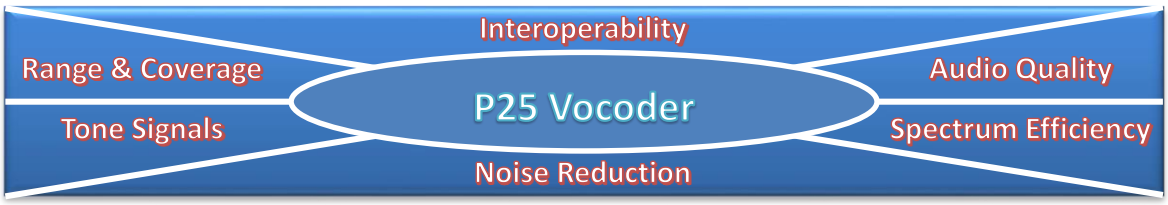
Project 25 Vocoder Standard

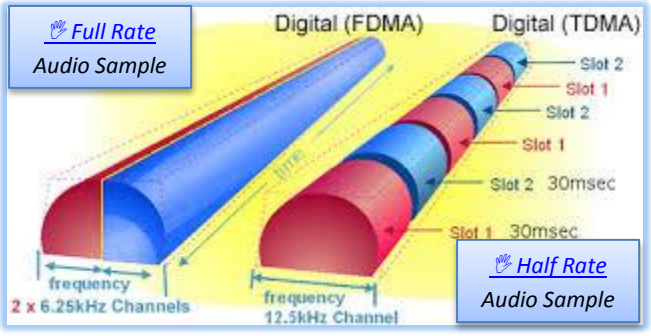


The suite of documents that compose the Project 25 standard as published in the TIA-102 series includes a state-of-the-art narrow band vocoder for public safety and private land mobile radio systems. An intrinsic part of the Project 25 suite of documents is the dual rate AMBE[1] Vocoder Description [1]. The P25[2] standard celebrates 25 years as a digital radio standard for communications by public safety and private LMR[3] users. Over the years, the vocoder has been improved during the life of the standard with the following technologies.

Click on the radio to listen to the vocoder.

- The vocoder operates at dual rates to support both 12.5 kHz and 6.25 kHz equivalent spectrum efficiency while maintaining interoperability.
- The vocoder features excellent audio quality and noise reduction to resist common noises encountered in public safety operating environments.
- The vocoder includes soft decision error correction to improve range and coverage for the users.
- The vocoder can also transparently encode tones to support common tone signals found in LMR[3] systems.

The dual rate feature of the vocoder supports operation in 12.5 kHz FDMA[4] systems in the full rate mode, and also 2:1 TDMA[5] in the half rate mode of operation with increased spectrum efficiency. The full rate mode of operation has been in use since the introduction of the TIA-102 standard, and it continues to be supported by the standard for backward compatibility and interoperability. The half rate mode was introduced when the standard was revised for TDMA operation to double the spectrum efficiency. The improvement in spectrum efficiency complies with the FCC regulations in some LMR radio bands. Newer properly equipped radios can operate in either FDMA or TDMA modes in order to interoperate with older radios that are only capable of FDMA. The standard [1] also includes a parametric conversion feature to convert full rate audio to half rate, or vice versa. This allows infrastructure equipment to route audio between FDMA channels and TDMA channels without reverting back to analog. This avoids tandem vocoders. The vocoder audio quality was measured during the evaluation of the TDMA standard[6] and the full rate and half rate modes were nearly equal.



Audio quality for vocoders is objectively evaluated by comparing an audio sample to its reproduction after processing by a vocoder. The comparison measures the differences and averages them to obtain a

score. Audio quality for vocoders can be conveniently evaluated today on a computer with a PESQ[7] test [4]. Audio quality was also measured more laboriously and subjectively in the past with a MOS[8] test using listener panels. The TIA-102 series includes both methods: PESQ is used in the TIA-102.BABG standard [3], and MOS is used in TIA-102.BABB standard [2]. A direct measurement of audio quality with either test requires a fairly large set of test material. Both standards use a set of 32 sentence pairs, from 8 different speakers, split between male and female genders. Each sentence pair has a time duration of 8 seconds. The evaluation of audio quality in difficult conditions requires multiple trials, often 10 or more. These requirements can be achieved in a controlled lab environment, but they are not convenient in a real operational LMR system. For this reason, a third audio quality evaluation based on BER[9] is used and this is called DAQ[10]. The TIA-102 standards for audio quality evaluation apply to most conditions routinely encountered in public safety environments. These include faded radio channel conditions and numerous acoustic background noise conditions. The TIA-102.BABG [3] standard permits radio vendors to evaluate the performance of the vocoder implementation to obtain the desired audio quality.

Audio Quality Technologies

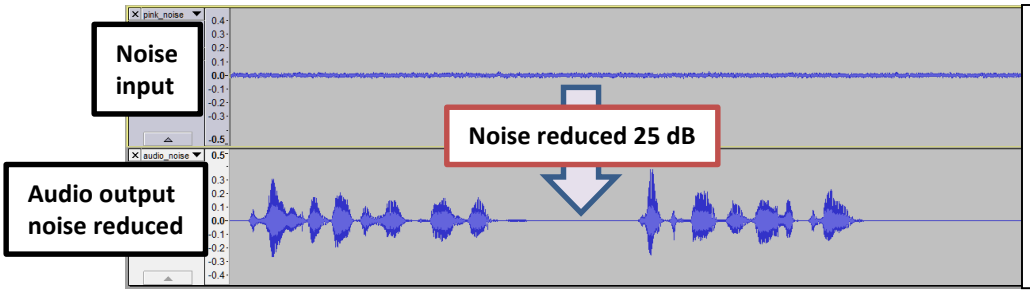
Mean Opinion Score (MOS)

Perceptual Evaluation of Speech Quality (PESQ)

Delivered Audio Quality (DAQ)

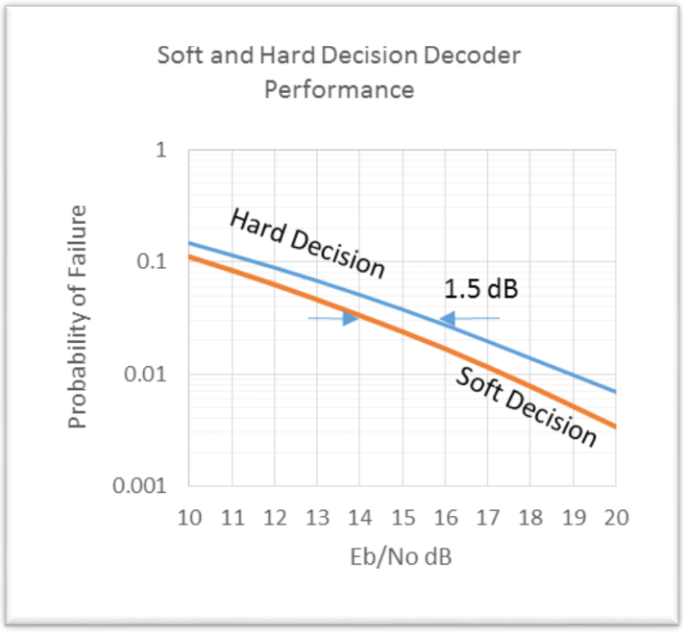
Bit Error Rate (BER)

The Project 25 standard vocoder uses a multi-band excitation technology. This begins in the transmitter by detecting and measuring the pitch of the speech. Further processing then digitizes the speech for transmission. But the detection and measurement of the pitch in the speech also permits the vocoder to discern speech from most kinds of noise that do not correlate to the limited range of human speech pitch periods. The vocoder can then selectively reduce the noise to benefit the audio quality of the speech for the listener. The kinds of noise rejected by the vocoder include a variety of noises that represent common conditions encountered in public safety and various mobile scenarios. The TIA-102.BABG standard evaluates audio quality with 15 different noise conditions including four different kinds of vehicles (car, boat, helicopter, fire truck), two different sirens, various noises encountered on a fire ground (low air alarm, PASS[11] alarm, fog nozzle, rotary saw, chain saw, fire truck water pump), street noise, babble noise, and a generic pink noise. The P25 vocoder provides a reduction of the noise of at least 1 dB for the PASS alarm case and up to 15 dB for the vehicle noises. In most cases the noise is reduced by 10 dB or more. This noise reduction is evaluated in the TIA-102.BABG [3] standard test. The standard specifies a reduction of the noise of at least 1 dB for the PASS alarm case and up to 15 dB for the vehicle noises. In most of the cases the noise is reduced by 10 dB or more.



High tier radios now feature noise cancellation for more improved audio quality in noisy environments. Noise cancellation uses more than one microphone in the transmitter to distinguish noise sources from speech. This allows for noise to be cancelled, thus improving the signal-to-noise ratio for the radio user. This is not a part of the vocoder technology, but it does apply to improve the audio quality in many public safety and private LMR applications.

A digital radio system transmits information over the radio channel in the form of bits. The bits can be corrupted by noise or interference in the transmission and this is expressed as a bit error rate or BER[9]. The measurement of BER is a convenient figure of merit for the quality of the radio channel and this is used extensively in the TIA-102 series of standards. The BER can be measured in fading conditions that often occur, and BER can also be measured in real operational radio systems. The vocoder uses error correcting codes to resist bit errors in the digitized speech transmissions. One improvement for recent implementations of the vocoder standard was the technology for soft decisions. In fading this improvement gives about 1.5 dB of improved range for the code words.



The TIA also publishes the TSB-88 series of bulletins for radio system performance measurement and validation. The TSB-88.1-D bulletin [5] uses the DAQ[10] evaluation method based on the BER on the radio channel. A typical DAQ specification for a public safety radio system would be DAQ 3.4, corresponding to 2% BER for FDMA systems, 2.4% BER for TDMA systems on the down link, and 2.6% BER for TDMA systems on the up link. The vocoder features resistance to fading conditions, even extreme fading that can corrupt speech frames with too many bit errors to correct. In such cases the vocoder can interpolate speech parameters for a short time until the fade is finished and normal transmission can resume.

The P25 vocoder standard also transmits tones that are sometimes used in LMR radio systems. Single tones can be transmitted as might be used in paging applications, and dual tones can be transmitted as are sometimes used with telephone style DTMF[12] signaling systems.

To summarize, the P25 standard is now celebrating 25 years of use in the radio industry. It features the AMBE vocoder that has been enhanced in that time to improve audio quality for the users. The vocoder now has a dual rate feature to support radio systems that double the spectrum efficiency. Full interoperability and backward compatibility is maintained with the vocoder by including the dual rate vocoder in subscriber radios and permitting parametric conversion between the rates in the standard. The audio quality of the implemented vocoder can now be conveniently evaluated with a PESQ test as

given in the TIA-102.BABG standard. The vocoder now uses soft decision error correction to obtain about 1.5 dB of improvement in receiver sensitivity. The audio quality in real operational LMR systems is defined in the TSB-88.1-D bulletin in terms of DAQ and BER and this can be measured for system validation. The vocoder also can transmit useful tone signals for LMR systems. The TIA-102 standard has enhanced the vocoder in all of these ways during the lifetime of the standard.

References

[1] TIA-102.BABA-A, *Project 25 Vocoder Standard*, 2014.

[2] TIA-102.BABB, *Project 25 Mean Opinion Score Conformance Test*, re-affirmed 2013

[3] TIA-102.BABG, *Project 25 Vocoder Methods of Measurement for Performance*, 2010

[4] ITU-T P.862, *Perceptual Evaluation of Speech Quality (PESQ)*, 2001.

[5] TSB-88.1-D, *Recommended Methods for Technology Independent Performance Modelling*, 2012

[1] AMBE = Advanced Multi-Band Excitation vocoder
[2] P25 = Project 25
[3] LMR = Land Mobile Radio
[4] FDMA = Frequency Division Multiple Access
[5] TDMA = Time Division Multiple Access
[6] The average measured MOS LQO difference between full rate and half rate was less than 0.18
[7] PESQ = Perceptual Evaluation of Speech Quality standardized in the P.862 standard[4]
[8] MOS = Mean Opinion Score
[9] BER = Bit Error Rate
[10] DAQ = Delivered Audio Quality as defined in [5]
[11] PASS = Personal Alarm Safety System as defined in NFPA 1982 standard
[12] DTMF = Dual Tone Multi-Frequency signaling tones standardized for telephone tone dialing