A program of the National Institute of Justice

Secure Communications Interoperability Operational Evaluation Interim Report

Advanced Generation of Interoperability for Law Enforcement (AGILE)

Report No. TE-02-01

May 24, 2002

National Law Enforcement and Corrections Technology Center—Northeast (NLECTC-NE)
Rome, NY 13441

This project is supported by multiple Interagency Agreements that include 99-IJ-R-034 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. Findings and conclusions of the research reported here are those of the authors and do not reflect the official position or policies of the U.S. Department of Justice. Use of products cited in this report does not represent product approval or endorsement by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. This project was supported by the National Law Enforcement and Corrections Technology Center—Northeast (NLECTC-NE). L-3 Communications Analytics, Incorporated provides technical support under contract to the NLECTC-NE.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

This Operational Evaluation Interim Report describes the assembly and deployment of a communications interoperability capability designed for use in situations in which communications interoperability is required in conjunction with secure communications. The focus of this report is on a project conducted with the Syracuse, New York, Police Department, using an ACU-1000 Intelligent Interconnect System. This capability has been deployed by the Syracuse Police Department (SPD) and provides an interfaced between the existing communications infrastructure of SPD and other law enforcement and public safety agencies in the Syracuse region. The resulting communications interoperability capability allows direct voice over-the-air radio communications among multiple law enforcement agencies, which utilize diverse radio systems operating in different frequency bands and different encryption schemes.

1.1 AGILE Test and Evaluation Initiative

This communications interoperability operational evaluation is part of the AGILE program. The AGILE program is a major commitment by the National Institute of Justice (NIJ) to address the issues of interoperability that hamper effective and efficient cooperation among multiple law enforcement and other public safety agencies. Interoperability issues appear in various ways: communications systems which cannot support inter-agency communications, information that is not accessible by all agencies who need it, and open case and suspect information maintained by one agency that is unknown by other agencies working on related cases. The AGILE program is a broad-based set of activities to address the varied aspects of the interoperability challenge, organized into three major thrust areas:

1) Research, development, test, and evaluation (RDT&E);
2) Standards identification, development, and adoption; and
3) Outreach and technical assistance.

A key component of the AGILE RDT&E thrust area is a set of Operational Evaluations. The objective of an operational evaluation is to integrate, test, and evaluate technologies that can contribute to addressing interoperability needs in a public safety environment. Operational evaluations focus on specific technology solutions to focused requirements, but include not only evaluation of the technology itself, but suitability for meeting the requirements, usability and utility, and technology support issues such as policies and procedures, training, and organization. Information collected from an Operational Evaluation includes: the operational requirements that the technology is to meet; a description of the solution in sufficient detail that other practitioners can replicate it; a qualitative evaluation of the impact of the technology on operations and the requirements; and lessons learned/best practices. Technical and systems engineering support for this effort is provided by the National Law Enforcement and Corrections Technology Center—Northeast (NLECTC-NE) (www.justnet.org/nlectcne).

1.2 Scope of this Document

This Operational Evaluation Interim Report describes the activities and results of the Operational Evaluation conducted with the Syracuse Police Department and the other participating agencies (Onondaga County Sheriff's Department, New York State Police). It is intended to provide examples of how communications interoperability can enhance law enforcement and public safety operations, provide a "blueprint" of a particular interoperability solution that can be replicated by other agencies, and document best practices and lessons learned for potential users. This report is an interim report documenting results to date. A final version of this report, including comparison of this approach to secure communications interoperability and other approaches, and including additional operational results, will be released at a later date.

1.3 Document Overview

The remainder of this document is divided into five sections. A summary of the requirements that led to the initial system deployment is outlined in Section 2. Section 3 includes a description of the ACU-1000 configuration integrated for this application. The results of the operational evaluation are documented in Section 4, and conclusions are presented in Section 5. In addition, there is one Appendix that includes a description of the original configuration of the system. The radios originally selected for use were replaced as funding became available; however, some design information for the original configuration may be of interest and is included in this Appendix.

1.4 References

1. *ACU-1000 Installation and Operation Manual*, Revision 2.1, October 1999, by JPS Communications, Inc., Raleigh NC.

2. Equipment manuals for each radio model (MCS™ 2000).

3. *Operational Test Bed—Alexandria Communications Interoperability Gateway Subsystem Description Document*, AGILE Report No. TE-00-01.

2. SECURE COMMUNICATIONS INTEROPERABILITY REQUIREMENTS

The steady increase in the demand for public safety service in recent years is motivating law enforcement agencies to increasingly cooperate across Federal, State and local boundaries. Such cooperation ranges from incident response to task force operations. A key element of the success of such operations is communications among participants. However, such communications are difficult at best among agencies that have radio systems operating in different frequency bands, or operating within the same frequency band but using incompatible modulation formats or trunking techniques that defeat interoperability. The inability of officers from different agencies that have incompatible radio systems to communicate leads to inefficient allocation of resources, inability to coordinate multi-agency activities effectively, and in the worst case, can compromise officer and public safety.

This situation is particularly true in situations in which communications must be secure to ensure officer safety and operation success. For State and local agencies, examples of such situations include counter-narcotics task forces and undercover operations.

The purpose of this section is to document the interoperability requirements and existing capabilities for interagency communications among public safety agencies in the Syracuse region. The primary application is in support of Weed and Seed operations, as discussed in Section 2.1. Deployment of a communications interoperability capability has potential to support other multi-agency communications requirements as well, which are outlined as secondary applications in Section 2.2.

2.1 Primary Applications

Part of the Weed and Seed operations in the city of Syracuse involve focused campaigns on drug dealers and other criminal enterprises. Typically, these operations involve some combination of the following agencies:

- Syracuse Police Department (SPD) Special Investigation Division (SID);
- New York State Police (NYSP) Community Narcotics Enforcement Team (CNET);
- Onondaga County Sheriff's Department;
- Federal Bureau of Investigation (FBI)
- Drug Enforcement Agency (DEA); and
- Bureau of Alcohol, Tobacco, and Firearms (BATF).

Often these operations involve officers and agents from multiple agencies working together in undercover investigations. These activities are characterized by encrypted communication over a relatively limited geographic area. In many cases, an unmarked vehicle is stationed in the vicinity to support communications and surveillance equipment. Surveillance and support teams typically carry portable radios, although a surveillance team could also be located in vehicles equipped with mobile radios.

The SPD radio system includes a channel dedicated for SID operations, and this channel is typically used for the Weed and Seed operations. Since only a single channel is used, to provide a means to communicate among participants, either agents of other agencies operate with SPD officers, or SPD portable radios are distributed to personnel from the other agencies. No means exists to directly interface the radio systems of the participating agencies with the SPD SID channel.

Investigation operations are limited by the lack of communications among the radio systems of the participating agencies. First, the operations are limited by the number of "spare" radios that can be provided by the SPD to other participating agencies. Second, officers must have two radios, one to communicate with other participants in the operation and one to communicate with their own agency. Three, additional SPD effort is required to round up, distribute, and collect the radios that are provided to other agencies.

To address these issues, a communications interoperability capability is required that provides the following capabilities/characteristics:

- Provides a means to link VHF (encrypted) and UHF (encrypted) radios, with different encryption schemes (Transcrypt®, DVP®, etc.).
- Does not impact the intelligibility of voice transmissions.
- Does not introduce a significant delay in voice retransmission.
- Uses the existing radio system infrastructure (repeaters, etc.).
- Mobile—can be deployed in a vehicle.

In addition to investigative operations, the conclusion of a Weed and Seed operation is typically marked by a roundup of suspects that are the subjects of the operation. The same agencies as listed above are also involved in roundup operations, although it is typically the uniformed divisions that are responsible for making arrests. In addition, the U.S. Marshal's Service may be involved in the transport of prisoners. Simultaneous execution is an important component of such operations, emphasizing the need for communications among the participating agencies. In addition to the area where suspects are being apprehended, a roundup operation also requires officers to transport suspects to the public safety facility in downtown Syracuse; thus the geographic extent of such an operation can extend to over half of the area of the city itself. Since roundup operations typically involve uniformed personnel, encrypted communications is generally not required.

2.2 Secondary Applications

In the course of analyzing the communications issues associated with the Weed and Seed operations as described above, additional multi-agency scenarios were identified. These scenarios involve the Syracuse Police Department and (in some cases) the agencies identified in Section 2.1, but also can involve other agencies that are not participants in the Weed and Seed program.

In this section, we document these scenarios and applications to capture the full scope of the interoperability needs in the Syracuse region. These applications represent potential for future expansion of the interoperability capabilities described in Section 3.

2.2.1 Event Management

The SPD is responsible for ensuring public safety at a number of events that occur in the city of Syracuse. SPD coordinates with other agencies to handle major events, such as, but not limited to:

1. Syracuse University sporting events and other events at the Carrier Dome;
2. Syracuse Crunch hockey games;
3. The air show at Hancock Airport (includes the Department of Public Works);
4. St. Patrick's Day Parade; and
5. Fireworks at the baseball stadium (includes City and county Fire Departments and the County Parks Police).

While by no means complete, this list provides representative examples of the types of events and the variety of public safety organizations with which the SPD must interface, including the Onondaga County Sheriff's Department, Syracuse University Security, the Syracuse Fire Department, the Department of Public Works, the Onondaga County Parks Police, and County Fire Departments.

For these specific events, a command center is often established with incident commander and representatives of other participating agencies. The center does not provide direct officer-to-officer communication, but facilitates interagency coordination by co-locating agency representatives at the command center.

It is also currently feasible to create a communications path from one agency's officers to another using a communications patch at the 911 Center. This capability can support pre-planned events.

2.2.2 Mutual Aid

On occasion, another agency will pursue a vehicle into the city of Syracuse. Communications between agency officers and SPD officers is useful to inform them of the status of the pursuit and coordinate any assistance that may be required.

Syracuse has jurisdiction over some areas that are surrounded on three sides by the county jurisdiction, the Onondaga County Sheriffs Department (OCSD). On occasion, the closest unit that can respond to an incident is from an agency in the neighboring jurisdiction. Direct communication among responding units is necessary to coordinate the most efficient response to such incidents. For example, a robbery occurred in a shopping mall that was on the city border. Since the bank was outside the city boundary, the call went to the OCSD. The city police car that sat at the other end of the shopping center never knew about the robbery. In another situation, a shooting occurred in an area of the city in which the closest city responder needed to get through significant downtown traffic. OCSD patrols were much closer geographically and with less intervening traffic, but could not be notified in a timely manner to coordinate a response. While a patch through the 911 Center is capable of linking different departments, current procedures require several minutes for the execution of a request to patch one agency through to another. Thus, it is not an effective means of providing a rapid response for scenarios such as vehicle pursuit incidents described above.

2.2.3 Coverage Extension

Another potential application of the interoperability capability, if deployed in a mobile mode, would be to provide support area coverage extension. Syracuse Police Department officers are occasionally involved in activities outside the city. These locations can include area such as Oswego and Cortland, which are beyond the designed range of the SPD land mobile radio system. In some cases, it is necessary for an officer to drive back towards Syracuse to maintain radio contact with the SPD dispatch.

The only capability currently available to provide coverage extension is a mobile repeater.

3. SYRACUSE UNIT SYSTEM DESCRIPTION

Based on the requirements documented in Section 2, a secure interoperative communications capability was integrated by the NLECTC-NE and deployed by the Syracuse Police Department. This system consists of radios, an ACU-1000 Intelligent Interconnect System, a power distribution system, and the cabling necessary to connect these components. The system is mounted in a 19-inch rack contained in a hard polyurethane shell. In addition, a PC-based Graphical User Interface (GUI), loaded on a laptop computer, can be used to control the ACU-1000. We refer to this hardware/software system as the Interoperability Unit.

The approach to achieving interoperability is shown in Figure 1. The two hexagons at the top of the figure represent the radio systems belonging to Syracuse Police Department (operating at UHF) and the Onondaga County Sheriff's Department (operating at VHF). Each system includes at least one repeater to provide coverage throughout that agency's jurisdiction. The different colors of the hexagons signify the different frequency bands at which each radio system operates. There are four radios mounted within the unit: two VHF radios and two UHF radios. The radios can be linked to SPD or OCSD or other agencies as needed (such as the New York State Police). There are two unused Radio Interface modules in the unit that can be used to interconnects additional radios if needed for a particular operation. The white boxes within the Radio box in the diagram represent these interfaces. The radios can operate at whatever band is required (800 MHz, UHF, VHF, etc.).

Each radio system being inter-connected through the ACU-1000 is interfaced to a Radio Interface module (shown in blue). The interface modules break the communications traffic into its essential elements: receive and transmit audio, and non-proprietary and/or industry-standard accessory port control signals (required to control the device to which the module is interfacing).

Consider a scenario in which a connection is established between channels of the SPD and the OCSD. A transmission from an SPD officer is picked up by the SPD repeater and broadcast to all SPD units. The Interoperability Unit also receives it simultaneously. The audio is then distributed through the ACU-1000, and then rebroadcast on the frequencies of the OCSD. The OCSD repeater site receives the transmission and in-tern re-broadcasts out to the individual radios of the OCSD.

In cases where secure (encrypted) communications is employed, the transmission from radio to repeater to radio attached to the Interoperability Unit is encrypted. The radio attached to the ACU-1000 decrypts the transmission and routes clear audio through the ACU-1000 backplane to the other agencies radio. The audio is then re-encrypted by the second agencies radio, re-transmitted through the second system's repeater to the receiving unit (which decrypts the signal for the user).

A connection can also include a telephone. Connections can be made between two or more systems. In addition to two-way connections between radios, the Interoperability Unit can simultaneously connect all interfaces (radios and telephone) to provide a conference call capability that can be used during multi-jurisdictional incidents. Connections are established & disconnected as needed. Under normal circumstances, when interoperability is not required, agency radio systems work independently.

Software to control the unit includes an intuitive user interface to connect and disconnect the radios integrated into the unit. While operating the unit, voice prompts provide users audible instructions for making/breaking connections. Setting up connections can be done remotely using standard DTMF tones (from a telephone or radio with DTMF keypad). Local control is provided via the operator interface module, or via the software interface program running on a Microsoft® Windows based PC.

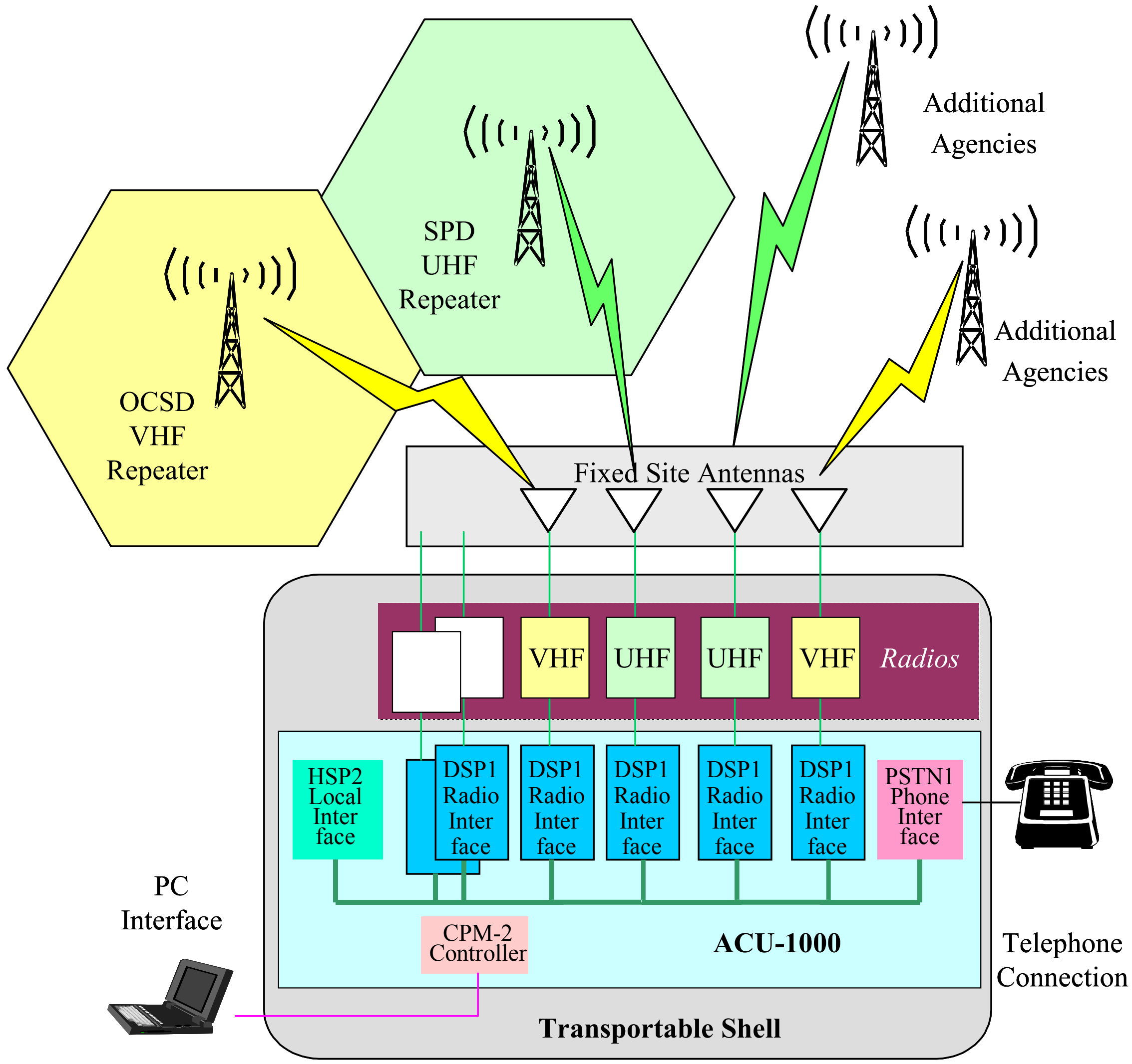


Figure 1: Secure Comm. Interoperability Architecture

The antennas used at the unit's base station are mounted on roof of SID building and linked by coax cable to the unit. While being deployed remotely the police van, the antennas are magnetically mounted on the van's roof. The radios and ACU-1000 are mounted in a mobile shell located at the SID building as a base, but can be loaded into a mobile van to be quickly deployed to a remote operations location. The radios are programmed with frequencies licensed to the participating agencies.

3.1 Equipment Rack

The radios and ACU-1000 are enclosed in a ruggedized polyurethane case with mounted wheels so the unit can be easily moved when not in the van. The unit also has matching attachable front and rear covers to protect the equipment from damage during transit or prolonged storage. A schematic of the layout of the rack as installed is depicted in Figure 2. The completed unit is pictured in Figures 3a and 3b. Table 1 list the major components mounted in the ruggedized plastic case.

Table 1: Major Components

MAJOR COMPONENTS
ACU-1000 Interconnect System
Motorola MCS 2000™ UHF Radio (Syracuse PD)
Motorola MCS 2000™ UHF Radio (Syracuse PD)
Motorola MCS 2000™ VHF Radio (Onondaga County Sheriff's Department)
Motorola MCS 2000™ VHF Radio (Onondaga County Sheriff's Department)
External Accessory Interface Panel
AC/DC Power Panel
DC Power Supply #1
DC Power Supply #2
AC Power Strip Panel

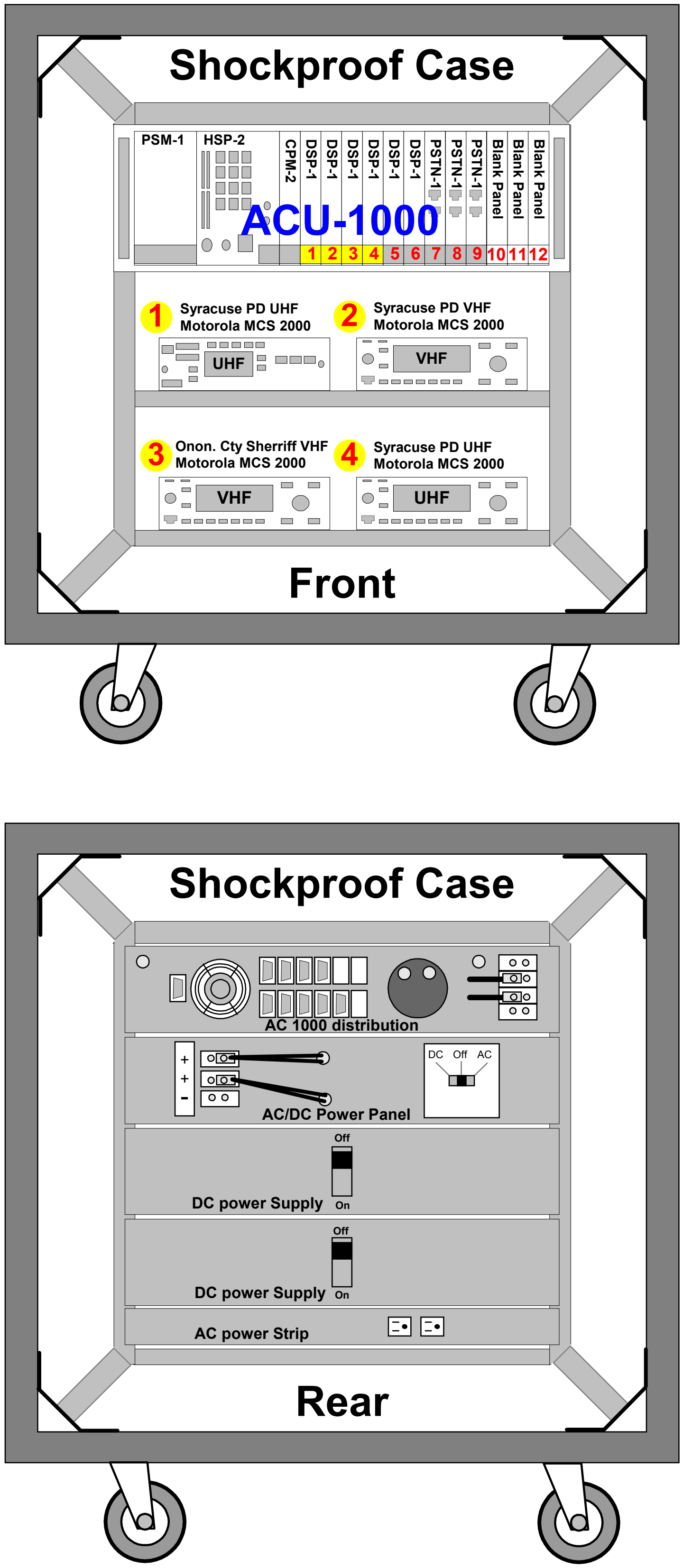


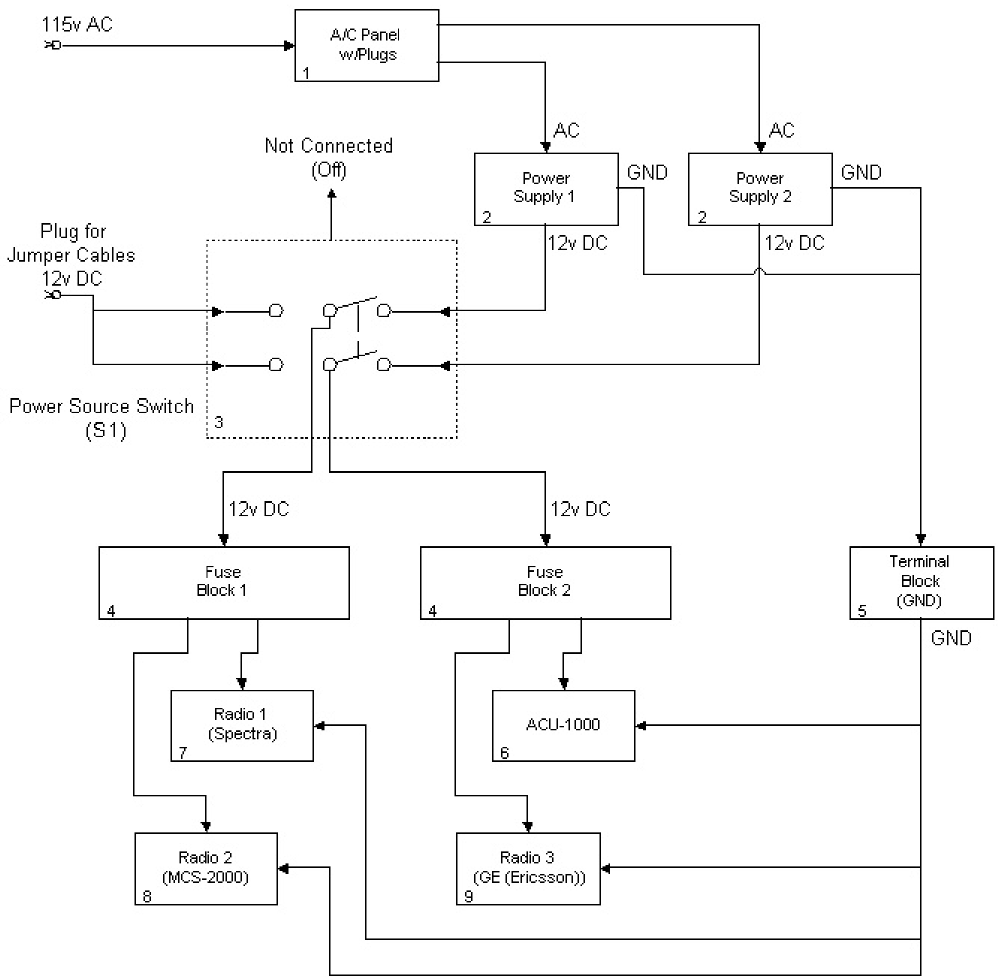
Figure 2: Drawing of Front/Rear view of Syracuse Interoperability Unit

Figure 3a: Front Picture of Syracuse Interoperability Unit

Figure 3b: Rear Picture of Syracuse Interoperability Unit

3.2 Power Distribution

The Interoperability Unit is designed powered via standard 115v AC, or from 12v DC pulled from any DC source such as a car battery. The unit includes a jumper cable/plug setup so while the unit is at a remote location, and standard 115v AC power is not available, the unit can be powered from a standard automotive battery. Figure 4 shows the unit power distribution in Syracuse.



POWER DISTRIBUTION PARTS LIST

No.	Part Make/Model No.	Qty
1	AC Power distribution panel	1
2	DuraComm RM -5012 AC -DC Power Supply	2
3	3 position DPDT Power Source Switch	1
4	Fused Power (+12v) distribution block	2
5	Unfused Ground distribution block	1
6	JPS Communications ACU -1000 Interconnect Module	1
7	Motorola Spectra Radio	1
8	Motorla MCS -2000 Radio	1
9	GE (Ericsson) Trunk Mount Radio	1

Figure 4: Syracuse Unit Power Distribution

3.3 Equipment Cooling Requirements

The unit is designed so that, when it is in use, both end covers should be removed. This will allow for the maximum airflow around the unit to cool the equipment. If need be, there is a small fan on the rear of the unit that can be activated to increase the airflow through the unit.

3.4 Computer

The computer used to run the ACU-1000 in the Interoperability Unit met the minimum ACU software requirements as follows:

- Operating System – Windows® 95/98/ME or NT
- Video card/display – supports either 800x600, 1024x768, or 1280x1024
- RAM – 64 MB
- Drive space – 12 MB (16 MB recommended)
- ACU interface – dedicated serial port
- Human interface – mouse, keyboard or touch screen

Note: For mobile applications where the ACU-1000 and computer will be operated in rugged or extreme conditions a Panasonic CF-28 Toughbook® notebook computer or equivalent should be considered. Ruggedized computers are designed to handle the rough handling and abuse that can take place when in a remote environment.

3.5 Radio Equipment

For initial operations, the Interoperability Unit includes four radios (two as designated spares) in two main frequency bands (VHF, UHF). The radios are programmed with frequencies corresponding to the channels of systems belonging to the participating agencies. Motorola MCS 2000™ Type II UHF radios are programmed with Syracuse Police Department channels. Motorola MCS 2000™ VHF radios are programmed with the Onondaga County Sheriff's Department channels and New York State Police channels. Additional channels can be programmed into the radios, and additional radios can be added as needed to accommodate other agencies. The radios currently installed are listed in Table 2.

Table 2: Radio Equipment

Radio Model	Frequency Band	Power Output
Motorola MCS 2000™ Type II	VHF	25W
Motorola MCS 2000™ Type II	UHF	20W

3.6 ACU-1000

The ACU-1000 system consists of a card cage, radio, telephone, and control interface modules, a power supply, and audio input/output modules. Individual modules are described in the following subsections, and the system configuration is summarized in Table 3.

3.6.1 Chassis and Backplane

The Chassis is a 19” wide EIA standard rack-mounted 3U Eurocard cage (5.25” tall, 11” deep) equipped with a backplane board into which the modules are plugged. An AC input module and power transformer assembly is located on a metal panel that is mounted to the backplane. The AC module is a combination AC line filter, power cable connector, input voltage selector, and fuse holder. The backplane provides internal 60-pin card edge connectors for the plug-in modules and D-subminiature connectors for external interfaces. The backplane includes a 16-line audio bus, 8-bit digital bus, and serial control bus.

3.6.2 PSM-1 Power Supply Module

This 60W DC power supply plugs into a dedicated slot at the left side of the chassis. It provides +15V unregulated, and +12V, -12V regulated DC. In addition to these voltages, each individual module generates +5V regulated DC from the +15V supply.

Table 3: ACU-1000 Hardware Configuration

Module	Description	Quantity	Hardware Revision	Software Revision
PSM-1	60W Power Supply Module	1	A	N/A
HSP-2	Handset and Speaker Module	1	C	U34 1069-123 105 U4 1069-180 100 U5 1096-1981 400
CPM-2	Control Processor Module (System “Brain”)	1	E	U4 1096-124 117 U5 V62C5181025L
PSTN-1	Interface to Telephone Network	1	C	U8 S/W 1096-201 211
LP-1	Local Phone Module	2		N/A
DSP-1	Digital Signal Processor (Radio Interface)	6	E	U8 S/W 1096-201 203

3.6.3 CPM-2 Control Processor Module

The CPM-2 module controls all other modules within the ACU-1000 system. The CPM-2 constantly polls all installed modules to track their current status via an internal eight-bit data bus. This module arbitrates the audio signals on the backplane, controls tone and voice prompting, and maintains password security. The CPM-2 keeps all system and module configuration parameters in flash memory. An RS-232 serial port supports remote control, programming, and monitoring of all functions within the ACU-1000 via a serially connected computer or console.

3.6.4 HSP-2 Handset/Speaker/Prompt Module

The HSP-2 module provides a means to locally monitor, control, and configure the ACU-1000 system. A local operator can monitor audio via an internal speaker, plug in external headphones, and use the operator handset included with the HSP-2. The handset includes a Push-To-Talk (PTT) switch that must be closed for the operator's voice to be transmitted. Control is via 3x4 DTMF keypad (standard telephone layout) that enables an operator to select a module and enter required control/configuration data. By interfacing to the PSTN-1 module, the operator may place telephone calls manually using the HSP-2 keypad and handset. The HSP-2 module also contains the system voice prompt generator. These voice prompts allow the ACU-1000 system to respond with messages in English that facilitate configuration and operation of the system.

3.6.5 PSTN-1 Telephone Interface Module

The PSTN-1 provides an interface between the ACU-1000 and a telephone network. This capability allows a user to dial a telephone number and place a telephone call from a radio (equipped with a DTMF keypad) or other device connected to the ACU-1000. It contains ring detect and Caller ID for automated system operation. It also provides Voice Operated Xmit (VOX) capability with configurable sensitivity and hang-time, a DTMF receiver/generator for control and call progress recognition. The front panel of the module provides two RJ-11C jacks for two telephones (only one local telephone may be in use at a time). The rear panel contains jacks for connecting one 4-wire telephone and two 2-wire terminals. These are useful when connections via the front panel connectors are not wanted (rear 2-wire terminals are controlled by internal jumpers that are tied to the front panel RJ-11C jacks). A complete discussion of the PSTN-1 module wiring can be found in the *ACU-1000 Installation and Operation Manual* (reference document 1).

3.6.6 Local Phone Module

The LP-1 module provides an interface to the ACU system for 2-wire devices that generate dialing information (such as a standard telephone set or a FAX machine). The module contains a loop current generator, ring voltage generator, dial and busy tone generators, and a DSP hybrid with VOX and a DTMF generator/receiver. In addition to interfacing a telephone, set into the ACU system the module can be used as a telephone "line card" in a mini-PBX system.

3.6.7 DSP-1 Digital Signal Processor Module

The DSP-1 module is a radio interface module. The ACU-1000 system needs one DSP-1 module for each radio employed by the system. This module sends and receives audio over 4-wire connections to/from the radio. Received audio is digitized through an analog to digital converter, and is then processed by the on-board DSP. It performs digital audio processing such as digital equalization, filtering, noise reduction, VOX, audio delay, and other features. The audio processing is user selected via the programmed configuration during set up. Received audio that is processed through the DSP-1, is then routed through the back plane to the appropriate interface modules that have been designated for interconnection by the user.

3.6.8 System Software

High-level system software resides on the CPM-2 and controls all aspects of the ACU-1000's operation. It contains the interface protocol necessary for external computer control and determines various aspects of the operator's interface, including the timing of system voice prompts.

3.6.9 Console Software/Graphical User Interface

Windows-based GUI software runs under Windows© 95 (or higher) on a PC connected to the ACU-1000 installed in the equipment rack. The computer is connected to the CPM-2 module RS-232 serial port via a DB-9 RS-232 Serial Cable. It provides a convenient user interface for configuring and controlling the ACU-1000.

An example of the graphical user interface is shown in Figure 5. In this example, the interface depicts five connections, establishing two different cross-banded nets, within the ACU-1000. The first net inter-connects the equipment rack handset, the PSTN-1 module, the OSD and the NYSP. The second net inter-connects the SID and DEA systems together.

The GUI is designed with five drop down menus that allow the user to navigate the different popup windows until the appropriate option/command is found; note that the + command button has been executed to establish the connection. A complete discussion of the user interface and commands can be found in the *ACU-1000 Installation and Operation Manual* (reference document 1).

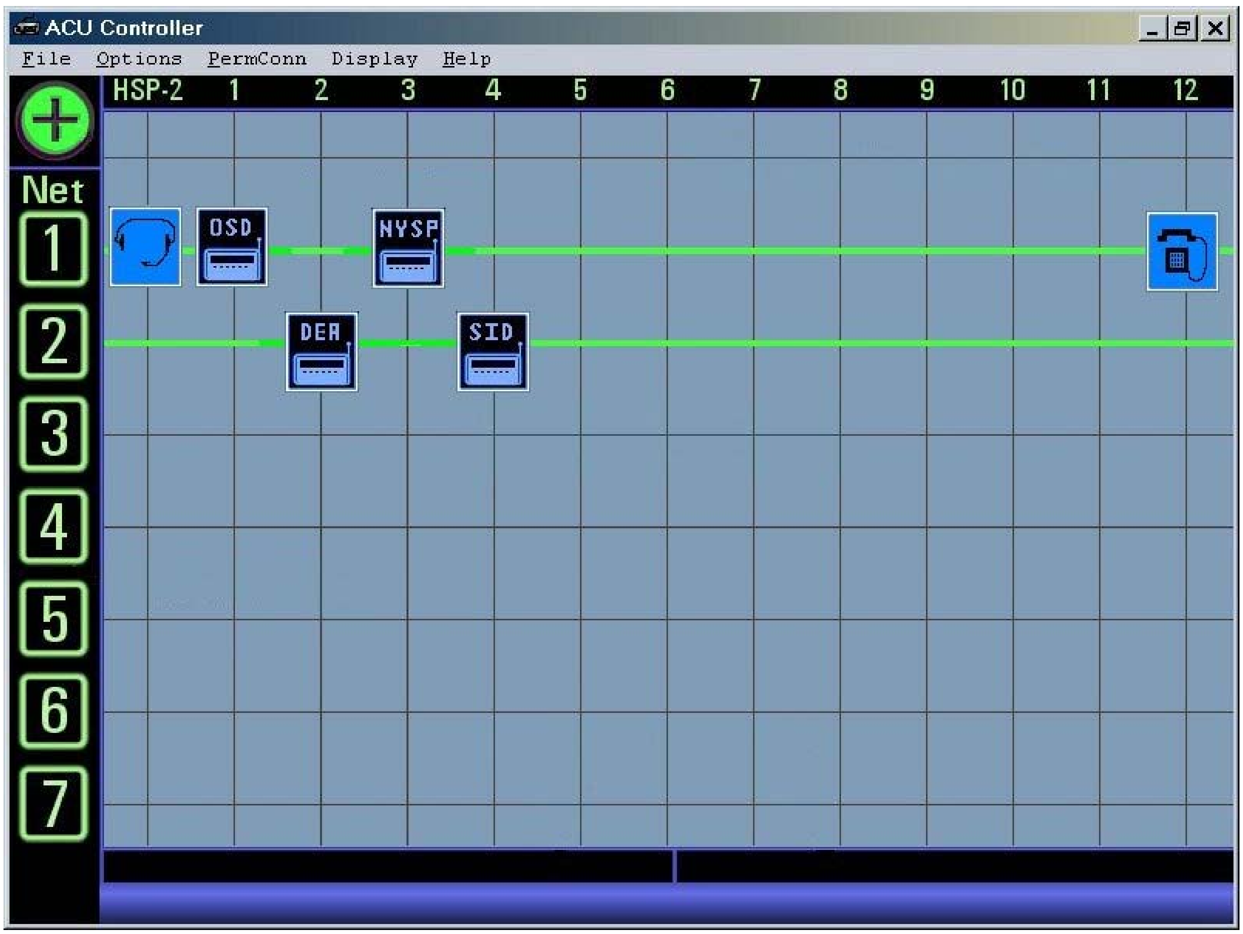


Figure 5: ACU-1000 Operator User Interface

3.7 Radio/ACU-1000 Interface for Radios

Cables were fabricated to connect the radios and the ACU-1000, based on the schematic shown in Figure 6.

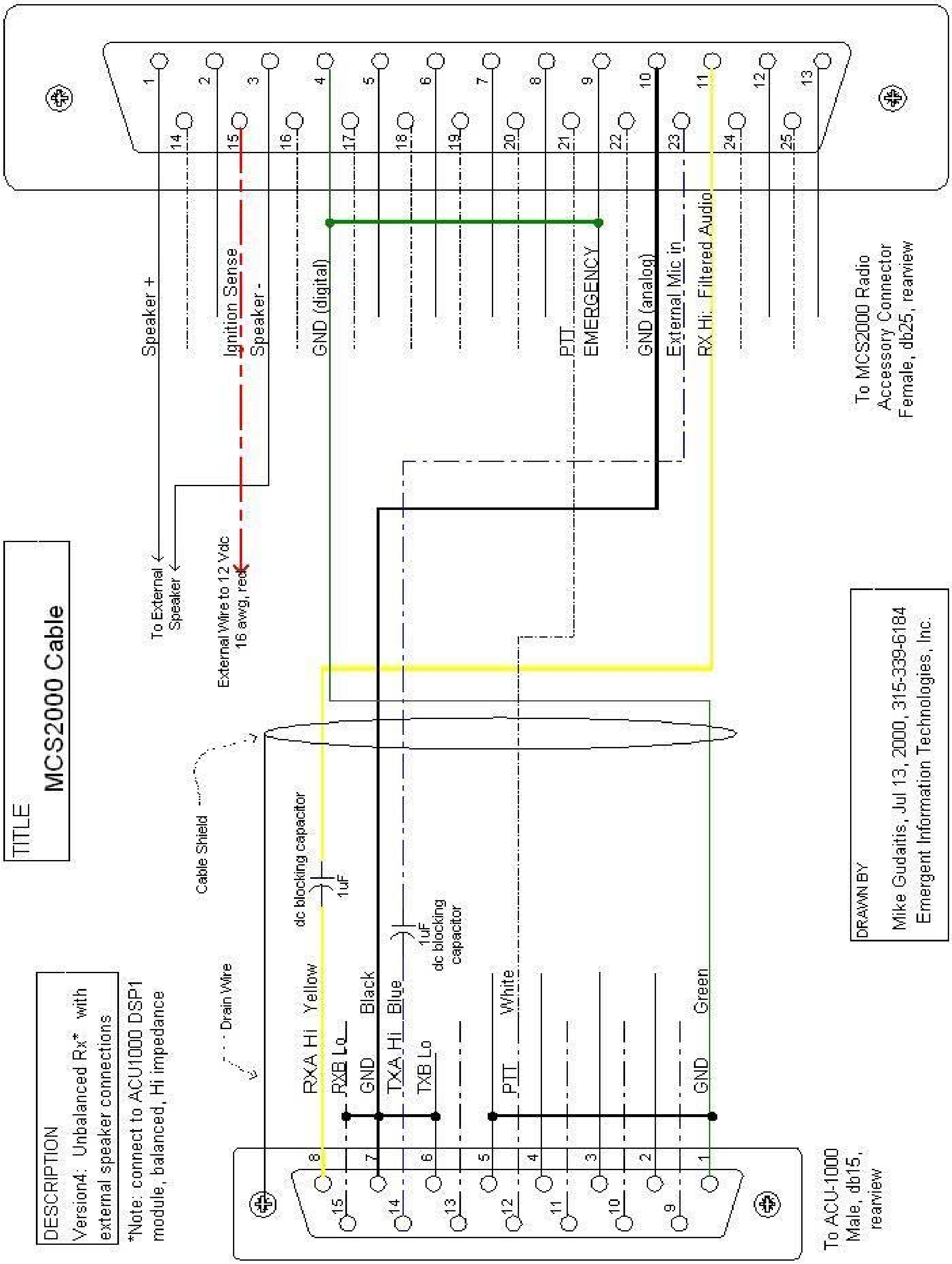


Figure 6: Cable Schematic for MCS 2000™ Radio

4. SYRACUSE OPERATIONAL EVALUATION

The operational evaluation of the Secure Communications Interoperability capability involved several steps. We began with laboratory tests under controlled conditions, followed by testing with the unit configured and deployed as planned for operational use. Each of these tests is described in a subsection that follows. The final subsection (Section 4.3) summarizes some operations in which the unit was deployed and used.

4.1 Laboratory Test

The objective of this lab test was to perform a qualitative assessment of the ACU-1000's ability to successfully crossband (interface) secure radios operating on different frequency bands. The testing was divided in to two functional areas, with multiple test cases in each area. To receive a pass rating during testing, the audio output (speech) had to be understandable with only minor distortion, based on a qualitative assessment. Multiple iterations were executed for each test case, with the exception of secure tests requiring the use of mobile radio 2, which did not have either an encryption or voice scrambler board installed. See Appendix A for additional information on communication security methods.

4.1.1 Radio to Radio Test

Functional area 1 tested the ACU-1000's ability to cross-band portable radios operating in secure mode. The objective of this test was to determine whether the back-to-back encrypt-decrypt-encrypt-decrypt cycle resulted in audio degradation that made transmissions unintelligible. In order to isolate any problems, we began by encrypting only of the two links. Later test cases involved encrypting both links. We did not run a test case with both links unencrypted as this mode had previously been tested in the field and worked well.

Particular attention was given to the ACU-1000's ability to cross-band radios that used different methods to secure the transmission. For test purposes all UHF mobile and portable radios had Motorola's DVP® encryption boards installed and all VHF mobile and portable radios had Transcrypt® voice scrambler boards installed, with the exception of mobile radio 2. Table 4 lists the test cases that were performed in functional area 1 with the results rated as either a pass or fail, (note during testing if all results were identical only one record will be listed).

The laboratory test was conducted during a one-day period. Multiple iterations of each test case were performed in random succession. In an effort to mitigate interference from outside RF sources the test was conducted within the interior of a commercial building with the ACU-1000 and portable radios located in a test area that did not have windows or direct access to the outside environment. The test area was separated from the exterior walls by a surrounding hallway and a suite of offices located on the far side of the hallway. To prevent unwanted interference to local public safety agencies that might be operating in close proximity to the test facility, two each NAT-10, 10 dB 50-ohm attenuators were placed in-line between each mobile radio and its associated antenna. Due to the pass/fail criteria being determined by the ability of a portable radio to process a clear, audible transmission, experienced radio operators were used. Each operator was assigned a specific radio for the duration of the test. Test iterations began by saying a standard test count of testing 1, 2, 3, 3, 2, 1, and then the cycle was repeated. Upon completion of each test a pass/fail rating was assigned. To receive a pass rating, a consensus of agreement that a clear audible transmission had been heard, was determined upon by the staff present. A failure rating was assigned in all other cases.

Table 4: Portable to ACU-1000 to Portable Interface Test

Transmitter (Portable)	ACU-1000 Interface (Mobiles)	Receiver (Portable)	Results (Pass/Fail)
UHF*	(1) UHF* (2) VHF	VHF	**Pass**
UHF*	(4) UHF* (2) VHF	VHF	**Pass**
UHF*	(1) UHF* (3) VHF	VHF	**Pass**
UHF*	(4) UHF* (3) VHF	VHF	**Pass**
VHF*	(2) VHF (1) UHF	UHF	**Not tested****
VHF*	(3) VHF* (1) UHF	UHF	**Pass**
VHF*	(2) VHF (4) UHF	UHF	**Not tested****
VHF*	(3) VHF* (4) UHF	UHF	**Pass**
UHF*	(1) UHF* (2) VHF	VHF*	**Not tested****
UHF*	(4) UHF* (2) VHF	VHF*	**Not tested****
UHF*	(1) UHF* (3) VHF*	VHF*	**Fail*****
UHF*	(4) UHF* (3) VHF*	VHF*	**Fail*****
VHF*	(2) VHF (1) UHF*	UHF*	**Not tested****
VHF*	(3) VHF* (1) UHF*	UHF*	**Pass**
VHF*	(2) VHF (4) UHF*	UHF*	**Not tested****
VHF*	(3) VHF* (4) UHF*	UHF*	**Pass**

* Denotes Radio in secure mode
** Transcrypt® board not installed in radio (2)
*** See Section 4.1.4

4.1.2 <u>Radio to Telephone Test</u>

Functional area 2 tested the ACU-1000s ability to interface a telephone set to a radio net(s) that were operating in a secure mode. Table 5, Table 6 and Table 7 list the test cases performed in functional area 2 with the results rated as either a pass or fail, (note during testing if all results were identical only one record will be listed).

Table 5: Local Phone Module (ACU-1000) to Portable Interface Test

Audio Out (Local Phone Module)	ACU-1000 Interface	Receiver (Portable)	Results (Pass/Fail)
LP-1	LP-1 (1) UHF*	UHF*	**Pass**
LP-1	LP-1 (4) UHF*	UHF*	**Pass**
LP-1	LP-1 (2) VHF	VHF*	**Not tested****
LP-1	LP-1 (3) VHF*	VHF*	**Pass**

* Denotes Radio in secure mode
** Transcrypt® board not installed in radio (2)

Table 6: Portable to Local Phone Module (ACU-1000) Interface Test

Transmitter (Portable)	ACU-1000 Interface	Audio In (Local Phone Module)	Results (Pass/Fail)
LP-1	LP-1 (1) UHF*	UHF*	**Pass**
LP-1	LP-1 (4) UHF*	UHF*	**Pass**
LP-1	LP-1 (2) VHF	VHF*	**Not tested****
LP-1	LP-1 (3) VHF*	VHF*	**Pass**

* Denotes Radio in secure mode
** Transcrypt® board not installed in radio (2)

Table 7: Portable/Local Phone Module/Portable Interface Test

Transmitter (Portable)	ACU-1000 Interface (Mobiles)	Receiver (Portable)	Audio In and Out (Local Phone Module)	Results (Pass/Fail)
UHF*	(1) UHF* (2) VHF	VHF	LP-1	**Pass**
UHF*	(4) UHF* (2) VHF	VHF	LP-1	**Pass**
UHF*	(1) UHF* (3) VHF	VHF	LP-1	**Pass**
UHF*	(4) UHF* (3) VHF	VHF	LP-1	**Pass**
VHF*	(2) VHF (1) UHF	UHF	LP-1	**Not tested****
VHF*	(3) VHF* (1) UHF	UHF	LP-1	**Pass**
VHF*	(2) VHF (4) UHF	UHF	LP-1	**Not tested****
VHF*	(3) VHF* (4) UHF	UHF	LP-1	**Pass**
UHF*	(1) UHF* (2) VHF	VHF*	LP-1	**Not tested****
UHF*	(4) UHF* (2) VHF	VHF*	LP-1	**Not tested****
UHF*	(1) UHF* (3) VHF*	VHF*	LP-1	**Fail*****
UHF*	(4) UHF* (3) VHF*	VHF*	LP-1	**Fail*****
VHF*	(2) VHF (1) UHF*	UHF*	LP-1	**Not tested****
VHF*	(3) VHF* (1) UHF*	UHF*	LP-1	**Pass**
VHF*	(2) VHF (4) UHF*	UHF*	LP-1	**Not tested****
VHF*	(3) VHF* (4) UHF*	UHF*	LP-1	**Pass**

* Denotes Radio in secure mode
** Transcrypt® board not installed in radio (2)
*** See Section 4.1.4

4.1.3 Optimization of ACU-1000 DSP-1 module(s)

During multiple iterations of each test case, the following settings achieved the best audio quality. Note settings listed may or may not give the desired audio quality and should be used as a baseline only. In order to achieve the best quality of audio, each DSP-1 module may require adjustments from baseline as parameters (working conditions) change. Table 8 lists the settings used during the test.

Table 8: DSP-1 Settings

DSP-1 Module Optimization (ACU-1000)	UHF DSP-1 Settings	VHF DSP-1 Settings
Audio EQ	#1	#1
Audio Delay	#6	#6
Sensitivity	max	max
Peaker Value	#3	#3
Tx Level	#4	#4
Rx Level	#3	#3

4.1.4 Retest

The following test cases (Table 9 and Table 10) were retested after it was discovered that the original interface ACU-1000/Radio interface must be modified in order to support a Motorola radio utilizing a Transcrypt® board. Modification should be made in accordance with Motorola reference Volume 1 MCS 2000™ Mobile Radio Service Instructions Pg 7-18 & 7-19. Pin 23 must be changed to pin 13 (see pin diagram) on the cable connecting the VHF radio (3) to the ACU-1000. Pin 23→ A7 or D7 supports Motorola proprietary DVP® only. If Transcrypt® is used for scrambling, (voice inversion) pin 13→B8 must be used (see Figure 7).

Table 9: "Retest" Portable to ACU-1000 to Portable Interface Test

Transmitter (Portable)	ACU-1000 Interface (Mobiles)	Receiver (Portable)	Results (Pass/Fail)
UHF*	(1) UHF* (3) VHF*	VHF*	**Pass**
UHF*	(4) UHF* (3) VHF*	VHF*	**Pass**

* Denotes Radio in secure mode

Table 10: "Retest" Portable/Local Phone Module/Portable Interface Test

Transmitter (Portable)	ACU-1000 Interface (Mobiles)	Receiver (Portable)	Audio In and Out (Local Phone Module)	Results (Pass/Fail)
UHF*	(1) UHF* (3) VHF*	VHF*	LP-1	**Pass**
UHF*	(4) UHF* (3) VHF*	VHF*	LP-1	**Pass**

* Denotes Radio in secure mode

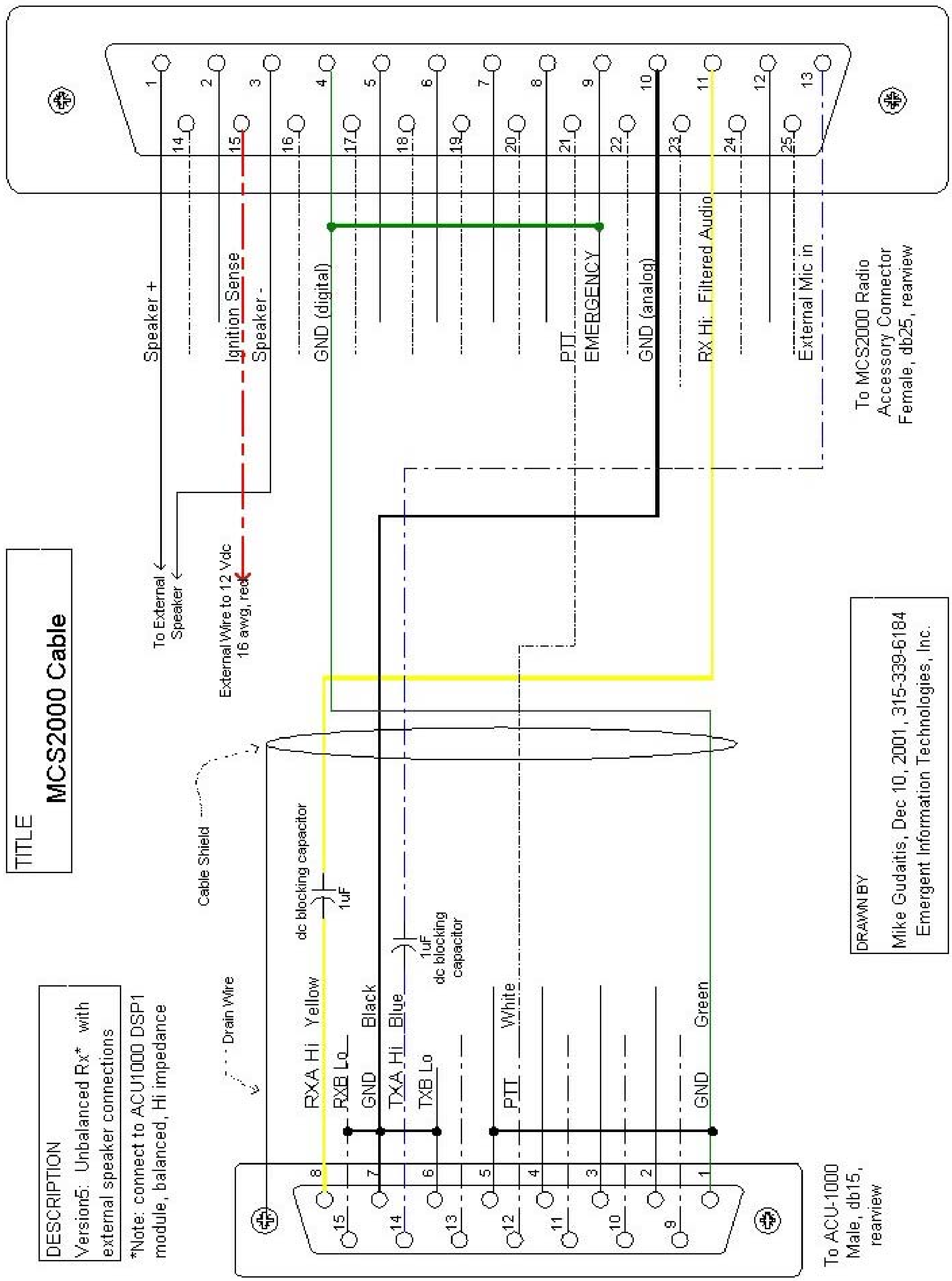


Figure 7: Cable Schematic for MCS 2000™ Radio (Transcrypt®)

4.2 Operational Test

The objective of the operational test was to perform a qualitative assessment of the ACU-1000's ability to successfully cross-band (interconnect) secure radios operating on different frequencies bands while in an operational environment. The test was conducted over a one-day period, with the cooperation of the Syracuse Police Department and the Onondaga County Sheriff's Department. An operational check was performed on equipment prior to the start of the test to minimize the chances of recording a false test result (due to equipment failure). Mobile and portable radios were used as they would be in an actual operation. The Sheriff's Department transmitted and received from various locations up to 15 miles from SPD Special Investigation Division (SID) headquarters. For the purposes of the test, the ACU-1000 was located at SID headquarters and used high quality gain antennas that were installed on the building. Weather conditions the day of the test were overcast (cloudy) with light snow and 30 degrees.

4.2.1 Test Parameters

The operational test demonstrated the ACU-1000's ability to cross-band portable radios operating in secure modes, in an operational environment. Particular attention was given to the ACU-1000's ability to cross-band radios that employ different encryption methods to secure the transmission. As with the laboratory test, initial cases used only one encrypted link to isolate any problems prior to encrypting both links. For test purposes, all UHF mobile/portable radios had Motorola's DVP® encryption boards installed, and all VHF mobile/portable radios had Transcrypt® voice scrambler boards installed. To qualify for a passing score while being tested, the audio output (speech) had to be understandable with only minor distortion. Multiple iterations were completed for each test case. Table 11 lists the test cases that were performed during the operational test, with the results rated as either a pass or fail (note if during testing, multiple results were identical only one record will be listed).

Table 11: Portable to ACU-1000 to Portable Interface Test

Transmitter (Portable)	ACU-1000 Interface (Mobiles)	Receiver (Portable)	Results (Pass/Fail)
UHF*	(1) UHF* (3) VHF	VHF	**Pass**
UHF*	(1) UHF* (3) VHF*	VHF*	**Pass**
VHF*	(3) VHF* (1) UHF	UHF	**Pass**
VHF*	(3) VHF* (1) UHF*	UHF*	**Pass**
UHF*	(1) UHF* (3) VHF	VHF	**Pass****
UHF*	(1) UHF* (3) VHF*	VHF*	**Pass****
VHF*	(3) VHF* (1) UHF	UHF	**Pass****
VHF*	(3) VHF* (1) UHF*	UHF*	**Pass****

* Denotes Radio in secure mode
** UHF Repeater used (noticeable delay going through repeater)

4.2.2 Optimization of ACU-1000 DSP-1 module(s)

During the multiple iterations of each test case, the following setting achieved the best audio quality. Note settings listed may or may not give the desired audio quality and should be used as a base line only. In order to achieve the best quality of audio each DSP-1 module may require adjusting as parameters (working conditions) change. Table 12 lists the settings used during testing.

Table 12: DSP-1 Settings

DSP-1 Module Optimization (ACU-1000)	DSP-1 Settings for SPD UHF Radio	DSP-1 Settings for OCSD VHF Radio
COR	-	-
DTMF	√	√
Mute When Squelched	√	√
Conference	√	√
DTMF	-	-
VMR (squelch type)	√	√
Active Low (cor)	√	√
Half (duplex)	√	√
PTT (priority)	√	√
RX Level	6	4
TX Level	0	0
SEC Level	0	0
DTMF	0	0
High Freq	0	0
RX Audio Delay	9	7
Radio Type	0	0
Noise Reduction Value	0	0
VOX/VMR Threshold	1	2
VOX/VMR Hang time	3	2
TX Keying Tones	0	0
Keying Tone Amplitude	1	1
COR Sampling Initial Delay	4	4
COR Sampling Width	2	2
COR Initial Time after PTT	3	3
Voice Prompt Delay	2	2

4.3 Operational Deployments

The Interoperability Unit has been deployed to support a number of operations to date. While none of the exercises has fully utilized the encryption capability, the deployments have been uniformly successful and represent a number of different operational scenarios in which interoperability among agencies can greatly enhance the capabilities of law enforcement and public safety agencies.

4.3.1 Ultimate Fishing Challenge

Drawing over 60,000 people over a three-day weekend in early August 2001, the Ultimate Fishing Challenge held at Onondaga Lake in Syracuse, New York, proved to be a tremendous success for the participants and organizers. With an event this large, local law enforcement officials had their own challenge—coordinating communications among several agencies that were responsible for ensuring public safety during the event. These agencies included the Syracuse Police Department, the Onondaga County Sheriff's Department, the New York State Police, the New York State Emergency Management Office, and local fire and rescue units. Both the New York State Police and the Onondaga County Sheriff's Department deployed helicopters over the lake to keep a watchful eye on the thousands of participants and spectators. The communications challenge stemmed from the fact that the departments were operating on a variety of frequency bands, including VHF, UHF, and 800 MHz.

The Interoperability Unit was installed at the temporary command center established in a fire department located north of the lake, as shown in Figure 8. During the first day's events, the ACU-1000 performed as expected. However, once the State Police's helicopter was airborne, the rotary blades interfered with the clarity of the communications. With a few minor adjustments to the settings in the ACU-1000, that problem was rectified. The unit worked well and was a key element in the ability of agencies to coordinate activities.

4.3.2 Traffic Management

Several hundred fireman, from throughout the Northeastern U.S., attended funeral services for two firemen who died while fighting a house fire in suburban Syracuse. The Syracuse PD, Onondaga County Sheriff's Department, New York State Police, and municipal police departments handled traffic control jointly by using the ACU-1000.

4.3.3 Drug Sweep

The Interoperability Unit was utilized for a counter-drug detail in Syracuse. The operation objective was to roundup 34 individuals that were the subject of ongoing investigations. No encrypted communications were used, but the Syracuse PD was inter-connected with the New York State Police. The ACU-1000 worked well and the radio-to-radio communications were understandable.

Figure 8: Interoperability Unit at the Ultimate Fishing Derby

5. CONCLUSIONS

At this point, operational evaluation work is ongoing. We anticipate additional lessons will be learned as the unit is deployed. However, we have drawn some initial conclusions based on the work done to date.

One of the major items investigated in this operational evaluation is the use of the ACU-1000 for applications requiring secure communications. Of particular interest is if during the process of encrypting/decrypting over one link, then re-encrypting/decrypting over a second link, degradation of the audio beyond the point where it was intelligible would be experienced. For Transcrypt® and DVP®, our results indicate that the audio quality of such transmissions was not significantly degraded. We also observed the delay times associated with transmissions on back-to-back encrypted links, and observed that while there was some delay, officers quickly adjusted and the delay did not significantly impact communications.

This evaluation only considered Transcrypt® and DVP® encryption. While these particular products are common among State and local agencies, we recognize that there are other encryption techniques and products. The results obtained in this evaluation are not directly applicable to back-to-back encryption using other products. However, as encryption approaches evolve and become more technically sophisticated, one area of enhancement should be the reduction of audio degradation associated with encrypted communications. Thus while agencies consider the use of an ACU-1000 to provide interoperability among links using encryption other than Transcrypt® and DVP®, they must verify that performance is adequate prior to operational use. We are optimistic that the ACU-1000 will handle any combination of encryption techniques.

As we discovered in our laboratory test, the addition of encryption boards may change the pin configuration of the interface cables.

Appendix A: ORIGINAL RADIO CONFIGURATION

The original configuration of the Interoperability Unit included three radios, one each for the Syracuse Police Department, Onondaga County Sheriff's Department, and the New York State Police. Each agency provided a radio from stock. Subsequently, four Motorola MCS 2000™ radios were purchased specifically for incorporation into the Interoperability new unit; these radios are more robust and functional than the original radios that were replaced, and four common radios will simplify support during the unit life cycle.

While this configuration is no longer in use, certain aspects of the design may be useful to agencies that use the same radio models that were originally interfaced to an ACU-1000. For this reason, technical documentation from the original configuration is included as an appendix to this report.

A.1 Equipment Rack

A schematic of the layout of the front of the original unit as installed is depicted in Figure 9. The front of the unit is pictured in Figure 10. The rear of the unit was not significantly changed from the original to the configuration described in Section 3.1. Table 13 list the major components mounted in the ruggedized plastic case.

Table 13: Major Components

MAJOR COMPONENTS
ACU-1000 Interconnect System
Motorola Astro Spectra™ UHF Radio (Syracuse PD)
GE (Ericsson) Radio (NY State Police)
Motorola MCS 2000™ VHF Radio (Onondaga Sheriff Department)
External Accessory Interface Panel
AC/DC Power Panel
DC Power Supply #1
DC Power Supply #2
AC Power Strip Panel

A.2 Original Radio Equipment

For initial operations, the Interoperability Unit includes three radios in two main frequency bands (VHF, UHF). The radios are listed in Table 14.

The radios were programmed with frequencies for frequencies corresponding to channels of the participating agencies. The Motorola Spectra™ VHF radio was programmed with Syracuse Police Dept. channels. The Motorola MCS 2000™ VHF radio was programmed with the Onondaga County Sheriff's Dept. channels. The GE (Ericsson) VHF radio was programmed with the New York State Police channels. More channels could have been programmed into the radios, and more radios can have been added as needed to accommodate additional agencies.

Table 14: Radio Equipment

Radio Model	Frequency Band	Power Output
Motorola Spectra™	UHF	40W
Motorola MCS 2000™ Type II	VHF	25W
GE (Ericsson)	VHF	100W

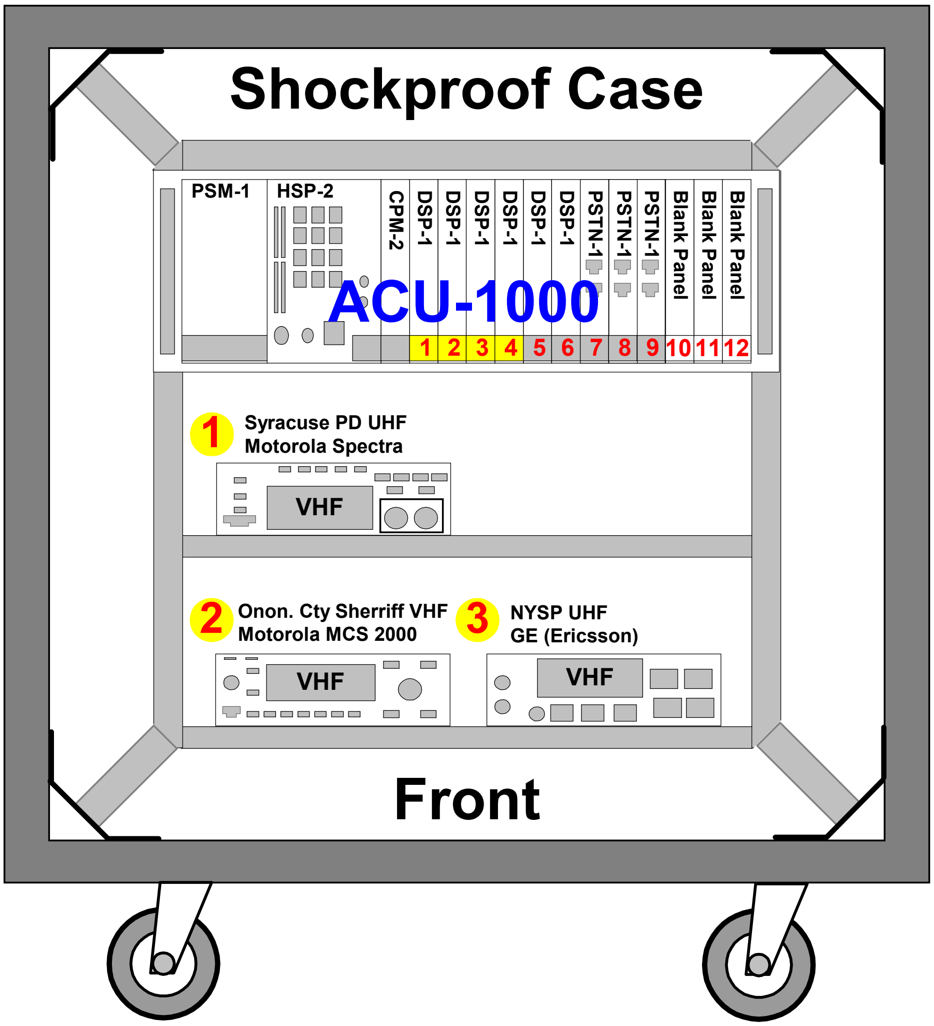


Figure 9: Drawing of Front View of Syracuse Interoperability Unit (Original Configuration)

Figure 10: Front Picture of Syracuse Interoperability Unit

A.3 Radio/ACU-1000 Interface for Original Radios

Cables were fabricated to connect the radios and the ACU-1000, based on the schematics shown in Figure 11, Figure 12, and Figure 13.

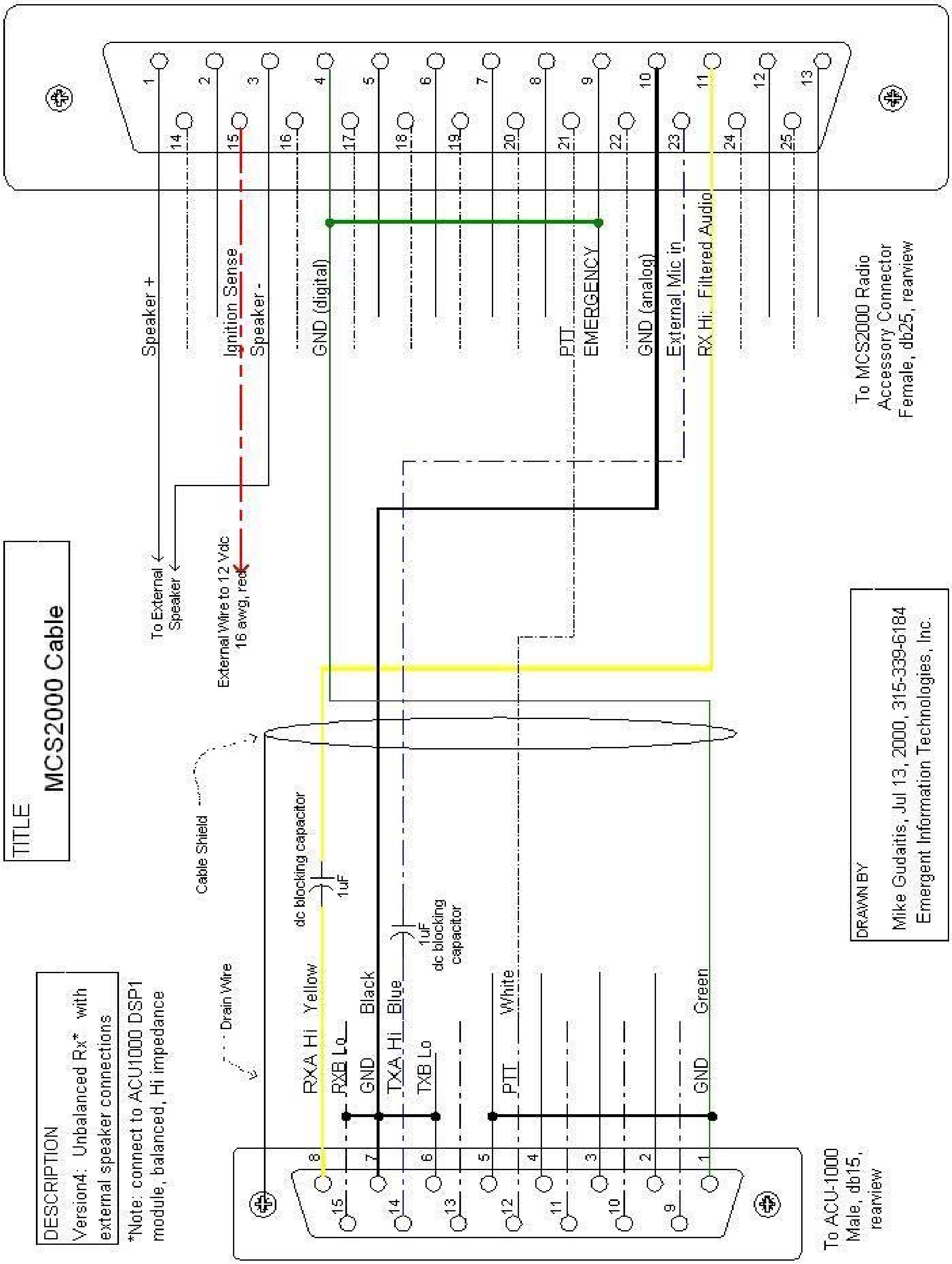


Figure 11: Cable Schematic for MCS 2000™ Radio

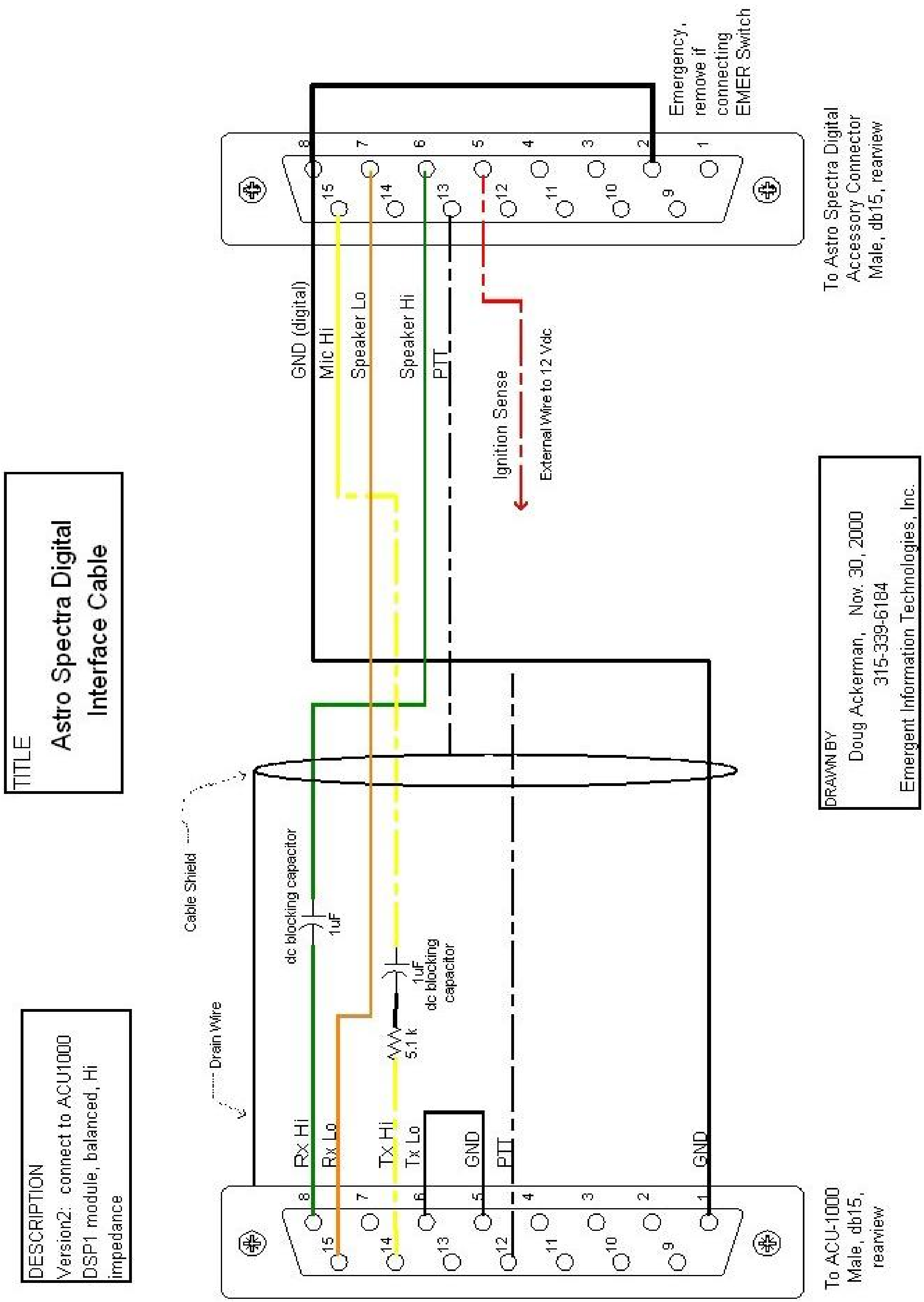


Figure 12: Cable Schematic for Astro Spectra™ Radio

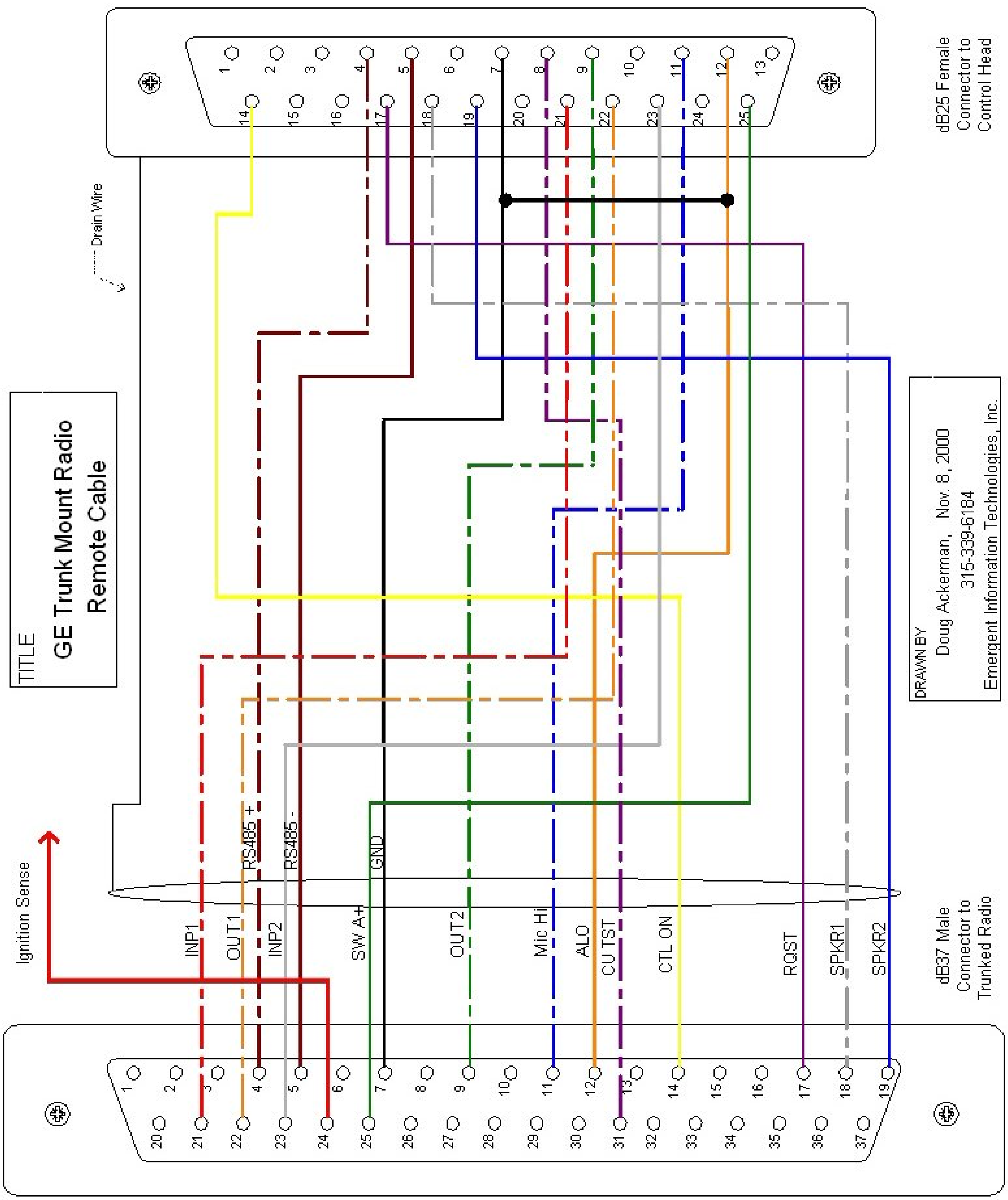


Figure 13: Cable Schematic for GE (Ericsson) Radio