Section 4

Baseline Requirements and Performance Standards

4.1 Introduction

This section summarizes the operational, functional, and technical requirements that were developed in the previous sections of this report and includes a brief discussion of the development of each set of requirements. An approach to validate and prioritize Wyoming's improved PSMC requirements was developed by Federal Engineering and the Project Team as presented in Section 3.6.1. The final prioritization of these requirements was performed by the State's PSMC Steering Committee and Project Team as guided by ***FE***.

Specific measurable and testable performance standards are identified, both for the system as well as for the potential vendor. The sources of information for this section were derived from work with stakeholders as described in previous sections as well as information provided by ***FE*** research and experience with PSMC systems in other states. This section will include a discussion of the performance of the existing infrastructure and its current capabilities.

The requirements, specifications, and performance standards described in this section will be presented in a formally structured and traceable format in Appendix A. That appendix is a "living document" that will be adjusted periodically as the plan moves forward. That structure is fundamental to the alternatives development and evaluation process, and will be used during the procurement phase for development of system acceptance criteria.

4.1.1 Baseline Requirements Methodology

Federal Engineering has used many techniques over the last six months to develop a comprehensive list of system requirements for the envisioned Wyoming public safety mobile communications network. During this period, ***FE*** created a web-based survey tool to collect user agency information, reviewed past studies, interviewed user groups and individual agencies, and visited typical field installations. This process has been augmented along the way through internal peer reviews with ***FE*** staff, as well as with additional inputs and intermediate reviews from the WYDOT technical staff, Project Team, and the Steering Committee members.

Information gathered was extensively analyzed to determine the breadth of commonly expressed needs and requirements. ***FE*** believes that the final validation and prioritization efforts of the Steering Committee have provided the guidance needed to move forward. These requirements are discussed in detail in Section 4.2 of this report. They are expanded upon in Section 4.4.

4.1.2 Performance Standards Methodology

Performance standards were derived from ***FE'***s experience and cross-checked with manufacturers' literature for commonly available, state-of-the-art public safety radio equipment. Standards were chosen that will satisfy Wyoming's demand for a modern system with a robust set of features and functionality to meet today's and tomorrow's needs. Federal Engineering also addressed infrastructure support areas such as: controllers, switches, microwave backbone, maintenance, interfacing to existing systems, testing, coverage, quality, and performance as well as tower and shelter requirements. In addition, ***FE*** has selected applicable standards from the following trade organizations including:

- ANSI/TIA/EIA.
- Military.
- APCO.
- Bellcore.
- NEC (National Electrical Code).
- Other industry standards and practices.

Section 4.4 of this report goes into extensive detail regarding these standards and test approaches.

4.2 Prioritized Requirements

Information on potential requirements was throughly analyzed by ***FE***, the Project Team and Steering Committee members to determine which requirements are considered Basic (essential or mandatory, with the highest priority rankings), which are Optional or can be selected on an applications basis (middle priority rankings), and which are Expandable and can be delayed for future system enhancements (lowest priority rankings). The Steering Committee was well informed through data provided in previous sections as well as their own peer networking over the years.

Table 4.1 gives an indexed summary of requirements. Categories are defined in Section 1.1.3, definitions of category requirements are found in Section 3.7.1, and requirements are defined in Exhibit 3.2.

Table 4.1 - Prioritization of Baseline Requirements

	Basic (B)	Optional (O)	Expandable (E)
Technical (T)	TB-1 Adopt mixed analog/digital capability, if digital is recommended TB-2 Upgrade with only narrowband capable equipment TB-3 Adopt APCO Project 25 standards TB-4 Upgrade network local sites to state standards TB-5 Upgrade state microwave for reliability (closed loops) TB-6 Add generators to all network sites, where necessary TB-7 Upgrade sites with UPS capacity	TO-1 Upgrade towers, where necessary TO-2 Upgrade grounding, where necessary TO-3 Upgrade shelters, where necessary TO-4 Expand generator fuel capacity to 10 days TO-5 Upgrade all network sites for building alarms	TE-1 Add air conditioning, if necessary TE-2 Add/improve site security at remote sites
Functional (F)	FB-1 Add systemwide encryption capability FB-2 Add low-speed (less than 19.2 kbps) data capability	FO-1 Allow casual use capability (*i.e.*, activating sirens) FO-2 Allow paging capability FO-3 Add AVL (automatic vehicle location) capability FO-4 Add subscriber ID capability FO-5 Add high-speed (greater than 19.2 kbps) data capability in selected areas	FE-1 Add mobile video capability FE-2 Add mobile e-mail capability FE-3 Add mobile voice mail capability FE-4 Add mobile card swipe capability FE-5 Add mobile printing capability
Coverage (C)	CB-1 Upgrade statewide mobile coverage CB-2 Upgrade portable coverage in selected areas CB-3 Add statewide roaming capability	CO-1 Upgrade statewide portable coverage CO-2 Upgrade in-building coverage for selected locations	
Interoperability (I)	IB-1 Improve statewide interoperability IB-2 Improve local interagency interoperability IB-3 Improve inter-county/regional interoperability IB-4 Improve interoperability with all state agencies (including WHP) IB-5 Improve interoperability with Federal agencies	IO-1 Add/improve neighboring state interoperability with state networks IO-2 Add/improve neighboring state interoperability with local networks	IE-1 Improve interoperability with all state agencies (excluding WHP)
Operational (O)	OB-1 Add channel(s) for tactical, backup, or reserve needs OB-2 Improve/maximize channel efficiency OB-3 Replace obsolete equipment, only with system upgrades OB-4 Enhance network reliability - add multiple master control points	OO-1 Require panic/emergency button on subscriber units	OE-1 Replace obsolete equipment, short-term

4.3 Requirements Details and Additional Areas

A great deal of analysis and thought was put into the development of the prioritized requirements, and it represents the consensus of the various State, local and Federal stakeholders that will be affected by the development of a new system. However, there are many other factors that will need to be included in the development of the final functional, technical, and operational requirements for a new statewide PSMC system. Many of these are considered baseline requirements, in that they are clearly needed today. Others are characteristics that Wyoming should consider as the RFI is prepared, and some may require additional discussion regarding such areas as service levels and equipment quantities.

The following subparagraphs will cover details on the areas that ***FE*** has identified, through its experience working within the PSMC environment as well as from the experience of other states and municipalities in developing RFI's and RFP's, that should be considered in these requirements. These descriptions support the system specifications and required features found in Appendix A.

The new PSMC system will provide a multi-agency network accessible by authorized users throughout the state, providing appropriate mobile and portable coverage throughout the state, while still providing for the required level of individual agency autonomy in the implementation, operation, and administration.

<u>4.3.1 Technical Requirements</u> - the specific technical capabilities typically relating to maturity of electronics, standards, spectrum and installation practices.

4.3.1.1 Integrated Voice and Data is desirable in order to minimize the proliferation of radios and antennas.
4.3.1.2 Fault-tolerant architecture.
4.3.1.3 Spectrum efficiency ultimately equivalent to 12.5 kHz per voice channel.

<u>4.3.2 Functional Requirements</u> - the capabilities available to the users.

4.3.2.1 Over-the-air programming (OTAP) of changes to subscriber unit characteristics, new features and software upgrades.
4.3.2.2 Secure encrypted communications where needed with over the air re-keying (OTAR) capability, supporting U.S. encryption standards.
4.3.2.3 Uninterrupted roaming throughout the system
4.3.2.4 Direct radio-to-radio operation.
4.3.2.5 Expandability to increase capacity and coverage.

4.3.2.6 Mobile data communications capability, access to database and network functions, automatic vehicle location (AVL) capable.

4.3.2.7 Paging would be designed to meet public safety dispatching requirements, considering:

- Capable of individual paging as well as group notifications.
- System shall be capable of supporting multiple levels of priority.
- Reliability - 99.99% available per year for the entire paging network.
- Network Management Monitor and Control for paging system resources and status.
- Text, voice, tone, and two-way text messaging capabilities.

<u>4.3.3 Coverage Requirements</u> - the geographic area in which signals are adequate to permit users to communicate with the network, considering:

- 95% mobile coverage in the served areas across the state.
- 90% portable coverage in the designated areas

<u>4.3.4 Interoperability Requirements</u> - the ability of different organizations to communicate with one another when necessary.

4.3.4.1 Full functionality between all participating agencies according to their level of authorization, type of equipment and equipment configuration.

4.3.4.2 Incorporation of current and future national mutual-aid channels in appropriate bands.

4.3.4.3 Interface with legacy systems during transition period.

<u>4.3.5 Operational Requirements -</u> how agencies operate and use their communications systems.

Nothing additional is needed to support Appendix A in this category.

4.4 Performance Standards

The purpose of this section is to present an analysis of the performance standards that are common in statewide public safety mobile radio systems and supportable by today's industry. Both vendors and government agencies were contacted to determine the approaches currently in use. Performance standards were analyzed for the following areas:

- Technologies and elements such as mobile radios, portable radios, base stations, controllers, repeaters, switches and backbone equipment.
- Support processes and design phases such as general system maintenance, defining specific interfaces to existing systems, day-to-day testing, scheduling, adding new users, and fleet maps.
- Overall system parameters such as system availability, radio coverage percentage, and circuit merit.

This analysis also outlined the optimal range of criteria for each performance standard, and explained how the measurements would be gathered. The standards are testable with the appropriate testing methodology identified. Results are provided in both narrative as well as tabular summary formats for each area.

4.4.1 Technology-based Performance Standards

Technologies and elements such as mobile radios, portable radios, base stations, repeaters, controllers, and backbone equipment have performance standards based upon industry-standard manufacturer's specifications for currently available and soon to be FCC required equipment. Exhibits 4.2 -Typical Portable Radio Performance Standards, 4.3 - Typical Mobile Radio Performance Standards, and 4.4 - General Performance Specifications provide detailed specifications that apply to the proposed PSMC environment. Exhibit 4.5 - List of Applicable Standards and Regulations, includes additional information regarding these standards.

4.4.1.1 Radio Equipment

Mobile, portable, base station, and repeater radio equipment all have the following performance standards as typically specified by public safety equipment manufacturers, including frequency accuracy/stability, deviation, and power output. Examples of these standards can be seen in Exhibits 4.2, 4.3, and 4.4.

4.4.1.2 Controllers

The controllers and audio switches of a system are essentially computers - therefore the performance standards are much different than the RF equipment previously discussed. The most important performance parameter of controller devices is their fault tolerance and therefore their redundancy. If the controller of a quantity of sites suffers a failure and is redundant, the radio system can continue processing calls and the user community is unaffected. If this controller has proper alarming the maintenance staff can be notified of the failure, effect repairs in a timely manner, and restore the controller's redundant operation. A similar situation is true of the audio switches. If there is built in redundancy, a single failure will not impact radio system operation. If this failure is properly alarmed, it can be repaired in a timely manner and redundancy can be restored.

4.4.1.3 Long Haul Communications Equipment

The microwave system will have performance standards such as frequency accuracy/stability, modulation, and power output. In addition, since the backbone system is transporting large quantities of site information it should have fault tolerant redundancy built in. Typically, a digital microwave system will have what is referred to as N + 1 redundancy on the low-speed or DS1 side. This means there is 1 redundant component backing up several or "N" other components on the input side of the system. In this scheme, if a digital multiplexer has seven DS1 cards there will be an eighth DS1 card that can automatically be switched online if a fault were to occur. This same multiplexer will have one for one redundancy on the high-speed or DS3 side. The high-speed multiplex card should have a complete redundant twin so that a single failure of this card will automatically allow the traffic to be switched over and not be lost.

4.4.1.4 Interfaces To Existing Equipment

Interfaces to existing equipment can typically be accomplished through a conventional base interface module. These modules take audio baseband and keying information from the existing equipment and interface it to the new radio system. This interface for a digital system converts the analog baseband signal into a digital format so that it can be transmitted over the digital system.

4.4.2 Support Processes and Design

4.4.2.1 System Maintenance

MTTR (Mean-Time-To-Repair) times for the actual equipment can be quite short but due to travel time to a remote site the total repair time may actually be quite lengthy. For instance, while the actual on-site MTTR of a base station/repeater is only two minutes (due to its modular design), a lengthy outage caused by the need for a service person to drive to a remote tower site will cause the system users to suffer.

Therefore, performance standards for system maintenance are typically based upon response time and restoration time. Response time is defined as the time duration from the communication system failure to the time a repair technician arrives on site or at a location where the restoration can be affected. Repair time is defined as the time to repair the communication failure once the repair technician has arrived on site or at a location where the restoration can be affected. Typical response time requirements are in the two hour range for major subsystems, primarily during normal business hours and often excluding sites with remote geographies. This is due to the diverse and vast distances a technician may have to traverse to get to a communication site. Typical repair time can be in the four hour range for major subsystems but are often only achievable with a comprehensive set of spare parts available to each location. In most cases, failures at locations other than major metropolitan areas are handled on a “best-effort” basis; repair efforts are greatly helped by the typical dedication of the maintenance staff and the ability for users to be trained to replace components with spares.

Response and repair time requirements can be shorter but typically the price for such accelerated arrangements is cost prohibitive. It may be possible to entice the vendor to shorten the majority of response or repair time by offering "rebates" for quick restoration times that can be used to offset lengthy restoration times. This may have the effect of encouraging the vendor to respond/repair quickly in hopes of offsetting the really difficult system problems that are unavoidable. Response and repair times can be greatly reduced with the use of automated alarm equipment, remote diagnostics and redundant system design. Typical performance standards or requirements for automated monitoring systems involve alarming of base station transmit power, antenna reflected power, channel bank failure, base station failure, receive illegal carrier, controller link failure and DIU (digital interface unit) failure.

4.4.2.2 Testing and Measurement

Standards for day-to-day operational system testing are typically set such that non-intrusive testing can be done at anytime deemed appropriate by the vendor or the purchaser and intrusive testing must be scheduled at times when it will have the least detrimental effect. Data on actual performance (including throughput, availability, and fault modes) is desired for improvement and eventual replacement of the new system.

4.4.2.3 Scheduling

Scheduling standards involve the requirement for scheduling “known outages” for the communication system. There is never a good time to take a public safety mobile communications system off the air. However, with proper scheduling the known outages for maintenance or upgrades can be much less intrusive. While there may be no set standard for this item, industry best practice would dictate that the outage be scheduled at the system’s lowest peak time. This may require outages to be scheduled at very odd hours, (*i.e.*, 3:00 *a.m.*). A thorough understanding of traffic patterns is essential in making these decisions. If the system has adequate traffic management, the least peak time can be determined which will allow for proper scheduling.

4.4.2.4 Adding New Users and Changing Databases

Standards can be set for adding new users. Two items which should be considered are:

- Which individuals have the authority to effect changes.
- The password security to make such changes.

Typically there should be only a select few individuals that have the authority to add a new user. For very large systems, it is typical to designate a few “trusted” personnel at each member agency with this authority.

4.4.3 Overall System Parameters

4.4.3.1 System Availability

System availability is the percentage of time that the services of the communications system are useable by operators, within the specified area. The major components of this system are the RF system and the long haul communication equipment. The RF system is comprised of the base stations, repeaters, controllers and audio switches. Wyoming’s long haul communication equipment is comprised of a digital microwave system and some leased lines. Often overlooked factors in overall availability are the communication site environmental systems such as HVAC systems, backup power, and the site’s structural integrity.

4.4.3.1.1 RF System Availability

This performance measure is an indication of the ability of the public safety radio system to process the call initiated by a responder. If any portion of the radio system has a failure, it may cause the call to not be processed properly. Depending on failure modes and fault tolerance, the call may go through properly even though the system has experienced a failure.

A common goal used in system availability is 99.999% or "Five 9's" for subsystems. This means that 99.999% of the time the specific subsystem will be available and able to process a radio call.

System availability can be adversely affected by a number of failures. To calculate availability, the major subsystems of the radio system are broken out and assessed separately. A typical trunked system may have a master controller, an audio switch, the trunking system, remote sites, base stations and various interfaces. If the six individual subsystems each have an availability of 99.999%, the total system availability would then be 99.994%. This is true since the individual subsystem availabilities are combined to create the overall system reliability. Therefore, a more realistic performance standard for overall system availability would be 99.5% or greater when calculated from the availabilities of component subsystems.

System availability can be calculated on a weekly basis and applied over calendar quarterly periods. Each subsystem identified in the preceding paragraph should be required to have an uptime greater than 99.8% when calculated on a weekly basis and applied over each calendar quarterly period for each individual subsystem, with the exception of the master controller, which must have an uptime greater than 99.999%. The system controller must have sufficient internal or external redundancy to maintain the required higher level of uptime.

4.4.3.1.2 Long Haul Communications Equipment Reliability

Another factor in availability and system operation is the reliability of long haul communication equipment. Microwave radio is most often the "backbone" system used to transport the signals between tower sites to the trunking controller and to the main switching point where an audio switch and the master controller are located. The reliability of digital microwave communications systems is typically designed to be 99.999%

4.4.3.1.3 Communications Site Environmental Systems

Communications site environmental systems such as HVAC or site structural integrity can have a detrimental affect on system availability if not properly designed and maintained. If the temperature of a communication site exceeds the operating parameters of the equipment, the system can fail and often in very odd ways (*i.e.*, multiple low-level failures combined to cause a communication outage). The same can be said of structural integrity. Proper maintenance and alarming can greatly reduce such calamities. The most common performance standard would be to require alarm contact closures (or actual measured readings) for such things as high and low temperature, humidity, smoke/fire, and intrusion detection.

4.4.3.2 Radio Coverage Percentage

4.4.3.2.1 Mobile and Portable Radio Coverage

Mobile and portable coverage performance is measured by a percentage of area that is predicted to have enough RF energy to allow a radio call to be processed properly. While it is unrealistic to expect coverage to be 100%, it can also be prohibitively expensive to achieve coverage in excess of 98%. Typically the standard that is used for public safety is between 95% and 98%. In addition to this standard, caveats may be added including: “outside with portable antenna at head level” or “in-building coverage” for portables. These additions may be required for clarification, to bound performance, and to ensure users get the system they require.

4.4.3.2.2 Other Coverage

Other coverage standards exist for aircraft and marine vessels, although there are limited applications for this in Wyoming. Aircraft coverage can be easily achieved as airborne aircraft act as very tall towers and usually have a clear line of site to terrestrial towers (assuming an omni-directional pattern). Generally aircraft do not suffer the same degradation to signal strength that ground based mobiles experience. The winding rivers and mountainous terrain surrounding many of Wyoming's bodies of water may make coverage for any vessels as difficult as for land-based units.

4.4.3.3 Voice Quality - Delivered Audio Quality (DAQ)

Measurement of voice quality performance tends to be highly technical in nature and can be accomplished following two steps:

1. Evaluation of a statistically large sample of recorded voice transmissions with concurrent measurements of the local mean of received signal power to determine a consistent and practical quantitative relationship between the local mean power and the circuit merit of the recovered voice.

2. Measurement of the local mean received signal power in a statistically large sample of uniformly-sized geographic areas to determine the probability of achieving a specific local mean signal level within that geographic area, or to determine the location of constant-probability contours that bound those areas.

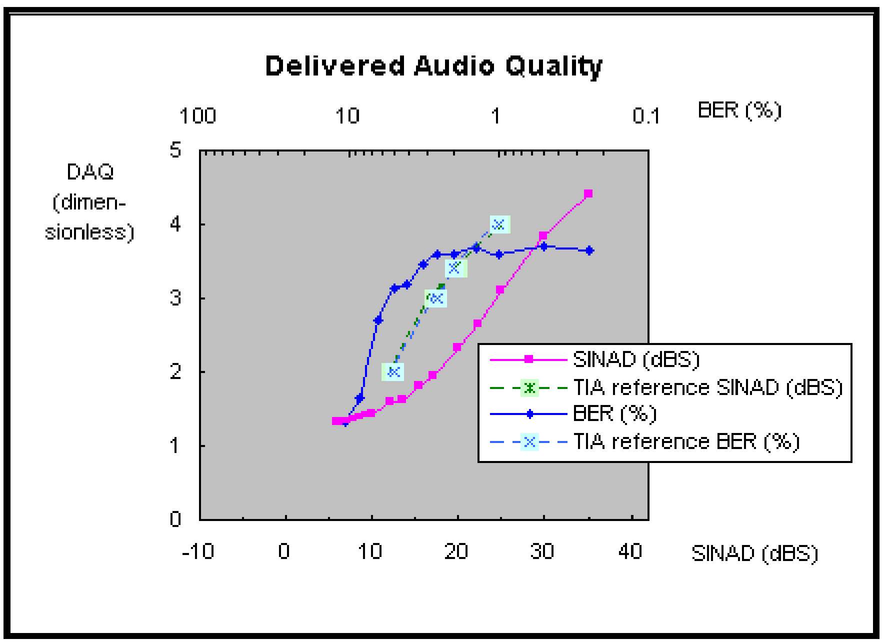
Provided that the radio receivers used in each of the above steps are of the same technology and whose performance specifications are known and calibrated, this method can yield practical and reliable predictions of the expected voice quality. This method presumes that subscriber radios will also be of the same technology and of known specifications as those used for the analysis. In practice, all testing and analysis should be done by the system operator, with test equipment and calibration services provided by the equipment manufacturer.

DAQ is a numeric rating of speech intelligibility. Listening panels (groups of individuals convened to subjectively assess perceived speech quality) score the perceived intelligibility of speech samples using the rating scale below:

DAQ 1 Unusable. Speech present but not understandable.
DAQ 2 Speech understandable with considerable effort. Requires frequent repetition due to noise/distortion.
DAQ 3 Speech understandable with slight effort. Requires occasional repetition due to noise/distortion.
DAQ 3.4 Speech understandable without repetition. Some noise/distortion present.
DAQ 4 Speech easily understood. Occasional noise/distortion present.
DAQ 5 Perfect.

An example of signal and voice quality measurements is presented in the following chart, Exhibit 4.1:

Exhibit 4.1 - Signal and Voice Quality Measurements



4.5 Acceptance Test Procedures

A comprehensive acceptance test procedure should be included in the equipment vendor's contract to ensure compliance with the RFP and industry practices. This section provides the means to verify all requirements for the PSMC network. This section identifies the specifics of what tests are to be performed, test setup, who performs the tests, the parameters to be tested, where the tests will be conducted, the data to be recorded, and when the tests will be conducted. Because coverage testing is a major component of this process, subsections describing it should be in greater detail than other subsections.

If the PSMC network is built out by region, acceptance will be on a per-region basis, with interoperability between multiple regions tested as the network is built out, and final acceptance when the overall statewide network is completed. The testing requirements include but are not limited to the following:

- Factory Integration (Staging) Test and Pre-Ship Acceptance.
- Shelter and Site Testing/Inspection
- Field Functionality Testing.
- Failure Mode Testing.
- Physical Configuration Audit.
- Coverage Testing.
- Interoperability Testing and Measures.
- Operational Testing by Users.
- Regional/Statewide Acceptance.

4.5.1. General Acceptance Test Principles:

The guiding principles of the acceptance testing process should include:

1. The State shall reserve the right to have a representative present for all testing, re-testing, or inspections.
2. The State should reserve the right to independently perform any test as specified.
3. All test/inspection results shall be documented and submitted to the State in hardcopy (paper) and softcopy (permanent CD-ROM) unless otherwise mutually agreed, in writing, in advance.
4. Any test/inspection that fails shall be documented on a master list of all test/inspection results plus on a separate list for failures only.
5. All tests shall be conducted utilizing certified calibrated test equipment each of which is traceable to the National Institute of Standards and Technology (NIST) and has not exceeded its calibration expiration date.

6. All tests shall be conducted utilizing equipment representative of off-the-shelf equipment that will be deployed throughout the network.
7. The vendor shall be held accountable to correct any test/inspection failure, and repeat the test/inspection that failed to verify compliance.

4.5.2 Factory Integration (Staging) Test and Pre-Ship Acceptance

This testing provides the ability to ensure that the equipment meets the minimum required level of specifications. The vendor must provide factory integration (staging) tests and pre-ship acceptance on all equipment (radio, network backbone, etc.) that will be being provided to create in a fully functional system.

Testing will cover the full hardware and software functionality of all equipment. Testing shall be done using the equipment (hardware and software) integrated, as it will be implemented in the field. Testing shall be conducted under both AC power and battery back-up power conditions, if appropriate. Acceptance for shipment to the sites shall be granted only after the State has received all test results and has verified that the equipment has passed all specified tests.

4.5.3 Shelter and Site Testing/Inspection

The current plan is that the State will retain responsibility for the site shelters. For new sites, the State should consider the following shelter tests/inspections:

1. Architectural and engineering drawings.
2. Compliance certificates.
3. Structural.
4. Electrical.
5. Grounding/Lightning.
6. Emergency Power.
7. Security.
8. HVAC.
9. Appearance and finish.
10. Lighting.
11. Equipment Racks and Cable Tray.
12. Materials.
13. Workmanship.
14. Fire-Suppression System.

History has shown that grounding is of great importance to system reliability and performance. A thorough grounding inspection should be done in accordance with Grounding Standard MIL-HDBK-419A and the National Electric Code. Specifically all metal conduits, trays, racks, cabinets, antennas, transmission lines, electrical service entrance conductors, telephone lines and any metallic conductors shall be properly bonded. Each row of equipment shall have a separate ground bus consisting of an AWG #2 or larger. Each bus shall be connected to the single point ground. Each cabinet or rack shall have a ground conductor bonding all components to the single ground near the equipment installation. Towers must be bonded to the external ground system using exothermic welds. All external grounds that compose this external ground system must be connected using exothermic welds. The external ground systems shall be tested for soil impedance in accordance with MIL-HDBK-419A and shall provide a ground resistance less than 10 ohms. Transmission lines shall be grounded with the manufacturer's specified proper size ground kits connected to the tower and entry port bus.

4.5.4 Field Functionality Testing

The Vendor shall conduct testing on a regional basis to verify the functionality of all equipment and systems deployed in the field. Major elements of the system include, but are not limited to, the following:

1. Telecommunications Backbone Network Tests (including any leased circuit services).
2. Land-Mobile Radio (LMR) System Tests (portable, mobile, control station).
3. Network Operational Control Tests.

4.5.4.1 Backbone Tests

The State should include the following tests for any new digital backbone microwave sites that are added to the system:

1. System Bit Error Rate (BER).
2. Transmitter Power Output and Reflected Power, or VSWR.
3. Hot-standby Transmitter Switching.
4. Space-Diversity Differential Absolute Delay Equalization.
5. Waveguide Pressurization.
6. Waveguide Return Loss.
7. Redundant Receiver Switching.
8. Network Management and Reporting System.
9. Protection Loop Switching.
10. Radio Local-Oscillator Frequency.
11. Unfaded Receive Signal Level.
12. Bit Error Performance.
13. Standby Power Generator.
14. Battery/UPS Power Supply.

4.5.4.2 LMR Testing

All functional aspects of the PSMC system would normally be tested. LMR tests would include the following:

1. Transmitter Power.
2. Transmitter Frequency.
3. Transmitter Modulation.
4. Voltage Standing-Wave Ratio (VSWR) for fixed and mobile stations.
5. Receiver Sensitivity.
6. Combiner Loss.
7. Multicoupler Loss.
8. System Failure Modes.
9. Grade of Service.

4.5.4.3 Radio System Feature Testing

Radio system feature sets should be tested to ensure the following typical call types can be properly completed (typical for trunked systems):

1. System All Call.
2. Group Call.
3. Emergency Group Call.
4. Private or Individual Call.

4.5.4.4 Tone Testing

The following typical trunking tones should be tested to ensure proper operation:

1. Transmit Grant Tone.
2. Out-of-Range Tone.
3. Group Scan.
4. Transmit Busy Lockout.
5. Call Busy or Queue Alert.
6. Emergency Declaration.
7. Clear.

4.5.4.5 Trunking System Features

The following typical trunking system features (if a trunk system is procured and these features specified) should be tested to ensure proper operation:

1. Continuous Control Channel Update.
2. Transmission/Message Trunking.
3. Call Queuing.
4. Call Priority.
5. Emergency Call Priority.

6. Call Validation.
7. Confirmed Call.
8. Unconfirmed Call.
9. Multi-site Routing.
10. Power Interruption.
11. Power Backup/UPS Verification.
12. Simulcast Alarm System.
13. Digital Voter Functional Tests.
14. Analog Voter Functional.
15. Telephone Interconnect Calls - Radio Originated.
16. Telephone Interconnect Calls - Telephone Originated.

4.5.4.6 Dispatch Features

Dispatch features should be tested to ensure the consoles can perform the following (as required - dependent upon existing console features):

1. Transmitting with Microphone or Headset.
2. Group Call.
3. Private or Individual Call.
4. Alert Tones.
5. Receiving Calls.
6. Call History.
7. Emergency Call.
8. Agency Broadcast.
9. Patch.
10. Simul-select.
11. Console Pre-Empt.
12. Console Intercom.
13. Console Crossmute.
14. Supervisor Console takeover.
15. Priority Override (Pre-empt).
16. Conventional Interface.
17. Cross Patching.
18. Telephone Interconnect answering and patching a Call.
19. Logging Recorder.

All functional aspects of the Network Operation Center (NOC) control system would be tested. Success criteria for the NOC system would be based on manufacturer specifications, engineering parameters, and State requirements. Where these specifications differ, the most stringent specification parameter, as determined by the State, would apply. Specific NOC tests would be identified by the State, appropriate to the proposed PSMC technology solution. Acceptance of the NOC shall be granted when all tests have been passed.

4.5.5 Failure Mode Testing

The backbone network (e.g. microwave system, leased lines, etc.) and the Land Mobile Radio system, collectively the infrastructure, are required to survive various degrees of failure of system components (including, but not limited to: power failure, microwave failure, base station/repeater failure, system switch failure, tower top preamp failure). The Vendor would document in its proposal all of the failure recovery modes inherent in the proposed infrastructure. During the initial regional build out, the vendor would simulate each of these failure modes and demonstrate successful failure recovery. As a further part of failure mode testing, automatic alarm reporting would be demonstrated, and telephone numbers for reporting equipment failure and service problem escalation procedures would be tested.

4.5.5.1 System Failure Priority Level Determination

Due to the complex nature of these systems, a certain degree of errors and failures are inevitable during acceptance testing. The following is a list of Priority Levels for such failures during acceptance testing:

1. Priority Level 1 failures are major system failures that render the system completely unusable or inoperable. Even one of these are unacceptable and require an explanation and a complete restart of the test period.
2. Priority Level 2 failures are major and minor system failures that significantly reduce system operability and usability. Even one of these are unacceptable and require an explanation and a complete restart of the test period.
3. Priority Level 3 failures are minor system failures that minimally reduce system operability or usability. These are undesired but acceptable and require an explanation. A complete restart of the test period is not required.
4. Priority Level 4 failures are minor system failures and punch-list items that have little effect on system operability and usability. These are undesired but acceptable and require an explanation. A complete restart of the test period is not required.

4.5.5.2 Failure Mode Definition

The following is a list of Priority Level 1 and 2 Acceptance Testing Failure Modes:

1. Loss of system.
2. Radio Frequency mobile coverage reliability < 95% throughout service area.
3. Loss of more than one radio site.
4. Loss of more than 10% of the total traffic capacity (channel failure).
5. Failure of a console position (if provided with system).
6. Failure of the alarm monitoring system.
7. Failure of any other critical component.

4.5.6 Physical Configuration Audit

A visual inspection, or physical configuration audit, should be done at the installation site to ensure tidiness and workmanship consistent with best current practices.

4.5.6.1 Physical Configuration Audit Documentation Requirements

The vendor would perform a physical configuration audit at each equipment location to verify that the installed system is accurately documented, thereby creating the network management and configuration control database. Some of this audit may be done in conjunction with the State if a new site or shelter is provided. This audit would be conducted at each location immediately after concluding testing of each service area, and would include:

1. Verification that the PSMC radio equipment is set to the frequencies identified in the system master frequency plan and as listed on the station license, a copy of which shall be posted at each site.
2. Verification that PSMC radio directional antennas are mounted at the elevations specified on the respective station license and oriented to the correct azimuth and polarization identified in the system master frequency plan and the station license.
3. Verify that all site drawings correspond accurately to all installed equipment fixtures, racks, and cabinets.
4. Verify site signal-flow wiring accurately corresponds to the cable running lists. Inventory major material items comprising each tower site.
5. Document uncorrected discrepancies remaining at the site.

4.5.6.2 Physical Configuration Audit Inventory Requirements

At each site the vendor would perform and document an inventory of the type, serial number, quantity, and latest revision number of all contractual deliverable documentation.

1. A combined inventory list would be provided to the State, along with a complete set of documentation – which would be included in the inventory list.
2. Discrepancies between installed items, equipment configurations, and quantity, type, and accuracy of documents would be documented and reported to the State.

4.5.7 Coverage Testing

Coverage test plans will be used to verify that the required coverage reliability and channel performance are provided by the network for voice and data communications throughout the service areas within the State. Coverage testing will generally be performed on a service area basis.

Separate sections of the test plan are dedicated to verifying data-transfer capability and voice communications. The voice communications section describes the types of service areas to be tested, the testing methodologies, the coverage reliability requirements, and the desired channel performance. The section for data transfer adds the data-transfer performance requirements. The testing methodology used would optimally be based on the Telecommunications Industry Association (TIA) Telecommunications Systems Bulletin TSB88-A, titled "Wireless Communications Systems, Performance in Noise- and Interference-Limited Situations, Recommended Methods for Technology-Independent Modeling, Simulation, and Verification."

4.5.7.1 Responsibilities

The primary burden of resources is placed on the vendor for this testing:

1. The vendor would prepare all drive-route planning and/or test-location planning, subject to approval of the State.
2. The vendor would also provide all test equipment to the State that is necessary to conduct its independent tests. This equipment would be identical to the equipment utilized by the vendor.
3. The vendor would provide test vehicle(s) and driver(s), and all equipment necessary to conduct the tests and record the data. The vendor would also provide a representative to conduct the tests.
4. At least two State representatives should be present during testing.

5. If, for any reason(s), test measurements are deemed unusable or inaccurate by the State, the test would be performed as many times as necessary to compile accurate and acceptable data.

4.5.7.2 Coverage Test Plans

The coverage test plans will be used to verify that specified required coverage reliability and channel performance are provided by the radio system throughout the service areas within the State for mobile communications. Within the State network, there will be a limited number (3-4) of classifications of service areas. An example of this would be

- Broad Service Area.
- Regional Service Area.
- Specific Geographical Area.

The following is a high level description of each type of service area:

- A *Broad Service Area* is any area that has a sufficient number of test 'tiles' that are uniformly distributed and that can be accessed by roads for coverage verification. A *Broad Service Area* may also contain *Regional Service Areas*, as well as portable in-building coverage area requirements.
- A *Regional Service Area* is any area that has a small proportion of roads in relation to the geographical area contained within the service area. These areas may or may not have sufficient road coverage to ensure that the required number of uniformly distributed test tiles can be accessed utilizing a conventional four-wheeled vehicle (automobile, truck, sport utility vehicle). A *Regional Service Area* may also contain *Specific Service Areas*, as well as portable in-building coverage area requirements.
- A *Specific Service Area* is any area deemed to require coverage, but may require special access methods to test. The *Specific Service Areas* will be based on a geographical area that can vary greatly in size. The area can be as small as a specific address, or may encompass a larger area such as a city or town. The *Specific Service Areas* will be tested separate from the test tiles used to validate *Broad* or *Regional Service Area* coverage.

4.5.7.3 Coverage Testing Modes

There would normally be at least two modes of coverage testing. The mode of testing to be employed would be determined by the State. Suggested modes of testing are:

- Service Area - this would determine the coverage in the service areas that are of most importance to measure. Since it is not possible to measure coverage in every square foot of the state, the most important (and some random) service areas should be chosen to validate the predicted coverage.

- Interference - in selected areas , especially where there is suspicion of interference from other transmission origins, testing should be done to insure that any interference does not degrade the quality of the communications below the desired level.

4.5.7.3.1 Bit-Error-Rate Testing

For digital services, a Bit-Error-Rate (BER) test would be performed on both the talk-out (outbound) path and the talk-in (inbound) path. The talk-out path is the network to a mobile or portable and the talk-in is the mobile or portable to the network. Talk-in testing may be evaluated using the talk-out test with a differential applied that corresponds to the difference in link budget between these links. However, irrespective of the test/analysis method, satisfactory in-service two-way performance is required.

The test equipment will measure BER while traveling in a drive-test vehicle representative of an actual vehicle used by PSMC users or by an alternative vehicle and/or method approved by the State, for all coverage verification

The test vehicle would be equipped with a mobile antenna system representative of that which will be used by PSMC network users, and be mounted in the same location as a user vehicle antenna would be mounted. Gains/losses associated with the mobile antenna and cabling must be known, and the recorded data adjusted accordingly.

Equipment used for testing would be representative of equipment that will be used by PSMC users. All equipment must perform within its specifications. At minimum, the data collected would consist of received signal strength (RSS), BER results, GPS position data (latitude & longitude) augmented by dead reckoning, date, and time stamp for all measurements. All data collected would be made available to the State for review and analysis. In addition to the BER test to validate coverage, speech samples shall be recorded and should be able to be referenced with BER measurements taken simultaneously.

4.5.7.3.2 Testing in Less-than-Full-Foliated Conditions

Full-foliated conditions are considered to occur from June 1 to October 1 inclusive. If testing is done under less-than-full-foliated conditions, coverage acceptance would only be conditional. Retesting of the service area using the initial drive route would normally be repeated to verify compliance during full-foliated conditions. Final acceptance would be granted if no coverage-related problems occurred during the full-foliated conditions.

4.5.7.3.3 Re-testing Methodology

If a service area failed to meet the channel performance requirement, the vendor would be expected to correct the coverage problem, after which re-testing of the entire service area would be required, using the same drive route and/or test locations. This process would continue until the service area had no failing adjacent tiles and meets the criterion for passing.

4.5.7.3.4 Portable Service Area Testing

Certain areas of the State where portable subscriber unit operation is critical would require that drive test thresholds be adjusted for higher signal levels to allow for the additional path losses due to “portable on-hip” operation, antenna gain, and transmit power. Portable operation would be spot checked along the drive route. In-building testing may also be required and will depend on the actual coverage area.

4.5.7.3.5 Data Coverage Test Plan

This plan would be determined based on the technology proposed. A similar process for testing the Voice coverage would be followed.

4.5.8 Interoperability Testing and Measures

By way of review, interoperability can most easily be achieved by using a common radio system from a single manufacturer. While this sounds easy to achieve it may be impractical given public safety budgets, sunken investments, and systems already in use. In an attempt to allow multiple vendor equipment to interoperate, a tremendous amount of work was done by APCO to develop a Common Air Interface standard and other interoperability standards. Equipment that meets P25 standards provides a limited level of interoperability between different vendors. This is no small feat in today's vendor proprietary, feature rich environment.

However, one must realize that P25 does not ensure interoperability due to the fact that different manufactures have selectively incorporated different portions of P25. In addition, P25 does not currently deal with trunking protocols which are proprietary to each manufacturer The net impact is that compatibility is assured by P25 for only the most basic of functions and may be lost when using today’s advanced systems features. P25 is an evolving standard and P25 Phase 2 is expected to deal with trunking protocol issues. When it is finalized and adopted, an additional level of interoperability will be achieved.

The following inter-site testing with other network sites would be performed after satisfactory completion of performance and coverage testing of each individual site:

4.5.8.1 Subscriber Static Functionality

Using a subscriber unit operating stationary at the new site, perform tests of all of the unit's voice and data services will be conducted with another subscriber in a random sampling of the other sites. Voice quality, Bit Error Rate and latency from one unit to the other would be included in the testing.

4.5.8.2 Mobility Management

While communicating in the new site's area, the tester would travel into the adjacent site's coverage area and note that the communication continued without interruption as the service area changed from the new site's area to the adjacent site's area. It may be desirable to perform this test in an area where the radio signal coverage transition to an adjacent region is more abrupt.

4.5.8.3 Inter-Working with Legacy Systems

Test the predefined functionality to be provided through interfaces with the state user units and consoles. This would also include tests of inter-regional communication with other systems through the appropriate gateway interface.

4.5.9 Operational Testing by Users

User agency personnel would perform functionality tests using portable radio units, consoles and vehicles with installed subscriber units and data terminal devices.

4.5.10 Regional/Statewide Acceptance

A plan to review the overall performance of the system in regional areas (preferably aligned with the geography and presence of major user groups) and at the statewide level should be outlined, with signoffs by appropriate representatives of the Regional groups and by the overall Project Coordinator at the statewide level.

4.6 Conclusions

The requirements, specifications, and standards called out above will be incorporated in a structured Request For Information (RFI) during Phase II of this program. The RFI process will poll the industry as to the current state of technology and the "real-world" economics involved in implementing the envisioned systems. By the end of Phase II, the System Specifications and Desired Features will be refined and eventually reconstituted in preparation for a Request For Proposal (RFP) to procure the required systems.

Exhibit 4.2 - Typical Portable Radio Performance Standards

Transmitter

Channel Spacing: 12.5 kHz
Maximum Frequency Separation:
Full Bandsplit
Frequency Stability*
(–30˚C to +60˚C; +25˚C Ref.):
±0.00015%
Modulation Limiting*:
12.5 kHz channels ±2.5 kHz
Emissions*
(Conducted & Radiated) –75 dBc
Audio Response*
(6 dB/Octave Pre-emphasis
from 300 to 3000 Hz) +1, –3 dB
FM Hum & Noise Radio*
12.5 kHz –40 dB
Audio Distortion* 1.5%

Receiver

Channel Spacing: 12.5/kHz
Maximum Frequency Separation:
Full Bandsplit
Audio Output Power* 500 mW
Frequency Stability*
(–30˚C to +60˚C; 25˚C Ref.) ±0.00015%
Analog Sensitivity*
12 dB SINAD .25 µV
Digital Sensitivity**
1% BER .40 µV
5% BER .25 µV
Selectivity*
12.5 kHz channels –63 dB
Intermodulation* –75 dB
Spurious Rejection* –75 dB
FM Hum and Noise*
12.5 kHz –40 dB
Audio Distortion* 1.5%

** Measured in the analog mode per TIA / EIA 603 under nominal conditions*

*** Measured in digital mode per TIA / EIA IS 102.CAAA under nominal conditions*

Exhibit 4.3 - Typical Mobile Radio Performance Standards

Specifications

VHF, UHF and 800 MHz Bands
Multiple modes of operation in a single radio
Digital clear and encrypted,
Analog and encrypted operation
Project 25 capable on conventional systems
Project 25 compliant interoperable voice signaling features
Narrow and wide bandwidth digital receiver (12.5, 25/30 kHz)
Enhanced encryption capability (optional):
16 Encryption keys
2 Encryption algorithms
Data capable
High quality, error corrected digital voice
High speed and embedded digital signaling
Meets Mil Specs 810
Programmable buttons
Dash and remote mount configurations

Standard Method Procedure Test Radio Performance

MIL-STD 810E 514.4 II Vibration
Meets or exceeds published Category 3 cargo transport specs following vibration testing.

MIL-STD 810E 514.4 I Vibration
Meets or exceeds published Category 10 (minimum integrity) specs following vibration testing.

MIL-STD 810E 516.4 VI Shock
Meets or exceeds specs following (Bench Handling) shock testing.

MIL-STD 810E 516.4 I Shock (Functional)
Meets or exceeds specs following shock testing.

MIL-STD 810E 516.4 V Shock (Crash hazard)
Meets or exceeds specs following shock testing.

MIL-STD 810E 506.3 I Rain (Wind driven)
Meets or exceeds specs following rain testing.

MIL-STD 810E 509.3 I Salt Fog
Meets or exceeds specs following salt fog testing.

MIL-STD 810E 510.3 I Blowing Dust
Meets or exceeds specs following dust testing.

MIL-STD 810E TESTING
Mobile radios also meet or exceed applicable requirements for MIL-STD 810C and 810D.

Encryption Algorithm Capacity:
2 algorithms per radio
Encryption Keys per Radio:
16 keys
Encryption Frame (VSELP): 360 msec
Re-sync Interval: Project 25-CAI:
360 msec
Encryption Keying: OTAR (Over-The-Air Rekeying) and Key Variable Loader
Synchronization: Counter Addressing and Cipher Feedback and Output Feedback

Code Key Generator:
External hand held microprocessor controlled
Encryption Key Tag
Capacity per System: 65,000
Number of Unique Keys:
Dependent on encryption algorithm
Code Key Initialization:
Internally derived pseudo-random initializing vector
Key Storage:
Volatile electronic memory or non-volatile electronic memory
Key Erasure:
Keyboard command, tamper detection and over-the-air command
Signaling Rate: 9.6 kbps

Error Correction Techniques:
Golay, BCH, Reed-Solomon codes

Exhibit 4.3 - Typical Mobile Radio Performance Standards (continued)

Data Access Control: Slotted CSMA
    Utilizes infrastructure-sourced data status bits embedded in both voice and data transmissions.
Voice Coding Method: VSELP
    Vector Sum Excited Linear Predictive Coding
IMBE (CAI): Improved Multi Band Excitation
CVSD: Continuously Variable Slope Delta Modulation
Voice Truncation: None
Frame Re-sync Interval: 180 msec

(Clear Digital Mode)
Forward Error Correction: Golay code
Error Mitigation: VSELP Dual Level
Level 1:
    Extrapolates and replaces 30 msec voice frames that exceed the error correction algorithm tolerance.
Level 2:
    Progressive muting of 30 msec voice frames that are too severely damaged for Level 1 replacement.
Error Mitigation: Project 25-CAI (IMBE) Dual Level
Level 1:
    Extrapolates and replaces 20 msec voice frames that exceed the error correction algorithm tolerance.
Level 2:
    Progressive muting of 20 msec voice frames that are too severely damaged for Level 1 replacement.
Code Book Structure:
    VSELP: Linear sum of basis vectors
    APCO Project-25 (IMBE): No Code book
Modulation: C4FM of QPSK-C family (Compatible Quadrature Phase Shift Keying) Protocol:
VSELP:
    4.8 kbps VSELP
    2.1 kbps Error Correction Coding
    2.7 kbps Embedded Signaling
Project 25-CAI:
    4.4 kbps IMBE
    2.8 kbps Error Correction Coding
    2.4 kbps Embedded Signaling
Channel Bandwidth:
    VSELP & Project 25-CAI & Analog: 12.5 kHz
    Analog: 25/30 kHz

Exhibit 4.4 - General Performance Specifications

(some characteristics are band dependent)

Channel Spacing: 12.5/25-30 kHz
Maximum Frequency Separation: Full Bandsplit
Optional Pre-Amp: Yes
Analog Sensitivity† 20 dB Quieting(25/30 kHz channel): 0.25-0.4 μV
12 dB SINAD per EIA (25/30 kHz channels): 0.2-0.3 μV
Digital Sensitivity*
- 1 % BER (12.5 kHz channels): 0.25-0.4 μV
- 5% BER (12.5 kHz ch): 0.2- 0.3 μV

Adjacent Channel Rejection (Selectivity)†
- (25/30 kHz channels)†: 80 dB
- (12.5 kHz ch)†: 65-75 dB

Intermod Rejection†*:(25/30 kHz ch): 80-85 dB
Spurious Response Rejection†*: 80-83 dB
Audio Output Distortion†*: (@ 3% Electrical Distortion): 5W (10W Opt)
Frequency Range/Bandsplits:
- 136-162 MHz, 146-174 MHz
- 403-433 MHz, 438-470 MHz, 450-482 MHz, 482-512 MHz
- 806-824 MHz, 851-870- MHz

Channel Spacing: 12.5/25-30 kHz
Maximum Frequency Separation: Full Bandsplit
Frequency Stability†:
Operating Frequency Accuracy* (–30˚C to +60˚C; +25˚C Ref.):
- VHF: ±0.00025%
- UHF: ±0.00020%
- 800: ±0.00015%

Modulation Limiting†: ±5.0 kHz
- 25/30 kHz channel: ±5.0 kHz, ±4.0 kHz (NPSPAC)
- 12.5 kHz channel: ±2.5 kHz

Modulation Fidelity (C4FM)* 12.5 kHz Digital Channels: ±2.8 kHz
FM Hum & Noise†:
- 30/25 kHz: 40-50 dB
- 12.5 kHz: 34-40 dB

Emissions (Conducted & Radiated)†*: –70 dBC (VHF/UHF) –60 dBC (800 MHz)

† Measured in analog mode per TIA/EIA 603.
* Measured in digital mode per TIA/EIA TSB102.CAAB

Exhibit 4.5 - List of Applicable Standards and Regulations

There following ancillary standards and regulations should be included in a PSMC procurement.

Electronic Industries Association (EIA) Standards:

TIA-603-B:	Land Mobile FM or PM Communications Equipment Measurement and Performance Standards
TSB-102-A:	APCO Project 25 Systems and Standards Definitions
TIA/EIA-102.CAAA:	Digital C4FM/CQPSK Transceiver Measurement Methods
TIA/EIA-102.CAAB:	Digital C4FM/CQPSK Transceiver Performance Recommendations

Federal Communications Commission Rules and Regulations.

Military Standards:

MIL-STD-810E: Environmental Test Methods and Engineering Guide
MIL-STD-810D: Environmental Test Methods and Engineering Guide

Commission on Accreditation for Law Enforcement Agencies, Inc. (CALEA) Standards.

Other Technical Standards (that may be applicable):

Analog base stations, mobiles, and portables shall meet the technical standards of TIA/EIA-603-B unless otherwise noted.

Common Air Interface: Improved Multi-Band Excitation (IMBE) Vocoder

Transmit Power Output: Transmit power output will be in accordance with limits established by the FCC in their type acceptance standards for frequency use and station class (*i.e.*, base station, mobile, portable)

Ambient Temperature Range: -30° C to +60° C. All specifications are referenced to +25° C (excluding battery)

Duty Cycle: 3 seconds receive, 3 seconds transmit, 54 seconds standby (5%, 5%, 90%)

Conformance to the following transceiver equipment standards is required in addition to conformance to Project 25 standards:

Talkgroups: 255 talkgroups or more per mobile/portable radio

Receiver Adjacent Channel Selectivity: -65 dB (mobiles/portables), -70 dB (base stations)

Offset Receiver Adjacent Channel Selectivity: -20 dB (mobiles/portables/base stations)

The following environmental standards are applicable for mobiles and portables regardless of method of employment (*i.e.*, mobiles that are marine, motorcycle, or aircraft mounted will meet the same standards for shock and vibrations as detailed below):

MIL-STD-810E: The mobiles and portables shall meet or exceed the following sections of MIL-STD-810E:

506.3 Rain, Procedure I (Blowing Rain)

509.3 Salt Fog, Procedure I (Aggravated Screening)

510.3 Sand and Dust, Procedure I (Blowing Dust)

514.4 Vibration, Procedure I, Category 10 (3 Axis)

516.4 Shock, Procedure I (Functional)

Alternatively, the following sections of MIL-STD-810D can be applied:

506.2 Rain, Procedure I (Blowing Rain)

509.2 Salt Fog, Procedure I (Aggravated Screening)

510.2 Sand and Dust, Procedure I (Blowing Dust)

514.3 Vibration, Procedure I, Category 10 (3 Axis)

516.3 Shock, Procedure I

Other Considerations:

Tower and Antenna Structures shall meet requirements of the American National Standards Institute ANSI/EIA RS-222-E

Transmission lines shall be supported at least every 24 inches on horizontal runs and every three feet on vertical runs

Transmission line surge suppression: Polyphaser IS-B50XX series or equivalent

Telephone lines protection: gas tubes complying with BELLCORE TR-TSY 000070 and TR-TSY-000072 specifications.

Antennas shall be rugged and designed for a service life of 25 years.

Cabling: Plenum-rated, if routed through areas used for return air handling. Cable separation of at least two inches between power and signal cables. Cables shall be bundled as to type: AC power, DC power, RF, ground, voice and data. Cables shall have hand-tight cable ties every three feet.