# *The real difference between digital and analog…*

*This article was inspired by pishposh@phreaker.net who posted a very similar article to an Internet mailing list.*

There is little doubt that two-way radio systems used for police and fire communication will eventually use digital modulation. I believe the current state of the digital art leaves a lot to be desired, and that digital modulation is a huge compromise in reliable and effective communication for first responders. Technology will improve with time, but the users of critical police and fire communications systems will be handicapped by digital modulation until significant advances are made in the software that converts voice to and from a compressed digital format.

The transition of public-safety radio communication from analog to digital modulation is marred in politics and finance. A huge amount of money is in play over this issue. Equipment manufacturers and sales organizations are highly motivated to create the illusion of premature obsolescence of analog radio technology, even though the need is not supported by operational benefit.

Digital modulation has one fundamental advantage over traditional analog modulation. It conveys information with mathematical precision. It can even correct minor imperfections through mathematics. Unfortunately, the benefits end there, and come at the cost of some important advantages of traditional analog modulation. Digital modulation precludes the ability of the human brain to decipher speech that has been corrupted by noise and interference. Audio recovery is impossible when the signal-to-noise ratio of a digitally modulated signal falls below a certain threshold. With analog modulation, the human ear and brain can "decode" speech that is buried beneath noise levels that digital circuits and algorithms cannot contend with. While analog and digital transmissions are both subject to dead spots and interference, digital modulation reduces human communication by eliminating the "gray area" afforded by analog equipment. Digital equipment (P25 IMBE) usually will not recover any audio in cases where an analog signal will be quite understandable, especially in cases where significant multipath interference is present.

Industry-standard codecs (or vocoder software) that convert spoken voice to digital data can not adequately distinguish between voice and background noise. For example, a firefighter using a digital portable radio while standing next to a fire engine that is pumping water will probably not be understandable over the radio because the codec cannot isolate the voice from the pump noise. Another example is a police officer who is trying to announce his or her location during a pursuit. The officer's digitized voice may be unintelligible because of the siren. A canine officer with a dog that is barking loudly may not be heard because of the competing noise from the dog. In all of these examples, it is likely that analog modulation would provide reliable communication.

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There is also a lesser, but still considerable, issue of software and firmware reliability. The greater simplicity of fixed circuit-based logic means analog systems can generally be perfected to a very high standard of reliability before leaving the design lab. Short of physical hardware deterioration, nothing typically alters the state at a later time. In the vastly more sophisticated world of software and firmware, not all bugs can be identified in the time manufacturers are willing to spend on pre-release testing. This places the onus of beta-testing on the users. In critical systems like public-safety communication, the result of bugs rearing their heads at inopportune moments can be life-threatening. While it's certainly possible to eliminate all bugs from a software or firmware environment given adequate time, this possibility tends to be thwarted by the irresistibility of constantly changing (upgrading) software and firmware code after manufacturing. Every new feature brings more bugs. Even bug fixes can introduce new bugs.

At the very least, until and unless a digital modulation scheme is invented that is as robust and as tolerant of low signals as the human ear happens to be, I see only one advantageous use for digital modulation in public-safety communication. Technology exists to encrypt digital signals. For special kinds of communication, like surveillance operations, the encryption afforded by digital outweighs the disadvantages of the medium itself. Otherwise, analog offers greater reliability through simplicity of design and robustness.

Given the public's perception of anything "digital" being cutting-edge and inherently superior to analog, I think the rush to digital is being driven less by technical considerations than by politics and bureaucracy trying to make itself appear proactive to voters and/or superiors according to the popular simplified perception of the analog vs/ digital issue. In the end, the disadvantages are borne by our first responders, and by the public itself.

Considering the apparent inevitability of all of this, we're fortunate that APCO had the foresight to establish the P25 standard early on. Had that not happened, inferior signal performance would have been the least of our worries today.

Sometimes, I swear that had Marconi invented digital transmission modes instead of analog ones, we would all be sitting around here, right now in 2007, dismantling our old, less glamorous digital systems, and placing orders for new, cutting edge "analog" technology with the miraculous powers of cutting through interference, extending signal range, and delivering true voice quality without heavy psychoacoustic speech codec artifacting.

I recommend that every agency executive who may be considering a digital radio system seriously consider the consequences. There is no need to convert to digital technology at this time. The day is coming that digital modulation will be required, but I estimate that it

will be after the year 2020. By then, we can hope that codec and compression technology will have advanced to an acceptable level.

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