# Agilent X-Series Signal Analyzer

This manual provides documentation for the following analyzers:

PXA Signal Analyzer N9030A

MXA Signal Analyzer N9020A

EXA Signal Analyzer N9010A

CXA Signal Analyzer N9000A

## N6152A & W6152A Digital Cable TV Measurement Application Measurement Guide

Agilent Technologies

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## Manual Part Number

N6152-90002

## Print Date

April 2011

Printed in USA

Agilent Technologies Inc.
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Santa Rosa, CA 95403

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Information on preventing analyzer damage can be found at:

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# Table of Contents

# Contents

# Contents

# 1 About the Digital Cable TV Measurement Application

The N6152A (for PXA, MXA, EXA) & W6152A (for CXA) Digital Cable TV measurement application offers two license options:

a. N6152A–2FP/W6152A-2FP. With this option, signals compliant with DVB-C (J.83/A) or J.83/C standards can be measured.

b. N6152A–3FP/W6152A-3FP. With this option, signals compliant with J.83/B standard can be measured.

These two options are not dependent on each other, and each option alone can run inside the software and support the corresponding measurements.

**NOTE**    The "FP" in the option name is short for fixed perpetual, which means you can only install the license key on the specific instruments for which it was created. For PXA, MXA, and EXA, there is another license type called "TP", short for transportable perpetual, which means you can transport this license key between instruments.

The transportable licenses for the two N6152A options are N6152A-2TP and N6152A-3TP. In this document, all the features and functions for N6152A-2FP, N6152A-3FP also apply to N6152A-2TP, N6152A-3TP.

This chapter provides the overall information on the N6152A & W6152A Digital Cable TV measurement application, and describes DVB-C (J.83/A), J.83/C, and J.83/B measurements made by the analyzer.

DVB-C, also known as ITU-T J.83/A, is mainly used in Europe.

J.83/C, used in Japan, has identical structure as DVB-C, except the channel bandwidth (6 MHz for J.83/C, and 8 MHz for DVB-C) and the roll-off factor of the baseband filter.

J.83/B, widely used in North America, has greater difference especially in FEC (forward error correction) coding and occupies a bandwidth of 6 MHz as in J.83/C.

# What Does the Digital Cable TV Application Do?

The digital cable TV application allows the analyzer to be used for testing a DVB-C (J.83/A), J.83/B, and J.83/C transmitter and exciter. This application is manufactured according to the following standard documents:

- ETSI EN 300 429 Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems

- ITU-T J.83 Digital multi-programme systems for television, sound and data services for cable distribution

- ETSI TR 101 290 Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems

- CM-SP-DRFI-109-100115 Data-Over_Cable Service Interface Specifications, Downstream RF Interface Specification

These documents define complex, multi-part measurements used to create and maintain an interference-free environment. For example, the documents include standardized test methods for the measurement of power, adjacent channel measurement, and other critical measurements.

The instrument automatically makes these measurements using the measurement methods and limits defined in the documents. The detailed results displayed by the measurements enable you to analyze DVB-C (J.83/A), J.83/B, and J.83/C transmitter's performance. You may alter the measurement parameters for specialized analysis. For infrastructure test, the analyzer will test transmitters in a non-interfering manner using a coupler or power splitter.

This analyzer makes the following measurements on DVB-C (J.83A), J.83/B, or J.83/C signals:

- Channel Power

- Adjacent Channel Power (ACP)

- Power Stat CCDF

- Spectrum Emission Mask

- Modulation Accuracy

- Monitor Spectrum

- IQ Waveform (Time Domain)

If the option BBA is installed, the ability to analyze baseband I/Q signal characteristics of mobile and base station transmitters is provided. The Baseband I/Q Input is available in the following measurements:

- Modulation Accuracy

- Power Stat CCDF

- IQ Waveform (Time Domain)
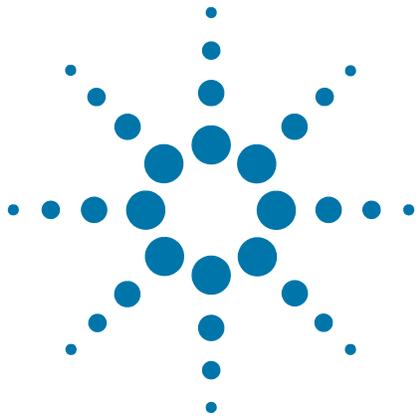
# 2 Making Digital Cable TV Measurements

This chapter first introduces the instructions common to all measurements, and then, discusses the operation steps specific to individual measurements.

As measurement procedures for DVB-C (J.83/A), J.83/B, and J.83/C signals are similar, in this chapter, measurements on DVB-C (J.83/A) signals are used to demonstrate the measurement details.

## Setting Up and Making a Measurement

### Making the Initial Signal Connection and Configuring the Measurement System

Set the DVB-C (J.83/A), J.83/B, or J.83/C transmitter under test to transmit RF power. This transmitting signal is connected to the RF input port of the instrument. Connect the equipment as shown below.

| | |
|---|---|
| **CAUTION** | Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The maximum signal level limits are marked next to the RF Input connectors on the front panel. |

1.  Connect the output signal from the transmitter to the RF input port of the analyzer using appropriate cables, attenuators, and adapters.

2.  Optional: If there is a frequency reference port on the transmitter, connect it to the EXT REF IN port of the analyzer with a cable for frequency synchronization.

*Figure 2-1*        *Digital Cable TV Measurement System*
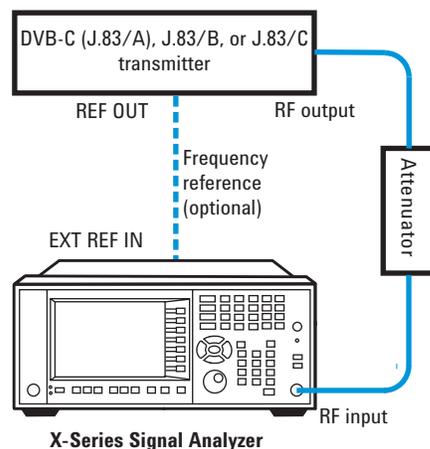


After finishing the connection, see the Input/Output key menus for details on selecting input ports, and the AMPTD Y Scale menu for details on setting internal attenuation to prevent overloading of the analyzer.

### Setting the DVB-C (J.83/A) Transmitters (Example)

Set up the DVB-C (J.83/A) transmitter to transmit the RF power as follows:

Standard:            DVB-C (J.83/A)

Frequency:            474 MHz (Channel Num: 21, Channel Table: PAL-B/G UHF)

Symbol Rate:      6.90 MHz

Modulation Type:   64 QAM

Filter Type:            Root Nyquist (Square-root raised-cosine filter)

Roll-off Factor:      0.15

Attenuator:           60 dB

Transmitted Power:  40 dBm (at RF output); -20 dBm (at the analyzer input)

### Using Analyzer Mode and Measurement Presets

To set your current measurement mode to a known factory default state, press **Mode Preset**. This initializes the analyzer mode by returning the mode setup and all of the measurement setups in that mode to the factory default parameters.

To preset the parameters that are specific to an active, selected measurement, press **Meas Setup**, **Meas Preset**. This returns all the measurement setup parameters to the factory defaults, but only for the currently selected measurement.

### The 3 Steps to Set Up and Make Measurements

Generally speaking, all measurements can be set up using the following three steps. The sequence starts at the Mode level, is followed by the Measurement level, then finally, the results displayed are adjusted and viewed.

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**NOTE**    Press the  Help  key on the front panel to enter the help system and see the detailed descriptions for the keys you are not familiar with. Press the  Cancel (Esc)  key on the front panel to exit the help system.

---

| Step | Action | Notes |
|------|--------|-------|
| **1  Select and set up the mode** | a.  Press **Mode**.<br><br>b.  Press a mode key, like **Spectrum Analyzer**, **IQ Analyzer (Basic)**, or **Digital Cable TV**.<br><br>c.  Press **Mode Preset**.<br><br>d.  Press **Mode Setup**. | All licensed, installed modes available are shown under the **Mode** key.<br><br>Using **Mode Setup**, make any required adjustments to the mode settings. These settings apply to all measurements in the mode. |
| **2  Select and set up the measurement** | a.  Press **Meas.**<br><br>b.  Select the specific measurement to be performed.<br><br>c.  Press **Meas Setup**. | The result data is shown on the display or is available for export.<br><br>Use **Meas Setup** to make any required adjustment to the selected measurement settings. The settings only apply to this measurement. |

| Step | Action | Notes |
|---|---|---|
| **3  Select and set up a view of the results** | Press **View/Display**. Set the display format and select a view for the current measurement data. | Depending on the mode and measurement selected, the graphical and tabular data presentations are available. |
| | | Use **Span X Scale** and **AMPTD Y Scale** to adjust the display of the measurement graphics. |

**NOTE**    You can change settings as needed, and the changes will be in effect on the next measurement cycle or view.

*Table 2-1*        *Main Keys and Functions for Making Measurements*

| Step | Primary Key | Setup Keys | Related Keys |
|---|---|---|---|
| 1. Select and set up a mode. | **Mode** | **Mode Setup, FREQ Channel** | **System**, **Input/Output** |
| 2. Select and set up a measurement. | **Meas** | **Meas Setup** | **BW, Sweep/Control, Restart, Single, Cont** |
| 3. Select and set up a view of the results. | **View/Display** | **SPAN X Scale, AMPTD Y Scale** | **Peak Search, Quick Save, Save** |

**NOTE**    If you encounter a problem, or get an error message, see the guide "**Instrument Messages**", which is provided on the Documentation CD ROM, and in the instrument here:

C:\Program Files\Agilent\SignalAnalysis\Infrastructure\Help\bookfiles.

## Common Measurement Steps – Setting up Digital Cable TV Mode

This section lists the steps common to all measurements in Digital Cable TV mode. Whatever measurements you're making, you need to begin with the following steps:

| Step | Notes |
|---|---|
| **1** Press **Mode**, **Digital Cable TV**. | |
| **2** Press **Mode Preset**. | |
| **3** Do one of the following to set the center frequency:<br><br>• Press **FREQ Channel**, **Center Freq**, 474, **MHz**.<br><br>• Press **FREQ Channel**, **Chan Table**, **PAL-B/G**, **PAL-B/G UHF** and then press **FREQ Channel**, **Channel**, 21. | The first method is to enter the frequency directly.<br><br>The second method is to set the frequency through channel table. Multiple channel tables are predefined in the instrument, including NTSC-M, NTSC-J, NTSC-Brazil, PAL-M, PAL-I, PAL-B/G, and PAL-D/K.<br><br>You can change the definition of the channel table following the steps in "Customizing the Channel Table Definition" on page 16. |
| **4** Press **Mode Setup**, **Radio Std**, **DVB-C (J.83/A)**. | The display of the Radio Std menu depends on the licenses installed in your instrument:<br><br>• If only N6152A-2FP (W6152A-2FP for CXA) is installed, two keys **DVB-C (J.83/A)** and **J.83/C** are displayed.<br><br>• If only N6152A-3FP (W6152A-3FP for CXA) is installed, one key **J.83/B** is displayed.<br><br>• If both licenses are installed, all three keys are displayed. |
| **5** Press **Mode Setup**, **Modulation Format**, **64QAM**. | This sets the Modulation format to 64QAM. |
| **6** Press **Mode Setup**, **Symbol Rate**, and toggle it to **Auto**. | If the Symbol Rate is set to auto, its value will be set automatically according to the the current combination of radio standard and modulation format as shown in Table 2-2.<br><br>If you're using a different symbol rate, toggle the **Symbol Rate** to **Man** and then enter the value manually. |

Table 2-2          *Symbol Rate (Auto) values*

| Radio standard | Modulation formats | Symbol Rate |
|---|---|---|
| DVB-C (J.83/A) | Any | 6.9 MHz |
| J.83/B | 64QAM | 5.056941 MHz |
| | Others | 5.360537 MHz |
| J.83/C | Any | 5.274 MHz |

### Customizing the Channel Table Definition

Channel table function enables you to specify the center frequency by entering the channel number under a specific channel table. In a channel table, each channel number corresponds to a center frequency exactly. The predefined channel tables comply with the industry standards.

A channel table file is used to export, edit, and then import the channel table settings so that you can customize the channel table to satisfy your measurement requirements.

The format of the channel table file is illustrated in Figure 2-2. The channel table file includes channel definitions for all the channel plans, such as NTSC-B, NTSC-J, NTSC-M, PAL-M, PAL-I, PAL-B/G, and PAL-D/K. Each channel plan is seperated with a blank line.

File default location:   My Documents\Digital Video\data

File type:            text file

File extention:       .txt

*Figure 2-2*          *Format of the Channel Table File*



**A**. Channel plan name. This is the channel plan for NTSC-B VHF;

**B**. Start channel number. Here, the start channel number is 7;

**C**. Channel count in the current channel plan. There are 7 channels in the predefined NTSC-B VHF.

**D**. Channel number and corresponding center frequency, unit Hz. For example, #7, 177142857 means the center frequency for the channel 7 is 177142857 Hz.

**E**. The start of another channel plan NTSC-B UHF.

Perform the following steps to customize the channel table:

| Step | Notes |
|------|-------|
| **1** Press **Save**, **Data**, **Channel Table**, and then press **Save As...**, save the current channel table file as ChannelPlan_0000.txt (for example). | This saves the data of the current channel table into a file. <br> You can save the file into the default directory "My Documents\Digital Video\data" or any other location you like. |
| **2** Open the saved channel table file ChannelPlan_0000.txt, find the channel plan you are going to edit, and then make your desired changes. | You can add your own channel definitions to the channel table file, edit the center frequency value for the predefined channel, or remove the channel definitions unnecessary for your test. <br><br> • Adding channel definitions <br><br> First, choose and find the channel plan you're going to edit on, for example, NTSC_B.VHF. Then, add the channel definitions including the channel number and the corresponding center frequency following the format "# channel number, center frequency". After that, edit the Start Channel and Channel Count values according to your changes. <br><br> • Editing the center frequency value for the channel <br><br> Choose and find the channel plan you're going to edit, and then enter the center frequency value for the channel. <br><br> • Removing unnecessary channel definitions <br><br> Choose and find the channel plan you are going to edit, and then delete the unnecessary channel definition. After that edit the Start Channel and Channel Count values. <br><br> Note that the name of the channel plan can't be changed. If it is changed, the modifications under this channel plan will not work and the default channel settings of the channel plan will work instead. |
| **3** Press **Recall**, **Data**, **Channel Table**, then press **Open...**, and open the channel table file you edited. | |
| **4** Press **FREQ Channel** to specify center frequency under the new channel table. | If the instrument is restarted, the channel table file needs to be recalled again. |

# Channel Power Measurements

This section explains how to make a Channel Power measurement on a digital cable TV transmitter. It measures the total RF power and power spectral density in the channel bandwidth.

| Step | Notes |
|------|-------|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the Digital Cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Meas**, **Channel Power**. | This selects the Channel Power measurement. |
| **3** View Channel Power measurement result. | In the figure below, the graph window shows the spectrum trace and the text window shows the total power and PSD (power spectral density) value. |
| | To change the integration bandwidth, press **Meas Setup**, **Integ BW**. |
| | To display a blue bar indicating the integrate bandwidth on the spectrum, press **View/Display**, and toggle **Bar Graph** to **On**. |
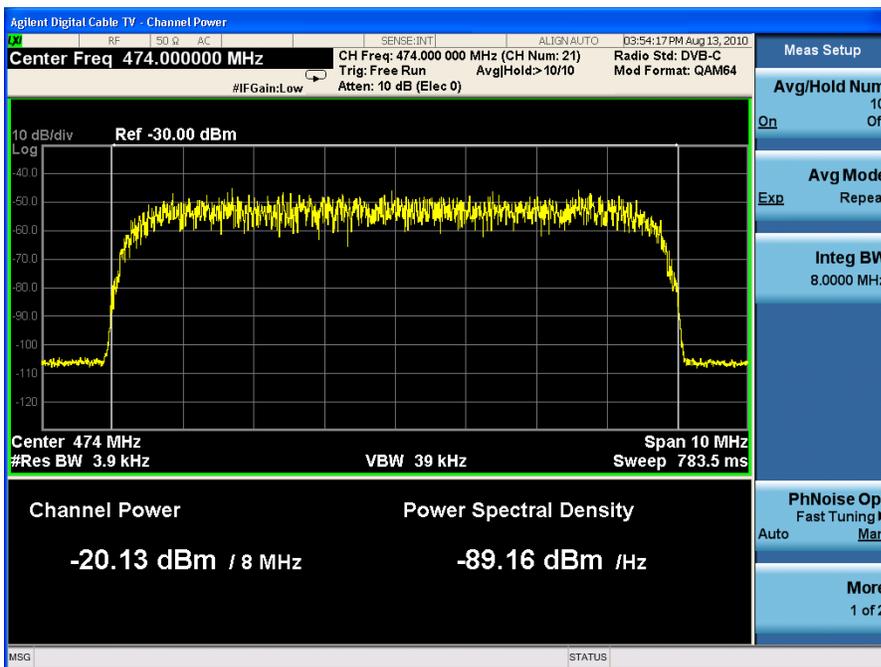
# ACP Measurements

This section describes the Adjacent Channel Leakage Power Ratio (ACLR or ACPR) measurements on a digital cable TV transmitter. ACPR is the measurement of the amount of interference, or power, in adjacent frequency channels.

| Step | Notes |
|---|---|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the Digital Cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Meas**, **ACP**. | |
| **3** Press **Meas Setup**, **More 1 of 2**, **Noise Correction** and toggle it to **On**. | This operation can reduce the noise levels and improve the ACP measurement results. |
| **4** View the ACP measurement result. | In the figure below, the graph window shows the bar graph with the spectrum trace overlay, and the text window shows the total power in reference channel, absolute, and relative power in offset channels. |
| | If the signal under test is compliant with J.83/B and the **Radio Std** under **Mode Setup** is set to be **J.83/B**, the limits requirement on the adjacent channel are predefined according to "ACP Requirements for J.83/B" on page 47, and Pass/Fail indicators will be shown on the left top of the screen. |
| | You can also define your own limit mask by configuring the related parameters such as settings under **Meas Setup**, **Carrier Setup** and **Offset/Limits**, and toggle **Limit Test** under **Meas Setup** to **On**. |

| Step | Notes |
| --- | --- |
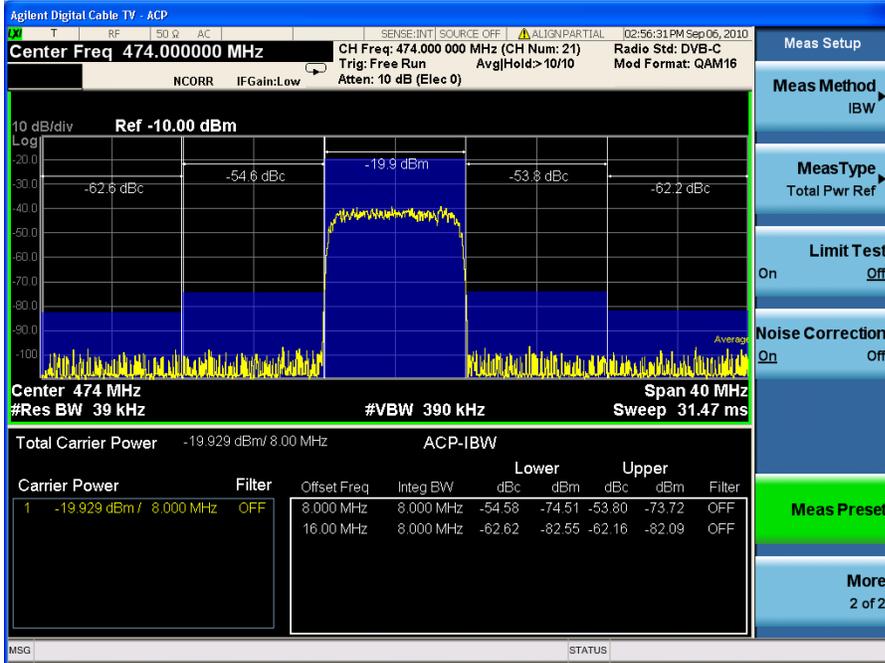
# Power Statistics CCDF Measurements

This section outlines how to make the Power Statistics Complementary Cumulative Distribution Function (Power Stat CCDF) measurements on a digital cable TV transmitter. Power Stat CCDF measurements characterize the higher level power statistics of a digitally modulated signal.

Power Statistics CCDF measurements can also be used to measure the BBIQ (Baseband I/Q) signals. For the detailed measurement procedure, refer to "Using Option BBA Baseband I/Q Inputs" on page 36.

| Step | Notes |
|------|-------|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the Digital Cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Power Stat CCDF**. | |
| **3** View the Power Stat CCDF measurement result. | In the following figure, the statistic data of the peak to average ratio is listed in the text window. |
| | In the graph window, the blue line is the Gaussian trace and the yellow line is the measurement result. The Info BW is the channel bandwidth that will be used for data acquisition. The default value is 8 MHz. You can manually change the Info BW by pressing **BW**, **Info BW**. |

| Step | Notes |
|------|-------|
| **4** Press **Trace/Detector**, **Ref Trace (On)** to display the user-definable reference trace (violet line). | The reference trace is a measurement trace stored as a reference trace to be compared to a later measurement. You can use the **Store Ref Trace** key to save the currently measured trace as the reference trace. This reference trace will be lost if you switch between modes or measurements. |
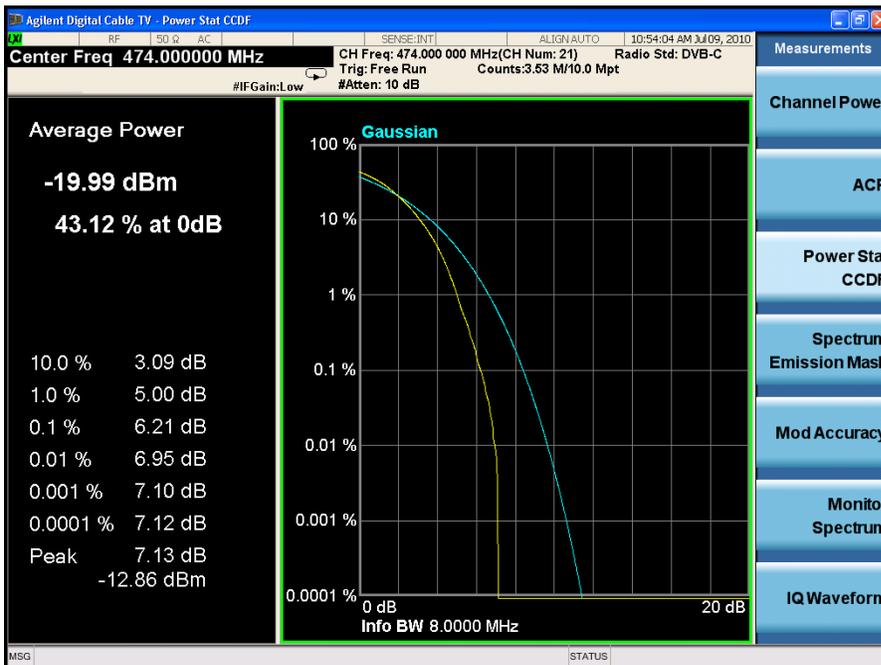


## Troubleshooting Hints

The Power Statistics CCDF measurements are useful in defining the signal power specifications for design criteria for systems, amplifiers, and other components.

# Spectrum Emission Mask Measurements

This section describes how to make a Spectrum Emission Mask (SEM) measurement on a digital cable TV transmitter. SEM measurements compare the power levels within given offset channels on both sides of the carrier frequency, to the power levels defined by the standards or manually set by the user.

| Step | Notes |
|---|---|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the Digital Cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Spectrum Emission Mask**. | |
| **3** View the Spectrum Emission Mask measurement result. | In the figure below, the top window shows the measured trace together with the limit mask and the bottom window lists the related parameters.<br><br>To make a spectrum emission mask measurement with your own limit mask, press **Meas Setup** and then set the parameters under the **Ref Channel** and **Offset/Limit** panel.<br><br>You can zoom on either the graphic window or the text window by pressing the Window Control keys at the left bottom of the front panel. |
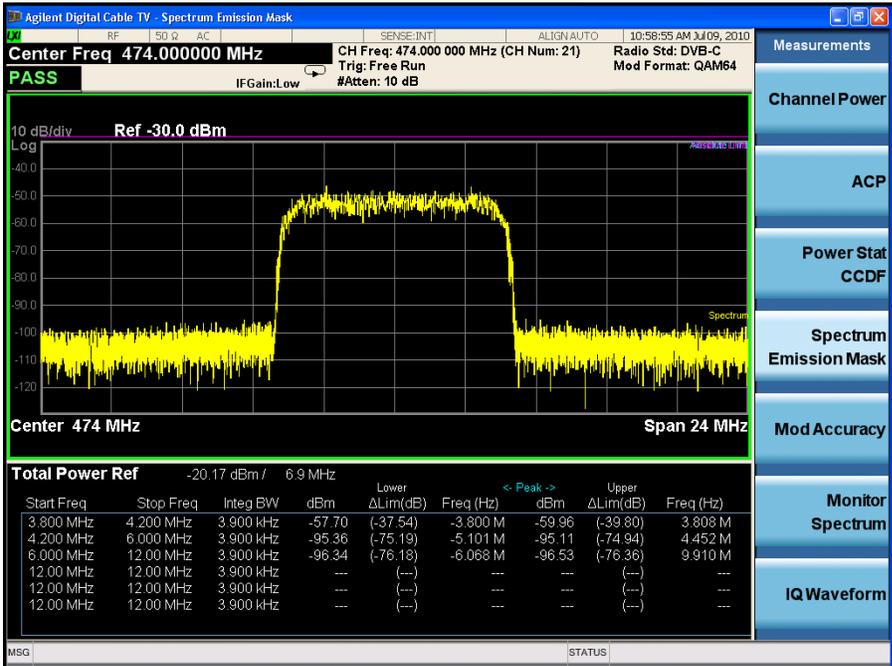
### Troubleshooting Hints

This Spectrum Emission Mask measurement can reveal degraded or defective parts in the transmitter section of the unit under test (UUT). The following are examples of typical causes for poor performance:

- Faulty DC power supply control of the transmitter power amplifier.

- RF power controller of the pre-power amplifier stage.

- I/Q control of the baseband stage.

- Degradation in the gain and output power level of the amplifier may be due to degraded gain control or increased distortion, or both.

- Degradation of the amplifier linearity or other performance characteristics.

## Modulation Accuracy Measurements

This section describes how to make a Modulation Accuracy measurement on a digital cable TV transmitter. Modulation Accuracy measurements provide methods for measuring the I/Q errors on digital cable TV transmitters or exciters. The results comprise EVM, MER, magnitude error, phase error, frequency error, quad error, IQ offset, gain imbalance, etc.

Mod Accuracy measurements can also be used to measure the BBIQ (Baseband I/Q) signals. For the detailed measurement procedure, refer to "Using Option BBA Baseband I/Q Inputs" on page 36.

| Step | Notes |
|---|---|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the Digital Cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Meas**, **Mod Accuracy**. | |
| **3** Press **View/Display**, **I/Q Measured Polar Graph** (default view). | Selects I/Q Measured Polar Graph view. You can also view the vector paths between the constellation points by pressing **I/Q Measured Polar Graph**, **I/Q Polar Vec/Constln**, **Vector** or **Vector Constellation**. |
| **4** View the I/Q Measured Polar Graph results. | In the figure below, the text window displays a summary of the results, including EVM, MER, Magnitude error, etc., and the graph window shows the constellation graphic of the signal under test. |

| Step | Notes |
|------|-------|
| **5** Press **View/Display**, **I/Q Error**. | This selects I/Q Error view. |
| **6** View the I/Q Error results. | Four windows are included in this view. The top left window shows EVM/MER vs. symbol results, the top right window shows the magnitude error vs. symbol results, the bottom left window shows the phase error vs. symbol results, and the bottom right window is a summary of these results. |
| | The symbol number in the result trace is determined by the value of **Meas Interval** under **Meas Setup**. |
| | To view the MER results in the top left window, press **AMPTD Y Scale**, **More 1 of 2**, and toggle the **Scale Type** to **MER**. |



| Step | Notes |
|------|-------|
| **7** Press **Meas Setup**, **Adaptive Equalizer** and toggle **Filter** to **On**. | This turns on the equalizer. |
| | Turning on the equalizer is necessary to display the channel frequency response. To learn more about this, refer to "Channel Frequency/Impulse Response" on page 54. |
| | You can set the length of the filter and the convergence factor of the filter under the **Meas Setup**, **Adptive Equalizer** panel. |
| **8** Press **View/Display**, **Channel Frequency Response**. | This selects the channel frequency response view. |
| **9** View the channel frequency response results. | In the figure below, the top window shows amplitude vs. frequency results, the middle window shows phase vs. frequency results, and the bottom window shows group delay vs. frequency results. |

| Step | Notes |
|------|-------|



| | |
|------|-------|
| **10** Press **View/Display**, **Channel Impulse Response**. | This selects the channel impulse response view.<br><br>Make sure the equalizer under **Meas Setup** is turned to **On** before viewing the channel impulse response results. To learn more about this, refer to "Channel Frequency/Impulse Response" on page 54. |
| **11** View the channel impulse response results. | The point number on the X axis of the channel impulse response trace is the length of the equalizer used.<br><br>To change the length of the equalizer, press **Meas Setup**, **Adaptive Equalizer**, **Filter Length**, and enter your desired value. |

| Step | Notes |
| --- | --- |



| Step | Notes |
| --- | --- |
| **12** Press **View/Display**, **BER**. | This selects the BER view. If the signal under test are Null TS packet, press **Meas Setup**, **Decode**, and toggle **Payload** to **NullPacket**.<br><br>If the Radio Std is set to J.83/B, you need to set the interleave level by pressing **Meas Setup**, **Decode**, **Interleave Level**. |
| **13** View the BER results. | In the figure below, four results are displayed, BER Before RS, BER after RS, Packet Error Ratio, and Interleaving Mode (I/J). For the calculation method of these results, refer to "BER" on page 55.<br><br>The "Interleaving Mode (I/J)" result indicates the interleaving mode for J.83B signals. It will be displayed as "---/---" if the Radio Std (under Mode Setup menu) is set to be DVB-C (J.83/A) or J.83/C.<br><br>If the Radio Std is set to J.83/B, the "Packet Error Ratio" result will be displayed as "---".<br><br>You can control the BER calculation stop time by setting the **BER Count Type** and **BER Bit Count** under **Meas Setup**, **Decode**. When the total bit count of the specified type exceeds the value of BER bit count for the first time, the calculation of BER stops. |
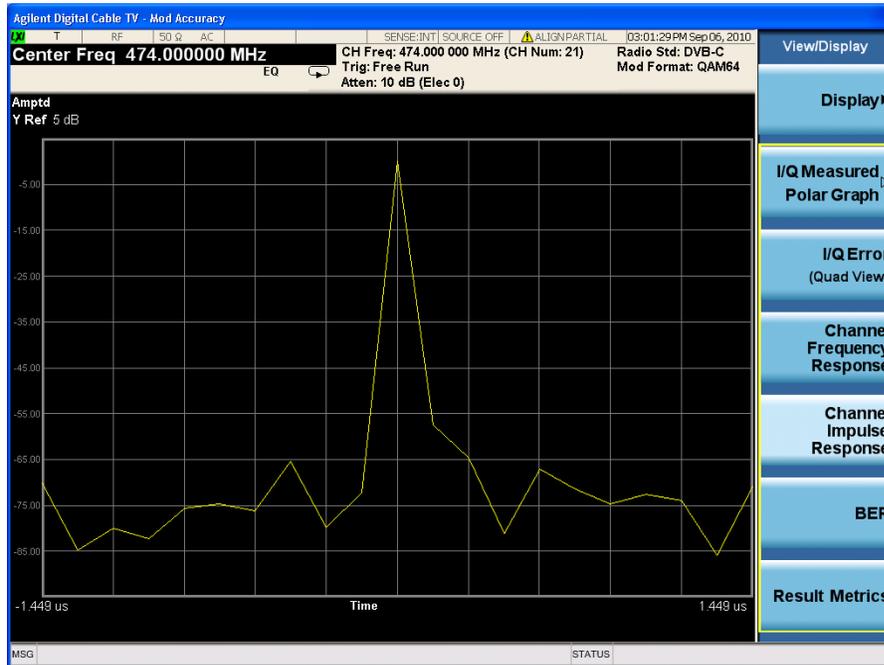
**Step**                                **Notes**
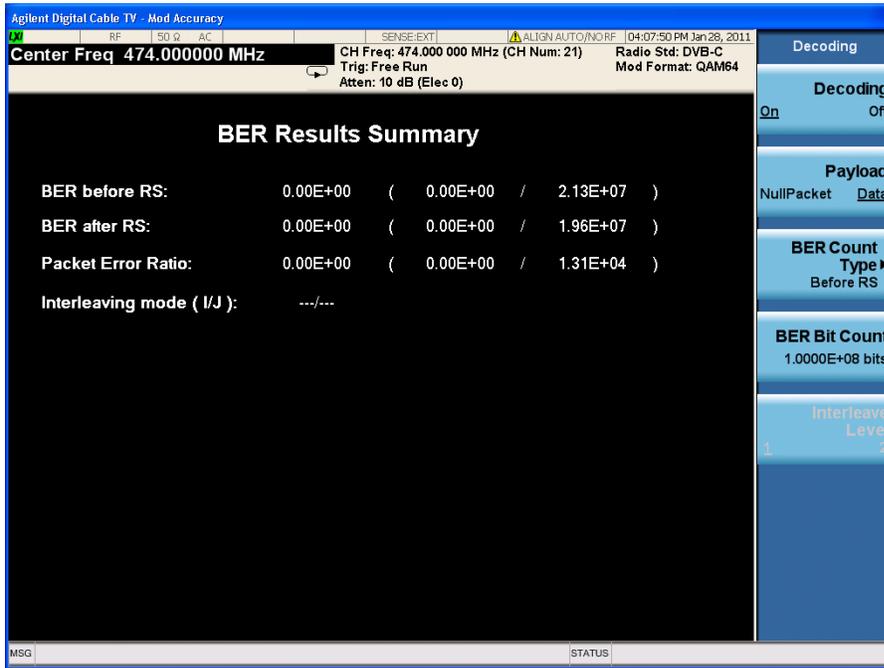


| 14 Press **View/Display**, **Result Metrics**. | This selects the result metric view. |
|---|---|
| 15 View the numeric results summary. | This view includes a summary of the modulation accuracy results.<br><br>The "Interleaving Mode (I/J)" result indicates the interleaving mode for J.83B signals. It will be displayed as "---/---" unless the **Radio Std** under **Mode Setup** menu is set to **J.83/B** and **Decoding** under **Meas Setup**, **Decode** is set to On . |

**Step**                                      **Notes**



Agilent Digital Cable TV - Mod Accuracy

RF    50 Ω    AC          SENSE:EXT    ⚠ALIGN AUTO/NO RF  04:08:42 PM Jan 28, 2011

Center Freq  474.000000 MHz    CH Freq: 474.000 000 MHz (CH Num: 21)    Radio Std: DVB-C
                               Trig: Free Run                           Mod Format: QAM64
                               Atten: 10 dB (Elec 0)

View/Display

Display▶

**Numeric Results Summary**

|  | RMS | Peak | Peak Position |
|---|---|---|---|
| EVM (/Smax) | 0.35 % | 0.96 % | at symbol 70 |
| MER (SNR): | 45.58 dB | 36.72 dB | at symbol 70 |
| Mag Err: | 0.21 % | 0.79 % | at symbol 42 |
| Phase Err: | 0.32 deg | -2.12 deg | at symbol 557 |

| Freq Error: | -6.94 Hz | Tx Power: | -19.27 dBm |
|---|---|---|---|
| IQ Offset: | -90.08 dB | | |
| Quad Error: | -0.007 deg | | |
| Gain Imbalance: | -0.026 dB | | |

Interleaving mode ( I/J ):        ---/---

I/Q Measured
Polar Graph

I/Q Error
(Quad View)

Channel
Frequency
Response

Channel
Impulse
Response

BER

Result Metrics

MSG                                      STATUS

# Monitor Spectrum Measurements

This section describes how to make a Monitor Spectrum measurement on a digital cable TV transmitter. Monitor Spectrum measurements show a spectrum domain display of the DVB-T/H signal.

| Step | Notes |
|------|-------|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the digital cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Meas**, **Monitor Spectrum**. | |
| **3** View the monitor spectrum measurement results. | The default display shows the current (yellow trace) data. |



| | |
|------|-------|
| **4** Press **Marker Function**, **Marker Noise**. | This turns on the marker function. The figure below is an example for marker noise. You can also select Band/Interval Power or Band/Interval Density to see the power or power density in a specified band, which is set using keys under the Band Adjust menu. |
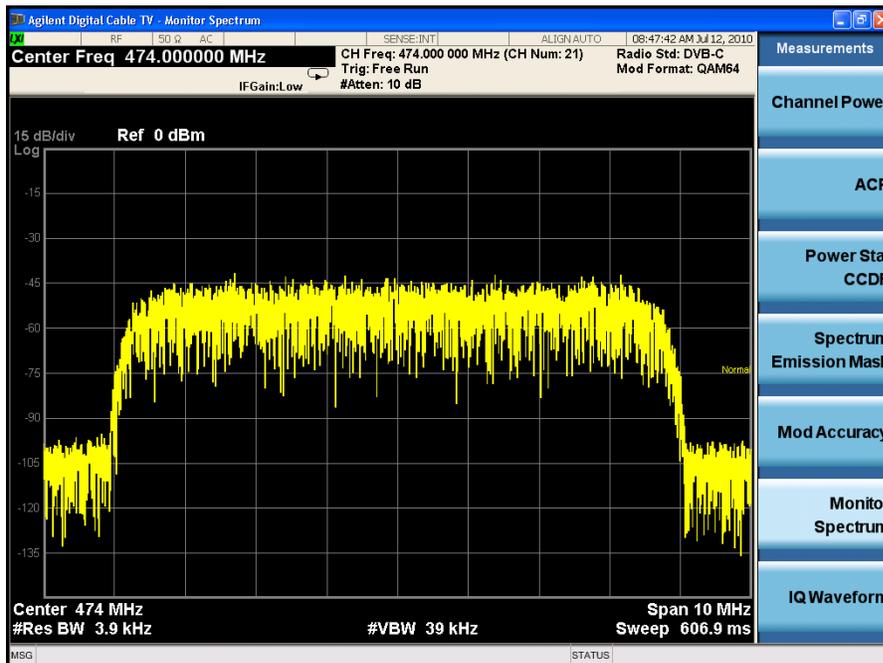
**Step**                                          **Notes**
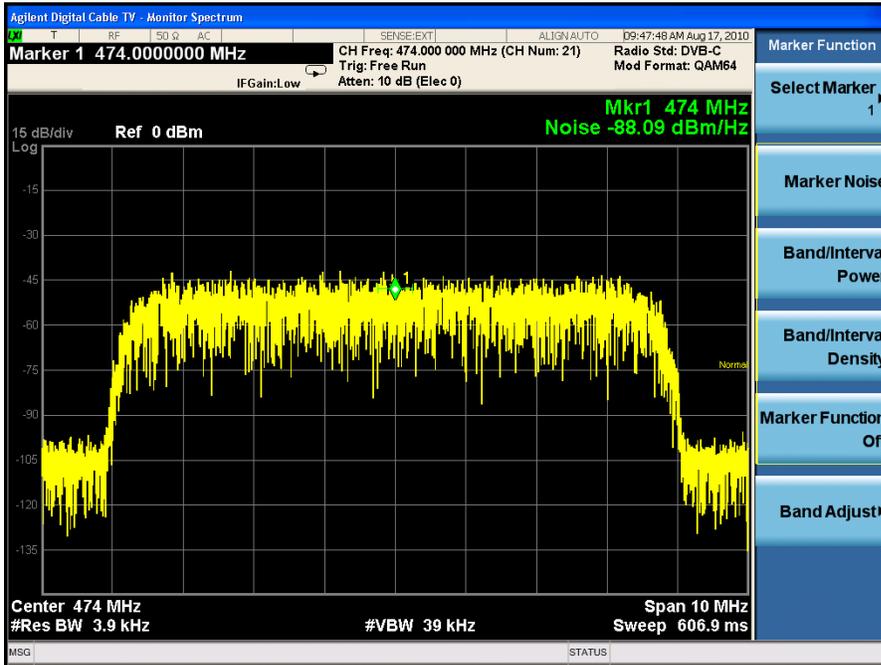


**5** To compare the current trace with the average/max hold/min hold trace, follow these steps:

- Press **Trace/Detector**, **Select Trace**, **Trace 1**, and then toggle **Update** to **Off**.

- Press **Select Trace**, **Trace 2**, press **Max Hold**, and then toggle **Update** to **On**, **Display** to **Show.**

The dark yellow trace is the clear write trace, and the blue trace is the max hold trace. You can also add other traces using the same procedure.

**Step**                                                    **Notes**
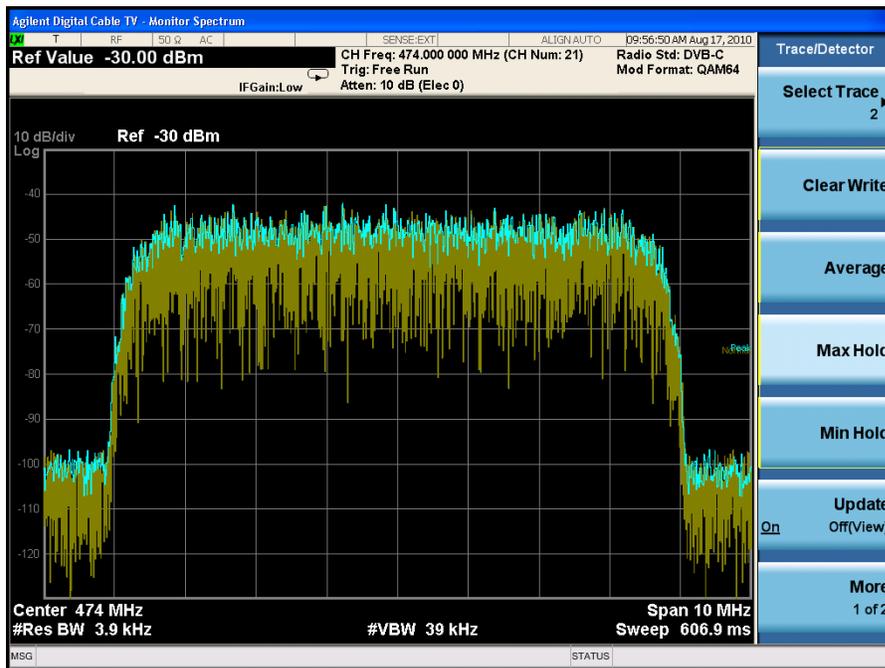
# IQ Waveform (Time Domain) Measurements

This section explains how to make a Waveform (time domain) measurement on a digital cable TV transmitter or exciter. The measurement of I and Q modulated waveforms in the time domain discloses the voltages which comprise the complex modulated waveform of a digital signal.

IQ Waveform (Time Domain) measurements can also be used to measure the BBIQ (Baseband I/Q) signals. For the detailed measurement procedure, refer to "Using Option BBA Baseband I/Q Inputs" on page 36.

| Step | Notes |
|---|---|
| **1** Set up the Digital Cable TV mode parameters according to "Common Measurement Steps – Setting up Digital Cable TV Mode" on page 15. | If the digital cable TV mode is NOT set up properly, the measurement results will be incorrect. |
| **2** Press **Meas**, **IQ Waveform**. | |
| **3** Press **View/Display**, **RF Envelope**. | Chooses the RF envelope view. |
| **4** View the RF envelope results. | Two windows are included in this view. The top window shows the RF envelope trace while the bottom window indicates the mean power and peak to mean ratio in time domain. |



| **5** Press **View/Display**, **IQ Waveform**. | This chooses the IQ waveform view. |

| Step | Notes |
| --- | --- |
| **6** View the IQ Waveform results. | This view shows the I and Q baseband waveform separately. To adjust the scale the of Y axis and X axis, set proper value to the keys under AMPTD Y Scale and SPAN X Scale menus. |



| | |
| --- | --- |
| **7** Press **AMPTD Y Scale**, and configure the settings for Y axis to a convenient scale for viewing. | |
| **8** Press **Span X Scale**, and configure the settings for X axis to a convenient time scale for viewing. | |
| **9** Press **Marker Function** key and select **Marker Noise**, **Band/Interval Power**, or **Band/Interval Density**. | You can use Band Adjust settings to set frequency span for those marker functions. |
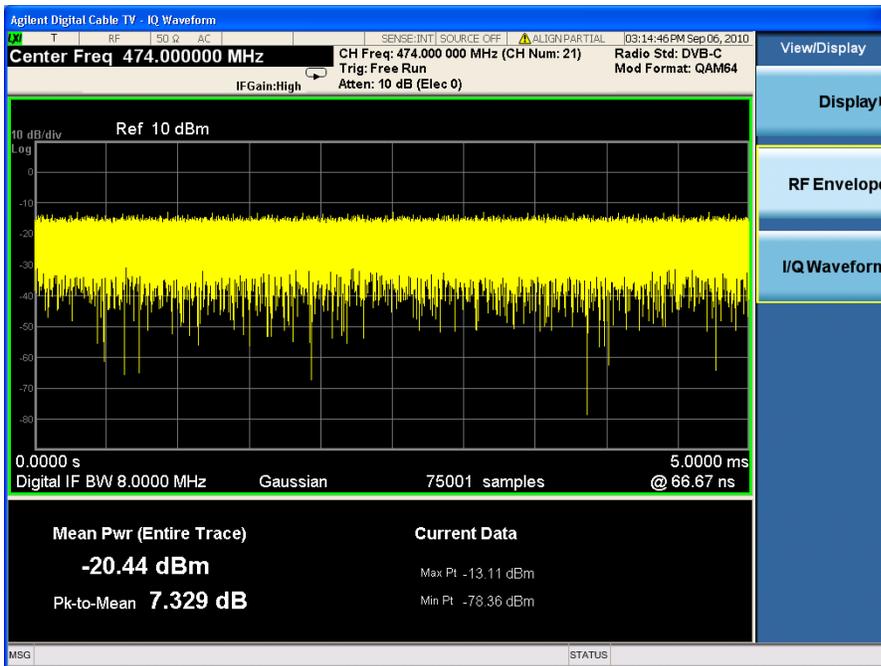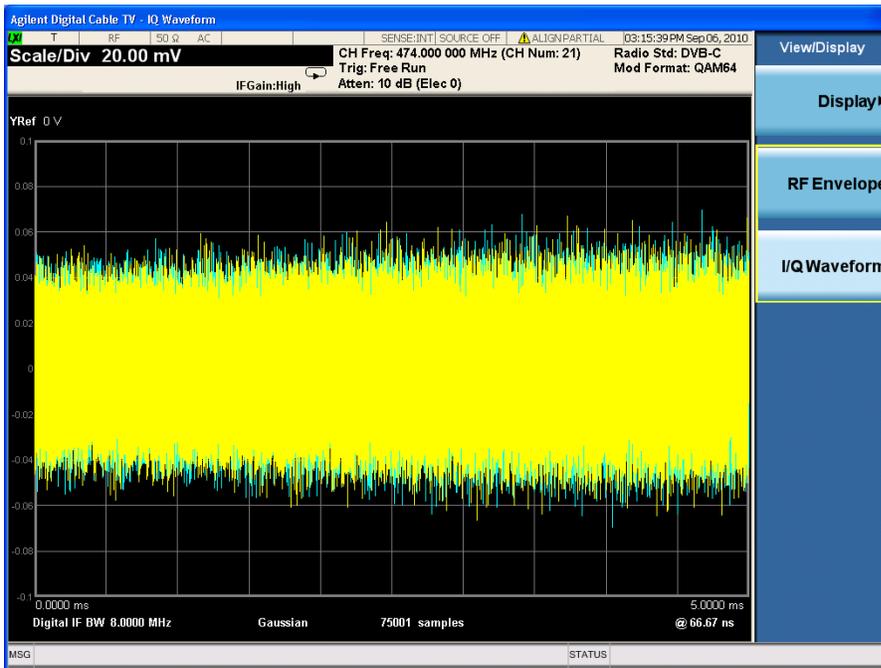
## Using Option BBA Baseband I/Q Inputs

### Baseband I/Q Measurements Available for X-Series Signal Analyzers

The following table shows the measurements that can be made using Baseband I/Q inputs:

*Table 2-3*                    *BBIQ Supported Measurements vs. Mode*

| Mode | Measurements |
|------|--------------|
| GSM | IQ Waveform<br>GMSK Phase & Freq<br>EDGE EVM |
| 802.16 OFDMA | IQ Waveform<br>Power Stat CCDF<br>Modulation Analysis |
| TD-SCDMA | IQ Waveform<br>Power Stat CCDF<br>Code Domain<br>Mod Accuracy |
| cdma2000 | IQ Waveform<br>Power Stat CCDF<br>Code Domain<br>Mod Accuracy<br>QPSK EVM |
| DTMB (CTTB) | IQ Waveform<br>Power Stat CCDF<br>Mod Accuracy |
| DVB-T/H with T2 | IQ Waveform<br>Power Stat CCDF<br>DVB-T/H Mod Accuracy<br>DVB-T2 Mod Accuracy |
| CMMB | IQ Waveform<br>Power Stat CCDF<br>Mod Accuracy |
| ISDB-T | IQ Waveform<br>Power Stat CCDF<br>Mod Accuracy |
| Digital Cable TV | IQ Waveform<br>Power Stat CCDF<br>Mod Accuracy |
| IQ Analyzer (Basic) | IQ Waveform<br>Complex Spectrum |

## Baseband I/Q Measurement Overview

The Baseband I/Q functionality is a hardware option, Option BBA. If the option is not installed in the instrument, the I/Q functionality cannot be enabled.

The Baseband I/Q option provides four input ports and one Calibration Output port. The input ports are I, I-bar, Q, and Q-bar. The I and I-bar together compose the I channel and the Q and Q-bar together compose the Q channel. Each channel has two modes of operation:

Single Ended
(unbalanced)         In this mode, only the main port (I or Q) is used and the complementary ports (I-bar or Q-bar) are ignored. The I and Q ports are in single-ended mode when Differential "Off" is selected.

Differential
(balanced)           In this mode, both main and complementary ports are used. To activate this mode, select Differential "On" from the I and Q Setup softkey menus.

The system supports a variety of input passive probes as well as the Agilent 1153A active differential probe using the Infinimax probe interface.

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**NOTE**          To avoid duplication, this section describes only the details unique to using the baseband I/Q inputs. For generic measurement details, refer to the previous sections in "Making Digital Cable TV Measurements" on page 11.

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To make measurements using baseband I/Q Inputs, make the following selections:

| Step | Notes |
|------|-------|
| **1** Select a measurement that supports baseband I/Q inputs by pressing **Meas**. | Table 2-3 lists the measurements that support baseband I/Q inputs in each mode. |
| **2** Select the I/Q Path. Press **Input/Output, I/Q, I/Q Path**, and then select from the choices displayed on the screen. | The path selected in this step is shown at the top of the measurement screen. |
| **3** Select the appropriate circuit location and probe(s) for measurements. | For details see "Selecting Input Probes for Baseband Measurements" on page 62 in the Concepts chapter. |
| **4** Select baseband I/Q input connectors and connect the I/Q signals to the corresponding I/Q ports on the instrument. | |

| Step | Notes |
|---|---|
| **5** If you have set the I/Q Path to **I+jQ** or to **I Only**, press **I Setup.** | |
| A. Select whether **Differential (Balanced)** input is **On** or **Off.** | |
| B. Select the input impedance, **Input Z**. | |
| C. Input a **Skew** value in seconds. | |
| D. Set up the I Probe by pressing **I Probe**. | |
|   a. Select probe **Attenuation**. | |
|   b. Calibrate the probe. Press **Calibrate...** to start the calibration procedure. Follow the calibration procedure, clicking **Next** at the end of each step. | |
| **6** If you have set the I/Q Path to **I+jQ** or to **Q Only**, press **Q Setup.** | |
| A. Select whether **Differential (Balanced)** input is **On** or **Off.** | |
| B. Select the input impedance, **Input Z**. | |
| C. Input a **Skew** value in seconds. | |
| D. Set up the I Probe by pressing **I Probe**. | |
|   a. Select probe **Attenuation**. | |
|   b. Calibrate the probe. Press **Calibrate...** to start the calibration procedure. Follow the calibration procedure, clicking **Next** at the end of each step. | |
| **7** Select the reference impedance by pressing **Reference Z**, and inputting a value from one ohm to one megohm. | The impedance selected is shown at the top of the measurement screen. |
| **8** If you are using cables that were not calibrated in the probe calibration step, press **I/Q Cable Calibrate...** Follow the calibration procedure, clicking **Next** at the end of each step. | |
| **9** After completing the baseband IQ setup procedures, make your desired measurement. | |
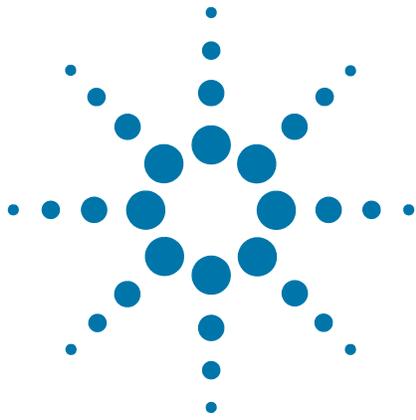
# 3 Concepts

This chapter provides details about the digital cable TV broadcast systems, including the three standards (DVB-C (J.83/A), J.83/B, J.83/C) supported in the N6152A & W6152A Digital Cable TV measurement application, and explains how the various measurements are performed by the instrument.

Suggestions for optimizing and troubleshooting your setup are provided, along with a list of related documents that are referenced for further information.

# Digital Cable TV Technical Overview

A general block diagram of the digital cable transmitter is shown in Figure 3-1 below.

The MPEG-2 transport streams are first organized in certain frame structure according to the current TV standard and then go through channel coding, which varies with the standards. After that, the signals are modulated to QAM formats.

*Figure 3-1*　　　　　　*Block Diagram of Digital Cable TV transmitter*
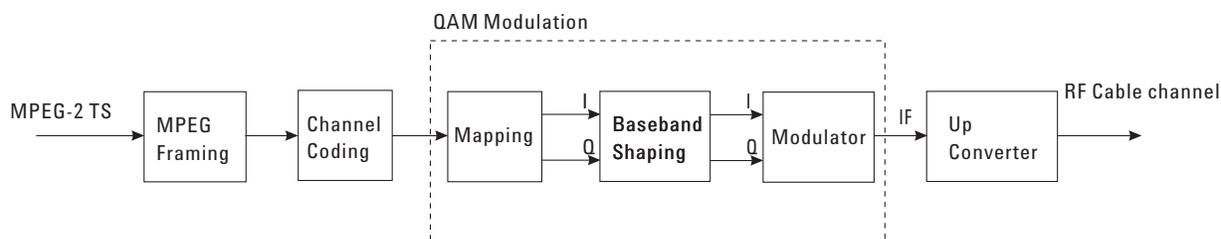


Table 3-1 shows a comparison of the specifications of the three digital cable TV (DVB-C (J.83/A), J.83/B, and J.83/C) standards.

*Table 3-1*　　　　　　*Comparison of specifications of the three digital cable TV standards*

| Item | | DVB-C (J.83/A) | J.83/B | J.83/C |
|---|---|---|---|---|
| Input Signals | | MPEG-2 TS | Modified MPEG-2 TS, with the sync byte replaced by a parity checksum. | MPEG-2 TS |
| Channel Coding | Randomization | Polynomial for PRBS is: $$1 + x^{14} + x^{15}$$ | 3-word polynomial for PRS is: $x^3 + x + \alpha^3$ over GF(128), where $$\alpha^7 + \alpha^3 + 1 = 0$$ | Polynomial for PRBS is: $$1 + x^{14} + x^{15}$$ |
| | FEC | RS (204,188) over GF (256) | RS (128,122) over GF (128) concatenated with convolutional coding | RS (204,188) over GF (256) |
| | Interleaving | Convolutional interleaving, depth is: $$I = 12$$ | Convolutional interleaving, depth: $$I = 128, 64, 32, 16, 8$$ $$J = 1, 2, 3, 4, 5, 6, 7, 8, 16$$ | Convolutional interleaving, depth is: $$I = 12$$ |
| | Trellis coding | None | Trellis coded modulation | None |

*Table 3-1*          *Comparison of specifications of the three digital cable TV standards*

| Item | | DVB-C (J.83/A) | J.83/B | J.83/C |
|------|--------|----------------|--------|--------|
| **Modulati-on** | Bandwidth | 8 MHz | 6 MHz | 6 MHz |
| | Constellation | 16QAM, 32QAM, 64QAM, 128QAM, 256QAM | 64QAM, 256QAM, 1024QAM | 16QAM, 32QAM, 64QAM, 128QAM, 256QAM |
| | Roll-off factor (baseband filter) | 0.15 | 0.18 for 64QAM, 0.12 for 256QAM, 1024QAM | 0.13 |

## MPEG Framing

In DVB-C(J.83/A) and J.83/C specifications, the MPEG-2 transport is comprised of 188 bytes, with one byte for synchronization.

In J.83/B, the sync byte is replaced with a parity checksum in the MPEG-2 transport packets, and reinserted in the receiver to provide standard MPEG-2 data output. Thus, J.83/B can transmit both MPEG-2 streams and other ATM (asynchronous transfer mode) streams.

## Channel Coding

Channel coding adds protection to the data under transmission. In the three digital cable TV standards, different channel coding methods are utilized to achieve different levels of protection.

### Channel Coding in DVB-C (J.83/A) and J.83/C

As shown in Figure 3-2, channel coding includes randomization, RS coding, and convolutional interleaving in DVB-C (J.83/A) and J.83/C standards.

*Figure 3-2*          *Channel Coding Structure in DVB-C (J.83/A) and J.83/C*

Channel Coding

Randomization → Reed-Solomon Coding → Convolutional Interleaving
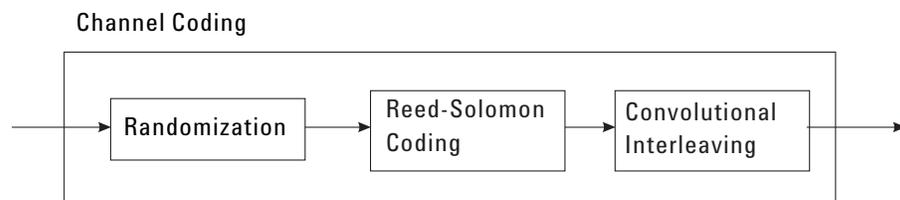
### Randomization

Randomization ensures the clock recovery in the receiver and provides backwards compatibility to satellite TV standards.

The polynomial for the Pseudo Random Binary Sequence (PRBS) generator is:

$$1 + x^{14} + x^{15}$$

The initial state of the PRBS register is "100101010000000".

**Reed-Solomon (RS) Coding**

Shortened RS(204, 188) code is used for error protection. This RS coder is set up for the MPEG-2 TS structure. 51 "0" bytes are appended to the input data and then deleted after going through the RS(255, 239) coder.

The code generator polynomial is:

$$g(x) = (x + \lambda^0)(x + \lambda^1)(x + \lambda^2)...(x + \lambda^{15})$$

where $\lambda = 02_{HEX}$.

**Convolutional interleaving**

Convolutional interleaving protects a signal from bursted errors. The convolutional interleaving indepth is $I = 12$, which means there are 12 branches in the interleaver. Each branch contains a First In First Out (FIFO) register, with $M = 17$ bytes data.

For synchronization purposes, the sync bytes are always transmitted in the first branch.

**Channel Coding in J.83/B**

Channel coding in J.83/B differs substantially from that in J.83/A and J.83/C, which is more elaborate.

*Figure 3-3*      *Channel Coding Structure in J.83/B*

Channel Coding
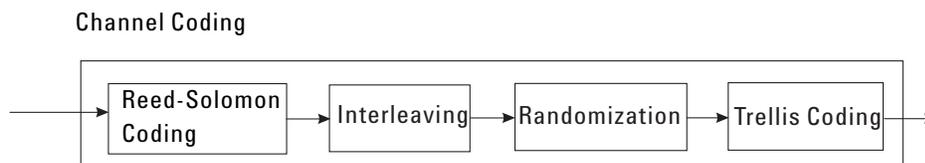


**Reed-Solomon (RS) Coding**

The MPEG-2 transport stream is encoded with a RS(128, 122) coder over GF(128), which can correct up to 3 symbols errors in each block.

The generator polynomial is:

$$g(x) = (x + \alpha)(x + \alpha^2)(x + \alpha^3)(x + a^4)(x + \alpha^5)$$

The primitive polynomial to form the GF(128) is:

$$\alpha^7 + a^3 + 1 = 0$$

**Interleaving**

Two interleaving modes are specified as Level 1 and Level 2.

- Level 1: For 64QAM only, the interleaving depth is $I = 128$, the length of each branch is $J = 1$;

- Level 2: For 64QAM and 256QAM, variable interleavings are defined, including the enlarged and reduced interleaving depth compared to level 1. In this mode, four bits are appended to convey the interleaving parameters.

  Reduced interleaving:

  $$(I, J) = (128, 1), (64, 2), (32, 4), (16, 8), (8, 16)$$

  Enhanced interleaving:

  $$I = 128, J = 1 \text{ to } 8$$

### Randomization

Randomization makes the symbols to distribute evenly in the constellation, and ensures clock recovery in the receiver.

The randomizer designed in J.83/B uses a Pseudorandom Noise (PN) sequence over GF(128). The polynomial for the linear feedback shift register is:

$$f(x) = x^3 + x + \alpha^3$$

The primitive polynomial to form the GF(128) is:

$$\alpha^7 + \alpha^3 + 1 = 0$$

### Trellis Coding

Trellis Coding is used as an inner code to improve the signal-to-noise ratio (SNR) threshold by enlarging the symbol constellation scale. At the same time, additional overhead is added. Thus, trellis coding is more appropriately named trellis coded modulation (TCM).

For 64QAM, trellis coding generates five QAM symbols for each 28-bit sequence (four 7-bit RS symbols), which forms a trellis group. A trellis group is divided into two subgroups A and B. The four least significant (LSB) bits of A and B subgroups are then processed by a differential precoder and a 4/5 punctured binary convolutional coder. The overall code rate is 14/15.

For 256QAM, trellis coding generates five QAM symbols for each 38-bit sequence. The process procedure is similar to that of 64QAM. The overall code rate is 19/20.

## Modulation

### Byte to Symbol Mapping

After channel coding, the output bytes are mapped to symbols according to the modulation formats in sequence. For $2^m$-QAM modulation, a symbol consists of m bits.

For DVB-C (J.83/A) and J.83/C signals, the two MSB (most significant bits) of each symbol are differentially coded to get a $\pi/2$ rotation invariant QAM constellation.

**Baseband Shaping**

Before modulation, the I and Q signals should go through a baseband shaping filter. The baseband filter applied in digital cable TV standards is a square-root raised-cosine filter.

The filter can be defined as:

$$H(f) = 1 \quad \text{for } |f| < f_N(1 - \alpha)$$

$$H(f) = \left\{ \frac{1}{2} + \frac{1}{2} \sin \frac{\pi}{2 f_N} \left[ \frac{f_N - |f|}{\alpha} \right] \right\}^{1/2} \quad \text{for} \quad f_N(1 + \alpha) \le |f| \le f_N(1 + \alpha)$$

$$H(f) = 0 \quad \text{for } (|f| > f_N(1 + \alpha))$$

where $f_N$ is the Nyquist frequency and $\alpha$ is the roll-off factor;

$\alpha$ is different for each digital cable TV standard, as listed in Table 3-1.

The amplitude characteristics of the filter is illustrated in Figure 3-4. Different standards have different specifications on $r_m$ and out–of-band rejection. For DVB-C (J.83/A) and J.83/C, $r_m$ is 0.4 and out-of-band rejection is more than 43 dB.

*Figure 3-4*        *Nyquist baseband filter characteristics*
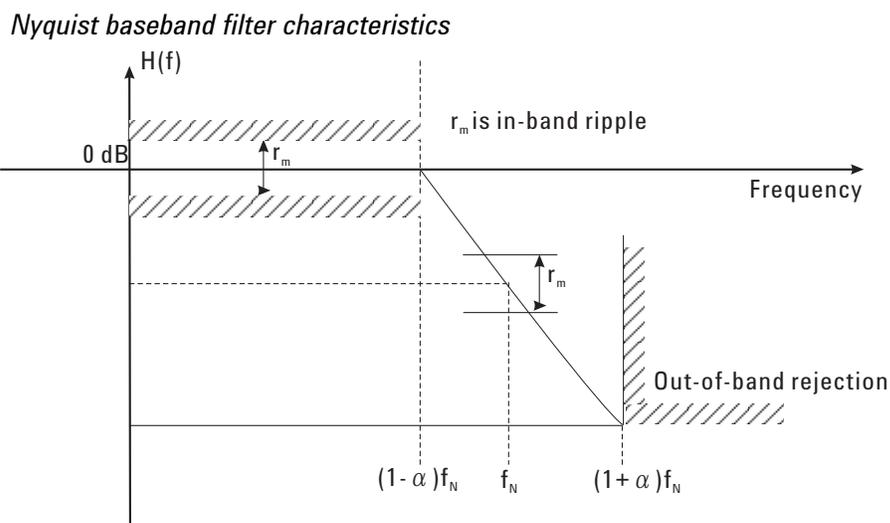


On the receiver side, the matched filter of this baseband filter should be applied to the received signals to recover the signal accurately. Thus, to properly measure the signal, you may need to set the parameters for the filter on the signal analyzer. The related measurements include channel power, ACP, spectrum emission mask, and modulation accuracy measurements.

**Constellation**

For DVB-C (J.83/A) and J.83/C signals, after differential coding, the constellation diagram is illustrated in Figure 3-5, taking 64QAM for example.

*Figure 3-5*        *Constellation Diagram for DVB-C (J.83/A) and J.83/C*

| | | | | Q | | | | |
|---|---|---|---|---|---|---|---|---|
| ○ 101100 | ○ 101110 | ○ 100110 | ○ 100100 | | ○ 001000 | ○ 001001 | ○ 001101 | ○ 001100 |
| ○ 101101 | ○ 101111 | ○ 100111 | ○ 100101 | | ○ 001010 | ○ 001011 | ○ 001111 | ○ 001110 |
| ○ 101001 | ○ 101011 | ○ 100011 | ○ 100001 | | ○ 000010 | ○ 000011 | ○ 000111 | ○ 000110 |
| ○ 101000 | ○ 101010 | ○ 100010 | ○ 100000 | | ○ 000000 | ○ 000001 | ○ 000101 | ○ 000100 I |
| ○ 110100 | ○ 110101 | ○ 110001 | ○ 110000 | | ○ 010000 | ○ 010010 | ○ 011010 | ○ 011000 |
| ○ 110110 | ○ 110111 | ○ 110011 | ○ 110010 | | ○ 010001 | ○ 010011 | ○ 011011 | ○ 011001 |
| ○ 111110 | ○ 111111 | ○ 111011 | ○ 111010 | | ○ 010101 | ○ 010111 | ○ 011111 | ○ 011101 |
| ○ 111100 | ○ 111101 | ○ 111001 | ○ 111000 | | ○ 010100 | ○ 010110 | ○ 011110 | ○ 011100 |

For J.83/B signals, the output from the trellis coded modulator is mapped to the constellation symbol using a look-up table, as shown below (taking 64-QAM for example).

*Figure 3-6*        *Look-up Table for Constellation in J.83/B standards*

| | | | Q | | | | |
|---|---|---|---|---|---|---|---|
| 110111 | 111011 | 010111 | 011011 | 100101 | 101111 | 110101 | 111111 |
| 110100 | 111000 | 010100 | 011000 | 100000 | 101010 | 110000 | 111010 |
| 100111 | 101011 | 000111 | 001011 | 000101 | 001111 | 010101 | 011111 |
| 100100 | 101000 | 000100 | 001000 | 000000 | 001010 | 010000 | 011010 I |
| 010011 | 011001 | 000011 | 001001 | 000001 | 001101 | 100001 | 101101 |
| 010110 | 011100 | 000110 | 001100 | 000010 | 001110 | 100010 | 101110 |
| 110011 | 111001 | 100011 | 101001 | 010001 | 011101 | 110001 | 111101 |
| 110110 | 111100 | 100110 | 101100 | 010010 | 011110 | 110010 | 111110 |

# Channel Power Measurement Concepts

## Purpose

The Channel Power measurement is a common test used in the digital video industry to measure the power characteristics of the transmitted power in defined frequency channel (8 MHz for DVB-C(J.83/A) signals, 6 MHz for J.83/B and J.83/C signals). It provides measurement results of total RF power inband and the power spectrum density.

This measurement is applied to design, characterize, evaluate, and verify the transmitters and exciters for digital cable TV signals.

## Measurement Method

The Channel Power measurement is a swept-frequency measurement. You can change the RBW (resolution bandwidth) and VBW (video bandwidth) settings manually. When setting the RBW, you need to consider the value carefully. If the value is too large, the measurement accuracy will be reduced, and if the value is too small, the measurement will take a long time to finish a sweep.

The power calculation method used to determine the total channel power is the integration bandwidth (IBW) method. The power in-band is integrated to calculate the total power.

To improve repeatability, you can increase the number of averages. The spectrum trace is shown in the graph window, while the absolute channel power in dBm and the mean power spectral density in dBm/Hz are shown in the text window.

# Adjacent Channel Power (ACP) Measurement Concepts

## Purpose

Adjacent Channel Power (ACP), as it applies to digital cable TV signals, is the power contained in a specified frequency channel bandwidth relative to the total carrier power. It may also be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band.

As a measurement of out-of-channel emissions, ACP combines both in-band and out-of-band specifications to provide useful figures-of-merit for spectral regrowth and emissions produced by components and circuit blocks without the rigor of performing a full spectrum emissions mask measurement.

## Measurement Method

This ACP measurement analyzes the total power levels within the defined carrier bandwidth and at given frequency offsets on both sides of the carrier frequency. This measurement allows the user to specify measurement bandwidths of the carrier channel and each of the offset frequency pairs up to 6. Each pair may be defined with unique measurement bandwidths.

In this measurement, the IBW method is used to calculate power. The channel integration bandwidth is analyzed using the user defined resolution bandwidth (RBW), which is much narrower than the channel bandwidth.

If **Total Pwr Ref** is selected as the measurement type, the reference is the total power in carrier channel, and the results are displayed as relative power in dBc and as absolute power in dBm. If **PSD Ref** (Power Spectral Density Reference) is selected, the reference is the PSD in carrier channel, the results are displayed as relative power in dB, and as absolute power in dBm/Hz.

### ACP Requirements for J.83/B

The out-of-band noise requirements for J.83/B defined in CM-SP-DRFI-109-100115 are listed in Table 3-2.

*Table 3-2*          *ACP Requirement for J.83/B*

| Item | Band | Limit |
|------|------|-------|
| 1 | Adjacent channel up to 750 kHz from channel edge | < -58 dBc |
| 2 | Adjacent channel (750 kHz from channel edge to 6 MHz from channel edge) | < -62 dBc |
| 3 | Second-adjacent channel (6 MHz from channel edge to 12 MHz from channel edge) | < -65 dBc |
| 4 | Third-adjacent channel (12 MHz from channel edge to 18 MHz from channel edge) | < -73 dBc |

# Power Statistics CCDF Measurement Concepts

## Purpose

Many digitally modulated signals appear noise-like in the time and frequency domain. This means that statistical measurements of the signals can be a useful characterization. Power Complementary Cumulative Distribution Function (CCDF) curves characterize the higher-level power statistics of a digitally-modulated signal. The curves can be useful in determining design parameters for digital Broadcast systems.

Peak-to-average power ratio is the ratio of the peak envelope power to the average envelope power of a signal. If the peak-to-average power ratio is small, the headroom required in the amplifier to prevent compression of the signal and interference with the adjacent frequency channels is small. Thus, the amplifier can operate more efficiently.

The amplifier must be capable of handling the different peak-to-average power ratios the signal exhibits for the different channel configurations, while maintaining good adjacent channel power (ACP) performance. From the measurement perspective, the statistics of the signal may impact the result of the measurement. Therefore, it is important to choose the signal's channel configuration carefully. You need to cover the real-life worst cases, such as those with the most stressful signal configurations or highest peak-to-average power ratios.

The power statistics CCDF measurement can be affected by many factors. For example, modulation filtering, modulation format, combining the multiple signals at different frequencies, number of active codes and correlation between symbols on different codes with spread spectrum systems. These factors are all related to modulation and signal parameters. External factors such as signal compression and expansion by non-linear components, group delay distortion from filtering, and power control within the observation interval also affect the measurement.

CCDF curves can help you in several situations:

- To determine the headroom required when designing a component.

- To confirm the power statistics of a given signal or stimulus. CCDF curves allow you to verify if the stimulus signal provided by another design team is adequate. For example, RF designers can use CCDF curves to verify that the signal provided by the digital signal processing (DSP) section is realistic.

- To confirm that a component design is adequate or to troubleshoot your subsystem or system design, you can make CCDF measurements at several points of a system.

## Measurement Method

The power measured in power statistics CCDF curves is actually instantaneous envelope power defined by the equation:

$$P = (I^2 + Q^2)/Z_0$$

(where I and Q are the quadrature voltage components of the waveform and Zo is the characteristic impedance).

Then, to obtain the distribution, make a frequency distribution table in the power calculated above. In this measurement, there are 30001 points that range from -200 dBm to 100 dBm by 0.01dB. For example: sampled power = 10 dBm, this means the 21000th index point of this table, so increase the variable that is indexed by this power.

After that, the CCDF trace vector can be made. The CCDF means a probability distribution more than any power and the trace starts from average power. The trace is obtained by converting the frequency distribution table of more than average power.

To make the power statistics CCDF measurement, the instrument uses digital signal processing (DSP) to sample the input signal in the channel bandwidth.

The Gaussian distribution line as the band-limited gaussian noise CCDF reference line, the user-definable reference trace, and the currently measured trace can be displayed on a semi-log graph. If the currently measured trace is above the user reference trace, it means that the higher peak power levels against the average power are included in the input signal.

# Spectrum Emission Mask Measurement Concepts

## Purpose

Spectrum Emission Mask measurements include the in-band and out-of-band spurious emissions. As it applies to digital cable TV standards, it is the power contained in a specified frequency bandwidth at certain offsets relative to the total carrier power. It may also be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band.

As a measurement of out-of-channel emissions, the spectrum emission mask measurement combines both in-band and out-of-band specifications to provide useful figures-of-merit for spectral regrowth and emissions produced by components and circuit blocks without the rigor of performing a full spectrum emissions mask measurement.

## Measurement Method

The spectrum emission mask measurement measures spurious signal levels in up to six pairs of offset/region frequencies and relates them to the carrier power. The reference channel integration bandwidth method is used to measure the carrier channel power.

The channel integration bandwidth is analyzed using the user defined resolution bandwidth (RBW), which is much narrower than the channel bandwidth. The measurement computes an average power of the channel or offset/region over a specified number of data acquisitions, automatically compensating for resolution bandwidth and noise bandwidth.

This measurement requires the user to specify measurement bandwidths of the carrier channel and each of the offset/region frequency pairs up to 6. Each pair may be defined with unique measurement bandwidths. The results are displayed both as relative power in dBc, and as absolute power in dBm.

# Modulation Accuracy Measurement Concepts

## Purpose

Measurement of modulation accuracy and quality are necessary to meet digital cable TV defined tests and ensure proper operation of the transmitters. This measurement takes into account all possible error mechanisms in the entire transmission chain including baseband filtering, I/Q modulation anomalies, filter amplitude and phase non-linearities, and power amplifier distortion. This measurement provides an overall indication of the performance level of the transmitter under test.

## Measurement Method

Modulation Accuracy measurement measures the performance of the transmitter or exciter's modulation circuitry.

In a digitally modulated signal, it is possible to predict what the ideal magnitude and phase of the carrier should be at any time, based on the transmitted data sequence. The transmitter's modulated signal is compared to an ideal signal vector. The difference between these two vectors is sampled and processed using DSP.

*Figure 3-7*             *Digital Cable Receiver Block Diagram*
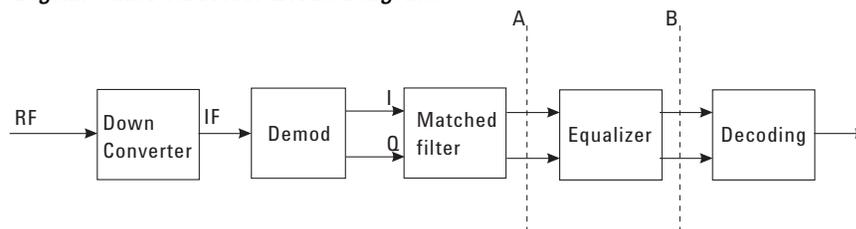


Figure 3-7 shows a block diagram of a digital cable receiver. The process procedure on a digital cable signal in the signal analyzer is similar to the receiver.

Parameters gauging the modulation accuracy, such as MER, EVM, Magnitude Error, etc., can all be measured at both points, A and B, which means before and after the equalizer separately. Thus, when such a figure is quoted, it should be stated whether or not an equalizer is being used.

In a Modulation Accuracy measurement, the following results are provided:

- EVM - peak and rms error vector magnitude

- MER - distance between measured and theoretical constellation points

- Magnitude Error - rms magnitude error

- Phase Error - rms phase error

- Freq Error - the frequency difference between the transmitter's actual center frequency and the frequency (or channel) that you entered

- IQ Offset - Offset of the constellation diagram center

- Quad Error - the orthogonal error between I and Q signals

- Gain Imbalance - a form of IQ gain imbalance

- Channel frequency/impulse response

- BER results

The detailed description of the parameters above is as follows:

**EVM**

EVM (Error Vector Magnitude) is a modulation quality metric widely used in digital broadcast systems. It is defined as:

$$EVM = \sqrt{\dfrac{\dfrac{1}{N}\displaystyle\sum_{j=1}^{N}(\delta I_j^2 + \delta Q_j^2)}{S_{max}^2}} \times 100\%$$

Where N is the number of data points in the measurement samples. $S_{max}$ is the magnitude of the vector to the outermost state of the constellation.

---

This definition is only used in the broadcast industry, and in the wireless industry EVM is defined as the ratio of error vector vs. RMS reference vector.

$$EVM = \dfrac{\sqrt{\dfrac{1}{N}\displaystyle\sum_{j=1}^{N}(\delta I_j^2 + \delta Q_j^2)}}{S_{rms}} \times 100\%$$

$S_{rms}$ is calculated in the following way: $S_{rms} = \sqrt{\dfrac{1}{N}\displaystyle\sum_{j=1}^{N}(I_j^2 + Q_j^2)}$

---

The representation of other definitions are expressed in Figure 3-8.

*Figure 3-8*                    *Digital Demodulation Error*
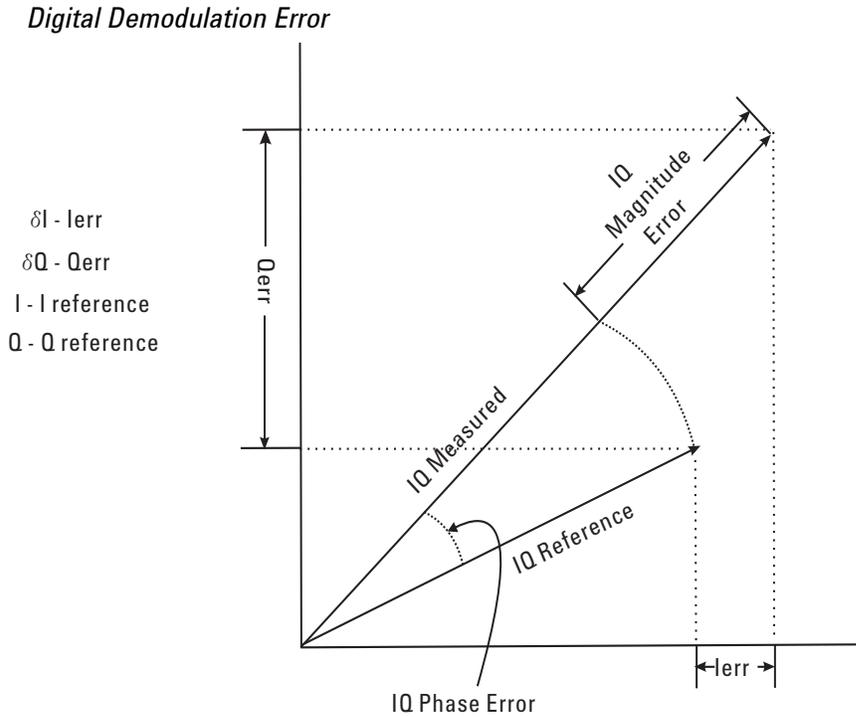


### MER

MER (Modulation Error Ratio) is a power ratio expressed in dB of the sum of squares of the magnitude of the ideal symbol vectors to the sum of the squares of the magnitudes of the symbol error vectors.

MER results is calculated to give the total signal degradation likely to be present at the input of the receiver, and indicate the ability of the receiver to correctly decode the signal.

The MER is calculated as follows:

$$MER = 10log_{10}\left[\frac{\sum\limits_{j=1}^{N}(I_j^2 + Q_j^2)}{\sum\limits_{j=1}^{N}(\delta I_j^2 + \delta Q_j^2)}\right] dB$$

N is the number of data points in the measurement samples.

The representations of other definitions are expressed in Figure 3-8.

### Magnitude Error

Magnitude Error, in %rms, is the difference in amplitude between the I/Q measured signal and the I/Q reference signal and is an indicator of the quality of the modulated signal amplitude component, as shown in Figure 3-8.

**Phase Error**

Phase error is the difference in phase between the I/Q reference signal and the I/Q measured signal for composite signal and is an indicator of the quality of the modulated signal phase component. The unit of phase error is degree. Phase Error is shown in Figure 3-8.

**Frequency Error**

Frequency Error shows the signal carrier frequency-error relative to analyzer's center frequency. This parameter is displayed in Hz and is the amount of frequency shift, from the analyzer's center frequency, that the analyzer must perform to achieve carrier lock.

Errors in RF frequency, LO frequency, or digitizer clock rate could all appear as carrier frequency error.

**IQ Offset**

IQ offset is the composite IQ offset (also called I/Q origin), which measures the offset of the composite constellation diagram center "x". When x occurs at the origin, IQ offset is zero. IQ offset units is a ratio, in dB, between the power of the vector magnitude of the IQ offset and the power of the normalized vector magnitude of 1.0. Carrier feedthrough itself is a transmission signal impairment caused by offsets in the modulation inputs to the quadrature modulator.

**Quad Error**

Quad Error (Quadrature Skew Error) indicates the orthogonal error between the I and Q signals.

Ideally, I and Q should be orthogonal (90 degrees apart). A quadrature skew error of 3 degrees means I and Q are 93 degrees apart. A quadrature skew error of -3 degrees means I and Q are 87 degrees apart.

**Gain Imbalance**

Gain Imbalance is another form of IQ Gain imbalance. It is calculated using the formula below:

$$AI = \begin{cases} \left( \dfrac{v_I}{v_Q} - 1 \right) \times 100\% & if \ v_I > v_Q \\ \left( 1 - \dfrac{v_Q}{v_I} \right) \times 100\% & if \ v_Q > v_I \end{cases}$$

Where $v_I$ and $v_Q$ represent I and Q gain respectively.

**Channel Frequency/Impulse Response**

Channel response indicates the linear distortions, like amplitude and phase errors, and echoes, which are caused by the cable, connection port, or amplifiers. Channel response is important to localize the discrete reflections in cable networks.

In this measurement application, channel impulse response is derived from the equalizer tap through an deconvolution algorithm. Channel frequency response is the FFT (Fast Fourier Transform) of channel impulse response.

**BER**

Here, the BER measurement methods for DVB-C (J.83/A), J.83/B, and J.83/C signals are discussed. Two alternative methods are available; One for "Out of Service" and the other for "In Service". For both methods, three results are provided for DVB-C (J.83/A) and J.83/C signals: BER before RS, BER after RS, and Packet Error Ratio. Two results are provided for J.83/B signals: BER before RS and BER after RS.

*Figure 3-9*          *RS decoding Diagram*
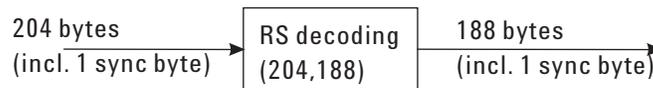


a. For DVB-C(J.83/A) and J.83/C signals
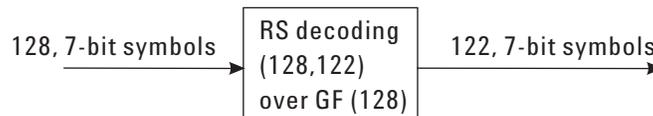


b. For J.83/B signals

- Out of Service

   The basic principle of this method is that a known fixed sequence named "Null TS" packets are transmitted. The "Null TS" sequence is defined in ETSI TR 101 290.

   — BER before RS: To obtain the BER before RS results, the known "Null TS" packets are RS coded again and compared with the TS packets before RS decoding. BER before RS can be expressed as:

   $$BER\ before\ RS\ =\ \frac{Number\ of\ erroneous\ bits}{Number\ of\ transmitted\ bits}$$

   — BER after RS: The number of erroneous bits are estimated by comparing the TS packets after RS decoding with the known "Null TS" packets. Then BER after RS can be expressed as:

   $$BER\ after\ RS\ =\ \frac{Number\ of\ erroneous\ bits\ after\ RS\ decoding}{Number\ of\ bits\ after\ RS\ decoding}$$

   — Packet Error Ratio (only for DVB-C (J.83/A) and J.83/C signals): The number of erroneous packets are estimated by comparing the TS packets after RS decoding with the known "Null TS" packets in packets. That is to say, if there is any error in a 188 bytes packet, this packet is marked as erroneous. The packet error ratio can be expressed as:

   $$Packet\ Error\ Ratio\ =\ \frac{Number\ of\ erroneous\ packets}{Number\ of\ packets}$$

- In Service

  — BER before RS: For the RS(204,188) decoder which is used in DVB-C (J.83/A) and J.83/C, it can correct eight bytes per packet. Here, a packet is defined to be 204 bytes. If there are less than eight byte errors, RS decoder can correct all the errors. Then the signal after RS decoder are RS coded and compared with the data before RS decoder at bit-level to count the number of corrected bits. If more than eight byte errors occur within one TS packet, none of the errors can be corrected. In this case, it is assumed that an non-correctable packet has nine byte errors and only one bit error exists in a byte error. Then BER before RS can be expressed as:

  $$BER\ before\ RS\ =\ \frac{Number\ of\ corrected\ bits\ +\ 9 \times Number\ of\ non\text{-}corretable\ packets}{Number\ of\ transmitted\ bits}$$

  For the RS(128,122) over GF (128) decoder which is used in J.83/B, it can correct three 7-bit symbols in 128 7-bit symbols. Here, a packet is defined to be 128 7-bit symbols. If there are less than three 7-bit-symbol errors, RS decoder can correct all the errors. Then the signal after RS decoder are RS coded and compared with the data before RS decoder at bit-level to count the number of corrected bits. If more than three 7-bit-symbol errors occur within a packet, none of the errors can be corrected. In this case, it is assumed that an non-correctable packet has four 7-bit-symbol errors and only one bit error exists in a 7-bit-symbol error. Then BER before RS can be expressed as:

  $$BER\ before\ RS\ =\ \frac{Number\ of\ corrected\ bits\ +\ 4 \times Number\ of\ non\text{-}corretable\ packets}{Number\ of\ transmitted\ bits}$$

  Notice that there are two premises for this method:

  1. BER before RS decoding is much larger than BER after RS decoding;

  2. One bit error exists in one erroneous byte or 7-bit symbol. When there is impulsive noise in the channel, this premise can't be fulfilled.

  — BER after RS: The RS(204,188) decoder can correct eight bytes per packet. If there are more erroneous bytes, the whole packet can't be corrected. It is assumed that a non-correctable packet contains nine byte errors, and one erroneous bit exists in a byte error. The BER after RS can be expressed as:

  $$BER\ after\ RS\ =\ \frac{9 \times Number\ of\ non\text{-}corretable\ packets}{Number\ of\ bits\ after\ RS\ decoding}$$

  The RS(128,122) over GF (128) decoder can correct three 7-bit symbols per packet. If there are more erroneous 7-bit symbols, the whole packet can't be corrected. It is assumed that a non-correctable packet contains four 7-bit-symbol errors, and one erroneous bit exists in a 7-bit-symbol error. The BER after RS can be expressed as:

  $$BER\ after\ RS\ =\ \frac{4 \times Number\ of\ non\text{-}corretable\ packets}{Number\ of\ bits\ after\ RS\ decoding}$$

— Packet Error Ratio (only for DVB-C (J.83/A) and J.83/C signals): If there are nine or more byte errors in a packet, the packet can't be corrected. This packet is counted as non-correctable. The packet error ratio can be expressed as:

$$Packet\ Error\ Ratio\ =\ \frac{Number\ of\ non\text{-}correctable\ packets}{Number\ of\ packets\ received}$$

# Monitor Spectrum Measurement Concepts

## Purpose

The Monitor Spectrum measurement provides spectrum analysis capability for the instrument. It is used as a quick, convenient means of looking at the entire spectrum. While the look and feel are similar to the Spectrum Analyzer mode, the functionality is greatly reduced for easy operation. The main purpose of the measurement is to show the spectrum. The default span should cover an appropriate frequency range of the application.

## Measurement Method

The measurement takes the sweep and acquires the data between the start frequency and stop frequency, then trace is displayed in the measurement window.

## Troubleshooting Hints

Changes made by the user to advanced spectrum settings, particularly to ADC range settings, can inadvertently result in spectrum measurements that are invalid and cause error messages to appear. Care needs to be taken when using advanced features.

# IQ Waveform Measurement Concepts

## Purpose

The Waveform measurement is a generic measurement for viewing the input signal waveforms in the time domain. This measurement is how the instrument performs the zero span functionality found in traditional spectrum analyzers.

Basic mode waveform measurement data may be displayed using either a Signal Envelope window, or an I/Q window which shows the I and Q signal waveforms in parameters of voltage versus time. The advantage of having an I/Q view available while making a waveform measurement is that it allows you to view complex components of the same signal without changing settings or measurements.

The Waveform measurement can be used to perform general purpose power measurements in the time domain with excellent accuracy.

## Measurement Method

The instrument makes repeated power measurements at a set frequency, similar to the way a swept-tuned spectrum analyzer makes zero span measurements. The input analog signal is converted to a digital signal, which then is processed into a representation of a Waveform measurement. The measurement relies on a high rate of sampling to create an accurate representation of a time domain signal.

# Baseband I/Q Inputs (Option BBA) Measurement Concepts

The N9020A Option BBA Baseband I/Q Inputs provides the ability to analyze baseband I/Q signal characteristics of mobile and base station transmitters. This option may be used only in conjunction with the following modes:

- IQ Analyzer (Basic)
-  802.16 OFDMA (WiMAX/WiBro)
- cdma2000
- GSM/EDGE
- TD-SCDMA
- DTMB (CTTB)
- DVB-T/H with T2
- CMMB
- ISDB-T
- Digital Cable TV

## What are Baseband I/Q Inputs?

Option BBA consists of a Baseband Input module, four input connectors, and a calibration output connector. The connectors are at the left side of the front panel. The two ports labeled "I" and "Q" are the "unbalanced" inputs.

An unbalanced or "single-ended" baseband measurement of an I or Q signal is made using a probe connected to the I or Q connector. A simultaneous I/Q unbalanced single-ended measurement may be made using two probes connected to the I and Q input connectors.

If "balanced" signals are available, they may be used to make a more accurate measurement. Balanced signals are signals present in two separate conductors, are symmetrical about ground, and are opposite in polarity, or out of phase by 180 degrees.

Measurements using balanced signals can have a higher signal to noise ratio resulting in improved accuracy. Noise coupled into each conductor equally in a "common mode" to both signals may be separated from the signal. The measure of this separation is "common-mode rejection".

To make a balanced measurement, the two connectors labeled "I" and "Q" are used in conjunction with the I and Q inputs. The terms "I-bar" and "Q-bar" may be applied to the signals, as well as the inputs themselves. Probes (customer provided) must be used to input balanced baseband I/Q signals. This may be referred to as a balanced measurement.

Balanced baseband measurements are made using the I and I-bar connectors for I only signal measurements, while the Q and Q-bar connectors are used for a Q only signal measurement. Balanced measurements of I/Q require differential probe connections to all four input connectors. For details of probe selection and use, refer to "Selecting Input Probes for Baseband Measurements" on page 62.

## What are Baseband I/Q Signals?

In transmitters, the term baseband I/Q refers to signals that are the fundamental products of individual I/Q modulators, before the I and Q component signals are combined, and before upconversion to IF or RF frequencies.

In receivers, baseband I/Q analysis may be used to test the I and Q products of I/Q demodulators, after a RF signal has been downconverted and demodulated.

## Why Make Measurements at Baseband?

Baseband I/Q measurements are a valuable means of making qualitative analyses of the following operating characteristics:

- I/Q signal layer access for performing format-specific demodulation measurements (for example, DTMB (CTTB), DVB-T/H with T2, CMMB, ISDB-T, Digital Cable TV).

- Modulation accuracy – that is, I/Q plane metrics:

  — error vector magnitude; rms, peak

  — frequency error

  — magnitude and phase errors

- CCDF of $I^2 + Q^2$

- Basic analysis of I and Q signals in isolation including: DC content, rms and peak to peak levels, CCDF of each channel

Comparisons of measurements made at baseband and RF frequencies produced by the same device are especially revealing. Once signal integrity is verified at baseband, impairments can be traced to specific stages of upconversion, amplification, or filtering by RF analysis. In addition, impairments to signal quality that are apparent at RF frequencies may be traceable to baseband using baseband analysis.

## Selecting Input Probes for Baseband Measurements

The selection of baseband measurement probe(s) and measurement method is primarily dependent on the location of the measurement point in the circuit. The probe must sample voltages without imposing an inappropriate load on the circuit.

The system supports a variety of 1 MΩ impedance input passive probes as well as the Agilent 1153A active differential probe using the InfiniMax probe interface.

The Agilent 1153A active probe can be used for both single-ended and differential measurements. In either case a single connection is made for each channel (on either the I or Q input). The input is automatically configured to the 50 Ω single-ended type measurement and the probe power is supplied through the InfiniMax interface. The probe can be configured for a variety of input coupling and low frequency rejection modes. In addition, a wide range of offset voltages and probe attenuation accessories are supported at the probe interface. The active probe has the advantage that it does not significantly load the circuit under test, even with unity gain probing.

With passive 1 MΩ probes, the probe will introduce a capacitive load on the circuit, unless a higher attenuation is used at the probe interface. Higher attenuation helps isolate the probe, however, it reduces the signal level and degrades the signal-to-noise-ratio of the measurement. Passive probes are available with a variety of attenuation values for a moderate cost. Many Agilent passive probes can be automatically identified by the system, setting the input impedance required as well as the nominal attenuation. For single-ended measurements a single probe is used for each channel. Other passive probes can be used, after manually setting the attenuation and probe impedance configurations.

For full differential measurements, the system supports probes on each of the four inputs. The attenuation for each of the probes should be the same for good common mode rejection and channel match.

### Supported Probes

The following table lists the probes currently supported by Option BBA:

| Probe Type | Model Number | Description |
|---|---|---|
| Active | 1130A | 1.5 GHz differential probe amp (No probe head) |
| | 1131A[a] | InfiniMax 3.5 GHz probe |
| | 1132A[a] | InfiniMax 5 GHz probe |
| | 1133A[a] | InfiniMax 7 GHz probe |
| Passive | 1161A | Miniature passive probe, 10:1, 10 MΩ, 1.5 m |

a. Probe heads are necessary to attach to your device properly. Probe connectivity kits such as the E2668A, E2669A or E2675A are needed. For more details, refer to the Agilent probe configuration guide, 5968-7141EN and 5989-6162EN.

### Probes without Stored Calibration

The following 115xA active probes may be used with the MXA's baseband IQ inputs and may use the same probe calibration utility software. However, the probe calibration data is not stored in the MXA and will be lost if power is cycled. Use of the E2655B de-skew and calibration kit, including the calibration fixture, is required because of the different physical configuration of the probes. (The physical connections are different mechanically, not electrically.)

| Probe Type | Model Number | Description |
|---|---|---|
| Active | 1153A | 200MHz differential probe |
| | 1156A | Active probe, 1.5 GHz |
| | 1157A | Active probe, 2.5 GHz |
| | 1158A | Active probe, 4 GHz |

Refer to the current Agilent probe data sheet for specific information regarding frequency of operation and power supply requirements.

## Baseband I/Q Measurement Views

Measurement result views made in the IQ Analyzer (Basic) mode are available for baseband signals if they relate to the nature of the signal itself. Many measurements which relate to the characteristics that baseband I and Q signals have when mixed and upconverted to signals in the RF spectrum can be made as well. However, measurements which relate to the characteristics of an upconverted signal that lie beyond the bandwidth available to the Baseband I/Q Input circuits can not be measured (the limits are dependent on the installed options: Standard – 10 Hz to 20 MHz, Option B25 – 10 Hz to 50 MHz, and Option S40 – 10 Hz to 80 MHz).

At RF frequencies, power measurements are conventionally displayed on a logarithmic vertical scale in dBm units, whereas measurements of baseband signals using Baseband I/Q inputs may be conveniently displayed as voltage using a linear vertical scale as well as a log scale.

### Spectrum Views and 0 Hz Center Frequency

To view the Spectrum display of I only or Q only signals, use the Complex Spectrum measurement capability in IQ Analyzer (Basic) Mode.

I only and Q only Spectrum views are conventional, displayed with 0 Hz at the left side of the horizontal axis. When upconverted or multiplied, an I only or Q only signal could ultimately lie above or below the carrier center frequency, but in either case it will only occupy half the bandwidth.

**Waveform Signal Envelope Views of I only or Q only**

To view the Signal Envelope display of I only or Q only signals, use the Waveform measurement capability in IQ Analyzer (Basic) Mode.

The I and Q Waveform of an I/Q signal is very different from the complex signal displayed in the RF Envelope view. That is because the RF Envelope is a product of both the I and Q modulation waveforms.

However, an I and Q Waveform measurement of an I only or Q only signal is exactly the same signal displayed in the RF Envelope view. That is because an I only or Q only waveform determines the I only or Q only signal envelope. Thus, the RF Envelope view can be used to measure an I only or Q only waveform directly.

# Other Sources of Measurement Information

Additional measurement application information is available through your local Agilent Technologies sales and service office. The following application notes document digital communications measurements in much greater detail than discussed in this measurement guide.

- Application Note 1298

  Digital Modulation in Communications Systems - An Introduction
  Agilent part number 5965-7160E

- Application Note

  Characterizing Digitally Modulated Signals with CCDF Curves
  Agilent part number 5968-5858E

Go to http://www.agilent.com/find/digital_video to find more products and literatures on digital video transmitter and receiver measurements.

## Instrument Updates at www.agilent.com

These web locations can be used to access the latest information about the instrument, including the latest firmware version.

http://www.agilent.com/find/cxa

http://www.agilent.com/find/exa

http://www.agilent.com/find/mxa

http://www.agilent.com/find/pxa