Keysight Technologies
Testing Voice Over LTE (VoLTE) Phones
Using the Keysight E7515A UXM Wireless Test Set, E6966B IMS-SIP Network Emulator Software and U8903B Audio Analyzer

Application Note
Introduction

This application note explains a test solution for LTE mobile phone developers, test engineers, and test lab personnel responsible for testing voice over LTE (VoLTE) phones. The featured test solution incorporates the Keysight Technologies, Inc. E7515A UXM wireless test set, E6966B IMS-SIP network emulator software, and the U8903B audio analyzer. It also provides suggestions for third-party products that can simplify VoLTE UE testing.

Throughout this document, [ ] are used to indicate hard keys on equipment, { } indicate soft keys found on screen menus, italics indicate screen menu names and settings, and the use of > between words indicates a string of keystroke commands.

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Installation and Verification of Keysight E6966B Software and Complementary Applications

The Keysight Technologies, Inc. E6966B IMS-SIP software is an integral part of the VoLTE test solution described in this document. This section contains information on the installation and initial configuration of the E6966B software and other complementary software that can prove useful for VoLTE testing.
Software downloads and licenses
Software download, license redemption, and installation instructions for the Keysight E6966B IMS-SIP network emulator software are available at www.keysight.com/find/E6966B_software.

Verifying configuration with IPv4 calls from Keysight client to Keysight client
To verify successful installation and configuration of the E6966B software, you can initiate two IMS-SIP clients on the PC and make a simple VoIP voice call between the two clients.

1. Set the IPv4 address on the PC on which you've installed the E6966B software to a static IP address (for Windows 7 this is accessed via Control Panel > Network and Sharing Center > Local Area Connection > Properties).
   Note: The IP addresses for the PC, UXM, router (if used), and test UE should all be on the same subnet.

2. Open the IMS-SIP server software via Start > All Programs > Keysight E6966B > IMS-SIP Server Emulator.
   a. In the IMS-SIP server software, review the error log (Errors tab at the bottom of the screen) to verify that there are no errors. If errors appear, refer to the Troubleshooting section of this document.
   b. Verify WCF Port: 8240 and Server Port: 5060 are shown at the bottom of the screen. If these are not shown, refer to the Troubleshooting section of this document.
   c. If "-----has not been activated" appears on the top frame of the server window refer to the Troubleshooting section of this document.
   d. If necessary, close and re-open the application until it runs without errors appearing in the error log (if prompted when restarting, save the new configuration as DefaultConfigSettings.xml.)
3. Connect the headphones and microphone to the PC before opening the IMS-SIP client application.

4. Open the IMS-SIP client application via Start > All Programs > Keysight E6966B > IMS-SIP Client Emulator.
   a. Review the Error Log (tab at the bottom of the screen) to verify that there are no errors. If errors appear, refer to the Troubleshooting section of this document. If necessary, close and re-open the application until it runs without errors appearing in the Error Log.
   b. In the Connection menu on the Configuration tab, enter the PC’s static IPv4 address for both SIP server IP address and Contact IP address.
   c. Select Register (upper left on screen).
   d. Verify that the lower left status changes from Not Registered to Registered. If registration fails, refer to the Troubleshooting section of this document.

5. In the IMS-SIP server software, the Keysight client should now appear as the first entry in the list of Registered Users.
6. In the IMS-SIP client software select the **Configuration** tab.
   a. Select the **File Locations** menu and press the button next to *Test file name location* under *Audio files*. Select the file *AudioSample_Male.wav* or *AudioSample_Female.wav*. The path to these files should have been set during the installation process but may vary depending on the PC configuration. The files can usually be located at `C:\ProgramData\Keysight\E6966B\IMS-SIP Client\samples\audio`, or similar.
   b. Select the **Audio** menu.
      i. Select the speaker device that corresponds to the headphones in use from the **Speaker** drop-down menu.
      ii. Similarly, select the microphone device from the **Microphone** drop-down menu.
      iii. Press **Play Local** to play the selected audio file to verify the headphone connection. The contents of the file should be heard. If not, refer to the *Troubleshooting* section.
      iv. Adjust the speaker volume controls as desired. (Refer also to the *Windows Volume Settings* section.)
      v. Press **Stop Local**.
      vi. Press **Start Loop Test**. Speak into the microphone and adjust the volume and/or change the microphone selection to hear voice echoed back in the headphones. Press **Stop Loop Test** when done.

7. Open a second instance of the IMS-SIP client software by selecting **Start > All Programs > Keysight E6966B > IMS-SIP Client Emulator**.
   a. When opening a second IMS-SIP client application on the same PC, the **Contact IP port** and **User name** will automatically be configured to be different from the first IMS-SIP client application. To confirm this, select the **Configuration** tab, then **Connection** menu.
   b. Otherwise, configure the second client as done above for the first client in Step 4b.
   c. Select **Register** on the second client. Verify that its state (lower left) changes to **Registered** and that it appears as the second entry in the **Registered Users** list on the server application.
8. On the first IMS-SIP client application select the VoIP tab, Call Location, and enter the User Name of the second client (e.g. +10000000002), then press Dial.

9. The second IMS-SIP client application should show Incoming Call.
   a. Select Answer on the second client. The call should be connected between the two clients.
   b. Speak into the microphone and hear voice echoed back, and observe the resulting waveform on the Audio Analyzer tab (you must first select the Enable analyzer check box).

Verifying configuration with IPv6 calls from Keysight client to Keysight client
IPv6 is enabled by default on Windows 7 PCs.

1. Repeat the prior procedure outlined in the Verifying configuration with IPv4 calls section, but with the following changes:
   a. In Windows double-click on the Local Area Connection icon.
      Enter a valid IPv6 address and subnet prefix length. All other settings can be blank.
   b. Open the server as instructed in the Verifying configuration with IPv4 calls section and select the appropriate Transmission Network Interface.
   c. Open both the first and second clients and on the Configuration tab, in the Connection menu, enter the IPv6 address given to the PC for both SIP server IP address and Contact IP address.
   d. Both clients should be able to register and make calls.
# Troubleshooting

Below are some of the most common issues encountered during the verification of the E6966B installation, along with recommended actions to address the conditions.

Note: To reset the server and client settings to their default values, close the software and locate the following files:
- **Server**: C:\User\Public\Documents\Keysight\E6966B\IMS-SIP Server\DataFiles\DefaultConfigSettings.xml
- **Client**: C:\User\Public\Documents\Keysight\E6966B\IMS-SIP Client\DataFiles\ImsSipClientSettings.xml

Delete the above files and re-open the software. The server/client will now open with default settings and re-create new versions of the above files.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Cause/corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Server error: “Start Transport: Error Opening Server Socket”</strong></td>
<td>Port clash with other SIP applications. Close all applications and open the server before running other SIP applications. Check other applications to verify that port 5060 is available for the server.</td>
</tr>
<tr>
<td><strong>Server’s WCF port not showing 8240 and/or client/server error: “Your process does not have access rights to this namespace”</strong></td>
<td>The IMS-SIP software needs to be run on a PC with administrator privileges. When launching the E6966B software, right-click and select <em>Run as Administrator</em>. Potential port clash with other applications. Re-install server on a clean PC.</td>
</tr>
<tr>
<td><strong>Server port not showing 5060</strong></td>
<td>Port clash with other SIP applications. Close all applications and open server before running other SIP applications. Check other applications to verify that port 5060 is available for the server.</td>
</tr>
<tr>
<td><strong>Client does not register with server, or not able to connect a voice call</strong></td>
<td>Verify that <em>Contact IP port</em> (on the <em>Configuration &gt; Connection</em> tab) for each instance of IMS-SIP client running in the PC is different and that there are no other applications using the selected ports. For example if Client 1 is set to have a <em>Contact IP port of 5080, select 5081 for Client 2</em>. Verify that the IMS-SIP server’s <em>Configuration &gt; General Configuration &gt; Transmission Network Interface</em> is set to an active Ethernet adaptor with a relevant IP address on the correct subnet. Also confirm that the IP address appears under <em>Reception IP Addresses</em> and that its corresponding check box is selected. When making calls without a fully-qualified URI (e.g. dialing +1222222222 rather than <a href="mailto:+1222222222@test.3gpp.com">+1222222222@test.3gpp.com</a>), verify that the <em>Realm/Domain</em> is set in the IMS-SIP server to match the setting in each IMS-SIP client.</td>
</tr>
<tr>
<td><strong>IMS-SIP server or client opens with “Has not been activated” message at top of window</strong></td>
<td>Licenses have not been properly installed. Open the Keysight License Manager application (padlock icon in Windows System Tray) and verify that E6966B-1FP/-1TP has been installed to activate both server and client, or E6966B-2FP/-2TP has been installed to activate only the client (E6966B-3FP/-3TP is required to enable the conference server emulator). Review installation instructions provided in the Verifying Keysight E6966B Installation section.</td>
</tr>
<tr>
<td><strong>When using Keysight IMS-SIP client to make calls to a Keysight IMS-SIP client in another PC, audio flows in just one direction</strong></td>
<td>Confirm the correct setting of the <em>Contact IP address</em> in each client. The <em>Contact IP address</em> should be set to match the IP address of the PC hosting the client.</td>
</tr>
<tr>
<td><strong>No sound from headphones or microphone not working</strong></td>
<td>Keysight IMS-SIP client software needs to be opened after new audio devices (e.g. headphones) have been added to the PC. The software queries Windows audio devices when it opens. Close the IMS-SIP client and re-open to enable the software to query and become synchronized with any changes to Windows audio device availability. Try using the headphone and microphone with another Windows audio application, for example Sound Recorder. Windows may not be configured properly to operate with headphones; drivers may not have been loaded or activated.</td>
</tr>
</tbody>
</table>
Audio paths

The Keysight IMS-SIP client includes a variety of audio paths to enable simple voice echo testing, playing, and recording .wav files. The software also includes facilities to play .wav files and loop back signals to enable gain calibration.

Windows volume settings

When adjusting volume settings to achieve calibrated line in/out audio levels, some care is needed to achieve expected results. The Keysight IMS-SIP client speaker volume slider controls the Windows 7 application volume for the selected device. Windows sets the total volume by multiplying the Windows 7 master volume by the application volume. When setting calibrated audio levels, set the Windows 7 master volume slider to maximum, and then make calibration volume adjustments using the slider in the Keysight IMS-SIP client.
Loading complementary applications

Wireshark

As a companion to the Keysight IMS-SIP server and client, downloading and installing Wireshark is recommended. Wireshark is the industry-standard IP and SIP protocol logging and analysis tool. It is freely available (GPL-licensed) for download, installation, and use. The Keysight IMS-SIP server and client include SIP logging. Wireshark complements this capability by providing more detailed and independent SIP logs, and adds the capability to decode aspects of RTP packets helpful for debugging interoperability and setting issues.

Sample Speech files

Sample speech files can be downloaded from a number of Internet sources. These files include reference recordings of Harvard Sentences available from the ITU and other sources. (Refer to the Obtaining and preparing audio files section for URLs.)

Audio editor

Sample rates can be adjusted to 8 or 16 kHz to suit the Keysight IMS-SIP client using a number of tools including Audacity, which is freely available for download, installation, and use. Audacity is an open-source digital audio editor and recording computer software application, available for Windows, OS X, Linux, and other operating systems. It can be used to edit .wav files and create test signals, for example sine wave tones and noise.

Emulators

Many delay and jitter emulators can be used successfully with the Keysight IMS-SIP server and client. ZTI NetDisturb is a low-cost tool that can be co-resident with the Keysight applications and used to add delay and jitter to any Ethernet link in the system.

Refer to the Third-Party Software and Hardware section for more information on loading complementary applications.
Making Voice Calls with VoLTE Phones

This section provides instructions for establishing an IMS/SIP voice call between a VoLTE-enabled UE and the E6966B IMS-SIP client, using the E7515A UXM wireless test set as the LTE/LTE-A network emulator. Instructions are also included for using two UXMs to test end-to-end VoLTE calls between two UEs.

IPv6 voice calls with a VoLTE-enabled UE

1. Connect the UXM and IMS-SIP server/client.
   a. Using an Ethernet (LAN) cable, connect the PC (with the E6966B IMS-SIP software installed) to a local router or directly to the Keysight E7515A UXM wireless test set. Windows 7 PCs can be connected directly to the UXM using an Ethernet cable (i.e. no router is required).

2. Verify connections:
   a. Set the UXM's IP address:
      i. From the UXM's Control Panel, select Config.
      ii. If using the rear panel GbE4 LAN port, select the ICM_GbE4 tab, uncheck Use DHCP, and set IP address to match the IMS-SIP server/client PC's subnet mask.
b. On the PC hosting the IMS-SIP server and client, open up a Windows command shell (for Windows 7, select Start, type cmd in the search box and press [Enter]).

c. Type Ping <UXM IP address> and look for replies to confirm that the UXM and the IMS-SIP server/client PC have IP connectivity.

3. Configure the Keysight E7515A UXM wireless test set.
UXM software 1.2.1.0 or above is recommended (these instructions assume UXM software version 1.4.1.0). Test set settings will vary depending on the band and other UE characteristics. The typical configuration for a Band 13 UE with a Gemalto W004v2 SIM is provided as an example. (See also SIM selection section.)

a. In setups including a router, the advertisement messages needed by the UE under test will be generated by the router. When not using a router, the UXM can instead be used to provide the router advertisement messages by selecting the IPv6 Router Advertisement (LTE) and IPv6 Router Advertisement (LAN) check boxes on the NAS sub-tab of the RRC/NAS tab.

b. Select UXM BSE mode (Cell tab > BSE Mode Selection).

The UXM has several modes of operation. Use of the Stack mode provides the settings needed to configure the base station to work with commercial UEs. In addition there is a Scenario mode, which provides the user with more flexibility to change settings and configure the messaging using the optional E7630A-MTP Message Editor software. For some VoLTE parameters it will be necessary to use Message Editor to create a scenario for a given network operator’s implementation and UE. Your Keysight application engineer will be able to help if you need support with this step.

c. Adjust the settings for cell 1 on the UXM to match those of your UE.

As a guide the following settings will need to be made:

- FDD or TDD technology
- Cell band and bandwidth
- EARFCN settings
- Appropriate SIM settings
d. On the **EPS Bearer Config** sub-tab of the **RRC/NAS** tab, ensure that the P-CSCF IP addresses match those of the IMS-SIP server and configure the UE IP address values, APN, and DNS addresses:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Default EPS bearer</strong></td>
<td>#5</td>
</tr>
<tr>
<td><strong>APN</strong></td>
<td>Keysight</td>
</tr>
<tr>
<td>Note: This APN name must match the UE’s expected IMS packet data network (PDN). This setting can be changed using a scenario file which has been generated by the Message Editor software or obtained from your Keysight application engineer.</td>
<td></td>
</tr>
<tr>
<td><strong>IPv4 Address</strong></td>
<td>UE bearer #5 IPv4 address (must match UXM and IMS-SIP server subnet mask; e.g. 192.168.1.51)</td>
</tr>
<tr>
<td><strong>IPv6 Address Network Prefix</strong></td>
<td>UE bearer #5 IPv6 address network prefix</td>
</tr>
<tr>
<td><strong>IPv6 Address IID</strong></td>
<td>UE bearer #5 IPv6 address interface ID</td>
</tr>
<tr>
<td><strong>DNS Server Configuration:</strong></td>
<td>Set to a valid IP address, such as the IMS-SIP server IP address</td>
</tr>
<tr>
<td><strong>IPv4 Address 1</strong></td>
<td>e.g. 192.168.1.230</td>
</tr>
<tr>
<td><strong>IPv6 Address 1</strong></td>
<td>e.g. 2001:0000:0000:0000:0210:01FF:FE23:4567</td>
</tr>
<tr>
<td><strong>P-CSCF Server Configuration:</strong></td>
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</tr>
<tr>
<td><strong>Default EPS bearer</strong></td>
<td>#6</td>
</tr>
<tr>
<td><strong>APN</strong></td>
<td>Keysight2</td>
</tr>
<tr>
<td>Note: This APN name must match the UE’s second PDN.</td>
<td></td>
</tr>
<tr>
<td><strong>IPv4 Address</strong></td>
<td>UE bearer #6 IPv4 address (must match UXM and IMS-SIP server subnet mask; e.g. 192.168.1.52)</td>
</tr>
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<td><strong>IPv6 Address Network Prefix</strong></td>
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</tr>
</tbody>
</table>

![EPS Bearer Config screenshot](image)

e. After establishing the settings, turn cell 1 on (or activate your scenario).
4. Configure the IMS-SIP software.
   a. Connect headphones and a microphone to the PC hosting the IMS-SIP software before opening the IMS-SIP client.
   b. Open the IMS-SIP server and then open the IMS-SIP client.
   c. As described in the Verifying configuration with IPv4 calls from Keysight client to Keysight client section, ensure that the connection IP addresses in the client are set to match those of the server.
   d. Select Register to register the IMS-SIP client with the IMS-SIP server.
   e. On the client, select the Configuration tab > Audio menu > Audio Codec Config and set the codecs as follows, or as required by your UE:
      i. On the General tab, under Available codecs, select AMR and/or AMR-wb
      ii. On the AMR and AMR-wb tabs:
         a. Check the box next to Octet Alignment and set the value to 1.
         b. Check the box next to Include Mode Set.
         c. Under Mode Set, check the box next to 12.2 kbit/s for AMR and 12.65 kbit/s for AMR-wb.

5. Connect and configure the VoLTE UE
   a. Load a suitable SIM, for example Gemalto W004v2. (See also SIM selection section.)
   b. Connect the VoLTE UE to the UXM’s RF connectors.
   c. The P-CSCF (IMS-SIP server address) is signalled to the UE from the UXM during registration and link setup. Some UEs will have a separate menu for P-CSCF that also needs to be set to match the IPv6 address of the IMS-SIP server PC.
   d. Power on the UE (and/or turn Airplane Mode off)
   e. Wait for the UE to connect to the UXM’s LTE cell.
   f. Wait for the UE to register with the IMS-SIP server.
6. Make a call.
   a. Calls should be possible from the UE to the Keysight IMS-SIP client, for example by dialling the client’s User name (such as +10000000001) on the UE and selecting an IMS call, or by entering the UE phone number in the Keysight IMS-SIP client’s Call location field (on the VoIP tab) and pressing Dial.
   b. The UE phone number is derived from settings on the SIM and can be seen in the Address of Record column of the IMS-SIP server’s Registered Users. An unmodified Gemalto W004v2 SIM will typically be configured for +11234567890.

7. Troubleshooting.
   In the event of a failure to establish a SIP call connection, or a failure to get an intelligible voice connection, review logs on the Keysight IMS-SIP server and IMS-SIP client, run Wireshark on the server PC to investigate, and review SIP messaging and RTP packet configurations.

Call waiting

With two or more instances of the Keysight IMS-SIP client open, it is possible to place calls from each of them to a VoLTE UE and test call waiting and call reject scenarios.

1. With settings established as described in the IPv6 voice call with a VoLTE-enabled UE section of this document, open a second instance of the Keysight IMS-SIP client.
2. As explained in the Verifying configuration with IPv4 calls from Keysight client to Keysight client section, ensure that the second client’s Contact IP port and User name are different from the first client’s.
3. Select Register on the second client. Verify that its state changes to Registered and that it appears as an additional entry in the Registered Users list in the server software.
4. It should be possible to place calls from either client instance to the VoLTE UE and from the VoLTE UE to each of the two client instances.
5. To test call waiting, place a call from the first client instance to the VoLTE UE. Once answered, place an additional call from the second client instance to the VoLTE UE. The UE should then be able to answer or reject the second call and/or flip between each call, placing each of the clients on hold in turn.
6. Using a similar procedure to select unique port numbers and user names (phone numbers), additional clients can be opened to verify that the VoLTE UE is able to reject additional calls.
Making end-to-end calls with two VoLTE phones

Using two UXMs and the Keysight IMS-SIP server connected to an IPv6 router, end-to-end calls can be made between VoLTE UEs. A router is needed to connect the two UXMs with the IMS-SIP server PC. (See also Router configuration.) An Ethernet switch or hub will not enable this configuration; a router is required.

1. Configure the IMS-SIP server and one of the UXMs and one of the VoLTE UEs as described in the IPv6 voice call with a VoLTE-enabled UE section.
2. Configure the second UXM with the same settings as the first with the following differences:
   a. Use a new IP address for UXM2
   b. Use new UE IP addresses for UE2
3. UE1 and UE2 should have the same settings but be loaded with different SIMs. Since the phone number of the UE is derived from the SIM, one of the UEs will need to have a SIM that has been modified to contain a different phone number.
4. With suitable RF cables, connect one UE to each UXM. Power on the UEs. Each will attach to its UXM and register with the IMS-SIP server. Calls can be placed from UE-to-UE and from each UE to and from Keysight IMS-SIP client(s) running on the server PC or other PCs connected to the LAN side of the router.
5. With suitable VoLTE UEs, video calls can also be connected.
**WiFi connection**

With an appropriate IPv4 or IPv6 WiFi router/access point connected to the Keysight IMS-SIP server and a WiFi-enabled phone, VoIP calls can be made. IMS client apps are available for both Android- and iOS-based smart phones from Google Play and the iTunes App Store.
Voice Quality Testing

Voice quality testing is typically assessed using perceptual evaluation of speech quality (PESQ) and perceptual objective listening quality (POLQA). PESQ offers a MOS (mean opinion score) of narrow- and wide-band telephony voice signals (listening quality) according to ITU-T P.862/P.862.1 (narrow-band) and P.862.2 (wide-band). POLQA according to ITU-T Rec. P.863 [2011] is the next-generation mobile voice quality testing standard for HD-Voice, VoIP, 3G, and 4G/LTE. (Both PESQ and POLQA are licenced from OPTICOM GmbH. More details can be found on its Web site: www.opticom.de.)

These standards rely on the same principle of comparing a degraded signal with a reference signal. The two signals are individually level-aligned and filtered depending on the preferred application. The two signals are then time-aligned in order to compensate for delays in the network and associated components. The two signals are then transferred from the time domain into a frequency-loudness domain and subtracted to give an estimate of the audible difference. After analysis a single MOS is generated. The MOS is commonly used to describe the voice quality on a scale from 1 (bad quality) to 5 (excellent quality).

Voice quality testing using the Keysight U8903B, UXM, and E6966B

To assess voice quality, the latest high-performance audio analyzer from Keysight, the U8903B, offers many powerful signal generation and analysis features, as well as an expanding array of digital and analog audio interfaces. PESQ and POLQA voice quality analysis are standard options for the U8903B, making it the ideal instrument for VoIP development and qualification.

Using a PC with a sound card supporting line in and out levels (see Third party software and hardware), the Keysight E6966B IMS-SIP client can be connected to the U8903B audio analyzer to perform PESQ and POLQA audio quality measurements. These tests can include cabled audio connections to the UE under test or acoustic coupling, depending on the options and accessories chosen.

The E6966B IMS-SIP client and server can be used with the U8903B audio analyzer and UXM test set and/or WiFi connections to phones with a variety of audio test configurations. Three basic examples are shown on the following pages.
1. U8903B is connected to the IMS-SIP client, loopback occurs in the UE.

The U8903B audio analyzer is connected to the IMS-SIP client via a USB sound module. The IMS-SIP client is connected via Ethernet to the E7515A UXM, which is running a call to a VoLTE UE that is configured for audio loopback. The UE audio loopback can be done externally using the speaker headphone jacks and with some attenuation to arrange suitable levelling. Alternatively individual UEs may have user settings or test modes that enable internal audio loopback. In this configuration, a reference file is played from the audio analyzer, through the USB module, IMS-SIP client, and UXM, and then looped back in the VoLTE UE and returned to the audio analyzer to make voice quality measurements.

2. U8903B is interfaced directly to the VoLTE UE, loopback occurs in the IMS-SIP client.

This arrangement is essentially the reverse of the first. In this configuration, the U8903B analog audio ports are connected directly to the VoLTE UE’s microphone and headphone socket. The UE is on an RF connection with the UXM, which is connected to the IMS-SIP client via Ethernet. In this configuration, a reference file is played from the audio analyzer directly to the UE, then looped back in the IMS-SIP client for analysis in the U8903B (audio loopback is performed easily in the IMS-SIP client by selecting Enable received audio loopback.)
3. Audio is applied to the UE and received from the IMS-SIP client or vice versa (no loopback).

In this configuration, a reference file can be sent directly to the VoLTE UE, which in turn sends it to the IMS-SIP client (via the UXM), which then sends it to the U8903B for analysis. Alternatively, the reference file can be sent to the IMS-SIP client and then received by the VoLTE UE, and then sent on to the U8903B for analysis.

These three configurations form the basic test scenarios. They can of course be expanded to include multiple UEs, WLAN, and impairment-inducing components, etc.
Audio interface reference levels and calibration

Before beginning voice quality test, you must set the IMS-SIP client speaker and microphone volumes to align the analog line in and out voltage levels with the required levels of codec full scale.

Calibration .wav files are included in the E6966B software installation, and include signal amplitudes referenced to codec full scale to calibrate line out voltages. A loop back function can be enabled to calibrate line in voltages.

An example calibration level can be performed based on the industry standard of 0 dBm in a 600-Ω system.

The 0 dB reference point (0 dB) is defined as:

<table>
<thead>
<tr>
<th>Domain</th>
<th>Reference point</th>
<th>Derivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog</td>
<td>0 dBm sine wave in a 600-Ω system (interpreted as 775 mV &lt;sub&gt;rms&lt;/sub&gt; or 1.09 V &lt;sub&gt;peak&lt;/sub&gt;)</td>
<td>10 x Log(P x 1000) = 0 dBm → P = 0.001 W; V&lt;sup&gt;2&lt;/sup&gt;/R = P → (0.775 V)&lt;sup&gt;2&lt;/sup&gt;/(600 Ω) = 0.001 W</td>
</tr>
<tr>
<td>Digital</td>
<td>3.14 dB below codec maximum full load (clipping point) (interpreted as 0.6966 or 69.66% full-scale PCM .wav file)</td>
<td>dBFS = 20 x Log(0.6966) = –3.14 dB</td>
</tr>
</tbody>
</table>

Input and output gain levels can be adjusted to equate the level of a 70 percent .wav file (approximately 0.6966) to an analog signal level of 775 mV<sub>rms</sub>.

Wave files of other than 70 percent and reference voltages of other than 775 mV<sub>rms</sub> can be used to achieve a variety of alignment levels between the digital and analog domains. While 775 mV<sub>rms</sub> mapping to 70 percent is a common signal level, 70 percent .wav file mapping to 1 V<sub>rms</sub> (approximately 2.2 dB higher codec drive level) is also a frequently used operating point. 3.14 dB corresponds to a 69.66 percent .wav file. Lower level uncertainties will be possible using 100 percent .wav file and calibrating to alternate voltage levels. The E6966B includes 50 percent (~6.0 dB), 70 percent (~3.1 dB), and 100 percent (0 dB) 1 kHz sine wave calibration files.

0 dBm, 600-Ω matched to 3.14 dB down from codec full load:

<table>
<thead>
<tr>
<th>Wave file</th>
<th>V&lt;sub&gt;rms&lt;/sub&gt;</th>
<th>V&lt;sub&gt;peak&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>~ 0.775 V</td>
<td>~ 1.095 V</td>
</tr>
<tr>
<td>100%</td>
<td>~ 1.112 V</td>
<td>~ 1.572 V</td>
</tr>
</tbody>
</table>
To illustrate the calibration of reference levels, the example provided uses an Acoustics Engineering Triton USB audio interface. A similar procedure can be followed using other audio interfaces.

1. Connect the USB audio interface to the Windows 7 PC hosting the IMS-SIP software, and self-install any necessary drivers.
2. Connect the USB audio interface to the U8903B audio analyzer.
3. Verify that the Windows 7 master volume is set to maximum. (See notes in the Windows volume settings section of this document.)
4. Open the E6966B IMS-SIP server and client, and register the client with the server.
5. On the IMS-SIP client’s Configuration tab:
   a. Select the File Locations menu.
      i. Under Audio files > Test file name location, navigate to and open the
         AudioSample_70percent_-3.1dB_1kHzSine_16k.wav file.
   b. Select the Audio menu.
      i. Set Speaker to USB Audio CODEC.
      ii. Set Microphone to USB Audio CODEC.
      iii. Press Reset Levels (Note: Default settings are optimized to be close for the
           Acoustics Engineering Triton USB audio interface).
      iv. Select Play Local.
6. Measure the left channel line out voltage from the USB audio interface using the U8903B. Verify that the line out voltage is close to 775 mVrms or 1.09 Vpeak.
7. On the IMS-SIP client’s Configuration > Audio menu:
   a. Adjust the Volume > Speaker setting if needed (until a line out voltage of
      775 mVrms or 1.09 Vpeak is achieved). The volume slider can be moved with the
      PC’s mouse, with fine adjustments made via mouse clicks on either side of the
      slider control.
   b. Select Stop Local once adjustment is complete.
8. Set the U8903B generator to output a 1 kHz sine wave at 775 mVrms or 1.09 Vpeak into
    the USB audio interface line in.
10. Verify that the line out voltage measured by the U8903B is 775 mVrms or 1.09 Vpeak.
11. On the IMS-SIP client’s Configuration > Audio menu:
    a. Adjust the Volume > Microphone slider if necessary to optimize the level.
    b. Select Stop Loop Test once adjustment is complete.

Note: Volume setting resolution limitations within the Keysight IMS-SIP client and Windows mean that to achieve the best possible calibration it is necessary to make additional level offset fine adjustments in the U8903B. These additional fine adjustments can be used to compensate for Windows’ level setting resolution limitations.
U8903B configuration and results

PESQ and POLQA voice quality analysis are standard options within the U8903B test sequencer. These measurements can be run in isolation or as part of a wider suite of tests within the sequencer.

Configuration and analysis of results is straightforward. In the Voice Quality {Settings} menu shown below, the Reference File is selected and directed to play through one of the generator channels. One of the analyzer channels is then used to record the degraded file for comparison. Other settings such as bandwidth and level alignment are also selected in this menu.

Once the setup is configured, Run Control > [On/Off] on the front panel is used to start the measurement or test sequence. When the measurement is complete, the left and right arrow buttons are used to sweep through the various pages of results. The screen shown below shows the reference and degraded waveforms after time alignment.
The listening quality against time plot is shown below; this gives an indication of where things may have gone wrong. The overall MOS score is also shown in this page.

Finally, the Levels results page shows the levels of various aspects of the signal.
Delay budgets

Nominal delays have been measured as follows:

<table>
<thead>
<tr>
<th>Delay area</th>
<th>Delay duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog audio line in to Acoustics Engineering Triton to Keysight IMS-SIP voice codec</td>
<td>24 ms</td>
</tr>
<tr>
<td>AMR or AMR-WB voice codec encoding</td>
<td>32 ms</td>
</tr>
<tr>
<td>Ethernet RTP transmission delay from PC to PC via IPv6 router</td>
<td>1 ms</td>
</tr>
<tr>
<td>Ethernet to LTE RF transmission delay via IPv6 router and Keysight UXM</td>
<td>11 ms</td>
</tr>
<tr>
<td>AMR or AMR-WB voice codec decoding</td>
<td>32 ms</td>
</tr>
<tr>
<td>Keysight IMS-SIP voice codec to analog line out via Acoustics Engineering Triton</td>
<td>24 ms</td>
</tr>
</tbody>
</table>

Delays were measured with the Keysight E7515A UXM and Cisco RVS4000 router and confirmed to be consistent with two Windows 7 (32-bit) PCs, Core i5 2.53 GHz and Core 2 Duo P8600 2.4 GHz. (Delays may vary slightly with PCs with significantly higher or lower performance.)

Delay variation for an end-to-end call between two Keysight IMS-SIP clients varied nominally by less than ±10 ms. Larger delay variations can be seen during initial call setup and when PCs are being used to run other CPU-intensive applications. Jitter buffer effects will also increase delay if the IP path has high levels of jitter.
Third Party Software and Hardware

The third party hardware and software products listed in this section have been found to work effectively with the E6966B IMS-SIP server and client, and the E7515A UXM wireless test set. Third party products are listed as examples and it is likely that other similar products also will work effectively.

Keysight does not endorse the stability or performance of third party products, other than to cite that in initial interoperability testing the products have functioned as expected. Keysight is not responsible for supporting third-party products. Some of the products listed are Open Source GPL licensed and free. Other products can be purchased from the companies listed.

Keysight does not have financial relationships with the companies listed and does not benefit from users selecting the example products listed or other equivalent items.

Router configuration

Suggested router configuration:

1. Log in from Web browser on PC. Refer to router manual for assistance.
2. Set IP address (for example, 192.168.1.1).
5. Set IPv6 address (for example, 2001::1 (length 64)).
6. Enable router advertisements.

Cisco RVS4000 or equivalent IPv6 router has been used effectively. http://www.cisco.com/en/US/products/ps9928/index.html

PC line in/out interface

The Acoustics Engineering Triton USB audio interface has been used as a suitable PC sound card to interface the Keysight IMS-SIP client to external audio analyzers such as the U8903B. The audio interface is connected by USB to the PC hosting the Keysight IMS-SIP client. Drivers self-install. When the Keysight IMS-SIP client software is opened, the speakers (USB audio CODEC), and the microphone (USB audio CODEC), can be selected from the speaker and microphone lists in the Audio section of the Configuration tab. The Acoustics Engineering Triton is currently only supported by the Keysight IMS-SIP client with Windows 7.

SIM selection

The Keysight UXM and IMS-SIP client and server can be configured to operate with VoLTE UEs with a variety of SIMs loaded. Band 13 VoLTE 2014 devices can be operated conveniently using Gemalto W004v2 SIMs. These are available directly from Gemalto to users with a non-disclosure agreement (NDA) in place with Verizon Wireless. Contact Keysight to obtain Gemalto e-mail ordering information.
Wireshark

Wireshark is the industry-standard protocol logging and analysis tool. The software is freely available to download and install from [http://www.wireshark.org/](http://www.wireshark.org/).

Wireshark can be co-resident on Windows 7 PCs running the Keysight IMS-SIP client and/or server. Key applications of Wireshark include:
- Reviewing more detailed SIP/SDP message contents
- Analyzing RTP payload formatting and contents
- Logging SIP call flows
- Saving logs for offline analysis and de-bug

Traffic of interest can be selected by entering filters, for example *RTP, SIP, RTP,* or *SIP.*

Obtaining and preparing audio files

Sample speech files can be downloaded from the links below and many other online sources:
- ITU P.501 – [http://www.itu.int/net/itu-t/sigdb/genaudio/Pseries.htm](http://www.itu.int/net/itu-t/sigdb/genaudio/Pseries.htm)

Audacity is a free software tool than can be used to change sampling rates (to required 8 and 16 kHz), normalize volume levels, and assemble test sequences. Audacity can also synthesize tones and noise signals. [http://audacity.sourceforge.net/](http://audacity.sourceforge.net/)

Adding delay and jitter

Delay and jitter can be added into any of the cabled Ethernet connections in the system. This can be used for subjective assessments of audio and video quality for VoLTE UE-to-UE-calling and for subjective parametric assessments of audio quality for calls between a VoLTE UE and the Keysight IMS-SIP client.

ZTI’s NetDisturb software application has been tested to work with the Keysight IMS server and client. In principle, other delay and jitter tools could also be used with the system. NetDisturb can be purchased online from [http://www.zti-telecom.com/EN/NetDisturb.html](http://www.zti-telecom.com/EN/NetDisturb.html). At the time of writing, limited-time trial licenses are also available.

NetDisturb can be loaded on the same Windows 7 PC as the Keysight IMS-SIP server, or can be run on a separate PC connected into the LAN. The software requires two additional Ethernet ports be made available on the server (or another) PC. Additional Ethernet ports can be added conveniently with USB-to-Ethernet adaptors, for example USB 2.0 gigabit Ethernet adaptors from [www.plugable.com](http://www.plugable.com).

NetDisturb makes full use of two Ethernet ports, providing a bridged connection with programmable impairments. The bridged connection appears transparent to other PCs and instruments on the LAN. When in use by NetDisturb, two Ethernet ports are set to be invisible to Windows and other applications running on the PC.

NetDisturb includes a feature set to apply impairments:
- In one direction or both directions
- On specific protocol and packet types or all packets
- Statistical delays and jitter or constant delays and jitter

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Conclusion

The Keysight E6966B IMS-SIP network emulator software and E7515A UXM wireless test set make it easy to confirm VoLTE functional performance with end-to-end voice calls, voice echo, video calls, SMS, IMS registration and emergency calls, and supplementary services such as conference call and call waiting. To go beyond functional VoLTE testing, the addition of a Keysight U8903B performance audio analyzer and audio interface enables in-depth PESQ and POLQA voice quality testing.
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