CT LABS
TESTING SERVICES

Location of Test: ***Azimuth Systems Headquarters, Acton, MA*** **Date of Test:** ***August 23–25, 2005***

Voice over Wi-Fi
Voice Quality Assessment Test

A CT Labs Summary Report for Azimuth Systems and Empirix, Inc.

Voice over Wireless LANs is a market ripe for growth. A recent study Frost & Sullivan projects a compounded annual growth of 159% for operators in the voice over wireless LAN (VoWLAN) market. Interoperability issues were among the key challenges mentioned in the report. Another factor that looms as critical for continued rapid market acceptance is voice quality.

The **Empirix** Hammer portfolio of emulation, troubleshooting and network monitoring products are the industry's most widely-used market surveys. Since the introduction of its first Voice over IP (VoIP) test system in 1995, the Hammer advanced call performance test product family has grown to include a full range of testing platforms, products and services that span the complete development and deployment lifecycle for next generation network services and IMS architectures.

The **Azimuth Systems** W-Series is the industry's first standardized platform for system level testing of 802.11 wireless devices such as VoWi-Fi handsets. W-Series systems provide the ability to configure an entire WLAN network in a bench top chassis designed for complete Radio Frequency (RF) isolation and control. The flexibility of the W-Series allows for the thorough evaluation of wireless LAN equipment under varying mobility and traffic conditions, as well as precise analysis of the results.

CT Labs was commissioned by Empirix and Azimuth Systems to perform a series of test demonstrations to evaluate true VoIP end-to-end voice quality over 802.11 WLANs. These tests included testing of true "to the headset" voice quality versus handset wireless range and voice quality during handset roaming, utilizing industry-standard Wi-Fi VoIP hand-held phones. These tests were performed utilizing Azimuth's W-Series test platform and the Hammer FX-TDM from Empirix.

Testing for end-to-end voice quality over 802.11 covered two key aspects of performance and quality of service: call range, to determine the voice quality performance of a Wi-Fi phone device as it is ranged away from the access point, and call roaming, to determine the effects on voice quality as a phone handset ranges from one access point to another.

This summary report highlights test results for the call range tests; the roaming test results are covered in the full-length version of this report. Please contact Empirix or Azimuth Systems for a copy of the full report.

Highlights

- *Empirix and Azimuth Systems join forces to stage VoWi-Fi true end-to-end Voice Quality test*
- *Off-the-shelf Voice over Wi-Fi phones tested*
- *Results clearly show the accuracy advantage of "to the headset" voice quality assessment under degraded 802.11 conditions*

Executive Summary

CT Labs performed the 802.11 WLAN range tests against two off-the-shelf Wi-Fi phone devices. Test results clearly show that while E-Model voice quality scores can provide an indicator of quality, the combined power of the Azimuth test platform in conjunction with the Empirix-based PESQ measurements provided significant improvements in accuracy. This is due to the enhanced test taking into account the effects of audio, RF, and packet processing by the phone devices themselves.

Regarding the voice quality performance of the phone devices, CT Labs found:

• Not all VoWi-Fi devices are created equal—indeed, major voice quality differences exist

• Voice quality performance while roaming was found to be a key differentiator

Overall, CT Labs found the combined Azimuth/Empirix testing environment to be a powerful combination, providing automated, repeatable tests that emulate real-world RF conditions while returning true end-to-end voice quality performance results, essential for verifying and tuning the end user's quality experience.

Statement of Test Purpose

CT Labs performed a series of tests to demonstrate the complementary benefits of each company's test platforms when applied to the task of voice quality assessment. Specifically, the goal was to measure the end-to-end voice quality of calls placed over VoWi-Fi phone devices that were subjected to various real-world wireless conditions.

The significance of this goal is to not only demonstrate that the technology exists today to perform real-world VoWi-Fi voice quality tests, but to illustrate the additive benefits of active, standards-based objective tests that verify voice quality to the earpiece and microphone wires of these devices. Such tests open up a new window for manufacturers that, ultimately, enable a refined view of the user's voice quality experience.

Overview − Objective Voice Quality Evaluation Techniques

Two distinctly different methods were employed for evaluating voice quality during this test: the passive E-Model technique provided as a built-in feature of the Azimuth test platform, and the active PESQ method as provided by the Empirix Hammer test platform. Both techniques have their place in a test lab environment, depending on available resources.

Both of these voice quality assessment techniques attempt to estimate the way humans perceive speech quality, the ultimate test. ITU-T standard P.800 defines a specific subjective methodology for evaluating voice quality by employing live listeners. The E-Model technique involves the passive evaluation of call-based packet flows. While this technique does provide an estimate of voice quality, VoIP-specific endpoint behaviors are not considered which, depending on the device, can significantly affect the quality score. PESQ is an active technique that involves driving reference audio material end-to-end while performing an analysis of the degraded audio sample as compared to the reference. Since PESQ is "endpoint-agnostic"; it will return accurate quality estimates for any type of phone device, configuration, or method of speech coding used.

Note that both E-Model and PESQ techniques can provide a quality rating score using the MOS-based "absolute category rating" method 5-grade scale:

5 = excellent
4 = good
3 = fair
2 = poor
1 = bad

Equipment and Products Staged

Azimuth-Provided Hardware/Software

- Azimuth DIRECTOR, Chassis, and RF Port Module (RFM-102)
- Azimuth testMAC (TMM-101) to analyze traffic streams
- Azimuth Mini RF Test Head (MTH-102)
- Azimuth Benchmarks and Tcl Library containing the Azimuth VoWi-Fi Range Benchmark Test
- Azimuth Near Field Antenna (to connect indirectly to the phone-under-test antenna)

Empirix-Provided Hardware/Software

- Empirix Hammer FX-TDM
- Hammer FX software release V2.0
- Voice quality test scripts (utilizing Hammer Visual Basic)

Devices Under Test

- **Voice over Wi-Fi Phones:** Two VoWi-Fi telephone products were evaluated during this test. Both were purchased as off-the-shelf products and configured in the test lab.
- **SIP Soft Phone:** The SIP soft phone that was used to terminate VoWi-Fi calls in this test was purchased from XTen (version 2.0, release 1103m). This soft phone was installed on an IBM Thinkpad laptop computer running Windows XP Professional.

The Azimuth VoWi-Fi Range Test Script

The VoWi-Fi Range Test measures voice quality of a handset-AP link as a function of path loss between the handset and the Access Point. The benchmark script automatically configures the VoWi-Fi client and the AP and steps the devices apart in small increments using programmable RF attenuation to emulate the ranging as it would occur in the real world. In this test, the Azimuth testMAC module captures and timestamps traffic on the RF and Ethernet, determining with high accuracy the packet loss, delay and jitter of the call as the path loss is increased in a controlled manner. The test uses the ITU-T G.107 E-model to calculate the estimated MOS score of the voice call at each attenuation point. In parallel, the Empirix Hammer FX-TDM measures the ITU-T P.862 PESQ-based objective MOS score at each point. The MOS score (E-Model and PESQ-based), packet loss, delay, and jitter are plotted against the path loss between the handset and the AP.

Testing Methodology

Tests were designed to evaluate the true end-to-end voice quality performance of voice transmission over an 802.11 infrastructure. The test plan was based on the capabilities of the Azimuth Director platform, in conjunction with the powerful and flexible Empirix Hammer FX call generation and analysis platform.

This report summarizes the *call range* methodology for verifying voice quality performance for voice carried over 802.11, where the goal was to determine the performance of a VoWi-Fi phone as it was ranged from the access point (the call roaming test results are contained in the full-length report).

Test Setup & Conditions

Equipment was configured as shown in Figure 1. Note that "downstream" refers to call audio transmitted from the soft phone through the AP **to** the VoWi-Fi phone; "upstream" refers to call audio received by the soft phone through the AP **from** VoWi-Fi phone.

Test conditions:

- Upstream range test: starting at 60 db path loss, in 1 db steps, until the MOS score dropped significantly.
- Downstream range test: starting at 70 db path loss[1], in 1 db steps, until the MOS score dropped significantly.

Test Procedure Summary

1. A baseline end-to-end test was performed in both call directions to validate the test setup.
2. Each of the two target VoWi-Fi phone devices was separately configured and verified for call connectivity to the SIP soft phone client.
3. A single VoWi-Fi phone was placed in its own MTH chamber. Before closing the chamber, a manual call was placed using the phone.
4. The Empirix Hammer FX-TDM test script was initiated, establishing audio connectivity on both sides of the call through the audio adapters.
5. The Azimuth VoWi-Fi Test Suite script was initiated, causing the virtual distance between the AP and the phone device to be varied.

Voice quality and related performance results were accumulated for each attenuation condition on both the Azimuth and Empirix test systems.

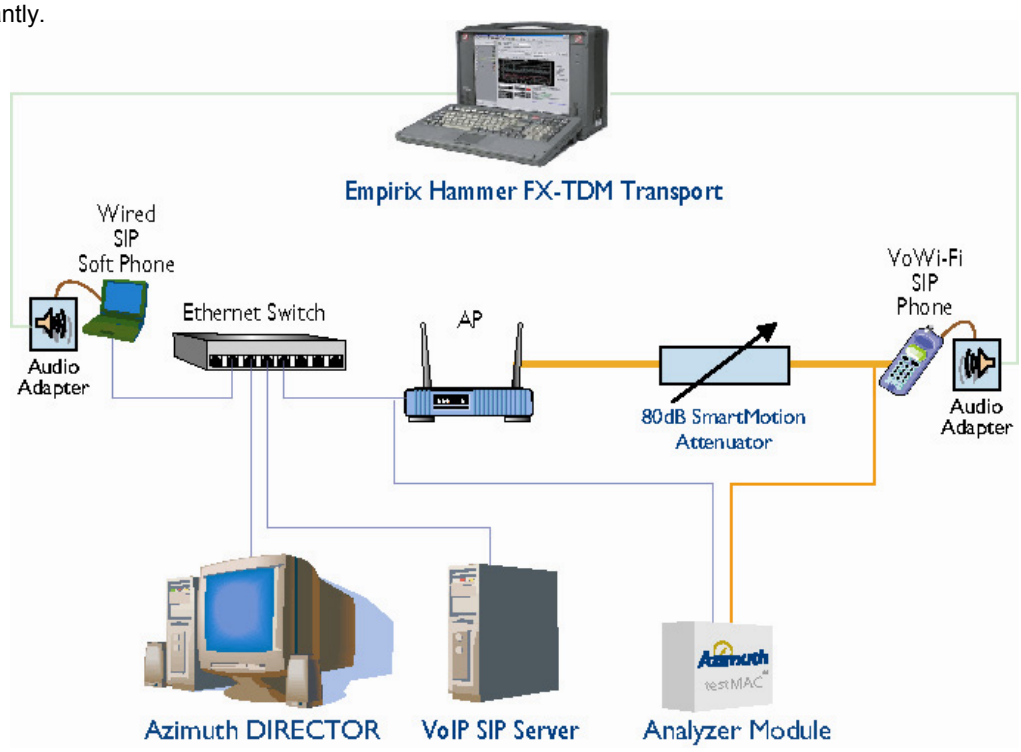
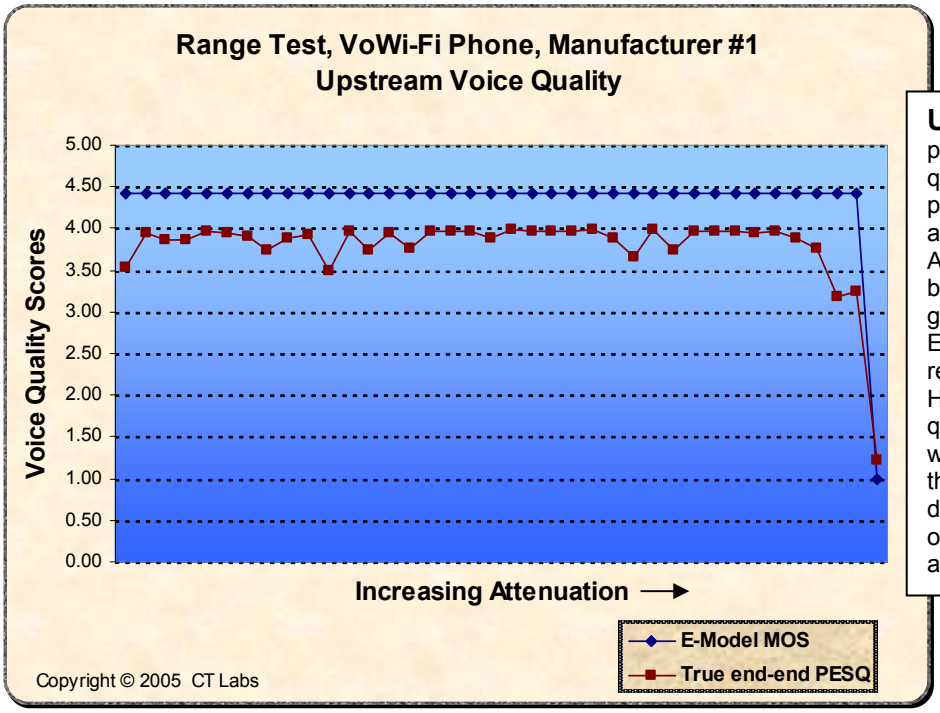


Figure 1: Test Setup for Handset Range vs Voice Quality Tests

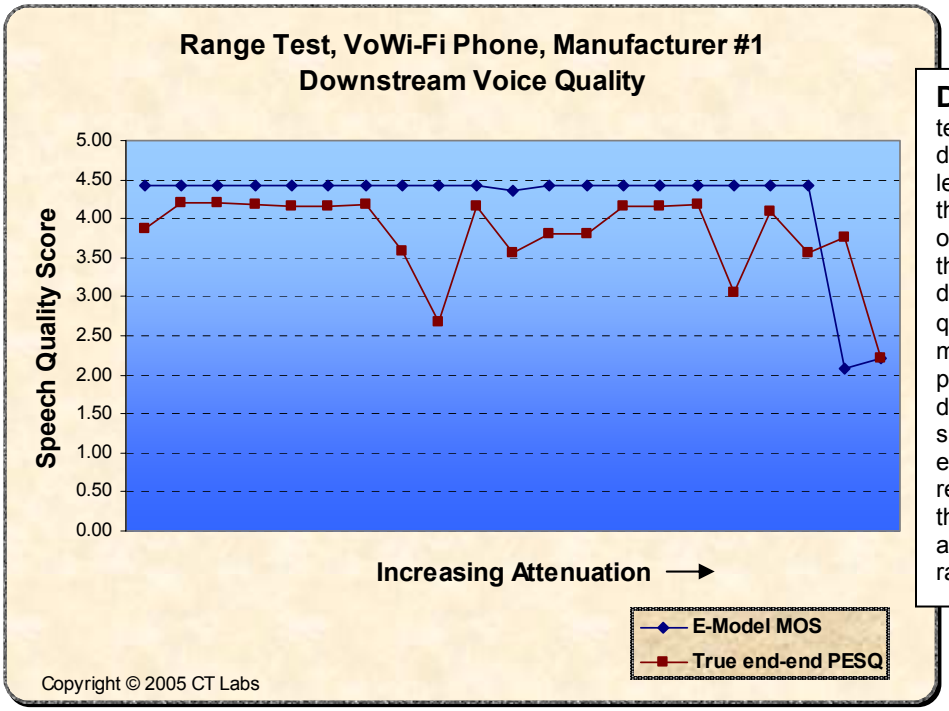
[1] The downstream range was reduced after the upstream test results yielded insignificant changes at lower attenuation levels.

Range Test Results

The two graphs presented on this page illustrate how one of the VoWi-Fi phones fared under the CT Labs-conducted range test. The results of all the tests are available in the full test report.



Upstream Test Results. Each data point in the graph represents a voice quality score that was taken for a particular path loss value. In the upstream test, RF attenuation between the Wi-Fi phone and AP was increased from 60 db (represented by the point on the far left-hand side of the graph) to 98 db. As the graph shows, the E-Model estimation of voice quality remained flat until the very last test point. However, the end-to-end PESQ voice quality estimates show a lower average as well as a sharp drop-off in quality during the last few test points. Knowing the device's true performance provides an opportunity to improve, the ultimate goal of any performance test.



Downstream Test Results. In this test, attenuation was increased from 70 db[1] (represented by the point on the far left-hand side of the graph) to 91 db. As the graph shows, the E-Model estimation of voice quality remained flat throughout the test until the last 2 points where it dropped to just above 2 on the MOS quality scale. The PESQ scores paint a more revealing picture of voice quality performance. Starting at a path loss of 76 db, the PESQ results show a fairly significant deviation from the E-Model estimate. While finding the specific internal reasons for quality issues was not a goal of this test, it is clear that there are product areas open to improvement under the range conditions provided by this test.

[1] The downstream range was reduced after the upstream test results yielded insignificant changes at lower attenuation levels.

Company Information

About Empirix

Empirix delivers a comprehensive range of testing and monitoring solutions that assure the performance of next-generation networks, contact centers and Web-based applications. Empirix provides products, services and support to thousands of customers worldwide, including Global 2000 enterprises, network equipment manufacturers and service providers. Headquartered in Bedford, Mass., Empirix has offices throughout the United States, Europe and Asia. For more information, visit http://www.empirix.com/.

About Azimuth Systems

Azimuth is the industry's leading provider of Wi-Fi communications test solutions. Our products are used by the world's leading Wi-Fi semiconductor and system vendors to test the performance, conformance and certification of wireless devices and networks supporting data, voice and video applications. Azimuth's W-Series, the industry's first standardized 802.11 test solution, leverages a patented architecture to provide a flexible platform that addresses research, development, QA and marketing engineering requirements. The company is based in Acton, Massachusetts and is backed by major venture capital companies. Azimuth may be contacted at (978) 263-6610 or at http://www.azimuthsystems.com.

About CT Labs

Background

CT Labs was founded in 1998 with the mission of providing outsource Q/A testing and marketing report services to the converged communications industry. The CT Labs team brings with it a wide range of talents and experience that gives us a unique ability to solve the most challenging test projects. Our open testing services philosophy enables us to provide our customers with test plans, test execution, testing reports, and even assistance in setting up specific testing environments in their own testing areas.

Facilities

Our test lab is well-equipped with tools and test platforms from our technology partners. In addition, CT Labs has the in-house expertise to develop specialized tools when off-the-shelf solutions are not available. CT Labs prides itself on keeping our lab current, enabling us to perform testing projects on cutting-edge next-generation network products and technologies.

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