Miracast Codec Timing
Application Note

Products:
- R&S®RTO  R&S®FSVR
- R&S®RTE  R&S®FSL
- R&S®RTM2000  R&S®FSC
- R&S®HMO1002  R&S®VTC
- R&S®FSW  R&S®VTE
- R&S®FSV

This application note describes the configuration of a Miracast wireless video transmission system and how to measure the delay times between a smart phone or tablet (source) and a television / monitor (sink) display. The accompanying software for Windows 7/8/10, Mac OS X and MATLAB additionally allows to measure the delay until the video signal is transmitted over the air and optionally until it is available on the HDMI cable of an external Miracast receiver.

Note:
Please find the most up-to-date document on our homepage http://www.rohde-schwarz.com/appnote/1MA250.

This document is complemented by software. The software may be updated even if the version of the document remains unchanged.
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1 Introduction

High resolution video processing and replay has recently become available in smaller screen devices such as smart phones and tablets. The increasing demand for wireless video transmission to larger monitor and TV screens for presentations, video playback and especially gaming requires minimal delay time between the source device and the target display. The Miracast standard defined by the WiFi Alliance is used for demonstrating the measurement method introduced in this paper. Since these transmission techniques consists of various components, it is important to know how much each one of them influences the total delay time. This application note describes how to measure the delay of various stages in a Miracast transmission system manually and also automatically via an application software with this note.

The following abbreviations are used for the R&S® test equipment:

- The R&S®FSW, R&S®FSV, R&S®FSVR, R&S®FSL, R&S®FSC Spectrum Analyzers are referred to as FSx.
- The R&S®RTO, R&S®RTE, R&S®RTM2000 Digital Oscilloscopes are referred to as RTx.
- The R&S®HMO1002 Digital Oscilloscope is referred to as HMO1002.
- The R&S®VTE or R&S®VTC Video Analyzers are referred to as VTx.
- R&S® stands for Rohde & Schwarz GmbH & Co KG.

MATLAB® is a trademark of The MathWorks, Inc.
2 Video over WLAN Transmission Standards

One transmission method suited for mobile phones is Miracast, a standard for wireless display defined by the WiFi Alliance. The WiFi Alliance is an association of several manufacturers for defining common requirements and ensuring platform independent communication. The specification contains all requirements that are necessary for the transmission and has been implemented in state of the art smart phones, media players, televisions and monitors.

A further transmission method is the Proprietary Standard Wireless Display by Intel, whereby a WiFi connection is made between a PC and a Wireless Display (WiDi). This additional monitor can be used to clone or expand the desktop. The measurement configuration for WiDi is the same as with Miracast and not explicitly mentioned in this application note.

The schematic of a Miracast transmission system is shown in Fig. 2-1.

![Fig. 2-1: Schematic of a Miracast video transmission system](image)

Data is fed to a graphic chip which prepares it for the source display and also generates an image signal stream for further processing. This stream is sent to the H264 coder where the data rate of the image information is reduced. This is followed by multiple information packaging. These packets are transmitted on a 802.11 – series WLAN channel, typically via a WiFi module using OFDM. The image data stream is received at the sink’s WLAN module and unpacked in the following stage. The generated transport stream passes a H264 decoder which creates the original image content. The images are then coded by TDMS, which is the standard for transporting data via HDMI interfaces. From here the content reaches the TV monitor where it is TDMS decoded and finally displayed on the TV video panel.
The schematic does not contain all processes, such as video signal buffers between some of the stages. These buffers also contribute to the total delay.
3 Delay Measurement of Mobile Display → Transmission Path → TV Display

3.1 Measurement Configuration

This measurement configuration allows to measure the delay between the moment an image is available on the source (mobile) display, in the air and on the sink (TV) display. The measurement configuration is shown in Fig. 2-1.

For this solution a smart phone with Android 4.2, Windows 8.1 and BlackBerry 10.2.1 or higher can be used. These operating systems support desktop mirroring according to the Miracast standard. In this example a mobile phone (source) connects to a Netgear Push2TV 2000 Miracast receiver which decodes the video signal and sends it to a television via High-Definition Multimedia Interface (HDMI). An optional VTx Video Analyzer can be used for determining the signal delay caused by the external Miracast receiver. There are photo diodes attached to the mobile phone and television display units which detect the frame change in the test video (see section 2.2). Any 4-channel oscilloscope e.g. RTO10x4, RTM2xx4, RTE2xx4 is desirable for manual evaluation because it can show all relevant waveforms simultaneously. Three input channels and the trigger output are needed. The delay between the rising slopes of both photo diodes is the latency of the whole system. Additionally, this measurement configuration also allows to detect frame changes in the RF signal. The spectrum analyzer (SA) is triggered by the scope’s trigger output in a 500 ms (600 ms) time span before and after the trigger signal the FSx spectrum analyzer detects a change in the data rate.
Oscilloscope settings:

- Horizontal Scale = 100 ms / div
- Horizontal Position = 0 s
- Vertical Scale = 100 mV / div
- Vertical Position = -2 DIVisions
- Trigger = Normal
- Trigger Source = Channel 1
- Trigger Output = Triggered by Channel 1
- Trigger Slope = Pos. Edge
- Trigger Level = 32 mV (only for RTx)
- Trigger Reference Point = 60 %
- Coupling Channel 1 = DC 50 Ω
- Coupling Channel 2 = DC 50 Ω
- Coupling Channel 3 = AC 50 Ω

Spectrum Analyzer settings:

- Center Frequency = e.g. 2.421 or 5.149 GHz (same as WiFi channel)
- Resolution Bandwidth (RBW) = 40MHz (measure complete channel)
- Trigger Mode = external
- Trigger = -500 ms (-600 ms with HMO)
- Sweep Time = 1 sec. (1.2 sec with HMO)
- Span = Zero Span (amplitude vs. time)

The transmitted data in 802.11g specified systems appears as bursts vs. time. With low data rates the distances between bursts are larger than with high data rates. The frame change immediately increases the transmission's data rate which can be observed on the oscilloscope by connecting the IF/Video DEMOD output (configured as video output) of the spectrum analyzer to an oscilloscope input. Now, all 3 signals can simultaneously be displayed on the oscilloscope (see Fig.3-2).
C1.1 **Source** corresponds to the output of the photo diode on the smart phone display. It shows an abrupt rise of voltage level indicating a frame change.

C2.1 **Sink** represents the voltage of the photo diode on the TV. It is obvious from the screen shot that the signal is quite noisy. This noise is caused by the jitter of the background lighting of the TV. Despite of the noise, it is possible to detect the level rise caused by the frame change and set a marker at that point. The time difference between both slopes can be determined with the oscilloscope’s cursors. In this case
\[ \Delta t = C2.1_X1 - C1.1_X1 = 178.982 \text{ ms} - 0 \text{ ms} = 178.982 \text{ ms} \]

C3.1 **RF** corresponds to the spectrum analyzer’s IF output signal. It represents the data rate transmitted over the air. The moment when the peak density increases can easily be identified and measured with the C3.1_X1 cursor. The latency between source display and the RF transmission can be read directly
\[ \Delta t = C3.1_X1 - C1.1_X1 = 53.995 \text{ ms} - 0 \text{ ms} = 53.995 \text{ ms} \]
3.2 Video Test Signal

The transmitted test video Cut NoiseColorCW720p1_5sek.asf contains two different scenes and is 1 second long (see Fig. 3-3).

Fig. 3-3: Two different scenes of the test video

One scene is a static test picture with a black rectangle in the middle and the other is a noisy picture with white rectangle. This video is a handy tool for the delay measurements because it aids in generating the required slopes. The photo diodes mentioned in section 3.3 are directed to the rectangle. When the test frame changes from the still one with the black rectangle to the noisy one with the white rectangle, the photo diode level increases. The change from the still to the noisy frame also increases the data rate due to video compression, here H.264. Motionless scenes are transmitted with smaller data rate. The change from still picture to noisy scene results in an instantaneous increase of data rate.

The video player used on the smart phone must be capable of playing the video in an endless and seamless loop for obtaining best measurement results.
3.3 Photo Diode Schematic

The following schematic in Fig. 3-4 shows a possible photo diode circuit. The photo diode TSL 254 requires 6V voltage which can be supplied by a DC power supply or 4 AA batteries. The power supply should be of better quality to avoid additional noise. A 100 kΩ potentiometer can be used to calibrate the output voltage.

![Photo Diode Schematic](image1)

The photo diode can be fitted into a small case with felt pieces to protect the mobile device and TV screens. The light of the screen is emitted through the hole towards the photo diode.

![Photo diode front casing](image2)

![Photo diode rear casing](image3)

On the rear of the casing mount a connector for the power supply and a BNC connector for the output voltage. A mounting screw for a microphone stand may also be fitted.
4 Measurement Automation

4.1 Why Automation?

It is error prone, less repeatable and more time consuming to manually configure the devices, tweak the cursor positions and document the test results. Therefore a MATLAB® script and program installers for Windows 7/8/10 and Mac OS X 10.x accompany this application note, allowing to set various device configurations, run multiple tests, display results via graphical user interface (GUI) and save them for further processing.

4.2 Performing the Measurement

4.2.1 Hardware Configuration

The hardware configuration used is nearly the same as the one in Fig. 3-1, with the difference that the demodulated RF signal can be measured directly with the spectrum analyzer, making the connection from the IF/Video-Demod output to channel 3 of the oscilloscope obsolete. In this case a 2 channel oscilloscope is sufficient.

The HDMI output of the Miracast receiver can alternatively be connected to the VTE for determining the signal delay between the mobile (source) and Miracast receiver.

Test software for various environments (Windows 7/8/10, Mac OS X 10.x, MATLAB® R2013) can be downloaded from the application note site. They run on the remote control computer which is connected to the instruments via LAN, USB or GPIB.

Fig. 4-1: Hardware configuration for automated tests
4.2.2 Software Configuration

For Windows 7/8/10 download and install MiracastCodecTiming_1.0.x.exe for 32-bit and MiracastCodecTiming64_1.0.x.exe for 64-bit. For Mac OS X 10.x download and install MiracastCodecTimingMc_1.0.x.dmg. These applications additionally require a current VISA runtime driver to be installed.

For the MATLAB® script unzip MiracastCodecTiming_1.0.0_Matlab.zip. It requires MATLAB® (R2013a and higher) with the Instrument Control Toolbox TMTTool, a current VISA runtime driver, and the RsScope, HMO and RsSpecan VXIpnx x86 or x64 drivers to be installed.

4.2.3 MATLAB® Instrument Drivers

The *.zip file also contains MATLAB® R - instrument drivers (instr_FSX.m, instr_HMO.m, instr RTX.m and instr_VTx.m). In case you install a future driver versions, it is necessary to generate MATLAB® R - instrument drivers by executing the command `makemid ('driver', 'filename')`. Enter the VXIpnx driver name for ‘driver’ and any name for ‘filename’. This must be performed for the FSx Spectrum Analyzer and RTx or HMO Oscilloscope and VTx Video Analyzer.

4.2.4 Running the Measurement GUI

The MATLAB® script can be started by double clicking on the Main.m file.

![Measurement GUI](image)

Fig. 4-2: Measurement GUI

Enter a valid VISA RESOURCE DESCRIPTOR in the Oscilloscope, Spectrum Analyzer and Video Analyzer edit lines, for instance TCPIP::RTO-200159::INSTR (Interface Type::<Instrument Name or IP address>::INSTR). The <Interface Type> can be TCPIP (LAN), GPIB0/1 (GPIOB).
INIT – Resets and configures the according instrument. If HMO1002 is selected in the oscilloscope menu and INIT has been pressed with RESET checked, it is necessary to turn ON the oscilloscope’s trigger output (AUX OUT BNC connector) manually by pressing the UTIL button (VERTICAL key field) → PAGE 1/2 → ACQ. TRIGGER EV.

READY – Is checked, when the device is initialized and configured.

TRIGGER LEVEL – Required voltage level of the first photo diode to trigger the RTx oscilloscope (not required for HMO).

TYPE – Select RTx or HMO1002 oscilloscope.

CENTER FREQUENCY – The RF frequency of the used WiFi channel, e.g..5.192 GHz.

USE IF/VIDEO-DEMOD – When checked, the demodulated RF signal is measured with the channel 3 of the oscilloscope instead of the spectrum analyzer.

MEASURE HDMI DELAY – When checked, it enables to measure the delay at the HDMI output of the Miracast Receiver (obsolete for receivers integrated in the TV) with a VTx AV analyzer. Its External Start Trigger is set to Positive Slope.

THRESHOLD – Should be set to a value between the lowest and the highest Avg. Picture Level. In this example 22.0% ≤ Threshold ≤ 47.5%. The default value is 35.0%.

Fig. 4-3: Determine Threshold from Avg. Picture Level
**SAVE DATA** – Saves measured delay results in milliseconds and the 3 curves (src, rf and snk) for each measurement in double binary format. The number of samples is file size / 8.

- Gets current date & time `<DateTime>` = “YYYY-MM-DD_HH-MM_SS_”
- Saves `<DateTime>_RESULTS.TXT` e.g. 5 measurements (in ms) with **MEAS HDMI ON**.
  
  Source2RF Delay: 36.6305 36.6200 37.6335 36.6295 36.6310  
  Source2RF Mean: 36.8289  
  Source2HD Delay: 6.124 6.201 5.999 6.350 6.110  
  Source2HD Mean: 6.1565  
  Source2Snk Delay: 175.746 177.104 176.500 174.692 175.223  
  Source2Snk Mean: 175.853

- Saves i (= 5) times
  - `<DateTime>_i_src.bin`
  - `<DateTime>_i_rf.bin`
  - `<DateTime>_i_snk.bin`

**START** – Performs the delay measurements `<MEASUREMENT>` times and displays the result of the first measurement.

---

**Fig. 4-4: Measurement Result Window**
### 5 Ordering Information

#### Digital Oscilloscope

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range</th>
<th>Bandwidth</th>
<th>Channels</th>
<th>Part Number</th>
</tr>
</thead>
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<td>200 MHz, 5 GSa/s, 10/20 MSa</td>
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#### Spectrum Analyzer

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<td>FSWxx</td>
<td>2 Hz to 67 GHz</td>
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#### Video Analyzer

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<td>MHL Analyzer/Generator Module</td>
<td>2115.7622.06</td>
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Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, radiomonitoring and radiolocation. Founded more than 80 years ago, this independent company has an extensive sales and service network and is present in more than 70 countries.

The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

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Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

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