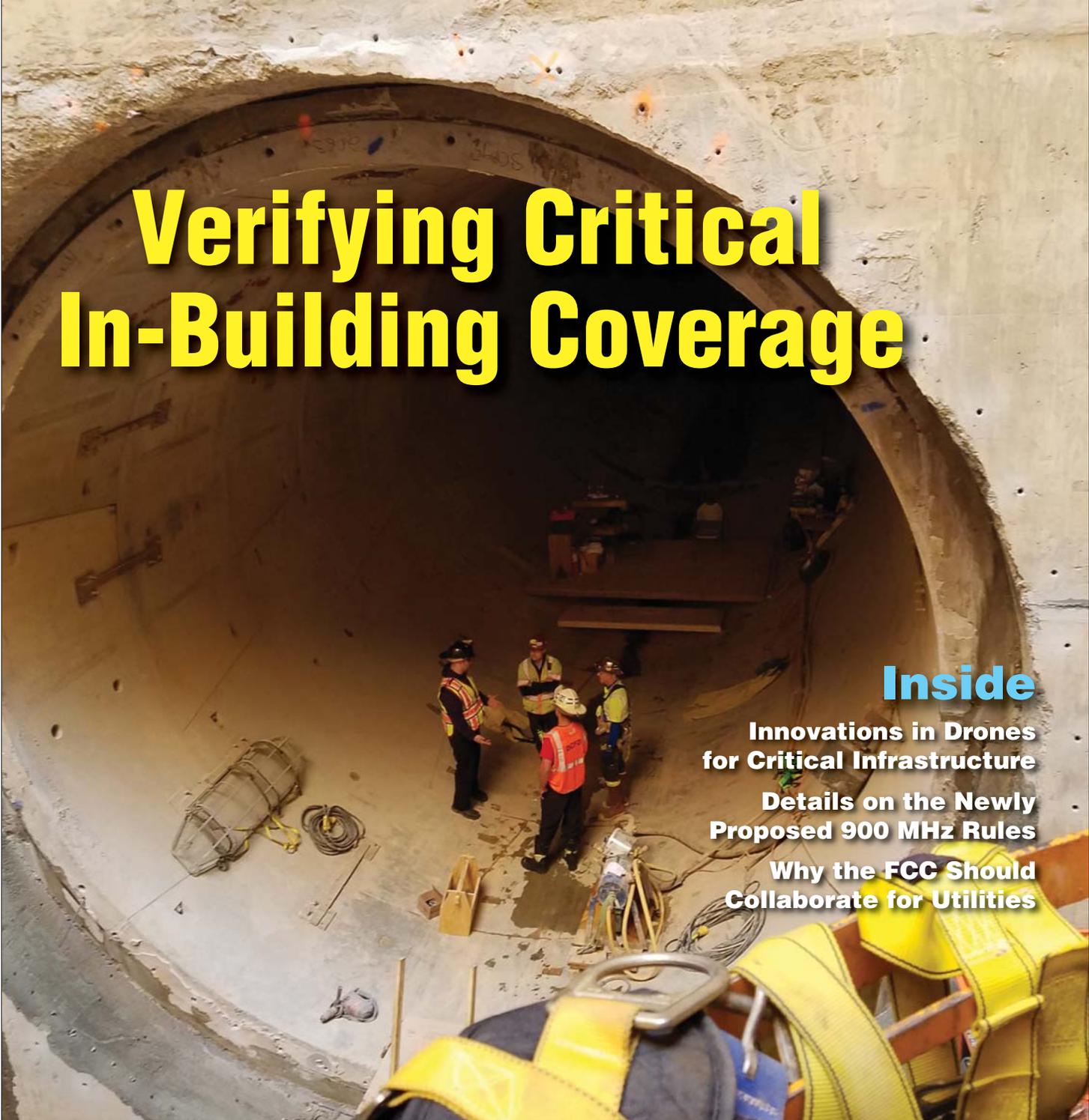
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Verifying Critical In-Building Coverage

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In-Building Coverage Verification

Evolving standards for in-building communications coverage provide a path for local jurisdictions to follow.

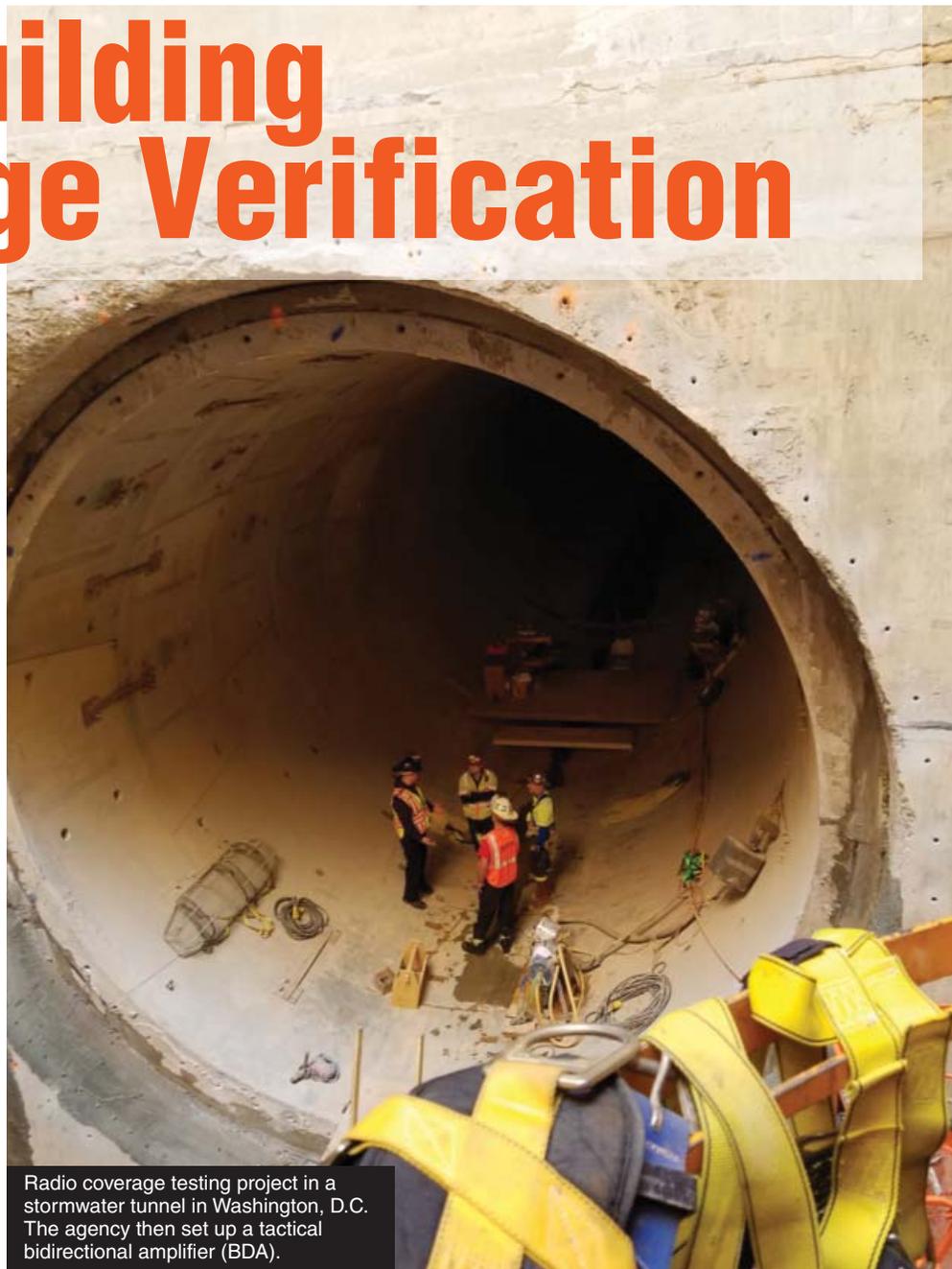
By David Adams
and John Johnson

For years, public-safety radio systems have been built to provide reliable mission-critical communications with sufficient outdoor coverage; however, in-building radio coverage has posed many challenges for system operators. This issue has become more urgent. First responders expect in-building radio coverage to be at least equal to their cellphone coverage, prompting governmental and first responder organizations to rapidly adopt in-building coverage requirements. These requirements are frequently based on codes developed by the National Fire Protection Agency (NFPA) and the International Code Council (ICC). New testing methods are crucial for implementing these requirements and making reliable in-building radio coverage the new norm.

Locally Adapted Standards

Following the events of 9/11, in-building coverage became an issue of national urgency in the United States; however, it is up to local officials in cities, counties and states, referred to as authorities having jurisdiction (AHJ), to create and enforce regulations. Early AHJ requirements varied widely in the absence of national and international standards.

In the early 2000s, the NFPA and the ICC, two organizations that pro-



Radio coverage testing project in a stormwater tunnel in Washington, D.C. The agency then set up a tactical bidirectional amplifier (BDA).

Photo courtesy Lafayette Group

vide leadership in various public-safety areas, began to add requirements for indoor network performance. The NFPA developed the NFPA 1221 standard, originally in NFPA 72, while the ICC developed the International Fire Code (IFC). Essentially, these codes state that building occupancy requires proof of meeting indoor coverage performance standards, following specific testing and reporting requirements. NFPA and IFC standards are typically updated every two to three years.

There are more than 20,000 AHJs in the U.S., and about 50 percent have some regulations in this area. Most

AHJs initially start with NFPA 1221 or IFC 510 but often adapt them. A requirement for annual retesting is common. Most agencies apply regulations only to new buildings or existing buildings with major renovations. Some jurisdictions adopt codes that apply to existing buildings that have not been renovated as well.

“In many cases, the local jurisdiction may enforce more stringent requirements than the ones outlined in NFPA 72, NFPA 1221 or IFC 510,” says Javier Herrero, a professional engineer at SmartRF Engineering. “It is very important for engineers and

system integrators to engage with the local AHJ early in the process and learn the specific requirements within that jurisdiction.”

Under NFPA and IFC standards, the building owner/property manager is responsible for conducting testing and producing reports. Owners need to understand the testing requirements and implement a plan for verifying coverage to acquire and maintain occupancy permits.

Test Requirements

NFPA 1221 and IFC 510 provide significant detail on how to evaluate in-building radio performance, and requirements evolve. These documents and other standards adopted by AHJs should be consulted to determine specific requirements, although NFPA and IFC requirements frequently adopted by AHJs have much in common.

Measurements are conducted in a manner that can be readily evaluated to determine if a building passes. The testing process begins by creating a grid of areas on a building’s floor plans. Measurements are conducted in each area for each channel (frequency) of interest to the AHJ. These measurements are compared to thresholds to determine whether each channel passes for that area, and a certain percentage of areas must pass for the overall building to receive a passing grade.

Critical areas such as fire pump rooms, lobbies, elevators, stairwells and equipment rooms must also be tested. Critical areas typically have tighter thresholds and passing percentage requirements that contribute to the overall grade of the building.

Recent standards require measuring signal power and voice quality for the downlink from network to radio and uplink from radio to network. Power measurements are compared with some fixed level in decibels, and the voice quality is compared to the digital audio quality (DAQ) grading scale.

Code Variations

Despite their similarities, NFPA and IFC standards have significant differences. When an AHJ adopts a standard, often two to four years after its release, the AHJ makes changes. For example, the Office of Unified Communications

(OUC) for the Washington, D.C., area, published a list of changes it made to the IFC recommendations. An AHJ may also adopt requirements based on TSB-88 LMR reliability and performance standards created by the Telecommunications Industry Association (TIA). Those responsible for testing may encounter a range of differences.

Both the NFPA and IFC call for a grid of 20 areas of generally equal size — 20 to 80 feet per side. However, if a floor is larger than 128,000 square feet, add 20 more areas. If tests in two adjacent areas fail, the NFPA says to use 80 areas, while IFC calls for 40 areas. Some jurisdictions focus on the size of the areas and even call for them to be close to square.

IFC states the test must be in the center. The tester is not allowed to move or retest. By contrast, the NFPA instructs the tester to move in an “X” through the center of the area, averaging five samples per side of the X. NFPA also states that the measurement device should be 3 to 4 feet off the ground with a vertical antenna. Some jurisdictions call for the device to be “on hip,” where others want the antenna to be above shoulder height.

Test the network, but which frequencies and channels? AHJs must make the list of channels that must be tested available; however, in real life these lists can be difficult to obtain. Multiple tests are usually required. For example, there might be several LMR systems and technologies in use by different agencies in an area, and public-safety Long Term Evolution (LTE) is starting to be included.

Signal strength has been included in different versions of NFPA and IFC requirements, but thresholds vary. For example, NFPA requires 90 percent of the areas be greater than -99 dB but not two adjacent, and IFC requires 95 percent of the areas be greater than -95 dB. NFPA also includes critical areas of 99 percent of the points, but IFC does not. Some AHJs use different values for areas or critical areas.

Recent NFPA and IFC releases added voice-quality testing requirements and specify using DAQ as a grading mechanism. Approaches to voice-quality testing vary, including how often voice quality must be



Photo courtesy Day Wireless Systems

Measuring coverage in a tunnel

checked, whether the testing applies while walking the X in the grid and whether an averaging requirement applies. Some AHJs call for the fire marshal to conduct quality tests, although most allow wireless service shops to do it. New York City and Washington D.C., among others, have approved certain companies to conduct these tests. New York City requires a recording of the audio from the tests for review by the government agency.

While recognizable speech is an important point, DAQ testing is subjective, time intensive and not easily reproducible. In 2018, IFC added an alternative — testing signal to interference and noise ratio (SINR) equivalent to DAQ 3.0. Some AHJs have also adopted bit error rates, another DAQ alternative. These alternatives are attractive because SINR and BER measurements are fast, accurate and repeatable. They can be conducted in every grid area without being burdensome and can be automated.

Recent releases added uplink testing requirements; however, neither NFPA nor IFC standards document where the measurements are to be taken or how the test should be executed. Uplink testing can also be difficult and expensive. As a result, many AHJs do not include or enforce uplink requirements.

NFPA requires an average of five samples per side of the X, which works for testing control channels, but what about traffic channels and DAQ? TSB-88 calls for a sample rate for confidence. IFC calls for a near/far test, and

NFPA 1221, AFC 510 and AHJ Common Requirements

Divide each floor into a grid of 20 generally equal areas

Test each area in the center

Conduct tests with radio or other AHJ-approved equipment

Grade each area pass/fail based on thresholds for test items, including

- Minimum signal strength level
- Signal quality sufficient for DAQ 3.0, or equivalent SINR in and out

Test additional critical areas (stricter criteria)

Grade a building as pass/fail based on percentage of areas and critical areas that passed

Record must be signed by AHJ-approved person

NFPA uses a similar two-radio test. Do requirements address multipath fading and its effect on measurements? Calibrated test equipment may be required, and annual retest requirements vary.

Why Grid Testing?

The grid-based approach used in the public-safety industry has distinct differences from testing that cellular operators have developed during recent decades. The cellular industry typically uses path-based testing to conduct tests. Path-based testing focuses on a wide range of technologies and services; coverage, capacity and handoffs; voice, data throughput and interference; and a finer granularity of measurements for deep analysis. This approach requires a higher degree of engineering capability and time but contributes to better-engineered network performance.

Public safety's grid-based testing is primarily used for emergency voice service, is primarily for coverage and tests a minimum voice quality level. The main advantage of the grid-based testing is the standardized approach to conducting measurements and assessing pass/fail while presenting the results in a format that is readily accessible to the governing agencies.

The Big Challenge — Scale

AHJs are increasingly enforcing

coverage and associated testing and expanding beyond new buildings. The number of tests required will be significant. There are about 6 million commercial buildings in the United States, and about 50,000 new buildings are built annually. Considering most AHJs require an annual retest, soon more than 1 million buildings will need to be tested every year.

Most tests are conducted with a time-consuming manual approach using a radio, pen and paper. Typically, before testing begins, test planners print out floor plans and mark them with grids and critical areas. At each testing area, skilled personnel individually collect signal strength and DAQ measurements from a radio and mark them on the floor plan. After testing is complete, results must be compiled and formatted into a report that satisfies AHJ requirements. This process can take about six hours or more per floor — about two weeks per 12-story building. Testing 1 million buildings per year would require approximately 40,000 testing personnel, which is probably not feasible.

With the introduction of an automated solution, the time to plan, execute and report results can be reduced to less than two hours per floor. A typical commercial building can be a three-day project start to finish. This allows for a typical tester to conduct

100 tests per year, conservatively increasing to 200 with efficiencies. Nationally, the scale is large but manageable. It will likely require from 1,000 to 3,000 people to be involved in testing in the near term, increasing to 5,000 or more if 1 million buildings are tested yearly.

An Ideal Test Solution

To address the many challenges of in-building public-safety communications testing, new solutions that enable a cost-effective use of personnel are required. Some of the characteristics that should be included are:

- Fast, simultaneous, accurate and consistent measurements across multiple bands/channels/technologies in a single test;
- Flexible approach to recording measurements in any required combination in one test, including customizing grids and test parameters; and
- Automated test execution, including all parameters and reporting.

Case Study

Service company Day Wireless Systems compared a widely used manual testing approach to an automated public-safety network testing solution from PCTEL.

“This project came up around the time we learned of a new automated solution,” says Jason Chambers, service manager at Day Wireless. “We knew we needed something like this if we were going to grow our business and still make money.”

The project involved two sister tunnels with three lanes of traffic per tunnel and two independent public-safety bidirectional amplifiers (BDAs) and distributed antenna systems (DAS) fed by five donors. Baseline and fire code compliance are required for each system.

The team used a manual approach in tunnel 1, with three technicians and five test devices per shift for two shifts. The process required lane closures on a major highway, 36 man-hours for on-site coverage testing, manual handwritten recording of 600 signal levels for test grids and 20 administrative hours to create a report.

Using the automated testing solution for tunnel 2, two technicians

during one shift spent seven man-hours for on-site coverage testing. No lane closures were required. About 600 signal levels were auto-recorded for test grids. Multiple frequency bands were tested simultaneously, and the report was automated. Benefits of using the new solution included the accuracy of the data and quality of reporting that far exceeded requirements, as well as an 80 percent reduction in time and costs.

“In order to be truly successful and fully engaged in providing the best DAS service to our customers, we had to invest in the best tools and software,” says Scott Umemoto, director of strategic technologies at Day Wireless Systems. “We did our research, and it was the best decision we made.”

The demand for ensuring in-building public-safety radio coverage

is increasing rapidly. Leading public-safety agencies have strict requirements for testing and demonstrating satisfactory performance. New tools are required to enable organizations to cost effectively meet these requirements. Testing and reporting processes should be automated as much as possible, using tools that can simultaneously measure multiple channels, bands and services. Where requirements allow, subjective manual DAQ measurements should be replaced with objective automated BER or SINR equivalents. With the right tools, jurisdictions across the United States can effectively enforce standards that ensure high-quality indoor coverage for first responders. ■

David Adams is director of business development for PCTEL. His career has focused

on solutions for service quality and performance management of mobile networks. Adams' recent concentration has been on public-safety networks, both Project 25 (P25) and Long Term Evolution (LTE) technologies. He focuses on in-building coverage and performance.

John Johnson is retired from the state of Tennessee after working over 31 years with both the Department of Safety and Emergency Management Agency. He currently works with Lafayette Group as a subject matter expert. Johnson is an Association of Public-Safety Communications Officials (APCO) International life member and served as the Tennessee APCO local frequency advisor for more than 20 years. He also is a member of the editorial advisory board of *MissionCritical Communications* magazine. Email feedback to editor@RRMediaGroup.com.