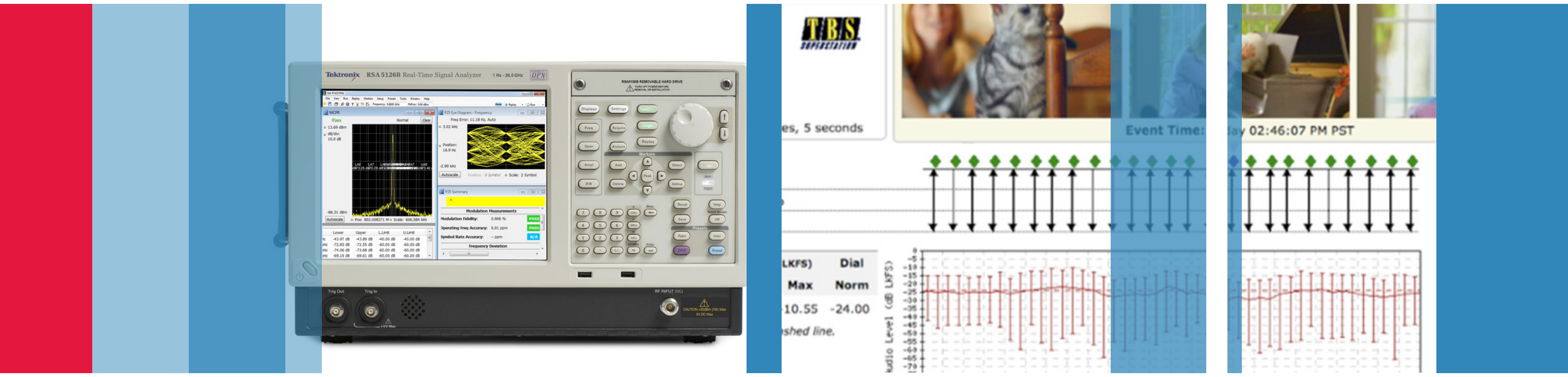



# Testing APCO Project 25 Transmitters with Tektronix Solutions

Application Note

## Background

In order to meet the growing communications needs of public safety, new digital land mobile radio (LMR) communications systems have been developed. The need for interoperable emergency communication was furthermore exacerbated during the disasters that the United States faced in 2001. At the time radio communication systems were incompatible and inoperable not just within a jurisdiction but within departments or agencies within the same community. In response to this need, Project 25 (P25 or APCO-25) was initiated collaboratively by US public safety agencies and manufacturers with the goal to homogenize the emergency communication systems. The Telecommunications Industry Association's TR-8 engineering committee facilitated the development of the standard and published the P25 suite of standards as the TIA-102 series of documents. Although developed primarily for North American public safety services, P25 technology and products are not limited to US public safety alone and have also been used in other countries worldwide including Australia, New Zealand, Brazil, Canada, India and Russia.

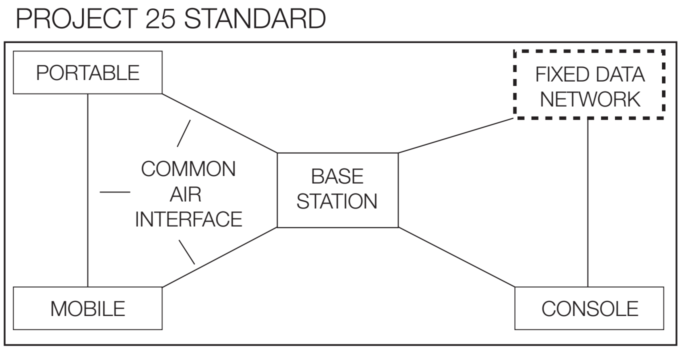



**Figure 1.** P25 Common Air Interface.

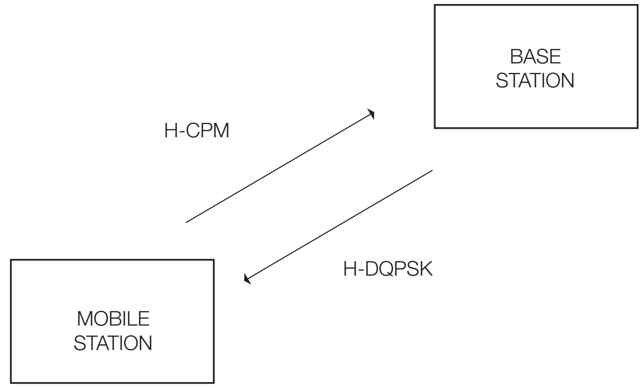



**Figure 2.** Inbound and Outbound modulation types.

## P25 Description

P25 specifies eight interfaces between different components of a land mobile radio system. This application note is only addressing the Common Air Interface (CAI) standard that specifies the signals transmitted between P25 compliant portable radios and the P25 network infrastructure of base stations or mobile radio stations (see Figure 1).

The P25-compliant technology has been deployed in two phases:

- **Phase 1:** Phase 1 radio systems operate in 12.5 kHz analog, digital or mixed mode using FDMA access method. Phase 1 radios use Continuous 4 level FM (C4FM) modulation for digital transmissions at 4800baud and 2 bits per symbol, yielding 9600 bits per second total channel throughput.
- **Phase 2:** To improve spectrum utilization, Phase 2 has been developed using a 2-slot TDMA scheme. Phase 2 uses the AMBE+2 voice codec to reduce the needed bitrate so that one voice channel will only require 6000 bits per second (including error correction and signaling). The uplink uses Harmonized Continuous Phase Modulation (H-CPM) allowing the use of non-linear amplifier in the radio whereas the downlink uses Harmonized Differential Quadrature Phase Shift Keyed Modulation (H-DQPSK) and requires linear amplifiers in the base stations. See Figure 2. Unfortunately, Phase 2 is not backwards compatible with Phase 1 (due to the TDMA versus FDMA operation).

**Future Phases:** The FCC recently allocated 20 MHz of the 700 MHz UHF radio band spectrum freed in the digital TV transition to public safety networks. The FCC expects providers to employ LTE for high-speed data and video applications.

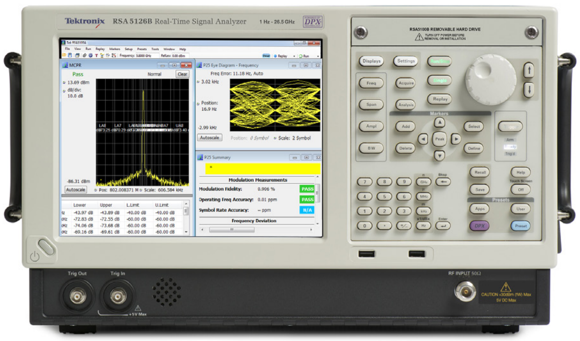


**Figure 3.** RSA5000 real-time spectrum analyzer with P25 analysis software (opt. 26).

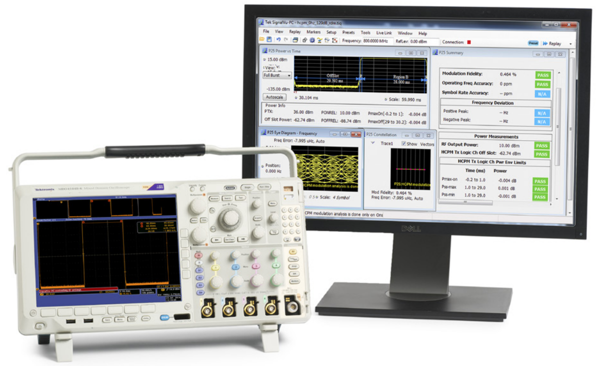


**Figure 4.** MDO4000B with SignalVu-PC running P25 analysis software (opt. SV26).

## P25 Transmitter Performance Testing Made Easy with Simplified Solution

The tests defined for Project 25 require high performance test equipment to measure increasingly stringent operational parameters and ensure that only compliant products reach the market. Once this equipment is deployed in the field, though, well implemented frequency plans are essential to circumvent interference between neighboring systems. The up-front equipment testing, monitoring and continued maintenance of deployed systems require flexible testing solutions. Tektronix has added key support capability to its RF portfolio of signal analyzers and assist with the many aspects of testing these new digital standards, monitoring and maintaining these networks.

The TIA-102 has written the methods to accomplish the measurements with swept spectrum analyzers; however, most P25 test engineers are able to simplify the execution of a number of the transmitter tests leveraging the architecture of the Real-Time Spectrum Analyzer (RTSA) platform. In addition, numerous TIA-102 tests requiring a multitude of dedicated instruments:

- Modulation Analyzer
- RF Signal Generator
- Audio Analyzer
- Spectrum Analyzer
- Power Meter
- and even an Oscilloscope

are now able to be done by using a single instrument - the Tektronix RTSA - exploiting the wide range of functionality in this instrument.

For more price-sensitive test engineers that are also looking for a mid-range oscilloscope, Tektronix offers P25 test capability for its MDO4000B Mixed Domain Oscilloscope. The MDO4000B has one RF input that will be connected to the P25 Device Under Test (DUT), the measurements are performed with the SignalVu-PC signal analysis software running on a PC. The IQ data captured on the MDO4000B is transferred to the PC through a direct live link established either via a USB or LAN connection.

| Measurement Type | TIA-102 Transmitter Measurements | Phase 1 | Phase 2 |
|---|---|---|---|
| Basic Power | RF Output power | Yes | Yes |
| Frequency | Operating frequency accuracy | Yes | Yes |
| Spectral | Modulation emission spectrum | Yes | Yes |
| Spectral | Unwanted emissions: conducted spurious | Yes | Yes |
| Spectral | Unwanted emissions: Non spurious adjacent channel power ratio | Yes | Yes |
| Frequency | Frequency deviation | Yes | H-CPM |
| Modulation | Modulation fidelity | Yes | Yes |
| Modulation | Symbol rate accuracy | Yes | Yes |
| Timing | Transmitter power and encoder attack time | Yes | |
| Timing | Transmitter power and encoder attack time with busy/idle operations | Yes | |
| Timing | Transmitter throughput delay | Yes | |
| Frequency | Transient frequency behavior | Yes | |
| Power | H-CPM Transmitter logical channel peak adjacent channel power ratio | | H-CPM |
| Power | H-CPM Transmitter logical channel off slot power | | H-CPM |
| Power | H-CPM Transmitter logical channel power envelope | | H-CPM |
| Timing | H-CPM Transmitter logical channel time alignment | | H-CPM |

**Table 1.** Measurements that are supported by the P25 analysis software.

## P25 CAI Transmitter Measurements

The basic power and spectral measurements are standard in the RTSA or SignalVu-PC to test transmitter performance. For the more complex tests e.g. modulation and timing tests, optional software enables the RTSA and SignalVu-PC products to perform a host of additional P25 CAI Phase 1 and Phase 2 transmitter measurements.

Table 1 provides the list of measurements that are supported by the P25 analysis software.

## TIA-102 Test Patterns

A number of test patterns are specified in the TIA-102 documents for use in performance testing of the transmitters. Users need to indicate in the Tektronix P25 software which test pattern is being used so the software can actually compare the measurement result to the standards limit.

The list of test patterns to be used to achieve P25 compliance testing is provided in Table 2 and Table 3.

| TIA-102 Test Patterns (all are w.r.t. inbound - C4FM) | Phase 1 (C4FM) Measurements |
|---|---|
| Standard Transmitter Test Pattern | RF Output Power |
| | Operating Frequency Accuracy |
| | Modulation Emission Spectrum |
| | Unwanted Emissions Adjacent Channel Power Ratio |
| | Modulation Fidelity |
| | Transmitter Power and Encoder Attack Time |
| This Measurement Uses Band Limited Pink Noise Signal (From Noise Source) | Throughput Delay |
| Transmitter Low Deviation Test Pattern | Operating Frequency Accuracy |
| | Intermodulation Attenuation |
| | Transient Frequency Behavior |
| | Frequency Deviation |
| Standard Transmitter Symbol Rate Pattern | Symbol Rate Accuracy |
| | Frequency Deviation |
| Standard C4FM Modulation Fidelity Test Pattern | Modulation Fidelity |

**Table 2.** Test Patterns used for Phase 1 (C4FM).

| Test Patterns (Inbound or Outbound) | Phase 2 Measurements |
|---|---|
| Inbound Symmetrical Time Slot Test Pattern | RF Output Power |
| | Modulation Emission Spectrum |
| | Modulation Fidelity |
| | H-CPM Peak ACPR |
| | H-CPM Off Slot Power |
| | H-CPM - Power Envelope |
| | Unwanted Emissions Adjacent Channel Power Ratio |
| Outbound Standard Transmitter Test Pattern | RF Output Power |
| | Operating Frequency Accuracy |
| | Modulation Emission Spectrum |
| | Intermodulation Attenuation |
| | Modulation Fidelity |
| | Unwanted Emissions Adjacent Channel Power Ratio |
| Low Deviation Test Pattern (Continuous Transmit Mode) | Operating Frequency Accuracy |
| Inbound Low Deviation or High Deviation Test Pattern | Frequency Deviation For HCPM |
| (Inbound and Outbound) High Deviation Test Pattern | Symbol Rate Accuracy |
| STTP-1031 Outbound Test Pattern<br>Inbound Standard Transmitter Test Pattern | H-CPM Transmitter Logical Channel Time Alignment |

**Table 3.** Test patterns used for Phase 2 both Inbound and Outbound testing.

| TIA -102 Transmitter Measurements | Tektronix P25 Analysis Software |
|---|---|
| RF Output Power | P25 Summary: RF Output Power |
| Operating Frequency Accuracy | P25 Summary: Operating Freq Accuracy |
| Modulation Emission Spectrum | SEM (Under RF measurements folder) |
| Unwanted Emissions: Non Spurious Adjacent Channel Power Ratio | MCPR (Under P25 Analysis folder) |
| Frequency Deviation | P25 Summary: Freq Dev |
| Modulation Fidelity | P25 Summary: Modulation Fidelity; P25 Constellation |
| Symbol Rate Accuracy | P25 Summary: Symbol Rate Accuracy |
| Transmitter Power And Encoder Attack Time | P25 Summary: Phase1 TX Attack Time |
| Transmitter Power And Encoder Attack Time With Busy/Idle Operations | P25 Summary: Phase1 TX Attack Time (Busy/Idle) |
| Transmitter Throughput Delay | P25 Summary: Phase1 TX throughput Delay |
| Transient Frequency Behavior | P25 Freq Dev vs. Time |
| H-CPM Transmitter Logical Channel Peak Adjacent Channel Power Ratio | P25 Summary: HCPM Tx Logic Ch Pk ACPR |
| H-CPM Transmitter Logical Channel Off Slot Power | P25 Power vs Time and P25 Summary and P25 Power vs Time: HCPM Tx Logic Ch Off Slot |
| H-CPM Transmitter Logical Channel Power Envelope | P25 Power vs Time and P25 Summary: HCPM Tx Logic Ch Pwr Env Limits |
| H-CPM Transmitter Logical Channel Time Alignment | P25 Summary: HCPM Tx Logic ChTime Alignt |

**Table 4.** Mapping TIA-102 measurement names and Tektronix P25 analysis measurement names.

# Mapping of TIA-102 Measurements to Tektronix P25 Analysis Software

Table 4 indicates where the measurements are located in the Displays folder. More detailed about each measurement is provided below.

# Performing TIA-102 Transmitter Measurements with the Tektronix P25 Analysis Software

## Using Presets

The Tektronix P25 analysis software allows users to quickly setup the analysis software so it is ready to perform P25 measurements. The preset will also display the 4 following measurements with the test pattern provided:

1. P25 Constellation – it illustrates modulation fidelity measurement and the constellation diagram shows a plot of the phase and amplitude of the demodulated signal
2. Time Overview – it shows the power of the signal in the time domain and also indicates on which portion of the signal, the software is performing its analysis.

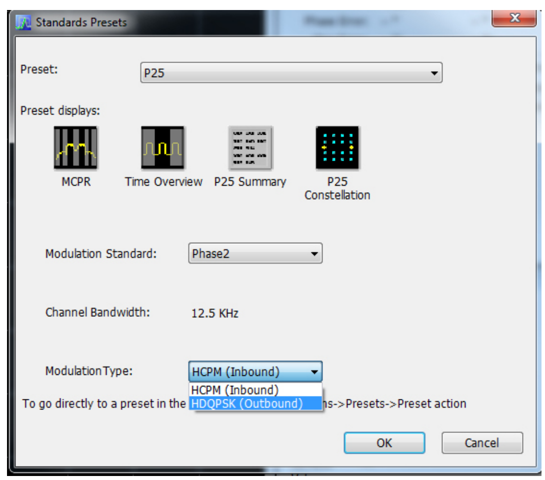



**Figure 5.** P25 Standard Presets

3. MCPR – it provides the unwanted emissions non spurious adjacent channel power ratio measurement to determine the spectral spreading of the signal. It measures the ratio between the total power of all adjacent channels to the main channel's power.
4. P25 Summary – it gives a summary of all the scalar measurements done on the test pattern acquired

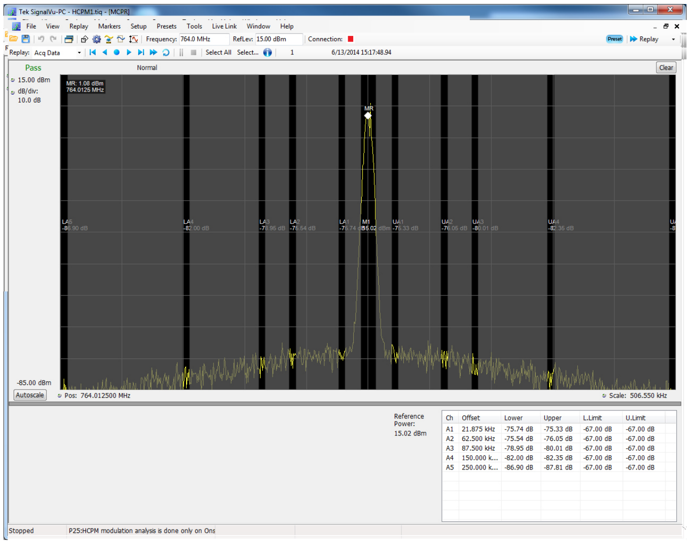



**Figure 6.1.** Adjacent Channel Power Ratio measurement passing.

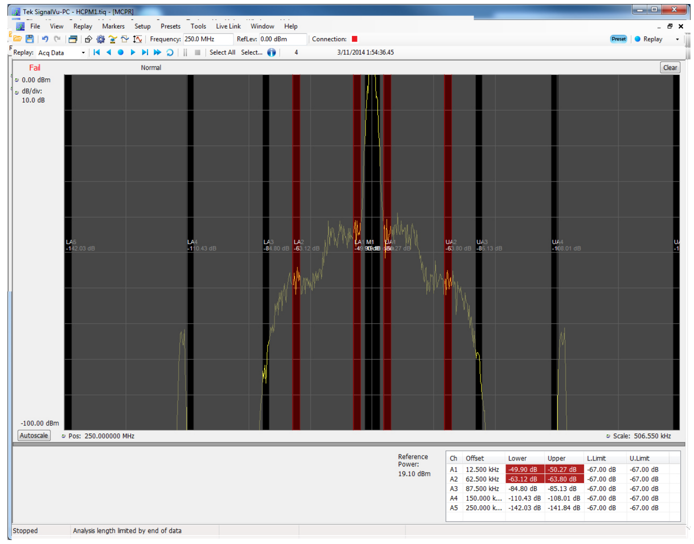
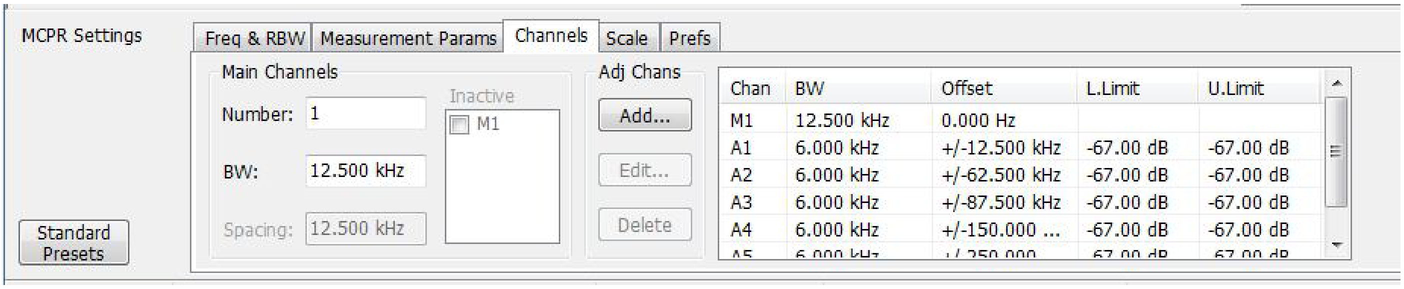



**Figure 6.2.** Adjacent Channel Power Ratio measurement failing.

## Pass/Fail information and Limits

Tektronix P25 analysis software provides not only the measurement value but also the ability to compare to a limit. By default the limit is set to what the standard is asking for a portable radio. The limit can be changed and edited via the settings control panel.

When the measurement has a graphical representation, general Pass/Fail information is provided at the top left corner of the display, the detailed failure is provided in the results table below the chart. See the example of the MCPR measurement. Figure 6.1 shows a Pass and Figure 6.2 shows a Fail.



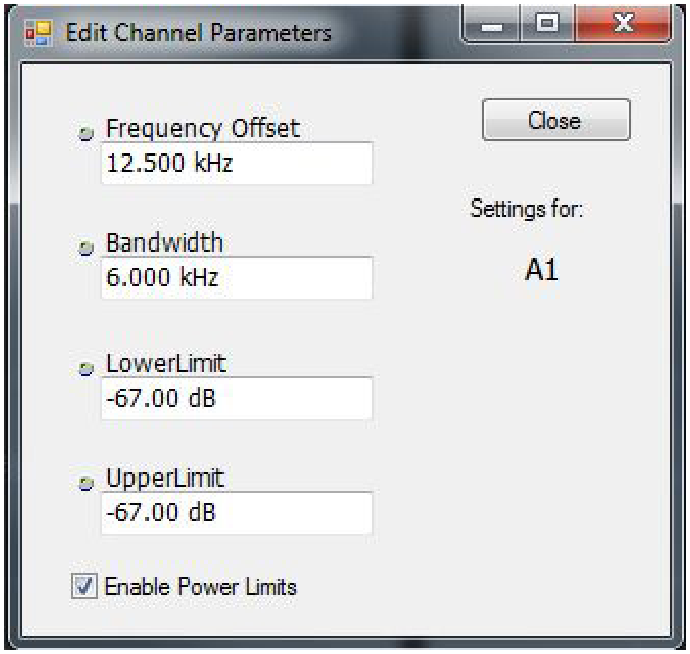




**Figure 7.** You can edit limits in the MCPR Control Panel.

Figure 7 shows a screenshot of the MCPR settings control panel. Once the user selects a row in the adjacent channels' table, he can choose to delete or edit that row. In particular the user can edit the limits.

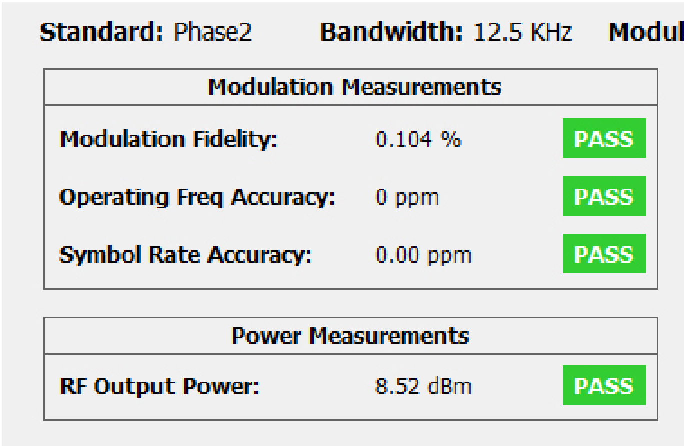



**Figure 8.** P25 Summary for scalar measurements with Pass/Fail information.

Pass/Fail information is also provided in the P25 Summary display for all scalar measurements that are enabled (see Figure 8). Limits can be found in the settings panel of the P25 Summary display; see Figure 9. Within that panel, users can change the default selection and make the choice of which measurement to compare for Pass/Fail. The default limits come from the performance recommendation limits given by the TIA-102 standard for a class A radio.

The P25 standard is chosen in the Modulation Parameters tab. Based on this choice, only the relevant measurements (for the chosen standard) will appear in the Limits tab.

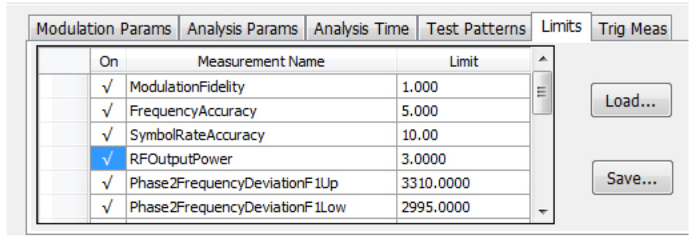



**Figure 9.** Limits table of the P25 Summary Control Panel.

There will be three conditions that can be reported when a comparison is sought by the user and provided along with the measurement result: Pass, Fail or N/A. If the user chooses to compare only a few measurements then only those will indicate Pass, Fail or N/A.

An “N/A” will be shown only when a measurement cannot be done for the given test pattern.

For example Symbol Rate Accuracy cannot be measured for any other test pattern other than high deviation or low deviation test pattern.

So this will be shown as “N/A” even if the user has selected to do a Pass/Fail.

More detailed information about the setting required to do measurements is provided in the On-Line Help.

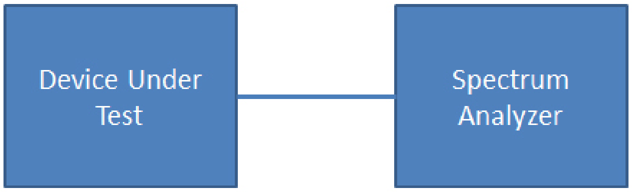



**Figure 10.** Test set-up for most un-triggered P25 measurements.

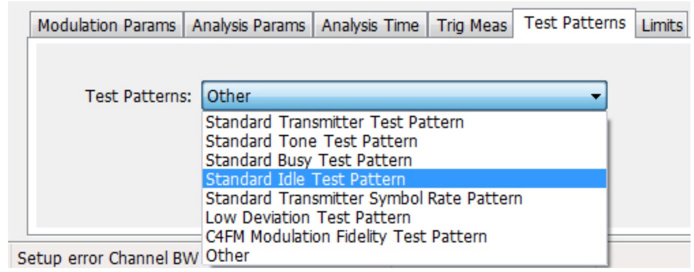



**Figure 11.** Selection of Test Patterns.

# Detailed Measurement Description

## Frequency Deviation

- **Applicability:** Frequency deviation is applicable to Phase 1 C4FM and Phase 2 H-CPM only.
- **Description:** It is a measurement of the frequency modulation deviation that results from two specific test patterns. The first one is a pattern of low deviation symbols, the second is a pattern of high deviation symbols.
- **Connectivity:** The user needs to connect the output of the Device Under Test (DUT) to the RF input of the Spectrum Analyzer as shown in Figure 10.
- **How-to:** The users should bring up the P25 Summary settings panel. In this panel, the users should verify no trigger measurement have been selected (under the Trig. Meas tab). Please refer to Figure 16. The users need to select "none". They also need to select the correct test pattern that is modulating the DUT before pressing Run (either Low or High Deviation). This test pattern is selected under the Test Patterns tab of the P25 Summary settings panel as shown in Figure 11.
- **Result:** The result is displayed in the P25 Summary display at the time of the measurement. See Figure 13. The Limits tab in the P25 Summary Settings panel allows you to compare the result against a limit set for Pass/Fail. The user needs to record the result before proceeding to the next measurement.

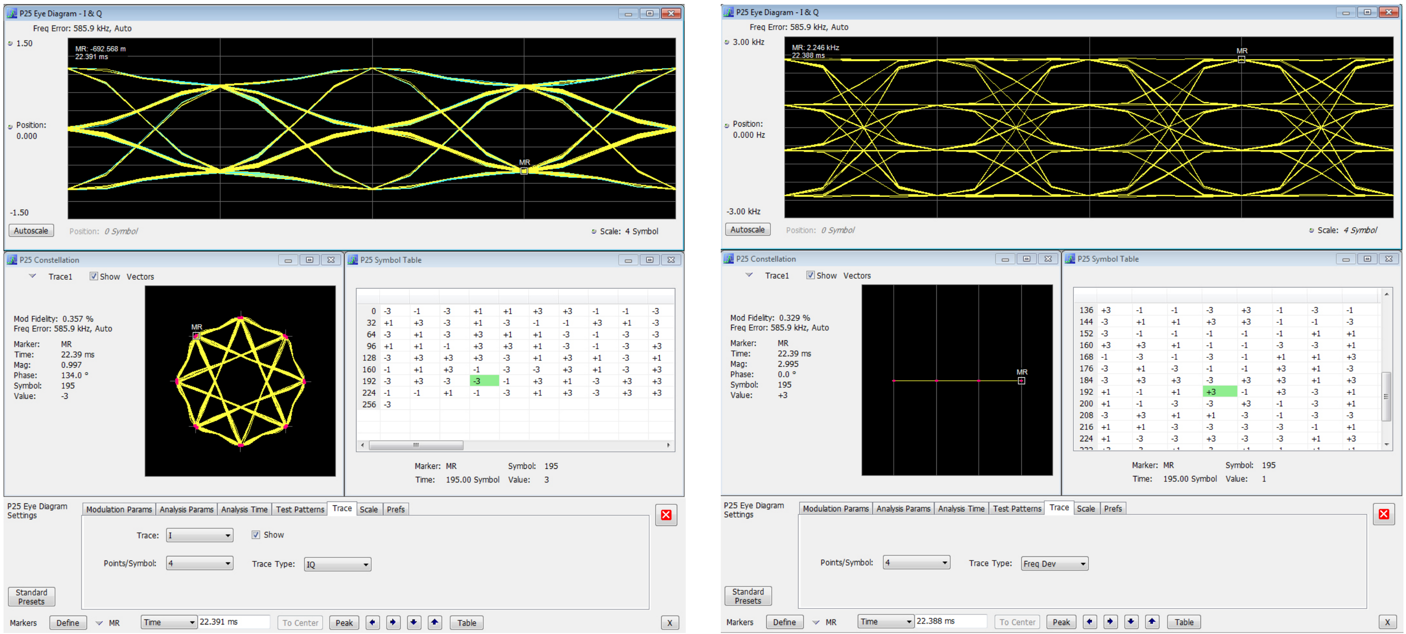



**Figure 12.** Correlated Markers in Eye Diagram, Constellation Diagram, and Symbol Table for H-DQPSK. The left screen shot shows the IQ traces, whereas the right screen shot shows the frequency deviation trace for the same H-DQPSK signal.

## Modulation Fidelity

- **Applicability:** This measurement is required for all phases and modulation types of P25 compliance testing.
- **Description:** Modulation fidelity measures the degree of closeness to an ideal theoretical transmitter.
- **Connectivity:** The setup for this test is similar to the frequency deviation test.
- **How-to:** The user needs to modulate the DUT with the standard transmitter test pattern, and then needs to make sure the parameters of the P25 Summary settings panel are setup for the right pattern and no trigger measurement.
- **Result:** The scalar results can be recorded from the P25 Summary display and from the P25 Constellation panel, that also provides a graphical representation of the phase and amplitude of the demodulated signal. Users should also look at the P25 Eye Diagram that illustrates the path that the frequency deviation takes when transitioning from one symbol to the next. Note that users can change the type of trace they want to display in both eye and constellation diagram. Under the Trace tab, and under Trace Type, the selection is either Frequency Deviation or IQ. The users should also see the P25 Symbol table that provides the symbol data for each symbol captured as shown in Figure 12. The Limits tab in the P25 Summary Settings control panel allows you to compare the result in the P25 Summary against a limit set for Pass/Fail.

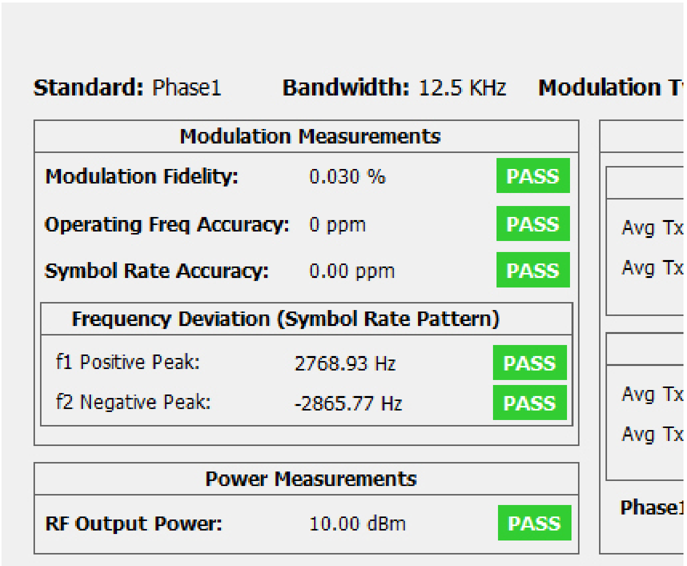



**Figure 13.** P25 Summary provides for Symbol Rate Accuracy and Frequency Deviation measurements of a symbol rate test pattern.

## Symbol Rate Accuracy

- **Applicability:** This measurement is required for all phases and modulation types of P25 compliance testing.
- **Description:** Incorrect symbol rate of a transmitted signal can lead to errors in the demodulation of the signal by the receiver. This may lead to errors and failing communication. This measurement is done with a specific test pattern.
- **Connectivity:** The user needs to connect the output of the DUT to the RF input of the Spectrum Analyzer.
- **How-to:** The user should bring up the P25 Summary settings panel. In this panel, the user should verify no Trigger Measurement have been selected (under the Trig. Meas. tab); They also need to select the correct test pattern that is modulating the DUT under the Test Patterns tab (either the standard transmitter symbol rate pattern for Phase 1 or the standard transmitter high deviation test pattern (inbound or outbound) for Phase 2 associated with the modulation of the DUT) before pressing Run. Please refer to Figure 11.
- **Result:** The scalar result is provided in the P25 Summary display at the time of the measurement. See Figure 13. The Limits tab in the P25 Summary Settings panel allows users to compare the results against limits set for Pass/Fail. The users need to record the result before proceeding to the next measurement.

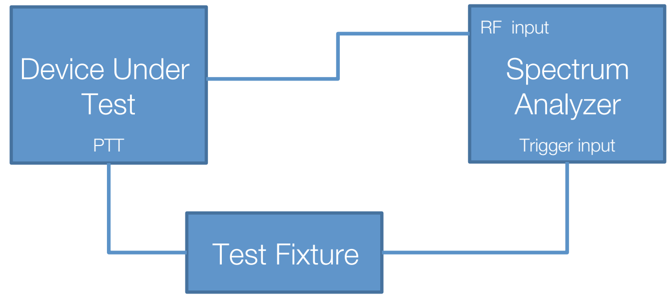



**Figure 14.** Test set-up for most triggered P25 measurements.

## Transmitter Power and Encoder Attack Times

- **Applicability:** These measurements are only required for Phase 1 C4FM compliance testing.
- **Description:** The transmitter power and encoder attack times are times required for a transmitter to prepare and transmit information on the radio channel after changing state from standby to transmit. The time interval for the transmitter output power to reach 50% of its max value from the trigger event defines the transmitter power time. The elapsed time from the trigger to the peak of the rising edge of the first symbol of synchronization defines the encoder attack time.
- **Connectivity:** The user will provide the trigger signal to the Spectrum Analyzer. The test needs to be set-up with a test fixture that creates the trigger signal as shown on Figure 14. This trigger signal is aligned with the Push to Talk control switch of the radio.

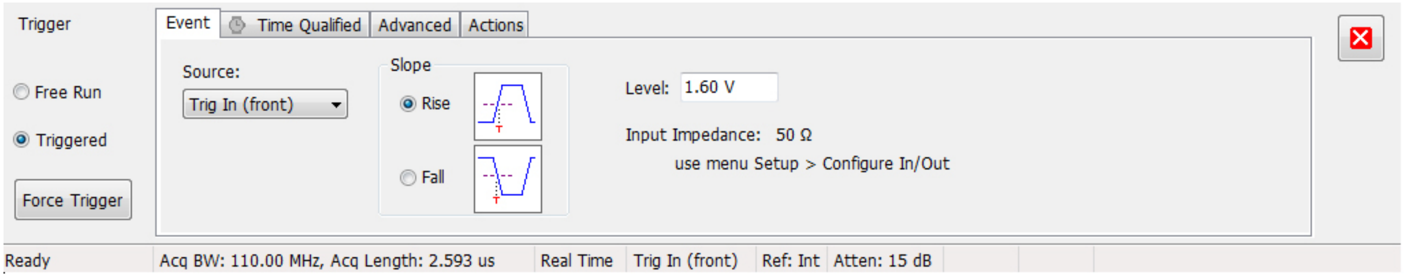



**Figure 15.** Operating Tektronix RSA5000 in triggered mode.

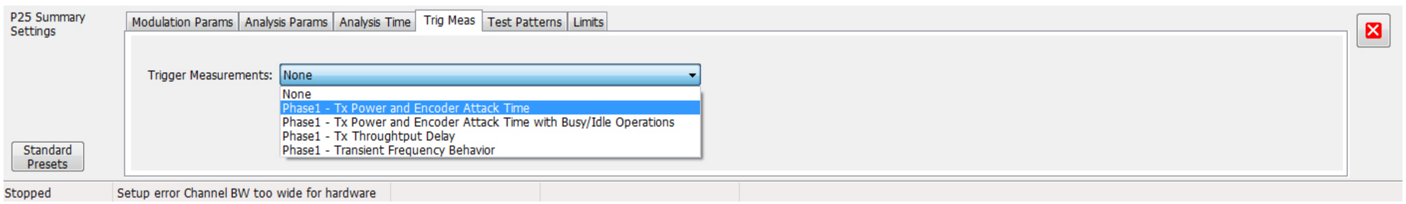



**Figure 16.** Selection of triggered measurements in the P25 Summary control panel.

- **How-to:** The Spectrum Analyzer needs to be set in triggered mode. This is done under the Trigger menu on Tektronix RSA5000 as shown in Figure 15. Then the P25 Summary settings panel needs to have that particular triggered measurement setup as shown in Figure 16. Per the standard, this measurement needs to be performed 10 times by the user; the actual result reported in P25 Summary is the average of all the times measured over a maximum of 10 iterations. After 10 iterations, the number reported is the average of the last 10 iterations. The user needs to select enough acquisition length (please use the Acquisition control panel) to ensure that sufficient data is available when the acquisition is triggered.

This measurement operates in Single Acquisition mode as the acquisition is triggered. The analysis is done by measuring the time taken from the trigger point to the point where the transmitter output power will reach 50% of its maximum value.

For encoder attack time, the initial frame synchronization word is searched in the demodulated output and the time taken from the trigger point to the start of the synchronization word is reported as the result.

Before starting a new measurement, the user needs to use the Clear button on the P25 Summary display. This button will clear the results and start the new averaging.

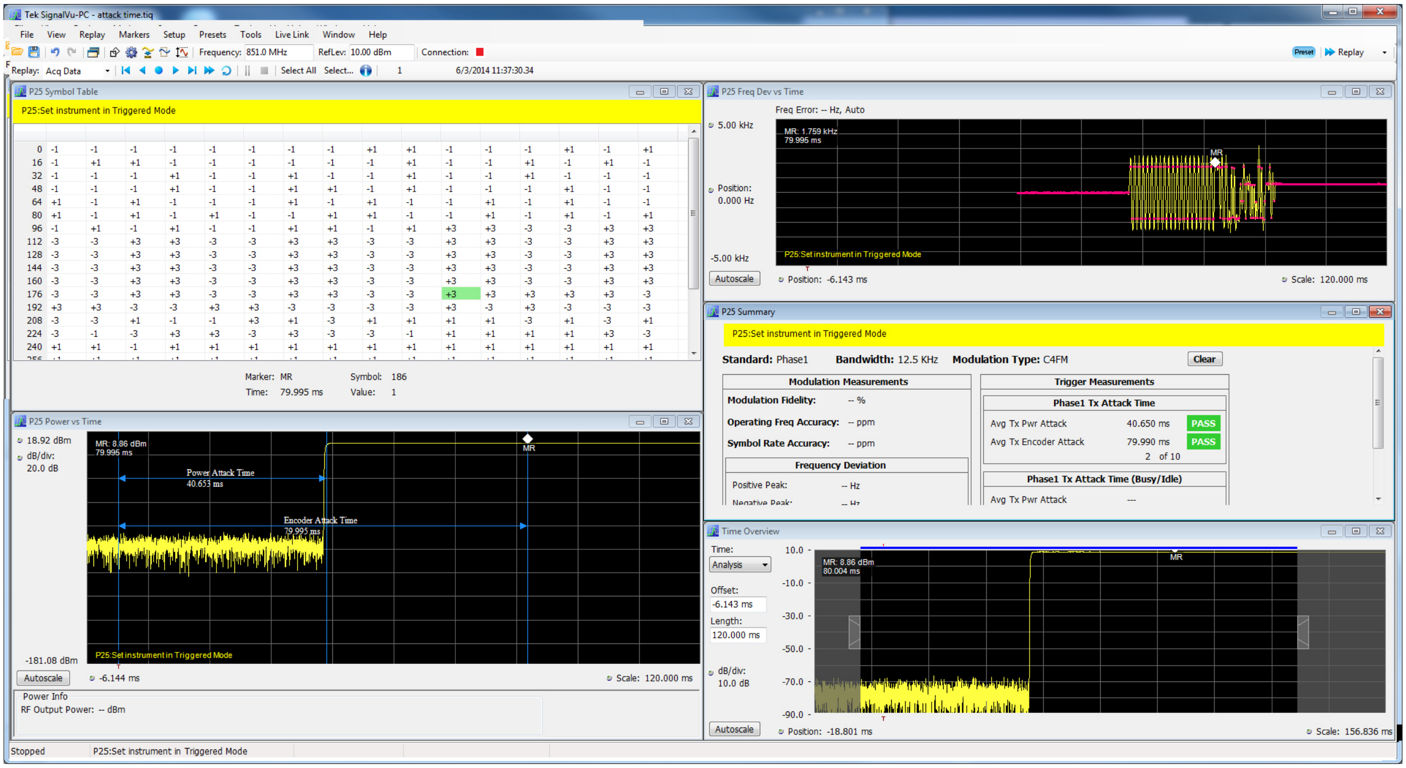



**Figure 17.** Power attack and encoder attack time results cross related over multiple displays.

- **Result:** The result is displayed in the P25 Summary display at the time of the measurement as shown in Figure 17. Note that only this result will be populated in the P25 Summary display and everything else will have no result. The P25 Power vs Time display shows marking from the trigger point to 50% ramp point and also up to the Synchronization word respectively for the transmitter power attack time and the transmitter encoder attack time. P25 Freq Dev vs Time can also be used to check for the synchronization word. In addition, users can also cross reference the first symbol of synchronization in the P25 Symbol Table.

The Limits tab in the P25 Summary Settings panel allows users to compare the results against limits set for Pass/Fail.

It is important for the user to record the result before proceeding to the next measurement, especially if the settings of the next measurement differ, as the results in the P25 Summary are instantaneous and not saved.

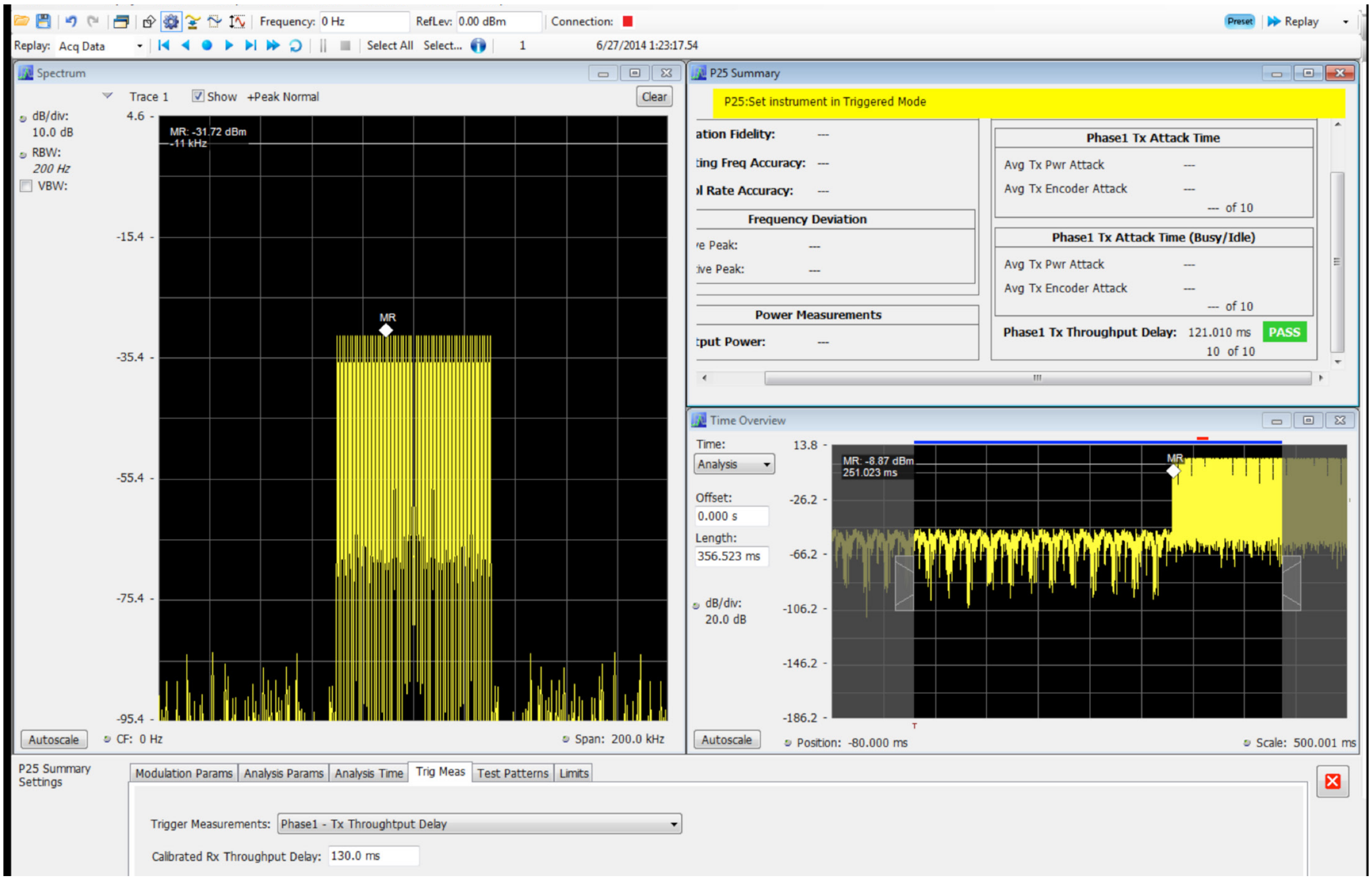



**Figure 18.** Transmitter throughput delay results cross related across multiple displays.

## Transmitter Throughput Delay

- **Applicability:** This measurement is only required for Phase 1 C4FM compliance testing.
- **Description:** The transmitter throughput delay is the time requires for audio changes in the microphone to be encoded and transmitted over the air. A calibrated receiver with a known receiver throughput delay is used to monitor the transmitted signal. The aggregate delay of the transmitter under test and calibrated receiver is measured and the desired transmitter throughput delay is then the aggregate delay less the delay of the calibrated receiver.
- **Connectivity:** The user will provide the trigger signal when the noise generator changes from no signal to band limited pink noise signal. The user connects the trigger to the Spectrum Analyzer trigger input. Tektronix RSA5000 needs to be operated in triggered mode as shown in Figure 14. The actual RF input to the Spectrum Analyzer comes after the noise signal from the source has passed through the DUT and calibrated receiver.
- **How-to:** The throughput delay measurement has to be selected under Trig Meas in the P25 Summary control panel in similar fashion as shown in Figure 16. This measurement needs to be performed 10 times by the user. The Level set by the user in the trigger menu is used by the analysis to determine if the RF input has hit the power level desired (after it has gone through the DUT and calibrated receiver). The time difference between the trigger point and the point when the input to the RSA has exceeded the level set by the user for triggering is calculated. The Calibrated Rx Throughput Delay entered by the user from the UI (this option comes up when Phase1 - Tx Throughput Delay is selected in Trigger Meas tab of the settings panel) is subtracted from the measured time and final result reported as throughput delay in the P25 Summary display. Please refer to Figure 18. The user should select enough acquisition length (from the Acquisition control panel) to ensure that sufficient data is available when the acquisition is triggered. The user needs to do the same experiment multiple times and the average result of the last 10 single acquisitions is reported. Clear option in Summary can be used to clear the results and start fresh. Limit comparison can be done too by selecting appropriate limits from the settings panel (Limits Tab).
- **Result:** The result is displayed in the P25 Summary display at the time of the measurement as shown in Figure 18. Then the user needs to record the result before proceeding to the next measurement.

| | Frequency Ranges (MHz) | | |
|---|---|---|---|
| Time Intervals | 30 to 300 MHz | 300 to 512 MHz | 512 to 1000 MHz |
| $t_1$ | 5.0 ms | 10.0 ms | 20.0 ms |
| $t_2$ | 20.0 ms | 25.0 ms | 50.0 ms |
| $t_3$ | 5 .0 ms | 10.0 ms | 10.0 ms |

**Table 5.** Mean transient frequency limits.

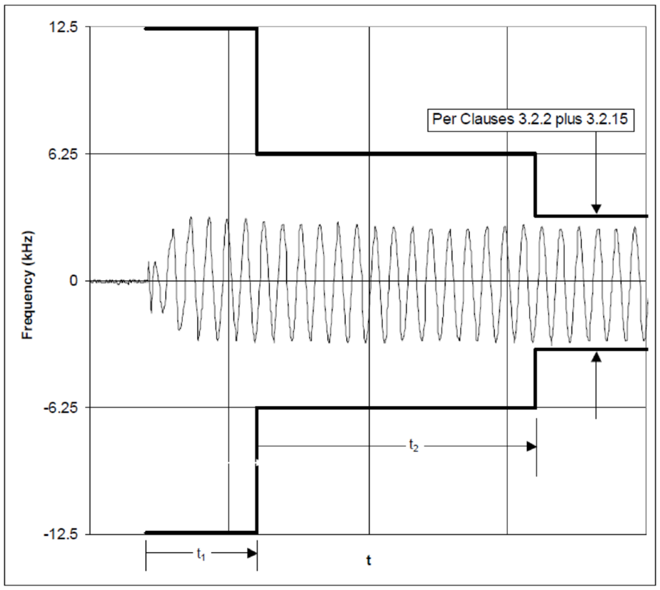



**Figure 19.1.** Turn-on transient behavior and mean frequency limits.

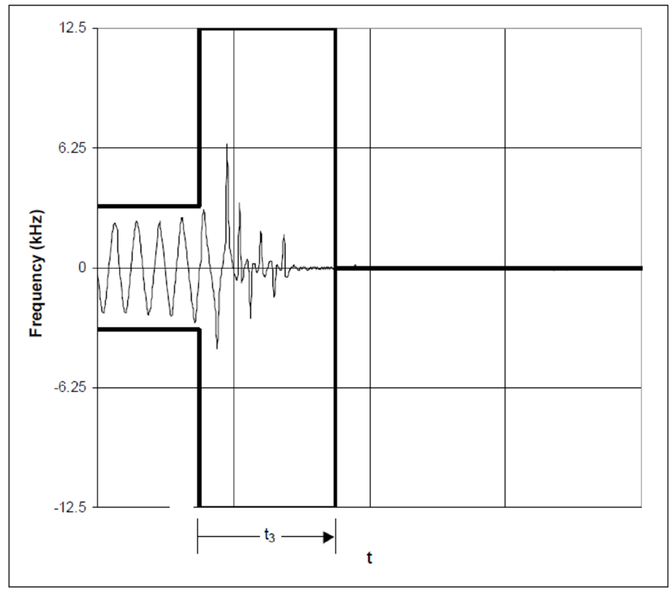



**Figure 19.2.** Turn-off transient behavior and mean frequency limits.

## Transient Frequency Behavior

- **Applicability:** This measurement is only required for Phase 1 C4FM compliance testing.
- **Description:** It measures the difference of the actual transmitter frequency versus the assigned transmitter frequency as a function of time when the RF output power is switched on or off. This is a graphical measurement that is captured under the P25 Freq Dev vs Time display. The behavior of the frequency deviation at turn-on and turn-off is measured during three specific times provided by Table 5. The actual ideal responses provided by the TIA-102 document are captured in Figures 19.1 and 19.2. The test pattern required to perform this measurement is the standard transmitter low deviation pattern.

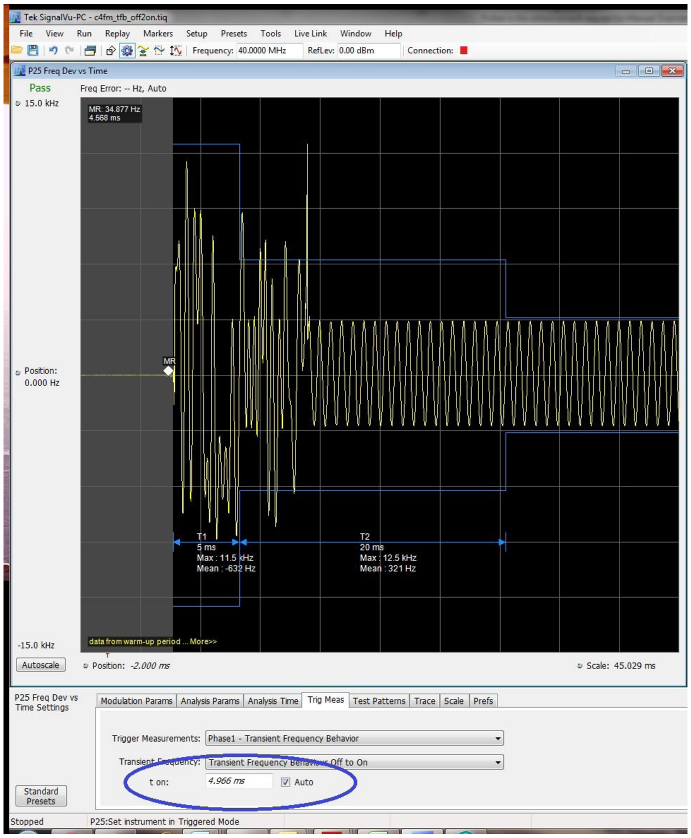



**Figure 20.** Transient Frequency Behavior measurement control.

- **Connectivity:** The user will provide a trigger of when the signal is switched on or off. The user connects the trigger signal to the Spectrum Analyzer trigger input. Tektronix RSA5000 needs to be operated in triggered mode as shown in Figure 14.
- **How-to:** The user is expected to select the relevant trigger measurement from the Trigger Meas tab of the P25 Freq Dev vs Time settings panel.
- This measurement can be done for On to Off and Off to On case. The choice of which experiment is being performed needs to be selected by the user by choosing from a drop down that appears in the Trig Meas Tab of the settings panel. Please refer to Figure 20.
- The user should select enough acquisition length (from the Acquisition control panel) to ensure that sufficient data is available when the acquisition is triggered. Approximately 100 ms of data after trigger should ensure that all cases are taken care of, as suggested by the standard.
- The identification of $t_{ON}$ is done by looking for a significant frequency deviation after a certain power level has been achieved. A manual override for the $t_{ON}$ is also provided when Transient Frequency Behavior measurement is chosen in the Trigger Meas tab. Please refer to Figure 20. This allows the user to manually override the $t_{ON}$ that is calculated (by releasing the Auto option) and place it as appropriate based on the Freq Dev vs Time display. The same holds good for $t_{OFF}$ as well when the measurement is being done for On to Off case. t1 and t2 regions are identified after $t_{ON}$ and t3 before $t_{OFF}$ (in case of ON to OFF)
- The mean and max frequency deviation is reported in the regions identified.

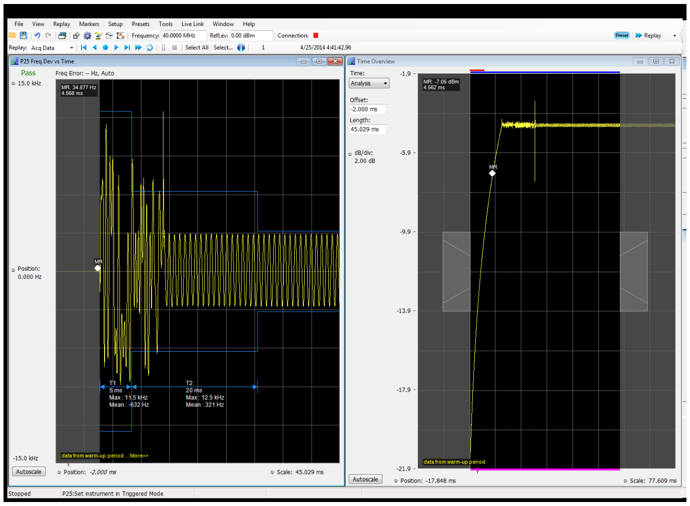


**Figure 21.** Transient Frequency Behavior OFF to ON displays.

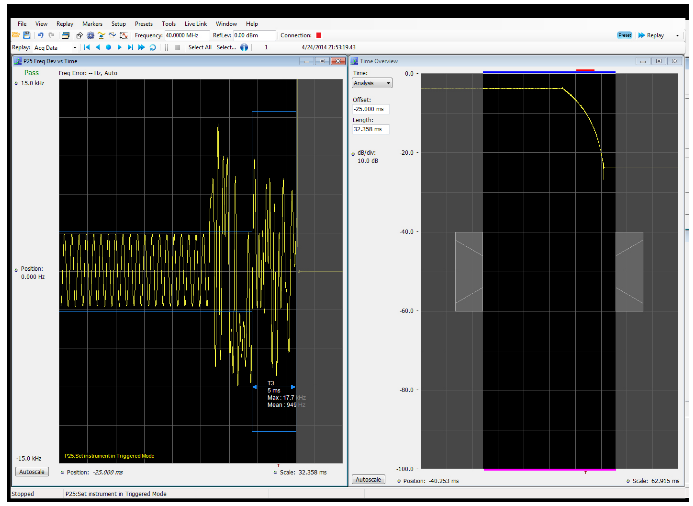


**Figure 22.** Transient Frequency Behavior ON to OFF displays.

- **Result:** The result is displayed in the P25 Freq Dev vs Time display at the time of the measurement as shown in Figure 21 for OFF to ON and Figure 22 for ON to OFF. Pass/Fail information is provided at the top left corner to the display.
- Then the user needs to save the screen shot of these displays before proceeding to the next measurement.

## H-CPM Transmitter Logical Channel Peak Adjacent Channel Power Ratio

- **Applicability:** This measurement is only required for Phase 2 Inbound compliance testing.
- **Description:** The H-CPM transmitter logical channel timeslot alignment is a measure of how accurately an inbound transmitter is time aligned with respect to the time slot transmitters operated in a TDMA mode. This test applies to the inbound transmitter only.
- **Connectivity:** The user needs to connect the output of the DUT to the RF input of the Spectrum Analyzer as shown in Figure 10.
- **How-to:** The user should bring up the P25 Summary display control panel. In this panel, the user should verify no Trigger Measurement have been selected (under the Trig. Meas tab), they also need to select the correct test pattern under Test Patterns that is modulating the DUT before pressing Run (an inbound symmetrical timeslot standard test pattern) as shown in Figure 23. This measurement is done by calculating power in the adjacent channels for the entire duration of data chosen by the user including the power ramp up and ramp down portions (standard recommends 360 ms of data for this measurement), unlike the other ACPR measurement where the analysis is done only for on slot region. The higher and lower adjacent channel power is reported in the P25 Summary under Power Measurements. The two results are then subtracted from the calculated RF Output Power and the minimum of the two results is presented as the Min Peak ACPR in P25 Summary. This measurement is only done for bursty H-CPM data and not for High Deviation and Low Deviation Test pattern.

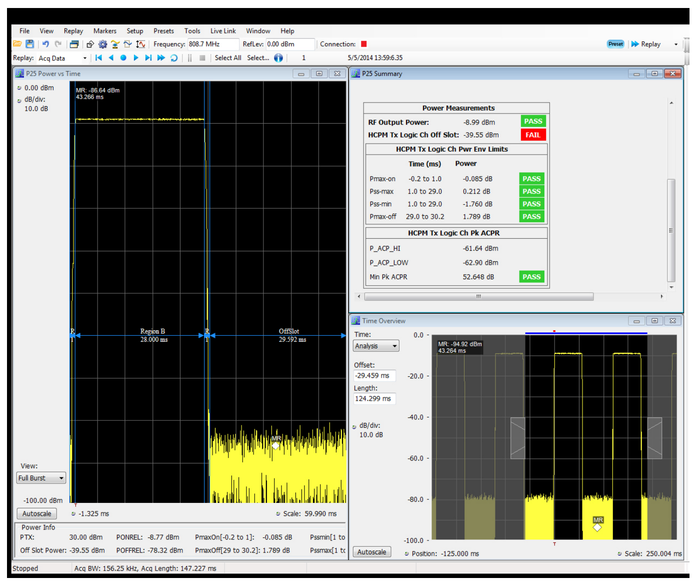


**Figure 23.** H-CPM Two-Slot TDMA timing diagram and logical channel peak ACPR measurement.

- **Result:** The result is displayed in the P25 Summary display at the time of the measurement. This measurement result is not shown in the P25 Summary when Trigger measurements are chosen. The limits tab in the control panel will allow the user to compare the results against limits set for Pass/Fail. The user needs to record the result before proceeding to the next measurement.

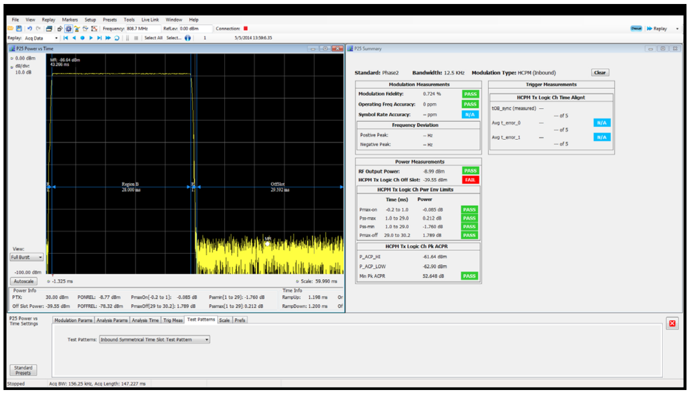


**Figure 24.** P25 Power vs. Time display shows the two-slot TDMA timing diagram and where the Transmitter Logical Channel Off Slot Power measurement is being made.

## H-CPM Transmitter Logical Channel Off Slot Power

- **Applicability:** This measurement is only required for Phase 2 Inbound compliance testing.
- **Description:** The TDMA off slot power is the output power of a TDMA transmitter during the off portion of a TDMA pulse. This test applies to the inbound transmitter only
- The transmission in a TDMA system consists of short bursts at regular intervals. The timing of the power envelope of these bursts is critical to the performance of a TDMA system. Figure 24 shows the transmitter power envelope for various timing parameters and their relationship to time slot boundaries of a logical channel.
- **Connectivity:** The test setup is similar to Figure 10; the DUT is connected directly to the Spectrum Analyzer.
- **How-to:** The user should bring up the P25 Power vs. Time display and its control panel. In the control panel, the user should verify no Trigger Measurement have been selected (under the Trig. Meas tab), they also need to select the correct test pattern under Test Patterns that is modulating the DUT before pressing Run (inbound symmetrical timeslot standard test pattern) as shown in Figure 24. Please be cautious when selecting the attenuator being used to protect the RF input of the Spectrum Analyzer, so that the off slot power of the signal doesn't reach the noise floor of the instrument.
- **Result:** The result is displayed in the P25 Summary display at the time of the measurement. The user needs to record the result before proceeding to the next measurement. In addition to seeing the scalar values in the P25 Summary display, the user can use the Time Overview and the P25 Power vs. Time display to see that the transmission of this P25 TDMA consists of an on-slot and an off-slot measured period. The timing of the off-slot region is provided in the display as shown in Figure 24. The timing parameters and their relationship to the time slot boundaries of a logical channel are also provided. Users can choose to compare the result against the Standards limit by selecting the corresponding measurement in the Limits tab of the P25 Summary settings.

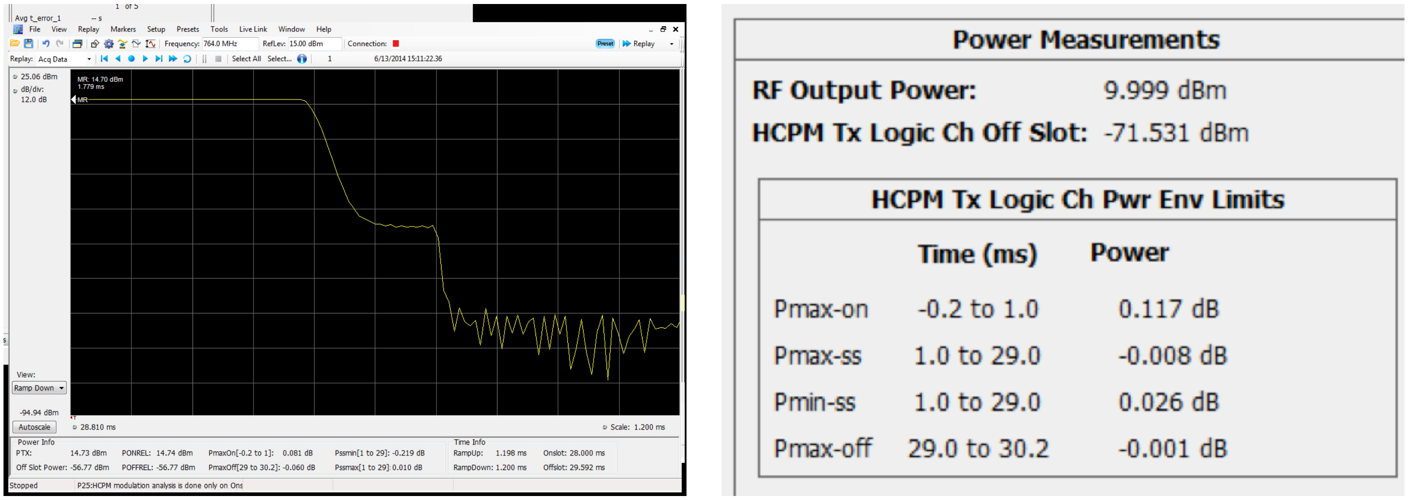



**Figure 25.** H-CPM TDMA transmitter power envelope ramp down trace shown in P25 Power vs. Time display and all power envelope measurements in P25 Summary.

## H-CPM Transmitter Logical Channel Power Envelope

- **Applicability:** This measurement is only required for Phase 2 Inbound compliance testing.
- **Description:** The H-CPM TDMA logical channel power envelope is a measure of how well a portable or mobile radio controls the transmitter power as it inserts an inbound H-CPM TDMA burst into a frame on a voice channel. This test applies to the inbound transmitter only.
- **Connectivity:** The test setup is similar to Figure 10; the DUT is connected directly to the Spectrum Analyzer.
- **How-to:** The user should bring up the P25 Summary display control panel. In this panel, the user should verify no trigger measurement have been selected (under the Trig. Meas. tab), they also need to select the correct test pattern under Test Patterns that is modulating the DUT before pressing Run (Inbound Symmetrical timeslot standard test pattern) as shown in Figure 24. This measurement is only done for bursty HCPM data and not for high deviation and low deviation test patterns.
- **Result:** The result is displayed in the P25 Summary display at the time of the measurement. The user needs to record the result before proceeding to the next measurement. In addition to seeing the scalar values in the P25 Summary display, the user can use the P25 Power vs Time display to visualize where the measurement is being made. The Limits tab in the settings panel will allow the user to compare the results against the Standards limits set for Pass/Fail.

## H-CPM Transmitter Logical Channel Time Alignment

- **Applicability:** This measurement is only required for Phase 2 Inbound compliance testing.
- **Description:** The H-CPM transmitter logical time slot alignment is a measure of how accurately an inbound transmitter is time aligned with respect to the time slot boundaries of the outbound voice channel transmitter. This definition applies to transmitters operated in a TDMA mode. This test applies to the inbound transmitter only.
- **Connectivity:** This measurement is done in two steps. Initially, the user will connect the output of the voice channel signal generator to the RF input of the Spectrum Analyzer and the trigger signal from the voice channel signal generator to the external trigger port of the instrument.
- **How-to:** This measurement is done in two steps: first by calculating tOB_sync using a HDQPSK data (and looking for ISCH pattern) and then using the result to calculate tIB_sync using HCPM data (and looking for the SACCH pattern).
- First the user needs to perform an autocorrelation of the STTP-1031-OB test pattern and the output reference waveform provided by the standard, to find the first autocorrelation peaks and record the tOB_sync time of the autocorrelation peak. This autocorrelation needs to be performed 5 times.
- This first step is done by choosing Time Alignment (tOB_sync measurement) in the Trig Meas tab in the settings panel. P25 Summary provides the average of tOB_sync.
- At that point the user can either use this number to proceed with the rest of the measurement or provides its own measurement by de-selecting Auto in the Trig Meas tab – the name of tOB_sync will change to tOB_sync (manual).
- **Connectivity:** To determine the inbound sync pattern correlation peak tIB_sync for channel 0 and channel 1, the user needs to trigger the instrument with an event positioned at the beginning of each super frame (360ms) of the transmitter signal. The signal is the STTP-1031-OB test pattern.
- **How-to:** To determine the inbound sync pattern correlation peak tIB_sync for channel 0 or 1, the user needs to perform an autocorrelation of the captured waveform with the inbound reference waveform provided by the standard. Then he needs to find the first autocorrelation peak and record the tIB_sync time of the autocorrelation peak. This autocorrelation needs to be performed 5 times for both channel 0 and channel 1. P25 Summary provides the average of tIB_sync for both channel 0 and channel 1 and also calculates the timing error based on these average numbers as shown in Figure 26.

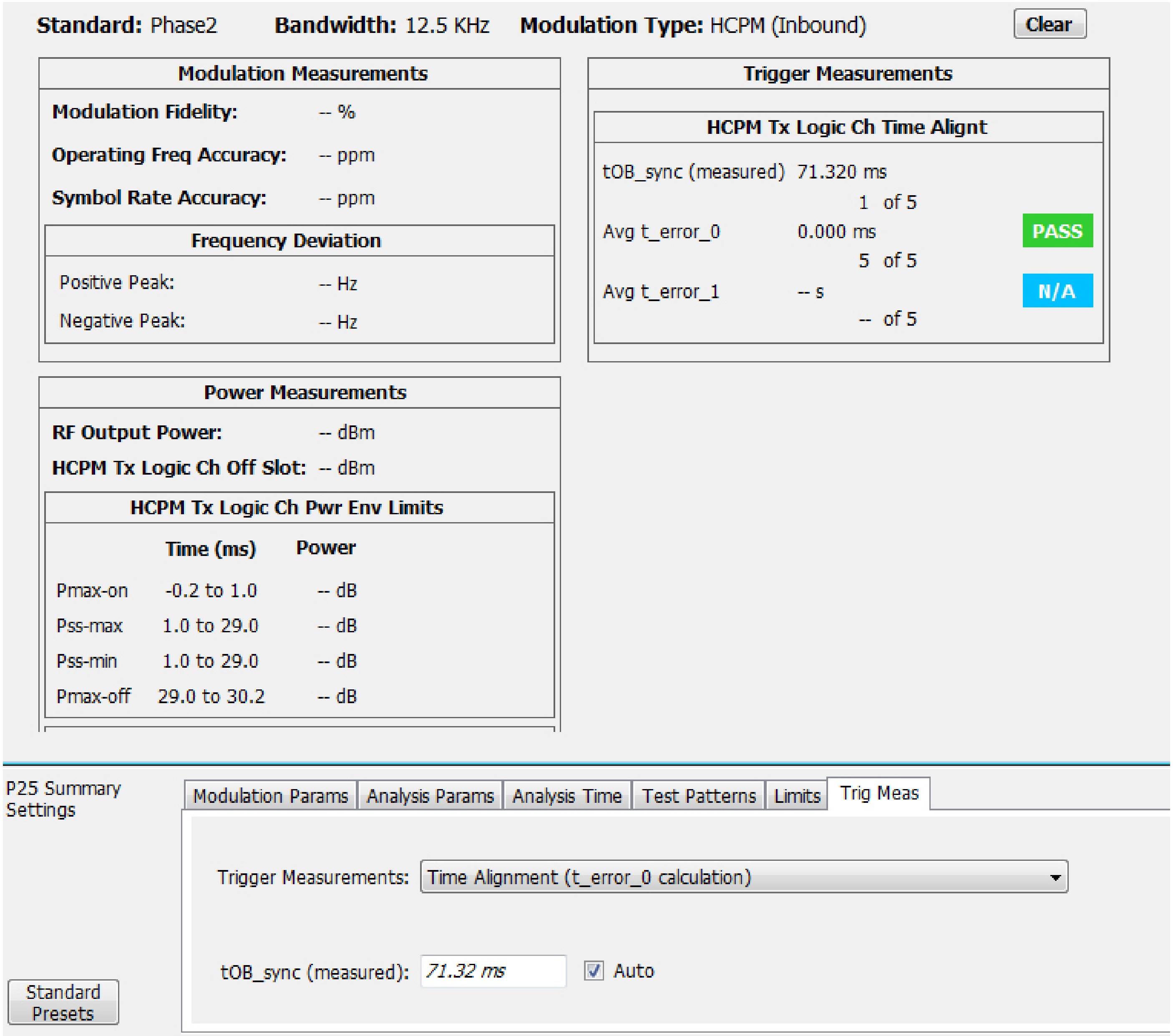



**Figure 26.** The results and controls for the H-CPM TDMA transmitter Logical channel time alignment measurements.

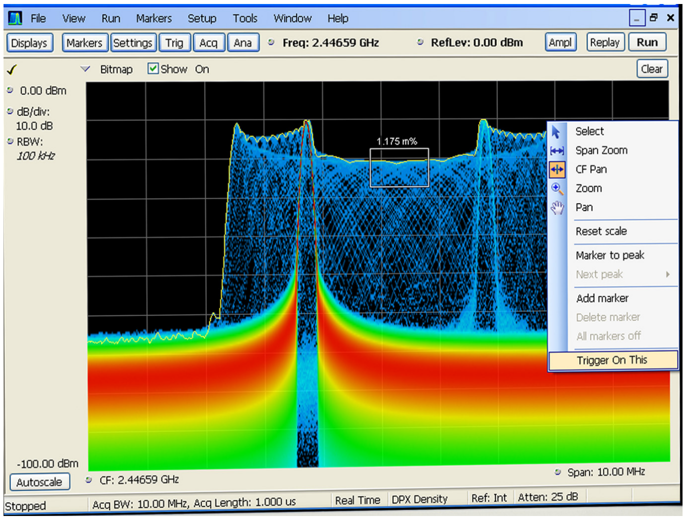



**Figure 27.** RSA5000 shows the ability of the RTSA to detect and trigger on any signals in the presence of more frequent signals, leveraging the Trigger on this feature.

## Assistance in RF Design and Debug of Project 25 Radios

The Tektronix Real-Time Spectrum Analyzer (RTSA) has the unique capability to capture difficult to detect transients and settling behavior that cannot be seen with other spectrum analyzers or functional testers. Spectral data can be seamlessly captured over time and time-correlated analysis can be provided in multiple domains – frequency, time, modulation, and more. The accumulated time record makes it possible to evaluate events before and after the trigger. Events, such as turn-on transients and PLL settling, can be triggered by the unique Frequency Mask Trigger on the RTSA, thus eliminating the need for complex triggering on spectrum analyzers. Single events will be captured for analysis on the RTSA that would otherwise be missed by other spectrum analyzers and functional tests.

## Interference Detection and Recording for End User Environments

No less important than radio performance in mission critical LMR communications is the proper maintenance and management of the radio spectrum. Frequency planners, engineers and technicians must have the ability to detect and mitigate both authorized and unauthorized transmissions that might induce interference on neighboring systems. While interference from co-channel or adjacent channel transmissions can be incapacitating, it is often intermittent in nature, which frustrates troubleshooting efforts. The advanced triggering and real time capture capabilities of the Real-Time Spectrum Analyzer (RTSA) allow field personnel to:

- Detect interference signals and illegal signals
- Monitor the spectrum occupancy and record observations
- Automatically trigger and record to disk interference signals

## Conclusion

The Tektronix's Real-Time Spectrum Analyzer (RTSA) provides essential test capability for the new Project 25 performance requirements. The RSA5000B and MDO4000B with SignalVu-PC are ideal solutions for equipment manufacturers and network operators testing and deploying new Project 25 communications networks. The up-front equipment testing, monitoring and continued maintenance of deployed systems require flexible testing solutions such as the RSA5000B and MDO4000B.

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**For Further Information**

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**




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