

In-Service Video Quality Metric (IVQM) User's Manual

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handbook series

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IN-SERVICE VIDEO QUALITY METRIC (IVQM) USER'S MANUAL

Margaret H. Pinson and Stephen Wolf¹

The purpose of this handbook is to provide a user's manual for the in-service video quality metric (IVQM) tool. IVQM performs automated processing of live video signals. This program runs under the Windows XP or Vista[®] 32-bit operating system on two PCs communicating through an IP connection. IVQM performs image acquisition, temporal registration, other video calibration (spatial registration, spatial scaling, valid region, and gain/level offset), and video quality estimation.

IVQM compares the source video sequence to the destination video sequence (i.e., as output by the video system under test). Each program alternates between video capture and video analysis. Every source/destination video sequence pair is processed through three main steps. First, the sequences are buffered onto a hard drive. Second, the sequences are temporally registered. Third, the video quality of the destination video sequence is estimated. Quality estimates are reported on a scale of zero to one, where zero means that no impairment is visible and one means that the video clip has reached the maximum impairment level. Some video sequences may also be used to estimate other calibration values (spatial registration, spatial scaling, valid region estimation, and gain/level offset). The user has control over how often these other calibration values are calculated.

Key words: automatic measurements; digital video; end-to-end; in-service; metrics; objective video quality performance; video calibration; video quality

1 INTRODUCTION

The Institute for Telecommunication Sciences (ITS) has developed an automated in-service video quality metric (IVQM) software tool that performs automated processing of video signals. Most of the video quality measurement algorithms implemented by the IVQM software tool are described in detail in [1]-[4]. These algorithms include calibration of the sampled video streams (e.g., gain/level offset, spatial scaling, spatial

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registration, valid region estimation, and temporal registration), as well as the calculation of video quality parameters and models of overall quality perception. The purpose of this document is to provide a user's manual for the IVQM tool.

Program IVQM runs under the Windows XP or Vista 32-bit operating system and requires two PCs connected to an IP network. Each PC must have a video capture device. These devices must be compliant with Windows Driver Model (WDM), Video for Windows (VfW) or another driver interface supported by the MATLAB[®] image acquisition toolbox (for information on other driver interfaces see <http://www.mathworks.com/access/helpdesk/help/toolbox/imaq/imaq.html>).

The “source” PC will capture and process the source video sequence. The “destination” PC will capture and process the destination video sequence (i.e., as output by some video transmission system). The pair of computers will communicate results over an IP network connection. IVQM alternates between image acquisition (i.e., video capture) and video analysis. The video analysis requires significantly more time than does the video capture. Video quality results are plotted on a graph and also presented to the user in an ASCII text report. The video sequences themselves are discarded.

2 REQUIREMENTS

IVQM requires two computers, each meeting the following minimum criteria:

- 2 GHz Pentium
- Windows XP 32-bit, Service Pack 3, or Vista 32-bit, Service Pack 1
- 2 GB RAM
- 4 GB free disk space
- FTP server *or* shared directory
- WDM, VfW or other MATLAB supported video capture device
- Time synchronization program (for video delay estimates)

IVQM requires the use of two computers. Each computer must have in excess of 1 GB of free memory that is available for use by the IVQM application. Thus, a minimum of 2 GB of memory is recommended to meet this requirement. Each computer must have a local hard drive with a minimum of 4 GB free disk space. The speed of these disk drives will impact performance.

Warning: Insufficient disk space or computer memory will prevent IVQM from running successfully.

The two computers must be connected to a common IP network. The computers can coordinate activities using one of two methods. The first method is to utilize a shared directory. The second method is to transmit files using FTP. When communicating by FTP, both computers must have a local FTP server installed and running. The remote FTP clients must be able to read, write, and delete files using the local FTP server.

Each computer must have a compatible video capture device. The performance and specifications of the video capture device will impact the accuracy of the video quality estimates produced by IVQM. At a minimum, the video capture system should be able to capture video at full frame rates (e.g., 30 fps, 29.97 fps, 25 fps) for the desired spatial resolution. The capture device must be WDM or VfW compliant, or be otherwise supported by the MATLAB image acquisition toolbox. The video capture device must provide video to the PC in either the YCbCr [10] (i.e., YUV) or RGB color space. Use matched video capture devices on both computers (i.e., the same brand and model). Otherwise, IVQM will be measuring the difference in quality of the frame capture devices. These video quality metric (VQM) differences may be substantial (e.g., 0.25 VQM). Five video capture devices that meet these requirements are:

- Leadtek's "Winfast TV USB-2 Interface TV/FM Tuner Box"
- Leadtek's "Winfast TV USB II Deluxe"
- Hauppauge's "Impact VCB" part# 64405, model# 00558
- Hauppauge's "WinTV-USB2"
- Pixel Magic Systems "SDI Capture Card"

Devices that support uncompressed video capture utilizing the Brooktree (Bt) Bt848, Bt849, Bt878 and Bt879 chipsets may work if the WDM video capture driver at the following location is installed: <http://btwincap.sourceforge.net/> . If you identify a compatible video capture device other than those listed above, please let us know (vqm@its.bldrdoc.gov).

Each computer may alternately capture MPEG-2 video streamed over the network (e.g., Internet Protocol Television - IPTV). This requires the following:

- “IPTVInterface.dll”, a Dynamically Linked Library (DLL) from Acreo. This DLL and its corresponding source code is available at www.acreo.se/iptvinterface (the DLL also comes bundled with IVQM).
- An MPEG-2 codec that is compatible with IPTVInterface.dll. The MPEG-2 Decoding and Streaming Plug-in for WMP v 3.6 from Elecard (available at www.elecard.com) provides an example of a compatible codec.

If the user desires to obtain useful estimates of video delay, each computer must have a program for synchronizing the system clocks of the source and destination computers with a time standard. One tool that satisfies this requirement is the NIST Time Program [5].

MATLAB does not need to be installed on either computer. As part of the installation procedure, the MATLAB Component Runtime library will be installed (see Section 3).

As a final note, some web cameras are compliant with the video capture device interface. Although these cameras can be used to explore the setup screen, they cannot be used for actual video quality estimation. Unfortunately, the camera signal cannot be simultaneously routed to both the IVQM program and the video transmission system under test.

3 INSTALLATION PROCEDURE

The IVQM software was developed using MATLAB and its associated toolboxes. It is therefore necessary to install the MATLAB Component Runtime (MCR) library before running IVQM.

If a prior version of IVQM was installed, you must first uninstall the old version of the MCR library before proceeding. To uninstall the old version of the MCR library, select “Start,” “Settings,” “Control Panel” and then double-click on “Add or Remove Programs.” Find the MATLAB Component Runtime library in the list of programs and select “Remove.”

Follow this installation procedure for IVQM:

1. Copy the files on the IVQM installation CD to a directory on your computer. This directory will be denoted as c:\ivqm for the rest of the installation instructions given below.
2. Double click MCRInstaller.exe in c:\ivqm and follow the instructions to install the MCR library on your computer.
3. After completing installation, check to make sure that the MCR library installed properly. From the “Start” menu, select “Control Panel,” and in the window that appears, double-click “Add or Remove Programs” and see if the MATLAB Component Runtime library appears in the list of installed programs. If not, repeat step 2.

4 OPERATIONAL OVERVIEW

4.1 Before Starting IVQM

Before starting IVQM, synchronize the clock of your computer with a time standard using a utility such as the NIST Time Program [5]. This action should be performed immediately *prior* to starting IVQM. This synchronization is necessary for IVQM to correctly display the video system's delay to the screen. The time synchronization should be performed multiple times for greater accuracy, to be certain that the computer's internal clock is correctly synchronized with a time standard. If the system clocks are not synchronized, the only impact to IVQM will be inaccurate reporting of the end-to-end video delay.

4.2 Starting IVQM

Open a command prompt window by selecting "Start," "All Programs," "Accessories," "Command Prompt." Change to the c:\ivqm installation directory in step 1 of section 3 by typing "cd c:\ivqm" at the command prompt. Alternately, you may set up your command window to start in directory c:\ivqm.

To start the IVQM software, type "ivqm" at the command prompt. The IVQM software will start and display the screen shown in Figure 1. The warning message is normal and will not affect the performance of the IVQM software. See Section 4.1 before starting the IVQM software.



Figure 1. Snapshot of initialization screen.

Note: After starting IVQM at a command prompt, please wait patiently for the initialization screen to appear. IVQM needs to load several dynamic linked libraries into memory.

Program IVQM shares tasks between the two computers. One of the two computers will be the master, while the other computer will be the slave. Some user interface controls are only available on the master computer (e.g., video quality model selection). The slave computer will receive these settings from the master computer. Other user interface controls must be set on each computer separately (e.g., how to communicate with the other computer). The video quality analysis displayed to the user will be identical on both computers.

Figure 1 shows a snapshot of the initialization screen presented to the user when IVQM starts. At this point, the user must select two choices using radio buttons: (1) master or slave, and (2) source or destination (video). When the options are set for one computer, the complimentary options must be selected for the other computer (i.e., if one computer is the master / source computer, then the other computer must be the slave / destination computer). Once these choices have been made, press the “start” button on each computer.

Note: After pressing the “start” button, please wait patiently for the setup screen to appear. IVQM needs to examine all video capture options, and this might take several minutes.

4.3 Setup Screen

The setup screen may be reached by pressing “start” from the initialization screen, or selecting “setup” from the Edit menu option on the monitoring screen. The master setup screen is divided into four sections (see Figure 2) and the slave setup screen is divided into two sections (see Figure 3). All of the items in Figure 2 and Figure 3 are explained in Sections 4.3.1, 4.3.2, 4.3.3, 4.3.4 and 4.3.5.

Most of the options on the setup screen are selected using pull-down menus. Each pull-down menu has a small gray down-arrow on the right hand side. Selecting the pull-down menu will present the user with a list of the available options. All other user inputs to the setup screen are text boxes. The keyboard shortcut “<CTRL>v” may be used to paste text into these text boxes.

Throughout this section, the two computers will be referred to as the “local” and “remote” computers. The local computer is the computer where setup is being performed, and the remote computer is the other computer.

Set-Up for In-Service VQM

End-to-End Communication Medium

FTP

Local FTP Site Path:
c:\ftp\ivqm

FTP Host:
ivqm1.its.bldrdoc.gov

FTP Username:
anonymous

FTP Password:

FTP sub-directory:
ivqm

Validate FTP Communication

Video Source

Video Capture Device

Video Capture Device:
WinFast TV USB II

Image Size & Color Space:
YUY2_720x480

Video Source:
composite

Capture Interlaced or Progressive:
Interlace, upper field first

Directory for Temporary Storage:
C:\temp\

Preview Video Stream

Calibration

Combined Temporal Registration Uncertainty
3 sec

Delay Between Source & Destination Capture
0 sec

Scale, Shift, Gain/Offset & Valid Region
Calculate at the beginning & combine all results

Number of Sequences Used:
7 sequences

Video Quality Model

Low Bandwidth Model

Video Sequence Length

10 sec

Accept Setup

Figure 2. Snapshot of setup screen, master computer.

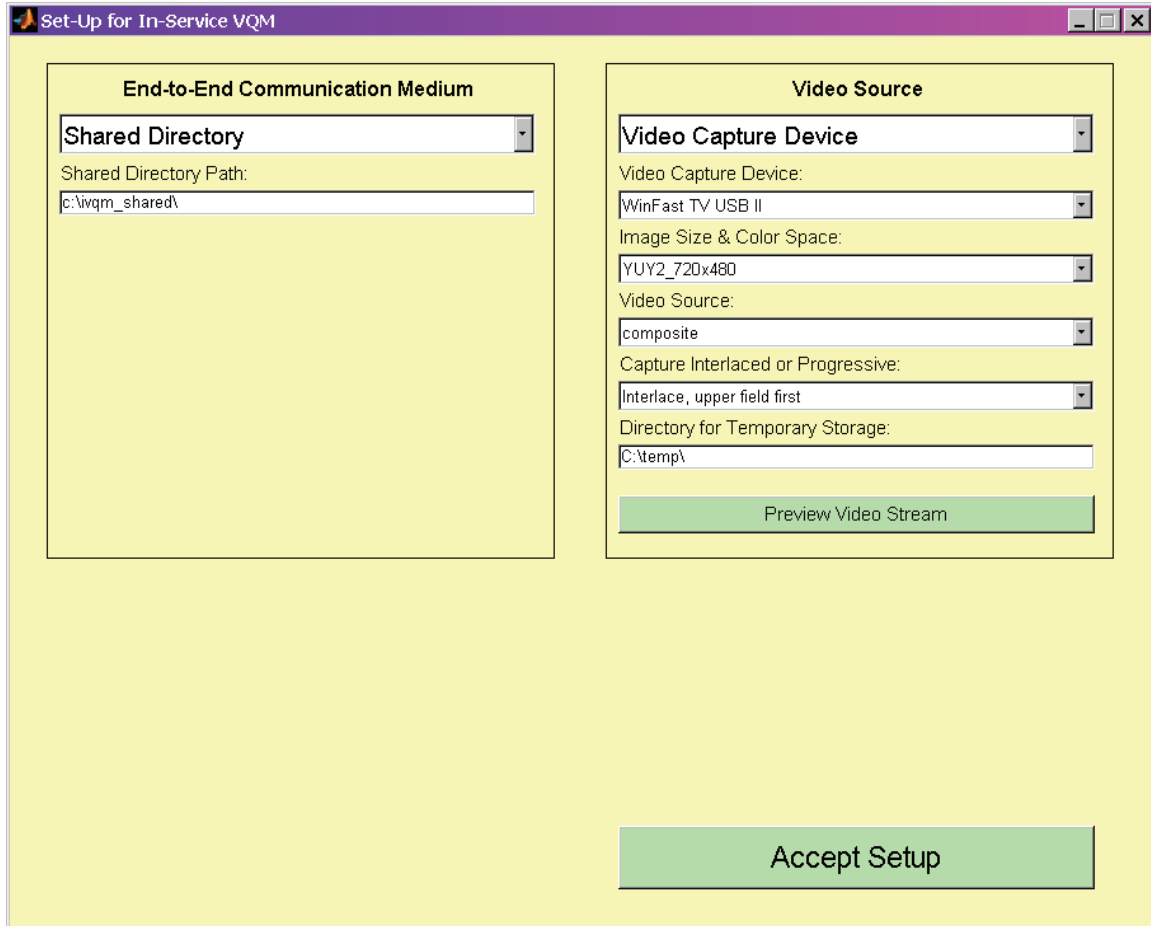


Figure 3. Snapshot of setup screen, slave computer.

4.3.1 End-To-End Communication Medium

There are two possible choices for end-to-end communication between the two computers. When communicating through a shared directory, the user has only to specify the shared directory path. The drive holding this shared directory must have several gigabytes of free space.

When communicating through FTP, the user must specify the following five pieces of information:

1. **Local FTP Site Path.** The directory path to the local FTP site's directory where the remote computer will be writing data. The drive holding this directory should have several gigabytes of free space.
2. **FTP Host.** The remote computer's FTP Host (e.g., name or address).
3. **FTP Username.** The username that should be entered to establish an FTP connection. For anonymous FTP, enter the username "anonymous."

4. **FTP Password.** The password associated with the above username. This field should be left blank if there is no password for the remote computer's FTP account (e.g., anonymous FTP).
5. **FTP Sub-Directory.** After connecting to the remote computer's FTP host, change to this sub-directory. If no change of directory is required, then this field should be left blank.

When all of the above five options have been specified, press the "Validate FTP Communication" button to check the FTP connection. This is an optional check. The same validation will be performed when the "Accept Setup" button is pressed.

4.3.2 Video Source

The choices for video source will depend upon the number of compliant devices available on your computer. Any device listed has met some – but perhaps not all – of the compliance criteria. To run using a video capture device, select the "Video Capture Device" option. If no compatible video capture devices are available on your system, then this option will not be available. The alternate choices for video source are "Validation File" and "IPTV Interface."

When capturing video, the user must specify the following five pieces of information. Start at the top, with "Video Capture Device," and work down. The first four pieces of information are interdependent, so changes may automatically modify other values.

1. **Video Capture Device.** The name of the video capture device, as reported to the computer by the device driver. All compliant video capture devices will be listed on the pull-down menu. **Warning:** Use matched video capture devices on both computers (i.e., the same brand and model). Otherwise, IVQM will be measuring the difference in quality of the frame capture devices. These differences may be substantial (e.g., 0.25 VQM).
2. **Image Size & Color Space.** Select the correct format information for the incoming video signal. Sometimes the driver will report this in terms of image size (e.g., 720x480) and color space (e.g., RGB). The strings used here are reported directly from the video capture device's driver. **Warning:** The image size selected must be identical on source and destination computers. Use the same color space on both computers, so that any color space conversion errors are introduced equally in both source and destination video sequences. YUV is the preferred color space for video capture (e.g., "YUY2" or "YUV" or "UYVY").
3. **Video Source.** If your device has multiple input video stream options, select the appropriate port. The strings used here are reported directly from the video capture device's driver.
4. **Capture Interlaced or Progressive.** The IVQM program initializes this field with the current best guess based upon the image size specified above.

Unfortunately, the device driver does not report this required information directly. After specifying this (and the above three options) the user is strongly encouraged to press the “Preview Video Stream” button to check the validity of this setting. The options available are “interlace, lower field first,” “interlace, upper field first,” and “progressive.” The interlace options are for video displays which separate each frame into two fields and alternately update each field; the progressive option is for systems that update the entire frame simultaneously. **Warning:** This option must be set identically on both source and destination computers.

5. **Directory for Temporary Storage.** The IVQM program requires up to 2 GB of disk space to buffer video sequences. Run speed will be impacted by the speed of the hard drive containing this directory.

When all of the above five fields have been entered, press the “Preview Video Stream” button to display a short sample of the selected video stream in a separate window. If “Capture Interlaced or Progressive” is progressive, the video will be played back one frame at a time. If “Capture Interlaced or Progressive” is interlaced, the video will be played back one field at a time using field freeze (i.e., one field is copied into both fields of the displayed frame). IVQM will beep and pause one second after displaying each field or frame. The preview window may be manually closed at any time and will be automatically closed when the “Accept Setup” button is pressed.

This “Preview Video Stream” button demonstrates whether or not the video capture device will operate as intended (e.g., whether the video capture device is fully compliant and capturing the video signal correctly). Pressing the “Preview Video Stream” button can be used to validate the “Capture Interlaced or Progressive” flag. If an interlaced / field freeze playback sequence appears to jump backwards in time, change from lower field first to upper field first (or vice versa).

One alternate choice for video source is “Validation File.” This run mode is intended for validation purposes *only*. Full functionality of the IVQM program is only available when using a compliant video capture device. When running from a validation file, enter the full path and name of the validation file.

The third choice for video source is “IPTV Interface.” This run mode captures MPEG-2 internet video streams. When capturing video, the user must specify the following two pieces of information.

1. **IPTV Address and Port Number (e.g., 224.1.1.1:1234).** The internet address of the MPEG-2 video stream to be captured.
2. **Directory for Temporary Storage.** The IVQM program requires up to 2 GB of disk space to buffer video sequences. Run speed will be impacted by the speed of the hard drive containing this directory.

When both fields have been entered, press the “Preview Video Stream” button to display a short sample of the selected video stream in a separate window. This functionality operates as described above. The only difference is that the IPTVInterface library will display the video as it is captured in a separate pop-up window, prior to IVQM’s playback in the preview window. Do not close the IPTVInterface library’s pop-up window – this window is essential to that library’s operation, and will close automatically.

4.3.3 Calibration

The accuracy of IVQM is significantly impacted by the accuracy of the calibration estimates. Therefore, care should be taken when selecting the calibration options.

The accuracy of calibration estimates can be improved significantly by combining calibration estimates from several different sequences. The automated calibration algorithms have been optimized for fast run-speed and lower bandwidth. The cost of this optimization is a slight decrease in accuracy. To compensate, we highly recommend choosing to run the optional calibration algorithms and to combine the results from multiple video sequences. See [4] and [9] for details on the automated calibration algorithms.

Calibration options are only available on the master computer.

4.3.3.1 *Combined Temporal Registration Uncertainty*

This option specifies the maximum delay uncertainty of the video transmission system, *plus* the maximum delay uncertainty of the end-to-end IP communication between the two computers. This uncertainty is increased by the random nature of coordinating a “record video now” request between two computers with independent clocks via an IP communication channel. The “combined temporal registration uncertainty” will be used together with the “delay between source & destination capture” (see Section 4.3.3.2) to synchronize video capture at the source and destination computers.

The combined temporal registration uncertainty determines the search window that is examined to temporally register the source and destination video sequences. This must be done every time a video sequence is captured. If the correct temporal registration lies outside of the uncertainty searched, then accurate video quality estimations cannot be calculated since the source and destination video streams cannot be temporally registered. However, there are drawbacks to choosing a too-large value. As uncertainty increases, IVQM will require longer periods of time and more memory to estimate video quality, as additional video must be captured to allow for the temporal registration uncertainty.

4.3.3.2 Delay Between Source & Destination Capture

This pull-down menu specifies a known delay through the video transmission system. The known delay will be associated with the combined time taken by coding, transmitting, and decoding the video sequence. This pull-down menu is by default zero seconds. Larger values are appropriate for a system where the user knows the delay through the system under test is large (e.g., 15 seconds) and thus the combined temporal registration uncertainty (Section 4.3.3.1) cannot be made large enough to include the known delay. When this menu is set to a non-zero value, the destination capture will begin approximately this number of seconds after the source capture.

4.3.3.3 Scale, Shift, Gain/Offset & Valid Region

This pull-down menu specifies how often IVQM will estimate the calibration values (i.e., other than temporal registration). These calibration algorithms estimate spatial scaling, spatial shift, luminance gain & offset, and valid video region. Spatial scaling detects transmission systems that spatially stretch or shrink the video picture. Spatial shift detects transmission systems that shift the video spatially (e.g., up or down). Luminance gain & offset are equivalent to detecting changes in the contrast and brightness of the destination video with respect to the source video. Valid region estimation eliminates the edges of captured video signals that do not contain valid picture information.

The above calibration values are normally constant for any given video transmission system. Any time-varying deviations from the overall, constant value are considered impairments. For example, if the spatial shift were to change dynamically over time, the video picture would appear to bob up and down. Because these calibration values are normally constant for a given video system under test, more accurate estimates can be obtained by combining calibration results from multiple video sequences.

Currently, there are six calibration options, listed below. Items to consider when selecting the calibration option include prior knowledge of the calibration parameters for the video system under test, the amount of IP bandwidth that is available to transmit the calibration information (i.e., calibration requires approximately 2 Mbits/sec for each video sequence that is calibrated), and whether or not the calibration parameters for the system under test are changing. The “scale, shift, gain/offset & valid region” calibration options are:

1. **Do not calculate.** Do not estimate the above calibration parameters. IVQM will run faster when this option is selected. However, the accuracy of the video quality estimations will be negatively impacted if the video system under test has calibration problems.
2. **Calculate at the beginning & combine all results.** The calibration parameters will be calculated using the first few video sequences captured. These results will be combined to form more accurate estimations, which will be applied to all later sequences. The number of results to be combined must also be specified, using

the “Number of Sequences Used” pull-down menu. Greater calibration accuracy should result when more sequences are used. This mode is preferred when watching the performance of a single transmission system over a long period of time.

3. **Calculate periodically & combine all results.** The calibration parameters will be calculated at a set interval (e.g., every 15 minutes). All results will be combined to form more accurate estimations. Thus, the longer IVQM runs, the more accurate the calibration will become. The interval must be set using the “Calculate Every” pull-down menu.
4. **Calculate periodically & combine last 9 results.** The calibration parameters will be calculated at a set interval (e.g., every 15 minutes). The last 9 results will be combined to form more accurate estimations. Thus, if the transmission system under test is changed, the calibration values will slowly converge to the new system’s calibration values. The interval must be set using the “Calculate Every” pull-down menu. This mode would be preferred when watching the performance of a transmission system that may change dynamically (e.g., from MPEG-2 to MPEG-4).
5. **Calculate periodically & combine last 3 results.** The calibration parameters will be calculated at a set interval (e.g., every 15 minutes). The last three results will be combined to form more accurate estimations. Thus, if the transmission system under test is changed, the calibration values will quickly converge to the new system’s calibration values. The interval must be set using the “Calculate Every” pull-down menu. Since only three video sequences are used to estimate calibration quantities, calibration estimates will be less accurate than the “combine last 9 results” option. However, IVQM will adjust faster to system changes.
6. **Calculate periodically and discard previous results.** The calibration parameters will be calculated at a set interval (e.g., every 15 minutes). All previous calibration results will be discarded. Thus, if the transmission system under test is changed, the calibration values will adjust to the new system’s calibration values as soon as the interval has passed. The interval must be set using the “Calculate Every” pull-down menu. Since only *one* video sequence is used to estimate calibration quantities, calibration values may occasionally be erratic (e.g., the accuracy of some calibration algorithms is sensitive to scene content).

The selected calibration option criteria will apply from the time “start” is pressed on both the master and slave computers, until “stop” is pressed on *either* the master or slave computer. See Section 5.6 for more information on starting and stopping cycles.

4.3.4 Video Quality

Video quality model options are only available on the master computer.

4.3.4.1 Video Quality Model (VQM)

Four video quality models are currently available.

1. **Developer's Model.** The Developer's Model minimizes CPU usage. This model requires about 1.2 Mbits/sec of IP bandwidth for 525-line / NTSC video sequences. The Developer's Model is fully documented in [1].
2. **General Model.** The NTIA General Model has been standardized by ANSI (ANSI T1.801.03-2003 [6]) and included in two ITU Recommendations (ITU-R BT.1683 [7] and ITU-T J.144 [8]). The General Model takes about 6 times longer than the Developer's Model to run and requires about 14 Mbits/sec of IP bandwidth for 525-line / NTSC video sequences. The NTIA General Model is also fully documented in [1] and summarized in [2].
3. **Low Bandwidth Model.** This model minimizes the IP network bandwidth, requiring approximately 10 kbits/sec bandwidth for 525-line / NTSC video sequences. The run-speed of this model is comparable to that of the General Model. An overview of the Low Bandwidth Model is given in [3].
4. **Fast Low Bandwidth Model.** This variant of the Low Bandwidth Model minimizes CPU usage.

The bandwidth of the IP network used to support end-to-end communication should be considered when choosing a model. The above bandwidth rates must be multiplied by the video sequence length (e.g., 10 seconds) to give the total bits to be transmitted for each captured video sequence. IVQM is not a real-time system. The speed of computing the requested VQM (Developer's, General, Low Bandwidth, and Fast Low Bandwidth) for a captured video sequence will depend upon the speed of the computer as well as the time required to transmit the features over the IP connection.

4.3.4.2 Video Sequence Length

This pull-down menu specifies the length of the video sequence used to estimate the selected VQM. The actual video capture will grab that length *plus* twice the combined temporal registration uncertainty selected in section 4.3.3.1. However, the VQM calculation will only utilize the length of video sequence specified by this pull-down menu.

4.3.5 Accept Setup

When you are satisfied with the setup options, press the “accept setup” button. IVQM will then check the validity of the setup information, including the video capture system’s operation and the communication medium’s availability. These checks will take several seconds. If a problem is found, this problem must be fixed before proceeding. If no problems are found, the setup screen will disappear and the user will be presented with the main IVQM screen.

Warning: While checking the setup, IVQM will perform a sample video capture to verify that the video capture device can capture video at full frame rate. If the capture frame rate (as measured by the video capture device) corresponds to a standard video frame rate, then IVQM will proceed to the monitoring screen. If IVQM detects a non-standard frame rate (e.g., 27.794 frames per second), IVQM will report this error and return to the setup screen. Usually, a non-standard frame rate indicates a slow video capture device. However, occasionally a video capture device that meets the full video frame rate capture benchmark will fail – perhaps due to the presence of other programs running on the computer. See Section 6, issue #2.

5 IVQM MONITORING SCREEN

Figure 4 depicts the IVQM monitoring screen on the master computer, and Figure 5 depicts the IVQM monitoring screen on the slave computer. On the time history plot, a green dot indicates correct operation, and a red dot indicates that one or more failed video capture events occurred between the previous and current VQM data points. The IVQM monitoring screen contains a menu bar, a time history plot of the selected VQM (Developer's, General, Low Bandwidth, and Fast Low Bandwidth), three sample frames from the last video capture (first, middle, and last), a text box listing detailed results, two buttons ("Start VQM" and "Stop VQM"), and a status bar at the bottom of the screen.

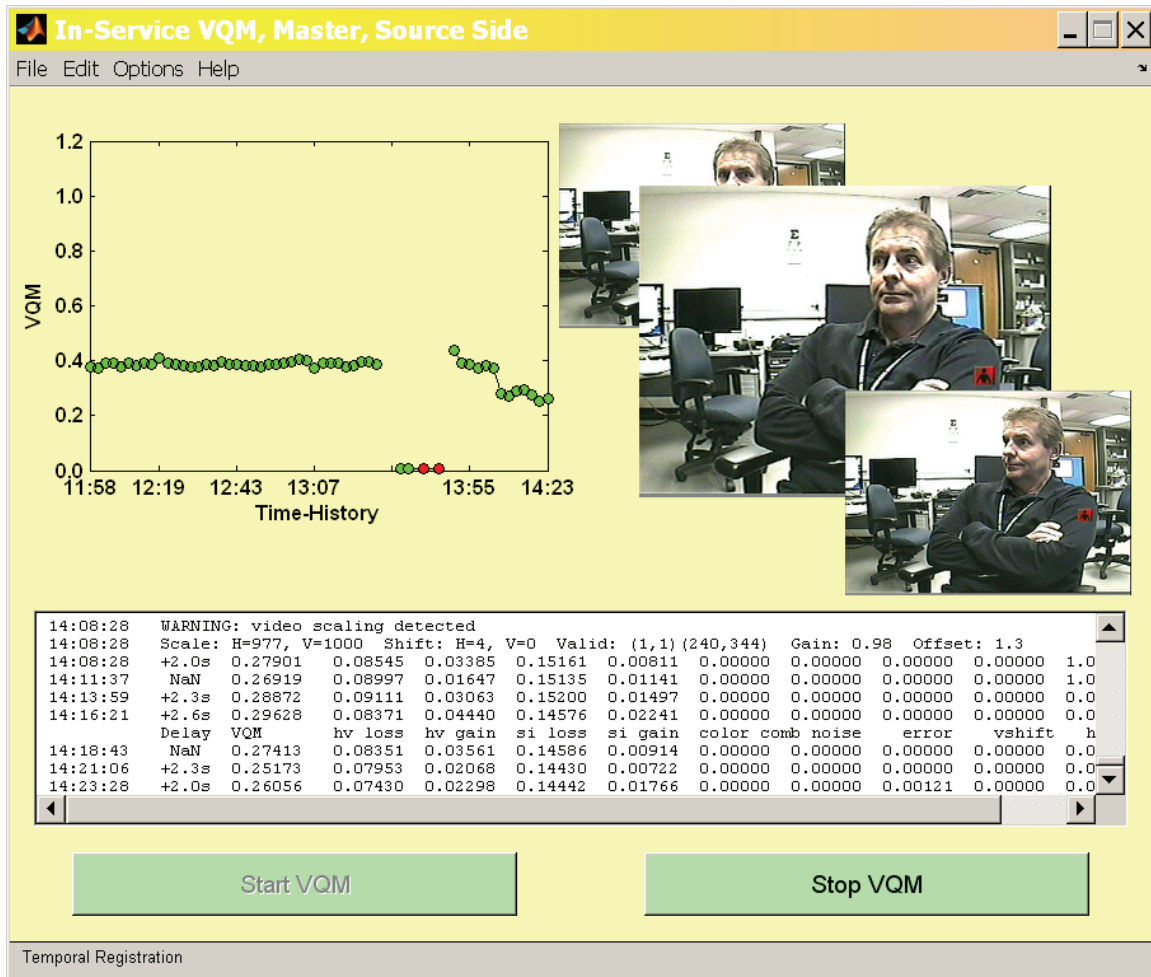


Figure 4. Snapshot of IVQM monitoring screen, master computer.

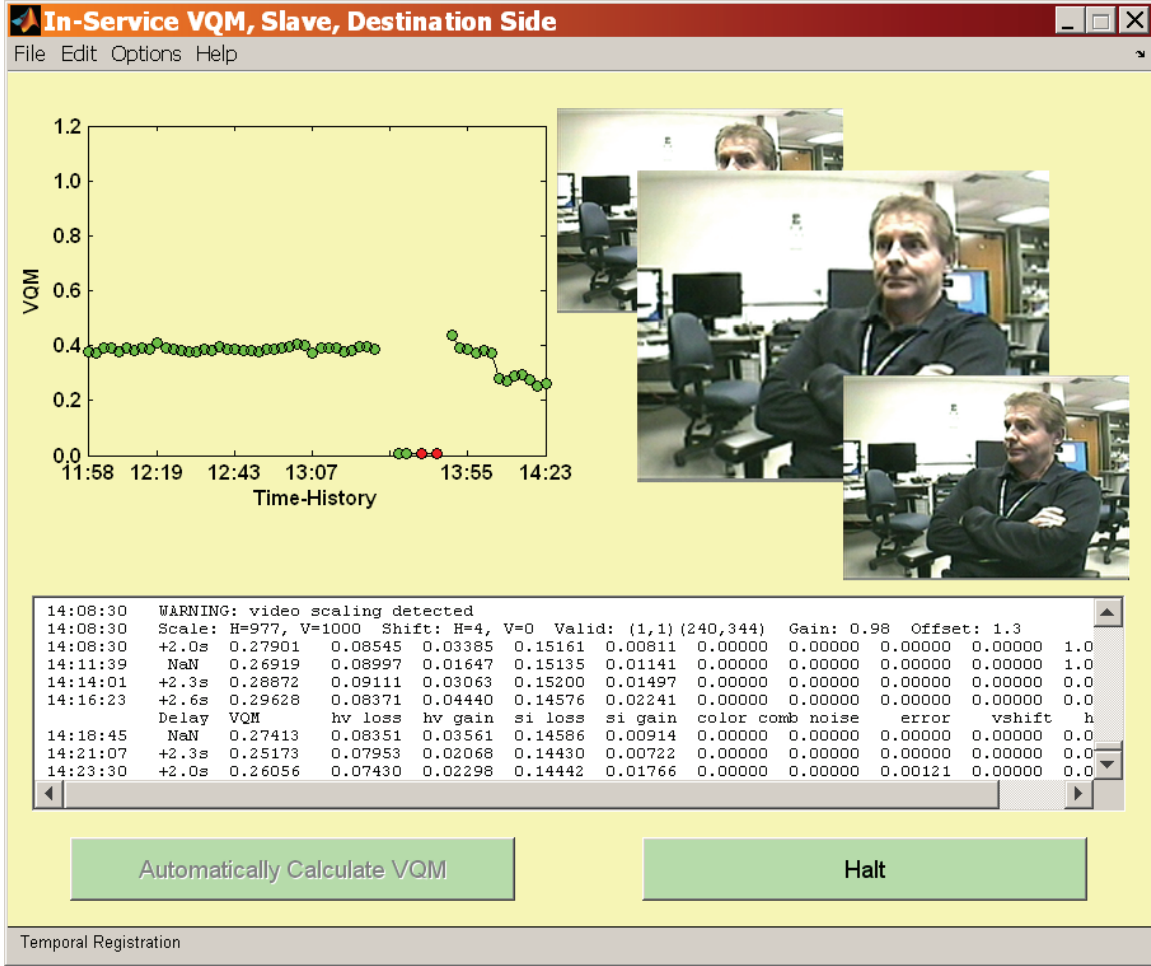


Figure 5. Snapshot of IVQM monitoring screen, slave computer.

5.1 Time History Plot of VQM

The upper left-hand corner of the monitoring screen contains a time-history plot of VQM scores. Quality estimates are reported on a scale from zero to one, where zero means that no impairment is visible and one means that the video clip has reached the maximum impairment level. The capture time of the sequences is displayed on the X-axis. Missing line segments between VQM values (red dots) indicate that the user stopped and then re-started the video quality estimation process. Calibration values and setup parameters may also have changed at those points.

5.2 Frames from Last Video Capture

Video frames from the last capture are displayed in the upper right-hand corner of the monitoring screen. IVQM displays the first, middle, and last frame captured. Please remember that the video segment captured includes twice the combined temporal registration uncertainty. Thus, only a portion of the captured sequence will be used to

estimate quality. The purpose of this display is to provide the user feedback about the video capture device's performance and the actual video segment used to estimate quality.

These frames will not be displayed when IPTV Interface is used to capture video from a network stream. In that case, a separate pop-up window will display the streaming video during capture.

5.3 Text Box Depicting Results

The bottom third of the monitoring screen contains a scrolling text box listing results. When IVQM starts monitoring, the setup of both master and slave computers will be displayed in this box. During operation, the box will be updated to list current calibration values and VQM estimates.

The calibration values will be listed only when they are updated. The calibration values will be preceded by the time at which the video capture occurred, according to the local computer's internal clock. These are the *combined* calibration results, calculated using the formula selected during setup (see Section 4.3.3.3). This formula is applied to video captured between the last press of the "Start" button on the master computer and the present time. The name of each calibration value is abbreviated to save space, as follows:

- **Scale: H=#, V=#** – The number following "H" indicates the horizontal spatial scaling factor with respect to 1000. The number following "V" indicates the vertical spatial scaling factor with respect to 1000. Numbers less than 1000 indicate that the destination video is stretched; numbers greater than 1000 indicate that the destination video is shrunken. A spatial scaling factor of 1000 indicates no spatial scaling. The fractional amount of stretching or shrinking is the reported value divided by 1000. See [4]. The calculation of spatial scaling is by default disabled and can be enabled using Menu Options (see Section 5.5).
- **Shift: H=#, V=#** – The number following "H" indicates the horizontal spatial shift, in pixels. Positive numbers indicate that the destination video is shifted to the right; and negative numbers indicate that the destination video is shifted to the left. The number following "V" indicates the vertical spatial shift, in *frame* lines. Positive numbers indicate that the destination video is shifted down; and negative numbers indicate that the destination is shifted up. For interlaced video signals, an odd number indicates re-framing. See [1].
- **Valid: (#_U,#_L)(#_B,#_R)** – These four coordinates identify the estimated valid region of the video signal. The coordinates (#_U,#_L) indicate the upper left coordinate, and (#_B,#_R) indicate the bottom-right coordinate. Numbering starts at (1,1) for the upper left-most pixel, and all coordinates are included in the valid region. These coordinates are reported with respect to the source video sequence's coordinates (i.e., after correcting for spatial scaling and shifting).
- **Gain: # Offset: #** – Luminance gain and offset estimates. Gain is like contrast; and offset is like brightness. Gain is a multiplicative factor centered on one that will usually fall between 0.9 and 1.1. Gain values greater than one indicate that

the destination video has a wider range of luminance values than the source video; and gain values less than one indicate that the destination video has a more narrow range of luminance values. Offset is an additive factor that will usually fall between -15 and +15. Offset values greater than zero indicate that the destination video is brighter than the source video; and offset values less than zero indicate that the destination video is dimmer.

The VQM estimate will be listed for every video capture. The following three values will always be displayed: time, delay, and VQM. At the beginning of the line will be reported the time at which the video capture occurred, according to the local computer's internal clock. The second value reported will be the delay through the video transmission system. The third value reported is the VQM that was calculated using the model selected in Section 4.3.4.1. If the user optionally requested parameter values, then the individual quality parameters comprising the current VQM will also be listed.

Special care should be taken when examining the delay through the video transmission system. The accuracy of this number depends entirely upon the accuracy of the synchronization of each computer's clock to a time standard *prior* to starting IVQM. Small transmission delays do not necessarily justify reducing the combined temporal registration uncertainty in Section 4.3.3.1 since this number also includes the maximum IP communications delay.

Occasionally, the automated temporal registration algorithm cannot estimate delay. This may, for example, occur when the video sequence being examined contains no motion or very little motion. In this event, the transmission delay will be reported as NaN (Not A Number) and IVQM will default to the last valid video transmission delay estimate.

Occasionally, IVQM will detect and report unusual events. Possible events include: dropped frames detected during frame capture (i.e., computer failed to capture video at full frame rate), excessive white level clipping, excessive black level clipping, scaling search limit exceeded, spatial shift search limit exceeded, and luminance gain & offset search limit exceeded. Any potential influence of the event on VQM accuracy will be included in the on-screen report.

5.4 Status Bar

The bottom of the monitoring screen is devoted to a gray status bar. When IVQM is monitoring video quality, the text in this gray bar will be updated with the current status and operations that are being performed.

5.5 Menu Options

Due to the demanding and complex algorithms being performed, the menu options may be difficult to select while monitoring a system.

On the “File” menu, the user has the option of exiting IVQM. The user also has the option to “Save Results As...” The latter choice brings up a window where the user may specify a text file name. The contents of the results text box will be saved to the specified file.

From the “File” menu of the master computer, the user can request that the video sequences be saved to disk. Video sequences will be saved on both source and destination computer. Video files will be written to the directory for temporary storage (see Section 4.3.2, item 5), using automatically generated file names based upon the master computer’s video capture time. Select “Save Current Video to AVI” to save the video sequence currently being processed in uncompressed AVI file format. Select “Save Current Video to UYVY” to save the video sequence currently being processed in uncompressed big-YUV file format (see [1] for a definition of the big-YUV file format). Select “Save Last Video to AVI” to save the previous video sequence (i.e., associated with the last VQM score) in AVI file format. Select “Save Last Video to UYVY” to save the previous video sequence in big-YUV file format.

On the “Edit” menu, the user has the option of returning to the setup screen (“Setup...”). This option will only be available when IVQM is *not* monitoring a video system. The user also has the option to “Clear Results Screen.” This will erase the contents of the results text box (see Section 5.3).

On the “Options” menu, the user has the option to “View Parameters.” Selecting this option will cause the individual parameters comprising the current model to be reported in the results text box, along with the VQM. See the models’ technical descriptions for a listing of the parameters that comprise the selected model [1]-[3]. On the “Options” menu, the user also has the option “Estimate Spatial Scaling.” This option is available only on the Master computer. When “Estimate Spatial Scaling” is checked, IVQM will estimate and remove spatial scaling (e.g., horizontal stretch) in the destination video.

On the “Help” menu, the “About...” option will display the version of IVQM being utilized.

5.6 Buttons

The operation of the two buttons differs slightly between the master and slave computers. The names on the buttons differ to remind the user of this difference.

On the master computer, the two buttons are “Start VQM” and “Stop VQM.” These buttons start and stop monitoring, respectively.

On the slave computer, the two buttons are “Automatically Calculate VQM” and “Halt.” The “Automatically Calculate VQM” button causes the slave to start and stop monitoring whenever the master computer’s buttons are pressed. The “Halt” button causes the slave to stop any current monitoring cycle (i.e., stop both the master and slave). Also, the slave computer will not re-start monitoring until the “Automatically Calculate VQM” button is pressed.

The program may take a while to stop the monitoring cycle after the “Stop VQM” or “Halt” button is pressed. The status of the buttons will indicate what is happening. For example, when “Stop VQM” has been pressed, the button text will be grayed out and that button will become non-responsive.

Thus, as long as the video capture and end-to-end communications options remain constant, monitoring can be controlled from the master computer with only limited input to the slave computer.

6 KNOWN ISSUES, BUGS, AND DEFECTS

Following is a list of the known issues in the IVQM software.

1. Out of Memory. Insufficient memory (e.g., less than 1 GB free system memory) will cause IVQM to fail in an awkward manner, without any proper failure notice. This will usually occur *after* IVQM starts monitoring a system and *prior* to the first VQM estimation. Modifying your computer's memory usage performance options may increase the amount of contiguous memory available to IVQM. To perform this modification, do the following. Right-click on "My Computer," select "Properties," and on the "System Properties" window that appears, select the "Advanced" tab. On that window, press the "Settings" button in the "Performance" section. Then in the "Performance Options" window that appears, select the "Advanced" tab. In the "Memory usage" section, select "System cache" and press "OK" and reboot your computer.
2. Video Capture Device Cannot Operate at Full Video Frame Rates. Occasionally, a video capture device that has worked perfectly will not be able to capture video at the full frame rate. Thus, when examining 525-line / NTSC video at 29.97 fps, the video capture device might only be able to capture 19.38 fps. IVQM will detect this problem when checking the setup validity (see Section 4.3.5) and after capturing video sequences for IVQM analysis. The IVQM software performs a check on each captured sequence to ensure that there were no dropped frames. If dropped frames are detected, a re-capture is initiated by the IVQM software. Occasional dropped frames are normal behavior for many video capture devices. However, if dropped frames are detected on every captured video sequence, there may be a bug or defect somewhere in the video capture device, device driver, or operating system. Please exit IVQM and reboot the computer to see if this resolves the issue. If the problem persists, replace the video capture device or check for an updated device driver.
3. Different Video Capture Devices on Source and Destination Computers. If at all possible, use matched video capture devices on both computers (i.e., the same brand and model). Otherwise, IVQM may be measuring the difference in quality between the two video capture devices. The impact on reported VQM values may be substantial (e.g., 0.25 VQM). If you suspect this may be an issue with your test setup, do the following test. Route identical video to both source and destination computers, and monitor quality at the largest possible image resolution with calibration selected. This setup will analyze the differences between the two video capture devices. If the resulting IVQM is higher than 0.1 on any of the time history points after calibration is completed (depending upon the calibration options selected, this might require several IVQM sequences to be analyzed), one of your video capture devices should be replaced.
4. Video Capture Device Compatibility. IVQM was developed to be compatible with multiple video capture devices. However, we have had limited success

locating compatible video capture devices that can capture at full uncompressed video frame rates. If you identify a compatible video capture device other than those listed in this documentation, please let us know (vqm@its.bldrdoc.gov).

5. System Time. Due to a defect in the underlying software used to develop the IVQM tool, the delay estimation ignores changes to system time after IVQM starts. Thus, the delay estimates will steadily become less accurate as IVQM operates.
6. Master / Slave Coordination. When beginning monitoring, the master & slave computers perform limited cross checks on the setup configurations. Thus, for example, the user must be careful to select identical video capture sizes on both systems.
7. IVQM Cannot Operate on Stored Video Files. IVQM is not designed for processing stored video files that contain the original and processed video sequences. The video source YUV file option that appears on the setup screen is intended solely as a diagnostic and validation tool.
8. QCIF & QSIF Not Supported. IVQM does not support QCIF and QSIF image sizes. Video stream resolution must be at least 320 pixels x 240 lines. The VQM models are not intended to be used on these smaller image resolutions.
9. Calibration Duration Erratic. The automated calibration will sometimes run faster and other times run slower. This is expected behavior.
10. Delay Experienced After Pressing Stop. When the user presses the “stop” or “halt” button, IVQM will often take quite a while to respond. The remote system may take significantly longer to halt than the local system. Please be patient. Multiple button presses will not speed up this process and may cause IVQM to malfunction.
11. Manual Crash Recovery. If IVQM aborts due to a software or hardware bug, then the user should manually erase all files in the transmission communications directories (i.e., the shared or FTP directories on source and destination computers). Failure to erase the contents of these directories prior to restarting IVQM may result in unpredictable behavior.
12. “Save As” File Incompatible with Notepad. The text file produced by the “Save As” option on the “File” menu is not formatted properly by the Windows program Notepad. The text file will be read and formatted properly by the Windows program Wordpad.
13. Scaling Algorithm Ineffectual with Some Content. The spatial scaling algorithm may yield poor results for some video scenes. Still scenes in particular may cause the spatial scaling algorithm to yield incorrect scaling values. Incorrect scaling factors (like other calibration errors) will cause the VQM to be erroneous and

typically too large (i.e., the VQM estimates will indicate worse quality than what would result if proper spatial scaling had been performed on the destination video).

7 REFERENCES

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- [3] S. Wolf and M. Pinson, "Low bandwidth reduced reference video quality monitoring system," in *Proc. First International Workshop on Video Processing and Quality Metrics for Consumer Electronics*, Scottsdale, Arizona, Jan. 23-25, 2005. Available at www.its.bldrdoc.gov/n3/video/documents.htm.
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- [6] ANSI T1.801.03 – 2003, "American National Standard for Telecommunications – Digital transport of one-way video signals – Parameters for objective performance assessment," American National Standards Institute. Available at www.ansi.org.
- [7] ITU-R Recommendation BT.1683, "Objective perceptual video quality measurement techniques for standard definition digital broadcast television in the presence of a full reference," Recommendations of the ITU, Radiocommunication Sector.
- [8] ITU-T Recommendation J.144, "Objective perceptual video quality measurement techniques for digital cable television in the presence of a full reference," Recommendations of the ITU, Telecommunication Standardization Sector.
- [9] ITU-T Recommendation J.244, "Full reference and reduced reference calibration methods for video transmission systems with constant misalignment of spatial and temporal domains with constant gain and offset," Recommendations of the ITU, Telecommunication Standardization Sector.
- [10] ITU-R Recommendation BT.601, "Encoding parameters of digital television for studios," Recommendations of the ITU, Radiocommunication Sector.