PUBLIC SAFETY PSWN PROGRAM WIRELESS NETWORK

Saving Lives and Property Through Improved Interoperability

Southwest Border Pilot Implementation

Interconnection of Incompatible, Proprietary 800 MHz Trunked Radio Systems

Console-to-Console Radio Frequency Link

A Solution for Public Safety Wireless Interoperability

Final

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PREFACE

This report provides a detailed description of one approach developed to meet an interoperability requirement among public safety agencies along the southwest border of Texas and the south central border of New Mexico. This location provided a unique opportunity to develop a solution that would allow agencies with disparate land mobile radio communications systems to communicate during the times when agency-to-agency radio interoperability was required. This particular geographic location was chosen for several reasons. This area not only serves as the border between two states, but also the serves as the border between two countries (i.e., United States and Mexico), thus many instances exist when local, state, and federal public safety agencies need to communicate.

This area also offered the opportunity to develop an interoperability solution between two incompatible trunked 800 Megahertz (MHz) radio systems. The City of Las Cruces, New Mexico, operates an Ericsson Enhanced Digital Access and Control System (EDACS) trunked radio system, and the City of El Paso, Texas, operates a Motorola SmartNet trunked radio system. The two systems utilize disparate channel access protocols, Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) respectively. Subscriber units from one system cannot communicate with subscriber units from the other system because of basic differences in the proprietary trunking protocol used by each vendor. Because the two cities do not use any 800 MHz mutual-aid calling channels for interoperability, a simpler, more cost-effective solution using trunked talk group-to-trunked talk group patching between the two trunked radio systems was chosen. This solution is called the Console-to-Console Radio Frequency Link (CCRFL).

This document provides the basic, essential information needed to understand how the CCRFL was implemented, and consequently, offers a resource for all public safety agencies interested in such a solution. More information on the CCRFL, and other means for achieving interoperability, is available from the Public Safety Wireless Network (PSWN) Program, which sponsored and funded the development of the CCRFL concept. The PSWN Program can be contacted by e-mail at information@pswn.gov or by telephone at 1-800-565-PSWN. The program's Web site, at www.pswn.gov, provides a wealth of information regarding public safety wireless interoperability.

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1. INTRODUCTION

The Public Safety Wireless Network (PSWN) Program works with public safety agencies nationwide to help achieve interoperability—seamless, coordinated, integrated public safety wireless communications that promote safe, efficient protection of life and property. The PSWN Program works with the public safety community to improve the interoperability of wireless communications by promoting coordination and partnerships, seeking funding alternatives, advocating adequate public safety spectrum allocations and efficient spectrum use, supporting technical standards development, and fostering secure communications.

The development and implementation, for proof-of-concept purposes, of technical solutions for interoperability among public safety networks is one of the PSWN Program's main areas of activity. These solutions, which are initiated as pilot projects in various regions throughout the country, are developed jointly by the PSWN Program Management Office (PMO) and public safety radio and operational personnel from the region. The individuals involved most directly in pilot development and operation constitute the pilot's Integrated Program Team, or IPT. IPT members focus the pilot effort and technical concept to be proven into a discrete, repeatable solution for an interoperability shortfall common among public safety agencies throughout the Nation. This approach allows the PSWN PMO to leverage the solution beyond the pilot region, and more broadly, to benefit the public safety community as a whole.

The PSWN Program sponsored a Southwest Border IPT for almost two years. After a case study was conducted of the entire southwest border, from San Diego, California, to Brownsville, Texas, the geographic area of southwest Texas, south central New Mexico, and the nearby border area of Mexico was chosen for implementation of an interoperability pilot project solution. The IPT first supported an assessment of interoperability needs in this particular part of the southwest border region. The IPT then focused on pilot proof-of-concept activities targeting a specific interoperability shortfall, namely, the need for an interoperability solution between two disparate trunked radio systems to support certain public safety response situations. In response, the PSWN Program and its southwest border IPT developed the Console-to-Console Radio Frequency Link (CCRFL) for the cities of El Paso, Texas, and Las Cruces, New Mexico. The IPT determined that the CCRFL equipment would be installed at the appropriate radio tower sites of each city's trunked radio system. Features of the CCRFL include—

- Redundant direct radio frequency (RF) links between the two cities' trunked radio systems
- No requirement for interstate leased telephone circuits
- Patching capabilities between all agencies that have access to either of the two trunked radio systems
- Enhanced local, state, and federal interoperability during emergency situations and special events.

The CCRFL consists of several components. These components work together to provide dispatcher control of console-to-console patches enabling public safety users of two disparate trunked radio systems to communicate directly with each other. In addition to direct talkgroup-to-talkgroup patches between the two trunked radio systems, the dispatchers may also patch conventional radios connected to their console switches between the two systems by utilizing the CCRFL. In El Paso, for example, an INS subscriber unit could be patched through the conventional VHF Intercity base station, through the CCRFL, and out to a Dona Anna County Sheriff's officer via the conventional VHF base station connected to the Las Cruces trunked radio system. This flexibility allows local, state, and federal agencies to communicate with each other using their own radios, during major events requiring public safety interoperability. As illustrated in Figure 1, the components used in the CCRFL include a remote-controlled Ericsson desktop trunked radio, a Motorola remote-controlled desktop trunked radio, two outdoor directional 800 megahertz (MHz) antennas with coaxial cable and connectors, a conventional interface card for each console electronics switch, and a dedicated 4-wire circuit from each console electronics switch to its associated transmitter site. The dashed arrows labeled "C.C.R.F.L." indicate the wireless RF links between the two disparate trunked radio systems. This connectivity is provided without leased telephone circuits and their recurring monthly costs. This solution uses commercial off-the-shelf (COTS) equipment, and can be readily duplicated in other regions where disparate radio systems need to be linked for radio interoperability.

The functional diagram in Figure 1 actually depicts two different methods of creating the CCRFL. Either city may initiate a link via the CCRFL, and in cases where two links are required; both cities may initiate CCRFL links simultaneously. An example of how the CCRFL would be initiated by each city is outlined below. The numbered steps below are shown in Figure 1 to indicate the sequence of events as either city initiates the CCRFL.

LAS CRUCES INITIATES THE CCRFL – SEE FIGURE 1 – DOTTED LINE

1-LC: A Dona Ana sheriff's unit calls in to the MVRDA dispatcher and requests to talk to an El Paso sheriff's unit

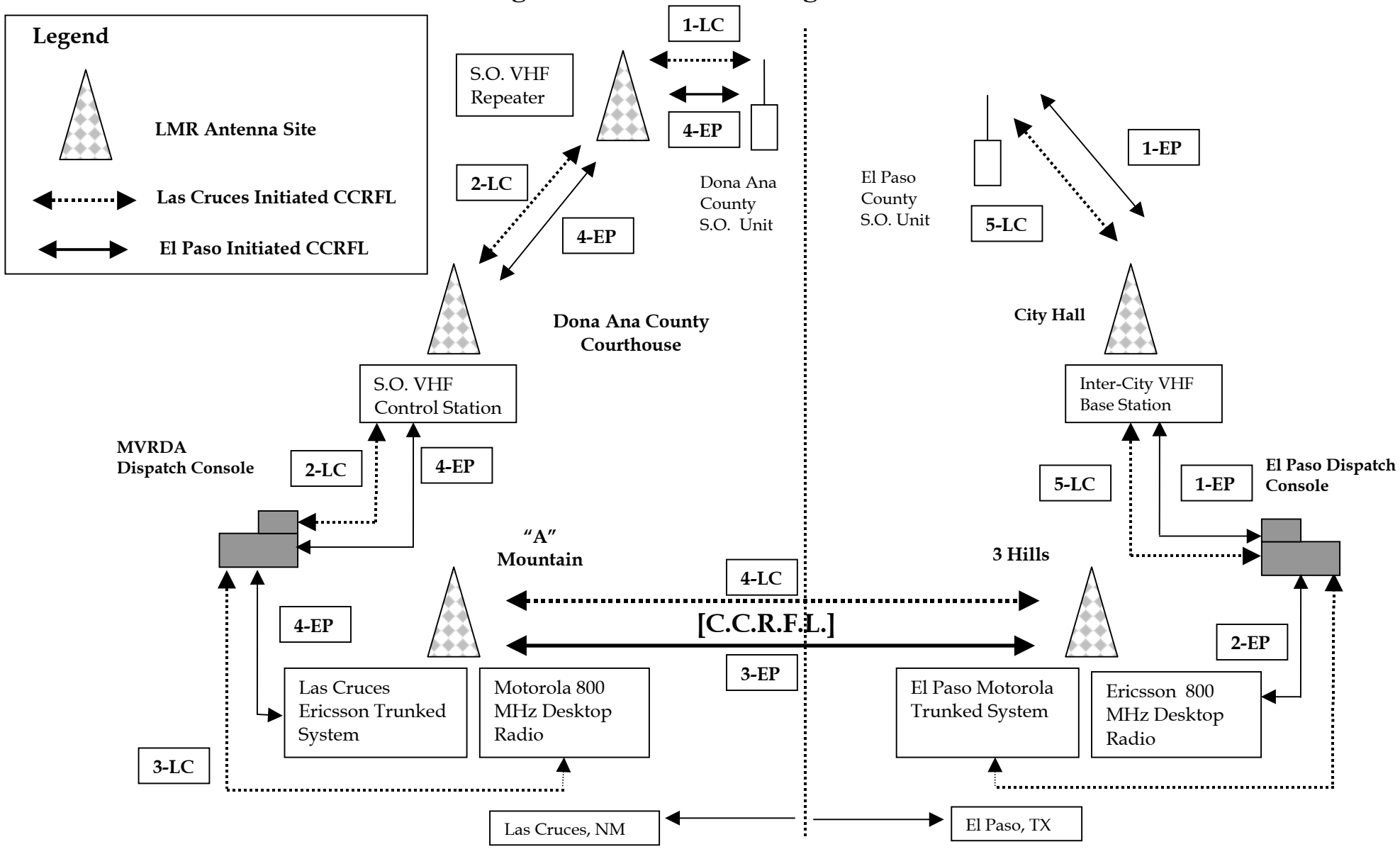
2-LC: This call is routed through the S.O. repeater, through the S.O. VHF control station, down the wireline circuit, to the MVRDA dispatcher

3-LC: The MVRDA dispatcher selects the Motorola 800 MHz desktop radio at "A" Mountain and patches it to the S.O. VHF control station

4-LC: The MVRDA dispatcher then talks out over the Motorola 800 MHz desktop radio at "A" Mountain to the El Paso Motorola trunked system at the 3 Hills site.

5-LC: The MVRDA dispatcher asks the El Paso dispatcher to patch the appropriate El Paso sheriff's unit to the CCRFL. The El Paso dispatcher then contacts the appropriate El Paso Sheriff's unit through the Intercity base station and patches him to the CCRFL. The El Paso dispatcher notifies the two sheriff's units to proceed with the call.

Figure 1: Functional Diagram for the CCRFL



EL PASO INITIATES THE CCRFL – SEE FIGURE 1 – SOLID LINE

1-EP: An El Paso sheriff's unit calls in to the El Paso dispatcher and requests to talk to a Dona Ana sheriff's unit. This call is routed through the Intercity VHF base station, to the El Paso dispatcher

2-EP: The El Paso dispatcher selects the Ericsson 800 MHz desktop radio at 3 Hills and patches it to the Inter-City VHF base station

3-EP: The El Paso dispatcher then talks out over the Ericsson 800 MHz desktop radio at 3 Hills to the Las Cruces Ericsson trunked system at "A" Mountain.

4-EP: The El Paso dispatcher asks the MVRDA dispatcher to patch the appropriate Dona Ana sheriff's unit to the CCRFL. The Dona Ana sheriff's unit is patched to the CCRFL via the S.O. VHF control station and the S.O. VHF repeater. The El Paso dispatcher notifies the El Paso sheriff's unit to proceed with the call.

The balance of this report describes the CCRFL in greater detail. The report is based on the implementation and initial operation of the CCRFL in the areas of Las Cruces (Dona Ana County), New Mexico, and El Paso (El Paso County), Texas. Accordingly, the details of the CCRFL configuration relate to specific requirements of those areas. With that caveat, the remainder of this report was written in as general a manner as possible to make it useful to all public safety agencies having a need for this type of interoperability solution.

2. SYSTEM COMPONENTS

The CCRFL integrates several COTS components into a public safety wireless interoperability solution appropriate for certain situations. A Motorola desktop trunked radio is installed at the Las Cruces "A" Mountain radio site, with an 800 MHz directional antenna used to complete the radio frequency link with the El Paso 3 Hills radio site. An Ericsson desktop trunked radio is installed at the El Paso 3 Hills radio site, with a directional 800 MHz antenna used to complete the radio frequency link with the Las Cruces "A" Mountain radio site. The CCRFL uses the two dispatch center console electronics switches to provide patches between the various agencies having access to the trunked radio systems.

Dispatchers create talk group-to-talk group patches between the agencies using 800 MHz subscriber units by linking the appropriate icons on their respective consoles. A T-1 multiplexer provides the 24 DS-0 channels from the radio site to the Mesilla Valley Regional Dispatch Authority (MVRDA) dispatch center in Las Cruces. The City of Las Cruces has several conventional base stations that allow its dispatchers to create console patches among trunked talk groups, trunked system subscribers, and conventional subscriber units. Some of these agencies using conventional base stations are the Dona Ana Sheriff Department, the New Mexico State Police, and the county fire departments. The City of El Paso has a state-of-the-art digital microwave network providing connectivity between the dispatch center and the 800 MHz trunked radio sites. The City of El Paso also has a very high frequency (VHF) conventional base station, known as Intercity, which is linked to a conventional port on its console electronics switch. This base station has an icon on the dispatcher console position that can be patched to any other icon, such as a trunked talk group, to create interoperability between the conventional subscriber and the trunked system subscriber. Federal, state, and local agencies having the Intercity frequency on their subscriber units can be patched into the El Paso trunked radio system for interoperability with agencies that have access to both cities' trunked radio systems.

The following subsections describe the CCRFL components in more detail.

2.1 Motorola Console Central Electronics Bank at the City of El Paso

For the interoperability solution to work, the Central Electronics Bank (CEB) in El Paso had to be configured and programmed to provide remote control of an Ericsson Orion 800 MHz trunked desktop radio. This arrangement required a Motorola console switch to provide remote control of the Ericsson desktop radio. This was not a problem, because both the CEB and the Ericsson desktop radio are capable of operating with the 2,175 (Hertz) Hz high- and low-level guard tone protocol for radio remote control. A 4-wire circuit, using in-band signaling, (2,175 Hz guard tone) was selected from the available circuits on the City of El Paso's digital microwave system. This microwave system provides connectivity among all the trunked radio transmitter sites and the CEB. To interface this circuit to the CEB, a base interface module (BIM) was selected from the available spare modules. This module provides a 4-wire interface between the remote desktop radio and the CEB, thus allowing transmit and receive audio signals to travel between the radio and the CEB. The BIM allows the console operator to remotely control the transmit and receive functions of the desktop radio.

Two icons were created on the dispatch consoles at the City of El Paso. The first icon, called "Las Cruces OUT," was created for the conventional connection to the Ericsson desktop radio at the 3 Hills site. This radio directly accesses a talk group on the Las Cruces trunked radio system. A second icon, called "Las Cruces IN," was created as a trunked talk group on the El Paso trunked radio system. This icon indicates that the Motorola desktop radio at the "A" Mountain site is calling directly into the El Paso trunked radio system. Either of these icons can be patched to a trunked talk group on the El Paso system or to an icon that designates a conventional base station, such as the Intercity base station used to contact the El Paso County Sheriff's Office. Installation of a trunked desktop radio at both the El Paso and Las Cruces transmitter sites creates a redundant CCRFL solution. If one of the desktop radios should fail, an interoperability patch can still be created on the other radio. If an interoperability event requires two simultaneous patches between the two systems, both desktop radios can be used at the same time. This configuration also allows either the Las Cruces dispatchers or the El Paso dispatchers to initiate a CCRFL.

2.2 Ericsson Console Electronics Switch at the City of Las Cruces

For the interoperability solution to work, the Console Electronics Switch (CES) in Las Cruces had to be configured and programmed to provide remote control of a Motorola Spectra 800 MHz trunked desktop radio. This arrangement required the CES to provide remote control of the Motorola desktop radio. Again, this was not a problem, because both the CES and the Motorola desktop radio are capable of operating with the 2,175 Hz high- and low-level guard tone protocol for radio remote control. There is existing leased T-1 service from the CES located at the MVRDA to the transmitter site at "A" Mountain. A spare 4-wire circuit (DS-0) was selected and connected to provide a 4-wire path from the remote Motorola desktop radio to the CES. A spare conventional interface (CI) was selected at the CES, and the connection between the CES and the desktop radio was completed. The CI provides a 4-wire interface between the remote desktop radio and the CES to allow transmit and receive audio signals to travel between the radio and the CES. The CI allows the console operator to remotely control the transmit and receive functions of the desktop radio.

Two icons were created on the dispatch consoles at the City of Las Cruces. The first icon, called "El Paso OUT," was created for the connection to the Motorola desktop radio at the "A" Mountain site. This radio directly accesses a talk group on the El Paso trunked radio system. A second icon, called "El Paso IN," was created as a trunked talk group on the Las Cruces trunked radio system. This icon indicates that the Ericsson desktop radio at the 3 Hills site is calling directly into the Las Cruces trunked radio system. Either of these icons can be patched to a trunked talk group on the Las Cruces system or to an icon that designates a conventional base station, such as the VHF base station used to contact the Dona Ana County Sheriff's Office.

2.3 Motorola 800 MHz Trunked Desktop Radio with Remote Control Option

A Motorola Spectra 800 MHz trunked desktop radio was installed at the Las Cruces city radio site on "A" Mountain in Las Cruces, New Mexico, as shown in Figure 2. On-site testing

had revealed a strong, reliable path from the "A" Mountain site to the El Paso transmitter site called 3 Hills, located on the west side of El Paso. The Motorola desktop radio was programmed by the City of El Paso for an interoperability talk group on the El Paso 800 MHz trunked radio system. After testing and programming were completed, the Motorola trunked desktop radio was installed by the City of Las Cruces at its "A" Mountain site. An 800 MHz directional yagi-type antenna was installed at about 25 feet above ground level (AGL) on the existing transmitter site tower, as shown in Figure 3 (area bordered in white). Low-loss ½-inch coaxial cable was installed from the antenna to the desktop radio with a surge suppressor on the cable where it entered the radio shelter. The desktop radio was connected to an uninterruptible power supply (UPS) to ensure it would continue to function if commercial power was interrupted. The desktop radio was ordered with a tone remote option operating on 2,175 Hz tone signaling, consistent with the programming of the CES that must remotely control the desktop radio. Upon completion of the installation, the dispatcher in Las Cruces was able to communicate with the dispatcher in El Paso by selecting the icon for the Motorola desktop radio and both transmitting and receiving normally.

Figure 2
Motorola Desktop Radio at "A" Mountain Site

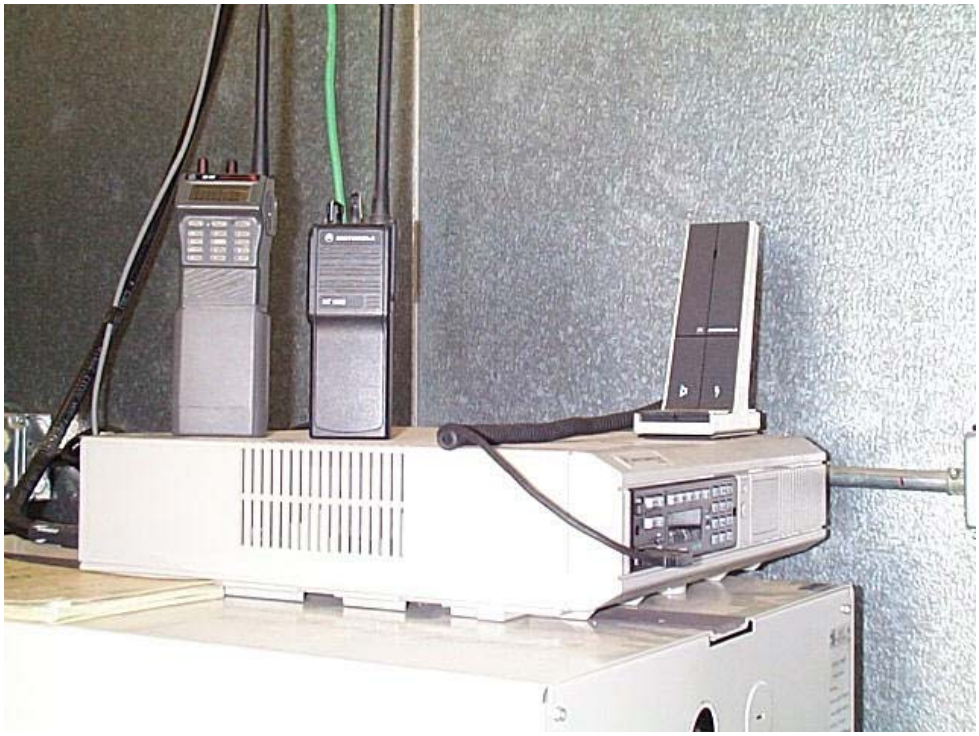
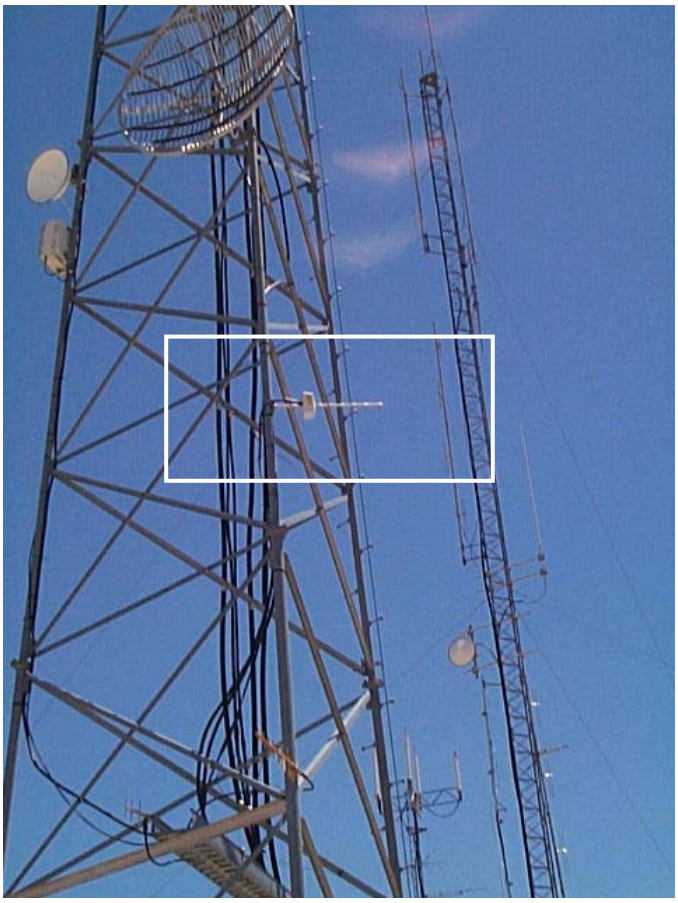


Figure 3
"A" Mountain Site Yagi Antenna



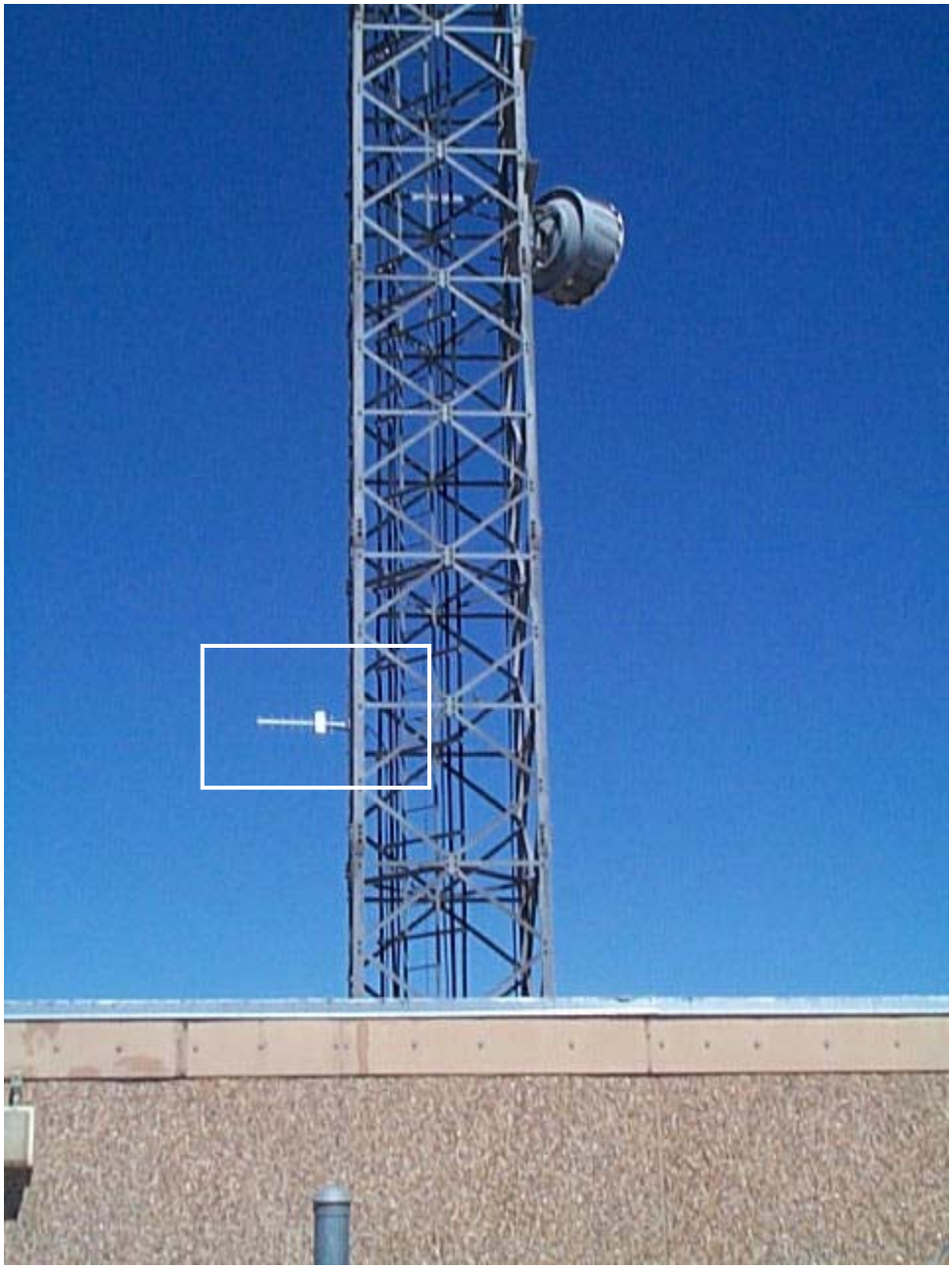
2.4 Ericsson 800 MHz Trunked Desktop Radio with Remote Control Option

An Ericsson Orion 800 MHz trunked desktop radio was installed at the El Paso city radio site on 3 Hills in El Paso, Texas, as shown in Figure 4. On-site testing had revealed a strong, reliable path from the 3 Hills site to the Las Cruces transmitter site on "A" Mountain. The Ericsson desktop radio was programmed by the City of Las Cruces for an interoperability talk group on the Las Cruces 800 MHz trunked radio system. This talk group was designated "El Paso In." After testing and programming was completed, the Ericsson trunked desktop radio was installed by the City of El Paso at its 3 Hills site. An 800 MHz directional yagi-type antenna was installed at about 25 feet AGL on the existing transmitter site tower, as shown in Figure 5 (area bordered in white). Low-loss ½-inch coaxial cable was installed from the antenna to the desktop radio with a surge suppressor on the cable where it entered the radio shelter. The desktop radio was connected to a UPS to ensure it would continue to function if commercial power was interrupted. The desktop radio was ordered with a tone remote option operating on 2,175 Hz tone signaling, consistent with the programming of the CEB that must remotely control the desktop radio. Upon completion of the installation, the dispatcher in El Paso was able to

communicate with the dispatcher in Las Cruces by selecting the icon for the Motorola desktop radio and both transmitting and receiving normally.

Figure 4
Ericsson Desktop Radio & Microwave Channels at 3 Hills Site

Figure 5
3 Hills Site Yagi Antenna



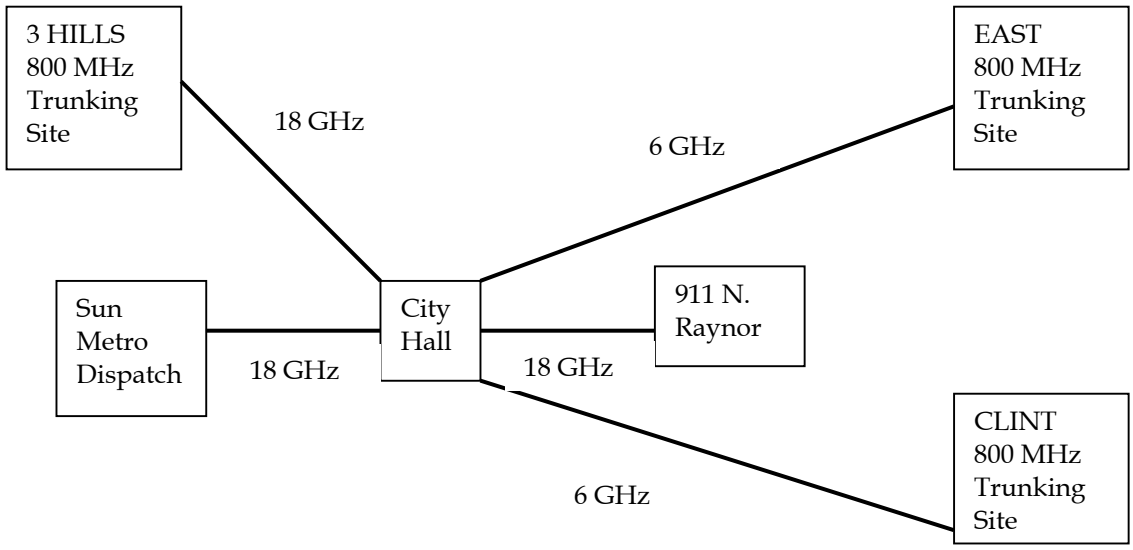
3. SYSTEM IMPLEMENTATION

The Ericsson (Las Cruces, NM) and Motorola (El Paso, TX) trunked 800 MHz radio systems were examined to identify the best approach for linking them together to provide improved interoperability for the public safety agencies participating in the pilot test project. This section describes how the CCRFL solution was implemented, and more specifically, how it was integrated into each city's trunked radio system. The intent of this section is to describe the solution in sufficient detail to enable the reader to understand the level of effort required to implement this particular interoperability in other regions of the country.

3.1 El Paso Digital Microwave Circuit

The City of El Paso operates a five-year-old Harris Farinon digital microwave system in the 6 gigahertz (GHz) and 18 GHz frequency bands that supports the city's trunked 800 MHz simulcast public safety radio system. This microwave system provides connectivity from the dispatch center at 911 N. Raynor to the desired radio site at the 3 Hills location. Digital channel banks located at each end of this desired "link" provide DS-0 connectivity for dispatcher remote control of the Ericsson desktop trunked radio installed at the radio site. The 3 Hills digital channel bank is shown in Figure 4. The "hub" of this microwave system is at City Hall in downtown El Paso. All microwave circuits must be connected to this hub and then cross-connected to the appropriate microwave radio providing the path to the desired end location. In this instance, a DS-0 channel was selected to connect the dispatch console at 911 N. Raynor to the corresponding channel bank DS-0 channel at the hub in City Hall. The DS-0 channel at City Hall provides the audio termination for that circuit from 911 N. Raynor. Next, a DS-0 channel from City Hall to the 3 Hills radio site was selected. Both ends of each of these two circuits were terminated in a DS-0 channel card. To complete the circuit, a 4-wire cross-connect was installed at City Hall between the two desired channel cards. The completed circuit was tested from 911 N. Raynor to City Hall, from City Hall to the 3 Hills radio site, and then from 911 N. Raynor to the 3 Hills radio site. Figure 6 shows the layout and routing of the City of El Paso's digital microwave backbone.

Figure 6
City of El Paso Digital Microwave System Layout



3.2 El Paso Console Connection and Programming

The previously designated DS-0 channel card at 911 N. Raynor was then cross-connected to the designated BIM in the CEB. The CEB was programmed to provide 4-wire audio and control tones to that particular BIM address. Note that this is a BIM and not a trunked base interface module (TBIM). Even though the Ericsson radio is a trunked desktop radio, it is treated as a conventional desktop radio by the El Paso CEB, to allow a simple remote control capability. The three dispatch supervisor consoles were then programmed to include the icon for the Ericsson desktop base station that was connected to the designated BIM. Clicking on this icon, designated "Las Cruces Out," allows the dispatch supervisor to link to and access the Ericsson desktop radio at the 3 Hills radio site. The Ericsson desktop radio then accesses a predetermined trunked talk group on the Las Cruces Ericsson trunked radio system. This talk group on the Las Cruces system is designated "El Paso In."

3.3 Ericsson Desktop Radio at El Paso 3 Hills Site

The site at 3 Hills was evaluated to determine the best location for the desktop trunked radio. It was decided that the best location should provide the most physical spacing between the desktop radio and the existing trunked repeaters installed at the site. The desktop radio was mounted on a 19-inch rack-mounted shelf in close proximity to the microwave channel bank and the antenna cable entrance for the building. This location was desirable because it kept both the cross-connect wiring from the radio to the microwave channel bank, and the coaxial cable from the radio to the outside antenna as short as possible, thus keeping cable losses to a minimum**.** The radio was mounted on the shelf, and the alternating current (AC) power cord was connected to the UPS power source at the radio site. The 4-wire audio connections from the microwave

channel bank for the designated DS-0 channel were cross-connected to the Ericsson trunked desktop radio. The 4-wire audio connection also included the in-band 2,175 Hz remote control guard tones. No other external connections were required for the remote control of the desktop radio.

To provide a strong and consistent radio path from the 3 Hills site in El Paso to the "A" Mountain site in Las Cruces, a directional yagi-type antenna was installed at 25 feet AGL on the tower at the 3 Hills site. This height was chosen to provide the maximum separation between the yagi antenna and the existing site trunking antennas mounted at the top of the tower, while still placing the antennas at such a height above ground level to deter any potential vandalism. The directional antenna was oriented at an azimuth of approximately 335 degrees to enable communications with the "A" Mountain site. Standard ½-inch hard-line coaxial cable was used to connect the antenna to the surge suppressor on the building entry panel. The cable was routed down the cable ladder of the 100-foot tower and connected using the proper mounting hardware. A grounded surge suppressor was installed on the end of the coaxial cable where it entered the building, and a jumper was installed between the surge suppressor and the desktop radio. Tests for continuity, shorts, and the proper transmit return loss were accomplished for the antenna cable, surge suppressor, and antenna itself by using a standing wave ratio (SWR) bridge.

3.4 Conventional Base Station Radios Attached to the El Paso CEB

The CCRFL provides a direct RF link between the dispatch consoles of the cities of Las Cruces and El Paso, allowing interoperable communications between dispatcher-selected talk groups on either trunked radio system. For example, a Las Cruces Police Department Patrol talk group can be patched to an El Paso Police Department Patrol talk group via the CCRFL. Once this patch is active, an El Paso patrol officer can communicate directly with a Las Cruces patrol officer. This patching capability is very beneficial in certain situations, but it also extends to all conventional base station radios that may be connected to the El Paso CEB. In this case, an Intercity base station is installed at City Hall that can be accessed by other agencies having the Intercity channel pair programmed into their subscriber units. By patching the Intercity base station to an 800 MHz trunked system talk group, it is possible for an El Paso police officer to communicate directly with an El Paso sheriff's deputy, while each uses his/her own mobile or portable radio unit.

3.5 Las Cruces Leased T-1 Service

The City of Las Cruces leases a full T-1 carrier from the local exchange carrier, Qwest (US West) to provide connectivity from the MVRDA console electronics switch to the radio site on "A" Mountain. This T-1 is used primarily to support the 12-channel Ericsson Enhanced Digital Access and Control System (EDACS) trunked radio system recently installed by the City of Las Cruces. The Las Cruces technician selected a DS-0 channel on the T-1 carrier multiplexer and verified its operation from end to end. The technician cross-connected the DS-0 channel at "A" Mountain to the Motorola desktop trunked radio. The technician then went to the MVRDA location and cross-connected the other end of the selected DS-0 channel to the console switch conventional interface card. With the console electronics switch and the Motorola desktop trunked radio both properly programmed, the technician tested the remote control capability of

the console electronics switch and the remote Motorola desktop trunked radio. With this test successfully completed, the leased DS-0 channel performance was deemed satisfactory.

3.6 Las Cruces Console Connection and Programming

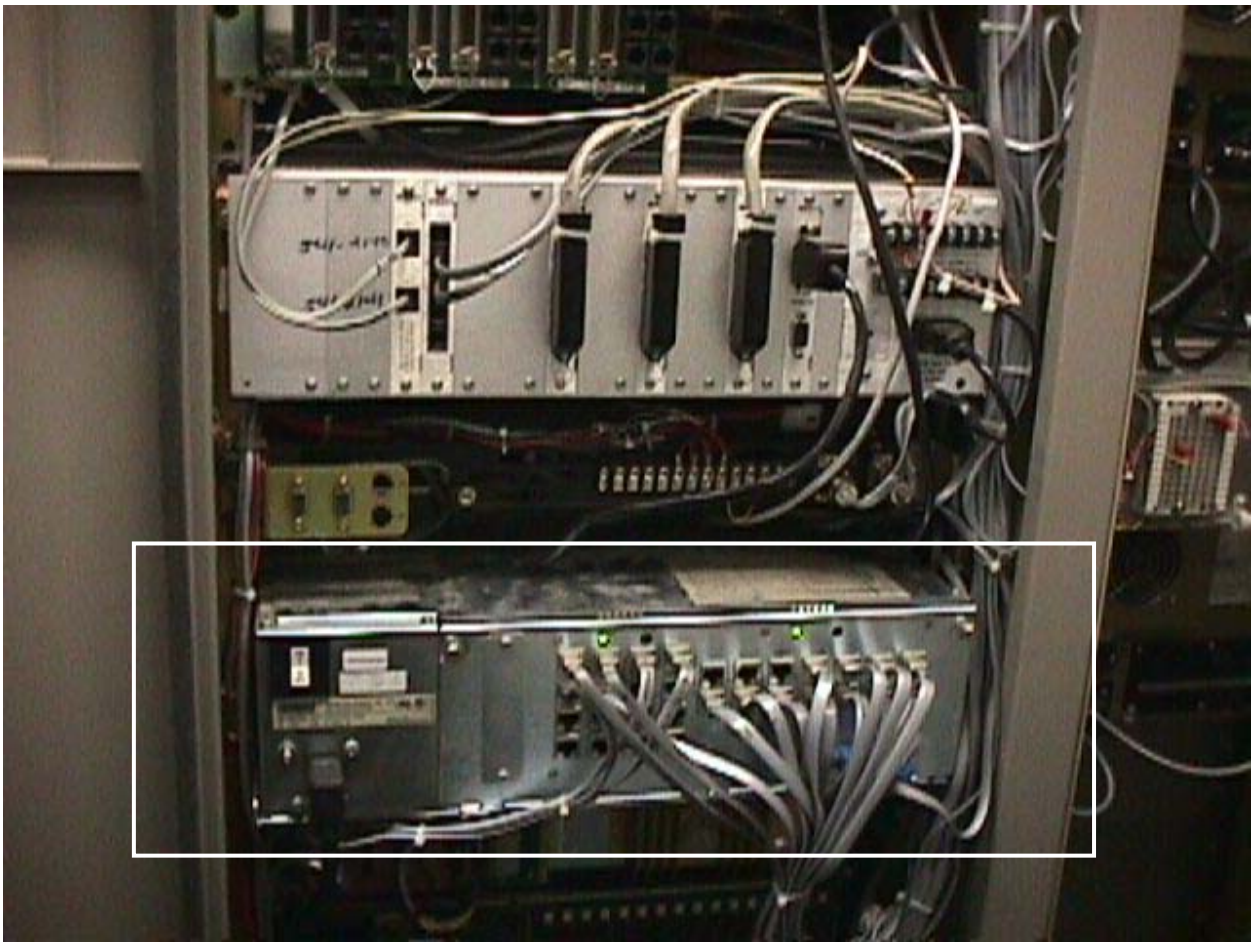
As stated in Section 3.5, the console electronics switch at the MVRDA location was connected to the remotely controlled Motorola desktop trunked radio via a leased DS-0 channel. This leased channel was connected to a conventional interface card in the console electronics switch. The console electronics switch was programmed by the Las Cruces technician to recognize the Motorola desktop trunked radio as a conventional base station. The conventional interface card provides 4-wire transmit and receive audio paths as well as the proper 2,175 Hz guard tone to remotely key the transmitter of the desktop trunked radio. The Motorola desktop trunked radio was designated as "El Paso Out" on the dispatch console positions at the MVRDA location. The console treats the "El Paso Out" icon in the same manner it treats the conventional interface to other non-trunked base stations connected to the console electronics switch. For example, the VHF base station of the Sheriff's Department connected to the console electronics switch is also treated as a conventional base station with 4-wire audio and tone remote control.

To accommodate interoperability "patches" originating from the City of El Paso, a trunked interoperability talk group was programmed into the Las Cruces trunked radio system. This trunked talk group, designated as "El Paso In," allows the Ericsson desktop trunked radio installed at the El Paso 3 Hills radio site to access the Las Cruces trunked radio system. This talk group provides direct access to the Las Cruces trunked radio system without going through the Motorola desktop trunked radio installed at "A" Mountain. The El Paso interoperability hardware is configured in the same manner as the Las Cruces interoperability hardware, which provides a redundant CCRFL capability. If one city has a component failure in the interoperability solution, the other city will, most likely, still be able to initiate interoperable communications via the CCRFL.

3.7 Motorola Desktop Radio at Las Cruces "A" Mountain Site

The site at "A" Mountain was evaluated to determine the best location for the desktop trunked radio. It was decided that the best location should provide the most physical spacing between the desktop radio and the existing trunked repeaters installed at the site. The desktop radio was mounted on top of an unused UPS cabinet close to the active UPS and the antenna cable entrance for the building, as shown in Figure 2. This location was desirable because it kept both the cross-connect wiring from the radio to the T-1 multiplex, and the coaxial cable from the radio to the outside antenna as short as possible, thus keeping cable losses to a minimum. The radio was placed on the unused UPS cabinet, and the AC power cord was connected to the UPS power source at the radio site. Next, the 4-wire audio connection from the T-1 multiplex for the designated DS-0 channel, as shown in Figure 7 (area bordered in white), was cross-connected to the Motorola trunked desktop radio. The 4-wire audio connection also included the in-band 2,175 Hz remote control guard tones. No other external connections were required for the remote control of the desktop radio.

Figure 7
Multiplexer at "A" Mountain Site

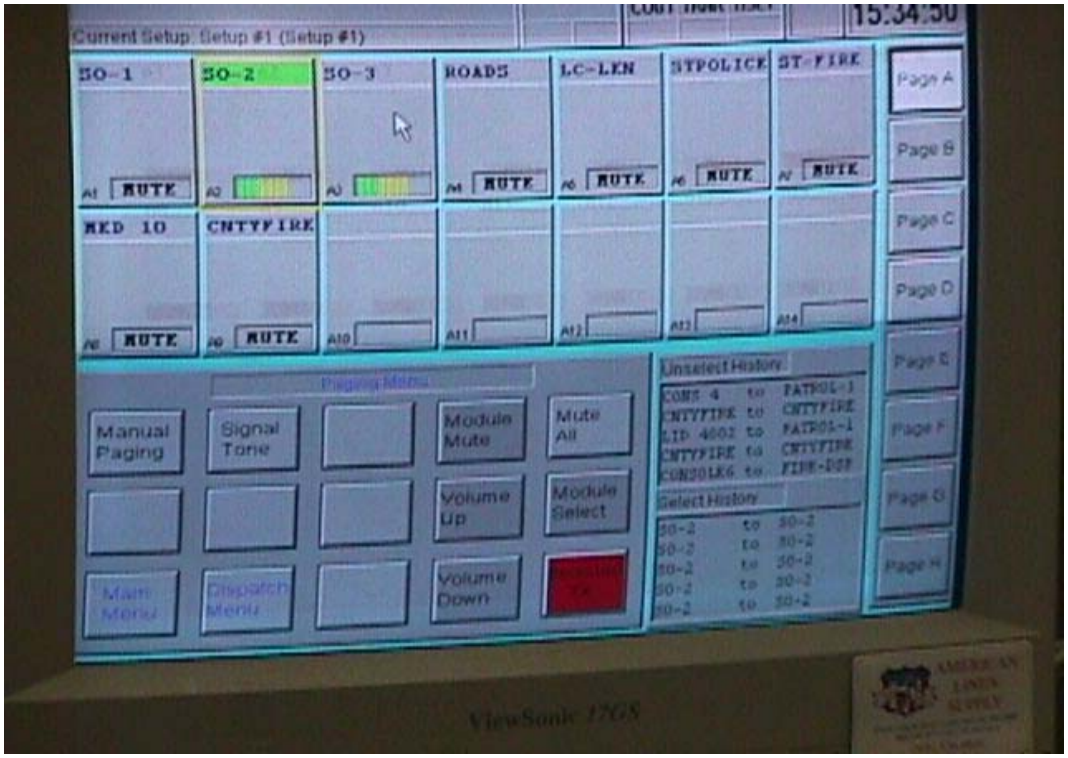


To provide a strong and consistent radio path from the "A" Mountain site in Las Cruces to the 3 Hills site in El Paso, a directional yagi-type antenna was installed at 25 feet AGL on the tower at the "A" Mountain site, as shown in Figure 3 (area bordered in white). This height was chosen to provide the maximum separation between the yagi antenna and the existing site trunking antennas mounted at the top of the tower, while still placing the antenna at a sufficient height above ground to deter any potential vandalism. The directional antenna was oriented at an azimuth of approximately 155 degrees to enable communications with the 3 Hills site. Standard ½-inch hard-line coaxial cable was used to connect the antenna to the surge suppressor on the building entry panel. The cable was routed down the cable ladder of the 100-foot tower and connected with the proper mounting hardware. A grounded surge suppressor was installed on the end of the coaxial cable where it entered the building, and a jumper was installed between the surge suppressor and the desktop radio. Tests for continuity, shorts, and the proper transmit return loss were accomplished for the antenna cable, surge suppressor, and antenna itself using an SWR bridge.

3.8 Conventional Base Station Radios Attached to the Las Cruces Console Switch

The CCRFL provides a direct RF link between the trunked radio systems, and ultimately, the dispatch consoles of the cities of Las Cruces and El Paso, allowing interoperable communications between dispatcher-selected talk groups on either trunked radio system. As described in Section 3.4, a Las Cruces Police Department Patrol talk group can be patched to an El Paso Police Department Patrol talk group via the CCRFL, allowing direct communication between the two officers. This patching capability also extends to all conventional base station radios that may be connected to the Las Cruces console electronics switch. For example, conventional base station radios for the Dona Ana County Sheriff's Office, the New Mexico Department of Public Safety, the County Road and Bridge department, and the local emergency medical services (EMS) providers are connected to the console electronics switch at MVRDA, as shown in a sample "page" from the dispatcher console in Figure 8.

Figure 8
MVRDA Console: Sample Dispatch Screen



4. FIELD TESTING AND OPTIMIZATION

4.1 City of El Paso Interoperability Link

A local Motorola authorized service shop installed and optimized the complete suite of interoperability equipment for both the 911 N. Raynor location and the 3 Hills radio site. During the installation process, each component of the interoperability link was tested and verified by the service technicians. The Motorola CEB is capable of patching conventional base stations to trunked talk groups, and vice versa. This capability makes the CCRFL a viable solution to the interoperability challenges of linking two completely different trunked radio systems together. Because the Ericsson EDACS trunked radio system and the Motorola SmartNet trunked radio system use different proprietary protocols in their trunking formats, it is impossible for EDACS users and SmartNet users to talk directly on each other's systems. To overcome this problem, the Motorola console in El Paso treats the Ericsson desktop radio like a conventional radio with a conventional BIM interface card. It uses conventional 2,175 Hz keying tones and analog transmit and receive audio to remotely control the radio. The Ericsson desktop radio communicates with the Las Cruces trunking system in the same manner as any other trunked subscriber unit.

The following interoperability patch test was initiated by the City of El Paso dispatch supervisor. To test the operation of the El Paso side of the interoperability solution, the El Paso dispatch supervisor called both the El Paso Sheriff's Office and the Las Cruces police dispatcher to notify them of the test. The El Paso dispatch supervisor then selected the "Las Cruces Out" icon on the console, pressed the transmit button, and called the Las Cruces dispatcher. Once that connection was established and verified, the El Paso dispatch supervisor selected the icon for the Intercity base station and patched it to the "Las Cruces Out" icon. The El Paso dispatch supervisor then called the sheriff's unit that was standing by on the Intercity frequency. Once that connection was established and verified, the El Paso dispatch supervisor instructed the sheriff's unit to call the Las Cruces dispatcher. The Las Cruces dispatcher, seeing and hearing activity on the "El Paso In" trunked talk group on the EDACS, then talked directly through the patch to the El Paso sheriff's unit. Once that connection was established and verified, the Las Cruces dispatcher took the final step and patched the "El Paso In" talk group on the Ericsson console to the conventional base station of the Dona Ana County Sheriff's Department. The Las Cruces dispatcher then called a Dona Ana County sheriff's unit that, by pre-arrangement, was standing by to call directly to the El Paso County sheriff's unit. Once that connection was established and verified, the two sheriff's units communicated directly with each other through the CCRFL interoperability solution.

4.2 City of Las Cruces Interoperability Link

The lead land mobile radio (LMR) technician for the City of Las Cruces installed the hardware and performed the console programming for the interoperability solution in Las Cruces. He also supervised a local radio shop that installed the antenna, coaxial cable, and desktop base station in the "A" Mountain radio site. The connectivity between the MVRDA console electronics switch and the "A" Mountain radio site is provided by a leased T-1 service.

A multiplexer is installed at each end of the leased service to provide 24 DS-0 circuits. The technician selected an unused DS-0 circuit and tested it for the proper levels. He cross-connected the DS-0 module at the MVRDA location to the appropriate conventional interface card. The technician programmed the console electronics switch to recognize the conventional interface card designated to remotely control the Motorola desktop trunked radio at the "A" Mountain site. The technician then went to the "A" Mountain site to verify that the console keying tones and transmit and receive audio were functioning properly at the input to the desktop trunked radio. With that completed, the desktop trunked radio was cross-connected to the appropriate DS-0 circuit on the multiplexer. The technician then contacted the dispatcher at the MVRDA location and had the dispatcher talk directly to the El Paso dispatch supervisor over the remotely controlled Motorola desktop trunked radio. This successful test verified that the interoperability link was working properly.

The next step was to have the Las Cruces dispatcher set up the interoperability link over the Motorola desktop trunked radio, which is designated "El Paso Out" on the console display. After communicating with the El Paso dispatch supervisor to verify the link was working properly, the Las Cruces dispatcher patched a local police trunked talk group to the "El Paso Out" icon on the console. At this point, a Las Cruces police officer was able to talk directly to the El Paso dispatch supervisor. Once this connection was established and verified, the El Paso dispatch supervisor patched a police trunked talk group to the "Las Cruces In" icon on the dispatcher's console. This created a patch that would allow a Las Cruces police officer to talk directly to an El Paso police officer. This patch was tested and verified to perform as designed.

The next step in the process was to verify that agencies having conventional radios connected to the El Paso and Las Cruces trunked console switches could be patched into the interoperability link between the two cities' systems. With the console-to-console link set up as described in the previous paragraph, the El Paso dispatch supervisor patched the Intercity base station radio into the interoperability link. An El Paso County sheriff's deputy then talked through the trunked system to trunked system patch to the Las Cruces dispatcher. Once this connection was established and verified, the Las Cruces dispatcher patched the Dona Ana County sheriff's office conventional base station to the interoperability link to complete the path from a Dona Ana County sheriff's unit to an El Paso County sheriff's unit. This is the ultimate test of the interoperability solution because it connects two conventional radio users via the two trunked radio systems.

The only significant problem with the CCRFL became apparent when the Las Cruces dispatcher attempted to patch a Dona Ana County sheriff's unit into the CCRFL to El Paso. This problem was unique, because it only occurred when the Las Cruces dispatcher initiated the CCRFL. Only when the El Paso dispatch supervisor initiated the CCRFL was the Dona Ana sheriff's unit able to communicate all the way to the El Paso county sheriff's unit with no problem. A Las Cruces trunked talk group user, such as the police department, could talk directly to the El Paso County sheriff's unit, but the Dona Ana County sheriff's unit could not. Further investigation revealed that the problem was in the MVRDA console electronics switch. Apparently, the console could not create a working patch between two conventional base stations via the console operator. The console electronics switch addresses both the Dona Ana county

sheriff's base station and the Motorola desktop trunked radio at "A" Mountain as conventional base stations to simplify remote control of each radio via CI cards.

To seek help concerning this problem, the Las Cruces technician contacted the Ericsson Technical Assistance Center (TAC). After discussing the problem, the TAC technician instructed the Las Cruces technician to perform a series of tests and report back with the results. Testing revealed that the Las Cruces technician had used the system manager terminal to create a "permanent" patch from the Motorola desktop trunked radio to a "monitor" talk group on the Las Cruces trunked system. He had created this talk group to allow him to monitor the patch performance on his Ericsson portable trunked radio. This permanent patch was removed, and further testing was initiated. When the Las Cruces dispatcher initiated the conventional channel-to-conventional channel patch, the Don Ana County sheriff's unit was then able to talk with the El Paso dispatch supervisor. This was the first time that this scenario had worked when the Las Cruces dispatcher initiated the CCRFL.

Next the El Paso dispatch supervisor attempted to patch the link to the Intercity base station so the El Paso County sheriff's unit could talk directly to the Dona Ana County sheriff's unit. In general, this patch has not always been successful because the Intercity base station located on City Hall has a relatively low antenna height and its coverage footprint is somewhat limited. This Intercity base station does not provide the coverage necessary to support the sheriff department's countywide jurisdiction. The Las Cruces dispatcher was now able to perform the conventional (Dona Ana County sheriff's unit) to conventional (Motorola desktop trunked radio) patch as designed, because the permanent trunked talkgroup-to-conventional channel radio patch had been removed. The desired communication from Dona Ana County sheriff's unit to El Paso County sheriff's unit was established and verified.

To further verify the Las Cruces initiated CCRFL, a trunked talk group was patched into the conventional (Dona Ana County sheriff's unit) to conventional (Motorola desktop trunked radio) patch to create a three-way patch. Further testing verified that this solution worked as designed with the Dona Ana County sheriff's unit, the El Paso County sheriff's unit, and the Las Cruces trunked unit all capable of communicating with each other over the three-way patch.

The problem with the Las Cruces console electronics switch had occurred because of the permanent conventional-to-trunked talk group patch. Once that patch was removed, and all patches were dynamically assigned by the dispatcher, the solution worked as designed.

5. SYSTEM TRAINING

Smooth and efficient creation and removal of CCRFL patches depend on appropriate dispatch personnel training in setting up and using the patching features of the dispatch consoles. The dispatch center managers for each City must ensure the console operators know how to create, use, and remove the patches necessary to operate the CCRFL interoperability solution. To remain proficient in the use of the CCRFL interoperability solution, each city must provide regular training for its dispatch personnel so they are prepared in times of crisis. If proper training and familiarization are not provided, the dispatch personnel operating the CCRFL, may not be able to accomplish patching procedures in a timely manner, directly impacting emergency incident response

6. CONCLUSIONS AND OBSERVATIONS

This interoperability pilot project has provided a very useful communications enhancement for the cities of Las Cruces, New Mexico, and El Paso, Texas, as well as the counties of Dona Ana and El Paso. During the course of the project, many challenges were addressed by the IPT. The coordination and cooperation of the participating agencies were key in producing a practical and effective interoperability solution allowing wireless communications between the users of two disparate trunked radio systems. Listed below are some of the key lessons learned from this pilot project:

- The IPT must reach consensus on the configuration for an interoperability solution that will best meet the needs of the various participating agencies.

- The lower capital costs of a wireless solution will typically be preferred to the higher recurring costs of leased wireline solutions, if the distance covered by the wireless link is within certain engineering parameters.

- Development and execution of an Interlocal Agreement (IA) or Memorandum of Understanding (MOU) early in the pilot project is essential to obtain buy-in from all affected agencies and to ensure project continuity in the event of personnel turnover.

- To obtain buy-in from all affected stakeholders, the IPT should make personal contact with all affected agencies, including service and installation personnel. This process is key to the success of the project.

- Public safety agency mission requirements often dictate that priorities be reassessed on a daily basis. Technical support personnel can not always immediately respond to pilot project initiatives due to higher priority responsibilities. Proactive communication between the IPT members and local support staff, to identify additional resource requirements, can help alleviate challenges associated with conflicting priorities. In the end, patience and persistence is key to the success of the pilot project.

- The IPT is the driving force behind the successful completion of the project. IPT members should regularly monitor project progress and identify additional technical support, as required, when project requirements exceed the expertise of on-site technical staff. This may include identifying available technical training courses, or inviting subject matter experts to assist in moving the project forward.

- The IPT must regularly monitor project progress to ensure interoperability needs are satisfied by the proposed solution. Since most interoperability solutions are comprised of a technical component as well as an intergovernmental agreement component, the IPT must consist of the appropriate blend of technical and management personnel to ensure the success of the project.

- Personnel from public safety agencies may not be able to attend IPT meetings on a regular basis due to higher mission priorities. The IPT, therefore, must keep accurate notes and generate detailed meeting minutes for all IPT members to ensure the entire project team is informed of project status and other developments.

- Often, the technical solution to an interoperability challenge is easier to address than the intergovernmental aspects of the given situation. Sensitivity to local, state, federal, and tribal agency needs is paramount to project success.

- In this particular pilot project, an Intercity VHF base station was used to complete the link between the City of El Paso and the El Paso County Sheriff's Department. This base station must have "carrier squelch" to allow all agencies with that particular frequency access to the base station. Without tone-coded squelch, the base station receiver will open for all signals it can detect, even noise bursts. For this reason, many dispatchers will mute or greatly reduce the audio from such a base station, which could make it unusable in many situations. Dispatcher training in the use of the Intercity base station is critical to its successful use as part of the interoperability solution.

- When adding a desktop trunked radio to an existing trunked radio site, care must be taken to keep the desktop trunked radio from causing interference with the existing trunked radio system. Frequency analyses, antenna spacing, the physical location of the desktop radio, output power, and the quality of the antenna coaxial cable are all key considerations when designing the radio frequency link for the trunked radio sites.

- The IPT must verify that the list of required components to implement the interoperability solution is complete prior to accomplishing the site survey. The site survey should be used to verify all identified components would function as designed when installed at the existing site. The site survey also provides the data needed to do the final design of the interoperability solution. Available rack mounting space, antenna tower mounting space, heating and conditioning capacity, AC power capacity, UPS capacity, and backup generator capacity are examples of information that should be gathered on site surveys.

- The IPT must conduct an on-going dialogue with the pilot project's participating agencies and associated support staff. If mission requirements or other routine responsibilities appear to be causing delays in project progress, it is incumbent on the IPT to maintain project momentum by exploring options such as subcontracting small portions of work to local service shops to facilitate stalled project activities. Agreements must be established early on in the pilot test process relative to how this, or other like options, would be addressed as the needs arise.

- The IPT must ensure that all of the interoperability equipment is powered by an Uninterruptible Power Supply (UPS). It is possible that the crisis precipitating use of the interoperability solution may also cause a power outage. Examples of this

scenario could include severe weather, large-scale accidents like plane crashes, or freeway pileups. The Motorola desktop trunked radio installed at the "A" Mountain site was originally plugged into non-UPS power supply. When power returned, the radio would not power up because the "ON" button had to be manually toggled to restore normal operation. Without UPS power, the radio would also be off the air during the time it would take for the generator to start up and stabilize.

- This interoperability solution has the particular distinction of being put into field use prior to completing system acceptance testing. Recently, the El Paso Police Department was in pursuit of suspected felons. EPPD was following a vehicle believed to be occupied by members of the "Texas 7" as it moved west on I-10 from El Paso to Las Cruces. Quick-thinking dispatch supervisors at 911 N. Raynor, in El Paso, requested a patch be set up between the El Paso and Las Cruces trunking systems using the CCRFL. By working closely with Dona Ana County sheriff's deputies, and the Las Cruces Police Department, the El Paso officers were able to stay in radio contact with the El Paso police dispatchers while continuing to track the suspected felons through Las Cruces, and beyond, on I-25 North.

APPENDIX A—ACRONYMS

AC	Alternating Current
AGL	Above Ground Level
BIM	Base Interface Module
CCRFL	Console to Console Radio Frequency Link
CEB	Console Electronics Bank
CES	Console Electronics Switch
CI	Conventional Interface
COTS	Commercial Off The Shelf
DS-0	Digital data service @ 64 kilobits per second
EDACS	Enhanced Digital Access and Control System
EMS	Emergency Medical Services
GHz	Gigahertz
Hz	Hertz
IA	Interlocal Agreement
IPT	Integrated Program Team
LMR	Land Mobile Radio
MHz	Megahertz
MOU	Memorandum of Understanding
MVRDA	Mesilla Valley Regional Dispatch Authority
PMO	Program Management Office
PSWN	Public Safety Wireless Network
RF	Radio Frequency
SWR	Standing Wave Ratio
T-1	Digital data service @ 1.544 megabits per second
TBIM	Trunked Base Interface Module
UPS	Uninterruptible Power Source
VHF	Very High Frequency