FREEDOM
Communication Technologies

R8000 Series
Communications Systems Analyzer

AUTOTUNE USER GUIDE

Motorola APX Series Radios

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FCT-1215 Rev. C

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

No table of figures entries found.

1. Introduction

The Freedom Communication Technologies R8000 Series Communications Systems Analyzer AutoTune™ (hereafter "AutoTune") is designed to provide an automated test and alignment solution for supported two-way radios.

2. Scope

This document is intended to provide information regarding the tests and alignments performed by AutoTune for Motorola APX portable and mobile two-way radios. This document is restricted to radio-specific information.

Please refer to the R8000 Series Communications System Analyzer Owner's Manual (FCT-1365) for an overview and basic operating instructions for AutoTune itself.

2.1. Supported Models

The following Motorola APX Series radio models are supported:

- APX 900
- APX 1000/1000i
- APX 1500/1500 Enhanced
- APX 2000
- SRX 2200
- APX 2500
- APX 4000/4000Li
- APX 4500/4500Li/4500 Enhanced
- APX 6000/6000Li/6000XE/6000 Enhanced
- APX 6500/6500 Enhanced
- APX 7000/7000XE
- APX 7500
- APX 8000/8000H/8000XE
- APX 8500/8500HP

2.2. Required Options

Option Name	Reason
P25 Conventional Test Mode (R8-P25)	Used to perform P25 Tx Tests and Sensitivity (P25 BER) tests.
P25 Phase 2 Test Mode (R8-P25_II)	Used to perform P25 Phase II Tx Tests and Sensitivity (P25 Phase II BER) tests
Motorola APX(R8-AT_APX)	Motorola APX AutoTune, including Enhanced ('B') series
Motorola APX8000 (R8-AT_APX8000)	Motorola APX 8x00 AutoTune

Table 2-1. Required R8x00 options for AutoTune for Motorola APX Series radios.

3. Motorola APX Portable Radio Test Setup

Before servicing a radio with AutoTune, ensure the analyzer is running the current system software version. Each system version release contains issue resolutions and/or new/enhanced features.

- On the analyzer, navigate to Settings > About… Note the System version shown.
- Browse to the Freedom software upgrades webpage: https://freedomcte.com/upgrades/
- If the first Current System Version shown on the webpage is more recent than the analyzer System version, follow the webpage instructions to download and apply the current system version software to your analyzer.

To perform the test and alignment procedures, the APX Portable radio must be connected to the R8000 Communications Systems Analyzer as shown in Figure 3-1. APX Portable Test Setup Diagram.

Make certain that the radio under test is configured as described in the corresponding diagram **before** attempting to perform an alignment or test. Failure to do so may result in poor radio performance and/or damage to the analyzer or radio equipment under test.

3.1. Cable Sweep

Every RF cable connected between a radio under test and the analyzer attenuates the signal propagating through it. The amount of attenuation varies by several factors such as operating frequency, cable length, and cable type. Ensuring this attenuation is accounted for by the analyzer is important to the accuracy of several tests and alignments, primarily power tests.

Sweep the RF cable used between the Radio and Analyzer, label the RF cable with the stored cable sweep name, and enable the Cable Sweep feature in the analyzer System, System Settings… menu. Refer to Application Note FCT-1017 *Utilizing Cable Sweep on the Freedom Communications System Analyzer* for instructions on how to perform a cable sweep.

3.2. Test Hardware

Test Aid	Recommended part	Description
USB radio programming cable	Motorola PMKN4013_	USB cable for programming and servicing radio.
Variable DC power supply	Astron VS-50M	DC power supply with sufficient current sourcing capability.
RF test cable	Megaphase RF Orange series	Shielded RF cable with low loss.
Reference cable	Pomona 5697	BNC cable for sweeping RF test cable.
6 dB attenuator	Mini-Circuits 15542	Attenuator for reducing Reference cable VSWR.
Audio cables	Pomona 5697	Connects analyzer and portable test set for audio signals.
Portable test set	Motorola RLN4460_	Routes signals between radio and analyzer for Rx audio and microphone tests.

Table 3-1. Portable Test Hardware Table

3.2.1. Battery Eliminator

Battery eliminators interface portable radios to DC power supplies. They're needed because batteries cannot produce consistent voltage/current when the radio is keyed for extended time periods, as it will be during an alignment. Attempting to use even a nominally good battery will eventually result in power alignment failures. A battery eliminator should always be used while performing portable radio alignments and tests with AutoTune to achieve consistent alignment performance.

For APX portable radio models, use the following Motorola battery eliminator parts. For more information, refer to the applicable Motorola basic radio service manual.

APX 900 / 1000 / 2000 / 4000

- Part Number: 66-012031001

APX 5000 / 6000 / 7000 / 8000 / SRX 2200

- Part Number: 66-009254001

3.3. APX Test Setup

Refer to the diagram below for the proper test setup. Note that the correct setting for each RLN4460 test set control is highlighted in yellow.

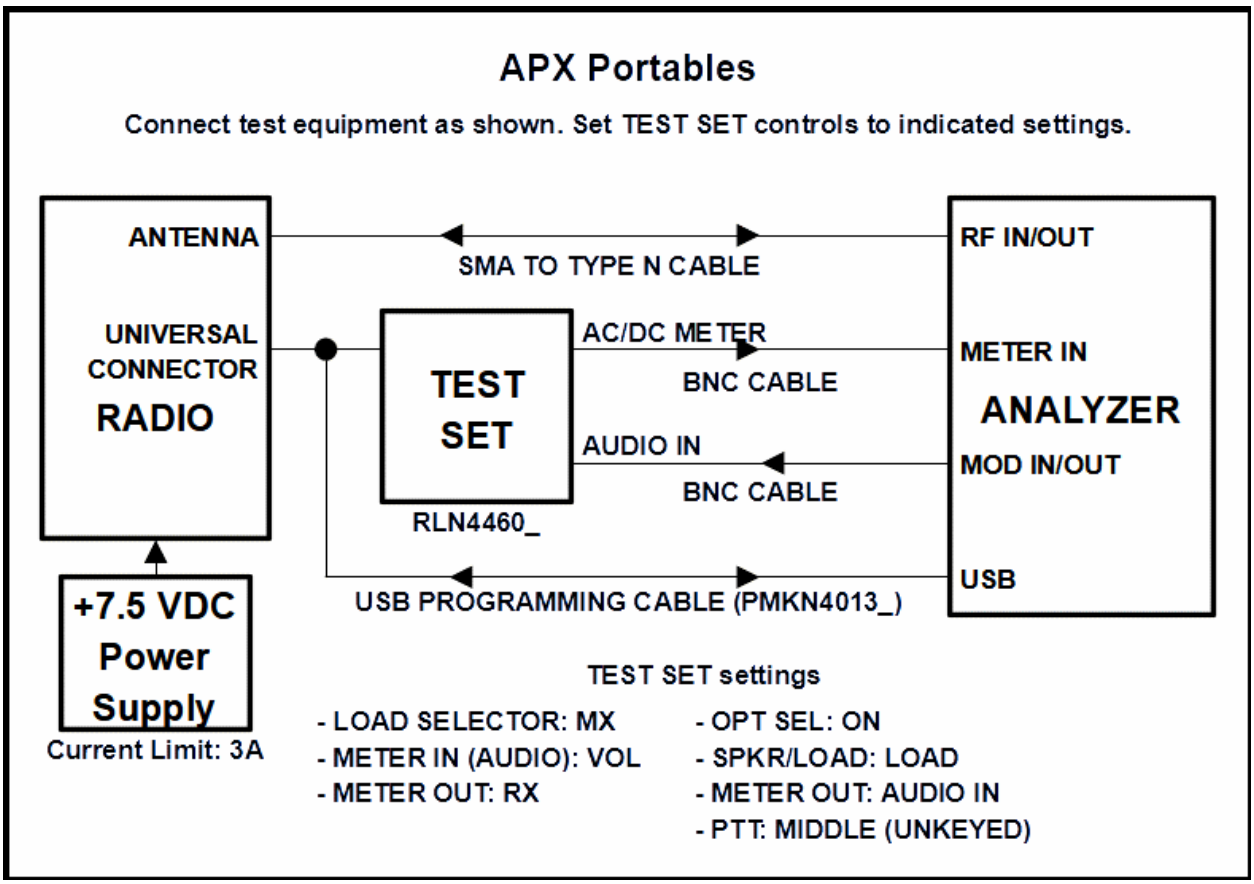

Figure 3-1. APX Portable Test Setup Diagram

4. Motorola APX Portable Alignment and Test Descriptions

Note: Throughout this section are references to Test Frequency. Test Frequencies are band- and mode -specific. A table of the frequencies used by each band may be found in the respective radio service manual. See the References section for more details.

Note: All analyzer Mode settings are Standard unless otherwise indicated.

4.1. Tx PA Bias (Auto)

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 4-1. Analyzer Configuration for Tx PA Bias (Auto) alignment

4.1.1. Alignment

Note: This alignment applies only to APX 8000, APX 6000 Enhanced, and APX NEXT portable models.

The Tx PA Bias alignment adjusts the radio power amplifier voltages. The radio is placed into Test Mode. The radio PA bias is enabled and the current bias auto-adjusted. The current bias is disabled. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Pass unless radio error.
Frequency	Test Frequency
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 4-2. Tx PA Bias (Auto) alignment results

4.2. Reference Frequency

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	30 dB

Table 4-3. Analyzer Configuration for Reference Frequency

4.2.1. Alignment

The radio is placed into Test Mode at the highest TX Test Frequency and commanded to transmit. Using a best linear fit algorithm, two frequency error measurements are taken at two different radio softpot values. These frequency error measurements are used to calculate the softpot value which minimizes frequency error. After programming this new softpot value into the radio, the radio softpot is fine tuned until minimum frequency error is detected. The frequency error is compared against test limits and the final results written to the log file.

Name	Description
Result	Pass or Fail. Frequency Error within Max Limit, Min Limit
Frequency	Test Frequency
Freq Error	Measured frequency error after alignment
Min Limit	Minimum Limit (inclusive) for frequency error
Max Limit	Maximum Limit (inclusive) for frequency error
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 4-4. Reference Frequency alignment results

4.2.2. Test

The radio is placed into Test Mode at the highest TX Test Frequency and commanded to transmit. The frequency error is measured by the analyzer and compared to test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Frequency Error within Max Limit, Min Limit
Frequency	Test Frequency
Freq Error	Measured frequency error
Max Limit	Maximum Limit (inclusive) for frequency error
Min Limit	Minimum Limit (inclusive) for frequency error
Softpot	Radio softpot which yields Freq Error

Table 4-5. Reference Frequency test results

4.3. TX Power Out

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 4-6. Analyzer Configuration for TX Power Out

4.3.1. Alignment

The TX Power Out alignment is composed of two parts: Tx Power Characterization Points tuning and Tx Power Characterization tuning.

Power Characterization Points tuning adjusts the characterization points to account for the variability of the power detection circuitry between radios. The radio is placed into Test Mode and commanded to transmit at the first Test Frequency. The output level is measured and then adjusted until near to a band-specific output level defined by the APX Tuner software help file.

This process is repeated for all test frequencies. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Power within manufacturer limits
Frequency	Test Frequency
Power	Measured radio output level
Target Power	Ideal Power
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 4-7. Power Characterization Points alignment results

Power Characterization tuning characterizes the power output level of the radio. The radio is placed into Test Mode and commanded to transmit. Beginning at the lowest TX Test Frequency, the output level is measured at two different points for each TX Test Frequency. These measurements are used to calculate and program power coefficients use to normalize the radio power output level across the radio band as specified by the radio's basic service manual.

This process is repeated for all test frequencies. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Power within manufacturer limits
Frequency	Test Frequency
Low Power	Measured low radio output level
High Power	Measured high radio output level
Diff (>1.5W)	Difference between Low Power and High Power. If outside indicated limit, alignment is marked as Fail.

Table 4-8. Tx Power Characterization alignment results

4.4. TX Attenuator Limit

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 4-9. Analyzer Configuration for Tx Attenuator Limit

4.4.1. Alignment

Note: The Tx Attenuator Limit alignment applies to APX 8000 models only.

The Tx Attenuator Limit alignment adjusts the attenuator limiting radio PA driver power.

The radio is placed into Test Mode and commanded to transmit at the first Test Frequency. The output level is measured and then adjusted until near to the band-specific output level defined by the APX Family Tuner software.

This process is repeated for all test frequencies. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Power within manufacturer limits
Frequency	Test Frequency
Power	Measured radio output level
Target	Ideal Power
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 4-10. Tx Attenuator Limit alignment results

4.5. TX PA Saturation Reference

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 4-11. Analyzer Configuration for Tx PA Saturation Reference

4.5.1. Alignment

The Tx PA Saturation Reference alignment adjusts the radio for optimal TDMA F2 performance.

The radio is placed into Test Mode and commanded to transmit at the first Test Frequency. The output level is measured and then adjusted until near to the band-specific output level defined by the APX Family Tuner software help file.

This process is repeated for all test frequencies. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Power within Min Limit, Max Limit
Frequency	Test Frequency
Power	Measured radio output level
Min Limit	Minimum inclusive limit for Power to Pass alignment
Max Limit	Maximum inclusive limit for Power to Pass alignment
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 4-12. Tx PA Saturation Reference alignment results

4.6. Tx Deviation Balance

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	20 dB

Table 4-13. Analyzer Configuration for Tx Deviation Balance alignment

4.6.1. Alignment

The radio is placed into Test Mode at the highest TX Test Frequency and commanded to transmit. The radio generates an 100 Hz modulation tone and the deviation of this tone is measured with the analyzer. The radio then generates a 3 kHz modulation tone and the deviation of this tone is measured with the analyzer. The radio softpot is adjusted until the deviation difference between the first and second tones is within range. This adjustment is performed for each TX Test Frequency and the percent difference is compared against test limits. The results for each TX Test Frequency are written to the log file.

Name	Description
Result	Pass or Fail. Percent difference between low and high tone deviation less than or equal to Variance.
Frequency	Test Frequency
Low Tone	Deviation measured at 100 Hz tone
High Tone	Deviation measured at 3 kHz tone
Variance	Measured difference between Low and High Tone deviation
Max Limit	Maximum passable percent difference (inclusive) between Low and High Tone deviation
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment

Table 4-14. Tx Deviation Balance alignment results

4.7. Rx Front End Filter

RF Control	Port	Frequency	Modulation
Generate	RF IN/OUT, RF GEN OUT	Test Frequency	FM

Table 4-15. Analyzer Configuration for Rx Front End Filter alignment

4.7.1. Alignment

Note: This alignment is only performed for UHF R1 and UHF R2 band models.

The Rx Front End Filter adjusts the radio's RF front end for optimal selectivity and sensitivity.

The radio is placed into Test Mode at the first Rx Test Frequency. Depending on the radio model under test, the analyzer generates a CW signal at -90 dBm or a 1 kHz modulation tone at 60% rated channel deviation at -80 dBm. The radio softpot is then auto-aligned. This adjustment is performed for each Rx Test Frequency. The results for each Rx Test Frequency are written to the test log file.

Name	Description
Result	Pass or Fail. Pass unless radio reports an error.
Frequency	Test Frequency
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment

Table 4-16. Rx Front End Filter alignment results

See Rx Analog Sensitivity (SINAD) for alignment verification test.

4.8. Front End Gain

RF Control	Port	Frequency	Modulation
Generate	RF IN/OUT, RF GEN OUT	Test Frequency	FM

Table 4-17. Analyzer Configuration for Front End Gain alignment

4.8.1. Alignment

Note: This alignment is only performed for APX 900 models.

The Rx Front End Gain adjusts the radio's RF front end for RSSI value correction.

The radio is placed into Test Mode at the first Rx Test Frequency. The analyzer generates a CW signal at -75 dBm. The radio softpot is then auto-aligned. This adjustment is performed for each Rx Test Frequency. The results for each Rx Test Frequency are written to the test log file.

Name	Description
Result	Pass or Fail. Pass unless radio reports an error.
Frequency	Test Frequency
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment
FE Gain	Front End Gain, in dB. FE Gain + RSSI is analyzer output level (-75 dBm).
RSSI	RSSI correction value, in dBm. FE Gain + RSSI is analyzer output level (-75 dBm).

Table 4-18. Front End Gain alignment results

4.9. Rx VLIF DCA Phase Error

RF Control	Port	Frequency	Modulation
Generate	RF IN/OUT, RF GEN OUT	Test Frequency	FM

Table 4-19. Analyzer Configuration for Rx VLIF DCA Phase Error alignment

4.9.1. Alignment

Note: This alignment is only performed for APX 900 portable models.

The Rx Front End Filter adjusts the radio's Rx VLIF DCA Phase Error.

The radio is placed into Test Mode at the first Rx Test Frequency. The analyzer generates a CW signal at -15 dBm into the radio. The radio softpot is then auto-aligned. This adjustment is performed for each Rx Test Frequency available. The results for each Rx Test Frequency are written to the test log file.

Name	Description
Result	Pass or Fail. Pass unless radio reports an error.
Frequency	Test Frequency
VLIF Phase Error	VLIF Phase Error parameters

Table 4-20. Rx VLIF DCA Phase Error alignment results

See Rx Analog Sensitivity (SINAD) for alignment verification test.

4.10. Rx Duty Cycle Adjustment

RF Control	Port	Frequency	Modulation
Generate	RF IN/OUT	Test Frequency	FM

Table 4-21. Analyzer Configuration for Rx Duty Cycle Adjustment alignment

4.10.1. Alignment

Note: This alignment is only performed for APX 8000, APX 6000 Enhanced, APX NEXT, and APX 900 portable models.

See Motorola APX Family Tuner Help for a description of this alignment.

The radio is placed into Test Mode at the first Rx Test Frequency. Depending on the radio model under test, the analyzer generates a CW signal at either -30 dBm or at -60 dBm. The radio softpot is then auto-aligned to minimize phase error. The results are written to the test log file.

Name	Description
Result	Pass or Fail. Pass unless radio reports an error.
Frequency	Test Frequency
Low/High Amp Err	Low/High side amplitude error (rad)
Low/High Phase Err	Low/High side phase error (rad)
Low/High SBS	Low/High side band suppression factor (APX 900 only)
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment

Table 4-22. R Duty Cycle Adjustment results

4.11. RF Power

This test verifies that previously aligned radio power meets rated power specifications.

4.11.1. Test

The radio is placed into Test Mode and commanded to transmit. Beginning at the lowest Tx Test Frequency, the output level is measured at each TX Test Frequency and compared against test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Power Out within Max Limit, Min Limit
Frequency	Test Frequency
Power Out	Measured radio output level
Min Limit	Minimum Limit (inclusive) for Power Out
Max Limit	Maximum Limit (inclusive) for Power Out

Table 4-23. RF Power test results

4.12. Rx Distortion

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-50 dBm

Table 4-24. Analyzer Configuration for Rx Distortion Test

4.12.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Rx Test Frequency. The radio audio output level is tested and if insufficient to measure distortion the volume is increased until sufficient to measure distortion. The audio signal's distortion level is then measured and compared to test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Distortion level within Max Limit, Min Limit
Frequency	Test Frequency
Distortion	Measured audio signal distortion level
Max Limit	Maximum Limit (inclusive) for Distortion to Pass

Table 4-25. Rx Distortion test results

4.13. Rx Analog Sensitivity (SINAD)

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-50 dBm

Table 4-26. Analyzer Configuration for Rx Analog Sensitivity (SINAD) test

4.13.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency. The radio audio output level is tested and if insufficient to measure SINAD the volume is increased until sufficient to measure SINAD. The output level of the analyzer is then adjusted until the radio audio signal's SINAD level measures about 12 dB. The current analyzer output level is then compared against test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Sensitivity (SINAD) level within Max Limit
Frequency	Test Frequency
12dB SINAD	Analyzer output level at which the radio SINAD level measures 12 dB
Max Limit	Maximum Limit (inclusive) for Sensitivity (SINAD) to Pass

Table 4-27. Rx Analog Sensitivity (SINAD) test results

4.14. Noise Squelch Threshold

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-125 dBm

Table 4-28. Analyzer Configuration for Noise Squelch Threshold test

4.14.1. Test

The purpose of this procedure is to verify that the squelch circuit operation performs as expected, blocking noise but allowing stronger signals to be heard. The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency. The radio audio output level is tested and if insufficient to measure the unsquelched condition the volume is increased. Beginning at -125 dBm, the analyzer output level is slowly increased until the radio unsquelches OR is 6 dBm above the Max Limit, whichever comes first. The Unsquelch analyzer output level is compared against test limits and the final results written to the log file.

Name	Description
Result	Pass or Fail. Noise Squelch Threshold level within Max Limit
Frequency	Test Frequency
Unsquelch	Analyzer output level at which the radio unsquelches
Max Limit	Maximum Limit (exclusive) for Noise Squelch Threshold to Pass

Table 4-29. Noise Squelch Threshold test results

4.15. Modulation Fidelity

NOTE: This test requires an analyzer with P25 Conventional test mode (R8-P25 option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 1 Modulation Fidelity at a given frequency. Modulation Fidelity (FSK error) represents how accurately a P25 transmitter reproduces an ideal theoretical modulation waveform. The TIA/EIA-102.CAAB measurement standard max limit is 5%. This is a test only; there is no alignment.

RF Control	Port	Frequency	Radio Modulation
Monitor	RF IN/OUT	Test Frequency	Standard Tx (O.153/V.52)

Table 4-30. Analyzer Configuration for Modulation Fidelity test

4.15.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 waveform signal. The analyzer measures the Modulation Fidelity response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Modulation Fidelity error within Max Limit
Frequency	Test Frequency
Mod Fi	Measured FSK error at Frequency
Max Limit	Maximum Limit (inclusive) for Modulation Fidelity to Pass

Table 4-31. Modulation Fidelity test results

4.16. Symbol Deviation

NOTE: This test requires an analyzer with P25 Conventional test mode (R8-P25 option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 1 Symbol Deviation at a given frequency. Symbol Deviation provides the deviation measurement at symbol decision times. The TIA/EIA-102.CAAB measurement standard max limit is 1800 Hz +/-180 Hz. This is a test only; there is no alignment.

RF Control	Port	Frequency	Radio Modulation
Monitor	RF IN/OUT	Test Frequency	Standard Tx (O.153/V.52)

Table 4-32. Analyzer Configuration for Symbol Deviation test

4.16.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 waveform signal. The analyzer measures the Symbol Deviation response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Symbol Deviation is within Max Limit
Frequency	Test Frequency
Symbol Dev	Measured Symbol Deviation at Frequency
Min Limit	Minimum Limit (inclusive) for Symbol Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Symbol Deviation to Pass

Table 4-33. Symbol Deviation test results

4.17. P25 Phase II Modulation Fidelity

NOTE: This test requires an analyzer with P25 Phase 2 Test Mode (R8-P25_II option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 2 Modulation Fidelity at a given frequency. Modulation Fidelity represents how accurately a P25 Phase 2 transmitter reproduces an ideal theoretical modulation waveform. The TIA/EIA-102.CCAB measurement standard max limit is 5%. This is a test only; there is no alignment.

Mode	Port	Frequency	Mon Mod Type	Test Pattern
Monitor	RF IN/OUT	Test Frequency	HCPM	1031 Hz Tone

Table 4-34. Analyzer Configuration for P25 Phase 2 Modulation Fidelity test

4.17.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 Phase 2 waveform signal. The analyzer measures the Modulation Fidelity response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Modulation Fidelity error within Max Limit
Frequency	Test Frequency
Mod Fi	Measured RMS error (%) at Frequency normalized across symbols
Max Limit	Maximum Limit (inclusive) for Modulation Fidelity to Pass

Table 4-35. P25 Phase 2 Modulation Fidelity test results

4.18. P25 Phase II Symbol Deviation

NOTE: This test requires an analyzer with P25 Phase 2 Test Mode (R8-P25_II option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 2 Symbol Deviation at a given frequency. Symbol Deviation is estimated by averaging the normalized frequency deviations (of the FM representation of the phase-based modulation) at symbol times in the received signal and then scaling by the maximum symbol value. The TIA/EIA-102.CCAA HCPM ideal deviation is 2992 Hz. The min and max limits are +/- 5%, or +/-150 Hz. This is a test only; there is no alignment.

Mode	Port	Frequency	Mod Mod Type	Test Pattern
Monitor	RF IN/OUT	Test Frequency	HCPM	1031 Hz Tone

Table 4-36. Analyzer Configuration for P25 Phase 2 Symbol Deviation test

4.18.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 Phase 2 waveform signal. The analyzer measures the Symbol Deviation response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Symbol Deviation is within Max Limit
Frequency	Test Frequency
Symbol Dev	Measured Symbol Deviation at Frequency
Min Limit	Minimum Limit (inclusive) for Symbol Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Symbol Deviation to Pass

Table 4-37. P25 Phase 2 Symbol Deviation test results

4.19. Rx Digital Sensitivity (P25 BER)

NOTE: This test requires an analyzer with P25 Conventional test mode (R8-P25 option) capability.

The purpose of this procedure is to measure the radio receiver's Bit Error Rate at a given frequency. The TIA/EIA.CAAA standard BER rate is 5%. This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Frequency	Framed 1011 Hz Pattern, 2.83 kHz deviation	-116.0 dBm

Table 4-38. Analyzer Configuration for Rx Digital Sensitivity (P25 BER) test

4.19.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency, ready to receive a C4FM-modulated signal from the analyzer. Once BER synchronization is detected, the analyzer output level is decreased until a BER of 5% is measured. The analyzer output level at 5% BER is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Digital Sensitivity (BER) output level within Max Limit
Frequency	Test Frequency
Bit Error Count	Number of bit errors reported in the measured superframe.
5% BER	Analyzer output level at which the radio BER measures 5%
Max Limit	Maximum Limit (inclusive) for Digital Sensitivity (BER) to Pass

Table 4-39. Rx Digital Sensitivity (P25 BER) test results

4.20. Rx Sensitivity (P25 Phase II BER)

NOTE: This test requires an analyzer with P25 Phase 2 Test Mode (R8-P25_II option) capability.

The purpose of this procedure is to measure the radio receiver's Bit Error Rate at a given frequency. The TIA/EIA.CCAA standard BER rate is 5%. This is a test only; there is no alignment.

Mode	Generate
Port	RF IN/OUT
Frequency	Test Frequency
Modulation Type	HDQPSK
Test Pattern	1031 Hz Tone
Level	-116.0 dBm

Table 4-40. Analyzer Configuration for Rx Sensitivity (P25 Phase II BER) test

4.20.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency, ready to receive a C4FM-modulated signal from the analyzer. Once BER synchronization is detected, the analyzer output level is decreased until a BER of 5% is measured. The analyzer output level at 5% BER is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Digital Sensitivity (BER) output level within Max Limit
Frequency	Test Frequency
Bit Error Count	Number of bit errors reported in the measured superframe
5% BER	Analyzer output level at which the radio BER measures 5%
Max Limit	Maximum Limit (inclusive) for Digital Sensitivity (BER) to Pass

Table 4-41. Rx Sensitivity (P25 Phase II BER) test results

4.21. Voice Modulation (internal)

The purpose of this procedure is to test the ability of the radio's internal microphone to accurately transfer the received signal.

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 4-42. Analyzer Configuration for Voice Modulation (internal) test

4.21.1. Test

The radio is placed into Test Mode at the lowest TX Test Frequency. The analyzer is setup as specified in this section's Analyzer Configuration table. The user is instructed to key the connected radio and place it next to the analyzer speaker (see Figure 4-1). The user is also instructed to adjust the analyzer volume until about 60% rated system deviation is seen on the analyzer display (see Figure 4-2). The deviation level is then measured by the analyzer and the user is instructed when to un-key the radio. The measured deviation is compared against test limits and the final results are written to the log file.

Figure 4-1. Place keyed radio next to analyzer speaker.

Figure 4-2. Adjust analyzer volume until about 60% rated system deviation is measured.

Name	Description
Result	Pass or Fail. Deviation within Min Limit, Max Limit
Frequency	Test Frequency
Deviation	Measured modulation deviation level
Min Limit	Minimum Limit (inclusive) for Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Deviation to Pass

Table 4-43. Voice Modulation (internal) test results

4.22. Voice Modulation (external)

The purpose of this procedure is to test the ability of an external microphone attached to the radio to effectively transfer the received signal.

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 4-44. Analyzer Configuration for Voice Modulation (external) test

4.22.1. Test

The radio is placed into Test Mode at the lowest TX Test Frequency. The analyzer is setup as specified in this section's Analyzer Configuration table. The analyzer generates a 1 kHz signal at 800 mV into the radio's external microphone accessory port via the radio test set. The radio is commanded to transmit and the resulting deviation level is then measured by the analyzer. The measured deviation is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Deviation within Min Limit, Max Limit
Frequency	Test Frequency
Deviation	Measured modulation deviation level
Min Limit	Minimum Limit (inclusive) for Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Deviation to Pass

Table 4-45. Voice Modulation (external) test results

5. Motorola APX Mobile Radio Test Setup

Before servicing a radio with AutoTune, ensure the analyzer is running the current system software version. Each system version release contains issue resolutions and/or new/enhanced features.

- On the analyzer, navigate to Settings > About… Note the System version shown.
- Browse to the Freedom software upgrades webpage: https://freedomcte.com/upgrades/
- If the first Current System Version shown on the webpage is more recent than the analyzer System version, follow the webpage instructions to download and apply the current system version software to your analyzer.

To perform the test and alignment procedures, the APX Mobile radio must be connected to the R8000 Communications Systems Analyzer as shown in Figure 5-1. Motorola APX Mobile Test Setup Diagram (mid power models) or Figure 5-2. Motorola APX Mobile High Power Test Setup Diagram (high power models).

CAUTION: Make certain that the radio under test is configured as described in the corresponding diagram **before** attempting to perform the indicated alignment or test. Failure to do so may result in poor radio performance and/or damage to the analyzer or radio equipment under test.

5.1. Cable Sweep

Every RF cable connected between a radio under test and the analyzer attenuates the signal propagating through it. The amount of attenuation varies by several factors such as operating frequency, cable length, and cable type. Ensuring this attenuation is accounted for by the analyzer is critical to test and alignment accuracy, especially for power alignments and sensitivity tests.

Sweep the RF cable used between the Radio and Analyzer, label the RF cable with the stored cable sweep name, and enable the Cable Sweep feature in the analyzer System, System Settings… menu. Refer to Application Note FCT-1017 *Utilizing Cable Sweep on the Freedom Communications System Analyzer* for instructions on how to perform a cable sweep.

5.2. Test Hardware

Test Aid	Recommended part	Description
USB radio programming cable	Motorola HKN6163_ Motorola HKN6184_	USB cable for programming and servicing radio.
Current Meter	Freedom USB-CS	For Tx PA Bias alignment
Variable DC power supply	Astron VS-50_	DC power supply with sufficient current sourcing capability.
RF test cable	Megaphase RF Orange series	Shielded RF cable with low loss.
Reference cable	Pomona 5697	BNC cable for sweeping RF test cable.
6 dB attenuator	Mini-Circuits 15542	Attenuator for reducing Reference cable VSWR.
High power attenuator	150-WA-FFN-06	150W 6dB attenuator for high power mobiles.
Audio cable	Pomona 5697	Connects audio from analyzer to breakout box.
Breakout box	Freedom 202161-01	Routes signals from radio to analyzer for Rx audio tests.
Microphone	Motorola RMN5052_	For Voice Modulation test

Table 5-1. Mobile Test Hardware Table

5.3. Motorola APX Mobile Test Setup

Refer to the diagram below for the proper test setup.

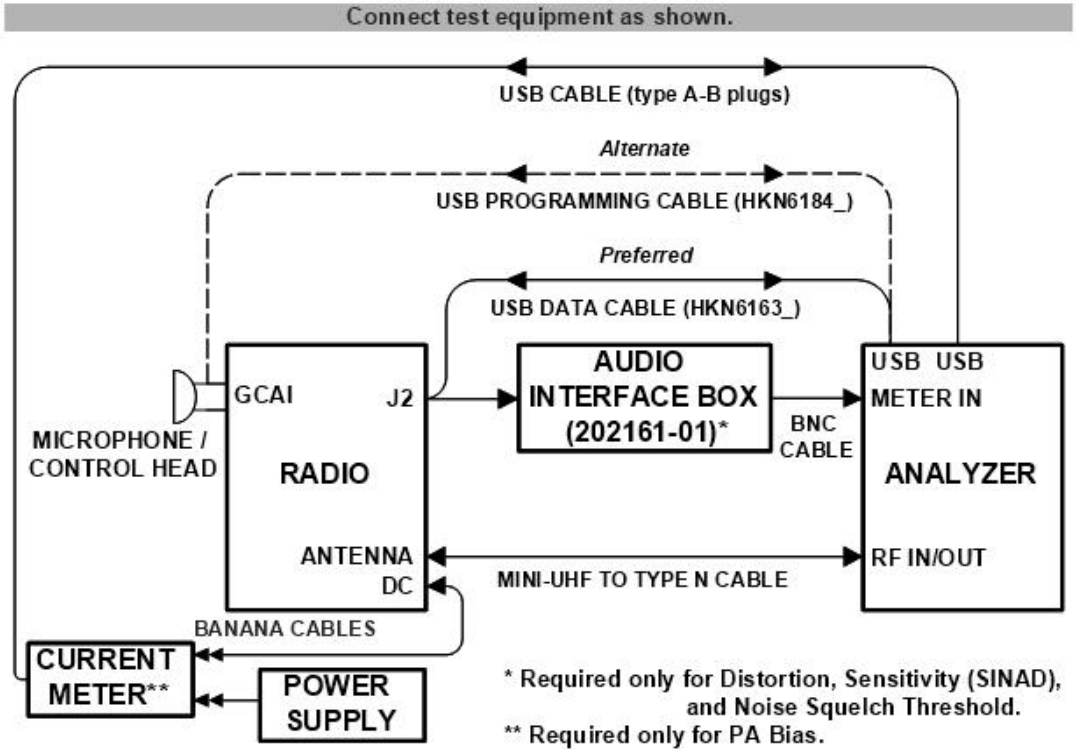

Figure 5-1. Motorola APX Mobile Test Setup Diagram

5.4. Motorola APX Mobile High Power Test Setup

Refer to the diagram below for the proper test setup.

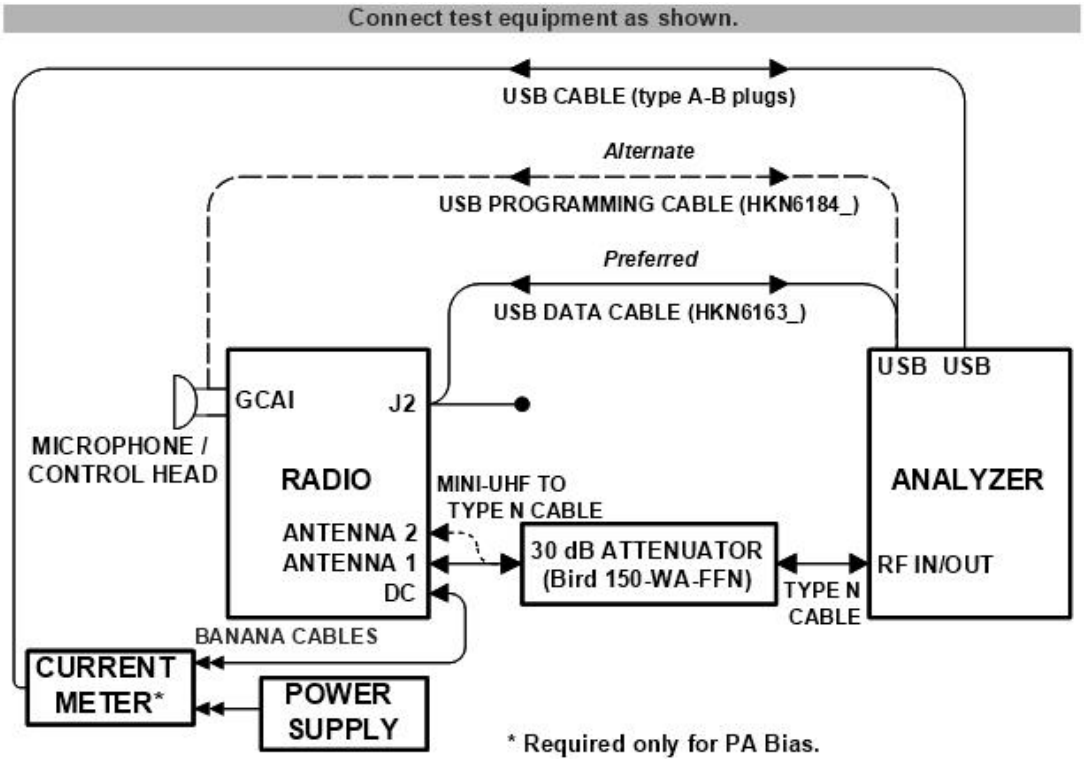

Figure 5-2. Motorola APX Mobile High Power Test Setup Diagram

6. Motorola APX Mobile Alignment and Test Descriptions

Note: Throughout this section are references to Test Frequency that are band and mode specific. A table of the frequencies used by each band may be found in the respective radio service manual. See the References section for more details.
Note: All analyzer Mode settings are Standard unless otherwise indicated.

Dual-Band: Some Motorola APX Mobile radios are dual-band capable. Additional notes for radio models configured with two bands are included in the following sections. If the radio under test is configured with a single band, these notes are not applicable.

Dual-Band: Dual Band equipped radios have two RF connectors at the rear of the radio. They are labeled on the top and on the rear of the radio to identify which band they should be used with. During servicing, it will be necessary to change the test setup cabling to test both bands. The test operator will be prompted to connect the RF cable to the appropriate RF Output port on the radio.

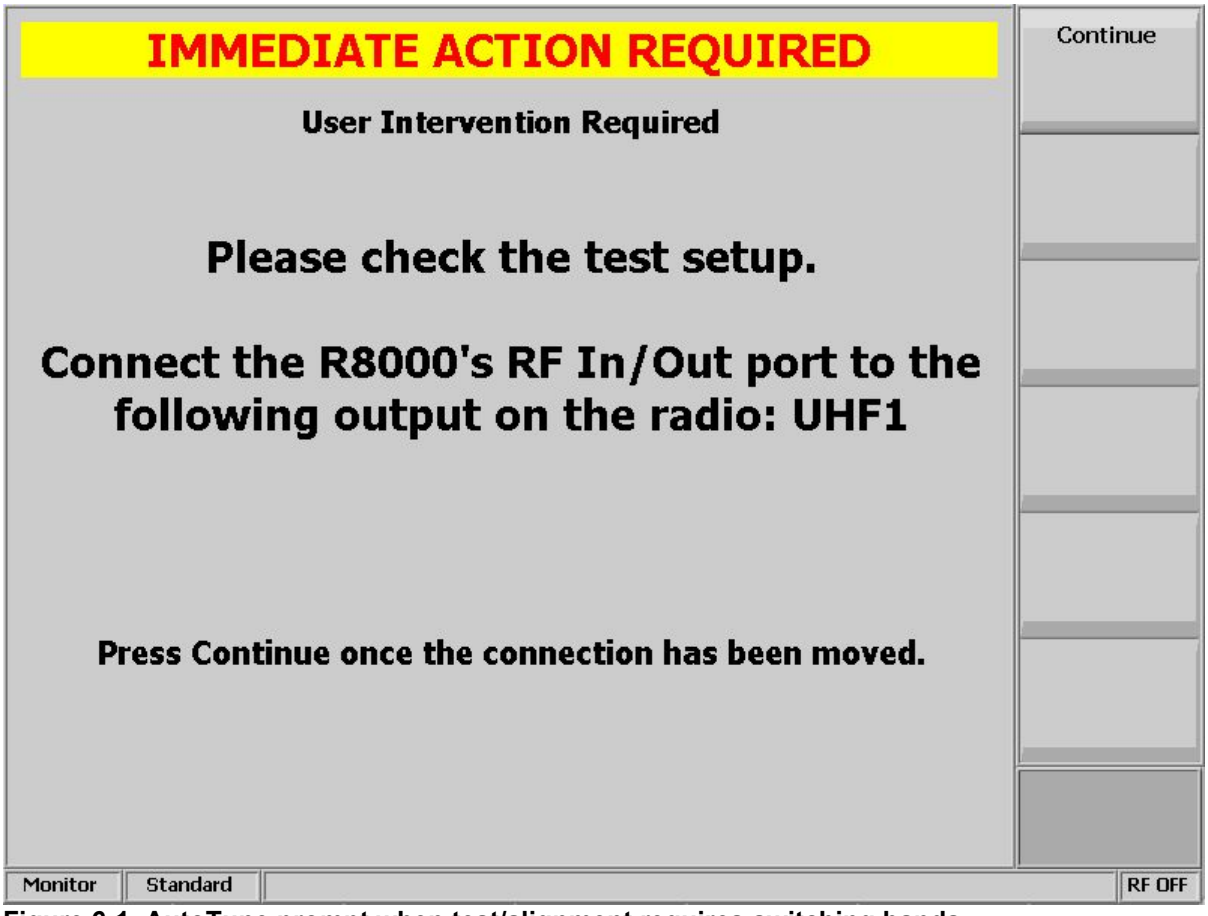

Figure 6-1. AutoTune prompt when test/alignment requires switching bands

6.1. Tx PA Bias

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 6-1. Analyzer Configuration for Tx PA Bias alignment

6.1.1. Alignment

Note: This alignment requires an external current meter (Freedom part # USB-CS) to perform.

APX 8500 Mobiles: The Tx PA Bias alignment adjusts the radio power amplifier voltages. The radio is placed into Test Mode, radio PA Bias is toggled, and baseline current is measured. If sufficient, the radio PA bias is toggled and the current measured again. The radio softpot is adjusted until the difference between the baseline and measured current is about the same as the values shown in APX Family Tuner. The process is repeated for remaining test frequencies. The final results are written to the log file.

APX Mobiles: The Tx PA Bias alignment adjusts the radio power amplifier voltages. The radio is placed into Test Mode baseline current is measured. If sufficient, the radio PA bias is enabled and the current measured again. The radio softpot is adjusted until the difference between the baseline and measured current is about the same as the values shown in APX Family Tuner. The process is repeated for remaining test frequencies and then the bias is disabled. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Power within Min, Max Limits to Pass
PA	Power amplifier number
Frequency	Test Frequency
Bias	Target current bias, in mA
Min Limit	Minimum limit (inclusive) for Bias current for Results to be a Pass
Max Limit	Maximum limit (inclusive) for Bias current for Results to be a Pass
Error	Percent error between Bias and (Max Limit+Min Limit)/2 target
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 6-2. Tx PA Bias alignment results

6.2. Reference Frequency

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	20 dB

Table 6-3. Analyzer Configuration for Reference Frequency

6.2.1. Alignment

The radio is placed into Test Mode at the highest TX Test Frequency and commanded to transmit. Using a best linear fit algorithm, two frequency error measurements are taken at two different radio softpot values. These frequency error measurements are used to calculate the softpot value which minimizes frequency error. After programming this new softpot value into the radio, the radio softpot is fine tuned until minimum frequency error is detected. The frequency error is compared against test limits and the final results written to the log file.

Dual-Band: This alignment is only performed at a single test frequency. The test frequency is the highest test frequency for the highest frequency band.

Name	Description
Result	Pass or Fail. Frequency Error within Max Limit, Min Limit
Frequency	Test Frequency
Freq Error	Measured frequency error after alignment
Min Limit	Minimum Limit (inclusive) for frequency error
Max Limit	Maximum Limit (inclusive) for frequency error
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 6-4. Reference Frequency alignment results

6.2.2. Test

The radio is placed into Test Mode at the highest TX Test Frequency and commanded to transmit. The frequency error is measured by the analyzer and compared to test limits. The final results are written to the log file.

Dual-Band: This test is only performed at a single test frequency. The test frequency is the highest test frequency for the highest frequency band.

Name	Description
Result	Pass or Fail. Frequency Error within Max Limit, Min Limit
Frequency	Test Frequency
Freq Error	Measured frequency error
Min Limit	Minimum Limit (inclusive) for frequency error
Max Limit	Maximum Limit (inclusive) for frequency error
Softpot	Radio softpot which yields Freq Error

Table 6-5. Reference Frequency test results

6.3. TX Power Out

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 6-6. Analyzer Configuration for TX Power Out

6.3.1. Alignment

The TX Power Out alignment is composed of two parts: Power Detection Calibration followed by Tx Power Characterization.

Power Detector Calibration tunes the radio power detector to minimize the power output variation across radios. The radio is placed into Test Mode and commanded to transmit at a mid-band Test Frequency. The output level is measured and then adjusted until near to a band-specific target output level supplied by the radio. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Power within Min, Max Limits to Pass
Frequency	Test Frequency
Power	Measured radio output power
Target	Ideal Power
Min Limit	Minimum limit (inclusive) for Power for Results to be a Pass.
Max Limit	Maximum limit (inclusive) for Power for Results to be a Pass.
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 6-7. Power Detection Calibration alignment results

Tx Power Characterization tuning characterizes the power output level of the radio. The radio is placed into Test Mode and commanded to transmit. Beginning at the lowest TX Test Frequency, the output level is measured at two different points for each TX Test Frequency. These measurements are used to calculate and program power coefficients use to normalize the radio power output level across the radio band as specified by the radio's basic service manual. After the alignment is complete, the power output level is measured again at each TX Test Frequency and compared against test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Diff (>1.5W) must be more than 1.5W to Pass
Frequency	Test Frequency
Low Power	Measured radio output level at low power
High Power	Measured radio output level at high power
Diff (>1.5W)	Calculated difference between High, Low Power

Table 6-8. Tx Power Characterization alignment results

6.4. TX Current Limit

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 6-9. Analyzer Configuration for Tx Current Limit

6.4.1. Alignment

The Tx Current Limit alignment adjusts a current protection circuit.

The radio is placed into Test Mode and commanded to transmit at the first Tx Test Frequency. The radio current protection circuit is auto-adjusted and the radio unkeyed. The process is repeated to all Tx Test Frequencies and the final results are written to the log file.

Name	Description
Result	Pass or Fail
Frequency	Test Frequency
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 6-10. Tx Current Limit alignment results

6.5. TX Voltage Limit

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 6-11. Analyzer Configuration for Tx Voltage Limit

6.5.1. Alignment

The Tx Current Limit alignment adjusts a voltage protection circuit.

The radio is placed into Test Mode and commanded to transmit at the first Tx Test Frequency. The radio voltage protection circuit is auto-adjusted and the radio unkeyed. The process is repeated to all Tx Test Frequencies and the final results are written to the log file.

Name	Description
Result	Pass or Fail
Frequency	Test Frequency
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot after alignment

Table 6-12. Tx Voltage Limit alignment results

6.6. Tx Deviation Balance

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	20 dB

Table 6-13. Analyzer Configuration for Tx Deviation Balance alignment

6.6.1. Alignment

The radio is placed into Test Mode at the highest TX Test Frequency and commanded to transmit. The radio generates a 100 Hz modulation tone and the deviation of this tone is measured with the analyzer. The radio then generates a 3 kHz modulation tone and the deviation of this tone is measured with the analyzer. The radio softpot is adjusted until the deviation difference between the first and second tones is within range. This adjustment is performed for each TX Test Frequency and the percent difference is compared against test limits. The results for each TX Test Frequency are written to the log file.

Name	Description
Result	Pass or Fail. Percent difference between low and high tone deviation less than or equal to Variance.
Frequency	Test Frequency
Low Tone	Deviation measured at 100 Hz tone
High Tone	Deviation measured at 3 kHz tone
Variance	Measured difference between Low and High Tone deviation
Max Limit	Maximum passable percent difference (inclusive) between Low and High Tone deviation
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment

Table 6-14. Tx Deviation Balance alignment results

6.7. Rx Front End Filter

RF Control	Port	Frequency	Modulation
Generate	RF IN/OUT, RF GEN OUT	Test Frequency	FM

Table 6-15. Analyzer Configuration for Rx Front End Filter alignment

6.7.1. Alignment

Note: This alignment is only performed for UHF R1 and UHF R2 band models.

The Rx Front End Filter adjusts the radio's RF front end for optimal selectivity and sensitivity.

The radio is placed into Test Mode at the first Rx Test Frequency. Depending on the radio model under test, the analyzer generates a CW signal at -90 dBm or a 1 kHz modulation tone at 60% rated channel deviation at -80 dBm. The radio softpot is then auto-aligned. This adjustment is performed for each Rx Test Frequency. The results for each Rx Test Frequency are written to the test log file.

Name	Description
Result	Pass or Fail. Pass unless radio reports an error.
Frequency	Test Frequency
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment

Table 6-16. Rx Front End Filter alignment results

6.8. Rx Distortion

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-50 dBm

Table 6-20. Analyzer Configuration for Rx Distortion Test

6.8.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Rx Test Frequency. The radio audio output level is tested and if insufficient to measure distortion the volume is increased until sufficient to measure distortion. The audio signal's distortion level is then measured and compared to test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Distortion level within Max Limit, Min Limit
Frequency	Test Frequency
Distortion	Measured audio signal distortion level
Max Limit	Maximum Limit (inclusive) for Distortion to Pass

Table 6-21. Rx Distortion test results

for alignment verification test.

6.9. Rx Duty Cycle Adjustment

RF Control	Port	Frequency	Modulation
Generate	RF IN/OUT	Test Frequency	FM

Table 6-17. Analyzer Configuration for Rx Duty Cycle Adjustment alignment

6.9.1. Alignment

Note: This alignment is only performed for APX 8500 and APX Mobile Enhanced models.

See Motorola APX Family Tuner Help for a description of this alignment.

The radio is placed into Test Mode at the first Rx Test Frequency. Depending on the radio model under test, the analyzer generates a CW signal at -60 dBm. The radio softpot is then auto-aligned to minimize phase error. The results are written to the test log file.

Name	Description
Result	Pass or Fail. Pass unless radio reports an error.
Frequency	Test Frequency
Low/High Amp Err	Low/High side amplitude error (rad)
Low/High Phase Err	Low/High side phase error (rad)
Old Softpot	Original radio softpot setting
New Softpot	Radio softpot setting after alignment

Table 6-18. R Duty Cycle Adjustment results

6.10. RF Power

This test verifies that previously aligned radio power meets rated power specifications.

6.10.1. Test

The radio is placed into Test Mode and commanded to transmit. Beginning at the lowest Tx Test Frequency, the output level is measured at each TX Test Frequency and compared against test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Power Out within Max Limit, Min Limit
Frequency	Test Frequency
Power Out	Measured radio output level
Min Limit	Minimum Limit (inclusive) for Power Out
Max Limit	Maximum Limit (inclusive) for Power Out

Table 6-19. RF Power test results

6.11. Rx Distortion

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-50 dBm

Table 6-20. Analyzer Configuration for Rx Distortion Test

6.11.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Rx Test Frequency. The radio audio output level is tested and if insufficient to measure distortion the volume is increased until sufficient to measure distortion. The audio signal's distortion level is then measured and compared to test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. Distortion level within Max Limit, Min Limit
Frequency	Test Frequency
Distortion	Measured audio signal distortion level
Max Limit	Maximum Limit (inclusive) for Distortion to Pass

Table 6-21. Rx Distortion test results

6.12. Rx Analog Sensitivity (SINAD)

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-50 dBm

Table 6-22. Analyzer Configuration for Rx Analog Sensitivity (SINAD) test

6.12.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency. The radio audio output level is tested and if insufficient to measure SINAD the volume is increased until sufficient to measure SINAD. The output level of the analyzer is then adjusted until the radio audio signal's SINAD level measures about 12 dB. The current analyzer output level is then compared against test limits. The final results are written to the log file.

Name	Description
Result	Pass or Fail. 12dB SINAD level within Max Limit
Frequency	Test Frequency
12dB SINAD	Analyzer output level at which the radio SINAD level measures 12 dB
Max Limit	Maximum Limit (inclusive) for Rx Analog Sensitivity (SINAD) to Pass

Table 6-23. Rx Analog Sensitivity (SINAD) test results

6.13. Noise Squelch Threshold

This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Freq	FM, 60% rated deviation	-125 dBm

Table 6-24. Analyzer Configuration for Noise Squelch Threshold test

6.13.1. Test

The purpose of this procedure is to verify that the squelch circuit operation performs as expected, blocking noise but allowing stronger signals to be heard. The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency. The radio audio output level is tested and if insufficient to measure the unsquelched condition the volume is increased. Beginning at -125 dBm, the analyzer output level is slowly increased until the radio unsquelches OR is 6 dBm above the Max Limit, whichever comes first. The Unsquelch analyzer output level is compared against test limits and the final results written to the log file.

Name	Description
Result	Pass or Fail. Noise Squelch Threshold level within Max Limit
Frequency	Test Frequency
Unsquelch	Analyzer output level at which the radio unsquelches
Max Limit	Maximum Limit (exclusive) for Noise Squelch Threshold to Pass

Table 6-25. Noise Squelch Threshold test results

6.14. Modulation Fidelity

NOTE: This test requires an analyzer with P25 Conventional test mode (R8-P25 option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 1 Modulation Fidelity at a given frequency. Modulation Fidelity (FSK error) represents how accurately a P25 transmitter reproduces an ideal theoretical modulation waveform. The TIA/EIA-102.CAAB measurement standard max limit is 5%. This is a test only; there is no alignment.

RF Control	Port	Frequency	Radio Modulation
Monitor	RF IN/OUT	Test Frequency	Standard Tx (O.153/V.52)

Table 6-26. Analyzer Configuration for Modulation Fidelity test

6.14.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 waveform signal. The analyzer measures the Modulation Fidelity response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Modulation Fidelity error within Max Limit
Frequency	Test Frequency
Mod Fi	Measured FSK error at Frequency
Max Limit	Maximum Limit (inclusive) for Modulation Fidelity to Pass

Table 6-27. Modulation Fidelity test results

6.15. Symbol Deviation

NOTE: This test requires an analyzer with P25 Conventional test mode (R8-P25 option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 1 Symbol Deviation at a given frequency. Symbol Deviation provides the deviation measurement at symbol decision times. The TIA/EIA-102.CAAB measurement standard max limit is 1800 Hz +/-180 Hz. This is a test only; there is no alignment.

RF Control	Port	Frequency	Radio Modulation
Monitor	RF IN/OUT	Test Frequency	Standard Tx (O.153/V.52)

Table 6-28. Analyzer Configuration for Symbol Deviation test

6.15.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 waveform signal. The analyzer measures the Symbol Deviation response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Symbol Deviation is within Max Limit
Frequency	Test Frequency
Symbol Dev	Measured Symbol Deviation at Frequency
Min Limit	Minimum Limit (inclusive) for Symbol Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Symbol Deviation to Pass

Table 6-29. Symbol Deviation test results

6.16. P25 Phase II Modulation Fidelity

NOTE: This test requires an analyzer with P25 Phase 2 Test Mode (R8-P25_II option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 2 Modulation Fidelity at a given frequency. Modulation Fidelity represents how accurately a P25 Phase 2 transmitter reproduces an ideal theoretical modulation waveform. The TIA/EIA-102.CCAB measurement standard max limit is 5%. This is a test only; there is no alignment.

Mode	Port	Frequency	Mon Mod Type	Test Pattern
Monitor	RF IN/OUT	Test Frequency	HCPM	1031 Hz Tone

Table 6-30. Analyzer Configuration for P25 Phase 2 Modulation Fidelity test

6.16.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 Phase 2 waveform signal. The analyzer measures the Modulation Fidelity response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Modulation Fidelity error within Max Limit
Frequency	Test Frequency
Mod Fi	Measured RMS error (%) at Frequency normalized across symbols
Max Limit	Maximum Limit (inclusive) for Modulation Fidelity to Pass

Table 6-31. P25 Phase 2 Modulation Fidelity test results

6.17. P25 Phase II Symbol Deviation

NOTE: This test requires an analyzer with P25 Phase 2 Test Mode (R8-P25_II option) capability.

The purpose of this procedure is to measure the radio transmitter's P25 Phase 2 Symbol Deviation at a given frequency. Symbol Deviation is estimated by averaging the normalized frequency deviations (of the FM representation of the phase-based modulation) at symbol times in the received signal and then scaling by the maximum symbol value. The TIA/EIA-102.CCAA HCPM ideal deviation is 2992 Hz. The min and max limits are +/- 5%, or +/-150 Hz. This is a test only; there is no alignment.

Mode	Port	Frequency	Mod Mod Type	Test Pattern
Monitor	RF IN/OUT	Test Frequency	HCPM	1031 Hz Tone

Table 6-32. Analyzer Configuration for P25 Phase 2 Symbol Deviation test

6.17.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest Tx Test Frequency and configured to generate the indicated P25 Phase 2 waveform signal. The analyzer measures the Symbol Deviation response which is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Measured Symbol Deviation is within Max Limit
Frequency	Test Frequency
Symbol Dev	Measured Symbol Deviation at Frequency
Min Limit	Minimum Limit (inclusive) for Symbol Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Symbol Deviation to Pass

Table 6-33. P25 Phase 2 Symbol Deviation test results

6.18. Rx Digital Sensitivity (P25 BER)

NOTE: This test requires an analyzer with P25 Conventional test mode (R8-P25 option) capability.

The purpose of this procedure is to measure the radio receiver's Bit Error Rate at a given frequency. The TIA/EIA.CAAA standard BER rate is 5%. This is a test only; there is no alignment.

RF Control	Port	Frequency	Modulation	Level
Generate	RF IN/OUT	Test Frequency	Framed 1011 Hz Pattern, 2.83 kHz deviation	-116.0 dBm

Table 6-34. Analyzer Configuration for Rx Digital Sensitivity (P25 BER) test

6.18.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency, ready to receive a C4FM-modulated signal from the analyzer. Once BER synchronization is detected, the analyzer output level is decreased until a BER of 5% is measured. The analyzer output level at 5% BER is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Digital Sensitivity (BER) output level within Max Limit
Frequency	Test Frequency
Bit Error Count	Number of bit errors reported in the measured superframe.
5% BER	Analyzer output level at which the radio BER measures 5%
Max Limit	Maximum Limit (inclusive) for Digital Sensitivity (BER) to Pass

Table 6-35. Rx Digital Sensitivity (P25 BER) test results

6.19. Rx Sensitivity (P25 Phase II BER)

NOTE: This test requires an analyzer with P25 Phase 2 Test Mode (R8-P25_II option) capability.

The purpose of this procedure is to measure the radio receiver's Bit Error Rate at a given frequency. The TIA/EIA.CCAA standard BER rate is 5%. This is a test only; there is no alignment.

Mode	Generate
Port	RF IN/OUT
Frequency	Test Frequency
Modulation Type	HDQPSK
Test Pattern	1031 Hz Tone
Level	-116.0 dBm

Table 6-36. Analyzer Configuration for Rx Sensitivity (P25 Phase II BER) test

6.19.1. Test

The analyzer is setup as specified in this section's Analyzer Configuration table. The radio is placed into Test Mode at the lowest RX Test Frequency, ready to receive a C4FM-modulated signal from the analyzer. Once BER synchronization is detected, the analyzer output level is decreased until a BER of 5% is measured. The analyzer output level at 5% BER is compared against test limits and the final results are written to the log file.

Name	Description
Result	Pass or Fail. Digital Sensitivity (BER) output level within Max Limit
Frequency	Test Frequency
Bit Error Count	Number of bit errors reported in the measured superframe
5% BER	Analyzer output level at which the radio BER measures 5%
Max Limit	Maximum Limit (inclusive) for Digital Sensitivity (BER) to Pass

Table 6-37. Rx Sensitivity (P25 Phase II BER) test results

6.20. Voice Modulation (internal)

Note: Motorola APX Mobile High Power models are not supported for this test.

The purpose of this procedure is to test the ability of the radio's external microphone audio circuit to accurately transfer the received microphone signal.

RF Control	Port	Frequency	Modulation	Attenuation
Monitor	RF IN/OUT	Test Frequency	FM	40 dB

Table 6-38. Analyzer Configuration for Voice Modulation (internal) test

6.20.1. Test

The radio is placed into Test Mode at the lowest TX Test Frequency. The analyzer is setup as specified in this section's Analyzer Configuration table. The user is instructed to key the connected radio microphone and place the microphone next to the analyzer speaker (see Figure 6-2). The user is also instructed to adjust the analyzer volume until about 60% rated system deviation is seen on the analyzer display (see Figure 6-3). The deviation level is then measured by the analyzer and the user is instructed when to un-key the microphone. The measured deviation is compared against test limits and the final results are written to the log file.

Figure 6-2. Place keyed microphone next to analyzer speaker.

Figure 6-3. Adjust analyzer volume until about 60% rated system deviation is measured.

Dual-Band: This test is only performed for the lowest RX Test Frequency in the lowest frequency band.

Name	Description
Result	Pass or Fail. Deviation within Min Limit, Max Limit
Frequency	Test Frequency
Deviation	Measured modulation deviation level
Min Limit	Minimum Limit (inclusive) for Deviation to Pass
Max Limit	Maximum Limit (inclusive) for Deviation to Pass

Table 6-39. Voice Modulation (internal) test results

7. Basic Troubleshooting

Symptom	Possible Cause(s)	Possible Solution(s)
Radio repeatedly fails communication initialization.	Serial link corruption.	Retry communicating with the radio after each of the following steps: • Power cycle the radio. • Restart the analyzer.
	Radio powered off	Power on radio
	Programming cable unconnected	Connect programming cable
Mobile radio won't power up.	Loose HKN6163_ cable connection.	Verify cable connection is OK.
	Motorola CPS Ignition Switch setting.	Use Motorola CPS software to set Radio Wide, Advanced, Ignition Switch setting to "Blank". This setting lets radio power up for testing without an ignition signal present. Be sure to return this setting to its original value when testing completed.
Portable radio consistently fails TX Power Out test and/or alignment.	DC Power supply current limiting preventing portable radio from getting adequate current.	Adjust DC power supply current limit to at least 3 Amps.

Table 7-1. AutoTune Troubleshooting Chart

8. Support Information

8.1. Technical Support

Document Library:	freedomcte.com/library/
Video Library:	freedomcte.com/videos/
Phone:	903.985.8999
Email:	Freedom.TechnicalSupport@astronics.com

8.2. Sales Support

Phone:	903.985.8999
Email:	Freedom.Sales@astronics.com

9. References

R8000 Series Communications System Analyzer Operator's Manual (FCT-1365_)

Freedom Communications System Analyzer R8200 User's Guide (FCT-1380_)

APX 6500, APX7500, 03, 05 & 09 Basic Service Manual (6875964M01-C)

APPENDIX A. Sample Test Result Report

```
================================================================================
                                Test Result Report
================================================================================
Date/Time: 5/20/2021 7:28 AM                        Operator ID: A.Technician

Info
-------------------------------------------------
Analyzer
---------
Model #:              R8100
Serial #:             810LSJ0013
Ref Clock Mode:       Output
Application:          4.2
RF Level Offset:      Off
RF In/Out Offset:     0.0 dB
RF Gen Out Offset:    0.0 dB
Cable Sweep:          On
Selected File:        RF 72 SWEEP ORNG
100 MHz Attenuation:  -0.218 dB
1 GHz Attenuation:    -1.047 dB

Radio
------
Model #:              H91TGD9PW5AN
Serial #:             579CSF0683
IP Address:           192.168.128.1
Band(s):              VHF UHF1 UHF2 700-800MHz
Host SW:              R20.35.00
DSP SW:               R20.35.00
UCM SW:               R010902
Encrypt Algorithm(s): None
-------------------------------------------------

Tx PA Bias (Auto) Align
=======================
Result  Frequency     Old Softpot  New Softpot
------  ------------  -----------  -----------
Pass    155.0000 MHz  1728         1728

Reference Oscillator Align
==========================
Result  Frequency     Freq Error  Min Limit  Max Limit  Old Softpot  New Softpot
------  ------------  ----------  ---------  ---------  -----------  -----------
Pass    869.8875 MHz  8 Hz        -50 Hz     50 Hz      1076         1076

Tx Attenuator Limit Align
=========================
Result  Frequency     Power  Target  Old Softpot  New Softpot
------  ------------  -----  ------  -----------  -----------
Pass    173.9875 MHz  6.3 W  6.6 W   97           106
Pass    469.9875 MHz  5.7 W  5.7 W   87           93
Pass    470.0125 MHz  5.5 W  5.7 W   90           93
Pass    775.0125 MHz  3.1 W  3.0 W   83           86
Pass    869.8875 MHz  3.7 W  3.6 W   67           70

Tx Power Characterization Points Align
======================================
Result  Frequency     Power   Target  Old Softpot  New Softpot
------  ------------  ------  ------  -----------  -----------
Pass    136.0125 MHz  6.3 W   6.3 W   3008         2943
Pass    155.0125 MHz  6.3 W   6.3 W   3064         2987
Pass    173.9875 MHz  6.3 W   6.3 W   3098         3021
Pass    380.0125 MHz  5.3 W   5.3 W   3292         3268
Pass    425.0125 MHz  5.3 W   5.3 W   3302         3273
Pass    469.9875 MHz  5.3 W   5.3 W   3302         3266
Pass    470.0125 MHz  5.3 W   5.3 W   3294         3257
Pass    495.0125 MHz  5.3 W   5.3 W   3279         3242
Pass    519.9875 MHz  5.3 W   5.3 W   3291         3247
Pass    764.1250 MHz  2.61 W  2.65 W  2915         2872
Pass    785.0125 MHz  2.56 W  2.65 W  2923         2879
Pass    805.9875 MHz  2.61 W  2.65 W  2910         2877
Pass    806.0125 MHz  3.3 W   3.3 W   2988         2955
Pass    838.0125 MHz  3.3 W   3.3 W   2992         2970
Pass    869.8875 MHz  3.3 W   3.3 W   2955         2935

Tx Power Characterization Align
===============================
Result  Frequency     Low Power  High Power  Diff (>1.5W)
------  ------------  ---------  ----------  ------------
Pass    136.0125 MHz  2.07 W     6.28 W      4.21 W
Pass    155.0125 MHz  1.75 W     6.25 W      4.51 W
Pass    173.9875 MHz  1.80 W     6.27 W      4.47 W
Pass    380.0125 MHz  1.72 W     5.22 W      3.50 W
Pass    425.0125 MHz  1.71 W     5.24 W      3.52 W
Pass    469.9875 MHz  1.74 W     5.28 W      3.54 W
Pass    470.0125 MHz  1.73 W     5.32 W      3.59 W
Pass    495.0125 MHz  1.74 W     5.30 W      3.56 W
Pass    519.9875 MHz  1.73 W     5.31 W      3.59 W
Pass    764.1250 MHz  0.83 W     2.59 W      1.75 W
Pass    785.0125 MHz  0.82 W     2.54 W      1.72 W
Pass    805.9875 MHz  0.84 W     2.61 W      1.77 W
Pass    806.0125 MHz  1.05 W     3.25 W      2.20 W
Pass    838.0125 MHz  1.06 W     3.29 W      2.23 W
Pass    869.8875 MHz  1.06 W     3.28 W      2.22 W

Tx Power Out Test
=================
Result  Frequency     Power   Min Limit  Max Limit
------  ------------  ------  ---------  ---------
Pass    136.0125 MHz  6.3 W   6.0 W      6.6 W
Pass    155.0125 MHz  6.3 W   6.0 W      6.6 W
Pass    173.9875 MHz  6.3 W   6.0 W      6.6 W
Pass    380.0125 MHz  5.3 W   5.0 W      5.6 W
Pass    425.0125 MHz  5.3 W   5.0 W      5.6 W
```

Pass	469.9875 MHz	5.3 W	5.0 W	5.6 W
Pass	470.0125 MHz	5.2 W	5.0 W	5.6 W
Pass	495.0125 MHz	5.3 W	5.0 W	5.6 W
Pass	519.9875 MHz	5.3 W	5.0 W	5.6 W
Pass	764.1250 MHz	2.65 W	2.35 W	2.95 W
Pass	785.0125 MHz	2.65 W	2.35 W	2.95 W
Pass	805.9875 MHz	2.65 W	2.35 W	2.95 W
Pass	806.0125 MHz	3.3 W	3.0 W	3.6 W
Pass	838.0125 MHz	3.3 W	3.0 W	3.6 W
Pass	869.8875 MHz	3.3 W	3.0 W	3.6 W

Tx Deviation Balance Align

Result	Frequency	Low Tone	High Tone	Variance	Max Limit	Old Softpot	New Softpot
Pass	493.0000 MHz	3.051 kHz	3.052 kHz	0.0 %	+/-0.2 %	46663	46775
Pass	478.0000 MHz	3.051 kHz	3.053 kHz	0.1 %	+/-0.2 %	51448	51432
Pass	463.0000 MHz	3.056 kHz	3.059 kHz	0.1 %	+/-0.2 %	53667	53620
Pass	460.8990 MHz	3.050 kHz	3.055 kHz	0.2 %	+/-0.2 %	44549	44657
Pass	448.2875 MHz	3.050 kHz	3.052 kHz	0.1 %	+/-0.2 %	49873	49876
Pass	435.4300 MHz	3.046 kHz	3.045 kHz	-0.0 %	+/-0.2 %	53150	52954
Pass	422.5800 MHz	3.050 kHz	3.050 kHz	-0.0 %	+/-0.2 %	48782	48811
Pass	168.0360 MHz	3.048 kHz	3.042 kHz	-0.2 %	+/-0.2 %	48199	48161

Rx Front End Filter Align UHF1

Result	Frequency	Old Softpot	New Softpot
Pass	380.0000 MHz	43	43
Pass	390.0000 MHz	50	50
Pass	400.0000 MHz	57	59
Pass	410.0000 MHz	65	66
Pass	420.0000 MHz	72	73
Pass	430.0000 MHz	80	81
Pass	440.0000 MHz	88	87
Pass	450.0000 MHz	97	97
Pass	460.0000 MHz	105	105
Pass	470.0000 MHz	113	113

Rx Front End Filter Align UHF2

Result	Frequency	Old Softpot	New Softpot
Pass	480.0000 MHz	122	122
Pass	490.0000 MHz	130	131
Pass	500.0000 MHz	140	140
Pass	510.0000 MHz	148	149
Pass	520.0000 MHz	160	158

Rx Duty Cycle Adjustment Align

Result	Frequency	Low/High Amp Err	Low/High Phase Err	Old Softpot	New Softpot
Pass	503.0000 MHz	1.000793/0.997894	-0.008545/0.000763	1118/1054	1054/1070

Rx Distortion Test

Result	Frequency	Distortion	Max Limit
Pass	136.0750 MHz	0.9 %	3.0 %

Rx Analog Sensitivity (SINAD) Test

Result	Frequency	12dB SINAD	Max Limit
Pass	136.0750 MHz	-120.1 dBm	-116.0 dBm

Noise Squelch Threshold Test

Result	Frequency	Unsquelch	Max Limit
Pass	136.0750 MHz	-127.0 dBm	-116.0 dBm

Modulation Fidelity Test

Result	Frequency	Mod Fi	Max Limit
Pass	136.0250 MHz	0.3 %	5.0 %
Pass	154.2250 MHz	0.3 %	5.0 %
Pass	173.9750 MHz	0.8 %	5.0 %
Pass	380.0250 MHz	0.4 %	5.0 %
Pass	424.9250 MHz	0.4 %	5.0 %
Pass	469.9250 MHz	0.7 %	5.0 %
Pass	471.0250 MHz	0.8 %	5.0 %
Pass	495.0250 MHz	0.8 %	5.0 %
Pass	519.9750 MHz	0.8 %	5.0 %
Pass	764.0125 MHz	0.7 %	5.0 %
Pass	794.0125 MHz	0.8 %	5.0 %
Pass	823.9875 MHz	0.7 %	5.0 %
Pass	851.0125 MHz	0.8 %	5.0 %
Pass	869.8875 MHz	0.5 %	5.0 %

Symbol Deviation Test

Result	Frequency	Symbol Dev	Min Limit	Max Limit
Pass	136.0250 MHz	1793.9 Hz	1620 Hz	1980 Hz
Pass	154.2250 MHz	1791.4 Hz	1620 Hz	1980 Hz
Pass	173.9750 MHz	1795.8 Hz	1620 Hz	1980 Hz
Pass	380.0250 MHz	1793.1 Hz	1620 Hz	1980 Hz
Pass	424.9250 MHz	1794.7 Hz	1620 Hz	1980 Hz
Pass	469.9250 MHz	1792.3 Hz	1620 Hz	1980 Hz
Pass	471.0250 MHz	1791.0 Hz	1620 Hz	1980 Hz
Pass	495.0250 MHz	1795.0 Hz	1620 Hz	1980 Hz
Pass	519.9750 MHz	1792.5 Hz	1620 Hz	1980 Hz
Pass	764.0125 MHz	1792.2 Hz	1620 Hz	1980 Hz
Pass	794.0125 MHz	1790.7 Hz	1620 Hz	1980 Hz
Pass	823.9875 MHz	1793.5 Hz	1620 Hz	1980 Hz

```
Pass    851.0125 MHz  1791.2 Hz   1620 Hz    1980 Hz
Pass    869.8875 MHz  1793.5 Hz   1620 Hz    1980 Hz

P25 Phase II Modulation Fidelity Test
=====================================
Result  Frequency     Mod Fi  Max Limit
------  ------------  ------  ---------
Pass    136.0250 MHz  0.9 %   5.0 %
Pass    154.2250 MHz  0.8 %   5.0 %
Pass    173.9750 MHz  0.8 %   5.0 %
Pass    380.0250 MHz  0.7 %   5.0 %
Pass    424.9250 MHz  0.9 %   5.0 %
Pass    469.9250 MHz  0.7 %   5.0 %
Pass    471.0250 MHz  0.9 %   5.0 %
Pass    495.0250 MHz  0.8 %   5.0 %
Pass    519.9750 MHz  0.7 %   5.0 %
Pass    764.0125 MHz  0.9 %   5.0 %
Pass    794.0125 MHz  0.8 %   5.0 %
Pass    823.9875 MHz  0.9 %   5.0 %
Pass    851.0125 MHz  0.8 %   5.0 %
Pass    869.8875 MHz  1.0 %   5.0 %

P25 Phase II Symbol Deviation Test
==================================
Result  Frequency     Symbol Dev  Min Limit  Max Limit
------  ------------  ----------  ---------  ---------
Pass    136.0250 MHz  3019.8 Hz   2842 Hz    3141 Hz
Pass    154.2250 MHz  3015.0 Hz   2842 Hz    3141 Hz
Pass    173.9750 MHz  3023.8 Hz   2842 Hz    3141 Hz
Pass    380.0250 MHz  3021.9 Hz   2842 Hz    3141 Hz
Pass    424.9250 MHz  3020.5 Hz   2842 Hz    3141 Hz
Pass    469.9250 MHz  3019.5 Hz   2842 Hz    3141 Hz
Pass    471.0250 MHz  3019.2 Hz   2842 Hz    3141 Hz
Pass    495.0250 MHz  3022.6 Hz   2842 Hz    3141 Hz
Pass    519.9750 MHz  3017.1 Hz   2842 Hz    3141 Hz
Pass    764.0125 MHz  3015.2 Hz   2842 Hz    3141 Hz
Pass    794.0125 MHz  3016.8 Hz   2842 Hz    3141 Hz
Pass    823.9875 MHz  3019.2 Hz   2842 Hz    3141 Hz
Pass    851.0125 MHz  3009.1 Hz   2842 Hz    3141 Hz
Pass    869.8875 MHz  3020.8 Hz   2842 Hz    3141 Hz

Rx Digital Sensitivity (P25 BER) Test
=====================================
Result  Frequency     Bit Error Count  5% BER      Max Limit
------  ------------  ---------------  ----------  ----------
Pass    136.0750 MHz  184              -121.4 dBm  -116.0 dBm

Rx Sensitivity (P25 Phase II BER) Test
======================================
Result  Frequency     Bit Error Count  5% BER      Max Limit
------  ------------  ---------------  ----------  ----------
Pass    136.0750 MHz  572              -121.3 dBm  -116.0 dBm

Voice Modulation (internal) Test
================================
Result  Frequency     Deviation  Min Limit  Max Limit
------  ------------  ---------  ---------  ---------
Pass    136.0250 MHz  2.3 kHz    2.1 kHz    2.5 kHz

Voice Modulation (external) Test
================================
Result  Frequency     Deviation  Min Limit  Max Limit
------  ------------  ---------  ---------  ---------
Pass    136.0250 MHz  2.2 kHz    2.1 kHz    2.5 kHz

Tests performed by AutoTune © 2021 Freedom Communication Technologies, Inc.  All Rights Reserved.
```

Figure A-1. Sample Test Result Report

APPENDIX B. Revision History

Rev. No/change	Revised By	Date	Approved By	Date	ECO#
See ECO – Rev C	M/Mullins	9/8/2021	C. Cox	10/21/21	0384
1.18 Updates – Rev B	L. Shirey	1/26/15	M. Mullins	1/26/15	14473
Original Release – Rev A	B. Tanner	7/30/12	M. Mullins	7/30/12	12691