

[Close](#)

Reliable Communications and the Hazard Zone

BY LEIF ANDERSON AND DOUG MUMMERT

Do you understand how your public safety radio works? Was it designed to support predictable and reliable communications in your most critical environment? Was it designed to accommodate wide-area communications outside a critical environment? How predicable or reliable is it? How would you measure its predictability or reliability? To answer these questions, the Phoenix (AZ) Fire Department (PFD) spent several years researching its own radio system requirements.

COMMUNICATIONS RELIABILITY

A newspaper article, “Cellphones Problematic for 911” (*USA Today*, August 18, 2009), questioned the reliability of cellular telephones vs. landline telephones as more people switch to cell phones. The article reported that a woman called 911 from her cell phone—she was experiencing severe difficulty breathing and could barely speak. The 911 operator misunderstood the street name and sent first responders to the wrong location. It took almost an hour for first responders to arrive at the correct location. Tragically, the caller died 40 minutes after arriving at the hospital, as a result of a blood clot in her lungs. If only the 911 call had been made from a landline phone, the caller’s address would have instantly popped up on the 911 operator’s screen and would have left no doubt as to where to send the first responders.

We’re all aware that cell phones are not as reliable as landline phones, but for some reason, cell phone users tend to assume that their cell phones will work 100 percent of the time, which is not a fair assumption. Other than the fact that cellular and landline devices are called “telephones,” there is almost nothing similar about the way they operate.

A landline phone is wired—i.e., connected by wire into a technologically simple system of land-based cables and circuits that is very predicable and reliable. In contrast, a cell phone is wireless and operates like a radio. Hence, it is limited by the physics of the electromagnetic waves and the radio frequencies of a technologically complex system of radio coverage and capacity; it is only generally predicable and reliable.

A cell phone is an extremely sophisticated full-duplex radio that only works if there is sufficient radio coverage and authorization to access the coverage. For example, our experience in our service area is that we’re probably able to complete a cellular call about 95 percent of the time, depending on our location in relation to existing coverage. Probably 10 percent of our calls are dropped at some point, ending the call and forcing us to redial. Although a cell phone is undeniably convenient, you should never assume it’s as predicable or reliable as a landline.

In 2004, the City of Phoenix began using a modern digital trunked 700-800 MHz multizone radio system. The PFD questioned the predictability and reliability of digital trunked radios vs. analog simplex radios as more fire departments switched to trunked radios. We continued to operate using our existing radio infrastructure while we researched our radio needs, identified potential solutions, and then evaluated the solutions against our needs. In common business terminology, “requirements” define a customer’s needs and “specifications” define a vendor’s solution. An outside consultant, Buford Goff & Associates, and the City of Phoenix Information Technology Services aided us in our research and the documentation of our requirements.

PFD RADIO SYSTEMS

Phoenix, the fifth most populated city in the United States, covers 517 square miles and is home to 1.5 million people. The PFD operates from 60 fire stations and responds to 160,000 incidents per year. The department also runs a regional fire department dispatch center and participates in an automatic-aid consortium with 19 other cities or fire jurisdictions. In contrast with mutual aid, the Phoenix regional dispatch center automatically dispatches the closest appropriate fire service resource, regardless of jurisdictional boundaries. Located within Maricopa County, the 12th largest metropolitan area in the United States, the automatic-aid consortium covers more than 2,200 square miles and includes 160 fire stations that respond to 350,000 incidents a year.

When discussing fire department communications systems, we are really talking about land mobile radio systems (LMRS). All technologies have their strengths and weaknesses, and understanding basic radio characteristics is important to determining your public safety radio system limits.

Radios communicate when a transmitter sends out a signal that one or more radios receive.

Simplex. In direct or simplex communication, a radio receives a signal from the radio that initially transmitted it. Simplex communications are technically simple—one radio transmits, the other radios receive. There is no intervening radio or system to interfere with fireground communications.

Repeated. Repeated or half-duplex radio communication is more complicated. Repeated communication uses two radio frequencies for communication—the transmitting radio transmits on frequency 1, a repeater receives the signal and then repeats the transmission on frequency 2, and all receiving radios receive this signal. If a firefighter’s audio transmission does not reach a repeater location, no one will hear the firefighter’s audio.

Trunked. As with repeated radio communication, trunked radios communicate with one or more repeaters, yet it’s dramatically more complex. Trunking uses system controllers, which are computers that randomly assign a radio frequency for the duration of a push-to-talk (PTT) transmission, and then releases the frequency for another use. Think of it as a roulette table—each of the 38 numbers on the wheel represents a frequency, each PTT transmission spins the wheel and the white ball in different directions to randomly select a number/frequency for the duration of the call. Each new PTT transmission starts the process all over again. Trunked portable and mobile radios communicate frequently with the system controller by sending data messages on a control channel. Again, if a firefighter’s audio transmission does not reach a repeater location, no one will hear the firefighter’s audio.

For more than 30 years, the PFD has operated on the fireground using supported analog simplex communications in the VHF band. The range of simplex communication via portable radios is typically limited to a few miles; simplex communication via mobile radios can operate at a range of between 50 and 100 miles. Simplex was specifically selected to support local fireground operations because it maintains positive communications between interior/exterior firefighters and the incident command team without depending on an external infrastructure. When firefighters using simplex radios are deployed to the structure's interior, they create a radio receiver network—as more firefighters move to the interior of the structure, the network's strength increases. As a part of this simplex network, all firefighters working in the hazard zone can hear all communications directly related to their work and safety.

Supported simplex refers to communications to and from the Phoenix regional dispatch center—high-powered transmitters provide talk-out capability from the dispatch center to the fireground and a system of receiver voters provide talk-in capability from the fireground to the dispatch center. Throughout the automatic-aid service area, receivers are networked together, creating a receiver voter system. The receiver voter compares the audio from all receivers and then routes (i.e., “votes for”) the audio from the receiver with the best audio quality to the dispatcher. Tactical radio operators (TROs) in the dispatch center become an integral part of the incident management team and firefighter safety by monitoring all radio traffic, incident benchmarks, and incident resources.

PHOENIX RADIO SYSTEM UPGRADE

The City of Phoenix began researching its prospects to upgrade or replace its multiple radio systems in the 1980s. Several city departments each used a separate radio infrastructure. Existing systems, based on 1950s technology, had overloaded frequencies and no available new frequencies and did not support secure operations, and possible Federal Communications Commission changes created a layer of risk.

Although the PFD had a robust and reliable system with sufficient capacity, as a result of pooling all automatic-aid partners' assets, most city departments felt the current systems did not meet their operational needs. Therefore, it was decided to consolidate the city's systems into a single trunked radio system. In 2000, at a cost of more than \$120 million, the City of Phoenix wisely purchased a state-of-the-art modern Project 25 digital trunked 700- to 800-MHz multizone radio system. To accommodate the fire automatic-aid consortium, the new system was regional, covering the entire automatic-aid service area as it was at the time of construction. Incredibly robust and extremely efficient, the trunked radio features included seven simulcast zones; 117 frequencies; 95-percent coverage with levels of 12 dB, 17 dB, and 23 dB to a portable radio on the hip with a swivel clip; and a two-percent grade of service (i.e., the probability of a call being blocked or delayed).

As far back as the late 1990s, we had heard of other firefighters throughout the country who questioned the predictability or reliability of their trunked radios for hazard zone use. Easily, a few questions came to mind: What if my fire is within the five percent of the service area that's not covered? Where exactly is the five percent that is not covered? What if my Mayday call for help is one of the two percent of calls that gets blocked or delayed? The first question we decided to ask was, “What does my fire department need or require from a radio system inside and outside the hazard zone, and will it meet all of those needs?”

PFD's RADIO REQUIREMENTS

In 2004, the PFD employed a well-respected radio consultant and conducted extensive study and research to determine the most appropriate radio communications technology for our hazard zone incident operations. The research used a qualitative assessment process to analyze the different technical options through actual firefighting scenarios.

Testing included analog simplex, digital trunked, and digital simplex in all of the various frequency bands currently available for public safety operations. The department collected and analyzed information using 30 building locations, including the building construction types defined by the National Fire Protection Association (NFPA). Firefighters were placed in standard tactical positions inside and outside the buildings, including the command post and a TRO position in the dispatch center.

We identified three basic radio communication paths: radio communications within the hazard zone (firefighter to firefighter, firefighter to command, command to firefighter); radio communications from the hazard zone to the TRO (firefighter to TRO, command to TRO); and radio communications from the TRO to the hazard zone (TRO to firefighter, TRO to command). Obviously, successful communications within the hazard zone were the priority.

The study demonstrated that analog simplex clearly outperformed all other technologies in all 30 fireground situations. In typical firefighting situations, once initial firefighters define an operational area (hazard zone), the need for wide-area communications with other radio users greatly diminishes for those firefighters working in the hazard zone. Hazard zone operations need a functionally simple and operationally predictable communications system to support firefighters and their fireground activities. Analog simplex provided reliable, consistent, and predictable communications between firefighters who were directly involved in the incident, and it did not depend on external infrastructure for communications between firefighters who were directly involved in the incident. Even though trunked radio architecture is robust, the sophistication of the trunked radio control structure that supports wide-area operation complicates local communications for hazard zone operations.

As a result of the study, the PFD requires using analog simplex for all hazard zone communications. Less than 10 percent of the total incidents dispatched result in the creation of a hazard zone; therefore, more than 90 percent of the total incidents dispatched qualify as nonhazard zone events. Last year, the PFD began using the trunked radio system for all nonhazard zone incidents.

In Phoenix, an analog simplex fireground is a given. Digital radio performance issues, as noted in NTIA Technical Report TR-08-453,¹ reinforced the analog decision. The report points out that analog outperforms digital when talking through an SCBA. It was found that digital radios did not meet NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services*, requirements for intelligibility. So the remaining question was, "How will we transport our analog simplex fireground transmissions to and from the incident commander and the regional dispatch center?" The potential solutions include VHF conventional, 700- to 800-MHz conventional, vehicular repeaters (digital or analog), dual-band portable radios, or improved digital vocoders. With the help of our local and nonnative radio experts, we began evaluating the list of solutions against our requirements.

DIGITAL VEHICULAR REPEATERS

Digital vehicular repeater systems (DVRS) appeared to be one of the most cost-effective solutions—other technologies were either not ready yet or appeared to be too expensive. Our DVRS field testing soundly proved that the concept could work. A lingering concern was the device’s activation and deactivation.

A DVRS is essentially two mobile radios that are connected together, thereby “repeating” radio transmissions from one side to the other. In our case, one was tuned to analog simplex in the VHF band, and the other was tuned to digital trunked in the 800-MHz band. Several DVRS were deployed to simulate the appearance of a DVRS on each arriving engine or ladder. The DVRS talk to each other using a control channel—the first-arriving DVRS assumes a primary role, and all other DVRS assume secondary roles. If for some reason the primary DVRS fails, a secondary DVRS with the best voted audio quality will assume the primary role. The DVRS receives the analog simplex fireground transmissions and repeats them to the dispatch center through the digital trunked radio infrastructure. The DVRS receives the digital trunked dispatch center transmissions and repeats them to the local fireground in analog simplex.

The PFD conducted DVRS testing in 11 buildings. Simulations featured 1,382 individual simplex transmissions between firefighters deployed throughout the buildings—firefighters graded successful transmissions and audio clarity.

Interior firefighters received 100 percent of the simplex transmissions. The incident command post successfully received 1,350 (97.7 percent) of the transmissions. Of the 32 command post failures, 24 were associated with simplex traffic from an elevator position, and only four transmissions were not received by at least one of the secondary DVRS—interior firefighters heard the failures and relayed the information to the incident command post. The incident command post received 100 percent of the dispatch center transmissions. At the dispatch center, only two of the 1,382 transmissions (0.2 percent) were scored as failures—a review of the recorded audio indicated usable audio in both transmissions.

Both labor and management did not want to overtask firefighters and worried that integrating new technology could create confusion or conflict during a response. Someone said, “Make it firefighter proof,” so we connected the DVRS to the mobile computer terminal in each apparatus. Pressing any status button that indicated the unit arrived “on-scene” of a hazard zone incident activated the DVRS—the dispatch center could also remotely activate the DVRS through the mobile computer. Pressing any status button that indicates the unit is “available” deactivated the DVRS. In effect, it automated the process because firefighters were performing the status changes on their mobile computers anyway.

CURRENT STATUS

The PFD successfully transitioned to digital trunked radios for all nonhazard zone incidents in 2009. Trunked radio systems were specifically developed to promote the efficient use of available radio frequencies (spectrum), and they also excel at enabling a great number of disparate radio users to talk

across great distances. Although neither of these attributes promotes reliable or predictable hazard zone communications, they clearly stand out for nonhazard zone communications. The PFD will complete the evaluation of all available solutions to transport our analog simplex hazard zone communications to and from our dispatch center in the second quarter of 2010.

For more information regarding firefighting communications concepts and technology, download the U.S. Fire Administration's Voice Radio Communications Guide for the Fire Service at <http://www.usfa.dhs.gov/media/press/2008releases/120108.shtm>.

Endnote

1. Atkinson, D.J., A.A. Catellier. "Intelligibility of Selected Radio Systems in the Presence of Fireground Noise: Test Plan and Results." NTIA Technical Report TR-08-453, June 2008. National Telecommunications and Information Administration, U.S. Department of Commerce. Download at <http://www.its.bldrdoc.gov/pub/ntia-rpt/08-453/08-453.pdf>.

LEIF ANDERSON is 26-year veteran of the fire service and a deputy chief with the Phoenix (AZ) Fire Department. He is the department's chief information officer and manages the department's communications and infrastructure, enterprise, and programming teams. Anderson is a member of the Inter-Agency Board, the Association of Public-Safety Communications Officials (APCO), and the National Fire Protection Association. An affiliate faculty member of Phoenix College for more than 12 years, he teaches fire science and emergency medical care. Anderson has been a featured speaker at the International Association of Fire Fighter's Redmond Symposium and the APCO International Conference.

DOUG MUMMERT is a division chief with the Phoenix (AZ) Fire Department. A 31-year veteran of the department, he is the department's communications and infrastructure officer. A veteran of the United States Air Force, Mummert is also a member of the department's FEMA Urban Search & Rescue Task Force (AZ-TF1) and All Hazards Incident Management Team. He is a member with the Association of Public-Safety Communications Officials, the National Fire Protection Association, the International Association of Fire Fighters, the International Association of Fire Chiefs, the National Emergency Number Association, the Fire Department Safety Officers Association, and the National Information Officers Association and is an officer of several professional and nonprofit organizations.

[More Fire Engineering Issue Articles](#)

[Fire Engineering Archives](#)

To access this Article, go to:

[http://www.fireengineering.com/fireengineering/en-us/index/articles/generic-article-tools-template.articles.fire-engineering.volume-163.Issue_5.Features.Reliable_Communications_and_the_Hazard_Zone.html](http://www.fireengineering.com/fireengineering/en-us/index/articles/generic-article-tools-template/articles.fire-engineering.volume-163.Issue_5.Features.Reliable_Communications_and_the_Hazard_Zone.html)