



WHITE PAPER

VQA Benefits for iDEN Networks

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Introduction

This white paper provides an overview of the iDEN network VSELP and AMBE++ codecs with a focus on the inherent limitations of these codecs, including voice distortions and over-sensitivity to background noise.

The second part of this paper describes how Ditech's Voice Quality Assurance solution for iDEN networks is able to address the limitations of the VSELP and AMBE++ codecs, allowing carriers to provide consistently high voice quality while unlocking the full capacity potential of the iDEN network.

Lastly, this white paper presents the results of subjective listening tests performed by an independent test laboratory to measure the benefits of VQA, showing that both iDEN codecs can confidently be deployed without added risk of customer complains or churn.

Background on iDEN Codecs

iDEN TDMA technology makes use of two interleaving methods, referred to as 6:1 and 3:1. The 6:1 interleaving method uses one voice packet slot per TDMA frame. Although this method is the most cost effective from a capacity standpoint, it offers the poorest voice quality. The 3:1 interleaving method uses two voice packets slots per TDMA frame, doubling the amount of bandwidth required, but providing much better voice quality.

The 3:1 interleaving method makes use of the VSELP codec, while the 6:1 method makes use of the AMBE++ codec. The pros and of cons of these codecs are discussed in detail below.

VSELP

The Vector Sum Excited Linear Prediction (VSELP) codec is defined in the IS-54 standard and supports an encoding rate of 8 kbps.

VSELP, like many other cellular codecs (GSM FR, GSM HR, AMR), is based on Linear Prediction. The Linear Predictive model assumes that the vocal cords are the source of the sound (excitation signal) and the shape of the vocal tract is a filter that shapes the speech. The signal is encoded by transmitting the excitation signal and the filter coefficients.

It is commonly accepted in the industry that VSELP shows poor performance of speech encoding in the presence of background noise. Thus it is important to apply noise reduction in the network, ideally even before speech is encoded to VSELP in order assure the best possible voice quality.

AMBE++

Advanced Multi-Band Excitation (AMBE) is a proprietary speech coding standard developed by Digital Voice Systems. The encoding has a data rate of 4 kbps.

The encoding techniques used in AMBE diverge from those used in CELP based codecs, in the sense that AMBE uses a multi-band excitation (MBE) model. MBE analyzes the speech signal in multiple frequency bands and creates excitation signals that are a composite of the frequency bands. Digital Voice Systems claim that the higher granularity in the modeling of the excitation signal allows the MBE speech model to achieve higher quality speech than the CELP based models while also achieving lower bit rates. However customer feedback and listening tests have shown that voice quality is significantly degraded using AMBE++ in comparison to other codecs, specifically:

- Speech sounds nasal (/m/, /n/, or /ng/)
- High frequency components of the speech are amplified (voice sounds sharp/metallic)
- Poor resilience to background noise can result in voiced speech being improperly encoded as unvoiced speech, making it sound as whispers.

Ditech's VQA solution for iDEN

VQA Overview

Ditech's Voice Quality Assurance solution is a comprehensive set of industry-leading voice processing algorithms including bi-directional Adaptive Noise



Cancellation (ANC), Acoustic Echo Cancellation (AEC), Automatic Level Control (ALC) and Enhanced Voice Intelligibility (EVI) that together mitigate the problems associated with environmental impairments (echo, noise and mismatched levels) as well as problems associated with the use of AMBE++ codecs, using the ASR (AMBE Spectral Reshaper) feature.

Noise Cancellation

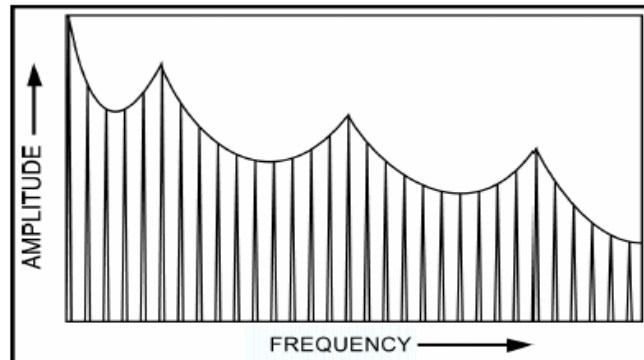
Besides the obvious benefits of noise cancellation in the listening quality, the poor resilience of the iDEN codecs (VSELP and AMBE++) to background noise makes it particularly important to provide noise cancellation in the network before speech gets encoded. Thus avoiding distortions caused by misclassification of the speech (voiced vs unvoiced) in high background noise environments typical in mobile communications.

Ditech's VQA Adaptive Noise Cancellation (ANC) feature offers robust and efficient noise cancellation using an advanced spectral subtraction technique based on masking properties of the human auditory system. It achieves high effective noise removal (both during speech inactive and active periods), without audible speech distortion.

Spectral Shaping

Introduction to Speech Formants

The sounds you make when you speak contain many different harmonics, created as your voice travels through your vocal tract. If you were to look at a spectral analysis of your voice, you would see a number of peaks in the spectrum, representing the strongest harmonics; these peaks are what your ear and brain use to distinguish between different sounds, and are called 'speech formants'. See diagram below.



An adult male voice typically has peaks in the lower frequencies at 500Hz and 1500Hz; these are called the "lower formants" and are the strongest in amplitude, representing the bulk of the speech. However, the subtleties of speech that make speech intelligible are contained in the higher formants; these occur with lower amplitude in frequencies ranging from 2500Hz all the way up to 7500Hz.

AMBE Spectral Reshaper

The AMBE Spectral Reshaper (ASR) feature has been designed to address the specific voice quality issues introduced by the use of AMBE++ codec.

ASR has been developed with the partnership of iDEN carriers and fine tuned based on network captures and work with Motorola's Acoustic Technology Center team (Motorola).

The AMBE++ codec emphasizes the high frequency formants. This effect is generally described by listeners as a metallic or sharp sounding voice.

To alleviate this effect, Ditech's spectral reshaper applies low pass filtering to the signal to remove most of the high frequency components. In conjunction the EVI (Enhanced Voice Intelligibility) feature is used to bring the lower and middle frequencies back up in order to smooth the voice spectrum.

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Figure 1: In the graph shown above the purple spectrum is of speech processed by AMBE++ and the blue spectrum is of the same speech enhanced by Ditech's ASR. Notice how the high energy components in the higher frequency region have been removed by ASR to give a smooth natural feel to speech

The AMBE++ codec emphasizes the fundamental frequency compared to the higher harmonics. The fundamental frequency corresponds to the pitch present in voiced portions of human speech. This effect is generally experienced by listeners as nasal voice.

Ditech's spectral reshaper broadens the peak corresponding to the fundamental frequency and lowers its energy to bring it down to levels present in normal speech.

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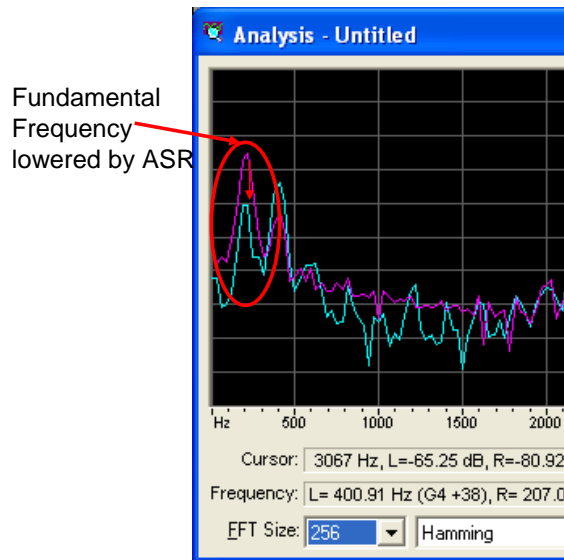


Figure 2: Spectrum showing enhancement of nasal quality of speech. Light blue spectrum shows how the unusually strong fundamental frequency in the purple spectrum was lowered to restore natural quality of speech

The resulting effect of the combined spectral reshaping functions is a more natural sounding and undistorted speech. AMBE++ codec processed with Ditech's VQA technology has been consistently preferred by a panel of naïve listeners.

Additional Voice Quality Features

The voice quality on iDEN network also greatly benefits from the additional VQA features Automatic Level Control (ALC) and Acoustic Echo Control (AEC).

To address mismatched signal levels from heterogeneous networks, ALC adjusts the signal level to approach a provisioned target level. ALC can adjust the signal level according to fixed gains or to environmental noise conditions, depending on the provisioned mode.

The proliferation of handsets, headsets and handsfree options with poor acoustic isolation exposes many users to acoustic echo. Ditech's bi-directional Acoustic Echo Control (AEC) solution suppresses acoustic echo from both near-end and far-end sources and ensures protection from even the strongest echo sources while maintaining excellent double-talk performance.



Comparative Listening Test

Overview

Ditech Networks in conjunction with Motorola Acoustic team in Schaumburg, IL collected a number of test utterances and contracted Dynastat to perform comparative listening tests on Ditech's VQA solution. The tests were based on ITU-T P.800 Annex E Comparison Category Rating (CCR) methodology. With this rating methodology, test participants listen to two versions of the same voice file and score the second version in relation to the first. The resulting score is called Comparative MOS (CMOS). A positive CMOS of over 0.14 represents a significant improvement in quality.¹

Test Methodology

Dynastat contracted external naïve listeners for the purpose of their test. The tests were all run using a slightly modified version of the ITU-T P.800 Annex E Comparison Category Rating (CCR) methodology.

The experiment involved one test session consisting of 72 trials or 72 pairs of utterances. A test session consisted of all 72 noisy listener test conditions. Listeners were asked to evaluate the overall quality of speech samples keeping their listening environment in mind. Speech samples were randomized according to guidelines provided in ITU-T P.800.

AMBE++ with VQA Results

The summary results of all test scenarios run by Dynastat in which AMBE++ alone was compared to the same voice file but with the addition of Ditech Networks' VQA (AMBE++ with VQA) in a noisy environment are provided in Table 1 below.

This demonstrates that Ditech Networks' VQA solution can provide dramatic improvement to the AMBE++ voice quality for iDEN subscribers.

Table 1: AMBE++ vs. AMBE++ w/VQA summary of all call type results in noisy listener environment

All Noisy Environment Scenarios
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¹ Based on information provided by Dynastat, a CMOS of 0.14 or greater has been seen as sufficient by service providers and vendors to justify selection of one codec over another on the basis of delivered voice quality.

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	Reference Condition	Test Condition	CMOS score
Dynastat	AMBE++	AMBE++ with VQA	+ 0.692

AMBE++ vs. VSELP results

The purpose of this test was to deliver a reference comparison for the performance improvement of AMBE++ vs. VSELP using the same test methodology used to generate the AMBE++ vs. AMBE++ with VQA results.

Because the reference test incorporated a subset of the overall test the AMBE++ vs. AMBE++ with VQA CMOS number is based only on the files used in the reference test and is therefore a different value than in Table 1. Ditech's VQA solution was NOT applied to either the VSELP or the AMBE++ for the reference test itself.

Table 2: Reference tests performance in noisy listener environment only

Reference Calling Scenarios with Noisy Environment			
	Reference Condition	Test Condition	CMOS score
Dynastat	AMBE++	AMBE++ with VQA	0.793
	AMBE++	VSELP	0.152

The reference test results provide data for the following conclusions:

- The results show the expected preference for VSELP over AMBE++.
- Ditech's VQA solution can deliver substantial voice quality improvement to subscribers using the AMBE++ codec.

The larger preference shown for AMBE++ with VQA when compared to the preference for VSELP vs. AMBE++ is likely the result of the overall quality

improvement provided by Ditech's VQA solution including noise cancellation, speech level management, Enhanced Voice Intelligibility (EVI) with AMBE++ Spectral Reshaper (ASR) features, which seamlessly transitions between enhancing "naturalness" in quiet listening conditions to enhancing intelligibility in noisy listening conditions.

Summary

Comparative listening tests of Ditech's VQA solution have been performed by an independent laboratory (Dynastat). The results of the subjective comparative listening tests conducted by Dynastat indicate that Ditech's VQA solution delivers significant improvement in overall voice quality for the AMBE++ codec. This improvement results from the following two key elements:

1. Enhancement of the intrinsic quality of the AMBE++ codec by returning the natural sound of the voice to mitigate complaints of "robotic," "nasal" or "difficulty in recognizing the speaker."
2. Mitigation of voice quality impairments (e.g. noise, speech level and echo) that cause degradation of customers' voice quality experience on live calls.

The results demonstrate that across a variety of environmental and reference conditions Ditech's VQA solution will provide iDEN users with a significantly higher voice quality experience while continuing to take advantage of the significant capacity savings offered by use of the AMBE++ codec.