FREEDOM
Communication Technologies

Application Note:
Testing P25 Conventional Radios Using the Freedom Communications System Analyzers

Motorola CPS and Tuner Software
Motorola provides a CD containing software programming facilities for the radio's channels and functions (CPS). The Tuner software is intended to provide adjustment and realignment of several of the radio's parameters, such as RX front end and RF Power

Radio Configuration
To enable the R8000 to test the radio in Analog and Digital modes the user must use the CPS software to configure the channels and settings of the radio

Note that all tests MUST BE conducted in the "simplex" single channel frequency mode.

Available Channels
For test purposes only, two test channels should be configured, one Digital and one Analog. The user may use any available spare channels to set up these configurations as long as the relevant channel frequencies are used to set up the R8000 monitor frequencies
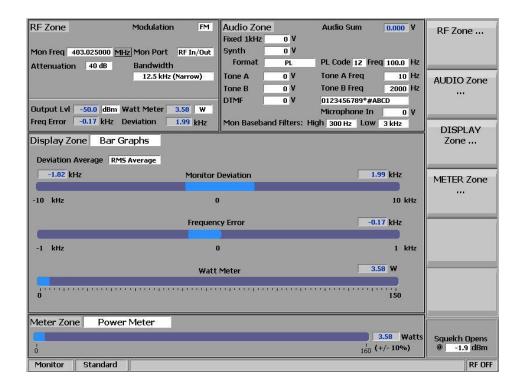
Conducting P25 Conventional Tests with the R8000 Test Configuration
If you have Motorola Test Box part No RLN4460, then a full suite of Analog and/or Digital radio performance tests may be conducted. The test procedures detailed below show a sub-set of tests that may be performed when the test box is not available. However, you will need the test box to conduct absolute TX & RX audio quality measurements such as TX modulation limiting and RX SINAD.
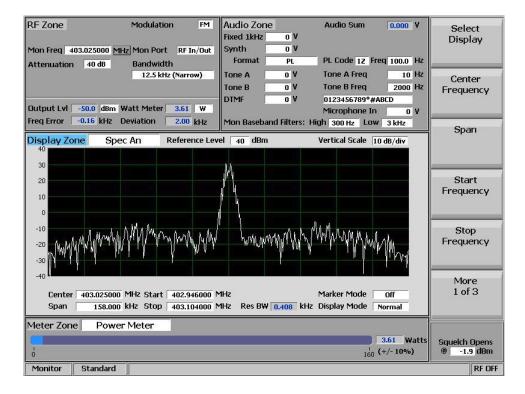
Analog Transmitter Tests
Set the R8000 configuration as follows:
- Press the blue "Monitor" hard key
- Select "RF Zone"
- Select "Monitor Frequency" and using the numeric keypad enter the frequency of the channel to be tested, for example: 403.025000 MHz.
- Select "Attenuation" and set to 40dB.
- Select "Modulation Type" and set to FM from the bottom softkey menu.
- Select "Bandwidth" and set to 12.5 KHz from the bottom softkey menu.
- Select "More 1 of 2".
- Select "Mon Port" and set to "RF In/Out" using the Up/Down (▲▼) keys or Spin Knob.
- Select "Input Level Units" and set to "Watts" to display broadband power.
- Select numeric key "4" to enter the Display Zone.
- Select "Select Display "and select "Bar Graphs" from the bottom menu.

- Optionally select "Spec An" if you wish to monitor the TX spectrum.
- Optionally select "Modulation Scope" to display the transmitted audio frequency and deviation that is modulating the TX.

Connect the radio's Antenna port using a SMA adaptor and coaxial cable to the RF In/Out port of the R8000.
- Turn on the radio and select the channel you have programmed for Analog.
- The configuration is now complete and you are ready to test the radio transmitter parameters.
- Key the PTT and observe the measurements being displayed on the R8000; RF Power, Deviation, Frequency Error, Modulating Audio Frequency and Deviation (Mod Scope). Speaking into the microphone will result in your speech being broadcast from the R8000 speaker.
- Adjust the "Squelch" control as needed.

Note 1:
Motorola Test Box RLN4460 is required to test more complex functions of the transmitter. The above procedure tests only the basic operation and functionality of the radio.

Note 2:
The R8000 configuration and settings above may be saved as a "Preset". This avoids having to go through the setup procedure every time you need to conduct this test.

Preset Save Procedure
- Press the blue "Test" hard key.
- Select "Save Configuration As".
- Using the Alpha Numeric keypad, Left/Right (◄►) keys and Spin Knob enter a file name that will identify this test to you at a later date. Example, "P25 ANL TX".
- Press the Enter key. This configuration will have populated into the list of available "Presets".
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Optional Test: Decoding TX Signaling Control Tones.
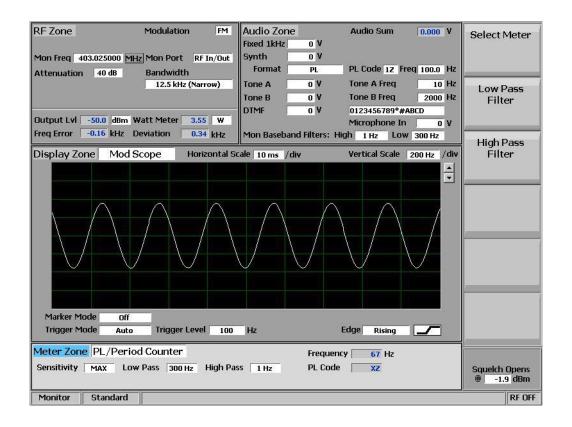
Private Line (PL)
If the radio is programmed to transmit a PL tone it can be decoded and displayed on the R8000:
- In the "Monitor" mode select numeric key "7" to enter the "Meter" zone.
- Select "Select Display", then "More 1 of 3", and select "PL/Period Counter".
- Select "Low Pass Filter" and set to 300Hz from the menu.
- Select "High Pass Filter" and set to 1Hz from the menu.
- Key the radio PTT to display the decoded PL.
- Save in "Presets" as "ANL PL DECODE".

Digital Private Line (DPL)
If the radio is programmed to transmit a DPL tone it can be decoded and displayed on the R8000.
- In the "Monitor" mode select numeric key "7" to enter the "Meter" zone.
- Select "Select Display", then "More 1 of 3", and select "DPL Decode".
- Key the radio PTT to display the decoded DPL.
- Save in "Presets" as "ANL DPL DECODE".

Analog Receiver Tests
- Press the blue "Generate" hard key.
- Select "RF Zone".
- Select "Generate Frequency" and using the numeric keypad enter the frequency of the channel to be tested, for example: 403.025000 MHz.
- Select "Modulation Type" and set to FM.
- Select "Output Level" and using the numeric keypad or Spin Knob enter the desired RF output power. -50dBm is a good place to start.
- Select "Gen Port" and set to RF In/Out using the Spin Knob.
- Select "Bandwidth" and set to 12.5 kHz from the bottom menu.
- Select "More 1 of 2" then select "Output Level Units" and set to dBm.
- Select numeric key "2" (shortcut key) to enter the "Audio Zone".
- Select "Fixed 1kHz Level" and set to 2 kHz using the numeric keypad or Spin Knob.
- Select "Fixed 1kHz Mode" and set to "Continuous".
- Press "More 1 of 5" until you reach the page 4 menu.
- Select "Microphone Mode" and set to "Continuous".
- Select "Microphone Level" and set to 3 kHz using keypad or Spin Knob.
- Select numeric key "4" (shortcut key) to enter "Display Zone".
- Select "Select Display" and set for "Mod Scope".
- Adjust the Scope's Vertical and Horizontal scales as desired to display the modulation being sent to the radio.
- Select numeric key "7" (shortcut key) to enter the "Meter Zone".
- Select "Select Meter" and set to "SINAD" from the bottom menu keys (requires test box).
- Connect the radio's antenna port using an SMA adaptor and coaxial cable to the RF In/Out port of the R8000. Turn on the radio and select the channel you have programmed for Analog.
- The configuration is now complete and you are ready to test the radio Receiver parameters.
- You will hear a 1 kHz tone on the radio's speaker, and speaking into the R8000 microphone will result in speech from the radio's speaker. A good approximation of RX sensitivity may be achieved by reducing the RF signal amplitude until the audible 1 kHz tone begins to weaken and distort.

Note 1:
The absolute measurement of SINAD and RX sensitivity requires Motorola Test Box RLN4460.
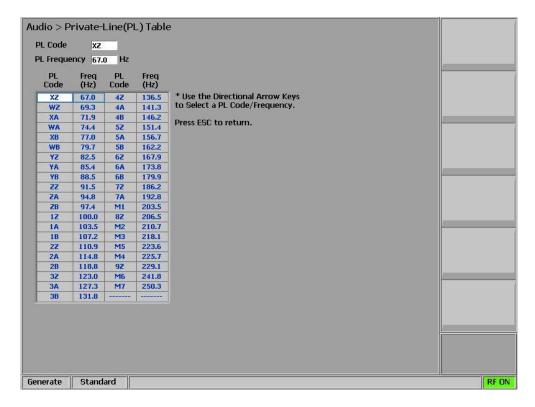

Preset Save Procedure:
- Press the blue "Test" hard key.
- Select "Save Configuration As".
- Using the Alpha Numeric keypad, Left/Right (◄►) keys, and Spin Knob enter a file name that will identify this test to you at a later date. Example: "P25 ANL RX".
- Press the Enter key. This configuration will populate into the list of available "Presets".

Optional Test: Encoding RX Signaling Control Tones.

Private Line (PL)
If the radio is programmed to receive a PL tone to break the RX squelch, the R8000 may be set to send these codes:
- In the "Generate" mode select numeric key "2" to enter the "Audio" Zone.
- Select "Synth Level" and set to the required PL deviation; 700Hz is a common setting for this parameter.
- Select "Format" and set to PL.
- Select "More 1 of 5" followed by "Synth Mode" and set to "Continuous".
- Select "PL Table" and select the desired PL from the table using the Up/Down (▲▼) keys.
- Press "Esc" to return to the main menu.
- The R8000 is now modulating the RF carrier with the required PL.

Audio > Private-Line(PL) Table

PL Code: XZ

PL Frequency: 67.0 Hz

PL Code	Freq (Hz)	PL Code	Freq (Hz)
XZ	67.0	4Z	136.5
WZ	69.3	4A	141.3
XA	71.9	4B	146.2
WA	74.4	5Z	151.4
XB	77.0	5A	156.7
WB	79.7	5B	162.2
YZ	82.5	6Z	167.9
YA	85.4	6A	173.8
YB	88.5	6B	179.9
ZZ	91.5	7Z	186.2
ZA	94.8	7A	192.8
ZB	97.4	M1	203.5
1Z	100.0	8Z	206.5
1A	103.5	M2	210.7
1B	107.2	M3	218.1
2Z	110.9	M5	223.6
2A	114.8	M4	225.7
2B	118.8	9Z	229.1
3Z	123.0	M6	241.8
3A	127.3	M7	250.3
3B	131.8	--------	--------

* Use the Directional Arrow Keys to Select a PL Code/Frequency.

Press ESC to return.

Generate   Standard   RF ON
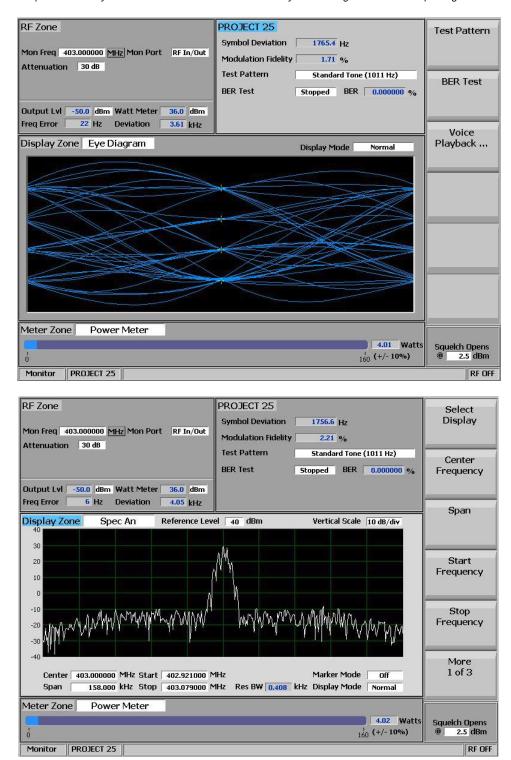
Digital Private Line (DPL)

If the radio is programmed to receive a DPL tone to break the RX squelch, the R8000 may be set to send these codes:
• In the "Generate" mode select numeric key "2" to enter the "Audio" zone.
• Select "Synth Level" and set to the required DPL deviation; 700Hz is a common setting for this parameter.
• Select "Format" and set to DPL
• Select "More 1 of 5" followed by "Synth Mode" and set to "Continuous".
• Select "DPL Table" and select the desired DPL from the list using the Up/Down (▲▼) keys.
• Press "Esc" to return to the main menu.
• The R8000 is now modulating the RF carrier with the required DPL.

Digital P25Transmitter Tests
• Press the blue "Monitor" hard key.
• Press the blue "Test" hard key.
• Select "Test Mode".
• Select "PROJECT 25".
• The Zones are now displaying the P25 Digital test parameters.
• Select "RF Zone" shortcut key "1".
• Select "Monitor Frequency" and using the numeric keypad enter the frequency of the channel to be tested, for example: 403.025000 MHz.
• Select "Attenuation" and set to 40dB using the Up/Down (▲▼) keys or Spin Knob.
• Select "Mon Port" and set to "RF In/Out".
• Select "Input Level Units" and set to "Watts" to display broadband power.
• Turn on the radio and set to the digital channel.
• Key the radio's PTT
• Note that the 'Symbol Deviation "Hz" and "Modulation Fidelity%" fields are displaying the quality of the radio's Digital Modulator.

- The "Eye Diagram" display is displaying the deviation of the carrier at the symbol decision times as measured though the post-detection filter. The tighter the four trajectories are to the "+" indicators the better the modulator performance.
- To observe the digital modulation on the Spectrum Analyzer, press hotkey "7" followed by "Select Display" and "Spectrum Analyzer"
- Adjust the Spectrum Analyzers "Reference Level" for the best dynamic range to view the input signal.

Note 1:
The R8000 configuration and settings above may be saved as a "Preset". This avoids having to go through the setup procedure every time you need to conduct this test.

Preset Save Procedure
• Press the blue "Test" hard key.
• Select "Save Configuration As".
• Using the Alpha Numeric keypad, Left/Right (◄►) keys and Spin Knob enter a file name that will identify this test to you at a later date. Example, "P25 DIG TX".
• Press the Enter key. This configuration will have populated into the list of available "Presets".
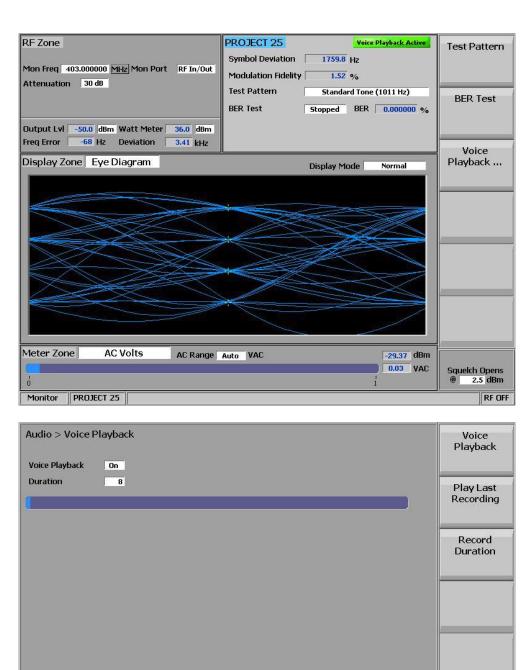
Voice Loop Back
The R8000 does not employ a vocoder or encryption device. To allow the se functions to be tested the R8000 employs a voice loop back function.

Operation
The patented voice loopback function requires the test operator to talk into the microphone of the radio. The analog voice is then digitized, coded and encrypted (if fitted) by the radios circuits and transmitted as a P25 frame. This frame is captured by the R8000 processing and applied to the digital modulator for re-transmission to the radios receiver. This signal is demodulated, decoded and decrypted (if fitted) by the radios circuits and the resulting audio can be heard on the radios speaker.

Set Up
• In PROJECT 25 TX test mode select the "Monitor" hard key then select "Audio Zone" using shortcut key "2".
• Select "Voice Playback".
• From the voice playback menu select the "Voice Playback" key, followed by "On".
• Select "Duration" and set the duration to the desired length of recoding, 1 to 10 seconds.
• Press "Escape" to go back to the main TX test screen.
• Press the radio's PTT and record your audio message
• Release the PTT, the R8000 will automatically go into the "Generate" mode and send the recorded message back to the radio.
• Listen for your message on the radio's speaker; don't forget to turn up the volume!
• The R8000 automatically returns to the TX test "Monitor" mode after the message is complete
• To replay your messages at any time press the "Voice Playback" key and "Play Last Recording" from the menu. Press "Esc" to return to the "Monitor" screen.
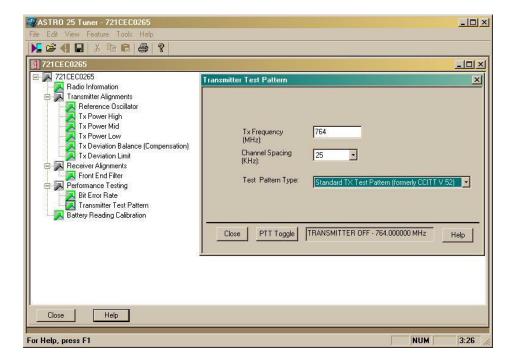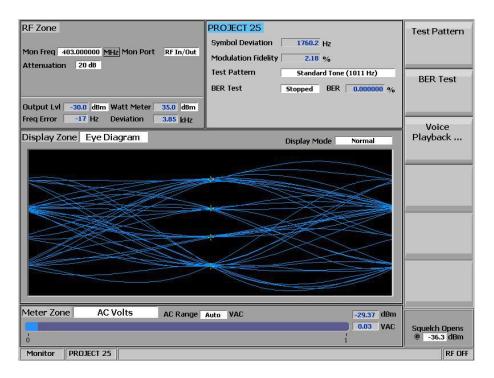
Bit Error Rate (BER) Tests

TX BER Test

TX BER tests require a PC running the Motorola Tuner software and that the radio be connected to the serial port of the computer through the programming and control cable supplied with the radio.

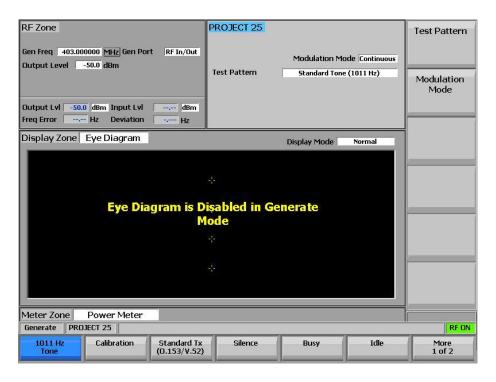With the power off, connect the radio to the PC's serial port using the supplied control cable.

- On the PC "Start" the Tuner software, then turn the radio power on.
- Press the "Read" icon on the software control panel. The radio will go into test mode and download its information to the PC.
- Under "Performance Testing" select 'Transmitter Test Pattern".
- In the "Tx Frequency (MHz)" display field enter the channel frequency to be tested.
- Select "Standard TX Test Pattern (formerly CCITT V.52)" in the "Test Pattern" field.
- On the R8000 in the "Monitor" mode select numeric key "2" to enter the Project 25 TX test menu.
- Select "Test Pattern" and set to "Standard Tx (O.153/V.52)".
- Press "BER Test" followed by "Start"
- On the Motorola Tuner control panel press "PTT Toggle"
- On the R8000 observe and ensure that the BER% display reads 0.000000%.

Digital Receiver Tests

- Press the blue "Generate" hard key.
- Press the blue "Test" hard key.
- Select "Test Mode".
- Select "PROJECT 25".
- Select numeric shortcut key "1" to enter the "RF Zone".
- Select "Generate Frequency" and using the numeric keypad enter the frequency of the channel to be tested, for example: 403.025000 MHz.
- Select "Output Level" and using the numeric keypad or Spin Knob enter the desired RF output power. -100dBm is a good place to start.
- Select "Gen Port" and set "RF In/Out" using the Spin Knob.
- Select shortcut key "2" to enter the "PROJECT 25" zone.
- Select "Test Pattern" and set to "1011 Hz Tone"
- Select "Modulation Mode" and set to "Continuous".
- Turn on the radio and set to the digital channel under test.
- You should now hear the 1011Hz digital test tone in the radio's speaker.
- Select shortcut key "1" to enter the "RF Zone".
- Select "Output Level".
- It is possible to get a very good approximation of the digital receiver's sensitivity by reducing the RF level using the Spin Knob until you hear the tone deteriorate or cut off. This normally occurs at around -121 to -122 dBm if you slowly approach the lower level in 1dB steps. This compares well with the -121dBm 12dB SINAD sensitivity achieved in Analog Mode.
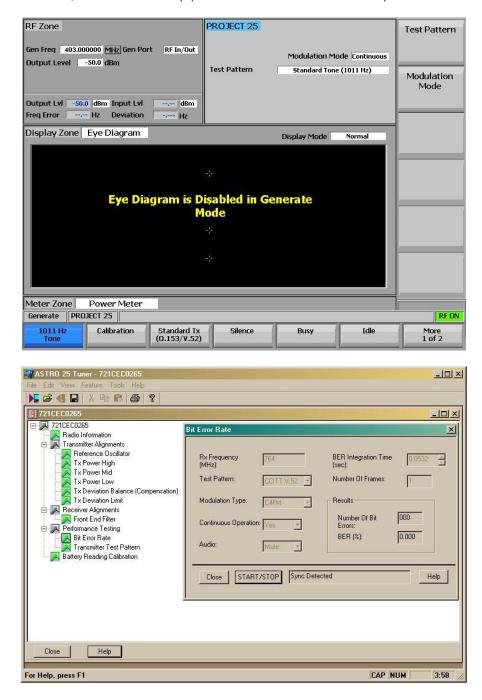
Preset Save Procedure
- Press the blue "Test" hard key.
- Select "Save Configuration As".
- Using the Alpha Numeric keypad, Left/Right (◄►) keys and Spin Knob enter a file name that will identify this test to you at a later date. Example, "P25 DIG RX".
- Press the Enter key. This configuration will have populated into the list of available "Presets".

RX BER Sensitivity Test
RX BER Sensitivity tests require a PC running the Motorola Tuner software and that the radio be connected to the serial port of the computer through the programming and control cable supplied with the radio.

- With the power off, connect the P25 radio to PC's serial port using the supplied control cable.
- On the PC "Start" the Tuner software, then turn the radio power on.
- Press the "Read" icon on the software control panel. The radio will go into test mode and download its information to the PC.
- Under "RX" select BER.
- In the "Frequency" display field enter the channel frequency to be tested.
- Select O.153 for the BER "Test pattern"
- Select "Yes" for continuous operation.
- Connect the radio's antenna port to the R8000 RF In/Out port.
- In the "RF" zone on the R8000 set the output level to -116dBm; this is the Motorola specification to measure 0.0000% BER.
- Select numeric key "2" followed by "Test Pattern" and set to "Calibration (O.153 1%)". **Note:** The calibration setting is provided to give a "confidence" level that the radio detects and reports a BER of 1%. This test pattern is set for 1 bit error in every 100 bits, i.e. 1%.
- Select "Modulation Mode" and set to "On".
- On the Motorola Tuner screen scroll down and observe the BER test result; this should be 1.00%.
- On the R8000, select "Test Pattern" and set to "O.153".
- On the Motorola Tuner screen, scroll down and observe the BER test result; this should be 0.0000%.
- In the "RF Zone" adjust the RF level in 0.5dB decrements until the observed BER approaches 1%. This level is the absolute Digital RX sensitivity.

- • Exit the tuner software, disconnect all test equipment and return the radio to normal operation.

Conclusion

This application note has described the configurations and settings of both the R8000 and the P25 radio that enables you to make the required tests in Analog and Digital modes. Whilst this application note describes the Motorola P25 radio, any manufacturers P25 conventional radio may be tested using these procedures provided that the appropriate "Tuner" software and control cables are available.