Digital Audio Continues to Evolve

The Latest Digital Radio Audio Test Results Specific to Firefighters

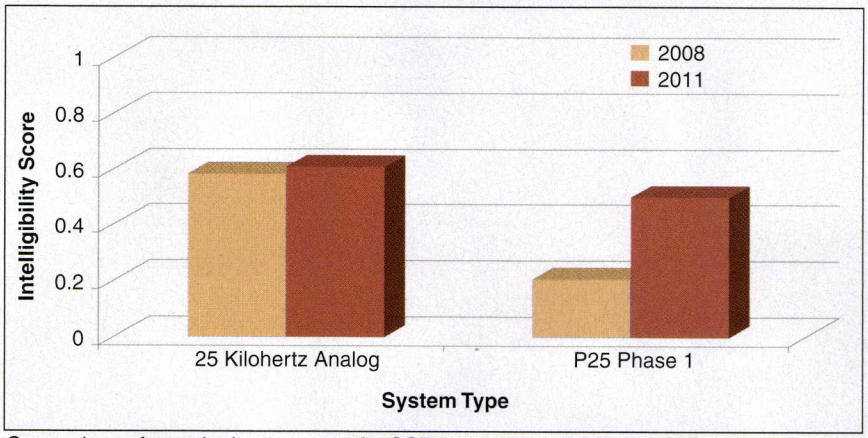
By D.J. Atkinson

In June 2008, the Public Safety Communications Research (PSCR) program published a report highlighting the challenges of achieving intelligible radio communications in the presence of high levels of background noise encountered on the fire ground. Since then, radio manufacturers and public safety cooperated to improve the intelligibility of fire ground communications. Under the sponsorship of the Department of Homeland Security (DHS) Office for Interoperability and Compatibility (OIC), the PSCR completed testing in March of some of the specific improvements applied to radio communications in the presence of high levels of background noise.

The following provides a brief overview of the recent test. Results from the test are then highlighted, demonstrating an overall improvement in intelligibility. The improvement observed in this test comes from changes to best practices and technical improvements to the voice coder (vocoder) used in Project 25 (P25) digital radios. In addition, this article examines potential intelligibility impacts of transitioning to P25 Phase 2, where the bit rate available to the vocoder is cut in half. Finally, this article notes conditions where intelligibility improvement is still desirable and suggests some ideas for future work.

Overview of the Test

The communications intelligibility test resulted from about 18 months of test plan development in the Audio Performance Working Group (APWG) of the P25 standards committees. The working group was created specifically to investigate improving the overall audio performance of P25 radio



Comparison of vocoder improvement for SCBA mask with PASS alarm noise

systems. The test plan was developed with input from practitioners and radio manufacturers participating in the APWG and was executed by the PSCR in Boulder, Colo.

The test had two primary objectives. The first was to evaluate the impact of best practice changes recommended by the International Association of Fire Chiefs (IAFC). The second was to evaluate the impact of technical changes to the vocoder implemented in P25 radio systems.

The test included 14 environments and four communications systems. The parameters that varied across the environments included no mask or one of two self-contained breathing apparatus (SCBA) masks, no background noise or one of three different background noises, and either a clean or impaired radio channel. The systems included in the test were 12.5-kilohertz analog, 25-kilohertz analog, P25 and P25 Phase 2.

About 60 public-safety practitioners from across the continental United States traveled to Boulder to participate. Participation consisted of a brief hearing screening and then sitting in a sound booth trying to understand the intelligibility test words. Participants listened to 1,500 to 2,000 words during a two- to four-hour period. Results were recorded by a computer program and analyzed after all participants had finished their testing.

Best Practices Improvements

In some of the environments tested in 2008, there was low intelligibility for all the systems tested. In response to this, the IAFC modified its best practices for radio use. Specifically, the IAFC recommended that a radio microphone be held tight against the voice port of an SCBA mask.

From a statistical standpoint, the results for the environment with an SCBA mask and no background noise are equivalent for the two analog systems. However, the P25 Phase 1 system benefited from a noticeable improvement in intelligibility based on the changed best practice. This shows that the best practice can help in some situations and doesn't appear to cause any degradation.

Technical Improvements

In 2008, the biggest difference between analog and P25 communications system intelligibility was observed in the environment that used a mask with a personal alert safety system (PASS) alarm as background noise. To increase the intelligibility of the P25 system, the vocoder developer designed and implemented enhancements to the vocoder. One enhancement was directed at improving intelligibility in the presence of PASS noise.

As expected, there was no significant change in the intelligibility of the analog system. However, there was marked improvement in P25

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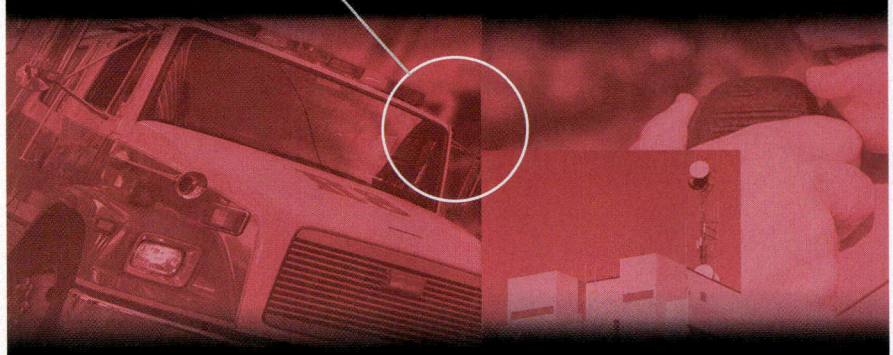

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Do PSCR's Testing Methods Relate to the Real World?

Two frequently asked questions relate to what basis Public Safety Communications Research (PSCR) uses for its intelligibility testing methods and how well those testing methods relate to the real world. The starting point for developing a repeatable test methodology is finding applicable standards.

The core of the testing method comes from NFPA 1981-2007, "Open-Circuit Self Contained Breathing Apparatus (SCBA) for Emergency Services," 2007 edition. This standard specifies the means for conducting intelligibility tests on SCBA for listeners in the same room as the talker, as well as setting performance objectives for that environment. It includes the listening environment, as well as specifying a modified rhyme test (MRT) as defined in ANSI S3.2, "American National Standard Method for Measuring the Intelligibility of Speech Over Communication Systems," 1989.

While these two standards provide the basis for the testing methods used by PSCR, they don't quite cover the exact scenarios under evaluation. PSCR had to extend these test methods to cover the addition of radio systems and high levels of public-safety-specific background noise to the test. The challenge is to do so in a repeatable manner that doesn't jeopardize the hearing of a talker who might be placed in such a high-noise environment for the 30 – 40 hours it would take to record the speech samples.

This is done through the use of a head and torso simulator (ITU-T Recommendation P.58, "Head and Torso Simulator (HATS) for Telephonometry," August 1996) containing an artificial mouth (ITU-T Recommendation P.51, "Artificial Mouth," August 1996). Use of the HATS addresses both repeatability and safety concerns in PSCR experiments. For repeatability, the HATS serves as a platform where pre-recorded speech material can be appropriately equalized and volume leveled so that all samples are consistent — a feat not practical for a live talker. Also, the HATS can sit in a room for days on end in loud environments without the noise causing hearing loss.

For validation, it becomes important to know if there are any measurable differences between using a live talker and using the HATS for the speech source. To perform this validation, a small experiment was conducted using the HATS and a talker for the same two environments: wearing an SCBA mask without background noise and wearing an SCBA mask with PASS noise present. All speech samples were spoken by the same talker to provide the most consistency across the test conditions. When statistically analyzed, there were no significant differences between the conditions using the HATS and those using a live talker. One can therefore infer that use of the HATS is a reasonable and safe approximation of putting a real talker into a high-noise environment, and should yield equivalent results.

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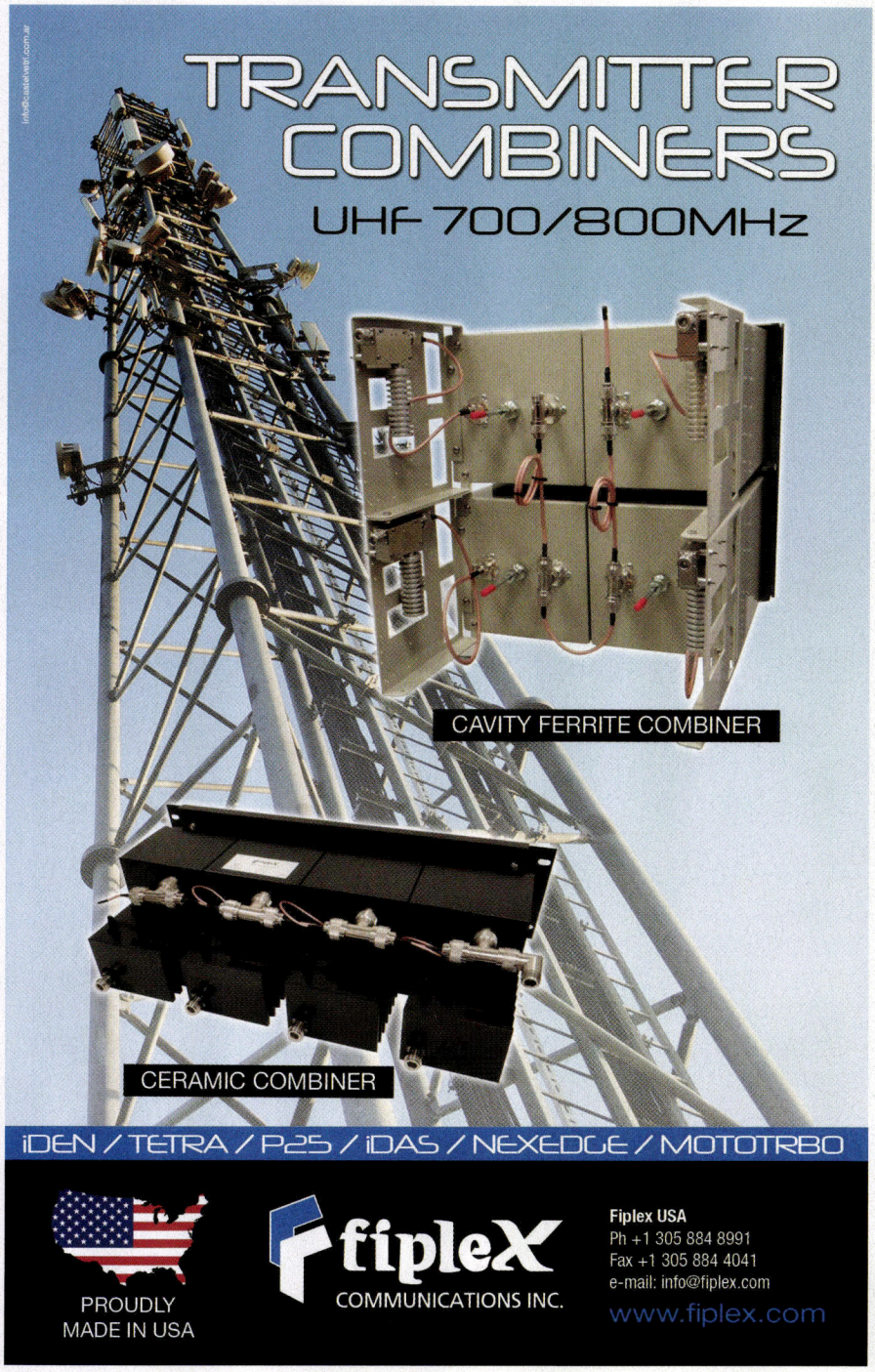

Phase 1 system intelligibility. Even so, the intelligibility of the P25 system in this environment is less than the analog system, meaning that there is still room for improvement.

P25 Phase 2 Expectations

The P25 committees are developing Phase 2 standards. P25 Phase 2 supports the move to 6.25-kilohertz-equivalent channels from the 12.5-kilohertz channels used for Phase 1. As the channel bandwidth is narrowed, the bit rate available to transport speech is also reduced. The Phase 2 vocoder must operate at half of the bit rate of the Phase 1 vocoder. Because the Phase 2 vocoder hadn't been evaluated in high-background-noise environments, this test included the Phase 2 vocoder.

In each of the 14 environments tested, the intelligibility of the Phase 1 and 2 vocoders were observed to be equivalent. This equivalence is because of selecting a vocoder for Phase 2 that is technologically similar to that used in Phase 1. A further benefit of this selection is that most improvements made to the Phase 1 vocoder (such as those made to help with the PASS alarm) are directly applicable to the Phase 2 vocoder.

General Observations

The effort practitioners and manufacturers are putting into improving intelligibility is making a difference. This comes from looking at all aspects of the system and making small improvements to multiple components, resulting in an overall large improvement. While this article only presents a couple of areas of improvement, manufacturers and users are working together to find others.

One remaining area for investigating intelligibility improvement is the application of active noise cancellation to microphones. Multiple manufacturers are now producing radios that include active noise cancellation, and anecdotal reports show noise cancellation provides notable improvements in intelligibility in high-background-noise environments. It may be useful to perform an experiment to quantify the benefits of noise-canceling microphones.

Also under investigation are alternative microphone accessories for radios. These include throat microphones, bone conduction microphones and microphones placed inside an SCBA mask. These alternative microphones can improve intelligibility, but the challenge comes in making them practical and affordable for the fire service.

Overall, excellent progress has been made to improve intelligibility in high-background-noise environments. With continued effort, there are promises of even more improvements. This will result in better communications for firefighters and improve their safety. ■

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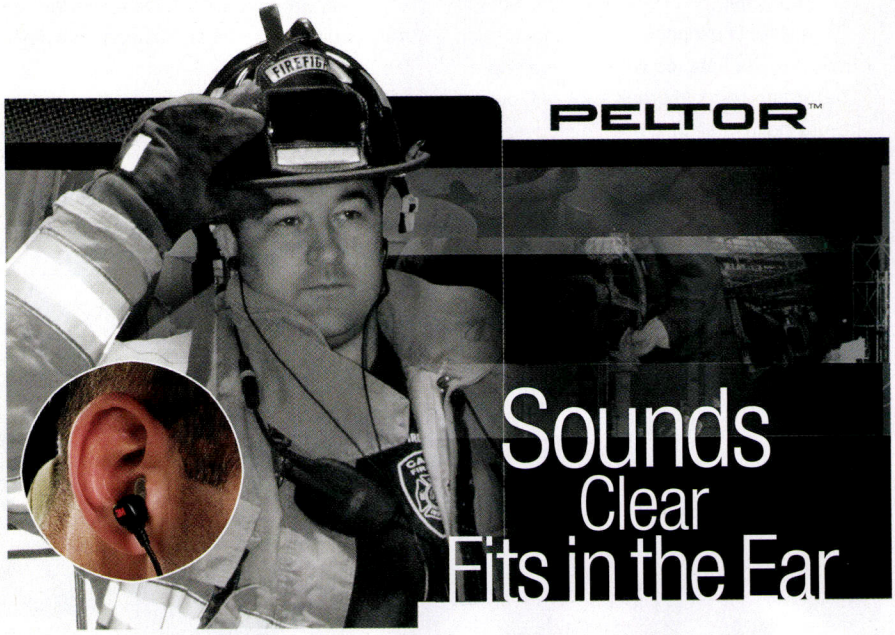

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Considerations for Developing Firefighter Communications Equipment

As the Public Safety Communications Research (PSCR) program worked with practitioners on the background noise issues associated with fire ground communications, many ideas were presented for improving communications intelligibility. Many ideas were useful, but others were less so because they didn't account for some of the special needs of the firefighter community. Here are some of the considerations that have come up in discussions between firefighters and communications equipment developers.

Firefighter communications equipment:

■ Should minimize wiring to the head. Wires to the head could become a snare hazard and should break away without breaking in case of snare. To recover properly, any wiring should be connectable while wearing thick gloves and should have a failover mode that allows the firefighter to communicate in case something becomes disconnected or broken.

■ Should not compromise the heat-protective envelope. Wires easily conduct heat and therefore can pass heat through a firefighter's heat-protective envelope, becoming a burn hazard. This is a special concern when wires run through the envelope to a sensitive area such as the ears, mouth or throat.

■ Should not increase the dress time of the firefighter. Emergency responders, especially fire and EMS, have optimized their equipment to be at the scene providing aid in the shortest time possible, because seconds can make a difference in saving a life, house or the safety of the responder.

■ Should consider the environmental conditions. Firefighters encounter water, smoke, vibration and heat, often while crawling on the floor. Some of the noises that firefighters encounter are hose, alarm, tool and vehicle noises.

■ Should consider the ensemble as a whole. Some of the components that are likely to cause issues with communications equipment are the helmet, Nomex hood, mask and gloves.

■ Should be flexible enough to work with different agencies' standard operating procedures. Agencies have different ways of wearing radios, different self-contained breathing apparatus (SCBA) equipment, different team sizes and placement, for example.

■ Must work well with the Project 25 (P25) vocoder.

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